Pest Management Strategic Plan for Wheat in the Western Great Plains
CO, KS, MT, NE, ND, SD, WY

Based on a Planning Conference held March 2014
Fort Collins, CO

Sponsored and Funded by the Western Integrated Pest Management Center
Hosted by Colorado State University

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Executive Summary

This Pest Management Strategic Plan (PMSP) is meant to facilitate communication among growers, industry representatives and other IPM professionals to regulators and granting agencies about the need for, and role of pest management practices, including pesticides, used in wheat production. To obtain broad-based industry input, PMSPs are developed for a commodity via workshops attended by producers, crop consultants, commodity groups, and pest management specialists from across the production region. PMSPs were originally intended for use by the Environmental Protection Agency (EPA), but also have proved valuable to the United States Department of Agriculture (USDA), Land Grant Universities, and pest management stakeholders at all levels.

Our goal was to develop a PMSP for wheat production in the western Great Plains, encompassing the states of Colorado, Kansas, Montana, Nebraska, North Dakota, South Dakota and Wyoming. While this region confronts a variety of pest issues, the primary motivation has been the rapid expansion of wheat stem sawfly and several biotypes of herbicide-resistant weeds. Such problems often are best addressed through regional communication and cooperation. This PMSP is based on information gathered at a workshop held 3-4 March 2014 in Fort Collins, CO. Twenty one participants representing the abovementioned states were in attendance. The main focus of the workshop was to identify research, education and regulatory issues affecting producer profitability and environmental quality.

Additional input was sought from various sectors of the regional wheat industry as the plan and this report were being finalized. While states included in this PMSP all grow hard red and hard white winter wheat, climate and pest problems vary significantly across the region. Additionally, there are significant acreages of spring wheat in the northern part of the region.

The proceedings of the meeting are outlined below. In summary, the most pressing problems and concerns identified were (1) wheat stem sawfly; (2) herbicide-resistant weeds, especially kochia; (3) decision making for fungicide applications against stripe rust; (4) management of virus diseases, particularly the complex vectored by wheat curl mite; (5) winter annual grasses; (6) brown wheat mite; and (7) efficacy of seed treatments both for diseases and soil insects (see also Table 1).

Outline of pest management needs identified at the PMSP meeting in Fort Collins, CO, March 3 and 4, 2014.

I. Key Disease Problems

- A. Rusts
    1. Stripe rust
        - a. Devastating in eastern CO
        - b. Showing up in MT, but rarely spray due to recent dryer weather.
        - c. More problematic in irrigated wheat
        - d. Fungicides work well if timed properly.
        - e. Decision making related to weather is difficult.
        - f. Inconsistent efficacy of fungicides due to late treatments (especially in

irrigated wheat)

g. Decision making and timing of fungicides need to be addressed

2. Leaf rust
   a. Sometimes in CO
   b. Rarely in MT
3. Stem rust
   a. Rarely in CO
   b. Never in MT
   c. Worried about UG99

B. Wheat curl mite vectored diseases

1. Wheat streak mosaic virus (WSMV)
   a. Corn-wheat systems a problem
   b. Common in irrigated systems in WY
   c. Predictions models needed for hail damaged or sawfly damaged wheat and the resulting volunteer wheat
2. High Plains Disease
3. Triticum mosaic virus
   a. Equally as important in NE as High Plains disease (number 2 & 3 on rating from survey)
4. Yield effects from wheat-curl-mite-vectored diseases
5. Varietal differences
6. Greater yield effects with High Plains disease and WSMV together
7. Different biotypes of wheat curl mite
8. MT uses later planting to help prevent wheat curl mite issues
   a. Late plantings often miss important moisture events
9. The most widespread management practice for wheat curl mite is managing volunteers
10. Some wheat varieties show some tolerance to wheat curl mite diseases
11. Need for resistant varieties

C. Barley Yellow Dwarf

1. High occurrence in KS
2. Inconsistent in CO (and inconsequential compared to WSMV)
3. NE said that this should be one disease where research money should be applied

D. Fusarium Root Rot

1. Every dry spring in eastern CO, but wheat seems to outgrow the disease
2. Doesn't matter if the seed was treated
3. Seed treatments a priority to prevent root rot?

E. Tan Spot and Rhizoctonia always present in wheat but little information on how they affect wheat crops

F. Nematodes
   1. Not a lot of research in wheat
   2. Not many nematicides available and none are labeled for wheat
   3. Research needed for nematode effects on yield (presence/absence also unknown)

II. Seed Treatments

A. Seed treatments differ among companies (i.e., some stick well to seed, others do not)

B. Non-target effects of seed treatment effects a concern

C. Problem in honey production

D. Clerids and coccinellids effects due to over-kill of prey

E. Fluency “sticker” in corn to keep dust from occurring (not available in wheat?)

F. Over use of seed treatments (i.e., used when potentially not needed)

G. Concerns of over use lowering efficacy of AI (one grower from MT is seeing lack of effectiveness in managing insects with current seed treatments)
   1. Most of MT wheat seed is treated
   2. WY, NE, CO rarely treat seed
   3. % of seed treatments will go up in KS

H. Accumulation in soil

I. Cost effectiveness of seed treatments in dryland production

J. Research lacking for effectiveness of seed treatments, especially for soil insects attacking wheat
   1. Recommend that growers leaving untreated strips to see the actual need for seed treatments
   2. SARE sustainable ag funds for soil conservation

III. Patent wheat seed

A. No seed saving concerns with industry

B. Some growers show animosity toward industry due to lack of grower control over seed

IV. Key insect problems

A. Spider Mites

1. Brown wheat mite
    a. Consistent issue in KS and CO
    b. Rarely problem in MT (Clerids appear to control them?) and NE
    c. Dimethoate works great, but supplies appear to run out
    d. Treatment issues due to timing and Economic Injury Level (EIL)
    e. Tillage
2. Banks grass mite
    a. Problems in eastern and southeastern CO
    b. No problems noticed in KS, some in NE
3. Winter grain mite
    a. Problem in KS in cooler, wetter weather conditions
    b. Treatment difficult due to lack of EIL

B. Cutworms

1. Army and pale western cutworms
    a. Sporadic problem in CO and MT
    b. Dry, loose soil in MT tends to get higher infestations
2. Dingy cutworm
    a. Occur in MT
    b. Pyrethroids work great

C. Wireworms

1. Problem in MT (#2 problem next to sawfly) and KS
2. Difficult to manage. No pesticide solution!
3. Do we need better soil insecticides?

D. Aphids

1. Russian wheat aphid
    a. Not a problem in SD
    b. Rare, sporadic problem in CO, KS, MT and WY
2. Greenbug

a. Problem in southern KS

3. English grain aphid
    a. Problem in SD and sporadic problem in MT
4. Bird cherry-oat aphid
    a. A few in MT and CO (mostly worried about disease transmission)

E. Wheat stem maggot
1. Sporadic, low levels in SD, MT and CO
2. MT noticed varietal differences?

F. Grasshoppers
1. Cyclic and sporadic (especially in WY and pivot corners in MT)
2. Damage dependent on species
3. Also dependent on proximity to rangeland (and whether treatment was done on pasture)
4. Preharvest issues with treating late-season wheat

G. Black grass bugs
1. Minor pest found damaging mostly along field edges

H. Wheathead armyworm
1. Minor pest in KS and CO (mostly occurring along field edges)

I. Wheat midge
1. A common issue in ND and SD
2. Becoming a concern in western MT in irrigated wheat

J. Say stink bug
1. Rare, but high impact when it does

K. Eastern heath snail
1. Feeds on basal portion of wheat plant
2. Becoming a huge concern in southeastern MT
3. Concerns for crop contamination and equipment damage

L. Wheat stem sawfly
1. $80 million loss/year in Montana
2. No satisfactory control
3. Solid stem varieties work ok
    a. Yield less

b. Not consistently solid

4. Emergence timing selected for when switched to planting winter wheat
5. Also cut barley
6. Many grass hosts
7. Harrowing kills 50-60% of sawfly
    a. Not enough control
    b. Bad for soil retention
8. Burning doesn't work
9. Stripper headers help with harvesting sawfly damaged wheat
10. Crop rotation is not effective
11. Oats – not a host but they are attractive to WSS
12. 3-5% sawfly will diapause for 2 years
13. 2 braconid parasitoids in MT spring wheat
    a. Have not adapted to early maturing winter wheat
    b. 7 total parasitoid species known, but only 2 species are found in high numbers in spring wheat
    c. Conservation of parasitoids is recommended in MT (some control is achieved with parasitoids)
    d. Planting varieties that work best with parasitoids
14. Clerids found in sawfly infested stubble in MT
15. Trap cropping helps reduce damage in MT
16. Varietal resistance is being looked at again
17. WSS are Holarctic (not found below the equator)
18. GMOs?
19. Short answer: Need more management research

V. Key Weed Problems

A. Winter Annual Grasses

1. Downy brome
    a. Huge problem in WY and MT
    b. Olympus has great control, but no cultivated grass species can be planted after treatment (MT)
    c. Clearfield wheats/Beyond has good control of winter annual grasses in WY and CO
    d. Maverick, Olympus, Beyond, glyphosate, etc. resistance showing up in MT
    e. Late season tillage and glyphosate has been used effectively in WY
2. Jointed goatgrass
    a. Emerging problem in MT

b. Crop rotations have mostly taken care of problem in CO

3. Wild rye
    a. Beyond not effective?

B. Broadleaves
1. Kochia!! – resistant Kochia is biggest concern in all states
2. Field bindweed
    a. Requires long term management (not always complete control)
3. Wild buckwheat – herbicide tolerance
4. Canada thistle
5. Russian thistle
6. Dalmatian toadflax in WY

C. Herbicide Resistance Issues:
1. Broadleaves (esp. Kochia) are requiring higher rates of glyphosate
2. Issues with mixing herbicides with different modes of action (eg., getting lowered effects of glyphosate due to plant response to other herbicides)
3. Growers need better education on herbicide modes of action
4. Stewardship education to farmers
5. Glyphosate and Dicamba have resistance issues
6. How chemicals are being used in non-crop areas (eg., road shoulders and fence lines) is of concern - may be selecting for resistance
7. Timing issues (time of day, plant growth stage)
8. Too low application rates causing resistance
9. Poor coverage causing resistance
10. Clearfield wheat
    a. Cost of system is high
    b. Generic ACC-ase is better than Beyond (~4 years before commercial release)
11. Livestock grazing and tillage experiments (much needed)
12. Weed pressure differences between no-till and tillage
13. Grants available through organic transition grants
14. Need consistent tillage controls at each site
15. Applied research and researchers are scarce
    a. Especially in extension and applied scientists at universities
    b. Need to revitalize applied research (Experiment Station Funds have been greatly reduced)
16. Ground beetle assemblages in weed seed management (research)
    a. High abundance of beetles with reduced tillage
    b. Beetles knock out broadleaves but not grass seed

c. Sterile seed to attract beetles to crop

VI. Summary of Pest Problems

A. Policy changes

B. Public policy with soil health is "spooky"
1. Vague term
2. Does not apply to all soils (ie., not all soils created the same)
3. Lack of experimental evidence
4. Needs
   a. Reasonable policies
   b. Based on good research (by university rather than industry)

C. Pesticide issues
1. Private Industry
   a. RNAi
   b. GMOs
      (1) Grower support
      (2) Consumer Benefit
      (3) More likely agronomic traits will push GMO forward
      (4) GMO with insect/pathogen resistance is wanted
      (5) Drought tolerance
      (6) Herbicide tolerance (some concerns with mixed herbicides)

D. Hybrid wheat

E. Soil health unknowns

F. Micronutrients?
1. Most studies with nutrients (fertilizers) are done by industry (some feel recommendations are "sketchy")
2. Fertilizer check-off funding available in MT

VII. Specific Needs

A. Research

B. Regulatory/Policy changes/updates

C. Education/Outreach

1. High Plains IPM Guide
2. Wheat Management Guide
3. iWheat

Table 1. Critical Needs: Pest Management Priorities for Wheat Production in the Western Great Plains (CO, KS, MT, ND, NE, SD, and WY).

Research	Extension	Education and Regulatory
Wheat stem sawfly research - all aspects	Dissemination of appropriate management information when available	Multistate effort coordinating research, engagement and resources
Herbicide resistance - all aspects, including resistant crop traits. Emphasis on kochia	Dissemination of information on operational guidelines to reduce the rate of resistance development	Policies to encourage the development of new modes of action
Seed treatments for insect and disease problems	Programs related for proper use of seed treatments, when and where use is recommended	New registrations for seed treatment active ingredients
Decision making and timing of fungicides	Programs related to decision making and timing of fungicides	
Documenting yield response, or lack of, to various fungicide applications under varying conditions, i.e. residue type, age and amount. Also, document fungicide effects on beneficial fungi and soil microorganisms.[1]	Educational programs to relay the implications of routine fungicide applications on beneficial fungi and soil microorganisms.	Pesticide safety and certification. Drift and carryover education
Prebreeding for UG99 stem rust	Stem rust surveillance	Quarantine
Resistance to viruses and/or wheat curl mite	Programs emphasizing vector-pathogen relationships and promoting volunteer management, crop sequences and planting dates	
Nematodes - distribution, yield effects, decision making, and management	Survey, recognition and management information	Tolerances for effective nematicides on wheat

Brown wheat mite - treatment decisions and effects of tillage	Dissemination of appropriate treatment guidelines	
	Programs and resources designed to train producers how to properly identify key pests of wheat in the region and most common biological agents present in wheat.[1]	

[1]Suggested by South Dakota participants. All others suggested at the Fort Collins meeting.

General Production Information

Wheat production in the region is summarized in the following table. The participating states represent the top four wheat producing states, as well as six of the top ten. Total production for the region in 2013 was nearly 957.9 million bushels, with a value of $6.5 billion. This represents 45% of the national production.

Table 2. Production Statistics (All Wheat: 2005-2014).

State	Rank[1]	Planted[2]	Harvested[3]	Yield[4]	Top 5 Counties[5]
Colorado	8	2,441	2,188	33.4	Kit Carson, Washington, Adams, Lincoln, Logan
Kansas	2	9,520	8,741	38.4	Sumner, McPherson, Reno, Mitchell, Harper
Montana	3	5,468	5,279	34.7	Chouteau, Hill, Liberty, Pondera, Teton
Nebraska	9	1,699	1,553	41.1	Cheyenne, Perkins, Box Butte, Furnas, Red Willow
North Dakota	1	8,146	7,869	40.0	Cavalier, Ward, Wells, Williams, Bottineau
South Dakota	4	2,865	2,749	43.7	Sully, Spink, Potter, Hand, Lyman
Wyoming	37	158	137	29.0	Laramie, Platte, Goshen, Campbell, Crook

[1]All wheat production, 2014
[2]Acres x 1000
[3]Acres x 1000
[4]Bushels per harvested acre
[5]Total production, 2008

Common Production Practices:

Colorado

Winter wheat generally is planted between September 1 and October 15. If the crop is planted too early, there is a higher risk for Russian wheat aphid, viral infections, and freeze injury. If wheat is planted too late, the plants may be underdeveloped when overwintering occurs (4 - 5 leaf stage is the optimal stage for overwintering) and will have reduced yield potential. The wheat plants will vernalize during overwintering if they are properly developed. Vernalization allows the shift from vegetative growth to reproductive growth in the spring. Preferred soil texture is well-drained, with a soil temperature of 60°F or lower. Most tillage practices can be categorized as reduced or no-till, however, under certain conditions crop residue problems may require more “conventional” tillage.

Seed should be planted at a depth of one to three inches Row spacing is generally seven to 12 inches. Optimal planting density is 500,000 - 1,000,000 seeds or more per acre, depending upon whether it is a dryland or irrigated system (in dryland systems, there are fewer plants per acre). This is equivalent to 30 - 50 pounds of seed per acre in dryland systems and 75 - 90 pounds of seed per acre for irrigated systems, depending on the variety and market class planted.

The following are common crop rotations: wheat-corn-fallow; wheat-sorghum-fallow; wheat-proso millet-fallow; wheat-corn-proso millet-fallow. Sunflower occasionally is added into the rotation. However, the dominant rotation remains wheat-fallow. It is recommended to plant winter wheat following fallow; if this is not possible, a short-season annual forage is planted in the spring to be harvested prior to August 1. No tillage is necessary when planting wheat; wheat is planted directly into the forage stubble. However, most growers in a wheat-fallow rotation will clean till (sweep) the seed bed before planting. Winter wheat usually is harvested from late June to late July. The crop is directly combined unless it is too weedy, in which case it may be windrowed and then combined.

Kansas

The hard red winter wheat class is adapted to Kansas temperatures and can withstand both cold and hot weather. Winter wheat in Kansas not only can survive the freezing temperatures of winter, but it needs the cold temperatures to vernalize and develop properly. Wheat is planted in early fall (mid-September through October) and harvested in the following summer. Normally, Kansas wheat harvest starts in mid June and continues through early July.

Optimum seeding dates vary across Kansas due to different environmental conditions. Seeding rates and planting dates vary across the state in response to lower rainfall and irrigation systems in western Kansas and higher rainfall in the eastern region of Kansas. Optimum seeding rates in western Kansas range from 600,000 to 900,000 seeds per acre planted. In central Kansas, the rate ranges from 750,000 to 900,000 seeds per acre. About 900,000-1,125,000 seeds per acre are planted in the eastern part of the state. With irrigation, seeding rates may range from 900,000 to 1,350,000 seeds per acre.

Seedbed preparation varies across the state depending on residue of the preceding crop and the need for moisture conservation. The amount of tillage in Kansas has been reduced during the past decade. Plowing is practiced on a limited basis in the continuous wheat areas of south central Kansas where residue management is difficult. Most farmers who till use one to two diskings or a single chisel operation to incorporate residues followed by another disking or field cultivation near planting time. In this cropping system, wheat varieties resistant to foliar diseases are planted to tolerate tan spot and Septoria leaf blotch. On the heavier, sloping soils of eastern Kansas, soil erosion by water is a major concern. Terraces, waterways, and crop residue management are required on the many highly erodible acres.

Where crop rotations are used, row crop residue is left until late summer when one or two diskings or field cultivations are used before wheat seeding. Many farmers have saved time and moisture by planting no-till wheat, double-cropping after row crop harvest. In western Kansas, where moisture conservation is the most important goal, the wheat-fallow system has been dominant. In this system, a wheat crop is produced every 2 years. But, the wheat-row crop-fallow rotation is gaining acreage and interest. In this system, two crops are grown in three years. Soil moisture is replenished by using conservation tillage methods so that a summer crop (corn, grain sorghum, sunflower, or millet) can be planted to utilize the stored moisture.

Montana

Winter wheat is planted sufficiently early in the fall to allow for four to six weeks of crop growth and development prior to dormancy. If the crop is planted too early, there is a higher risk insect and disease problems, as well as excessive water use. If wheat is planted too late, the plants may be underdeveloped when overwintering occurs (4 - 5 leaf stage is the optimal stage for overwintering) and will have reduced yield potential. However, dormant seeding is an option in certain environments.
Most tillage practices are categorized as reduced or no-till, however, under certain conditions crop residue problems may require more “conventional” tillage.

Fertilization recommendations focus on the proper timing and placement of nitrogen and phosphorus. The other important mineral nutrients generally are found at adequate levels in the soil.

Seed should be planted into moisture at a depth of one to three inches. Row spacing is generally seven to 12 inches. Optimal planting rates are 40 to 80 pounds of seed per acre, depending upon the production environment. Higher seeding rates are recommend when planting late.

Spring wheat should be planted when soil temperatures at two inches depth reach 40°F. The crop should be seeded at 60 pounds of seed per acre, although, if planting is delayed then the rate should be increased to 90 pounds. Seeds should planted into moisture at a depth of one to two inches.

Crop rotations replacing some of the fallow period with a spring-seeded crop have advantages over wheat-fallow as observed elsewhere in the region. Spring peas, lentils, mustards, canola, and camelina can be used in such systems. Additional advantages regarding wheat residue management have been noted. Winter wheat usually is harvested in July and August, while spring wheat harvest usually occurs during August and September. The crop is directly combined unless it is weedy.

Nebraska

Winter wheat generally is planted during the month of September, with the optimal dates determined by latitude and elevation. If the crop is planted too early, there is a higher risk for Russian wheat aphid, Hessian fly, viral infections and freeze injury. If wheat is planted too late, the plants may be underdeveloped when overwintering occurs (4 - 5 leaf stage is the optimal stage for overwintering) and will have reduced yield potential. The wheat plants will vernalize during overwintering if they are properly developed. Vernalization allows the shift from vegetative growth to reproductive growth in the spring. Preferred soil texture is well-drained, with a soil temperature of 60°F or lower. Most tillage practices can be categorized as reduced or no-till, however, under certain conditions crop-residue problems may require more "conventional" tillage.

Soil fertility recommendations emphasize nitrogen and phosphorus. Certain, relatively rare, situations may call for additional applications of potassium, zinc or sulfur.

