

# Wheat Production and Pest Management

*for the Great Plains Region*



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## Authors



Ms. Roberta Armenta  
Department of Bioagricultural Sciences and Pest  
Management  
1177 Campus Delivery  
Colorado State University  
Fort Collins, CO 80523-1177  
berta@rams.colostate.edu

Paul Burgener, Agricultural Economics Research  
Analyst  
University of Nebraska Panhandle Research and  
Extension Center  
4502 Ave. I  
Scottsbluff, NE 69361  
pburgener2@unl.edu

Jeff Edwards, Associate Professor  
Department of Plant and Soil Sciences  
368 Agricultural Hall  
Oklahoma State University  
Stillwater, OK 74078-6028  
jeff.edwards@okstate.edu

Dr. Norman C. Elliot, Research Leader  
USDA Agricultural Research Service  
1301 North Western Road  
Stillwater, Oklahoma 74075-2714  
norman.elliott@ars.usda.gov

Dr. Neil C. Hansen, Associate Professor  
Department of Soil and Crop Sciences  
C138 Plant Science Building  
Colorado State University  
neil.hansen@colostate.edu

Dr. Gary L. Hein  
Director - Doctor of Plant Health Professional  
Program and Professor of Entomology  
University of Nebraska-Lincoln  
271 Plant Sciences Hall  
Lincoln, NE 68583-0933  
ghein1@unl.edu

Dale Leikam  
Agronomic Consultant and President, Fluid  
Fertilizer Foundation  
(Formerly Nutrient Management Specialist at Kansas  
State University)  
2805 Claflin Road, Suite 200  
Manhattan, KS 66502  
dale.leikam@sbcglobal.net

Drew J. Lyon, Dryland Cropping Systems  
Specialist & Fenster Distinguished Professor of  
Dryland Agriculture  
University of Nebraska Panhandle Research and  
Extension Center  
4502 Ave. I  
Scottsbluff, NE 69361  
dlyon1@unl.edu

Gregory S. McMaster, Research Agronomist  
USDA Agricultural Research Service  
2150 Centre Avenue, Bldg. D, Suite 200  
Fort Collins, CO 80526  
greg.mcmaster@ars.usda.gov

Case R. Medlin, Ph.D, Field Development  
Representative  
DuPont Crop Protection  
101 Crossroad Ct.  
Paradise, TX 76073  
Case.R.Medlin@USA.DuPont.com

Dr. Jerry Michels, Professor  
Texas Agrilife Research and Extension Center at  
Amarillo  
6500 Amarillo Boulevard West  
Amarillo, TX 79106  
gmichels@ag.tamu.edu



Frank B. Peairs, Professor  
Department of Bioagricultural Sciences and Pest  
Management  
1177 Campus Delivery  
Colorado State University  
Fort Collins, CO 80523-1177  
frank.peairs@colostate.edu

Dr. Gary A. Peterson, Professor and Head  
Department of Soil and Crop Sciences  
C127 Plant Science Building  
Colorado State University  
Fort Collins, CO 80523-1177  
gary.peterson@colostate.edu

Dr. Thomas W. Phillips, Professor and Head  
Department of Entomology  
123 Waters Hall  
Kansas State University  
Manhattan, KS 66506  
twp1@ksu.edu

Randy R. Price, Assistant Professor  
Department of Biological and Agricultural  
Engineering  
148 Seaton  
Kansas State University  
rrprice@ksu.edu

Mark D. Schrock, Professor  
Department of Biological and Agricultural  
Engineering  
129 Seaton  
Kansas State University  
mschrock@ksu.edu

James P. Shroyer, Professor  
Department of Agronomy  
2014 Throckmorton Hall  
Kansas State University  
Manhattan, KS 66506  
jshroyer@ksu.edu

Dr. Phillip E. Sloderbeck, Professor  
and Interim Area Extension Director - Southwest  
4500 E. Mary St.  
Garden City, KS 67846-9132  
psloderb@oznet.ksu.edu

John A. Smith, Professor  
University of Nebraska Panhandle Research &  
Extension Center  
4502 Ave. I  
Scottsbluff, NE 69361  
jsmith5@unl.edu

Dr. Randal K. Taylor, Professor  
Department of Biosystems and Agricultural  
Engineering  
111 Agricultural Hall  
Oklahoma State University  
Stillwater, OK 74078  
randy.taylor@okstate.edu

Dr. Dwayne G. Westfall, Professor  
Department of Soil and Crop Sciences  
C133 Plant Science Building  
Colorado State University  
dwayne.westfall@colostate.edu

W.W. Wilhelm (deceased)  
USDA Agricultural Research Service  
316 Biochemistry Hall  
University of Nebraska – East Campus  
Lincoln, NE 68583-0938





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# Introduction

## Wheat Production and Pest Management in the Great Plains

By Norman Elliott

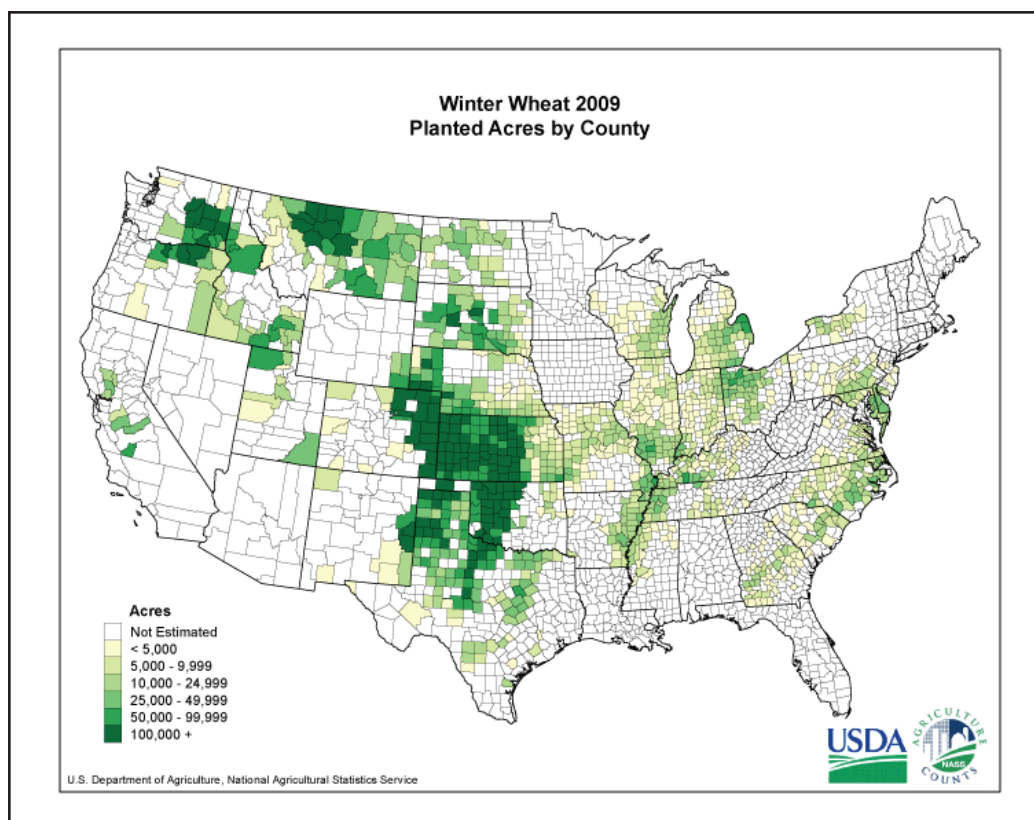
Wheat is the major crop grown in the Great Plains. In 2006 there were 40.6 million acres planted to winter wheat in the United States, and 62 percent of that total, 25.2 million acres, was planted in the six state region of the Great Plains represented by Colorado, Kansas, Nebraska, Oklahoma, Texas, and Wyoming (*Figure 1.1*). The value of the wheat harvested in the six states was \$2.4 billion of the total \$5.4 billion nationwide. Wheat is a significant part of total crop production in the region, and production in the region is a significant part of total production nationwide (*Figure 1.2*).



**Figure 1.1**  
The Great Plains region.

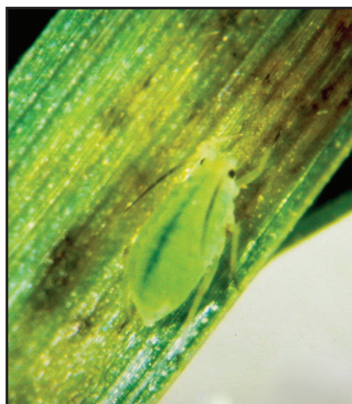


**Figure 1.2**  
Wheat Production in  
the United States.



Wheat is especially important for dryland crop production in the Great Plains where low and variable precipitation levels make production of less drought tolerant crops challenging. Wheat is commonly grown in a wheat-fallow rotation in the semiarid High Plains, while continuous wheat predominates the higher precipitation areas to the east. These “wheat only” cropping systems are effective in producing an acceptable amount of grain while limiting the risk of crop failure. However, there are drawbacks associated with wheat only production, including suboptimal soil moisture and land use efficiencies, high soil erosion, and costs associated with controlling pests such as the Russian wheat aphid (*Diuraphis noxia*), greenbug (*Schizaphis graminum*), winter annual grasses, and some diseases.

Conservation tillage systems, especially no-till, have contributed to a trend toward more intensive and diversified cropping in Great Plains dryland production. Crops including corn, grain sorghum, sunflowers, proso millet, cotton, soybean, canola, and other alternative species are incorporated into diversified rotations. The crops involved have varied based on geographic location within the Great Plains and, more specifically, on climate and soils. Wheat producers have found crop diversification, in the form of more complex and intensive crop rotations, to be an effective way to increase profits, lower risk, and reduce pest losses. Diversified crop rotations can reduce annual yield variability and allow for more effective pest management, especially in the case of weedy winter annual grasses, which are a persistent problem in wheat only production systems. These are two incentives for producers to consider the option of moving away from “wheat only” cropping systems. All other factors being equal, reducing yield variability over time and making pest management more effective and less costly will lead to greater profitability.



**Figure 1.3 (left)**  
Greenbug.



**Figure 1.4 (middle)**  
Russian wheat aphid.



**Figure 1.5 (right)**  
Bird cherry-oat aphid.

## Arthropod Pests of Wheat in the Great Plains

Over 30 insect and mite species attack wheat in the United States. Most rarely cause damage to wheat or occur in localized areas, and therefore, are of minor economic significance. In the Great Plains, the greenbug (*Schizaphis graminum*) (Figure 1.3) and Russian wheat aphid (*Diuraphis noxia*) (Figure 1.4) are major pests that frequently cause damage to wheat over large parts of the region. When outbreaks occur, they must be managed to avoid significant yield losses.

Some insect or mite pests are important primarily because of the plant diseases they transmit. The bird cherry-oat aphid (*Rhopalosiphum padi*) (Figure 1.5) is a pest of wheat and barley in the region and can cause direct yield losses when populations are high during early crop growth stages. However, such infestations rarely occur. This aphid also transmits the virus that causes barley yellow dwarf disease (BYDV), and even though economic losses from BYDV are usually low, they occasionally can be substantial. The Areawide Integrated Pest Management Program (AWIPM) demonstrated lower incidence of cereal aphids in more diversified cropping systems; however, due to the generally low levels of the disease during the study, reduced BYDV incidence could not be established.

The wheat curl mite (*Aceria tosichella*) is important in the High Plains. The wheat curl mite transmits three wheat viruses in the High Plains (wheat streak mosaic virus, High Plains virus, and Triticum mosaic virus). This disease complex is the most serious arthropod vectored cereal disease problem in the High Plains. Widespread outbreaks are rare, but isolated fields or groups of fields with severe disease occur in most years. Management of this disease complex involves cultural practices, control of volunteer wheat, and delayed planting dates. Diversifying the wheat-fallow system could have both positive and negative effects on virus epidemiology. Avoid growing wheat adjacent to wheat stubble (volunteer wheat) to reduce the potential for WSMV and HPV problems. In addition, the presence of sunflower or millet may allow for increased presence of alternate summer hosts for the mite, particularly summer annual grasses and volunteer wheat. The presence of nearby dryland corn, an alternate mite host, also can increase the potential for these diseases in some years.

The wheat stem sawfly (*Cephus cinctus*) is a pest in the northern part of the region. Host plant resistance and trap crops are used to control it. Reduced tillage has increased sawfly populations in Wyoming and Nebraska, but crop diversification can have the opposite effect.

Cutworms and armyworms are occasionally important pests of wheat. The fall armyworm (*Spodoptera frugiperda*) attacks wheat seedlings in the autumn in the southern Great Plains and can destroy an entire crop. More commonly, damage is limited to skeletonizing of young wheat leaves. The armyworm (*Pseudaletia unipuncta*) is a problem at heading, and occasionally causes severe losses by clipping the stems just below the head. The army cutworm (*Euxoa auxiliaris*) feeds on wheat leaves in late autumn and again in spring, whereas the pale western cutworm (*Agrotis orthogonia*) feeds only in spring and cuts stems at the soil level. Both species can cause large losses. Climate plays an important role in determining outbreaks of armyworms and cutworms, so cropping practices have minimal effects on outbreaks. Insecticides are the primary management tool for these pests (reference Chapter 7—“Arthropod Pests of Wheat”).

## Weeds of Wheat in the Great Plains

Winter annual grasses such as jointed goat grass, downy brome, and volunteer rye constitute the most serious weed threats to winter wheat production in the Great Plains. Winter annual grasses reduce wheat yields and cost Great Plains wheat producers millions of dollars each year. Widespread adoption of reduced tillage farming and continuous wheat or wheat fallow systems have aided establishment and spread of winter annual grasses. The life cycles of these grasses are similar to that of winter wheat, making the use of herbicides nearly impossible. Also, winter annual grasses typically shed their seed slightly before wheat harvest, thus ensuring their survival in the system.