Seed should be planted at a depth of one to three inches. Row spacing is generally seven to 12 inches. Optimal planting density is 600,000 - 1,000,000 seeds or more per acre for dryland production, depending upon the location in the state. The recommended seeding rate for irrigated production ranges from 1 to 2.5 million seeds per acre. Lower rates are used for earlier planting dates, while higher rates are used to compensate for the reduced tillering associated with late planting.

The following are common crop rotations: wheat-corn-fallow; wheat-sorghum-fallow; wheat-proso millet-fallow; wheat-corn-proso millet-fallow. Sunflower occasionally added into the rotation. However, the dominant rotation remains wheat-fallow. Winter wheat usually is harvested during July. The crop is directly combined unless it is weedy.

North Dakota

Winter wheat is planted during the first half of September in the northern part of the state and during the second half of the month in the southern part of the state. Winter hardiness is an important trait in selecting winter wheat varieties. Varieties developed in northern areas, like North Dakota, tend to be hardier than those developed in more southern areas like Nebraska. Less hardy varieties should be planted into standing stubble. Spring wheat is planted in late April and May. Most tillage practices are categorized as reduced or no-till, however, under certain conditions crop residue problems may require more “conventional” tillage.

Fertilization recommendations focus on the proper timing and placement of nitrogen and phosphorus. Other nutrients that may be recommended under certain conditions include potassium, sulfur, copper and chloride.

Winter wheat seed should be planted into moisture at a depth of one to 1.5 inches, while spring wheat is seeded at two inches or shallower. Row spacing is generally six to nine inches. The recommended seeding rate is one million seeds per acre, or about 80 to 100 pounds.

Spring wheat should be planted when soil temperatures at two inches depth reach 40°F. The crop should be seeded at 1 to 1.5 million seeds per acre. Higher rates are used if planting is delayed. Seeds should planted into moisture at a depth of one to two inches.

Crop rotations that replace some of the fallow period with a spring-seeded crop have advantages over dryland wheat-fallow similar to those observed elsewhere in the region. Spring peas, lentils, mustards, canola, and camelina can be used in such systems. Winter wheat usually is harvested in August, while spring wheat harvest usually occurs during August and September. The crop is directly combined unless it is weedy.

South Dakota

Winter wheat is planted during the second half of September through early October. Winter hardiness is an important trait in selecting winter wheat varieties. Spring wheat should be planted in late March and April no later than mid-May to avoid heat stress during grain fill. Early varieties also are recommended, for the same reason. Most tillage practices are categorized as reduced or no-till, however, under certain conditions crop residue problems may require more “conventional” tillage.

Fertilization recommendations focus on proper timing and placement of nitrogen and phosphorus. Other recommended nutrients under certain conditions may include potassium, sulfur and chloride.

Winter wheat seed should be planted into moisture at a depth of 1.0 to 1.5 inches, while spring wheat is seeded at two inches or shallower. Row spacing is generally 6 - 10 inches. The recommended seeding rate is 960,000 to 1.2 million seeds per acre and up to 1.5 million seeds when planting late.

Spring wheat should be seeded at 1.2 million seeds per acre. Higher rates are used to compensate for the reduced tillering associated with later planting dates. Seeds should planted into moisture at a depth of 1 - 2 inches. Row spacing is generally 6 - 12 inches.

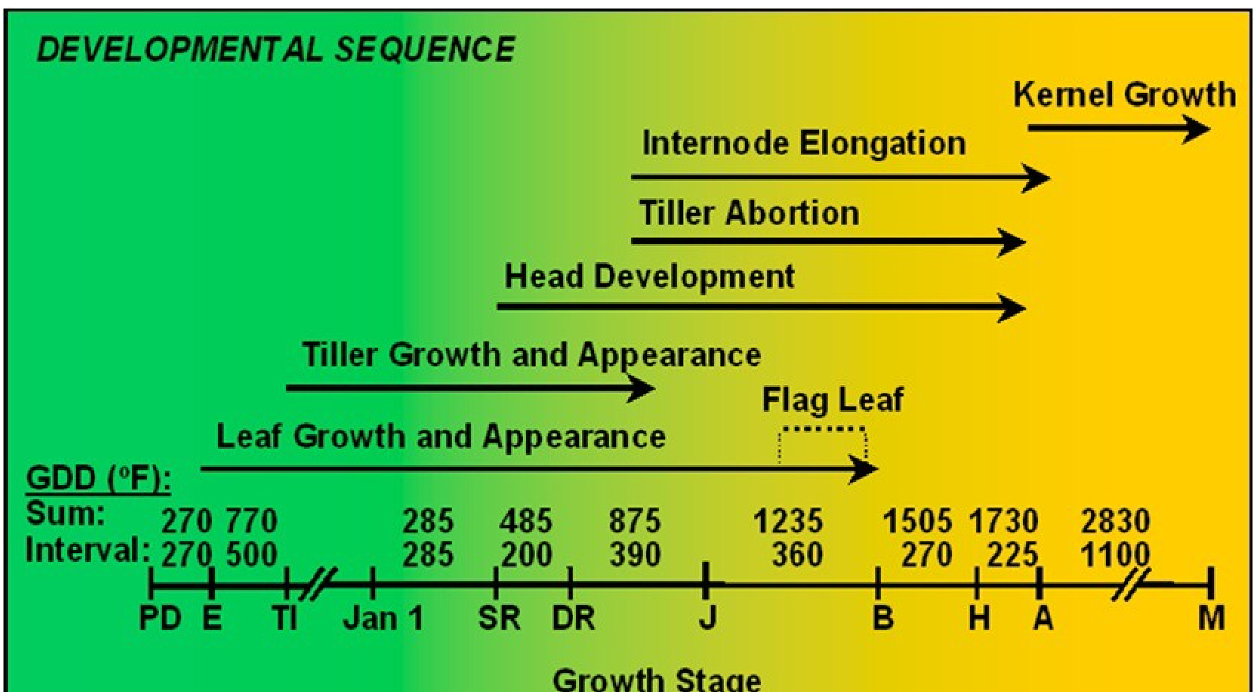
Crop rotations that employ wheat, corn and a variety of broadleaf crops, both cool and warm-season , have been used with some success. These include peas, canola, lentils, soybean and sunflower. Winter wheat usually is harvested in July and August, while spring wheat harvest usually occurs during August and September. The crop is directly combined unless it is weedy.

Wyoming

Production practices in Wyoming are similar to those described above for western Nebraska.

Wheat Growth and Development

Wheat yield is determined by the interaction of environment and the plant growth and development process, seed germination to grain maturity. Important environmental components affecting this process include temperature, water, nutrients and pests. Important plant components of this interaction include plants per unit area (acre), heads per plant, kernels per head, and kernel size. Each of these yield components is most sensitive to environmental effects during the developmental periods during which its potential is set and achieved. For example, the number of plants per acre is



(**PD** = planting date, **E** = emergence, **TI** = initiation of tillering, **SR** = single ridge, **DR** = double ridge, **J** = jointing, **B** = booting, **H** = heading, **A** = anthesis/flowering, **M** = maturity.)

Figure 1. Growing degree days and wheat development (adapted from Peairs, F. B., ed. 2010. Wheat production and pest management for the Great Plains region. Colorado State University Extension Bulletin XCM235.)

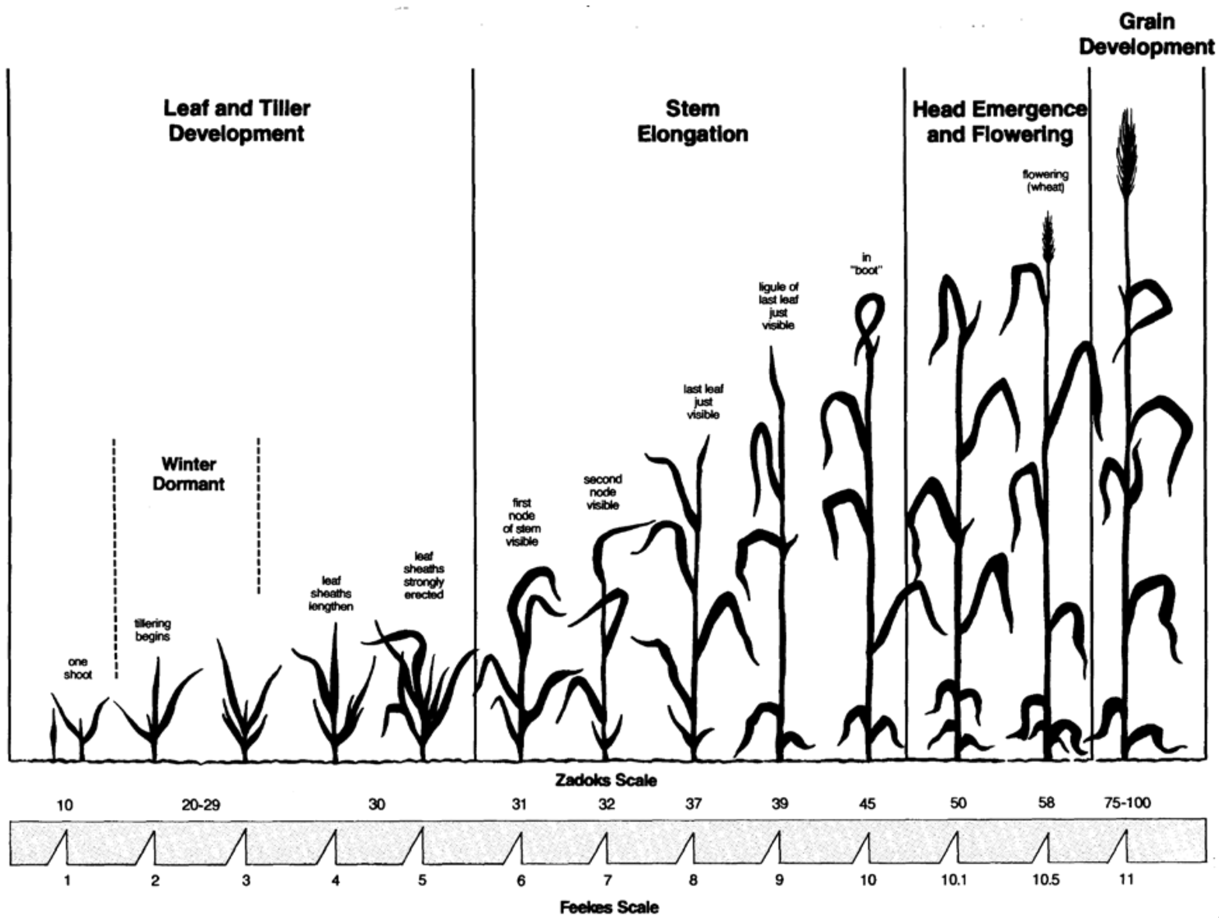


Figure 2. Feekes and Zadoks scales for growth staging wheat.

determined by germination and seedling survival, which, in turn, is affected by environmental factors such as temperature, soil moisture, and pathogens. In dryland production systems of the Great Plains, the most important yield component seems to be heads per acre, so management approaches that promote good plant populations and tillering are important (seeding rates, planter adjustments, planting date, tillage, fertilization).

Because of the great variability in the temperatures and precipitation that drive wheat growth and development, it is best to use growing degree days to predict various stages. Figure 1 provides relationship between accumulated degree days and the development process for winter wheat. Spring wheat would follow the same sequence, but at a more accelerated pace. These totals are affected somewhat by moisture availability, so the process may be accelerated under drought conditions.

The main growth stages of wheat, mentioned in Figure 1, are often presented in a numerical scale. The Feekes and Zadoks scales are used commonly in the region, as shown in Figure 2.

The key growth stages for determining wheat yield are emergence, jointing, and flowering. Patchy emergence reduces the number of heads per acre. Delayed emergence reduces the heat unit accumulation that is critical in leaf and tiller production. The jointing growth stage is when the survival of most tillers is determined. Head and kernel number, thus, also are determined at or near jointing. Flowering is when the number of kernels per head is set, which, in turn, determines how much of the potential yield will be realized. Hot and dry conditions at flowering can reduce this number.

In addition to management for optimal yields, the wheat developmental sequence is also an important consideration in many aspects of IPM. Among the most important of these are timing of scouting and pesticide applications and economic threshold calculations.

For more details see:

Peairs, F. B., ed. 2010. Wheat production and pest management for the Great Plains region. Colorado State University Extension Bulletin XCM235.

http://www.cerealsdb.uk.net/cerealgenomics/WheatBP/Documents/DOC_WheatBP.php

Pest Management

Wheat producers have an array of pest management tactics available to them that can aid in the reduction or prevention of economically significant losses to pests. These can be divided into preventive and reactive approaches. Preventive tactics include practices such as variety selection, tillage, planting dates and crop management. Reactive tactics primarily involve the use of pesticides, given that these allow the user to take a “wait and see” stance regarding pest problems.

Variety Selection

Important criteria for variety selection include adaptation, yield potential and pest and disease resistance. Selecting a variety that is well adapted to local conditions is key to avoiding a variety of stresses that can interact negatively with pests and diseases. Yield potential should be judged against performance of other varieties under local conditions. The importance of pest and disease resistance as a selection criterion depends on the prevalence and economic significance of a given problem in the area. Variety trial results are the main source of information regarding adaptation and yield potential, while resistance information is usually provided as part of a variety’s description. Keep in mind that pest populations may evolve to overcome resistance.

Tillage

A variety of tillage implements and practices have been developed for wheat production in the western Great Plains. While effective, they are being replaced by no-till. Tillage can produce important reductions in pest abundance by burial, mechanical destruction and exposure to heat and desiccation. The benefits of these reductions generally are outweighed by the benefits provided by no-till in terms of soil and water conservation. The emergence of herbicide -esistant weed biotypes may call for a reassessment of tillage as a pest management tool.

Planting Dates

Within a window of agronomic acceptability, planting dates can be modified to allow a crop or susceptible growth stage to avoid pest or disease occurrence. Early planting of winter wheat can help avoid late season problems during the following spring, while delayed planting may allow the crop to escape problems in the fall. Early planting of spring grains can result in a more vigorous and mature crop when pests or diseases occur. These benefits need to weighed against other important risks such as late spring freeze injury and heat stress during flowering.

Crop Rotation

More diverse cropping systems, achieved primarily through crop rotations, have become increasingly popular in the region because of their improved water use efficiency and generally greater annualized productivity and profitability. This increased diversity is thought to facilitate weed management as well as reduce the prevalence of certain pests and diseases through increased biological control.

Crop Management

A healthy crop is most able to tolerate pest and disease injury. Practices that promote crop health include proper seedbed preparation, adequate fertilization, soil conservation, water conservation and management, control of pests and diseases, and volunteer and weed management. Nutrient management not only insures a healthy plant, but also helps avoid overfertilization, particularly with nitrogen. In addition to cost savings, problems with pest issues associated with excess N, such as aphids and mildews, will be avoided.

Weed and Volunteer Management

Weeds and volunteer wheat plants stress the crop by competing for nutrients, water and sunlight. Under western Great Plains conditions, the competition for soil moisture is of particular significance. Additionally, weeds can complicate harvest operations and their seeds can contaminate grain as it is moved into storage or commerce. Weeds, particularly volunteers, also serve as important sources of a variety of pests and pathogens, including Russian wheat aphid and other cereal aphids, brown wheat mite, wheat curl mite, Hessian fly, BYDV, WSMV and leaf rusts. Allowing for a two week interval between control of volunteers and the emergence of the new crop will go a long way towards minimizing these problems.

Residue Management

Pests and diseases often pass fallow periods on crop residues. Appropriate residue management can reduce the size of these initial sources of infestations. Soil and water conservation considerations are similar to those for tillage.

Scouting and Monitoring

Knowledge of the distribution and abundance of the various pests, diseases and weeds that affect wheat and their potential for affecting crop yield and quality is essential for sound pest-management decisions. The availability of effective methods for detecting and assessing infestations is quite variable across the pest complex. The cost of sampling is also variable and can be problematic, given the low profit margins associated with wheat production. Nonetheless this is a key element of effective pest management and should remain a research emphasis.

Chemical Control

Effective chemicals controls are available for most of the pests, weeds and diseases that affect wheat production regionally. Notable exceptions include wheat stem sawfly, wheat curl mite and herbicide-resistant weeds such as glyphosate-resistant kochia. Less available, however, are research-based treatment guidelines. This should be another ongoing research emphasis.

Summary

Integrated pest management approaches rely on the integration of a variety of tactics to manage pest, weed and disease issues in a cost-effective and environmentally sound manner. Wheat producers in the western Great Plains have access to many pest-management tactics, with the challenge being how to combine them in an optimal fashion to maximize their profitability and sustainability.

Table 3a. Wheat pest management practices in the western Great Plains (disease, insect and weed pests): Prevention

Prevention Practice	% Acres Where Practice is Implemented – 2012						
	CO	KS	MT[1]	NE	ND[2]	SD[3]	WY
Beneficial insect or vertebrate habitat	13	12	6, 21, 5	15	3	15, 12	NA
Conventional tillage for crop residues	18	36	21, 23, 8	31	35	18, 21	NA
Crop residues removed or burned	4	13	6, 1, 0	4	11	11, 5	NA
Equipment cleaned after field work	50	58	56, 62, 52	45	77	44, 48	NA
Fallowing for insects	53	30	36, 30, 11	42	3	9, 1	NA
Flaming for weeds	1	2	2, 2, —	0	0	0, 0	NA
No-till or minimum till	72	71	85, 79, 62	67	72	91, 85	NA
On farm seed treatment	13	32	91, 73, 60	34	62	68, 43	NA
Vegetation in field edges, ditches, or fence lines	41	37	22, 15, 8	47	60	28, 41	NA
Water management	3	4	—, 4, 1	4	0	0, 2	NA

[1]Winter, spring, durum
[2]Spring
[3]Winter, spring
Source: USDA NASS Quick Stats, 2012, Wyoming data not available.

Table 3b. Wheat pest management practices in the western Great Plains (disease, insect and weed pests): Avoidance

Prevention Practice	% Acres Where Practice is Implemented – 2012						
	CO	KS	MT[1]	NE	ND[2]	SD[3]	WY
Crop or plant variety chosen for pest resistance	40	47	57, 73, 43	45	97, 50	59, 95	NA
Planting locations planned to avoid pests	26	24	27, 18, 12	19	28, 33	33, 43	NA
Planting or harvesting dates adjusted	27	27	24, 20, 5	39	31, 33	46, 16	NA
Rotated crops during past 3 years	62	76	65, 73, 90	75	97, 82	91, 95	NA
Row spacing, plant density, or row directions	27	23	16, 54, 6	19	50, 17	58, 50	NA

[1]Winter, spring, durum
[2]Spring, durum
[3]Winter, spring
Source: USDA NASS Quick Stats, 2012, Wyoming data not available.

Table 3c. Wheat pest management practices in the western Great Plains (disease, insect and weed pests): Monitoring

Prevention Practice	% Acres Where Practice is Implemented – 2012						
	CO	KS	MT[1]	NE	ND[2]	SD[3]	WY
Diagnostic lab services	12	10	5, 7, 7	6	12, 10	6, 7	NA
Field maps to assist decisions	9	11	17, 17, 7	9	12, 15	7, 19	NA
Established scouting process	8	9	16, 13, 2	14	18, 11	9, 19	NA
Scouted in response to pest advisory	(Z)	8	3, 7, —	9	16, 4	6, 14	NA
Scouted based on pest development model)	5	2	1, 1, 0	6	11, 4	6, 9	NA
No scouting for pests or beneficial organisms	4	10	5, 4, 2	17	2, 1	14, 1	NA
General observations for pests or beneficial	39	31	28, 38, 34	30	14, 40	21, 22	NA
Deliberate scouting for pests or beneficial	57	59	67, 58, 64	53	84, 59	65, 76	NA
Scouting for diseases by employee	(Z)	0	2, 1, 0	0	0, 1	2, 2	NA
Scouting for diseases by farm supply company or	1	8	1, 3, 2	5	6, 4	44, 13	NA
Scouting for diseases by independent crop	5	18	5, 1, 3	6	20, 3	8, 30	NA
Scouted for diseases by operator, partner, or	94	75	92, 95, 95	89	75, 92	46, 55	NA
Scouted for diseases	75	75	83, 86, 93	67	85, 89	76, 79	NA
Scouting for arthropods by employee	(Z)	0	2, 1, 0	0	0, 1	2, 2	NA
Scouting for arthropods by farm supply company	1	8	(Z), 1, 1	3	0, 7	46, 2	NA
Scouting for arthropods by independent crop	6	16	5, 1, 0	9	20, 5	7, 29	NA
Scouted for arthropods by operator, partner, or	93	76	93, 95, 99	88	74, 87	45, 55	NA
Scouted for arthropods	85	70	79, 79, 87	59	84, 81	71, 63	NA
Scouting for weeds by employee	(Z)	1	2, 1, 0	0	0, 1	2, 1	NA
Scouting for weeds by farm supply company or	1	5	1, 3, 2	9	5, 5	39, 11	NA
Scouting for weeds by independent crop	5	13	4, 1, 5	5	19, 4	7, 24	NA
Scouted for weeds by operator, partner, or family	94	82	93, 96, 93	86	76, 90	52, 63	NA
Scouted for weeds by operator, partner, or family	96	89	95, 96, 98	83	98, 99	86, 98	NA
Weather data used to assist decisions	26	49	55, 60, 65	45	72, 77	60, 64	NA

Prevention Practice	% Acres Where Practice is Implemented – 2012						
	CO	KS	MT[1]	NE	ND[2]	SD[3]	WY
Written or electronic pest records	33	25	24, 17, 12	31	32, 19	59, 43	NA

[1]Winter, spring, durum
[2]Spring, durum
[3]Winter, spring
[z]Less than half the rounding unit.
Source: USDA NASS Quick Stats, 2012, Wyoming data not available

Table 3d. Wheat pest management practices in the western Great Plains (disease, insect and weed pests): Suppression

Prevention Practice	% Acres Where Practice is Implemented – 2012						
	CO	KS	MT[1]	NE	ND[2]	SD[3]	WY
Beneficial organisms applied or released	0	0	0, —, 0	0	0, 0	—, 3	NA
Biological pesticides applied	0	0	—, —, 1	3	1, 0	—, 3	NA
Buffer strips or border rows to isolate organic from	3	6	14, 5, 2	10	4, 4	13, 4	NA
Floral lures, attractants, repellants, pheromone	0	0	0, 2, 0	0	—, 4	1, —	NA
Ground covers, mulches, or other physical barriers	65	54	58, 56, 40	80	62, 57	85, 78	NA
Rotation of pesticide modes of action	15	11	16, 30, 30	23	43, 37	12, 16	NA
Scouting data compared to published information	13	17	16, 13, 2	19	23, 14	6, 40	NA
Trap crops	1	—	0, —, 0	3	0, 0	0, 0	NA

[1]Winter, spring, durum
[2]Spring, durum
[3]Winter, spring
Source: USDA NASS Quick Stats, 2012, Wyoming data not available

Table 4. Fungicide, herbicide, insecticide use in the western Great Plains; (% acres treated, 2012)

Practice	% Acres Where Practice is Implemented – 2009						
	CO	KS	MT[1]	NE	ND[2]	SD[3]	WY
Fungicides							
Azoxystrobin	—	6	—	3	—	—	NA
Propiconazole	—	11	5, 10, 7	3	36, 30	—	NA
Prothioconazole	—	—	—	—	11, 12	3, 5	NA
Pyraclostrobin	—	2	—	14	21, —	17, —	NA
Tebuconazole	—	6	—	—	21, 21	11, —	NA
Trifloxystrobin	—	—	—	—	—	5, —	NA
Total	—	21	7, 10, 9	17	64, 51	56, 39	NA
Herbicides							
2,4-D	64	22	43, 37, 42	42	4, 23	21, 12	NA
Atrazine	4	—	—	—	—	—	NA
Bromoxynil	—	—	25, 29, 47	—	58, 46	21, 51	NA
Chlorsulfuron	—	27	—	—	—	—	NA
Clodinafop-propargil	—	—	—, 52, —	—	—, 19	—	NA
Clopyralid	—	—	—, —, 6	—	46, 17	14, 47	NA
Dicamba	35	25	11, 11, 15	8	—, 19	—	NA
Fenoxaprop	—	—	—, —, 16	—	16, 34	—	NA
Flucarbazone	—	25	11, 14, 7	—	25, 24	—	NA
Fluroxypyr	—	—	17, 27, 19	—	55, 36	14, 58	NA
Glyphosate	48	15	50, 48, 69	18	45, 72	29, 6	NA
Imazamox	—	—	—	10	—	—	NA
Kantor	—	—	16, 13, 9	—	—, 9	—, 7	NA
MCPA	—	3	11, 23, 53	—	17, 25	7, 27	NA
Methanone	—	—	—	—	21, —	6, —	NA
Metsulfuron-methyl	33	17	10 —, —	12	—	—	NA

Practice	% Acres Where Practice is Implemented – 2009						
	CO	KS	MT[1]	NE	ND[2]	SD[3]	WY
Pinoxaden	—	—	—, 12, —	—	17, —	—	NA
Propoxycarbazone	—	2	9 —, —	—	—	—	NA
Pyroxsulam	—	—	29, 13, —	—	—	—, 8	NA
Sulfosulfuron	—	—	10 —, —	—	—	—	NA
Thifensulfuron	23	11	8, 8, 16	6	25, 18	36, 22	NA
Triasulfuron	—	9	—	15	—	—	NA
Tribenuron-methyl	23	11	9, 10, 17	5	26, 19	38, 22	NA
Total	81	67	95, 93, 96	61	99, 100	75, 93	NA
Insecticides							
Chlorpyrifos	—	—	—, 4, 3	—	—	—	NA
Dimethoate	—	—	—	—	—	—	NA
Lambda-cyhalothrin	—	—	—, 5, —	—	5, 7	—	NA
Total	—	—	—, 10, 5	—	5, 7	—	NA

[1]Winter, spring, durum
[2]Spring, durum
[1]Winter, spring
Source: USDA NASS Quick Stats, 2012

Arthropod Management

(Adapted from the High Plains Integrated Pest Management Guide for the Western High Plains, http://wiki.bugwood.org/HPIPM:Main_Page)

Also see Appendix C for individual state arthropod management information, and cultural, biological and chemical controls.

Key pests

Greenbug, Schizaphis graminum (Rondani)

Greenbugs are small, 1.6 millimeters (1/16 inch), yellowish-green aphids with a darker green stripe down the middle of the back. The cornicles are pale with a dusky tip. The antennae are mostly black and longer than half the body length.

Greenbugs may overwinter as eggs, nymphs, or adults. In early spring, wingless females hatch and within seven to 18 days begin giving birth to live young. These may become either winged or wingless. This aphid produces from five to 14 generations per season with all but the last generation composed entirely of females. As the weather cools in the fall females produce winged males and females.

Plant Response and Damage

Greenbugs can infest small grains at almost any time during the growing season. Infestations may occur at irregular spots within the field or as a general infestation throughout the field. As they suck plant sap, the aphid injects toxic salivary secretions into the plant cells. The toxin kills the cells and results in a yellow or reddish stippling on the leaves.

Greenbug is attacked by several natural enemies, but the major ones are lady beetles and parasitic wasps. Pale, bloated aphid bodies (mummies) are a sign of aphid parasitism by wasps. It is advisable to delay treatment when parasitism levels reach between 10 and 15 percent (unless greenbug numbers are extremely high).

The scouting technique known as Glance 'n Go and the Greenbug Calculator can be used not only to assess the level of biological control, but also to determine the need to treat with an insecticide.

One observation of greenbug behavior is worth mention. When migrating, winged greenbugs are known to prefer settling in thin stands compared to nearby denser stands. No practical cultural management practices have been derived from this observation.

Consider an insecticide application if greenbug abundance exceeds the levels indicated below for the current crop growth stage. Glance 'n Go and the Greenbug Calculator also can be used to determine the need to treat with an insecticide.

Table 5. Small grain aphids per stem which justify chemical control.

Type of aphid	Seedling	Boot to heading	Flowering	Milky ripe	Milk- medium dough
Greenbug	5-15	25	>25	>25	>25
Corn leaf aphid	20	30	>25	>25	>25
Birdcherry-oat aphid	20	30	5	10	>10
English grain aphid	30	50	5	10	>10

Russian wheat aphid, Diuraphis noxia (Kurdjumov)

Two forms of Russian wheat aphid (RWA) are found in the High Plains during the year: a wingless female and a winged female. Most severe spring infestations of winter grains are caused by wingless aphids that overwintered in the crop. Winged aphids begin to appear in the High Plains in April and May and flights peak during July in most wheat-producing areas of the region. At this time winged aphids include both local aphids and immigrants from the south.

Winged aphids infest late-maturing winter wheat and spring grains, but they will not infest corn, millet or sorghum. They also will infest a number of cool season grasses, particularly wheat grasses. These grasses serve as alternate hosts for RWA during the period between grain harvest and the appearance of new wheat in the fall. Volunteer wheat and barley are important sources of RWA for the new fall crop as soon as it emerges. Weather conditions that favor cool season grasses and volunteers will increase the number of aphids infesting the new wheat crop in the fall.

RWA can be found in winter wheat, usually on the younger leaves, from emergence in the fall to grain ripening. Aphid feeding prevents young leaves from unrolling. RWA colonies are found within the tubes formed by these tightly curled leaves. This not only makes it difficult to achieve good insecticide coverage, but also interferes with the ability of predaceous insects to reach and attack aphids. Leaves infested by RWA have long white, purple or yellowish streaks. Under some conditions, infested wheat tillers have a purplish color. Heavily infested plants are stunted and some may appear prostrate or flattened.

After flowering, some heads are twisted or distorted and have a bleached appearance. Heads often have a "fish hook" shape caused by awns trapped by tightly curled flag leaves. At this time most RWA are found feeding on the stem within the flag leaf sheath or on developing kernels. There may be poorly formed or blank grains and the entire head sometimes is killed.

In addition to preserving biological control agents and judicious use of effective insecticides, certain other practices can provide additional control of the aphid. These practices should also help with other pest problems and make good agronomic sense as well.

Control volunteer wheat and barley. Although many grass species help RWA survive the summer, volunteers are the most important source of infestation for the new crop in the fall. Try to have a three week volunteer-free period prior to emergence of fall seedlings.

Adjust planting dates. Plant winter wheat as late as possible in northeastern, southwestern and western Colorado, western Nebraska and Wyoming. Recommended planting dates for southeast Colorado are more variable. Spring grains should be planted as early as possible.

Produce a healthy, stress-free crop. RWA often gets its start in stressed fields or stressed portions of fields and causes relatively more damage to stressed plants. Test the soil and fertilize accordingly. Plant certified, treated seed. Select a variety that is well adapted to local growing conditions.

Chemical control of Russian wheat aphid will probably not be necessary on resistant wheat varieties, but may still be necessary on susceptible types and on barley. Treatment guidelines are given below. If one tiller shows damage, then the plant should be considered damaged. Aphids can be very difficult to find during cold weather, so base treatment decisions on damage alone under such conditions.

Table 6. Treatment guidelines for Russian wheat aphid by crop stage.

Crop Stage	Level at which aphids should be treated
Fall	
Any growth stage	10-20% damaged plants
Spring	
Regrowth to early boot	5-10% damaged and infested tillers
Early boot to flowering	10-20% damaged and infested tillers
After flowering	More than 20% damaged and infested tillers

An alternative threshold for the period from spring regrowth to heading is:

% Infested tillers = (Control Costs per Acre x 200)/Expected Crop Value per Acre

Wheat stem sawfly, Cephus cinctus Norton

The wheat stem sawfly has been a key pest of spring wheat in North Dakota and Montana for more than a century. It was not a severe problem in winter wheat because the earlier maturing winter wheat was not attractive for egg laying and larvae were not able to complete development. Since the 1980s, however, winter wheat in the northern plains has been damaged more severely by the sawfly. In the central High Plains wheat stem sawfly has not been a pest of significance, presumably because of the predominance of winter wheat and lack of spring wheat. However, over the last decade serious infestations have occurred in southeastern Wyoming, in adjoining counties in Nebraska and, most recently, in northeastern Colorado.

The adult wheat stem sawfly is a wasp-like insect about ¾ inch long. It has smoky colored wings and a shiny black body with three yellow bands across the abdomen. When present in the field the adults are often seen resting upside down on the wheat stem. The sawflies will be active in the field when temperatures are above 50° F, with calm winds. They are not strong fliers and generally fly no further than the nearest wheat field or other suitable host grasses. This often results in the greatest damage in

field margins closest to fields containing wheat stubble from the previous season. The adult emergence and flight continues for three to six weeks, with adults beginning to emerge in May and can still be present in early June. Females lay eggs immediately upon emergence and typically live about 1 week. They preferentially select the largest wheat stems available and insert eggs into the first available internode or when a stem is fully developed, below the uppermost node. If sawflies are abundant, eggs may be laid in smaller stems, and multiple eggs may be laid in a single stem. However, only one larva will survive in each stem due to cannibalism. Females lay an average of 30 to 50 eggs, depending on the size
of available host stems. Eggs are difficult to detect because they occur inside the stem.

Sawfly larvae are always found within the stem and will assume an S-shaped position when taken out of the stem. They move slowly down the stem as they feed, for approximately 30 days. Sawfly larvae are cream colored, have a broad head, and are ½ to ¾ of an inch in length when fully grown. When they are mature they move down towards soil level and cut a V-shaped notch around the interior of the stem. They then seal the interior of the stem just below the notch with frass and move down near the crown. The upper stem often breaks just prior to harvest at this weakened notch. The remaining stem containing the overwintering chamber is referred to as the "stub". The larvae overwinter in the stubs, slightly below soil level, before pupating in early spring. They produce a clear protective covering that protects them from excess moisture and moisture loss.

The presence of wheat stem sawfly can be verified by splitting the suspected stem from top to bottom and examining the interior of the stem. If the stem is packed with a sawdust-like material, the stem was infested with a wheat stem sawfly larva. The sawfly larva will likely still be in the stem in a chamber just above the crown. Another clue to the presence of infested wheat is the occurrence of a darkened area on the stem just below the nodes. This symptom results from the internal feeding of the sawfly and can be used to detect the level of infestation without having to split each stem. As wheat approaches harvest, the stems of the infested tillers may begin to lodge. The proportion of infested stems that lodge depends on weather and plant conditions. Both the lower end of the loose stem and the remaining stub have a distinct uniform cut at the break site, and both ends will have a saucer-shaped appearance with the hollow stem packed with sawdust. Adults can be sampled with a standard insect sweep net, and a pheromone is available.

The most dramatic impact of the wheat stem sawfly is the lodging of damaged stems and the subsequent losses from not being able to completely harvest these stems. This damage is very apparent at harvest time and will be easily observed by the combine operator. However, not all infested stems will break off and lodge. Yield loss of five to ten percent due to unrecoverable wheat heads are common. In addition to losses from lodging, sawfly larvae cause physiological damage of 10 to 20 percent to the infested stems.

The wheat stem sawfly can use several hollow stem wild grasses as hosts, including quackgrass, smooth brome and wheatgrasses. The sawfly will not damage corn or broadleaf crops. Cereal crops other than wheat are not adequate hosts for the wheat stem sawfly to complete its development even though eggs may be laid in the stems of these grasses.

Tillage reduces wheat stem sawfly survival, however, its impact on overall sawfly abundance and on damage to the next wheat crop is variable. Shallow tillage after harvest lifts the crowns and loosens the soil around them. This maximizes larval exposure to the late summer dryness and winter cold, increasing mortality. Intense tillage that buries stubble also reduces sawfly survival, but to a lesser degree. Intense tillage may interfere with important biological control agents and will increase the risk of soil erosion. No-till has been linked to many of the recent wheat stem sawfly problems in the region. However, the advantages of controlling the sawfly with tillage must be weighed against the considerable benefits of no-till.

Planting attractive varieties of trap crops such as barley, oat or triticale along the edge of wheat fields may be effective in decreasing damage and reducing the number of sawflies the following year. The sawflies will oviposit in the trap crop, but the larvae will be unable to complete development. Additionally, the trap crop can be removed as hay to increase sawfly mortality. This method is especially effective when the sawfly abundance is low to moderate and significant infestations are limited to the field margins. However, when sawflies are abundant, females may move past the trap crop and into the wheat to oviposit, resulting in significant damage.

Planting wheat in larger blocks as opposed to narrow strips is another cultural practice that may reduce sawfly damage potential. This minimizes the amount of field border adjacent to stubble where sawfly adults will be emerging, and thus, the part of the field most vulnerable to infestation. Sawflies are not strong fliers and tend to fly only until they reach a stem that is suitable for egg laying, which is the basis for this practice. Though the soil erosion benefits of planting in narrow strips may be reduced, larger fields are still a viable option if erosion is addressed by no-till practices.

Solid stem spring wheats have been successful at reducing the amount of damage from the wheat stem sawfly. However, this resistance is influenced by environmental conditions, and yield potential may be lower for these varieties. No winter wheat varieties adapted to the central High Plains region have solid stems; however, Montana has recently released the first solid-stemmed winter wheat varieties.

Several natural enemies to the wheat stem sawfly have been noted in the northern plains, and these are thought to be important mortality factors. The presence and effectiveness of natural enemies in the central High Plains has not been determined.

Currently available insecticides are ineffective and cost-prohibitive. The most promising strategy seems to be control of adults to prevent egg laying. However, the prolonged flight period likely would require repeated treatments and there is no evidence for the effectiveness of this approach. Using solid-stemmed cultivars and cultural controls are currently the most effective alternatives.

Hessian fly, Mayetiola destructor (Say)

Hessian fly larvae are small, 4.8 millimeters (3/16 inch), greenish-white, legless, headless maggots found underneath lower leaf sheaths. The pupal stage appears as a small, 4.8 millimeters (3/16 inch), brown seed-like cases containing a maggot, often referred to as a "flaxseed." Adult flies have a red-brown to dusky-black body and dusky wings. They resemble mosquitoes in form and are about four millimeters (1/6 inch) long.

Hessian flies overwinter as flaxseeds in volunteer or fall-sown wheat. After adults emerge in the spring they mate, lay eggs, and die after one to two days. Females lay eggs on the upper leaf surfaces that hatch in about three to 10 days. Newly hatched maggots crawl down the leaf and enter the plant at the junction of the sheath and stem. There may be one or more generations in the spring and in the fall.

Maggots feed by rasping plant tissue and sucking plant juices that ooze from the irritated surface of the stems of wheat and barley. Plant tissues near feeding sites are stunted and abnormal. Leaves may appear thickened, erect and bluish green in color. The central stem is often missing. Infested stems usually break over at the time of head formation.

There are tolerant and resistant wheat varieties available. Some adapted varieties have moderate resistance.

Small, parasitic wasps attack Hessian fly maggots and may be important in suppressing populations. Currently, there are no management practices for increasing parasite populations.

Delayed planting has been used to manage Hessian fly successfuly in some states, under conditions where soil erosion is not a risk. Deep plowing of infested stubble will reduce numbers of surviving flies. Crop rotations that include barley or other crops should reduce fly populations.

Neonicotinoid seed protectants are effective against Hessian fly. Also, studies in the southeastern United States indicate that well-timed pyrethroid applications can be effective as a Hessian fly rescue treatment.

Wheat midge, Sitodiplosis mosellana (Géhin)

The wheat midge was introduced to North America in the early 1800s. It is a key pest in the northern Great Plains, primarily northern Montana and North Dakota, and in Canadian wheat production areas. Infestations have not been seen in more southerly growing regions.

Wheat midge is a small (approximately 3 mm long), delicate, mosquito-like orange fly. Adults emerge over a four to six week period around the time of wheat head emergence and flowering. Females fly at dusk when temperatures are above 59°F and wind speed is below 6 mph. During the day, they rest within the humid crop canopy. Eggs are deposited on florets or developing kernels just before anthesis. These hatch in four to seven days and the orange-colored larvae feed on developing kernels. Individual kernels can support several larvae. Mature larvae complete their feeding in two to three weeks, dropping to the soil in August after either rain or a heavy dew. They overwinter in cocoons in the soil. There is one generation per year.

The wheat midge cocoons are easily transported on soil adhering to cultivation or harvest equipment. Larvae can remain dormant in the soil for several years if conditions to induce pupation do not occur.

Wheat is the preferred host of wheat midge and is susceptible between heading and flowering stages. Barley is not susceptible to wheat midge. The larvae feed on the developing kernel, reducing grain size by 30 to 50 % per larva. In addition, damaged seeds are more susceptible to pathogen invasion, may fail to germinate, and may produce weak seedlings when they do germinate.

Wheat midges are attracted to wheat that is between heading and flowering. Monitoring efforts should begin with head emergence through completion of flowering. Scouting for wheat midge is best done by visually inspecting fields on warm nights (59°F or above) at dusk (9-10 p.m.), when females are depositing eggs. Females fly in an irregular pattern over the canopy and tend to flutter between plants. The number of adults on four to five wheat heads should be counted on a minimum of four sites per field.

Wheat midge may be confused with lauxanid flies, a much stouter yellow fly, more closely resembling a housefly and which has a much stronger, more direct flight pattern. Lauxanids tend to sit on plants horizontally or with their head pointing down where wheat midges generally sit on plants with their heads pointing up. If one female per four to five heads is found, and 30% to 50% of the first heads are flowering, insecticide application will likely provide an economic return. Optimum control will be achieved when 70% of the crop is in the heading-to-flowering stages. When more than 80% of heads are flowering, application is not recommended due to reduced insecticide efficacy and for protection of the parasitic wasp that attacks midge eggs.

Crop rotation to winter wheat, barley or a non-host crop can prevent wheat midge population build up. Surveys of overwintering midge cocoons in the soil can help determine if it is necessary to rotate to one of these crops. Early seeding can result in earlier crop maturation, making the crop less attractive during the midge flight. Later planted spring wheat crops are at the greatest risk for midge infestation.