There are no herbicides available that provide selective control of all winter annual grasses in winter wheat, unless a herbicide-tolerant wheat variety is available. The areawide pest management program demonstrated that winter annual grasses are reduced in diversified wheat production systems when compared to “wheat only” cropping systems.

**Figure 1.6**  
Kochia.



A variety of annual broadleaf weeds are important in wheat as well. Mustards and henbit are important winter annual broadleaf weeds in the Great Plains, while kochia (*Figure 1.6*), sunflower, and Russian thistle are important summer annuals. Kochia is the most common summer annual weed in winter wheat in the Great Plains and has rapidly developed herbicide resistance. In a recent survey, more than 50 percent of kochia plants in dryland sites were resistant to sulfonylurea herbicides.



Use of a second crop in a 3-year rotation allows for cheaper, less chemical-intensive control of winter annual grasses and kochia. The rotation allows for the use of herbicides and for grass germination in a non-grass crop that is competitive with the winter annual grasses. Diversified wheat cropping systems tend to have lower annual broadleaf weed densities in the AWIPM study (reference Chapter 8—“Managing Weeds in Winter Wheat”).

## Wheat Diseases in the Great Plains

Viral and fungal diseases are important in winter wheat production in the Great Plains. The arthropod transmitted viral diseases include wheat streak mosaic virus and its associated mite-vectored diseases, and barley yellow dwarf virus.

Important soil borne fungal and viral pathogens occur in the Great Plains. *Fusarium* species and *Cochliobolus sativa* cause Fusarium root rot and common root rot, respectively. Fusarium and common root rot are limited to dry soils and, as such, are more common in the High Plains than in eastern parts of the Great Plains. Take-all disease (caused by *Gaeumannomyces graminis* var. *tritici*), Rhizoctonia root rot (caused by several *Rhizoctinia* species), and Pythium root rot (caused by several *Pythium* species) are favored by wet soils. However, these diseases are not restricted to high rainfall areas, and yields may be significantly affected during short periods of wet soils during early crop establishment and growth. Take-all, Fusarium root rots, and Pythium root rots occur throughout the Great Plains. Soilborne wheat mosaic is widespread but is most important in the eastern Great Plains because its fungal vector prefers wet soils. These problems are influenced by climate, soil type, and agronomic practices. Diversified crop rotations are not considered to be effective against these pathogens because they can survive for several years in the soil.

Leaf rusts, stem rusts, and powdery mildew are important leaf diseases of wheat in the Great Plains. The rusts are managed mainly with resistant varieties and, to a lesser extent, with fungicides. However, races of rust fungi that can overcome resistance often develop, so diversification within a region is important. Powdery mildew is similar to rusts in that infection spreads by spores released in the environment. Resistant varieties are widely used. No role for crop diversification in rust and powdery mildew management has been demonstrated. Diversification might be expected to reduce their importance because fewer susceptible plants would be available to contract the disease within a region, thus reducing the chance for widespread outbreaks to develop (see also Chapter 9—“Disease Management of Wheat”).

## Areawide IPM Program (AWIPM)

The purpose of the AWIPM program was to demonstrate the role of diversified crop rotations and host plant resistance in managing the Russian wheat aphid and greenbug in dryland wheat production systems. A secondary, but equally important, objective was to demonstrate the benefits of diversification to weed management and crop profitability. We also sought to provide tools to enhance the grower’s ability to economically manage Russian wheat aphids and greenbugs.

Our approach was to build Russian wheat aphid and greenbug population suppression, particularly biological control and plant resistance, directly into agronomically and economically desirable cropping systems. We hypothesized that biological control would be enhanced by using diversified cropping systems that would increase the abundance and effectiveness of natural enemies by providing reservoirs for them in alternate crops during the summer when wheat was not growing. The diversified crop rotations were those already in use by some growers and were appropriate to the local agronomic circumstances. The program evolved during its five-year lifespan as it became clear that some of our initial assumptions were incorrect, and we focused the available resources on promising avenues of inquiry. In particular, we examined the socioeconomic aspects of various crop production systems, since these factors influence the decision to diversify production much more than pest management considerations. Our observations are discussed, where relevant, throughout this guide.

# The Wheat Plant

## Development, Growth, and Yield

*By Gregory S. McMaster and W.W. Wilhelm*

**F**inal grain yield is the result of developmental and growth processes of the wheat plant from seed germination through grain maturity. Knowing the sequence and timing of events during wheat development helps us understand how yield potential is determined, assess how the plant “perceives” its environment, and improve management practices through the prediction of future crop growth stages. Wilting and tissue color change are common signals indicating water or nutrient stress, which, combined with knowledge of how the wheat plant develops, can provide ways to estimate the outcome of yield-impacting situations. This, in turn, can guide the selection and application of management tools to minimize reductions in yield and profitability. This chapter describes the yield components of wheat, how the wheat plant develops, how yield potential is determined, and methods to predict when certain growth stages are reached under water-stressed and non-stressed growth conditions.

The wheat plant is remarkably resilient and flexible in forming final yield because it can take alternative paths in reaching a given level of productivity. The following five yield components determine yield potential:

1. Plants per unit area (acre)
2. Number of heads (spikes) per plant
3. Number of spikelets per head
4. Number of kernels per spikelet
5. Kernel size



**Figure 2.1**  
Healthy wheat crop.



## Yield Components

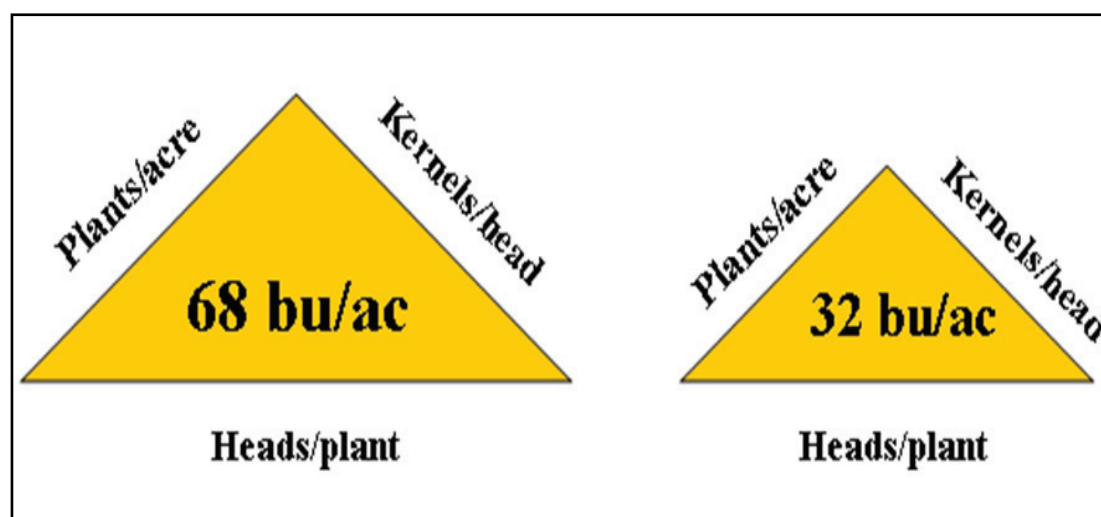
Each yield component has a period during which it is most sensitive to environmental and management conditions. These periods correspond to the developmental stages in which the potential of a component is set and then realized. For example, number of plants per unit area is influenced by seeding rate, germination percentage, and seedling survival. Seedbed conditions, temperature, water content, soil-seed contact, etc., affect germination and seedling survival rates. *Table 2.1* shows other examples of factors and management practices that affect specific yield components.

A triangle is a useful representation of how yield components interact to achieve a given yield (*Figure 2.2*). Number of spikelets per head and number of kernels per spikelet can be combined to create kernels per head. The triangles shown in *Figure 2.2* represent the yield potential at the beginning of grain filling for two different growing conditions. Final yield is determined by the kernel number per unit area and the size of these kernels. Grain filling can be thought of as a pipe (the process of) delivering material (carbohydrate) to fill the triangle (kernels). Under favorable conditions, all kernels fill to their potential, and yield is high. Under stressful conditions the flow of carbohydrate to the kernels is reduced because fewer carbohydrates are available or there is less time for filling and, as a result, yield is less than the potential.

In semi-arid production systems of the Great Plains, yield components related to number of plant parts (number of tillers per acre, number of kernels per head) generally are more important in determining yield than size of the parts (kernel size). This reflects the fact that the size of kernels tends to be more stable than number of heads or kernels. It follows that the number of heads per acre is the yield component most affected by environmental conditions, including management. In other words, management practices that promote good plant populations and tillering are critical for optimal yields (*Table 2.1*).

**Figure 2.2**

These yield components define the potential yield for the environmental conditions experienced during critical crop growth stages. Once kernel number is set, grain filling rate and duration define final yield by determining kernel weight.

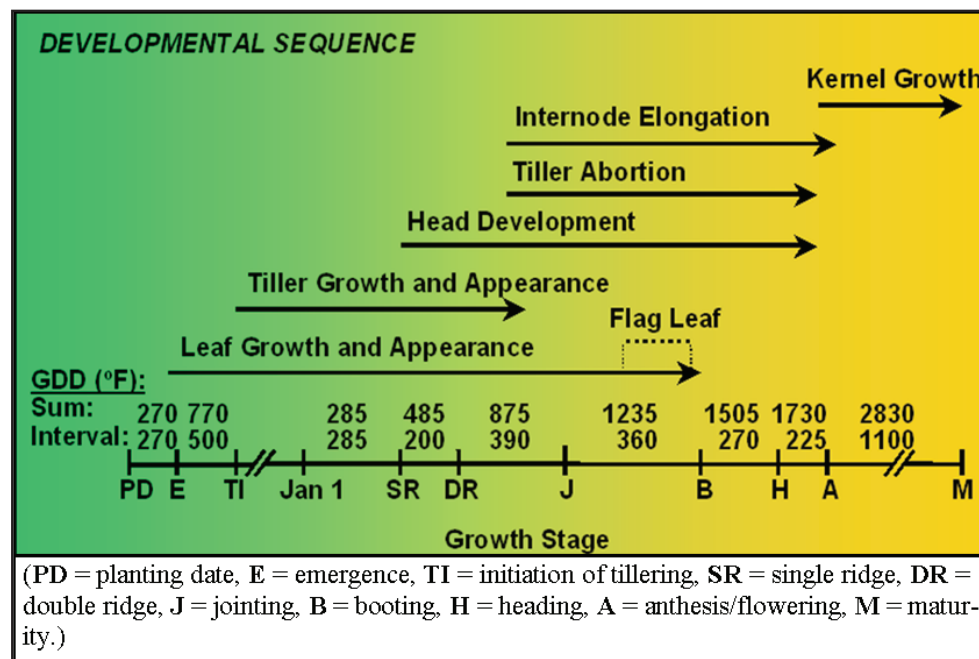


**Table 2.1**  
Environmental factors and management practices that determine yield components.

Yield component	Characteristic	Environmental factors	Management practices
Plants per unit area	Seeding density	NA	Planter adjustment Seed number, size, and viability
	Soil seed contact	Soil water content Seedbed condition	Planter adjustment Planting speed Tillage and residue
	Germination	Soil temperature Soil water content Rainfall	Seeding depth Tillage
	Seedling survival	Soil temperature Soil water content Rainfall	Seeding depth Irrigation Tillage
Tillers (heads) per plant	Tiller production	Air temperature Soil water/nutrient content Interplant competition Radiation	Planting date and rate Plant nutrition Soil cover/mulch Irrigation
	Tiller abortion	Air temperature Soil water/nutrient content Interplant competition Radiation	Planting date and rate Plant nutrition Soil cover/mulch Irrigation
Spikelets per head	Spikelet production	Soil water/nutrient content Interplant competition Tiller age Radiation/air temperature	Plant nutrition Soil cover/mulch Irrigation
	Spikelet production	Soil water/nutrient content Interplant competition Tiller age Radiation/air temperature	Plant nutrition Soil cover/mulch Irrigation
Kernels per spikelet	Kernel set (i.e., pollination)	Soil water/nutrient content Interplant competition Tiller age Radiation/air temperature	Plant nutrition Soil cover/mulch Irrigation
	Kernel production	Soil water/nutrient content Interplant competition Tiller age Radiation/air temperature	Plant nutrition Soil cover/mulch Irrigation
Kernel size	Rate of grain filling	Soil water content Interplant competition Tiller age Radiation/air temperature	Plant nutrition Soil cover/mulch Irrigation
	Duration of grain filling	Soil water/nutrient content Interplant competition Tiller age Radiation/air temperature	Plant nutrition Soil cover/mulch Irrigation

**Figure 2.3**

Developmental sequence of the winter wheat growing point (shoot apex) and correlated growth stages, and the approximate growing degree-days (GDD in °F) at which they occur.



Yield components are determined throughout the orderly and predictable development and growth of the wheat plant. Most important developmental events occur at the growing point (shoot apex) and can be timed using the externally recognizable growth stages. *Figure 2.3* depicts the sequence of these key developmental events from seed germination to plant maturity and the simultaneous growth stages that can be used to time them. Use this figure to determine which yield components are being affected at any given time during crop growth and development. All cultivars follow this developmental sequence, but they can vary in the rates and duration of developmental events. *Table 2.2* shows how the timing of a growth stage is affected by cultivar and location. These variations are an important consideration in cultivar selection. The overall developmental sequence is also important in understanding why management practices frequently target certain growth stages for maximum efficacy.