Brown wheat mite, Petrobia latens (Müller)

Brown wheat mite (BWM) spends the summer in the soil as a white egg that is resistant to hot, dry conditions. In the fall, as temperature and moisture conditions improve, these eggs start to develop and hatch after 10 days incubation. Females follow in about two weeks. These females lay round, red eggs which give rise to further fall (one or two) and spring (two or three) generations. As summer conditions return, a generation of females is produced which lay only the white oversummering egg. Both egg types are placed on soil particles near the base of the wheat plant.

BWM feeds during the day and spend the night in the soil. Their activity peaks at about mid-afternoon on warm, calm days (the best time to scout). This mite is not affected by cold temperatures, but populations are quickly reduced by driving rains of 1/3 inch or more.

Damage from BWM has been reported from a wide variety of crops, including sorghum, onions, fruit trees, carrots, cotton, lettuce, iris, alfalfa and clover. Regionally, this mite is considered to be a pest primarily of fall-seeded small grains that are drought-stressed, and Kentucky bluegrass turf.

Chemical control is the only effective BWM management practice. The economic threshold is not well defined, but it is at least several hundred mites per row-foot in the early spring. The decision to treat is difficult since the mite is associated with drought stress. If it rains, mite levels may be significantly reduced regardless of the use of insecticides, while if it does not rain the crop yield may be so reduced by drought that it may not be worth treating. Also, if white eggs are present and red eggs are mostly hatched, the population is in natural decline, and treatment is not economically sustainable. Treatment selection is affected by considerations regarding co-infesting pests, primarily Russian wheat aphid and Banks grass mite.

Wheat curl mite: Aceria tosichella Keifer

The wheat curl mite is widely distributed throughout North America, attacking most cereals and several native and introduced grasses. Its economic importance relates to its ability to transmit wheat streak mosaic virus and High Plains viruses. These diseases affect both corn and wheat. In the central High Plains, most corn varieties have relatively strong resistance to both diseases. However, wheat varieties are generally susceptible.

The wheat curl mite is very small and has only two pairs of legs. In the field, mites can best be detected on plants with the aid of a 20x magnifier. Mites are nearly always found in protected areas of the plant such as a curled leaf or the leaf whorl, axil or sheath. On the leaves, mites often lie in the depressions between the leaf veins.

Wheat curl mites can build to very large populations rapidly when conditions are favorable. They go through two nymphal stages after hatching from eggs, and develop from eggs to adults laying eggs in about eight to 10 days (at 25°C). They rely on air currents to move them from plant to plant. They are very light and will float much like dust particles.

Wheat curl mite feeding on wheat causes the edges of young leaves to curl very tightly. The mites colonize this curl until the leaf is fully expanded and the curl is no longer tightly rolled. As the plant grows the subsequent leaf can be trapped in the previous leaf's curl causing distorted leaves. If the awns become trapped in the curl of the flag leaf, the head will become arched and seed set may be reduced on the head. Wheat curl mite damage is not normally considered important because mite populations heavy enough to cause serious plant damage usually occur only on plants that have serious virus infections and very limited yield potential.

Wheat streak mosaic is primarily a problem on winter wheat. Early symptoms of wheat streak are a yellow mosaic pattern of discontinuous lines on the youngest leaves. Later, more extensive yellowing, stunting and prostrate growth will develop in severely infected plants. Most corn hybrids are tolerant or immune to wheat steak mosaic virus, but a few inbred lines are susceptible. A field planted with a tolerant corn hybrid may serve as an infestation source in the fall to an adjacent winter wheat field. High Plains disease has recently been found to be a problem in corn and wheat in the western Great Plains. Only a few commercial corn lines are susceptible, but many sweet corn varieties are very susceptible. High Plains disease symptoms range from white spotting or a distinct mosaic to elongate chlorotic spots. Plants infected early may be severely stunted and die. The effects of both viruses being present together in wheat or corn are not well understood.

In order for wheat curl mites to move into the fall-planted winter wheat crop they must survive the summer in significant numbers on an over-summering host. Wheat curl mites are found on winter wheat from the fall until maturity the following summer. The mites are not capable of surviving for very long off green plants so there must be "green bridge" hosts for them to survive on until new wheat is present in the fall. The most effective green bridge results when hail occurs prior to wheat maturity and harvest. Kernels shelled out by the hail fall to the ground and in the presence of high moisture the seeds germinate rapidly and volunteer wheat begins to grow. Wheat curl mites present in the heads of the wheat then move to this new volunteer as the headed wheat dries down and matures. Infestations of mites establish colonies and transmit viruses to the volunteer. If this volunteer is not destroyed before the next wheat crop emerges in the fall, the mites will then move from the volunteer to the new wheat crop and transmit disease.

Corn and foxtail millet also are green bridge hosts. The ability of these crops to serve as a bridge is determined by environmental conditions and the maturity and condition of the bridge crop when wheat is emerging. Plants with only rank growth when wheat is emerging in the fall will have reduced potential for buildup of mite populations and movement. Other potential green bridge hosts include volunteers that emerges after harvest, and weed and other grass hosts for the mites. Significant populations of mites will only build in these green bridge sources when summer conditions are favorable for the mites.

Delayed planting lengthens the green bridge period, and allows less time for mites and virus to build up in the winter wheat in the fall. Plant at agronomically practical dates, and if fields are at an increased risk from mite infestation (i.e. next to uncontrolled volunteer, corn, foxtail millet etc.), plant these fields last or as late as practical. Corn hybrids that are tolerant to wheat streak mosaic virus and are good hosts to the mites should be planted with caution in areas where this disease is a problem in winter wheat.

Other arthropod pests

Grasshoppers (Orthoptera: Acrididae)

There are many different species of grasshoppers, with some having a greater pest potential than others. Correctly identifying a species is important because (1) species vary in their biotic potential and in their capacity for causing damage; (2) depending on their food habits, species may be either pests or beneficial; (3) certain species of pest grasshoppers are highly migratory and often pose a serious threat to distant crops; (4) species vary in their seasonal cycle (period of hatching, development, and reproduction), which, in turn, affects the timing of control treatments; (5) because current chemical and biological methods of controlling grasshoppers are more sophisticated, their effective use requires greater knowledge of the pests' life histories and habits; and (6) as environmental impacts of control are more finely evaluated, identification of species is important in the selection of management strategies. Common crop-damaging species include: differential grasshopper, Melanoplus differentialis; migratory grasshopper, Melanoplus sanguinipes; twostriped grasshopper, Melanoplus bivitattus; redlegged grasshopper, Melanoplus femurrubrum; and clearwinged grasshopper, Camnula pellucida. These prefer areas with a mix of grasses and broadleaf weeds. This includes wheat with adjacent or nearby undisturbed areas such as roadside ditches, crop borders, abandoned cropland, and over-grazed pastures or rangeland. Well-managed rangeland or pasture is usually not a source.

Most grasshoppers overwinter as eggs enclosed in a pod laid in the top few inches of undisturbed soil. These elongate pods may contain from eight to 30 eggs, and females may produce up to 100 eggs during the season. Grasshoppers hatch earlier in a warm spring, with the two-striped grasshopper being the earliest. It hatches from mid-to-late May, while the other species will from one to three weeks later. Hatching will continue well into June. Nymphs start feeding immediately and have the same host range as adults. Nymphs will mature into winged adults in five to six weeks. Adults can start dispersing from nymphal feeding areas by late June and early July. Few nymphs will be present by August. Grasshoppers feed during the day and rest during the afternoon and night on vegetation.

Grasshoppers are defoliators and damage wheat during two periods. First, wheat establishment can be impacted when grasshoppers move into the emerging crop in the fall. Also, grasshoppers can move into wheat in late spring when wheat is headed and cause serious damage.

Early-seeded winter wheat has the greatest probability of emerging while adults are still active. Light frosts may kill nearby broadleaf hosts, such as sunflower, causing the grasshoppers to move into wheat. Newly emerged winter wheat can be damaged to the point of stand loss.

Grasshoppers can move into and defoliate wheat in spring and early summer as well. The most serious damage occurs when they enter the maturing crop and the only available green tissue is the stem just below the head. Feeding at this time results in severed stems and complete loss of the heads.

Survey for nymphs after hatching because the problem starts outside the crop. A sweep net can be used to collect local grasshoppers to determine their age for treatment timing and to verify that they belong to one of the crop-damaging species.

If a crop-damaging species is present, the grasshoppers need to be counted in order the determine the need for treatment, which is done by the square foot method. Imagine a of one-square-foot area several feet in front of you and count the grasshoppers in or jumping out of this area. When first learning this method, it may be helpful to use a square-foot frame to help estimate the sample area. Make 18 separate counts at randomly selected sites that are 50 to 75 feet apart. Try to include all the plant species present and try to make counts on both north- and south-facing slopes.

Make abandoned or weedy areas less attractive to cropland grasshoppers by planting dense grass stands and reducing broadleaf plants. Delayed seeding of winter wheat where grasshoppers are a concern can reduce the potential for damage, but may not be effective if the first heavy frost occurs later in the fall. Doubling the seeding rate on the first and second passes with the drill may allow some plant survival in the field borders.

Once the number of grasshoppers per square yard has been estimated, use the tables below to determine if treatment is necessary. This is a general table for use in most field crops. Since adults rapidly consume a great deal of leaf material and the wheat plant has very little leaf area at this time, light to moderate infestations in the field and borders can result in stand loss in field margins.

Carbaryl-based bran baits can be applied in the crop pre- or post-emergence, or in adjacent areas with short, dry vegetation. The bait must be applied uniformly and reapplication may be necessary after rain or heavy dew.

Foliar insecticides applied to the crop margins and surrounding border areas to control nymphs will, in most years, provide adequate control. Treating 150 feet beyond the crop edge should be usually sufficient. Timing of fall border treatments is critical for optimum grasshopper control. The best time to spray the borders is just before the wheat emerges. If an application is made too early, there will be no residual insecticide activity in the borders when the wheat emerges, and grasshopper populations may build back up too quickly. If it is applied too late, some of the earliest emerging wheat may already be damaged. Treating a 150 foot border should be adequate under most conditions, however, season-long control when grasshoppers are abundant may require as much as a quarter-mile border treatment. Retreatment may be necessary, so monitor border areas and crop margins to insure that adults are not reentering the field.

Using insecticide-treated seed in the field margins can help control moderate grasshopper infestations in emerging wheat. Some damage still will occur, the rate of feeding will be reduced noticeably. Do not expect complete control if grasshoppers are abundant.

Table 7. Spring treatment guidelines for immature and adult grasshoppers in winter wheat (modified from University of Minnesota information).

	Immatures/yd^2			Adults/yd^2		
Rating	Margins	Field	Treat?	Margins	Field	Treat?
Nonthreatening	<25	<15	No	<10	<3	No
Light	25-35	15-25	No	10-20	3-7	Yes, if there is potential for head clipping
Nonthreatening	50-75	30-45	Depends on prices, crop condition	21-40	8-14	Yes, if there is potential for head clipping
Severe	>100	>60	Yes, monitor for retreatment	>41	>15	Yes, consider wider border treatments and monitor for retreatment

Table 8. Fall treatment guidelines for adult grasshoppers in winter wheat (modified from University of Minnesota information).

	Adults/yd^2		
Rating	Margins	Field	Treat?
Nonthreatening	<10	<3	No
Light	10-20	3-7	Yes
Nonthreatening	21-40	8-14	Yes, consider wider border treatments
Severe	>41	>15	Yes, use wider border treatments and monitor for retreatment

Bird cherry-oat aphid, Rhopalosiphum padi (Linnaeus)

Bird cherry-oat aphid is olive-green with a reddish-orange area across its rear end. It is a medium-sized aphid, with long antennae, long and dark tube-shaped cornicles ('tailpipes'), and dark-colored legs. Bird cherry-oat aphid may be one of the first aphids to colonize small grain plants in the spring, and often persists on winter cereal grains into late winter. It may overwinter as adults and nymphs within small-grain fields in southern areas of the High Plains and further north in moderate winters.

Bird cherry-oat aphid feeds on barley, oats, rye, triticale, and wheat by sucking plant juices. Its feeding may stunt plants and lead to yield loss, but it does not cause symptoms of yellowing and leaf curling. Bird cherry-oat aphid is a vector of barley yellow dwarf virus. Often, naturally occurring predators and parasites keep aphid populations under control.

Control of volunteer cereals before emergence of the new crop should be considered to reduce aphid population buildup. Bird cherry-oat aphids may be more abundant in spring wheat fields with no preplant tillage than in those with preplant tillage. Bird cherry-oat aphids routinely infest lower parts of young tillers and may be concealed by surface residue in fields without preplant tillage. Populations tend to be higher for early-planted winter wheat, and thus, planting date will impact the risk of infestation. For instance, planting winter wheat on 20 September or later in South Dakota reduces cereal aphid infestations and resulting BYDV incidence compared to earlier plantings.

Consider an insecticide application if birdcherry cherry-oat aphid abundance exceeds the levels indicated in Table 5.

English grain aphid, Sitobion avenae (Fabricius)

The English grain aphid is a yellow green to reddish brown, medium sized aphid with antennae greater than half the body length. The cornicles, ("tailpipes") are medium sized and black. Antennae and leg joints are dark colored.

This aphid overwinters mainly adult and immature females, but a few individuals may overwinter in the egg stage. With warm spring temperature they begin giving birth to live young. Males appear during the fall and mate with egglaying females.

English grain aphid colonies often develop on leaves and then move to heads in the boot stage. Aphids may cluster about the bracts of wheat heads or other grains. The wheat kernels may shrivel as a result of aphid feeding. This aphid is a vector of barley yellow dwarf virus.

English grain aphid are vulnerable to many kinds of common aphid parasites and predators. Common predators include lady beetles and damsel bugs.

Consider an insecticide application if English grain aphid abundance exceeds the levels indicated in Table 5.

Corn leaf aphid, Rhopalosiphum maidis (Fitch)

Corn leaf aphids are small, bluish-green aphids with a purplish patch around the base of the prominent cornicles (“tailpipes”). They are usually wingless and have short antennae. The aphids feed in groups, first appearing in the whorl. Adult females give birth to live young, they do not lay eggs, with about two nymphs being produced per day. Each nymph takes about nine days to mature at 21°C (70°F). As the aphids develop, they shed skins that remain as small gray flakes of debris on the host plants.

These aphids suck plant juices but damage is usually minor, however they are a vector of Barley Yellow Dwarf virus. Heavily infested leaves may wilt and have yellow or dead areas. Also, honeydew secreted by the aphid may accumulate on the plant, facilitating mold growth and giving the leaves a purplish-black appearance. Often, naturally occurring predators and parasites keep aphid populations under control. Consider an insecticide application if corn leaf aphid abundance exceeds the levels indicated in Table 5.

Rice root aphid, Rhopalosiphum rufiabdominalis

This aphid is similar in appearance to bird cherry-oat aphid, being olive-green with a red-orange patch surrounding the base of each cornicle (“tailpipe”). It is an occasional pest of winter wheat, occurring most frequently on seedling wheat in the fall and often is the first aphid found infesting wheat. It shows a preference to feed at or below the soil surface on the crown and roots of seedling plants. It is a vector of Barley Yellow Dwarf virus. They are suspected to be a cause of early-season virus infections. Control is not recommended.

Sipha maydis (Passerini)

Sipha maydis is new to North America. It is a small, pear-shaped, shiny brown-to-black aphid covered with lighter colored spines or hairs. The spines may not be visible without magnification. The cornicles, ("tailpipes"), are greatly reduced, similar to Russian wheat aphid, medium sized and black. The antennae and legs are lighter in color than the body.

Little is known about this aphid's life cycle. It likely overwinters mainly in the adult and nymph stages, but a few individuals may overwinter in the egg stage. Only females overwinter, and with warm spring temperature they begin giving birth to live young. Males appear during the fall and mate with egg laying females.

Sipha maydis is known to feed on a broad range of cool season grass hosts, including barley, wheat and oats. It is expected to occur in environments similar to those where greenbug and/or Russian wheat aphid are found.

Sipha maydis feeds on the upper sides of the lower parts of leaves and occasionally on stems and spikes. It may be tended by ants. Damaged leaves are yellowish and may be rolled or desiccated. This aphid is a vector of barley yellow dwarf virus and cucumber mosaic virus.

Sipha maydis is expected to be vulnerable to the same kinds of parasites and predators that attack other cereal aphids. Common predators may include lady beetles and damsel bugs.

Nothing is known regarding the effect of S. maydis on grain yield and quality. Consider an insecticide application if Sipha maydis abundance exceeds the levels indicated for bird cherry-oat aphid in Table 5.

Say stink bug, Chlorochroa sayi (Stål)

Say stink bugs are large insects with a triangular-shaped thorax. Adults are green during the summer and fade to brown or gray in the fall. Females lay small, cylindrical eggs in groups on plant surfaces which later hatch into nymphs. Nymphs appear as small, underdeveloped adults without wing covers. They undergo a gradual transformation over three to four weeks as they turn into adults. Stink bugs overwinter as adults underneath plant debris. There are one to three generation per year, depending on the length of the growing season.

Say stink bugs feed on weeds, particularly Russian thistle, and other wild hosts early in the growing season, then disperse into cereal grain fields during heading and grain fill. Other affected crops include alfalfa and sugar beet. Both adults and nymphs have piercing-sucking mouthparts, which they insert into plant tissues to suck out juices. Cereal plants are attractive starting in boot stage, and the bugs will continue to feed on maturing grains until they harden to the point where the mouthparts can no longer be inserted. Feeding during boot stage can result in sterile, sun-bleached heads. Early feeding can reduce both grain number and weight, while later feeding just reduces grain weight. Shriveled, deformed, and light grains are symptomatic of Say stink bug feeding.

Feeding by one or more stink bugs per head between late boot and milk stage can result in yield losses of 75% or more. Damage potential diminishes rapidly after milk stage, although small reductions in test weight have been observed from feeding during the dough stages.

Consider treatment if infestations exceed three to four adult stink bugs per 100 sweeps with a standard insect sweep net between boot stage and the milk stage of grain fill. Keep in mind that stink bug abundance may be much greater in field margins, and that stink bugs are highly mobile, so infestations may be temporary. Also, stink bugs may be attracted to late season secondary tillers that contribute little to yield.

Cereal leaf beetle, Oulema melanopus (Linnaeus)

Adult cereal leaf beetles, have a metallic blue head and wing covers, a red pronotum (neck), and yellow-orange legs. Newly laid eggs are elliptical, yellow, and about the size of a pin head; they reflect light well. Larvae are dark and slug-like in appearance. Their skin is yellow or yellowish brown and covered by a mass of slimy, dark, fecal material. Clusters of adult beetles overwinter in grass stems, grain stubble, cracks, and fenceposts. In the spring the adults emerge when maximum daily temperatures reach about 50°F. They immediately begin heavy feeding on wild grasses and then move to winter wheat and spring oats and barley if available. Adults prefer spring grains to winter wheat.

Within two weeks, the beetles quit feeding and the females begin laying eggs. One female may lay up to 300 eggs, depositing each egg on its side, singly or in rows of three or four. Normally, eggs are placed on the upper leaf surface near the midrib of the leaf. Eggs hatch in four to 23 days, depending on temperature. After feeding for 10 to 14 days, the mature larvae crawl down the plant into the soil to pupate. The entire length of larval feeding can extend beyond two weeks because of extended egg laying and egg hatch. In two to three weeks, a new generation of adult beetles emerge. The newly emerged adults feed on a variety of plants, but prefer succulent grasses, grain, and young corn. After about two weeks of feeding, the adult goes into a period of summer dormancy. As temperatures drop in the fall, the adult beetles search out suitable overwintering sites.

Most adult damage is easily outgrown by the plant. Larvae have a unique feeding pattern, they eat the upper layer green mesophyll cells, which create the green color and generate plant energy. They feed down to the cuticle, staying between the leaf veins. When viewed closely, elongated slits are apparent following the veins. This feeding pattern gives the leaves a "frosted" appearance when viewed from a distance.

Five species of exotic parasites have been used as biological control agents, including an egg parasite, Anaphes flavipes (Forester), and a larval parasite, Tetrastichus julis (Walker). The importance of these parasites is not clearly established, but T. julis has become established in northwestern Wyoming and Montana where cereal leaf beetle occurs. Parasitism by T. julis currently varies greatly (zero to 100 percent of larvae dissected, averaging 26 percent). This high variation may be due to the parasite's recent introduction.

Eggs near hatching and larvae are the target of insecticide control and are monitored by plant inspection since thresholds are expressed as egg and larvae per plant or per stem/tiller. Examine 10 plants per location and select one location for every 10 acres of field. Count number of eggs and larvae per plant (small plants) or per stem/tiller (large plants) and get an average number of eggs and larvae per plant or stem/tiller.

Boot stage is a critical point in plant development and impact of cereal leaf beetle feeding damage can be felt on both yield and grain quality. Before boot stage, the threshold is three eggs and larvae or more per stem/tiller. Larvae feeding in early growth stages can have a general significant impact on plant vigor. At boot stage feeding is generally restricted to the flag leaf, which can significantly impact grain yield and quality. The threshold is decreased at the boot stage to one larva or more per flag leaf. These thresholds may need to be lowered for malting quality barley because of its higher quality and high-grain-quality needs.

False wireworm (Eleodes spp.)

Several species of false wireworms occur in the Great Plains, including the prairie false wireworm. The flightless adults are known as darkling beetles. These are large black or reddish brown beetles, which can be recognized by the odd angle that the body is held at when they run. The larvae are similar in appearance to wireworm larvae. False wireworm adults lay their eggs in soil and most of the life cycle is spent in the larval stage. Larvae will be found at varying depths in the soil, depending on temperature and moisture. Life cycles are variable, lasting from one to three years.

False wireworms damage wheat by feeding on seeds, seedlings and young plants, resulting in lost stand. Yield losses occur if plant population losses are large enough to overcome the compensatory ability of the crop.

Cultural practices that promote rapid germination and seedling growth to shorten the period that the plant is most vulnerable to attack. Seed protectants labeled for wireworms also may be used to control false wireworms.

Wireworm (Coleoptera: Elateridae)

Wireworms are the larval stage of a family of beetles commonly called "click beetles." There are several species of wireworm and their life cycles may require one or more years per generation. The insects usually overwinter in the adult stage. Adults are brownish or even blackish in color, elongate and tapering toward each end but moreso toward the rear. The earliest stages of larvae are very small and white, later stages have a characteristic hard-shell appearance and a yellow-brown color. Mature larvae range from ½ to one inch in length, depending on the species.

Females deposit eggs in the soil among grass roots. When the eggs hatch the larvae feed on the roots of corn and other grasses, including wheat. The larvae mature in from two to five years. Fully developed larvae form pupation chambers in the soil and pupate. Adults emerge from the pupae and remain in the soil until the following spring.

Wireworms are found around the roots of wheat plants. Young wheat plants killed in irregular areas of the field is characteristic of their damage. This damage usually occurs in the fall and occasionally in the spring.

Clean summer fallow, fall tillage to crush pupae, and flooding to kill larvae are some examples of cultural practices. Generally, healthy, well-fertilized plants tend to outgrow wireworm damage. Several seed protectant products are labeled for wireworms.

Armyworm, Mythimna unipuncta (Haworth)

Mature armyworms, larvae are about 1.5 inches in length, smooth-bodied, and dark gray to greenish-black in color. They are characterized by five stripes, three on the back and two on the sides, running the length of the body. While the stripes on the back are variable in color, the stripes on the sides are pale orange with a white outline. The head capsule is remarkable for its "honeycomb" of black markings.

The armyworm is unable to survive winters in most of the region, and armyworm moths immigrate in early summer. They lay their eggs in rows or clusters on the lower leaves of various grass crops. Dense grassy vegetation is preferred for oviposition. Newly hatched larvae move with a looping (inchworm) action. Larvae feed at night and on cloudy days, and hide under crop debris during sunny periods. One or more generation may occur per year.

Armyworm feeding is mostly limited to grasses, although it will feed on a number of other plants when starved. In Colorado, armyworm is mostly a pest of corn and spring grains, with only occasional infestations occurring in winter wheat. In Wyoming and Nebraska, grass hayfields are periodically damaged.

Armyworm outbreaks only occur occasionally because they have many natural enemies that usually prevent the development of economically significant infestations. Because of the sporadic and unpredictable nature of armyworm outbreaks, management options are limited to the use of insecticides. Scout for armyworm in field margins, low areas with rank growth, or areas of lodged plants. Look for feeding damage, frass (droppings) around the base of the plant, or plant material that has been severed by armyworm feeding and fallen to the ground. Check for larvae in and under debris around damaged plants and in heads of barley or wheat.

Consider treating armyworm infestations in small grains if all of the following conditions are met

(1) Larval counts exceed the appropriate level in table 9.

(2) Larvae are 0.75 to 1.25 inches in length.

(3) Most larvae are not parasitized. (Look for white eggs behind the head or small brown cocoons attached to the body.)

(4) Leaf feeding or head clipping is evident.

Table 9. Action thresholds for armyworm by damage.

Situation	Action Threshold
Preheading — defoliation in lower leaves	5 larvae per square foot
Head clipping	2 larvae per square foot

Army cutworm, Euxoa auxiliaris (Grote)

The army cutworm has one generation per year and spends the winter as a partially grown caterpillar. It will feed on warmer days throughout the winter. In the spring it feeds more frequently and development proceeds more rapidly. As daytime temperatures rise, the army cutworm is found under soil clods and other debris during the day. In spite of spending so much time in the soil, this is a climbing cutworm that always feeds above ground.

After development is complete a small pupation chamber is built several inches below the soil surface. Moths emerge in May and June and migrate to higher elevations in the Rocky Mountains to escape high summertime temperatures. These moths are the "millers" that become a household nuisance following outbreaks. In late summer and early fall the moths return to the plains to lay their eggs in wheat fields and other cultivated areas. With sufficient moisture eggs hatch and larvae of the next generation start feeding as weather conditions permit.

Army cutworms have a very wide host range and will feed on most crops grown. They will feed on just about any green tissue presented to them, although they will show preferences when given a choice. For example, army cutworms have been observed to prefer broadleaf weeds in wheat fields to wheat. Damage to wheat occurs in the spring.

Because of the sporadic nature of army cutworm outbreaks, management options are limited to the use of insecticides. Consider treatment if counts are more than four to five per square foot. Pyrethroid insecticides have been the most effective treatments against this pest in university tests.

Fall armyworm, Spodoptera frugiperda (J.E. Smith)

Adult fall armyworms are about one inch long, with dark and light gray forewings mottled with light and dark spots. The hind wings are grayish to pinkish-white. Fall armyworm larvae have a white inverted

Y-shaped mark on the front of their dark head. They are smooth skinned and vary in color from light tan or green to nearly black, with three yellowish-white hairlines down the back. There is a wider dark stripe and a wavy yellow-red stripe on each side. The larval stage lasts from three to four weeks. Fully developed larvae are about 38 millimeters (1.5 inches) long. Unlike armyworms, fall armyworms feed during the day and night, but are usually most active in the morning or late afternoon.

Fall armyworm attacks winter wheat in the fall. Small larvae chewing on seedling leaves causes "windowpane" damage (small areas of the leave with no green tissue). Larvae usually hide in or around the base of seedlings. Within a few days the larvae are large enough to destroy entire leaves. Larger caterpillars do the most damage and are capble of destroying entire stands.

Early-planted fields are most likely to be infested. Fields with 25 to 30 percent of plants with windowpane injury should be re-examined daily and treated immediately if stand establishment appears threatened.

Pale western cutworm, Agrotis orthogonia Morrison

The pale western cutworm is a subterranean soft bodied caterpillar; grayish-white in color, unmarked by spots or stripes, with two distinct vertical brown bars on the front of the head capsule. A fully developed larvae is about 25 millimeters (one inch) in length.

Adult moths emerge from the soil in late summer and fall. Eggs are deposited in loose soil and usually hatch within two weeks. Hatch may be delayed for up to several months if moisture and temperature conditions are unfavorable. Larvae prefer loose, sandy or dusty soil and are found most easily in the driest parts of the field, such as hilltops. After feeding is completed, pale western cutworm larvae move to pupal chambers constructed several inches below the soil surface. Adult emergence can begin in late July.

Outbreaks are associated with dry conditions in the previous spring. If the preceding May and June had fewer than 10 days with ¼ inch or more of rainfall, then pale western cutworm populations can be expected to increase. If the preceding May and June had more than 15 such days, the cutworm will almost totally disappear. Rainfall events of more than ¼ inch tend to drive the cutworms to the soil surface and exposes them to more than usual levels of predation and parasitization.

Pale western cutworm is a subterranean cutworm feeding on stems at the crown. Small grains, corn, and a variety of other crops have been damaged by pale western cutworm.

Because of the sporadic nature of pale western cutworm outbreaks, management options are limited to the use of insecticides. Pale western cutworms seem to feed more under dry conditions, so yield relationships are difficult to define. Early detection of their presence is essential. Consider insecticide treatment if more than two to three larvae per foot of row are present. Pyrethroid insecticides have been the most effective treatments against this pest in university tests.

Wheat head armyworm, Faronta diffusa (Walker)

Wheat head armyworm larvae are grayish or greenish gray caterpillars with distinct white, green, and brown lateral stripes. They are distinguished from other armyworms by a relatively larger head with two straight dark bands over the top, and a slender body. The worms hide around the base of the plants during the day. The adult moth has a dark streak running the length of the forewing. The dark streak is interrupted near the middle of the wing and then continues to the outer wing margin.

This insect spends the winter as a pupa in the soil. Moths emerge to lay eggs in the spring, and larvae can be found in wheat by June. There are two generations of wheat head armyworm per year in northern regions. A second moth flight occurs in late August.

First generation wheat head armyworm larvae feed on foliage, and later feed on the ripening seed head. They feed on a variety of grasses and cereal crops and seem to prefer the heads. Timothy is considered to be a preferred host. Damage to wheat kernels is similar in appearance to damage by stored grain weevils, with kernels appearing hollowed out.

No chemical control data or economic threshold studies are available for this insect. Infestations are often limited to field margins.

Wheat stem maggot, Meromyza americana Fitch

Adult wheat stem maggots are yellowish-white flies, about five millimeters (1/4 inch) long, with three conspicuous black stripes on the thorax and abdomen and bright green eyes. The maggots are white and legless and have a pair of hook-like mouthparts.

Wheat stem maggot passes the winter in the larval stage, in the lower parts of the stems of wheat and other hosts. They pupate in the spring and the adults emerge in June. Females lay eggs, about 30 per female, on the leaves and stems of wheat and other hosts. The newly hatched maggots of this generation enter the leaf sheaths and tunnel into the tender tissues of the stem. Maggots feed for about three weeks before pupating. Another generation of flies emerges in midsummer to lay eggs on volunteer and other grasses. The fall generation emerges in late August to early September and lays eggs in the new winter wheat crop.

Wheat stem maggots construct two to three inch tunnels in wheat. Damage becomes evident during seed development when wheat heads and upper internodes turn white while the lower stem and leaves remain green. A single maggot will be found inside the straw just above the last node. The plant stem pulls out easily and if larvae are not found, the stem is usually cut off. This pest attacks cereal crops, including wheat, rye, barley, and oats. Other hosts include bluegrass, millet, timothy, and a range of other native and introduced grass species.

Parasites which attack wheat stem maggot include Bracon meromyzae Gahan and Coelinidea meromyzae (Forbes). These parasites are important in maintaining pest populations at low densities.

The use of delayed planting, following the dates recommended to escape Hessian fly infestation, is an effective management practice for wheat stem maggot. Destruction of volunteer plants is also recommended. Incorporation of non-susceptible crops such as corn, sunflower, flax, soybeans, safflower, oats, and legumes into rotation systems will reduce the numbers of this pest. The effectiveness of chemical control is unknown.

Winter grain mite, Penthaleus major (Dugés)

Winter grain mites are brown or black in color and have a red to orange anal pore on the abdomen. Their most striking feature is the four pairs of red legs, with the first and fourth pair longer than the middle pairs. The winter grain mite relies on a moist environment and, therefore, is rare in the region. Winter grain mites feed on cereals, including wheat, oat and barley, and grasses. They may also feed on vegetables, flowers, legumes and weeds.

Two generations of winter grain mites occur per year. They oversummer in egg stage, and eggs hatch in approximately 110 days, usually in October. The yellowish eggs are wrinkled in appearance and difficult to see. Egg hatch is favored by cool, wet fall weather. The optimum temperature for egg hatching is 44-55°F, and adult activity occurs mostly between 40 and 75°F. Newly hatched larvae have six legs and a pink or orange body. They feed on plant growth at ground level. Eight-legged nymphs molt three times, with the third resulting in the adult stage described above. This first generation of adults feeds higher in the plant and peaks in abundance during December or January.

The eggs laid by this generation give rise to the second generation. These eggs are known as winter eggs and hatch in 25 to 35 days. The second generation develops in the same manner as the first, with peak feeding from March to May. This generation produces the oversummering eggs. Each generation lasts approximately 100 days from egg to death of the adult.

Winter grain mite feeding causes silvery leaf discoloration due to the loss of chlorophyl. There should be several mites per plant as well as visible feeding damage for treatment to be considered. Scout for winter grain mite early in the morning or during cool, cloudy weather when this mite is most likely to be visible. Check for mites under crust and clods on the surface of moist soil under wheat plants. Under hot, dry conditions, scout several inches under the soil. Winter grain mites prefer to feed during cooler periods, such as sunset and into the night, and can be observed on the tops of plants during this time.

The winter grain mite is not considered a major pest and, therefore, few control methods are available. However, in areas where infestation has been significant, crop rotation has been effective in reducing mite populations. No effective biological control agents are known. Insecticide efficacy data are not available.

Banks grass mites, Oligonychus pratensis (Banks)

Fertilized females move into winter wheat in the fall as their summer hosts, especially field corn but also other grasses, begin to dry down. These overwintering forms are bright orange in color. With the onset of winter conditions, the mites move to the crowns of the wheat plant where they will feed until spring. In the spring small pearly white eggs are laid which eventually give rise to pale to bright green male and female adults. There will be continuous generations of mites on wheat and summer hosts until the return to winter wheat in the following fall.

Banks grass mite attacks a wide variety of grasses. In the High Plains, it is considered to be a serious pest of corn and an occasional pest of turf, sorghum and wheat. It produces heavy webbing to protect colonies consisting of eggs, immatures and adults. Damaged leaves first become yellow and then brown and necrotic. Heavy populations can kill small plants and reduce kernel size in larger plants.

Banks grass mite most commonly damages wheat in the fall in areas near maturing field corn. Insecticide applications to the field margin(s) bordering corn are often all that is necessary to prevent economic damage. Spring infestations in wheat are not common in the region.

Table 10. Wheat Arthropod Pest Prioritization

Pest	Priority						
	CO	KS	MT	ND	NE	SD	WY
Army cutworm	O	K				O	M
Armyworm	O	O				M	M
Bird cherry-oat aphid	M	K				O	M
Brown wheat mite	K	K				O	O
Fall armyworm	M	O				M	M
False wireworm	O	O				M	M
English grain aphid	M	M				O	M
Grasshoppers	O	O				O	O
Greenbug	M	O				O	M
Hessian fly	M	K				O	M
Pale western cutworm	O	O				O	M
Russian wheat aphid	O	M				M	K
Western wheat aphid	M	M				M	M
Wheat curl mite	K	K				K	K
Wheathead armyworm	M	M				M	M
Wheat midge	M	M				M	M
Wheat stem maggot	M	M				M	M
Wheat stem sawfly	K	?				O	K
White grubs	O	O				M	M

Pests rated as key (K), occasional (O) or minor (M).

Montana, Nebraska and North Dakota data had not been provided at press time, and will be added as they become available.

Disease Management

(Adapted from the High Plains Integrated Pest Management Guide for the Western High Plains, http://wiki.bugwood.org/HPIPM:Main_Page)

See Appendix D for cultural control and seed-treatment information

Diseases Caused By Fungi

Common Bunt (Tilletia caries and T. laevis)

Common bunt (also called stinking smut and common smut) occurs in all wheat-growing areas. Spores are seed- and soilborne as well as windborne.

Kernels in heads of affected wheat plants are replaced with grayish-brown sori that produce a fishy odor; the outer hull of infected wheat kernels may remain intact ("bunt balls"). Teliospores contain trimethylamine, a volatile, malodorous 'fishy' smelling chemical that is the basis for the term "stinking smut". Trimethylamine production varies among the different strains of this fungus. The pericarp (fragile outer covering) of infected wheat kernels remains intact until the infested field is harvested, at which time the pericarp ruptures, and powdery spores are released. Spores contaminate healthy seed at this time. Common bunt spore clouds are flammable and can combust during threshing. Plants infected by common bunt fungi may be stunted, but generally appear to be healthy until heads emerge. Diseased heads are slender and stay green longer than healthy heads and appear greasy. The glumes of infected heads spread apart. Formerly common, this disease is now controlled with seed certification programs and seed treatments.

The disease can be successfully controlled by planting high-quality seed free from the pathogens. Resistant varieties are available. Early fall planting when soils are warm (>60°F) can reduce common bunt infection, but is not advised because it can increase some insects and other diseases. Seed treatments effectively reduce seedborne common bunt.

Common Root Rot (Cochliobolus sativus, Bipolaris sorokiniana)

Common root rot (foot rot) takes the form of seedling blight, root rot and spot blotch. It occurs from September to June, during periods of moisture. Brown to black lesions occurs on primary and secondary roots and subcrown internode. Brown discoloration of crowns is observed. Yellowing of plants appear
in the spring. Infected plants have poor tillering and later may be spindly with small heads. Scattered pockets of dead and dying plants may be observed in April. Symptoms are usually more acute on wind-prone hills and knobs. The more common symptoms are those initially seen on the subcrown internode. These are small oval brown necrotic lesions that, as the plant matures, may coalesce to

encompass the entire subcrown internode. Annual losses of 3-5% from common root rot are typical in the High Plains region.

The common root rot fungus survives in the soil or in infected debris from previous crops. Because this fungus survives as spores directly in the soil, it can persist longer than many other root-disease organisms that rely mainly on survival in debris from previous crops. Some spores remain viable in soil after eight to 10 years. For that reason, and because many wild grasses are able to support low levels of the fungus, it is not practical to eliminate this pathogen from a field. Fortunately, this is not necessary. After two to three years in non-susceptible row crops, the spore level in soil is significantly reduced, and disease is considerably reduced.

Spores in the soil infect the growing roots and crowns and cause a discrete lesion or discolored infected spot. Severe disease is the result of multiple infections. The more spores there are in the soil the more lesions will appear. When many lesions are present on the crown and root system, the plant is weakened and yield reduced. New infections continue to arise throughout the growing season, so that crown roots and side tillers also become infected. These lesions can lead to complete decay of the root system.

Cochliobolus sativus may be carried on seed and cause both reduced emergence and more severe seedling blight. The seed-borne infection plays little, if any, role in adult-plant root and crown rot.

Management includes planting adapted varieties, appropriate crop rotation, planting into a firm, mellow seedbed, controlling weeds in summer fallow, planting good quality seed, and use of recommended sowing dates. All of these practices also reduce the risk of winter injury. Seed treatment fungicides provide an early window of protection in the fall against common root rot.

Dryland Root Rot (Fusarium culmorum, F. pseudograminearum, F. graminearum)

The roots, crown, and lower nodes and internodes of wheat will turn brown on infected plants. Discoloration may extend up to two internodes above the soil, and cottony pink-colored mycelium will often grow within or between the culm and lower leaf sheath.

Dryland root rot can be managed through shallow seeding, seed treatments and planting clean seed. Avoid excessive nitrogen fertilization. Crop rotation with a broadleaf, non-host crop also can help reduce disease

Rhizoctonia solani persists in the soil or on the soil surface for long periods of time, and is widespread. Early-season infection is characterized by localized circular areas in wheat fields with stunted, dull grayish-blue or dead wheat plants. Infected roots typically have abnormally pointed, and sometimes discolored tips (“spear-points”). Later-season infection is characterized by oval lesions with dark brown borders and pale centers on the lower portions of wheat stems. The ends of the lesions are typically pointed and stems may be girdled. Plants appear stunted, discolored, and may produce a "white head" of underdeveloped kernels or exhibit delayed maturity. Affected wheat plants may lodge or fall over, typically at the 2nd or 3rd internode from the soil surface. Mycelium beneath lesions on maturing stems is often abundant and ashy-white in color. Leaf sheath tissue rots, leaving a characteristic, diagnostic hole rather than the fibrous net seen with foot rot. Small black sclerotia may develop in the space between the stem and leaf sheath. This disease may be misdiagnosed as take-all root rot, Pythium root rot, drought or nutrient deficiency.

Disease development is favored by cool, wet weather and planting soon after a glyphosate application. Glyphosate inhibits the defense system of the plant (volunteer wheat or grassy weeds), allowing it to build to large populations in the roots. Reduced tillage (including "no-till") also favors disease development by the increased retention of host debris and lack of soil disturbance to break hyphal networks. Rhizoctonia root rot is more likely to develop on plants growing in periphery of wet spots and in areas where there was standing water over the winter.

Rhizoctonia root rot can cause large yield losses of wheat, including stand reductions up to 100%. Primary inoculum originates from soil-borne sclerotia or from mycelium in host debris, volunteer plants or weeds. Severe infections cause premature ripening and lodging of wheat plants. Root infections can occur at any time during the growing season, given favorable conditions.

Delay planting two to three weeks after tillage or an herbicide (especially glyphosate) application to allow the plant material to decay. Rhizoctonia solani is active in the top four to six inches of soil, thus soil tillage helps to breakup pathogen mycelium and helps to promote the breakdown of infected crop residue.