## Yield Potential

Timely and uniform emergence can help reduce soil erosion, minimize winter-kill, and particularly maximize yield potential by promoting fall production of tillers. Many factors determine when emergence occurs. Under normal conditions, emergence occurs about 7 to 14 days after planting (*Table 2.2*). However, emergence will be delayed if seeds are planted deep, the soil is extremely dry or cool, or crusting occurs. Farmers have several options for addressing seedbed soil water that is marginal or inadequate for uniform germination and seedling emergence. One option is to proceed with planting and hope for subsequent rains, but this is a risky strategy given the highly unpredictable weather in the Great Plains and low likelihood of timely rains in the fall. Another is to alter soil management practices to maintain soil water in the seedbed by minimizing soil disturbance and residue burial or removal. No-till systems can help retain seedbed moisture and promote good germination, reducing dependence on timely rains after planting. If only the surface soil is dry, deeper planting (into moist soil) may also improve germination, emergence, and survival.

**Table 2.2**

Average dates (dryland conditions) selected cultivars reached certain growth stages.

Cultivar	Site	Sowing	Emerge	Start of tillering	Spring start	Jointing	Heading	Maturity
Centurk	Akron, CO	Sep 12	Sep 19	Oct 2	Mar 2	Apr 30	May 28	Jul 9
Centurk	Paxton, NE	Sep 18	Sep 26	Oct 6	Mar 14	Apr 30	Jun 4	Jul 7
Centurk	Garden City, KS	Sep 18	Sep 24	Oct 8	Mar 9	Apr 17	May 23	Jun 29
Scout 66	Albin, WY	Sep 6	Sep 15	Sep 28	Mar 23	May 7	Jun 12	Jul 17
Scout 66	Mankato, KS	Oct 2	Oct 9	Oct 20	Mar 10	May 18	Jun 14	Jul 16
TAM 101	Medford, OK	Sep 28	Oct 5	Oct 17	Mar 2	Apr 21	May 20	Jun 18
Larned	Tribune, KS	Sep 11	Sep 18	Sep 28	Mar 9	Apr 30	May 30	Jul 1
Prowers99	Akron, CO	Sep 26	NR	NR	NR	May 4	Jun 3	Jun 29
Prowers99	Fort Collins, CO	Oct 6	Oct 23	NR	NR	May 4	Jun 1	Jul 2
TAM 107	Akron, CO	Sep 26	NR	NR	NR	Apr 30	May 29	Jun 27
TAM 107	Fort Collins, CO	Sep 15	Sep 24	Oct 5	NR	May 8	May 27	Jul 9

NR: Data not recorded for this site.



Leaf and tiller appearance are linked and start soon after emergence. Tillering usually begins about two weeks after emergence, if temperatures are adequate (*Table 2.2*). Leaves and tillers form at the growing point of each stem during the fall, winter, and early spring until the single ridge growing point growth stage, usually in March. The double ridge growing point growth stage signals the initiation of the wheat head and the shift towards reproductive growth stages. The double ridge stage is when spikelets are being initiated, which strongly influences the number of kernels per head. Fortunately, it is protected from low temperatures because it occurs while the growing point is underground. The double ridge growth stage is only visible under magnification, and occurs towards the end of tillering.

Spikelets and florets (i.e., flowers) form from the double ridge stage until booting. Booting marks the completion of the flag leaf, the major source of carbohydrates for grain filling. Different parts of the flower are initiated from booting until heading or flowering, which usually occurs in early June. Heading and flowering occur in very rapid succession. The maximum kernel number per head is determined during flowering. Subsequent stress-induced abortion may reduce kernel number per head slightly, but no additional kernels are formed after pollination. All yield components related to kernel number (i.e., number of plants, tillers, heads, spikelets, and florets/kernels) have been determined by flowering.

The final developmental stages relate to kernel growth, where yield is created. The last stage is maturity, the process of finalizing yield and drying of grain to harvest water content. Kernel size is set during this stage, with maximum size determined by mid-July.

## Development

Development is orderly and predictable, following the pattern shown in *Figure 2.3*. Temperature and available soil water, both highly variable in the Great Plains, are the most important factors influencing development. While *Table 2.2* gives the calendar date that various growth stages were reached, it is more accurate to use heat units (HU) or growing degree-days (GDD) to measure the time it takes for a wheat plant to reach a given developmental stage. In warm falls, more leaves and tillers are formed on the plant, and during cool springs, growth stages are delayed. This is because plants develop in response to temperature rather than time. Heat units or growing degree-days, as estimates of thermal time, can be used to calculate when growth stages are reached and the rate of many growing point (shoot apex) developmental events, such as leaf and tiller appearance. One common way of calculating GDD is to average daily temperature (TAVG) and subtract a base temperature (TBASE). The TBASE, which represents the point at which wheat development stops, is usually set at 32°F and is subtracted from the result.

$$\text{TAVG} = \frac{\text{daily maximum temp.} + \text{daily minimum temp.}}{2}$$

$$\text{GDD} = \text{TAVG} - 32 \quad (\text{GDD} \geq 0)$$

Accumulated GDD (summed each day) can predict the occurrence of key developmental events, such as growth stages and the appearance of specific leaves and tillers. However, the required GDD for a given developmental event can vary among cultivars.

Predicting when growth stages should occur is straightforward if there is adequate soil water. Emergence of half the seedlings is expected to occur once 270 GDD have accumulated after planting or after adequate rainfall if you planted into a dry seedbed. The first tillers are expected to appear approximately 540 GDD after emergence. The remaining growth stages all occur after winter, when the vernalization requirement of winter wheat has been satisfied. By starting accumulation of GDD on January 1, the growth stages from jointing to maturity can be predicted (*Table 2.3*). Estimates are provided for both irrigated and dryland conditions because limited soil water tends to accelerate development, especially for flowering and maturity. The dryland GDD in *Table 2.3* were obtained during two years of very low rainfall, so larger values should be used in years with greater rainfall.

*Table 2.3* gives the basis for predicting growth stages for irrigated and dryland conditions. The PhenologyMMS computer program is being developed to simulate the growth stages of different crops and determine how development is influenced by available soil water. Results of some of the most important growth stages for locations across the Great Plains are shown in *Table 2.4*. Soil water had little influence on early leaf number or the jointing growth stage, but flowering occurred about four days earlier under dry conditions and maturity about 12 days earlier.

**Table 2.3**

Growing degree days required by winter wheat to reach important growth stages, under irrigated and dryland conditions.

Interval	Irrigated (GDD)	Dryland (GDD)	Reduction in Dryland (%)
Jan 1 to jointing <sup>1</sup>	871	875	0
Jointing to flag leaf complete (begin booting)	284	274	4
Flag leaf complete to heading	295	257	13
Heading to flowering	239	211	12
Anthesis to maturity	1278	1003	22

<sup>1</sup>Data are for means of 12 winter wheat varieties grown at two locations (Fort Collins and Akron, Colorado) for two years. Note that irrigation did not begin until just before this growth stage, so there is little difference between the two treatments. (From McMaster et al., 2005, *Journal of Agricultural Science*, Cambridge 143:1-14)

\*\* $(1 - \text{Dryland GDD} / \text{Irrigated GDD}) \times 100$

**Table 2.4**

Average simulated occurrence of key winter wheat growth stages at several western High Plains locations

Location	# of Years	Mean date of 2 leaves	Jointing		Anthesis		Maturity	
		Optimal	Optimal	Stress	Optimal	Stress	Optimal	Stress
<b>Akron, CO</b>	29	10/10	4/28	4/27	6/2	5/29	7/9	6/28
Range (# days)		-6 to 11	-19 to 21	-19 to 22	-13 to 14	-15 to 15	-9 to 12	-10 to 12
<b>Colby, KS</b>	21	10/8	4/18	4/17	5/22	5/18	6/27	6/16
Range (# days)		-5 to 9	-17 to 19	-16 to 19	-14 to 14	-13 to 14	-8 to 12	-9 to 13
<b>Durant, OK</b>	74	9/30	3/9	3/9	4/12	4/8	5/21	5/9
Range (# days)		-3 to 4	-24 to 30	-24 to 30	-22 to 24	-21 to 24	-16 to 22	-18 to 20
<b>Fort Collins, CO</b>	30	10/14	5/1	5/1	6/5	6/1	7/13	7/1
Range (# days)		-10 to 10	-24 to 12	-24 to 12	-25 to 8	-25 to 8	-18 to 9	-19 to 9
<b>Rocky Ford, CO</b>	28	10/8	4/14	4/14	5/18	5/14	6/25	6/13
Range (# days)		-5 to 23	-20 to 14	-21 to 13	-20 to 17	-20 to 13	-15 to 16	-17 to 14
<b>Shelton, NE</b>	14	10/9	4/27	4/26	5/29	5/25	7/3	6/22
Range (# days)		-4 to 4	-12 to 14	-12 to 15	-11 to 11	-11 to 11	-4 to 10	-7 to 10
<b>Sidney, NE</b>	23	10/14	5/3	5/3	6/6	6/2	7/13	7/2
Range (#days)		-7 to 9	-13 to 17	-14 to 16	-14 to 12	-14 to 13	-7 to 9	-8 to 9
<b>Sterling, CO</b>	13	10/10	4/27	4/26	5/31	5/27	7/7	6/26
Range (# days)		-5 to 3	-11 to 9	-10 to 10	-11 to 7	-11 to 7	-8 to 7	-9 to 8
<b>Stratton, CO</b>	19	10/8	4/21	4/21	5/27	5/23	7/3	6/22
Range (# days)		-3 to 4	-10 to 16	-11 to 16	-10 to 11	-10 to 11	-7 to 10	-7 to 10
<b>Walsh, CO</b>	12	10/6	4/7	4/7	5/14	5/10	6/21	6/9
Range (# days)		-5 to 4	-8 to 15	-8 to 14	-11 to 10	-11 to 10	-7 to 8	-9 to 9

\*\*Simulations were generated by The PhenologyMMS computer program. The number of historical years of weather data for each location is given in the 2<sup>nd</sup> column.

Updated versions of the software are available at <http://arsagsoftware.ars.usda.gov>.

A uniform naming scheme for leaves and tillers allows us to communicate effectively about plant development and interpret how a wheat plant has responded to its environment. For instance, if a specific tiller is absent but a later-appearing tiller is present, then conditions likely were stressful for the plant for the period of thermal time when the absent tiller was to appear.

Naming of leaves is based on the order of their appearance on the stem, with the first leaf denoted as L1, the second as L2, and so on until the last leaf, the flag leaf, is produced. Each leaf appears about 180 GDD after the previous one. The first seedling leaf is on the main stem and has a distinctive rounded tip; all other leaves have pointed tips. About 12 to 14 leaves are normally formed on the main stem, with fewer leaves forming on tillers. Buds are formed at the base of each leaf where it attaches to the stem and produces tillers. Tillers appearing from main stem leaves are primary tillers. The primary tiller emerging from the first leaf (L1) is called T1, and the primary tiller emerging from the main stem L2 leaf is T2, and so forth. Tillers appearing from leaves on primary tillers are termed secondary tillers, and identified with two digits, where the first digit refers to the primary tiller and the second to the leaf number. For example, T11 is the secondary tiller formed in the axil of leaf L1 on tiller T1.

Because winter wheat leaves normally appear at 180 GDD intervals, the number of leaves can be estimated from weather records. For instance, the fourth leaf should appear when 630 GDD has accumulated:

$$90 (L1) + 180 (L2) + 180 (L3) + 180 (L4) = 630$$

(Ninety GDD are used for the main stem leaf L1 because it appeared at seedling emergence and was already partially grown).

Thermal time also can be used to time management practices. For example, if an herbicide label says application should be at the 3.5 leaf stage, then the treatment should be made at 540 GDD after planting. Observed emergence date is more accurate than planting date to begin GDD accumulation. *Figure 2.3* and *Tables 2.3* and *2.4* can provide thermal time estimates for ideal application timing for a variety of growth stages.

A given tiller appears only during a specific window of time and only if conditions are suitable. This tiller production window generally occurs after 1.5 to 2.5 leaves have appeared above, or roughly 270 GDD after the corresponding leaf appears. This knowledge can be used to evaluate management practices and yield production. For example, if the T2 tiller is absent but the T3 tiller is present, stress likely occurred during the T2 window, knowing that T2 and T3 should appear at about 630 and 810 GDD after emergence. Weather data can be used to calculate stress and management practices available to alleviate the stress.

Use this knowledge of wheat plant development, thermal time, and leaf and tiller appearance to maximize the most important yield component—number of heads per acre. The number of heads per acre depends on how many seedlings emerge, how many tillers appear on each plant, and how many tillers survive to produce a head. However, the tillers that contribute the most to final yield are T1, T2, and T11, so planting times should be adjusted to insure that these tillers are produced in the fall. This requires the accumulation of at least 540 GDD before fall growth stops (the T2 tiller appears at about the 3.5 leaf stage of the main stem).

If these tillers appear in the fall, they can grow sufficiently and produce a head. Typically, more tillers than heads are produced by a wheat plant. Shortly before jointing the plant begins aborting tillers unlikely to form heads; generally, those with fewer than four leaves. A few additional tillers may be lost up to anthesis, but the tiller number per acre is essentially set by the time of jointing. Consequently, the later emergence occurs, the more likely it is that a tiller will have insufficient leaves and will be aborted. This reduces the heads produced per acre, unless seeding rate is increased to compensate for this lower tiller production.

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 survival of most tillers is determined during the jointing growth stage, and many of the developmental processes related to head and kernel number occur 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 severely reduce grain set and initial kernel development and growth.