Management practices that favor good, vigorous growth of the wheat plant generally limit damage due to Rhizoctonia root rot. Avoid planting in wet soils or in areas where the soil will be kept overly moist during seed germination and seedling development. Late autumn shallow seeding of wheat tends to suppress disease development. Rotate wheat with legumes or other non-host crops. Maintain a balanced soil fertility program; research indicates that zinc helps to reduce the incidence of Rhizoctonia root rot in wheat. Infected winter wheat plants may be able to outgrow Rhizoctonia root rot by production of new roots. Effective and economical chemical controls currently do not exist for control of Rhizoctonia root rot of wheat, but some seed treatments may be partially effective.

Fusarium Head Blight (Fusarium graminearum)

The primary fungus causing fusarium head blight (scab) is Fusarium graminearum. Fusarium pseudograminearum and Fusarium culmorum also may be involved. Symptoms may include tan to brown discoloration at the base of the head, diseased spikelets (partial bleaching of the head) or entire head turns white, pink/orange color on the surface of the glumes in the presence of moisture, infected kernels are shriveled, white, and chalky in appearance.

This disease results in low yields, low test weights and low seed germination. Infected kernels contain vomitoxin (deoxynivalenol). The threshold level for human food is 1 ppm and feed is 2 ppm. There are higher tolerances for contaminated grain as livestock feed. There is a zero tolerance for vomitoxin in malt barley.

Fusarium head blight is introduced into a field through infected seed or wind-borne inoculum. The causal agents can overwinter on crop stubble such as wheat, barley, and corn, and spread rapidly by rain splash and wind. The head, and in particular the open female flower during anthesis, is most susceptible to infection. Some infection can occur during kernel development. Moist environmental conditions, including rain, irrigation, fog, and higher evening dew periods, favor spore production and infection.

Management practices include planting healthy, high germination seed, rotation to broadleaf crops, withholding irrigation prior to and during flowering, and incorporation of cereal straw or corn stubble to accelerate degradation and inoculum destruction. Scab tolerant varieties are available in some areas.

Treated seed should be considered when planting into fields (1) with an history of scab, (2) An high crop residue of wheat, barley, or corn that resides on the soil surface, or (3) a wet environement during flowering is predicted due to weather or irrigation. Foliar sprays must be applied at the first sign of anthers extruding from the head to protect the flowers from infection.

Karnal Bunt (Tilletia indica)

Developing wheat kernels become infected and are completely or incompletely converted into smut spores. Typically, only a few seeds per head are infected. Infected kernels are filled with brownish-black, fishy-odored teliospores. Teliospores persist in soil and on wheat seeds. Soilborne teliospores are the principal source of primary inoculum. Teliospores germinate at or near the soil surface in response to free moisture and produce primary and secondary sporidia. During periods of cool humid or wet conditions, sporidia are wind-dispersed and infect spikelets by direct penetration of the glumes and ovary wall.

Karnal bunt is difficult to control in areas where temperature and moisture conditions that favor the pathogen regularly occur. Chemical seed treatments will inhibit the germination of seedborne teliospores. Certain fungicides applied at heading protect against spikelet infections. No cultivar is known to be immune to the disease, however durum wheats and triticales are less susceptible than bread wheats.

Prevention via quarantine methods currently is used to keep Karnal Bunt from becoming established in the major wheat growing areas of North America.

Leaf Rust (Puccinia triticina)

Leaf rust is a widely distributed diseases of winter wheat. In this region is appears mid-May to early July and September to October. Spores produced by Puccinia triticina appear in pustules formed on wheat foliage, stems and/or heads in the fall or spring. Some chlorosis or necrosis also can be associated with this disease. As wheat nears maturity, the orange-colored spores are replaced with dark-grey to black teliospores.

Several varieties with at least a moderate level of resistance and differing parentage, maturity and disease reaction should be planted. Fungicide use should be based on severity rust in states to the south, maturity of the winter wheat crop (late crops more at risk), susceptibility of the varieties being grown, forecasts for wet weather, use of irrigation, early detection of rust, and yield potential. The objective of fungicide treatments is to protect the flag leaf.

Loose Smut (Ustilago tritici)

Loose smut becomes noticeable just after heading. Diseased heads emerge before healthy ones. Diseased heads are blackened and very distinctive from green, healthy heads. Within a few days, the spores are dislodged so that only the bare spikelet remains. Unlike common bunt and karnal, spores of loose smut have no odor.

Infections occur only during flowering and are favored by wet weather and cool to moderate temperatures. The loose smut fungus is strictly seedborne. It comes into the field within the embryoes of seed. Once the infected seeds germinate, the fungus again becomes active. It grows upward in the plant within the growing points to where the heads are forming. Where the kernels should be, the fungus forms a loose mass of spores. The formation of these spores is timed so that they can be blown to the open flowers of neighboring plants, where they invade the ovaries to repeat the cycle.

Yield loss is directly proportional to number of heads infected. Usually losses are less than 1%, but losses up to 27% have been reported.

Plant certified seed that is free of the pathogen. Seed also can be treated with systemic fungicides.

Powdery Mildew (Blumeria graminis)

Powdery mildew of wheat is caused by by strains of Erysiphe graminis f. sp. tritici that attack only wheat. This pathogen is found in humid and semi-arid environments throughout the world, and survives between wheat crops on volunteer wheat as cleistothecia on crop debris and as conidial spores in warm climates.

Symptoms include white cotton-like mycelium on leaves that later turn a dull gray-brown. They can appear anytime after seedling emergence, and are usually most severe on the upper surfaces of lower leaves. The opposite side of the leaf normally appears chlorotic. Fungal fruiting bodies (cleistothecia) are visible on infected plants as distinct brown-to-black dots within mildew colonies. The pathogen reduces wheat photosynthetic area and vigor, utilizes host nutrients, and increases water transpiration. Heavily infected plants can be killed. Yield losses from powdery mildew can approach 40% under favorable conditions, and are most severe when infection occurs when disease develops before or during flowering.

Resistant varieties provide a practical disease control strategy, but resistance can quickly breakdown if a new race of the fungus develops. The crop should receive adequate fertilization. Crop rotation and sanitation of wheat residue and volunteers can reduce pathogen survival, but airborne conidia and favorable environmental conditions nonetheless can result in severe disease.

Fungicides effectively control powdery mildew, but may be cost prohibitive. Certain seed treatments control seedling infections.

Septoria Leaf Blotch (Septoria tritici, and others)

Septoria leaf and glume blotch, economically important in most wheat-growing regions, is caused by Septoria tritici, S. nodorum, and S. avenae f. sp. tricicea. Septoria tritici appears to be the most important in the High Plains. Wheat strains of Septoria spp. are also weakly virulent on barley, rye, and other grasses, especially bluegrass. The pathogen survives on crop debris, seed and volunteer wheat, but airborne ascospores also can serve as primary inoculum.

Symptoms can develop throughout the growing season on all above ground plant parts. Initial symptoms include chlorotic specks, usually on leaves in contact with the soil. These later expand into irregularly shaped necrotic lesions. Lesions tend to be restricted laterally and form parallel to each other. Lesions also can be water-soaked and later turn dry, yellow and then red-brown. Glumes and awns can sometimes be infected. Yield losses of 10 to 20% are common under favorable conditions, but yield losses in the High Plains average 2 to 6% annually.

No resistant varieties are available, but some varieties possess some level of resistance and should be planted if available. Early maturing varieties tend to be most susceptible. Plant only high-quality pathogen-free seed. Bury or otherwise destroy wheat stubble and volunteers. Reduced or no-till wheat production increases Septoria leaf blotch, but longer rotations (at least two years) reduce pathogen carry-over. Discourage thick, lush canopies favorable to the disease by increasing row spacing and avoiding excess fertilization and irrigation.

Seed treatment reduces seedborne inoculum and seedling blight. Foliar fungicides provide effective disease control, but generally are not economical for dryland wheat in most years.

Stem Rust (Puccinia graminis sp. tritici)

Stem rust has pustules similar to leaf rust that can be found on stems, leaves, and spikes. However, the spores of stem rust tend to be more of a brick-red to brown color rather than the reddish-orange spores indicative of leaf rust. Pustules of stem rust also tend to be larger and sometimes more diamond shaped compared to leaf rust, which are more circular. Yield reduction depends on time of infection, fungal strain, variety, and disease severity.

Several varieties with at least a moderate level of resistance and differing parentage, maturity and disease reaction should be planted. Fungicide use should be based on severity rust in states to the south, maturity of the winter wheat crop (late crops more at risk), susceptibility of the varieties being grown, forecasts for wet weather, use of irrigation, early detection of rust, and yield potential. The objective of fungicide treatments is to protect the flag leaf.

Stripe Rust (Puccinia striiformis sp. tritici)

Symptoms initially appear as chlorotic flecks or patches on leaves. Small, yellow-orange pustules develop. In seedlings, distinct stripes do not develop, but on more mature plants that have begun stem elongation, pustules form in stripes between leaf veins. As plants mature, the yellowish-orange pustules turn black.

Several varieties with at least a moderate level of resistance and differing parentage, maturity and disease reaction should be planted. Fungicide use should be based on severity of rust in states to the south, maturity of the winter wheat crop (late crops more at risk), susceptibility of the varieties being grown, forecasts for wet weather, use of irrigation, early detection of rust, and yield potential. The objective of fungicide treatments is to protect the flag leaf, however, stripe rust early in the season (tillering stage) also will lead to yield loss.

Tan Spot (Phyrenophora tritici-repentis)

Tan spot lesions on leaves characteristically have a small, tan-to-brown center, which is surrounded by a yellow circular border. As leaves mature, lesions expand, kill tissue, and can impart a tannish hue to leaves. Lesions, which initially are found in late winter or early spring on lower leaves, result from infection by spores released from fruiting bodies (raised black fungal structures) that formed on wheat residue left in the field after harvest.

Crop rotation with non-host crops is effective, as is clean tillage. Stubble management that leaves a residue cover should allow residue breakdown within a year. Systemic fungicides also can be used to reduce disease severity. Fungicide use should be based symptom severity, presence of nearby infected residue, maturity of the winter wheat crop (late crops more at risk), forecasts for wet weather, and yield potential. The objective of fungicide treatments is to protect the flag leaf.

Take-All (Gaeumannomyces graminis var. tritici)

Take-all is a major disease of autumn-seeded wheat. A superficial, brownish-black, shiny mycelial mat is found on roots and lower stems. Under prolonged moist conditions, the leaf sheath surrounding this mycelial plate may become speckled in appearance. Typical symptoms are not always produced in infected plants, making diagnosis of Take-all more difficult. A close examination of roots for internal and superficial dark colored mycelium and runner hyphae may be necessary. Gaeumannomyces graminis var. tritici persists in infected host plants and in host debris. Wheat roots become infected as they grow through the soil near infested debris. During hot and dry conditions, the pathogen becomes inactive.

The pathogen is favored by neutral to alkaline soils, especially those deficient in nitrogen and /or phosphorus, poorly drained soils, continuous cropping of wheat, and high levels of infected host residues.

Diseased stems are weakened at their base, causing them to lean and fall non-directionally (as in Foot Rot). Disease severity is related to the extent and time of infection of roots and stem (culm) bases. Many wheat plants can withstand mild root infections and appear symptomless; severely infected wheat plants are stunted and ripen prematurely, significantly reducing seed yields.

The sudden development and appearance of whiteheads after a period of hot, dry weather gives the impression that the disease develops late in the season and that disease development is favored by hot, dry conditions. However, pathogen activity is actually favored by cooler temperatures earlier in the growing season, and later occurring hot, dry weather accelerates the water stress and premature ripening.

No wheat or barley cultivars are resistant to infection by the take-all fungus. Crop rotation is the best way to control take-all. Tillage fragments and hastens the decomposition of the infected residue. Adequate fertilization is recommended.

Diseases Caused By Viruses

Barley Yellow Dwarf

This disease is caused by numerous viruses in either the genus Luteovirus or Polerovirus that are transmitted by most cereal aphids (see arthropod management above) with the notable exception of Russian wheat aphid. Symptoms may appear in the fall or the spring, depending on the time of infection and weather. Infections in fields often appear in circular areas, with the most severely stunted and discolored plants occurring at the centers of the circles. Seedling infections may be lethal and cause older leaves to become bright yellow. With spring infections, flag leaves may exhibit a reddish-purple or yellow discoloration.

Resistant varieties are available. Delayed planting reduces the time available for infection in the fall, which typically results in the most severe disease. Removal of grassy weed hosts also can help. Control of aphid vectors with seed treatments can reduce early spread of the disease. Properly timed foliar sprays also can reduce disease spread.

High Plains Disease

This disease is caused by the High Plains virus (Wheat Mosaic Virus), which is transmitted to wheat by wheat curl mite, Aceria tosichella. Infected leaves exhibit a mosaic pattern and chlorotic spots. Co-infection with Wheat Streak Mosaic virus results in plants that are mottled, chlorotic, severely stunted, and, possibly, dead plants. Mottling and a yellow mosaic pattern in parallel, discontinuous streaks develops on leaves.

See the wheat curl mite section above for management recommendations.

Wheat Soilborne Mosaic

Wheat Soilborne Mosaic Virus is transmitted into wheat roots via a soilborne fungus-like protist, Polymyxa graminis. Symptoms of wheat soilborne mosaic appear in early spring. Symptomatic plants usually are observed in low-lying, wet areas and are stunted, with yellowish-green foliage. The foliage will have small green spots or islands on a light green or yellowish green background.

Planting resistant varieties is the only effective available management tactic.

Wheat Spindle Streak Mosaic

Wheat Spindle Streak Mosaic Virus also is transmitted into wheat roots via a soilborne fungus-like protist, Polymyxa graminis. Wheat plants infected by Wheat Spindle Streak Mosaic Virus generally appear in early spring. Infected plants most often are in low-lying wet areas and appear similar to those infected with Wheat Soilborne Mosaic Virus. However, plants infected with wheat spindle streak mosaic will have leaves that are light to medium green with yellowish spindles or streaks.

Planting resistant varieties is the only effective available management tactic.

Wheat Streak Mosaic

Wheat Streak Mosaic Virus is transmitted to wheat via the wheat curl mite, Aceria tosichella. Leaves of infected plants generally appear light to medium green with yellow streaks, which usually are longer than those associated with Wheat Spindle Streak Mosaic Virus. Varying degrees of chlorosis and necrosis occur.

A few wheat varieties resistant to wheat streak mosaic are available, but resistance may be temperature dependent. See also the wheat curl mite section above for additional management recommendations.

Wheat Disease Activity Calendar

It is difficult to summarize disease activity in the Great Plains due to wide differences in climatic conditions. Often, the overwintering structures or vectors are present throughout the growing season, and outbreaks are dependent on weather conditions that may or may not encourage disease development.

Wheat Foliar Fungicide Efficacy.

The USDA-CSREES NCERA-184 Committee (Management of Diseases of Small Grains) compiles an efficacy summary for foliar fungicides in wheat. The most recent of these is provided below, in lieu of individual state data.

Weed Management

A well-designed weed management program should include as many of the following tactics as practical: delayed planting and harvest, crop rotation, use of quality seed, good seed-bed preparation and other cultural practices that promote a vigorous, healthy crop, tillage, and chemical control before and after harvest with herbicides. Field monitoring (scouting) is an important way to determine the spectrum of weeds present in a field. An important activity in scouting for weeds is preparing a weed map. A weed map is a diagram of the field with notations on weed location, identification and the estimated size of the weed-infested areas. Maps that show locations of different weed infestations are helpful in planning short- and long-term weed control programs. A good weed map may be a way of catching a herbicide-resistant weed problem before it becomes widespread.

A weed map should be made prior to treatment either in the fall or early spring. Knowing the location of annual weeds aids in spot treatments and will allow efficient and timely herbicide application. Growers may be better prepared to select the most appropriate herbicide and proper treatment rate.

Another time to prepare a field weed map is during the last visit to the field prior to harvest. Familiarity with the location of perennial weeds such as bindweed will help the grower to develop special tillage programs and future spot treatments with herbicides. Information taken earlier on winter weeds such as mustards will be important in preparing a weed map. Many of these weeds mature before the last trip over the field. Weed maps of annual weeds permit long-range, integrated annual weed control planning, including spot treatments, tillage, and timeliness of herbicide applications.

Tillage has traditionally been a method to control weeds in winter wheat. Clean till is still widely practiced, but more recently, there has been a shift to no-till, strip till, or other minimum tillage systems, because of the expense for fuel and wear and tear on equipment. Much of the tillage expense saved by no-till wheat production will be spent on chemical weed control, but by planning the switch in advance, producers can keep their fields with problem weeds in tillage and only move cleaner fields into no-till production. Producers should avoid no-tilling fields infested with weeds that have no good in-season chemical control measures (e.g. jointed goatgrass, feral rye, rescue grass etc.). Still, there are solutions to even these problem weeds, such as crop rotation or using the Clearfield wheat production system (see below).

Sanitation

Proper cleanout of a combine can reduce the spread of undesirable weeds. Also, if hay is being purchased to supplement cattle feeding in fallow fields, make sure the hay is certified.

Chemical Control

Chemical control in winter wheat involves the use of pre-emergent (PRE), early pre-plant (EPP), pre-plant incorporated (PPI) and post-plant herbicides. There is also a newer technology available, so called herbicide-tolerant wheat, which allows certain herbicides to be sprayed post emergence on the crop that, without the tolerant trait, would have been significantly damaged.

A common one is Clearfield Wheat,® which consists of a herbicide-tolerant trait that was developed so Beyond® herbicide can be applied to any wheat plants containing the trait without causing crop injury. Clearfield is a non-transgenic wheat because it was developed using conventional breeding technique. It allows for the effective control of some weed species, but requires certain stewardship activities to preserve its effectiveness and avoid selection of herbicide-resistant weeds.

Weeds of wheat (Adapted from the High Plains Integrated Pest Management Guide for the Western High Plains, http://wiki.bugwood.org/HPIPM:Main_Page)

See Appendix E for cultural and chemical controls.

Broadleaf weeds

Blue mustard (Chroispora tenella)

This is a winter annual that germinates in the fall and produces a rosette with deeply lobed leaves, similar in appearance to a dandelion. It bears purple or blue flowers at the top of the plant in March through April. Leaves on the flowering stems are coarsely toothed and have wavy margins. The plant may grow from one to 1.5 feet in height. Seedpods mature in early summer.

Mustards bolt early, making control difficult. Herbicide applications should be made in late winter or very early spring before they bolt to effectively control them.

Canada thistle (Cirsium arvense)

This is a creeping perennial in the sunflower family. Flowers are usually purple but occasionally white and 1/2 to 3/4 of an inch in diameter. Seeds are about 1/8 of an inch long, flattened, brownish in color with a tuft of white hairs (pappus) at the top. Leaves are alternate, oblong or lance-shaped, and divided into spiny-tipped irregular lobes. Stems can reach one to four feet tall. Canada thistle has an extensive creeping root system. Seedlings form a rosette with irregularly lobed spiny leaves.

Canada thistle can form dense monocultures, displacing desirable vegetation and reducing available forage for livestock and wildlife. It also has a large economic impact due to its impact on crop yields and control costs.

The key to Canada thistle control is to stress the plant and force it to use stored root nutrients. Canada thistle can recover from almost any stress, including control attempts, because of root nutrient stores. Therefore, returning infested land to a productive state occurs only over time. Success requires a sound management plan implemented over several years.

Two weevils and a leaf beetle have been established for biological control of Canada thistle. Chemical control is most effective when combined with cultural or mechanical control.

Common lambsquarters (Chenopodium album)

This summer annual is a member of the goosefoot family. As a seedling, it has two long, linear-shaped cotyledons, and the first ovate-shaped true leaves are opposite. Mature plants have broadly triangle-shaped leaves with irregular, shallow-toothed margins. The stems can be green or reddish, are grooved, and can be smooth or hairless. Mature plants generally reach a height of two to six feet. At flowering, very small, green or gray-green flowers are tightly clustered at the tips of stems and branches. Seeds are mostly black, smooth and shiny. This plant only reproduces by seed, and once plants flower, they set seed over a relatively short period before they die. Common lambsquarters seeds can remain viable in the soil for several decades.

Cultural practices that help control common lambsquarters include anything that makes the crop more competitive and reduces the success of the weed. Such practices include selecting crops with quick emergence, altering planting dates relative to weed emergence, planting to narrow rows and using higher seeding rates for greater crop competition, placing fertilizer with the crop (not the weed), and implementing crop rotations that discourage summer annual weed success.

Photosystem II inhibitor and ALS inhibitor resistant populations have been reported.

False chamomile (Matricaria perforata)

This is an annual-to-short-lived perennial in the sunflower family, also known as scentless chamomile, mayweed, and scentless mayweed. This plant has a taproot with extensive secondary roots. Stems are one to three feet tall and frequently branched, especially from the crown area. Leaves are dark green and finely divided. Flowers occur singly at end of branches, with yellow disk flowers and ray flowers with white petals. Seeds are gray to black, 1/16 inch long, and three-angled. False chamomile does not grow well in competitive crops, but if it becomes established on bare soil or in weak plant stands it can become very aggressive and can cause significant crop yield losses.

Seeds germinate throughout the growing season. Annual forms emerge in spring and early summer, and biennial forms emerge in summer or fall and overwinter as rosettes. Perennial forms emerge in spring or summer and produce seed early in the season. Flowers can be found from May to October.

Prevention and maintaining competitive vegetative cover are keys for managing false chamomile infestations. Spot treating small infestations on bare ground near fields can prevent spread of the weed. False chamomile can be widely dispersed as a contaminant in crop seed and feed, on equipment, and in water. Tilling in late fall and early spring can control rosettes of biennial and perennial forms before they become more difficult to control, and can also control seedlings.

Field Bindweed (Convolvulus arvensis)

This is an introduced perennial broadleaf weed in the morning glory family that can reach four or more feet. It reproduces by seeds and the rhizomes. The solitary flower is trumpet shaped, white with a five-lobed calyx. The leaves are alternate, simple. Stems are twining or trailing.

It is a major perennial weed problem. Herbicides provide the most effective control, however, several treatments and proper timing of applications are required.

Field pennycress (Thlaspi arvense)

This winter or summer annual is from one to 2.5 feet tall and will occasionally branch. Plants occurring as winter annuals form a rosette of leaves up to six inches across. Summer annuals develop a central stem with several side stems. Stems are glabrous, ribbed, and may be winged along the ribs. The hairless leaves have slightly wavy margins, sometimes with a few blunt teeth. Flowers are tiny with four white petals and four green sepals. Foliage may have a mustard-garlic aroma. Seedpods have two cells, each containing several seeds, surrounded by a wide membranous wing. Plants spread by reseeding, with no vegetative reproduction occurring. Seeds germinate easily and can maintain their ability to germinate as long as 20 years in the soil.

There is known resistance to ALS herbicides in Canada.

Flixweed (Descuraninia sophia)

This mustard is an introduced weed, classified as a winter annual or a biennial. It reproduces by seed. Flowers are bright yellow to whitish, with four petals arranged in a raceme. Leaves are alternate, stalked and two to three times divided. Stems are erect, simple or branched and sometimes glandular. Tansy mustard is very similar in appearance and growth habits.

Herbicide applications should be made in late winter or very early spring before bolting.

Horseweed (Marestail) (Conyza canadensis)

Horseweed is a native annual forb in the sunflower family. It can reach three feet and reproduces by seed. The flower contains pinkish ray flowers and numerous disk flowers arranged in a panicle of heads. Leaves are alternate, blades simple arranged on an erect simple, unbranched stem.

Marestail can germinate in fall, or spring. If it germinates in March, it can reduce wheat yields due to competition with the wheat crop and interfere with harvest. It is very tolerant to glyphosate. Treat when the plants are small and in the rosette stage of growth.

Kochia (Kochia scoparia)

This is an introduced annual weed in the goosefoot family. It forms a bushy plant and grows to six feet. It reproduces by seed. The flower is green and arranged in a spike. Stems are erect, highly branched and turn red as they age.

Resistance to sulfonyl urea and glyphosate herbicides makes this a difficult weed to manage.

Prickly lettuce (Lactuca serriola)

This is an introduced annual weed, reaching nearly five feet. It reproduces by seed. The flower is yellow, with a dark blue stripe on the lower side, and many petals. Flowers are arranged in a panicle containing up to 100 flowers. Leaves are alternate, attached basaly and simple. Stems are erect, with some branching.

Treat before bolting. Resistance to ALS-inhibiting herbicides has been reported.

Prostrate knotweed (Polygonum aviculare)

This is an introduced annual in the buckwheat family. The lanceolate leaves are arranged alternately along the stem. Stems are branching, growing prostrate along the ground, and range from four to 24 inches in length. Stems are swollen at the nodes with a thin membranous sheath (ocrea) encircling the stem at each leaf base. The inconspicuous, white to pinkish-white flowers occur in the leaf axils, between the stems and leaves.

Prostrate knotweed is one of the earliest germinating summer annual weeds. Seedlings emerge from the top inch of soil. Flowering occurs from June to November. Seed dispersal occurs via animals, rain, streams, irrigation systems and other water courses.

Mechanical methods are more effective in combination with chemical treatments. The best control results will be obtained in the spring when plants are still upright and actively growing, from seedling to flower stage. Pre-emergence herbicides can be effective if applied in late fall/winter.

Redroot pigweed (Amaranthus retroflexus)

This is an introduced annual amaranth. It has an erect stem, one to 6.6 feet tall, that is commonly freely branched. Inflorescences are usually densely crowded. There are often additional dense clusters of flowers in the axils of upper leaves. The taproot can grow 3.9 to 95 inches deep. It is found in dry to moist conditions.

Plants can result from germination of newly released seed, or from the seedbank whenever soil moisture is adequate. Most redroot pigweed emerges in late spring and early summer. It tends to set seed over a relatively short period as plants mature. Seeds can survive in the soil for up to 20 years.

Management should emphasize preventing establishment. Tillage and cultivation aid in control, as does high seeding rates. Redroot pigweed resistance to photosystem II inhibitor and ALS inhibitor herbicides has been documented.

Russian thistle (Salsola iberica, S. kali, S. pestifer, and S. collina).

These are introduced weeds in the in the goosefoot family, and the different species have different distributions. Seedlings have long fleshy leaves. Stems on mature plants are six inches to three feet tall and are rounded, bushy, and highly branched. Stems are purple and red striped. Leaves are alternate, the first leaves are long, stringlike and soft. Later leaves are short, scale-like and tipped with a stiff spine. Flowers are inconspicuous and borne in axils of the upper leaves. Each flower is accompanied by a pair of spiny, floral bracts. Fruits are small one-seeded and have winged tips. Seeds are round, black, smooth, and shiny. Roots consist of a taproot that can grow three feet or more in depth with extensive lateral roots.

Russian thistle is well adapted to cultivated dryland agriculture, but is also found on disturbed rangeland, and wasteland. Russian thistle colonizes barren desert areas that cannot support other flora, and invades many different disturbed plant communities. After seeds mature in the fall, the plant stem separates from the root. The plant is then blown by winds, dispersing seeds as it tumbles.

Treat before bolting. Resistance to ALS-inhibiting herbicides has been reported.

Shepherd's purse (Capsella bursa-pastoris)

Shepardspurse is an introduced annual mustard. It can reach nearly two feet and reproduces by seed. The flower is white with petals twice as long as the sepals and arranged in a raceme that elongates as it matures. Leaves are alternate and blades simple. Stems are erect and slightly branched. Treat before bolting.

Tansy mustard (Descurainia pinnata)

This weed is very similar in appearance and growth habits to flixweed, described above. Herbicide applications should be made in late winter or very early spring prior to bolting.

Waterhemp (Amaranthus tuberculatus)

This species is similar in appearance, biology and management to other pigweed species. Significant herbicide resistance problems are associated with this species.

Wild sunflower (Helianthus annuus)

This weed is also a cultivated crop. It is native broadleaf plant in the sunflower family and can reach seven feet. It reproduces by seed. Flowers consist of ray and disk flowers arranged in a head. Leaves are alternate and attached to an erect stem that is course and branched above, single at base.

Wild vetch (Vicia sativa, V. villosa)

Common and hairy vetch also are desirable forage species. They are introduced cool season winter annual legumes. They reproduce by seed. The flower is five-petaled, one to three centimeters and ranges in color from whitish to bluish tored or bright pink. The flowers occur in the leaf axils. Leaves are alternate, pinnatelycompound. Stems are four-sided, hollow, prostrate, and can reach four to six feet.

Wild Buckwheat (Polygonum convolvulus)

This annual weed germinates in early spring. Plants climb on wheat, causing severe lodging and harvesting problems. It prefers moist soils and high nitrogen levels. Some factors contributing to wild buckwheat problems include (1) the seeds are similar in diameter to wheat, (2) seeds don't thresh completely, (3) seeds are often planted with wheat, and (4) it has high seed production.

Wild buckwheat is partially resistant to herbicides commonly used for mustard control. Several herbicides are available but must be used in strict accordance with label instructions to be effective.

Grassy weeds

Cheat (Bromus secalinus)

This is an introduced annual grassy weed that can reach two feet. It reproduces by seed. The flower has four to seven spikelets arranged in a panicle. The leaves are blades with sheathes and the stem is erect.

Crop rotations with a broadleaf crop, a warm season grass crop, or fallow provide herbicide flexibility.

Downy brome (Bromus tectorum)

This is an introduced annual grassy weed that is similar in appearance and management to cheat, described above.

Feral rye (Secale cereale)

This cereal crop also is a winter annual weed of winter wheat that can reach four to five feet. It reproduces by seed. Flowers have two to three spikelets arranged on a compound spike, attached to an erect stem.

Crop rotations with a broadleaf crop, a warm season grass crop, or fallow provide herbicide flexibility. Clearfield (2 gene) herbicide programs are effective.

Foxtail barley (Hordeum jubatum)

This is a shallow-rooted, annual to perennial bunchgrass. It grows one to two feet tall, and produces a nodding pale green to purple, bushy spike that fades to a tawny color and becomes very brittle at maturity. Leaves are grayish green and have a rough texture. The sheath margin has numerous soft hairs. Seeds are elliptic, yellowish brown, 1/4 inch long with four to eight long awns.

Foxtail barley is often found in saline areas and will do well under drought conditions. Foxtail barley plants emerge from both seeds and buds. Seeds will germinate in the fall and spring. Each plant is capable of producing more than 180 seeds. Seeds are short lived and survive best at the soil surface.

Foxtail barley can be grazed in the early spring but becomes hazardous as it matures. Foxtail barley is a concern in low or no till cropping systems. Fall-seeded cereals may allow foxtail barley populations to increase because the crop and weed develop during the same period with few herbicide control options.

The best long-term control strategies include cultural and mechanical controls and herbicide applications. Establishing vigorous crops that are suited to a site’s environmental and soil conditions, as well as employing tillage and/or herbicide applications at different times of the year, will help eliminate this weed from crop and pasture lands.

Japanese brome (Bromus japonicus)

This weed is similar in appearance and management to cheat, described above.

Jointed goatgrass (Aegilops cylindrica)

This winter annual grass was introduced from Turkey in the late 1800s. It reproduces by seed. It will grow to 30 inches with erect stems. Seeds are similar to wheat in size and shape, making it difficult to separate from harvested wheat seed.

Cultural methods used against jointed goatgrass infestations include burning wheat stubble, rotating crops, increasing the wheat seeding rate, selecting a competitive cultivar, narrow row spacing and delayed planting after a shallow fall tillage. Clearfield herbicide programs are effective.

Worker Activities and Potential Exposure to Pesticides

Exposure in wheat due to worker activity is limited due to the mechanized nature of wheat production. Most wheat farms are family operations with mainly family members or a one or two person labor force. All tillage, planting, and harvesting is done by mechanical means. Harvesting is typically done through custom harvesters, hired by the producer to harvest their crop. Wheat grown for seed can be hand weeded or rouged for rye or other crop or weed contamination if it is in small areas. With the exception of a primary herbicide application, the extent of which is documented in Tables xxx, most other pesticide applications are in response to environmental and pest conditions that vary from year to year. Potential worker exposure times include (1) pre-planting burndown herbicides, (2) treated seed, (3) a primary herbicide application at 3-5 leaves crop growth stage, (4) insecticide applications targeting insect and mite pests from emergence through heading, (5) fungicide applications to protect the flag leaf, (6) pre-harvest herbicide application, and (7) post-harvest herbicide burn down of volunteer grain and perennial weeds.

Appendices

Tables containing regional information are contained in the text above. Tables providing individual state information, where available, have been placed in the appendices that follow.

Appendix A. Individual state wheat growth and development information.

Table A1-a. Winter Wheat Growth and Development Calendar - Colorado

Feekes Growth Stage	J	F	M	A	M	J	J	A	S	O	N	D
1									x	x	x	
2										x	x	x
3	x	x										
4			x									
5			x	x								
6			x	x								
7				x	x							
8					x							
9					x							
10					x	x						
11						x	x					

Table A1-b. Winter Wheat Growth and Development Calendar - Kansas

Feekes Growth Stage	J	F	M	A	M	J	J	A	S	O	N	D
1									x	x	x	
2										x	x	x
3	x	x										
4			x									
5			x	x								
6			x	x								
7				x	x							
8					x							
9					x							
10					x							
11						x						

Table A1-c. Winter Wheat Growth and Development Calendar - South Dakota

Feekes Growth Stage	J	F	M	A	M	J	J	A	S	O	N	D
1									x	x		
2									x	x	x	
3			x						x	x	x	
4			x	x	x							
5				x	x							
6				x	x							
7				x	x							
8					x	x						
9					x	x						
10					x	x						
11						x	x					

Table A1-d. Spring Wheat Growth and Development Calendar - South Dakota

Feekes Growth Stage	J	F	M	A	M	J	J	A	S	O	N	D
1			x	x								
2			x	x								
3				x								
4				x	x							
5				x	x							
6				x	x							
7				x	x							
8					x	x						
9					x	x						
10					x	x						
11						x	x					

Appendix B. Individual state production calendars.

Table B1-a. Winter Wheat Production Calendar - Colorado

Production Practice	J	F	M	A	M	J	J	A	S	O	N	D
Select, clean, treat seed							x	x				
Seed bed preparation								x	x			
Pre-plant weed control							x	x	x			
Pre-plant fertilizer							x	x	x			
Seeding									x	x	x	
Pre-emergence weed control							x	x	x	x		
Topdress N	x	x	x									
Post-emergence weed control		x	x	x						x	x	x
Harvest							x	x				

Table B1-b. Winter Wheat Production Calendar - Kansas

Production Practice	J	F	M	A	M	J	J	A	S	O	N	D
Select, clean, treat seed							x	x				
Seed bed preparation								x	x			
Pre-plant weed control							x	x	x			
Pre-plant fertilizer							x	x	x			
Seeding									x	x	x	
Pre-emergence weed control							x	x	x	x		
Topdress N	x	x	x									
Post-emergence weed control		x	x	x						x	x	x
Harvest						x	x					

Table B1-c. Winter Wheat Production Calendar - South Dakota

Production Practice	J	F	M	A	M	J	J	A	S	O	N	D
Select, clean, treat seed							x	x				
Seed bed preparation							x	x	x			
Pre-plant weed control							x	x	x			
Pre-plant fertilizer								x	x			
Seeding									x	x		
Pre-emergence weed control									x	x		
Topdress N			x	x								
Post-emergence weed control					x	x						
Harvest						x	x					

Table B1-d. Spring Wheat Production Calendar - South Dakota

Production Practice	J	F	M	A	M	J	J	A	S	O	N	D
Select, clean, treat seed	x	x	x									
Seed bed preparation		x	x	x								
Pre-plant weed control		x	x	x								
Pre-plant fertilizer		x	x	x								
Seeding		x	x	x								
Pre-emergence weed control		x	x	x								
Topdress N				x	x							
Post-emergence weed control					x	x						
Harvest							x	x				

Appendix C. Individual state arthropod pest management information.

Table C1-a. Wheat Arthropod Pest Treatment Calendar - Colorado

Pest	J	F	M	A	M	J	J	A	S	O	N	D
Army cutworm			X	X								
Armyworm						X						
Bird cherry-oat aphid						X						
Brown wheat mite			X	X								
Fall armyworm												
False wireworm								X	X			
English grain aphid						X						
Grasshoppers						X			X			
Greenbug												
Hessian fly												
Pale western cutworm			X	X								
Russian wheat aphid			X	X	X							
Western wheat aphid												
Wheat curl mite												
Wheathead armyworm												
Wheat midge												
Wheat stem maggot												
Wheat stem sawfly												
White grubs												

Table C1-b. Wheat Arthropod Pest Treatment Calendar - Kansas

Pest	J	F	M	A	M	J	J	A	S	O	N	D
Army cutworm				X								
Armyworm												
Bird cherry-oat aphid			X	X						X		
Brown wheat mite			X	X								
Fall armyworm					X							
False wireworm												
English grain aphid					X							
Grasshoppers												
Greenbug				X	X							
Hessian fly												
Pale western cutworm												
Russian wheat aphid			X	X								
Western wheat aphid												
Wheat curl mite												
Wheathead armyworm												
Wheat midge												
Wheat stem maggot												
Wheat stem sawfly												
White grubs												

Table C1-c. Wheat Arthropod Pest Treatment Calendar - South Dakota

Pest	J	F	M	A	M	J	J	A	S	O	N	D
Army cutworm		x	x	x								
Armyworm						x						
Bird cherry-oat aphid					x	x		x	x			
Brown wheat mite			x	x								
Fall armyworm									x			
False wireworm												
English grain aphid					x	x						
Grasshoppers						x			x	x		
Greenbug					x	x			x	x		
Hessian fly									x			
Pale western cutworm		x	x	x								
Russian wheat aphid									x			
Western wheat aphid												
Wheat curl mite								x	x			
Wheathead armyworm												
Wheat midge												
Wheat stem maggot												
Wheat stem sawfly												
White grubs												

Table C1-d. Wheat Arthropod Pest Treatment Calendar - Wyoming

Pest	J	F	M	A	M	J	J	A	S	O	N	D
Army cutworm												
Armyworm												
Bird cherry-oat aphid												
Brown wheat mite				X								
Fall armyworm												
False wireworm												
English grain aphid												
Grasshoppers									X			
Greenbug												
Hessian fly												
Pale western cutworm												
Russian wheat aphid				X	X							
Western wheat aphid												
Wheat curl mite								X	X			
Wheathead armyworm												
Wheat midge												
Wheat stem maggot												
Wheat stem sawfly						X						
White grubs												

Table C2-a. Wheat Arthropod Pests: Biological Control Efficacy - Colorado

Pest	Biological Control Agent									
	Ground beetles	Predatory midges	Fungi	Predatory mites	Big-eyed bugs	Nematodes	Lacewings	Lady beetles	Rove beetles	Parasitoids
Army cutworm										
Armyworm										
Bird cherry-oat aphid		O						O		O
Brown wheat mite										
Fall armyworm										
False wireworm										
English grain aphid		O						O		O
Grasshoppers			O							
Greenbug		O						O		O
Hessian fly										
Pale western cutworm										
Russian wheat aphid		O						O		O
Western wheat aphid										
Wheat curl mite										
Wheathead armyworm										
Wheat midge										
Wheat stem maggot										
Wheat stem sawfly										
White grubs										

Ratings = effective (E), occasionally effective (O), ineffective (I). Blank = unknown.

Table C2-b. Wheat Arthropod Pests: Biological Control Efficacy - Kansas

Pest	Biological Control Agent									
	Ground beetles	Predatory midges	Fungi	Predatory mites	Big-eyed bugs	Nematodes	Lacewings	Lady beetles	Rove beetles	Parasitoids
Army cutworm										O
Armyworm										
Bird cherry-oat aphid							O	O		
Brown wheat mite										
Fall armyworm										O
False wireworm										
English grain aphid							O	O		
Grasshoppers			O							
Greenbug							O	O		
Hessian fly										
Pale western cutworm										
Russian wheat aphid							O	O		O
Western wheat aphid										
Wheat curl mite										
Wheathead armyworm										O
Wheat midge										
Wheat stem maggot										
Wheat stem sawfly										
White grubs										

Ratings = effective (E), occasionally effective (O), ineffective (I). Blank = unknown.

Table C2-c. Wheat Arthropod Pests: Biological Control Efficacy - South Dakota

Pest	Biological Control Agent									
	Ground beetles	Predatory midges	Fungi	Predatory mites	Big-eyed bugs	Nematodes	Lacewings	Lady beetles	Rove beetles	Parasitoids
Army cutworm										
Armyworm										
Bird cherry-oat aphid							O	O		O
Brown wheat mite										
Fall armyworm										
False wireworm										
English grain aphid							O	O		O
Grasshoppers			O							
Greenbug							O	O		O
Hessian fly										
Pale western cutworm										
Russian wheat aphid										
Western wheat aphid										
Wheat curl mite										
Wheathead armyworm										
Wheat midge										
Wheat stem maggot										
Wheat stem sawfly										
White grubs										

Ratings = effective (E), occasionally effective (O), ineffective (I). Blank = unknown.

Table C3-a. Wheat Arthropod Pests: Cultural Control Efficacy - Colorado

Pest	Cultural Control													
	Baited traps	Crop rotation	Resistant varieties	Volunteer	Sticky traps	Certified seed	Weed control	Fertility management	Irrigation management	Planting date	Tillage	Reducing plant stress	Harvest timing	Reduced tillage
Army cutworm				O			O							
Armyworm														
Bird cherry-oat aphid														
Brown wheat mite				O			O							
Fall armyworm														
False wireworm														
English grain aphid														
Grasshoppers										O				
Greenbug				O										
Hessian fly				O						E				
Pale western cutworm				O			O							
Russian wheat aphid				O			O	O		O				
Western wheat aphid														
Wheat curl mite				E			O							
Wheathead armyworm														
Wheat midge														
Wheat stem maggot														
Wheat stem sawfly														
White grubs														

Ratings = effective (E), occasionally effective (O), minimally effective (M). Blank = unknown.