We have briefly discussed how the wheat plant develops from planting through maturity and when yield components are determined. The developmental sequence is followed by all wheat plants. However, the timing of developmental events differs among cultivars, fields, and years. Thermal time (GDD) can be used to time events accurately and predict the occurrence of future crop growth stages when combined with forecast temperatures. Although GDD are extremely valuable for predicting the timing of future events, these are only estimates and not exact predictions. As shown in *Tables 2.3 and 2.4*, soil water availability has a strong influence on the accuracy of these estimates, particularly for the timing of anthesis and maturity. Variations in GDD between growth stages for different cultivars can be used to aid cultivar selection for your specific needs. Using the GDD approach to predict growth stages also can help in planning the optimal timing of management practices (e.g., planting date and herbicide applications).



# Winter Wheat Variety Selection

By Roberta Armenta

The variety selection process is an important step in reducing production risks and maximizing wheat yield and economic return. When making variety decisions, some essential factors to consider include winter hardiness, insect and disease resistance characteristics, heading date, lodging, test weight, and yield. It is important for wheat growers to weigh the advantages and disadvantages of numerous varieties to find those that best fit their intended market and that are well adapted to local growing conditions. Breeding programs across the Great Plains have produced many improved winter wheat varieties, focusing on special areas of emphasis for the Great Plains region.

All current varieties in the commercial market are ***pure-line varieties***, meaning varieties that are genetically homogenous. These varieties are developed when selected genotypes, with superior and desired characteristics, undergo multiple generations of inbreeding. Plants of these varieties are genetically the same.

## Important Varietal Characteristics

### Grain Yield Performance

Increases in winter wheat yield performances in the Great Plains over the past few decades are due to the development and improvement of winter wheat varieties and various management practices. Growers can make systematic and informed decisions as to which varieties will maximize economic returns under local growing conditions. By testing new varieties and management technologies, producers can find and adopt techniques that work best for them. Many valuable resource tools are available for growers including university variety trials (*Figure 3.1*), other demonstration plots, associated field days, and related publications. State organizations (Colorado Wheat Research Foundation, Kansas Wheat Commission, Montana Wheat & Barley Committee, Nebraska Wheat Board, Oklahoma Wheat Commission, South Dakota Wheat Commission, and Texas Wheat Producers Board & Association), and national organizations (National Agriculture Statistics Service, National Association of Wheat Growers, U.S. Department of Agriculture, and U.S. Wheat Associates) all provide valuable wheat production information.



**Figure 3.1**  
Colorado State University has many winter wheat variety testing sites across Colorado.

Producers should base variety selection on yield performance over several years and locations. Use a three-year average performance summary instead of performance in a single year or single location. Performance in a single year and/or location is unreliable because crop performance varies with environmental conditions, and conditions may not be representative of those that a producer will encounter on average. University variety testing programs generally are designed to predict the performance of one variety relative to others, instead of predicting actual grain yield.

Variety performance may not be exactly the same on individual farms as predicted in trials due to limited test locations and the variable growing conditions of the region. In addition, yield performance is more difficult to predict than other varietal traits such as test weight, protein content, height, maturity, and disease tolerance or resistance. Plant new varieties on a small scale in your operation before using them on large acreages.

### **End-Use Quality**

The end-use quality of winter wheat refers to the ultimate application for which the product (wheat) is intended for. Important characteristics that are valued by the end-user, such as milling and baking properties, must be considered by the grower. Growers can control variety selection and fertility programs, both of which are factors that affect quality. Variety descriptions provide information on varietal traits and can be used to select varieties predicted to provide good end-use quality. Reference the resources provided at the end of the chapter for more information.

Although yield performance and end-use quality are important traits to consider when selecting winter wheat varieties, other traits should be considered as well. These include winterhardiness, pest and disease resistance, herbicide tolerance, maturity, and plant height. There is no one perfect wheat variety for every location, but it is possible to use varietal trait information to select the best available varieties for a given location or expected conditions. In order to minimize production risks and maximize the chances for optimal economic returns, it is best to grow several varieties.

### **Maturity**

Maturity refers to the number of days that a variety takes to produce harvestable grain. Variations in maturity are useful for avoiding certain environmental stresses such as freeze injury, heat damage, drought injury, and disease. For example, late-maturing varieties may be less prone to late season frost because they are less likely to be flowering than an earlier-maturing variety. On the other hand, early-maturing wheat varieties may avoid the high temperatures and drought stress often experienced later in the growing season. Such varieties also are more likely to escape leaf diseases during grain fill. Choose a combination of varieties with a range of maturities to spread the risk from environmental stresses and the workload at harvest.

## Winterhardiness

Winterhardiness refers to a plant's ability to withstand cold temperatures in the late fall, winter, or early spring. The importance of this trait will vary with the severity of the winter season. Abrupt drops in fall temperatures reduce the time available for developing winterhardiness and leave crops vulnerable to freeze injury (*Figure 3.2*). Management practices can help protect crops. For example, fields with standing stubble tend to have a warmer and more stable soil temperature than tilled fields. Standing stubble increases snow collection, which insulates by reflecting radiant heat back into the soil. In addition, stubble tends to delay spring regrowth, which can protect plants from early spring freeze events.



**Figure 3.2**  
Freeze damaged  
wheat heads.

## Disease Resistance

The need for disease resistance traits will vary with location. Resistance to foliar diseases is important in more humid regions, while wheat streak mosaic virus (WSMV) and leaf rust is of greater concern in the Great Plains. Look for varieties with at least moderate resistance or tolerance to diseases known to be important locally (refer to Chapter 9—“Disease Management of Wheat”). Resistant and tolerant varieties are available for Great Plains problems such as bunts and smuts, barley yellow dwarf virus, wheat soilborne mosaic virus, stripe rust, and stem rust.

## Insect Resistance

Insect resistance traits are available in certain varieties and are useful in areas where a given pest is a consistent problem (refer to Chapter 7—“Arthropod Pests in Wheat”). Resistance is available to greenbug, Hessian fly, Russian wheat aphid, and wheat stem sawfly. Even moderate resistance may be sufficient to avoid expensive insecticide treatments. The selection of insect-resistant varieties is complicated by pest biotypes virulent on previously resistant varieties. Biotypes are known for greenbug, Hessian fly, and Russian wheat aphid. Variety descriptions will indicate which biotypes are affected by the resistance trait. Consider selecting a more competitive variety and relying on other pest management approaches if resistance is not available in a well-adapted, competitive variety.



**Figure 3.3**  
Lodging of wheat.



### **Plant Height, Straw Strength, and Coleoptile Length**

Plant height, straw strength, and coleoptile length are interrelated variety traits and should be used to meet the production conditions of different regions. The coleoptile is a protective structure that covers the shoot until emergence through the soil surface. If the coleoptile does not reach the surface, then the plant will die. Coleoptile length determines planting depth and is highly correlated with plant height at maturity. Tall varieties, with their longer coleoptiles, are better suited for planting deep into dry soils. However, such varieties tend to have weaker straw strength, making plants more likely to lodge (*Figure 3.3*). Varieties with good straw strength are less likely to lodge, but other factors, such as excessive nitrogen application or high rainfall, can reduce straw strength.

### **Additional Resources**

Many tools and information resources are available to growers, seed producers, and wheat industry representatives. These resources provide the Great Plains region's wheat industry with information about new varieties and good varietal selection decision making. It is recommended that those in the wheat industry use as many of these tools as possible when researching possible variety choices.

### **University Extension Services and Local Wheat Programs**

Because production conditions are so variable across the Great Plains, local universities conduct performance trials at test plots located throughout the region to demonstrate the performance of a variety across different environmental conditions. To guide producers in their selection decisions and further the development of promising varietal lines, the breeding programs include a broad range of environmental conditions including variation in precipitation levels, varietal maturity, seasonal temperatures, hail and freeze occurrences, and disease and pest occurrences. Performance results are published soon after harvest every year and are available through University websites, extension offices and websites, and state wheat commissions. Local crop reports, market information, and research news also are available through these outlets.

**Colorado**

Colorado Wheat (CWAC, CAWG, CWRP): ([www.coloradowheat.org](http://www.coloradowheat.org) or call 1-800-WHEAT-10)

Colorado State University Cooperative Extension: (<http://www.ext.colostate.edu/>)

CSU Crops Testing Program: (<http://www.extsoilcrop.colostate.edu/CropVar/>)

CSU Wheat Breeding and Genetics Program: (<http://wheat.colostate.edu/>)

**Kansas**

Kansas Wheat Commission and Kansas Association of Wheat Growers: (<http://www.kswheat.com/>)

K-State Research and Extension: (<http://www.ksre.ksu.edu/wheatpage/>)

Wheat Genetic and Genomic Resources Center: (<http://www.k-state.edu/wgrc/>)

**Montana**

Montana Wheat and Barley Committee: (<http://wbc.agr.mt.gov/>)

Montana State University Extension: (<http://www.msuextension.org/>)

**Nebraska**

Nebraska Wheat Page: (<http://www.nebraskawheat.com/>)

University of Nebraska-Lincoln Extension Service: (<http://cropwatch.unl.edu/web/wheat/home>)

**North Dakota**

North Dakota Wheat Commission: (<http://www.ndwheat.com/>)

North Dakota State University Extension: (<http://www.ag.ndsu.edu/smgrains/>)

**Oklahoma**

Oklahoma Wheat Commission: (<http://www.state.ok.us/~wheat/>)

Oklahoma Wheat Growers Association: (<http://www.owga.org/>)

Oklahoma State University Extension Service: (<http://www.wheat.okstate.edu/>)

**South Dakota**

South Dakota Wheat Growers: (<http://www.sdwg.com/SDWG/default.aspx>)

South Dakota Wheat Commission: (<http://www.sdwheat.org/>)

South Dakota State University Extension Crop Management: (<http://plantsci.sdstate.edu/varietytrials/>)



## **Texas**

Texas Wheat Producers Board and Association: (<http://www.texaswheat.org/>)

Texas A&M University Variety Testing Information:  
(<http://varietytesting.tamu.edu/wheat/>)

## **Wyoming**

Wyoming Wheat Growers Association: ([www.wyomingwheat.com](http://www.wyomingwheat.com))

University of Wyoming Cooperative Extension Service: (<http://ces.uwyo.edu/>)

## **Wheat Field Days and Field Tours**

Wheat Field Days are held every year in the late spring to early summer at various locations across the Great Plains region. Wheat Field Days are a good opportunity for growers to learn about new varieties developed by the wheat breeding programs. Wheat producers are able to view the performance of numerous varieties side-by-side under local growing conditions, allowing for them to make informed decisions about which varieties will work best in their wheat programs. Also included in Field Days are presentations by University wheat specialists, highlighting new wheat varieties, emerging wheat production issues, and trial conditions. Field tours are also available at some universities across the Great Plains, with benefits similar to those of Field Days. For more information, contact your local university extension office.

# Diversified Cropping Systems

*By D.G. Westfall, G.A. Peterson, and N.C. Hansen*

The limiting factor for production of dryland crops in semiarid environments is available soil moisture. The wheat-fallow (WF) production system, managed under stubble-mulch tillage, has been the backbone of dryland agriculture in the west-central Great Plains for decades. Over the years, this system has resulted in relatively stable yields because of the soil moisture stored during the fallow period. However, years of tillage for weed control and seed bed preparation have decreased precipitation storage due to soil organic matter loss, degradation of soil structure, increased potential for soil erosion (particularly by wind), and decreased precipitation infiltration. Only about 25 percent of the precipitation received during the 14-month fallow period is stored in the soil for use by the next wheat crop.

Research in Colorado and surrounding states over the past 20 years has shown that it is possible to diversify the cropping system and reduce the frequency of summer fallow by decreasing or eliminating tillage. We can produce crops three out of four years, or more, because of two factors: 1) decreased tillage stores a greater proportion of the annual precipitation in the soil, and 2) having crops present when precipitation initially occurs increases precipitation use efficiency. Adoption of diversified cropping systems also restores soil quality and increases profitability. However, producers must assess their ability and desire to intensify management and accept the increased risk associated with the adoption of diversified cropping systems. Below we outline factors that affect soil moisture storage, cropping systems diversification, and other issues that affect successful production of diversified cropping systems in our water limited environment.

## Storing Soil Water for Crop Use

There are three principles of soil water conservation:

1. Precipitation capture—storing precipitation in the soil.
2. Water retention—retaining soil water for later use by crops.
3. Water use efficiency—using the water efficiently for the production of marketable yield.

### Precipitation Capture

Conserving water begins with the capture of precipitation—including rain and snow. Precipitation capture is affected by soil texture, soil aggregation, and soil pore size. All of these factors affect water runoff which can be a significant water loss mechanism.

### Promoting Infiltration

Soil texture greatly affects water infiltration. Coarse textured soils (sandy loams, etc.) have large pores that promote high infiltration rates. Fine-textured soils (silt loams and clay loams) generally have smaller pores and lower infiltration rates. Soil texture cannot be changed, so we must work within this constraint. However, we can improve infiltration rates by soil management techniques that promote soil aggregation.

Soil aggregation impacts the pore distribution of a soil. The degree of aggregation can be changed by soil management techniques. Frequent tillage destroys soil aggregation. Conversely, no-till (along with crop residue additions) can help restore aggregation. Finer texture soils must have good structure that promotes large pore spaces so water can enter the soil. Any practice, such as tillage, that destroys soil aggregates or decreases soil aggregate size and decreases surface pore space ultimately will reduce water infiltration into the soil and promote evaporation and runoff.

### Maintaining Crop Residue Cover

Protecting soil aggregates from raindrop impact is another key to maintaining water capture. The crop residue maintained on the soil surface by no-till absorbs raindrop energy and protects soil aggregates during rainfall events. The amount of crop residue maintained on the soil surface is directly related to cropping intensity (*Table 4.1*). In a low evapotranspiration (ET) environment (i.e., Sterling, CO), a WF system had an average of only 2,680 pounds per acre of crop residue on the soil surface over a 12-year period as contrasted to 4,690 pounds per acre in the wheat-corn-millet-fallow (WCMF) diversified cropping system. The same relationship for cropping systems existed across the climate gradient, but the quantities of residue were less at locations in higher ET environments (i.e., Walsh, CO). The 2,480 pounds per acre of residue on the soil surface in the WCMF cropping system at the high ET location will protect the soil better against raindrop impact and wind erosion than will the 1,570 pounds per acre of residue in the WF cropping system.

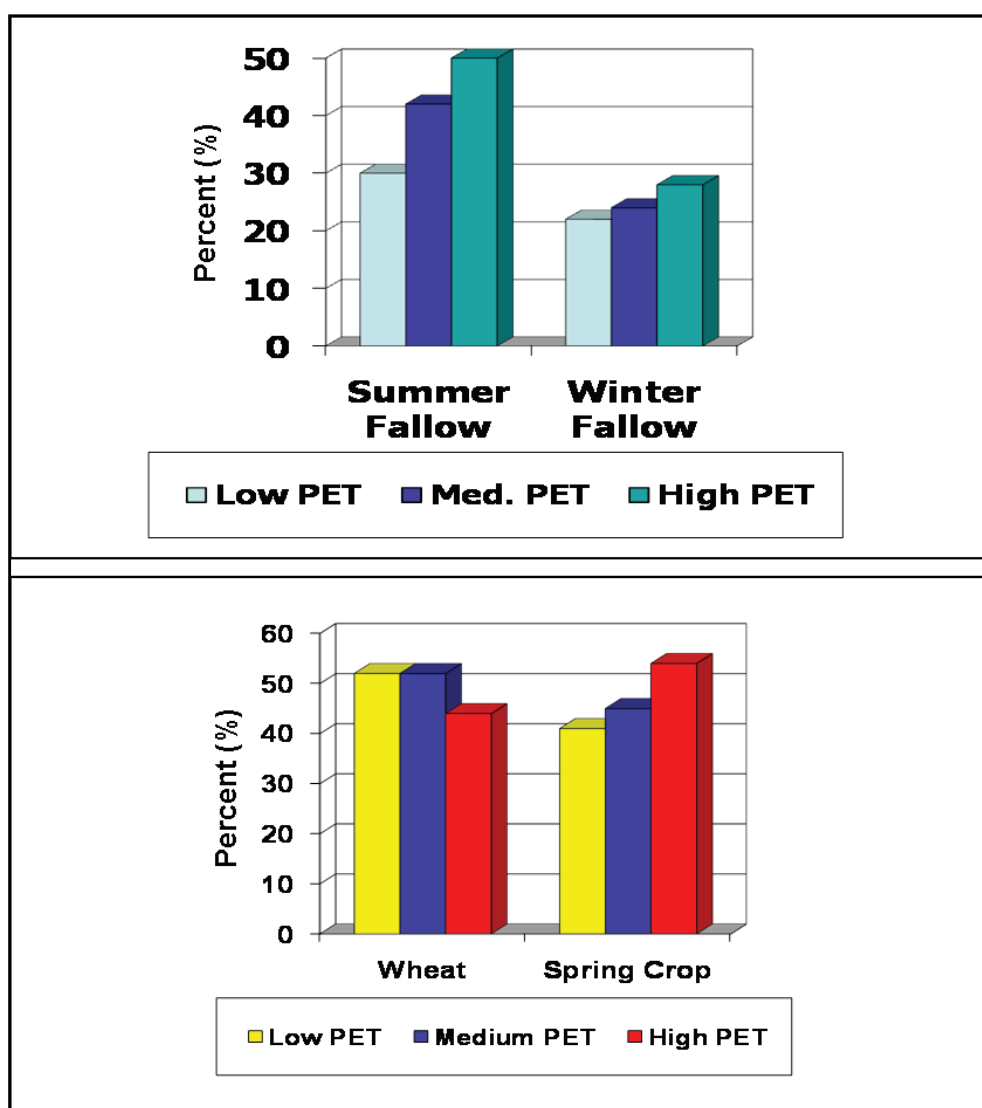
**Table 4.1**  
The average annual crop residue on the soil surface at winter wheat planting in diversified cropping systems as affected by climate (evapotranspiration) over a 12-year period.

Location	Cropping System <sup>1</sup> (Lb residue on soil surface per ac)			
	WF	WCF	WCMF	CC
Low ET <sup>2</sup>	2,680	4,530	4,690	6,261
Medium ET	3,030	4,370	4,330	5,620
High ET	1,570	2,240	2,480	2,480

<sup>1</sup>WF=wheat-fallow, WCF=wheat-corn-fallow, WCMF=wheat-corn-millet-fallow, CC=continuous cropping  
<sup>2</sup>ET=evapotranspiration

Crop residue is lost during both fallow and cropping periods. During the traditional summer fallow period, about 30 to 50 percent of the crop residue is lost (*Figure 4.1*) by microbial decomposition and physical destruction by the wind. **Climate has a great impact on residue loss.** In a low ET location, the loss during summer fallow is about 30 percent, while at a high ET location, the loss may be as much as 50 percent. Residue loss is much lower during the winter fallow period—when temperatures are lower and there is potential snow cover—ranging from 22 to 28 percent (*Figure 4.1*). Crop residue loss during the cropping period is greater than during either fallow period (*Figure 4.2*), irrespective of evapotranspiration rate. About 45 to 52 percent of the crop residue is lost during the winter wheat growing period and from 42 to 54 percent during a spring crop (e.g., corn or proso millet) growing period.

Residue loss is a constant process driven by climate and microbial activity, which interact to result in large losses over time. Crop diversification results in increased residue production and greater residue retention (*Table 4.1*). The crop canopy also absorbs raindrop energy and thus preserves soil structure. Summer crops are present when about 77 percent (*Figure 4.3*) of the annual precipitation is received, providing excellent soil protection.



**Figure 4.1**

The percentage of residue disappearance during fallow periods in the summer and winter (PET=potential evapotranspiration).

**Figure 4.2**

Percentage of crop residue loss during winter wheat and spring cropping periods.



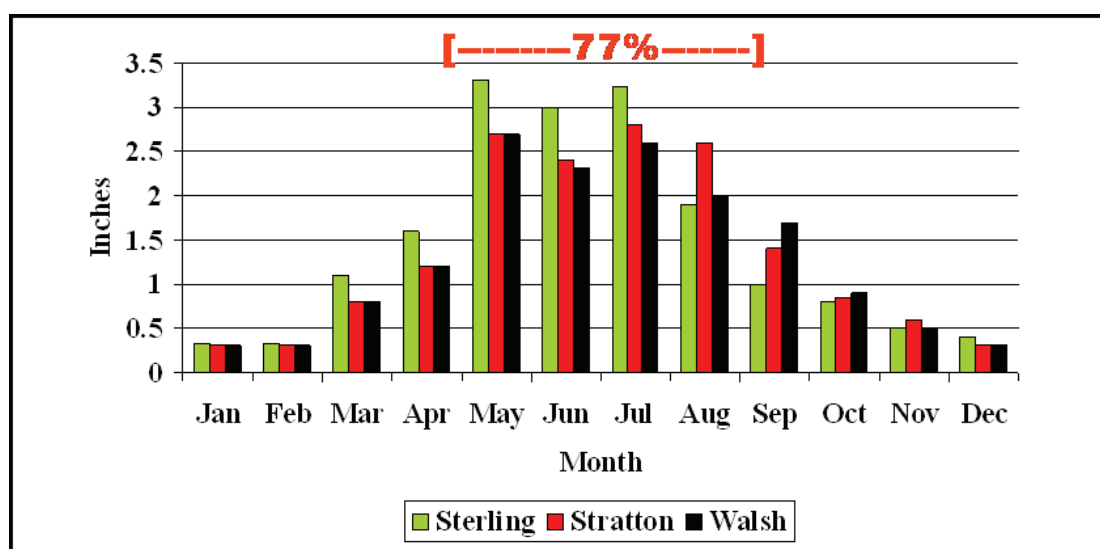
**Table 4.2**

The percentage of residue lost with different tillage operations.

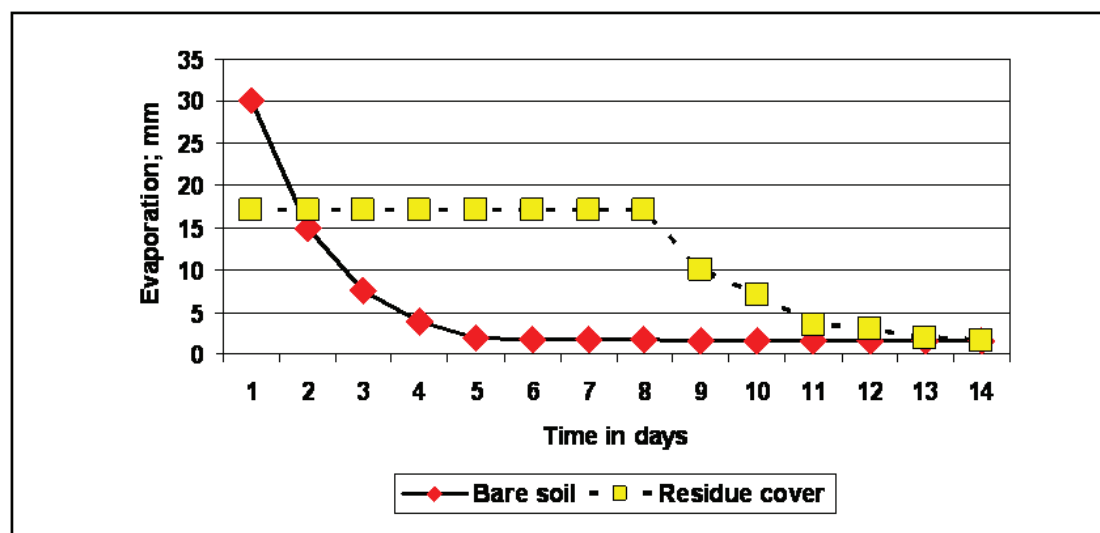
Operation	% of Residue Lost
Spraying	0
Sweep (24 inch)	10
Disk drill	20
Disk chisel	10
Rod weeder	15
Chisel plow (straight points)	25
Chisel plow (twisted points)	50
Tandem disk (3 inch depth)	80
Tandem disk (6 inch depth)	90
Moldboard plow	90-100

**Figure 4.3**

Long-term precipitation distribution in eastern Colorado.

**Figure 4.4**

Soil water evaporation from a bare and residue covered soil.



Crop residues greatly slow the rate of soil water evaporation. Each tillage operation results in the loss of residue, with the amount of loss dependent on the amount of soil disturbance (*Table 4.2*). In addition to protecting soil structure, residues also retard soil surface evaporation. However, if enough time passes without a rainfall event, soil under the residue will lose as much water as bare soil (*Figure 4.4*). Nonetheless, residue covered soil loses water over a longer period, thus allowing greater opportunity for infiltration and use by a growing crop. These water savings will not be as great if a summer crop is not grown.

### Decreasing Runoff and Soil Erosion

Runoff from high intensity rainfall is a smaller, but potentially important, loss of water. In eastern Colorado, a majority of the annual precipitation comes in the form of brief, high intensity, summer thunderstorms, often resulting in runoff and erosion. The amount of runoff depends on soil type, slope length and steepness, and on soil surface conditions. Management practices that reduce this runoff will improve precipitation use efficiency.

Runoff represents a short-term water loss to the cropping system, while soil erosion induced by runoff can cause long-term and permanent damage to agricultural systems. It is estimated that between 2 and 6.8 billion tons of soil per year is lost from cropland in the United States due to erosion. While wind erosion may dominate in dryland cropping systems, water erosion rates can also threaten the soil's ability to sustain crop production in the long-term. Management practices that protect the soil surface from crusting and runoff can greatly reduce soil erosion rates. Soil erosion can be decreased by 80 to 90 percent in no-till systems when compared to conventionally tilled land.

Recently, a coupled analysis of historical hourly rainfall intensity data and field measurements from Sterling and Stratton, Colorado were used to estimate potential runoff and soil erosion from dryland agroecosystems (*Table 4.3*). The estimates were made separately for wet years (average to above average rainfall) and for dry years (below average rainfall) and for scenarios with low and high runoff probability. Low probability runoff scenarios correspond to flatter land with good residue cover, while high runoff probability corresponds to steeper slopes with little residue cover. Runoff was estimated to range between 0.3 inches for drought years and management with good surface protection to 3.2 inches for wet years and management with poor protection of the soil surface. The potential to capture as much as three inches of precipitation through improved management practices will translate into greater crop yield and higher profitability. Annual rates of erosion by water were estimated to range between about 0.4 tons per acre to as high as 4.1 tons per acre (*Table 4.3*). Soil erosion rates are too high for long term sustainability of crop production if management practices do not provide soil surface protection. Management that protects the soil surface and reduces the probability of runoff is an effective means of soil erosion control. Residue management achieved through no-till or minimum till practices is the most effective means of reducing runoff and soil erosion.

**Table 4.3**

Average annual amount of high intensity rainfall (>0.5 in/hr) and estimates of runoff and soil erosion at Sterling and Stratton, Colorado for years with average to above average annual precipitation (wet years) and years with below average precipitation (dry years).