Table C3-b. Wheat Arthropod Pests: Cultural Control Efficacy - Kansas

Pest	Cultural Control													
	Baited traps	Crop rotation	Resistant varieties	Volunteer	Sticky traps	Certified seed	Weed control	Fertility management	Irrigation management	Planting date	Tillage	Reducing plant stress	Harvest timing	Reduced tillage
Army cutworm														
Armyworm														
Bird cherry-oat aphid														
Brown wheat mite		E		E					O					
Fall armyworm														
False wireworm											E			
English grain aphid														
Grasshoppers														
Greenbug														E
Hessian fly			E	E						E				
Pale western cutworm														
Russian wheat aphid														
Western wheat aphid														
Wheat curl mite				E										
Wheathead armyworm														
Wheat midge														
Wheat stem maggot														
Wheat stem sawfly														
White grubs														

Ratings = effective (E), occasionally effective (O), minimally effective (M). Blank = unknown.

Table C3-c. Wheat Arthropod Pests: Cultural Control Efficacy - South Dakota

Pest	Cultural Control													
	Baited traps	Crop rotation	Resistant varieties	Volunteer	Sticky traps	Certified seed	Weed control	Fertility management	Irrigation management	Planting date	Tillage	Reducing plant stress	Harvest timing	Reduced tillage
Army cutworm							O			O				O
Armyworm														
Bird cherry-oat aphid										O				
Brown wheat mite														
Fall armyworm														
False wireworm														
English grain aphid														
Grasshoppers										O				
Greenbug										O				
Hessian fly										E				
Pale western cutworm														
Russian wheat aphid										O				
Western wheat aphid														
Wheat curl mite				O			O			O				
Wheathead armyworm														
Wheat midge														
Wheat stem maggot		O												
Wheat stem sawfly		O	M											
White grubs														

Ratings = effective (E), occasionally effective (O), minimally effective (M). Blank = unknown.

Table C4-a. Wheat Arthropod Pests: Chemical Control Efficacy - Colorado

Pest		Insecticide													
	beta cyfluthrin	carbaryl	chlorpyriphos	Cobalt	cyfluthrin	dimethoate	gamma cyhalothrin	imidaclopri	lambda cyhalothrin	Lannate	malathion	Prevathon	spinodad	Thiamethoxam	zeta cypermethrin
Army cutworm	E				E		E		E						H
Armyworm															
Bird cherry-oat aphid			E	E											
Brown wheat mite			M			E			M						
Fall armyworm															
False wireworm															
English grain aphid			E	E											
Grasshoppers															
Greenbug			E	E											
Hessian fly															
Pale western cutworm	E				E		E		E						H
Russian wheat aphid			E	E		M			M						
Western wheat aphid															
Wheat curl mite															
Wheathead armyworm															
Wheat midge															
Wheat stem maggot															
Wheat stem sawfly															
White grubs															
Toxicity to beneficial insects															

Insecticide efficacy = excellent (E), moderate (M), or poor (P). Toxicity to beneficial insects as high (H), medium (M) or low (L). Blank = unknown.

Table C4-b. Wheat Arthropod Pests: Chemical Control Efficacy - Wyoming

Pest		Insecticide													
	beta cyfluthrin	carbaryl	chlorpyriphos	Cobalt	cyfluthrin	dimethoate	gamma cyhalothrin	imidaclopri	lambda cyhalothrin	Lannate	malathion	Prevathon	spinodad	Thiamethoxam	zeta cypermethrin
Army cutworm															
Armyworm															
Bird cherry-oat aphid															
Brown wheat mite	P	P	M			M	P		P		P		P		P
Fall armyworm															
False wireworm															
English grain aphid															
Grasshoppers	M	M	E			M					M				M
Greenbug															
Hessian fly															
Pale western cutworm															
Russian wheat aphid	P	P	E			M	P		P		P				P
Western wheat aphid															
Wheat curl mite															
Wheathead armyworm															
Wheat midge															
Wheat stem maggot															
Wheat stem sawfly	E	E	E								E				
White grubs															
Toxicity to beneficial insects			H			H					M				

Insecticide efficacy = excellent (E), moderate (M), or poor (P). Toxicity to beneficial insects as high (H), medium (M) or low (L). Blank = unknown.

Appendix D. Individual state disease management information.

Table D1-a. Wheat Diseases: Cultural Control Efficacy - South Dakota

Disease	Cultural Control									
	Crop rotation	Resistant varieties	Sanitation	Clean seed	Fertility management	Irrigation management	Clean seed	Weed Mgt.	Volunteer management	Harvest timing
Common Bunt	O	M	O	E	M		E	M	M	M
Common Root Rot	E	O	E	M	O			O	O	M
Dryland Root Rot	E	O	E	M	O			O	O	M
Fusarium head blight	E	O	E	M	M			M	M	M
Glume Blotch	E	O	E							
Karnal Bunt	O			E						
Leaf Rust		E								
Loose Smut	O		O	E						
Powdery Mildew	O	O								
Seedling Blight	E									
Septoria leaf blotch	E	O	E							
Stinking Smut	E		O	E						
Stripe Rust		E								
Tan Spot	E	O	O							
Virus: Barley Yellow Dwarf		M								
Virus: High Plains Disease	O	M	E						E	
Virus: Wheat Soilborne										
Virus: Wheat Spindle Streak										
Virus: Wheat Streak Mosaic	M	M	E						E	

Practices rated as effective (E), occasionally effective (O), minimally effective (M). Blank if unknown.

Table D2-a. Wheat Diseases: Seed Treatment Efficacy - South Dakota

	Seed Treatment													
Disease	Captan	Carboxin	Difenoconazole	Imadicloprid	Imazilil	Maneb	Mefenoxam	Metalaxyl	Pentachloronitrobenzene	Tebuconazole	Thiamethoxam	Triticonazole	Thiram	Triadimenol
Common Bunt										M			ME	
Common Root Rot										M		M		
Dryland Root Rot														
Fusarium head blight														
Glume Blotch														
Karnal Bunt														
Leaf Rust														
Loose Smut										M				
Powdery Mildew														
Seedling Blight							E	E		M			M	
Septoria leaf blotch														
Stinking Smut														
Stripe Rust														
Tan Spot														

Efficacy rated as excellent (E), moderate (M), or poor (P). Blank if unknown.

Appendix E. Individual state weed management information.

Table E1-a. Wheat Broadleaf Weeds: Cultural Control Efficacy - Kansas

Weed	Cultural Practice										
	Crop rotation	Tolerant varieties	Sanitation	Certified seed	Weed free seed	Fertility management	Irrigation management	Planting date	Tillage	Reducing plant stress	Harvest timing
Blue mustard	O	M	E	O	E	M		M	O		M
False chamomile											
Field pennycress	O	M	E	E	E	M		M	O		M
Flixweed	O	M	E	E	E	M		M	O		M
Horseweed	O	M	E	E	E	O		O	E		M
Knotweed											
Kochia	M	M	E	E	E	O		M	E		M
Lambsquarters	M	M	E	E	E	O		M	O		M
Penn smartweed											
Prickly lettuce	M	M	E	E	E	O		O	O		M
Redroot pigweed	M	M	O	E	E	O		M	M		M
Russian thistle	O	O	E	E	E	O		M	M		M
Shepherd's purse	E	M	E	E	E	O		O	O		M
Sunflower	O	O	O	E	E	O		M	M		M
Tansy mustard	O	M	E	E	E	O		O	O		M
Waterhemp	O	M	O	O	O	O		M	O		M
Wild Vetch											
Wild Buckwheat	E	O	O	E	E	O		O	O	M	E

Practices rated as effective (E), occasionally effective (O), minimally effective (M). Blank if unknown.

Table E1-b. Wheat Broadleaf Weeds: Cultural Control Efficacy - South Dakota

Weed	Cultural Practice										
	Crop rotation	Tolerant varieties	Sanitation	Certified seed	Weed free seed	Fertility management	Irrigation management	Planting date	Tillage	Reducing plant stress	Harvest timing
Blue mustard	E		E		E			O		E	
False chamomile											
Field pennycress	E		E		E			E		E	
Flixweed	E		E		E			O		E	
Horseweed	O		O		E			O		E	
Knotweed											
Kochia	E		E		E			E		E	
Lambsquarters	E		E		E			E		E	
Prickly lettuce	O		E		O			O		E	
Redroot pigweed	E		E		E			E		E	
Russian thistle	O		E		O			E		E	
Shepherd's purse	E		E		E			E		E	
Sunflower	E		E		E			E		E	
Tansy mustard											
Waterhemp											
Wild Vetch											
Wild Buckwheat	E		E		E			E		E	

Practices rated as effective (E), occasionally effective (O), minimally effective (M). Blank if unknown.

Table E2-a. Wheat Grassy Weeds: Cultural Control Efficacy - Kansas

Weed	Cultural Practice										
	Crop rotation	Tolerant varieties	Sanitation	Certified seed	Weed free seed	Fertility management	Irrigation management	Planting date	Tillage	Reducing plant stress	Harvest timing
Downy brome	E	M	E	E	E	O	M	O	O	O	M
Japanese brome	E	O	E	E	E	O	M	O	O	O	M
Jointed goatgrass	E	M	E	E	E	O	M	M	O	M	M
Feral rye	E	M	M	E	E	O	M	M	M	M	M
Foxtail barley	E		E	E	E	O	M	O	O	O	M

Practices rated as effective (E), occasionally effective (O), minimally effective (M). Blank if unknown.

Table E2-b. Wheat Grassy Weeds: Cultural Control Efficacy - South Dakota

Weed	Cultural Practice										
	Crop rotation	Tolerant varieties	Sanitation	Certified seed	Weed free seed	Fertility management	Irrigation management	Planting date	Tillage	Reducing plant stress	Harvest timing
Downy brome	E		E	E	E	O		E		E	O
Japanese brome	E		E	E	E	E		E		E	O
Jointed goatgrass	O		E	E	E	M		O		O	O
Feral rye	E		E	E	E	M		O		O	O
Foxtail barley	O		O	E	E	E		E		E	E

Practices rated as effective (E), occasionally effective (O), minimally effective (M). Blank if unknown.

Table E3-a. Wheat Broadleaf Weeds: Chemical Control Efficacy - Kansas

Weed	Herbicide																												
	2,4-D	Affinity Broadspec +	Agility	Aim + 2,4-D	Ally Extra	Ally Extra SG + 2,4-D	Ally XP	Ally XP + 2,4-D	Ally XP + Starane Ultra	Amber	Amber + 2,4-D	Amber +	Beyond	Bronate Advanced	Curtail	Curtail M	Dicamba + 2,4-D	Finesse	Finesse + 2,4-D	Harmony Extra +2,4-D	Huskie + 2,4-D	Maverick (Fall applied)	MSPA	Olympus (Fall applied)	Peak	Peak + 2,4-D	Power Flex (Fall Applied)	Rave	Starane NXT	Widematch
Blue mustard	E	E	E	O	E	E	E	E	E	E	E	E	E	E			E	E	E	E	E	E		E	E	E	E	E	O	O
False chamomile																														
Field pennycress	E	E	E	O	E	E	E	E	E	E	E	E	E	E			E	E	E	E	E	E		E	E	E	E	E	O	O
Flixweed	E	E	E	O	E	E	E	E	E	E	E	E	E	E			E	E	E	E	E	E		E	E	E	E	E	O	O
Horseweed	E	O	O	O	O	E	O	E	E	O	E	E	O	O			E	E	E	E	E	E		E	E	E		E	O	O
Knotweed	O																													
Kochia	M	O	O	O	O	O	O	O	E	O	O	E	O	O			E	E	E	O	E			E	E	E	E	E	E	O
Lambsquarters	O	E	E	O	E	E	E	E	E	E	E	E	E	E			E	E	E	O	E	O		E	E	E	E	E	E	O
Penn smartweed			E																											
Prickly lettuce	E	O	O	O	E	E	E	E	E	E	E	E	O	O			O	E	E	E	E	O		E	E	E	E	E	O	O
Redroot pigweed	E	E	E	E	E	E	E	E	E	O	E	E	E	E			E	E	E	M	O	E		E	E	E	O	E	E	O

Weed	Herbicide																													
	2,4-D	Affinity Broadspec +	Agility	Aim + 2,4-D	Ally Extra	Ally Extra SG + 2,4-D	Ally XP	Ally XP + 2,4-D	Ally XP + Starane Ultra	Amber	Amber + 2,4-D	Amber +	Beyond	Bronate Advanced	Curtail	Curtail M	Dicamba + 2,4-D	Finesse	Finesse + 2,4-D	Harmony Extra +2,4-D	Huskie + 2,4-D	Maverick (Fall applied)	MSPA	Olympus (Fall applied)	Peak	Peak + 2,4-D	Power Flex (Fall Applied)	Rave	Starane NXT	Widematch
Russian thistle	E	E	E	E	E	E	E	E	E	E	E	E	E	E			E	E	E	M	E	E		E	E	E	E	E	O	O
Shepherd's purse	E	E	E	M	E	E	E	E	E	E	E	E	E	E			E													
Sunflower	E	E	E	O	E	O	O	O	O	O	O	O	O	O			E													
Tansy mustard	E	E	E	E	E	E	E	E	E	E	E	E	E	E			E													
Waterhemp																														
Wild Vetch																														
Wild Buckwheat	M	E	E	M	E	E	E	E	E	E	E	E	E	E			E													

Products rated as effective (E), moderately effective (O), minimally effective (M). Blank if unknown.

Table E3-b. Wheat Broadleaf Weeds: Chemical Control Efficacy - South Dakota

Weed	Herbicide																													
	2,4-D	Affinity Broadspec +	Agility	Aim + 2,4-D	Ally Extra	Ally Extra SG + 2,4-D	Ally XP	Ally XP + 2,4-D	Ally XP + Starane Ultra	Amber	Amber + 2,4-D	Amber +	Beyond	Bronate Advanced	Curtail	Curtail M	Dicamba + 2,4-D	Finesse	Finesse + 2,4-D	Harmony Extra +2,4-D	Huskie + 2,4-D	Maverick (Fall applied)	MSPA	Olympus (Fall applied)	Peak	Peak + 2,4-D	Power Flex (Fall Applied)	Rave	Starane NXT	Widematch
Blue mustard	E	E	O	O	E	E	E	E	E	E	E	E	E	E	O	O	E	E	E	E	E	E		E	E	E	E	E	O	O
False chamomile																														
Field pennycress	E	E	O	O	E	E	E	E	E	E	E	E	E	E	O	O	E	E	E	E	E	E		O	E	E	O	E	O	O
Flixweed	E	O	O	E	E	E	E	E	E	E	E	E	E	E	O	O	E	E	E	E	E	E		E	E	E	O	E	O	O
Horseweed	E	O	O	O	E	E	E	E	O	O	O	E	E	O	O	O	E	O	O	O	E	M		M	O	O	M	O	E	E
Knotweed	O	O	O	O	E	E	E	E	E	O	O	O	E	E	O	O	E	O	O	O	E	M		M	O	O	M	O	E	E
Kochia	O	M	M	O	M	M	M	M	E	M	M	M	E	E	O	O	O	M	M	M	E	M		M	M	M	M	O	E	E
Lambsquarters	E	E	O	O	E	E	E	E	E	M	O	O	E	E	O	O	E	O	O	O	E	M		M	O	O	M	O	E	E
Penn smartweed	E	E	O	O	E	E	E	E	E	O	O	O	E	E	O	O	E	O	O	O	E	M		M	O	O	M	O	E	E
Prickly lettuce	E	M	O	O	O	O	O	O	M	M	M	O	O	E	E	E	E	M	M	M	E	M		M	O	O	M	O	O	E
Redroot pigweed	E	E	O	O	E	E	E	E	E	E	O	O	E	E	O	O	E	O	O	O	E	M		M	O	O	M	O	E	E

Weed	Herbicide																													
	2,4-D	Affinity Broadspec +	Agility	Aim + 2,4-D	Ally Extra	Ally Extra SG + 2,4-D	Ally XP	Ally XP + 2,4-D	Ally XP + Starane Ultra	Amber	Amber + 2,4-D	Amber +	Beyond	Bronate Advanced	Curtail	Curtail M	Dicamba + 2,4-D	Finesse	Finesse + 2,4-D	Harmony Extra +2,4-D	Huskie + 2,4-D	Maverick (Fall applied)	MSPA	Olympus (Fall applied)	Peak	Peak + 2,4-D	Power Flex (Fall Applied)	Rave	Starane NXT	Widematch
Russian thistle	O	E	O	O	M	M	M	M	M	M	M	M	E	E	O	O	O	M	M	M	E	M		M	M	M	M	O	E	E
Shepherd's purse	E	E	E	E	E	E	E	E	E	E	E	O	O	E	E	O	O	E	E	E	E	O		O	E	E	E	E	O	O
Sunflower	E	O	O	O	O	O	O	O	O	O	O	O	O	E	E	O	O	E	O	O	E	M		M	O	O	M	O	E	E
Tansy mustard	E	E	O	O	O	O	O	O	O	O	O	E	E	E	E	O	O	E	E	E	E	E		E	E	E	E	E	O	O
Waterhemp																														
Wild Vetch																														
Wild Buckwheat	O	E	E	E	E	E	E	E	E	E	E	O	O	E	E	O	O	E	E	O	E	M		M	M	M	M	O	E	O

Products rated as effective (E), moderately effective (O), minimally effective (M). Blank if unknown.

Table E4-a. Wheat Grassy Weeds: Chemical Control Efficacy - Kansas

Weed	Herbicide																													
	2,4-D	Affinity Broadspec +	Agility	Aim + 2,4-D	Ally Extra	Ally Extra SG + 2,4-D	Ally XP	Ally XP + 2,4-D	Ally XP + Starane Ultra	Amber	Amber + 2,4-D	Amber +	Beyond	Bronate Advanced	Curtail	Curtail M	Dicamba + 2,4-D	Finesse	Finesse + 2,4-D	Harmony Extra +2,4-D	Huskie + 2,4-D	Maverick (Fall applied)	MSPA	Olympus (Fall applied)	Peak	Peak + 2,4-D	Power Flex (Fall Applied)	Rave	Starane NXT	Widematch
Downy brome	M	M	M	M	M	M	M	M	M	O	M		E	M	M	M	M	O	M	M	M	O		E	M	M	E	M	M	M
Japanese brome	M	M	M	M	M	M	M	M	M	O	M		E	M	M	M	M	O	M	M	M	O		E	M	M	E	M	M	M
Jointed goatgrass	M	M	M	M	M	M	M	M	M	M	M		O	M	M	M	M	M	M	M	M	M		M	M	M	M	M	M	M
Feral rye	M	M	M	M	M	M	M	M	M	M	M		O	M	M	M	M	M	M	M	M	M		M	M	M	M	M	M	M
Foxtail barley	M	M	M	M	M	M	M	M	M	M	M		M	M	M	M	M	M	M	M	M	M		M	M	M	M	M	M	M

Products as effective (E), moderately effective (O), minimally effective (M). Blank if unknown.

Table E4-b. Wheat Grassy Weeds: Chemical Control Efficacy - South Dakota

Weed	Herbicide																													
	2,4-D	Affinity Broadspec +	Agility	Aim + 2,4-D	Ally Extra	Ally Extra SG + 2,4-D	Ally XP	Ally XP + 2,4-D	Ally XP + Starane Ultra	Amber	Amber + 2,4-D	Amber +	Beyond	Bronate Advanced	Curtail	Curtail M	Dicamba + 2,4-D	Finesse	Finesse + 2,4-D	Harmony Extra +2,4-D	Huskie + 2,4-D	Maverick (Fall applied)	MSPA	Olympus (Fall applied)	Peak	Peak + 2,4-D	Power Flex (Fall Applied)	Rave	Starane NXT	Widematch
Downy brome	M	M	M	M	M	M	M	M	M	M	M	M	E	M	M	M	M	M	M	M	M	E		E	M	M	O	E	M	M
Japanese brome	M	M	M	M	M	M	M	M	M	M	M	M	E	M	M	M	M	M	M	M	M	E		E	M	M	O	E	M	M
Jointed goatgrass	M	M	M	M	M	M	M	M	M	M	M	M	E	M	M	M	M	M	M	M	M	E		E	M	M	O	O	M	M
Feral rye	M	M	M	M	M	M	M	M	M	M	M	M	E	M	M	M	M	M	M	M	M	E		E	M	M	O	O	M	M
Foxtail barley	M	M	M	M	M	M	M	M	M	M	M	M	E	M	M	M	M	M	M	M	M	E		E	M	M	O	O	M	M

Products as effective (E), moderately effective (O), minimally effective (M). Blank if unknown.