Location	Year Type	Rainfall <sup>3</sup> (inches)	High Runoff Probability <sup>1</sup>		Low Runoff Probability <sup>2</sup>	
			Water Runoff (inches)	Soil Erosion (inches)	Water Runoff (inches)	Soil Erosion (inches)
Sterling	Wet	5.9	3.2	4.1	0.8	1.1
	Dry	2.4	1.3	1.7	0.3	0.4
Stratton	Wet	2.8	1.5	2.0	0.4	0.5
	Dry	3.5	1.9	2.4	0.5	0.6

<sup>1</sup>Poor surface protection with little crop residue

<sup>2</sup>Good surface protection with adequate crop residue

<sup>3</sup>Average annual amount of high intensity rainfall (>0.5 in/hr)

**Table 4.4**

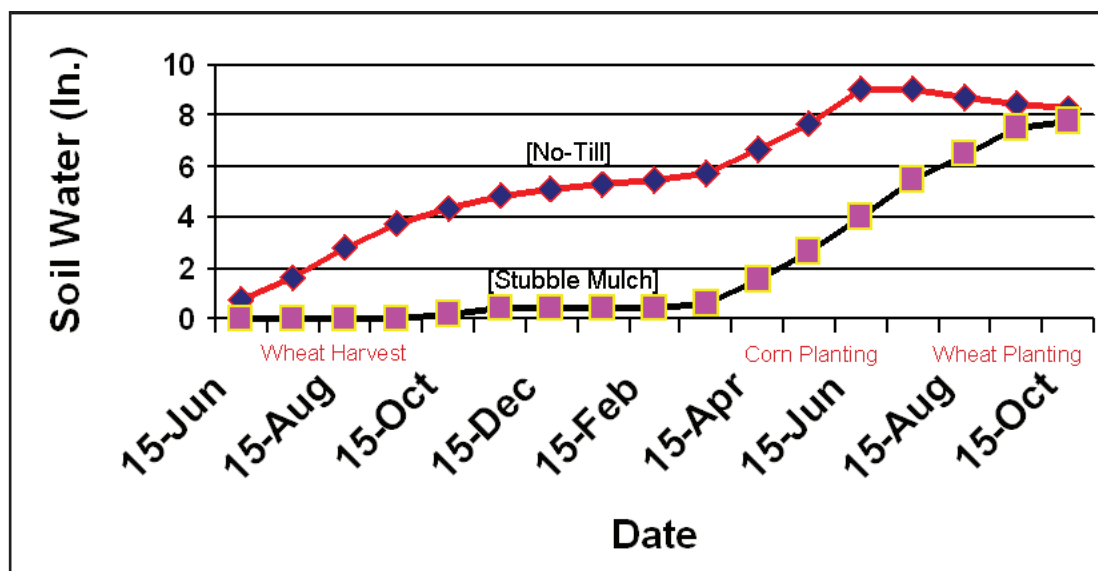
Typical soil water loss from different tillage operations 1 and 4 days after tillage.

Operation	Water Lost (in inches)	
	1 Day	4 Day
One Way	0.33	0.51
Chisel	0.29	0.48
Sweep	0.09	0.14
Rod Weeder	0.04	0.22

## Snow Melt and Capture

Efficient capture of snow water has two features: catching the snow and capturing the melt water. Because snow often is accompanied by wind, the principles of snow catch are similar to those used in protecting soil against erosion by wind. Standing crop residue, shelter belts, strip cropping, and artificial barriers have all been used to maximize snow-catch. Standing crop residues conserved 37 percent of the overwinter precipitation, while fields with no standing residues conserved only 9 percent. The proportion of the land area covered by standing crop residues in a field obviously affects snow catch. Raising the cutting height of sunflower stalks increased stored soil water from snow in another study. With any kind of residue, the greater the height, the greater the potential snow capture.

Snowfall capture is the simplest part of capturing the snow water resource. Unfortunately, getting snowmelt water into the soil is far less predictable and manageable due to soil freezing. Infiltration rates for frozen soils are determined by two factors: soil frost structure (i.e., small granulated units versus massive concrete-like units) and soil water content at the time of freezing. Soils frozen at low water content do not impede infiltration because they granulate, leaving adequate open pore space for infiltration. In contrast, soils frozen at high water contents freeze into dense, massive, concrete-like structures that are nearly impermeable to water. Rapid warming accompanied by rainfall on such frozen soils can cause major runoff and erosion.



**Figure 4.5**  
Water storage calendar with no-till compared to stubble mulch tillage.

## Turning Stored Water into Crop Production

The effect of no-till on precipitation storage is shown in *Figure 4.5*. During the fallow period after wheat harvest (late June through the winter), little precipitation storage occurs in a typical stubble mulch system due to water use by weeds. In the spring and second summer of the fallow period, farmers till to control weeds and precipitation storage occurs, reaching a maximum in early September. In addition to evaporation losses due to the high summer temperatures, each tillage operation results in loss of stored soil water, with the amount dependent on the type of tillage (*Table 4.4*). About 25 percent of the precipitation received during the entire fallow period is stored under a typical stubble-mulch tillage system. However, 40 to 60 percent of precipitation can be stored using no-till due to reduced evaporation and weed management during the previous crop and the entire fallow period. Soil surface residues decrease evaporation rates by lowering soil temperatures, which increases precipitation storage. The soil water content reaches a maximum by June, and no additional precipitation storage occurs for the remainder of the summer fallow period because the soil has reached its maximum water-holding capacity under no-till management. However, as shown in *Figure 4.3*, most of the precipitation occurs after May. If the soil profile is full, most of the precipitation is lost to evaporation, deep percolation, or runoff.

The increased soil water stored under no-till usually does not result in a significant increase in wheat yields in a WF system under “normal” rainfall conditions because the soil profile in a stubble-mulch system will be full in the fall. However, under drought conditions, increased wheat yields may occur in a WF system under no-till. Under normal rainfall conditions, crop diversification is required to take advantage of the increase in water storage efficiency in no-till systems. Increased crop production and profit are achieved by integrating a summer crop into the production system.

## Diversifying Dryland Cropping Systems

Adoption of diversified cropping systems requires a change in management philosophy and intensity (*Figure 4.6*). To ensure a successful diversified crop production system, you must begin to plan for the next crop while the current crop is growing.

### Diversified Cropping Options

Among the summer crops adapted to the Great Plains climate are triticale (*Triticosecale* Wittmack), dry pea (*Pisum sativum* L.), foxtail millet (*Setaria italica* L. Beauv.), and proso millet (*Panicum miliaceum* L.). Sorghum is an excellent substitute for corn in production areas south of Cheyenne Wells, Colorado. In the more northern areas, early fall freezes often cause yield losses in grain sorghum.

Summer crops should be planted into crop residue that has been maintained in a weed free condition using either no-till or minimum tillage management. Use drills or planters that result in minimal soil disturbance during planting operations, thus allowing the retention of as much crop residue as possible.

Diversified cropping systems can vary greatly. The most common systems are winter wheat-corn-fallow (WCF), winter wheat-sorghum-fallow (WSF), winter wheat-proso millet (WMF), and winter wheat-corn-proso millet-fallow (WCMF). Diverse cropping systems without a fallow period include WCCM, WM, and continuous proso millet. However, continuous cropping systems have had little success in recent dry years due to inadequate soil moisture in the fall for winter wheat establishment and inadequate stored soil moisture to carry the wheat crop through periods of limited rainfall during the spring and summer. A fallow period prior to winter wheat planting will usually be required to keep this crop in your system.

**Figure 4.6**

Corn growing in winter wheat stubble in a diversified cropping system.





## Weed Control

Weed control in the growing wheat crop is the essential first step in adding a summer crop to the WF rotation. A residual herbicide applied in the growing wheat will result in weed free conditions until after harvest. Weeds in the maturing wheat crop use the valuable moisture that we receive from summer rains. After wheat harvest, the greatest weed problems are usually kochia, sunflower, and volunteer wheat. Uncontrolled, these weeds will use all of the rainfall received, and crops will enter winter with a dry soil profile. Three to five inches of water can be stored between wheat harvest and fall freeze up in weed free wheat stubble using no-till management. Each tillage operation to control weeds causes reductions in soil moisture. This can be as much as 0.5 inches per tillage operation if the surface soil is moist (*Table 4.4*), especially during the hot summer months following wheat harvest.

## Water Use Efficiency

Once water has been captured and retained in soil, it is important to ensure efficient use by plants. Available water for a particular crop equals the sum of the stored available soil water and the rainfall that is received during the crop growth cycle.

The amount of soil water available to a crop is controlled by its rooting depth. Crops such as winter wheat and sunflower extract water from depths of six feet or more if there is no dry soil layer in the profile. Corn roots extract water to at least five feet, while perennial crops like alfalfa may extract water up to a ten foot soil depth. In areas that have excellent water holding capacity, the six foot soil reservoir, if at field capacity, is substantial for most crops. Soils within the loam to silty clay loam textural classes will contain 12 to 15 inches of plant available water in a six foot depth if at field capacity. No-till provides the best opportunity to reach the field capacity water content.

During hot summers, a full water profile protects the crop during dry periods. However, the soil water profile generally will not be large enough to carry most crops through to maturity with no rainfall. At a plant water use rate of 0.2 to 0.3 inches per day, a profile of 14 inches of water would supply the crop for 45 to 60 days. Thus, the capture of the precipitation that occurs during the crop cycle also is critical.

The most critical growth stage for water availability in plants is always during the reproductive period. The combination of stored water and rainfall is needed to meet the water needs during this period and thus maximize grain yields. No-till practices will maximize soil water storage and provide the best chance of maintaining the crop, even when summer rainfall is lacking or is untimely. It is best to choose crops for rotation that have their critical water need when rainfall is most expected. Wheat and other cool season plants are well suited to these conditions. The reproductive stages of corn and sunflower occur later in the summer and are more likely to experience stress than wheat. ***In all cases, maximizing soil water storage before planting is extremely important, and no-till practices are most useful in achieving this goal.***

Adequate fertilization, especially with nitrogen (N) and phosphorus (P), is critical to getting the most out of precipitation and stored soil water. Research at Akron, Colorado showed that wheat roots require adequate fertilization to exploit the entire soil profile. Soil tests and appropriate crop yield goals help determine the amounts of N and P required. Intensified cropping systems, where more crops are being harvested, will have greater fertilizer requirements, especially N, than WF systems. Adequate fertilization allows you to realize the maximum profit from the water you worked so hard to save.

## Barriers to Diversifying Cropping Systems

1. ***Learning about and applying new technology.*** The learning curve can be steep for operators unfamiliar with chemical weed control, but working with neighbors who have successfully adopted diversified cropping systems is an excellent means of making a smooth transition. Local agricultural chemical dealers also are excellent sources of information.
2. ***Purchasing the equipment required for effective no-till management.*** You will need a good sprayer that meets your crop-specific demands. Custom herbicide application is available, but owning your sprayer insures timeliness of important operations. It should be equipped with a good marker system or have an electronic guidance system. You will also need planting equipment designed to handle surface residues. Depending on the crops you choose to produce, you may need to purchase both a grain drill and a row planter. However, if you choose a WMF rotation, a grain drill will suffice for all planting operations.
3. ***Learning how to be timely with all operations,*** especially herbicide applications for weed control. The old stubble mulch WF system is very forgiving in terms of timeliness of tillage weed control. Effective herbicidal weed control requires timely applications to get the best performance from the chemicals. Managing weeds in no-till systems requires a watchful eye at all times.
4. ***Being familiar with lease agreements.*** The old crop share ( $\frac{2}{3}$  tenant and  $\frac{1}{3}$  landlord) contract, where the landlord invests only in  $\frac{1}{3}$  of the fertilizer expense, is not adequate for a diversified intensive cropping system. Either the crop share must be adjusted, or the landlord must pay an appropriate share of herbicide and seed expenses.

Fortunately, many producers have successfully overcome all of these barriers and are now profiting from their conversion from stubble mulch WF to a no-till diversified cropping system.

## Rewards of Diversified Cropping Systems

The most direct reward to the producer is increased profit. Combining no-till management with intensified diverse cropping systems increases profit by 25 to 45 percent, depending on crop choices and commodity prices.

In addition to the direct profit reward, no-till management with intensive cropping greatly decreases both wind and water erosion potential. Your fields will not "blow" on windy days because diversified systems are soil conserving. Other rewards include increased surface soil organic matter, which will improve precipitation capture in the long-term, providing a positive feedback to your operation and even greater profits in the future.

# Wheat Fertility Management

## Water and Nutrient Management in the Great Plains

By Dale Leikam

Seventeen nutrients are recognized as required for normal growth and development of wheat and other crops. Three of these essential nutrients—carbon, hydrogen, and oxygen—are obtained by plants from the air or water. The remaining 14 essential nutrients generally come from the soil. Nitrogen (N), phosphorus (P), and potassium (K) are classified as macronutrients. Sulfur (S), magnesium (Mg), and calcium (Ca) are typically classified as secondary nutrients, while iron (Fe), zinc (Zn), chlorine (Cl), manganese (Mn), copper (Cu), boron (B), molybdenum (Mo), and nickel (Ni) are referred to as micronutrients. The availability and plant uptake of all nutrients are influenced by many soil and environmental conditions; such as soil moisture, temperature, pH, density, and other chemical and physical properties of soil. Nutrients that most commonly limit wheat growth and development in the Great Plains are nitrogen, phosphorus, sulfur, chloride, and iron. While there is often ongoing discussion about possible deficiencies of copper, zinc, molybdenum, and manganese of wheat grown in the Great Plains, there are little or no research data indicating that these deficiencies commonly occur. Likewise, potassium deficiencies for wheat in the Great Plains are relatively rare.

### The Soil Testing and Fertility Program

The cornerstone of any well designed fertility program is a sound soil testing program. ***Soil testing is essential for making wise fertility program decisions.*** However, it is important to remember that a single soil sample or test from a field has only limited value since soil test values may vary from year-to-year. The real value is the development of a soil test history so that trends can be evaluated and acted upon. Unfortunately, large acreages of wheat have little, if any, soil test history, and providing a fertility history is really what soil testing does best.

A common complaint about soil testing is that different recommendations often result if the same sample is sent to different laboratories—both University and commercial. There are several things to keep in mind relative to these concerns. First, the final product of soil testing is not a specific prescription for the amount of fertilizer to apply to a specific field. The product of soil testing is an additional piece of important information to use when developing a farmer/field specific fertility recommendation. Second, fertilizer recommendations must include more than just a suggested application rate—application method and timing are equally important. Third, differences in rate recommendations are generally the result of a difference in the interpretation of

analytical results and not a difference in laboratory analytical values. And finally, soil testing is not the same thing as fertilizer recommendations; these terms should not be used interchangeably. The following steps are involved in developing a fertility program for a specific farmer/field utilizing soil testing:

1. Collecting a good representative sample (representative of field or portion of field).
2. Proper care of the sample after collection (contamination, microbial processes, etc.).
3. Chemical analysis at laboratory (appropriate tests that have regional meaning).
4. Interpretation of analytical results relative to the historical research base.
5. Integrating interpretations to fit farmer/field specific goals and conditions.

### **Sampling**

The importance of collecting a good sample cannot be overemphasized. No matter how accurate the analytical results or how knowledgeable the person who interprets the results, the developed fertility programs cannot be better than the initial sample collected. If the sample is not representative of the field or area of the field in question, the analytical results will be of little value.

While there can be large variations in soil test values within a field, equally large variations exist for samples collected only inches apart. As a result of this variability, it is necessary to collect and consolidate 15 to 20 individual subsamples from each field or portion of a field regardless of the acreage represented by the sample. At a minimum, it is best to collect a separate composite sample for every 40 acres in a field. Regardless of whether the field is to be managed uniformly across or if inputs will be variably managed within a field, it is best to delineate and individually sample portions of the fields that are similar (e.g. top, side-slope, bottom of hills; high, medium, low yielding portions of a field; etc.). The greater the number of samples collected from a field, the better the information base will be on which to develop an overall fertility program.

Soil sampling depth is extremely important and should be consistent from person-to-person and year-to-year. Proper sampling depth for soil pH, organic matter (OM), phosphorus (P), potassium (K), and zinc (Zn) is the surface six to eight inches, since this is the depth that the soil tests were calibrated for in university research. Sampling deeper or shallower than this will provide misleading results. An exception is made for no-till and very reduced-till systems where soil pH should be monitored and managed at a depth of two to three inches since that is the limit of the depth to which soil acidity accumulates in these systems. For available nitrogen (N), chloride (Cl), and sulfur (S), samples should be collected to a minimum depth of 24 inches since these nutrients are mobile in soils. The importance of consistency of sampling depth cannot be overemphasized. Remember, consistency of sampling depth from person-to-person and year-to-year is extremely important for developing the longer term value of a soil test history.

## Caring For Samples

After collecting the sample, proper care is essential to obtaining reliable results. Very small amounts of contaminants can have large effects on analytical results obtained at the laboratory. It is recommended that plastic pails be used for compositing the subsamples in the field. Metal pails often contaminate the sample rendering it useless for zinc and iron analysis. Plastic pails with rounded surfaces are also easier to keep clean.

If available nitrate-N and sulfate-S is requested for analysis, the samples should be delivered to the laboratory immediately after collection in order to minimize microbial mineralization of organic nutrients. If the samples cannot be delivered to the laboratory in a timely manner, the samples should be air-dried or frozen. Normally, spreading samples on a clean surface and air drying the samples overnight will be adequate, although very wet samples may take longer. All samples should be submitted to the laboratory as soon as possible to minimize the potential for contamination.

## Laboratory Analysis

Soil testing laboratories are in business to provide accurate analytical results in a timely manner by utilizing tests that are appropriate for specific conditions in a geographic region. While soil testing laboratories can perform analytical tests for any and all essential crop nutrients, it is not always appropriate to run tests for nutrients that research has not shown a need for. If a crop response has not been observed in research trials for a given crop or geographic area, proper correlation, calibration, and interpretation of the laboratory analytical results are not possible. There are many good commercial and university laboratories in the Great Plains region with stringent quality control procedures that make the chance for error quite low. In fact, the actual chemical analysis by the laboratory is generally the step that results in the least amount of variability in the overall soil testing process.

## Interpretation of Results

Following the actual soil test analysis by the laboratory, the results must be interpreted to be of any value. In general, recommendation guidelines for the amount of a nutrient to apply are most often based on a specific year or field soil test value and on an interpretation of research data collected for that specific soil test over a period of years. For nutrients such as P, K, and Zn, soil testing generally provides an index of the relative ability of a soil to supply a nutrient to the crop, not the amount of available nutrient present in the soil. For these nutrients, what soil testing does best is provide an estimation of the probability of obtaining an economical response if that specific nutrient is applied to the crop. Secondly, it offers a long-term approximation of the percent of maximum yield that will be realized if the nutrient in question is not applied. ***Soil testing does not accurately predict the specific rate of a nutrient (e.g. P, K, Zn) to be applied for optimum crop production in all situations.***

Sound wheat fertility programs depend on a comprehensive soil testing program, accurate and appropriate procedures, reliable guidelines based on long-term research, and knowledge of how to refine guidelines into efficient and profitable fertility programs.



## Soil Acidity (pH) Management

Identifying and correcting potential soil acidity problems is a priority in any successful crop production program. Low soil pH can severely reduce plant growth, and correcting soil acidity problems may have the highest priority. For much of the Great Plains, soil acidity has not historically been much of a concern since soil pH values were originally higher than in areas further east. Over the past several decades, however, change has occurred in certain important hard red winter wheat areas. In the 1970s and 1980s, extreme soil acidity developed in parts of southern Kansas and northern Oklahoma, and drastic yield reductions occurred consequentially. Soil acidity was generally thought to be of no real concern in this area, and soil pH was not adequately monitored. More recently, low soil pH values have become more common in other areas of the Great Plains, including a few western areas of the region

The application of nitrogen fertilizers, along with decomposition of soil organic matter and plant residues, results in residual soil acidity. When ammonium N is converted to nitrate N by soil microbes, the formation of residual soil acidity results. Anhydrous ammonia has been blamed for much of this soil acidity, but all N fertilizers—including urea, ammonium nitrate, and UAN solution—result in the same amount of residual acidity at equivalent N application rates. Ammonium sulfate is more residually acidic per pound of N applied than other conventional N sources. Also, as long-term, no-till systems continue to be adopted, monitoring soil pH in the surface two to three inches will become more and more critical—even in western Great Plains areas previously thought to have only “high pH” soils, since the residual acidity of broadcast N applications accumulates in the surface one to three inches of long-term, no-till systems.

**Figure 5.1 (left)**  
Wheat exhibiting the symptoms of aluminum toxicity, caused by a low soil pH.



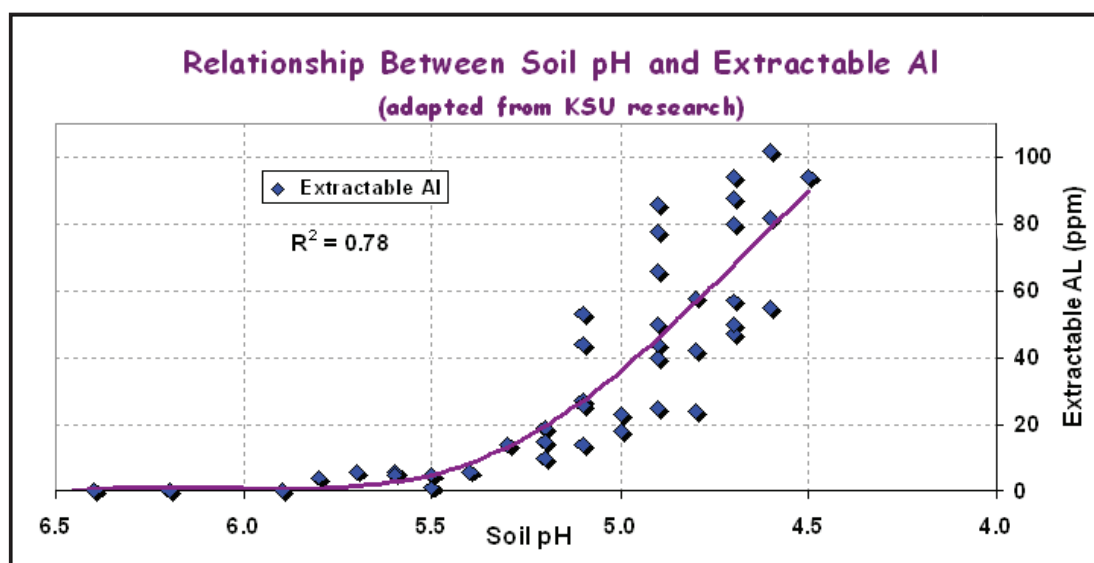
**Figure 5.2 (right)**  
Thickened and shortened nodes caused by aluminum toxicity.



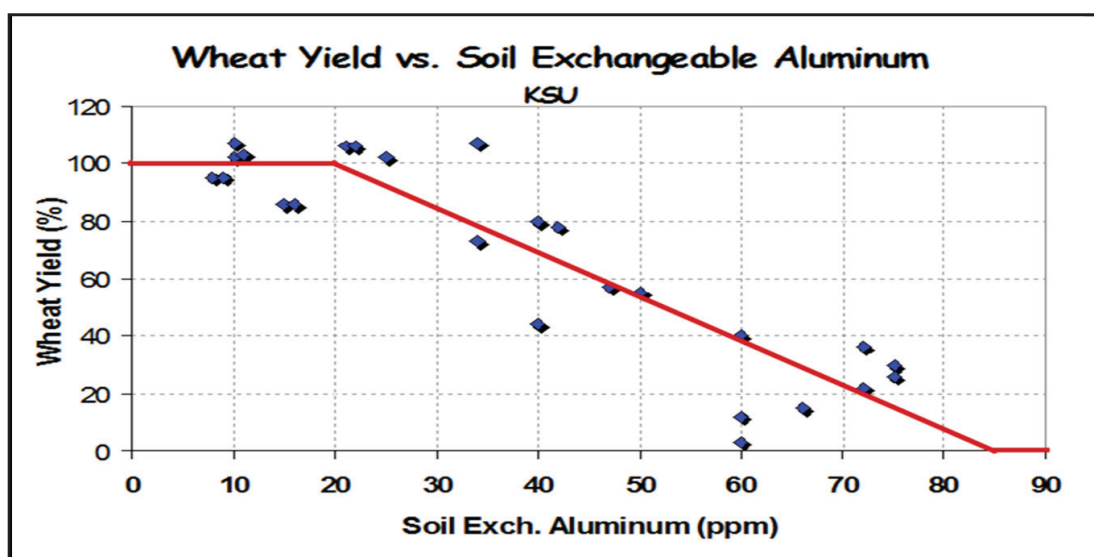
## Aluminum Toxicity Symptoms

The yield damaging effect of low soil pH on wheat growth and development is generally from aluminum toxicity. Aluminum toxicity in wheat reduces root development and causes roots to appear brown and stubby (*Figure 5.1*). Wheat also exhibits poor plant vigor, reduced leaf size, and thickened nodes (*Figure 5.2*).

As the soil pH falls below 5.5, the potential for aluminum-containing soil minerals to dissolve into soil solution in some parts of the field increases, and as soil pH falls below 5.0, soil solution aluminum levels increase dramatically. A soil with a pH of 4.5 contains 1000 times as much soluble aluminum as a similar soil having a pH of 5.5. It is this dramatic increase in aluminum levels at lower soil pH values that have caught many wheat producers off guard. While a wheat plant may appear relatively normal at a pH of 5.0, severe effects are noted at a pH of 4.5, and complete crop failure usually results at a pH of about 4.0. *Figures 5.3* and *Figure 5.4* summarize research conducted by Kansas State University and illustrate how soil pH influences soil water aluminum (Al) concentration and how soil water Al concentration affects wheat grain yield.



**Figure 5.3**  
Soil pH influences soil water Al concentration.



**Figure 5.4**  
Influence of soil water Al concentration on wheat grain yield.

Soil acidity problems are very noticeable on wheat seedlings. Stunting and thickening of the roots will cause stunting of the plant due to the inability of the root system to provide adequate water and nutrients. Phosphorus deficiency and drought stress symptoms will typically be exhibited by the plant—even if phosphorus and water supplies seem adequate. The stunted plant will often have a flattened, prostrate appearance.

## Management

If soil pH is below 5.2, managing soil acidity should have a high priority. Soil acidity prevents development of a strong vigorous root system, that in turn prevents normal wheat growth and development. Consequently, the effectiveness of other inputs vital to efficient and profitable wheat production will be impaired. Frequently, elevated soil test levels of other nutrients will be evident on strongly acidic fields since the uptake, and subsequent removal, of essential nutrients will be much lower.

Soil acidity is easily corrected with liming. However, lime application rates needed to correct the soil pH (increase pH to 6.5-6.8) are often very high. Also, economical sources of lime are often not available in most of the Great Plains. As a general rule, if the soil pH is less than 5.5 and 25 percent of the lime required to bring the pH up to 6.8 is applied (most generally the normal lab recommendation), the resulting soil pH should increase to about 5.5, and little yield loss will occur. Keep in mind, however, at reduced rates lime will need to be applied more frequently. Lime applied at 25 percent of the recommended rate should keep the soil pH high enough to alleviate aluminum toxicity for 2 to 5 years, but fields should be carefully monitored to prevent yield loss. Applying about 50 percent of the lime required to increase soil pH to 6.8 should result in a soil pH of about 6.0.

All liming materials will neutralize soil acidity equally as long as equivalent rates of effective lime are applied. Regardless of the source of lime (dry agricultural, fluid, or commercial pelleted lime), the appropriate rate should be based on the Effective Calcium Carbonate Equivalent (ECCE) content of the lime (also referred to as ECC, ENV, etc.). The ECCE of liming materials vary depending on the composition, fineness of grind, and purity of the material. Purchase decisions should be based on the ECCE value provided by lime vendors. There are no short cuts or miracle liming materials for correcting soil pH. In order to neutralize soil acidity, a given amount of ECCE will be required, regardless of source.

Another practice proven to be helpful in managing soil aluminum toxicity problems are drill-row applications of 30 to 40 pounds of P<sub>2</sub>O<sub>5</sub> with seed. When soluble phosphate fertilizer is placed with the seed, relatively insoluble aluminum phosphates form, which take the soluble Al out of soil solution in the area of the developing seedling. The seedling root system can then develop normally. Keep in mind, however, the soil acidity has not been neutralized and lime or P fertilizer application will be necessary for the next crop. Drill-row phosphate applications are one year, stop-gap measures when it is not practical to lime before planting.



## Nitrogen Fertility Management

Nitrogen is the nutrient with the highest potential for limiting profitable wheat production. Since N is a constituent of chlorophyll, the green pigment allowing plants to convert the energy in sunlight into carbohydrates, a shortage of available N has wide ranging effects on wheat growth and development. Nitrogen is also an essential constituent of proteins, nucleic acids, and many other plant components and processes.

### Symptoms

Deficiency symptoms of N include reduced root growth, slowed development, smaller leaf size and reduced tillering. During the reproductive development stages, N deficiencies in wheat adversely affect spikelet formation, floret formation, kernel fill, and result in reduced grain protein. Adequate N must be available to the growing wheat plant during all phases of plant development.

The most obvious visual indication of N deficiency in wheat is the lack of dark green color (*Figure 5.5*). In small plants, the whole plant will have a light green color, while in older plants the lower leaves will turn yellow and die from the tips back (*Figure 5.6*). Until the milk stage, plants should have an overall dark green color since N in the lower leaves has not begun to be translocated to the grain in substantial quantities. If the plant does not have a good green color or the lower leaves begin to yellow much before this stage of development, N is likely deficient. During the milk stage of kernel development, the plant will begin to move large amounts of N from the leaf tissue to the grain. The plant will gradually yellow from the bottom up as the plant approaches maturity.

Stunted growth and poor tillering are also visible indications of N deficiency, although shortages of other nutrients, especially phosphorus, will provide similar symptoms. Low grain protein is also an indication that N was limiting during growth and development. For most hard red winter wheat varieties, grain protein of less than 12 percent may indicate that N was deficient.



**Figure 5.5**  
Wheat exhibiting N deficiency symptoms.



**Figure 5.6**  
Nitrogen deficient plants (left) compared to healthy plants (right).

## How Much Fertilizer N?

Nitrogen requirements for wheat are generally thought of as being directly related to yield potential. Hard red winter wheat with a protein content of 12 percent will require a total of about 2.4 pounds of available N per bushel of production. Keep in mind that these N requirements need to be met by both soil and fertilizer N sources. This includes residual profile N, N mineralized from soil organic matter, credits from previous manure application, and N from previous legume crops. Some states use residual profile N and yield goal to estimate wheat N needs, while Nebraska bases N needs on residual profile N and wheat-fertilizer price. Kansas uses soil organic matter, yield potential, and residual profile N for N recommendations. Final rate suggestions are fairly similar among these approaches. A suggested N rate recommendation approach is presented below:

### **Hard Red Winter Wheat**

$$\text{N Rec (lbs N/A)} = (\text{Yield Goal} \times 2.4) - (2 \text{ ft Nitrate-N}) - (10 \times \% \text{ OM}) - (\text{Other N Credits})$$

Manure and legume crops included in rotation with wheat may provide a portion of the N needed by the wheat crop, but likely not as much as for summer growing crops. Nitrogen found in legumes and manure is unavailable in organic form and is not available until decomposed by soil microbes. Since wheat growth occurs in relatively cool soils, significant amounts of decomposition do not occur during the time that wheat is actively growing. This is the reason that no N credit is given for a soybean crop harvested immediately prior to wheat planting.

In the Great Plains hard red winter wheat region, a soil nitrate N test is a management tool that can be used to estimate residual soil nitrogen. The amount of nitrate N present in the top two to three feet of soil provides a reliable estimate of the amount of available N present in the soil profile from prior soil organic matter N mineralization, legume and manure decomposition, as well as any residual N carryover from the previous crop. Winter wheat is sown in the fall when soils are still relatively warm, and additional N will be released by microbial organic matter decomposition after the wheat is planted until the soil cools. Preferably, soil samples are collected no earlier than about two to three weeks prior to planting so that a good estimate of mineralized N is obtained. Soil samples collected earlier will not measure some N mineralized in late summer or early fall, while waiting longer to collect samples may not allow enough time before preplant N must be applied.



## Time of N Application

The key to successful wheat N management programs is having adequate amounts of N available in the root zone when it is needed by the wheat crop. Focusing strictly on fertilizer N application rate will not make a producer money unless it is applied in a timely manner. While large amounts of N are not required in the early stages of wheat growth and development, adequate amounts are essential for setting the stage for profitable wheat production. Too often, the wheat plants perceived need for N is related entirely to the amount of above ground growth that is occurring. Since the bulk of the wheat plant's visible dry matter production occurs after jointing, it is assumed this is also the most critical time for N application. The important growth that is not visually apparent, the development of the root system, is often forgotten.

For winter wheat, much of the root system develops in the fall—a time when a relatively small amount of vegetative dry matter accumulates. Fall root system development may be greatly reduced if the amount of available N in the fall is inadequate. Well developed, vigorous, and deep root systems reduce the potential for winter injury and increase water use efficiency. Spring wheat has a shorter time period to develop a root system than winter wheat, and quick development of a deep, well developed root system is equally important.

Additionally, productive main tillers of winter wheat are generally developed in the fall. Since tiller formation occurs early (fall and upon breaking winter dormancy for winter wheat), allowances for early N nutrition are extremely important. Also, spikelet formation occurs in the three to four week period prior to jointing, and adequate N needs to be in the root zone during this period to assure optimum head size development during this critical development stage.

In most of the hard red winter wheat region, top-dress applications can be made in late fall or during the late winter or early spring period. In these areas, the lack of overwinter precipitation needed to move the fertilizer N into the wheat root zone often results in temporary positional unavailability of the applied nitrogen. Additionally, herbicides are often included in the top-dress application, and some of these herbicides have provided best results when applied in the fall or very early spring when the weeds are very small.

Typically, winter wheat recommendations call for top-dress N to be applied by jointing, but there are sound reasons to not wait this long. If top-dress applications are made late, near or after jointing, and sufficient precipitation is not received to move the applied N into the root zone, the applied N will be positionally unavailable and yields will suffer. On the other hand, waiting until jointing to make top-dress applications increases the risk of not getting the required N on until well after jointing in the event of a wet spell—or possibly not getting it applied at all. Furthermore, equipment traffic in wheat fields causes minimum damage if applications are made early. After jointing, the stem below the joint may be broken by application equipment resulting in tracks that remain through harvest and increased susceptibility to disease.

### ***Medium- to Fine-Textured Soils***

While research across the Great Plains on medium-fine textured soils has not shown agronomic benefit to splitting N applications between preplant and top-dress, this is a good option in many situations. Applying 30 to 40 pounds of N preplant and saving the balance of required N for a top-dress application provides N early for the important fall growing period, while allowing the producer to more accurately assess the yield potential and fine-tune the final N application rate. With the advent of more and more long-term, no-till wheat in the region, the importance of applying some of the N preplant would seem to be especially valuable. However, there have not been advantages to making multiple split top-dress N applications.

### ***Sands and Clays***

For wheat grown on the sands, clay-pan, and poorly drained soils, about 30 to 40 pounds of N per acre should be preplant applied to ensure early root development and tillering, while protecting the bulk of the total required fertilizer N from potential movement deep into the soil profile with fall-winter precipitation. The balance should be applied in a top-dress application at, or slightly before, wheat green-up. This will allow for adequate N nutrition during tillering and spikelet formation stages of wheat development, while protecting against potential N loss during the winter.

### ***Irrigation Systems***

For irrigated wheat grown under center pivot irrigation systems, especially on sandy soils, splitting the N between preplant, spring green-up, and jointing is a fertility management system that should be strongly considered. By applying N through the irrigation system, the N will not be dependent on precipitation to place it in the root system and application is not likely to be delayed by weather, while application costs will be minimized.

At a minimum, top-dress N applications should be in the root zone by jointing. While top-dress N applications are sometimes referred to as "foliar" applications, top-dress applied N is not taken up through the leaves—it is moved into the root zone with precipitation and taken up through the roots. Early top-dress N applications are essential. All too often, top-dress applications are made too late, and production efficiency and profitability suffer.

### ***Nitrogen Sources***

All of the commonly available N sources will perform well when fitted into a well designed fertility management program. For preplant N applications, urea, UAN solution, and anhydrous ammonia all fit into many production programs adequately (except in poorly drained soils). Both UAN solution and ammonia are often subsurface injected, while both UAN solution and urea can be broadcast surface applied. UAN solution may also be surface banded. For wheat grown in rotations that include tillage, all of these options have performed similarly. For no-till systems, subsurface injection of UAN solution and anhydrous ammonia would likely perform more consistently than surface broadcast applications. Surface band ('dribble' and 'streaming') of UAN would be intermediate.

For top-dress applications to non-sandy, well drained soils, urea, UAN solution, and ammonium nitrate should all perform equally well. UAN solution is often the preferred N source because of application flexibility. UAN solution can be dribble applied in coarse surface applied streams (streaming) or used to carry the weed control program if herbicides are to be included in the late winter top-dress application. Some question the susceptibility of urea and UAN solution to potential N volatilization losses, but conditions conducive to volatilization losses do not occur during the time wheat should be top-dressed. Many years of research have conclusively shown all of these N sources to be effective for top-dress applications.

### **Leaf Burn**

Top-dress applications of UAN solution sometimes cause leaf burn. Leaf burn becomes more visually apparent the later the applications are made and results from the ammonium nitrate portion of the N in UAN solution. Urea generally causes little, if any, leaf burn. However, if top-dress applications are made early enough to prevent leaf burn to the last developing leaves, especially the flag leaf, then there are no negative effects on grain yield. These cosmetic effects can be minimized by the same early applications that provide for best agronomic performance since air temperatures are cooler, and the amount of leaf tissue exposed is not as great as compared to later applications. Top-dress N application rarely causes much leaf burn when applied at spring green-up. All things being equal, the amount of leaf burn will gradually increase through jointing as air temperatures warm.

### **How Late Is Too Late For Top-dress Applications?**

When top-dress N applications are not made before jointing, concerns arise regarding the practicality and profitability of making applications. These factors vary depending on the specific conditions present. Even if the field is expected to be only marginally deficient in N, profitable applications through Feekes Stage 7 (second node detectable) could still be made. Tire tracks would cause some damage since the growing point is now well above the soil surface, and applicators with narrow tires are recommended. Aerial application by airplane is best but is often not readily available. Rainfall is needed to move these applications into the root zone.

As the plant approaches boot stage, the decision becomes more difficult. If the field is definitely N deficient, an application of N would still likely be profitable if timely rainfall occurs, but provisions for not injuring the flag leaf would need to be taken. Dry materials by airplane would be the best choice. Again, the effectiveness of this application will be largely dependent on receiving timely and sufficient rainfall to move the N into the root zone. By early heading (Feekes Stage 10.2), the likelihood of a profitable response is probably gone except for in severely N deficient fields, and if rainfall is received immediately.

## Phosphorus Fertility Management

Wheat is very responsive to fertilizer P applications on soils that do not provide adequate amounts of this essential nutrient. After nitrogen, phosphorus most commonly limits wheat growth and development. Across the Great Plains region, large acreages of wheat have reduced profitability due to inadequate fertilizer P. Adequate fertilizer P is more important than fertilizer nitrogen in some cases. About 0.5 pounds of P<sub>2</sub>O<sub>5</sub> is removed with each bushel of wheat.

Functions of P in plant growth and development include major roles in energy metabolism and transfer. Phosphorus also has vital roles in respiration, cell division, and photosynthesis. Additionally, phosphorus is required for protein formation and many other plant constituents and processes. A shortage of phosphorus adversely affects many aspects of wheat growth, development, and reproduction.

### P Deficiency Symptoms

Early shortages of P in wheat result in substantially reduced root system development and stunted overall plant growth. Because of its importance in root growth and development, shortages often result in increased susceptibility to winter injury. This inadequate early root development also increases the susceptibility to moisture stress. In addition, adequate P is needed for tillering, head formation, and grain filling. While purpling of stems and lower leaves is a common symptom of P deficiency, stunted growth and poor tillering are more visible early indications of P deficiency in wheat. Purpling is not always apparent in wheat. As wheat approaches heading, poorly tillered stands and maturity delays of several days are a result of P deficiency.

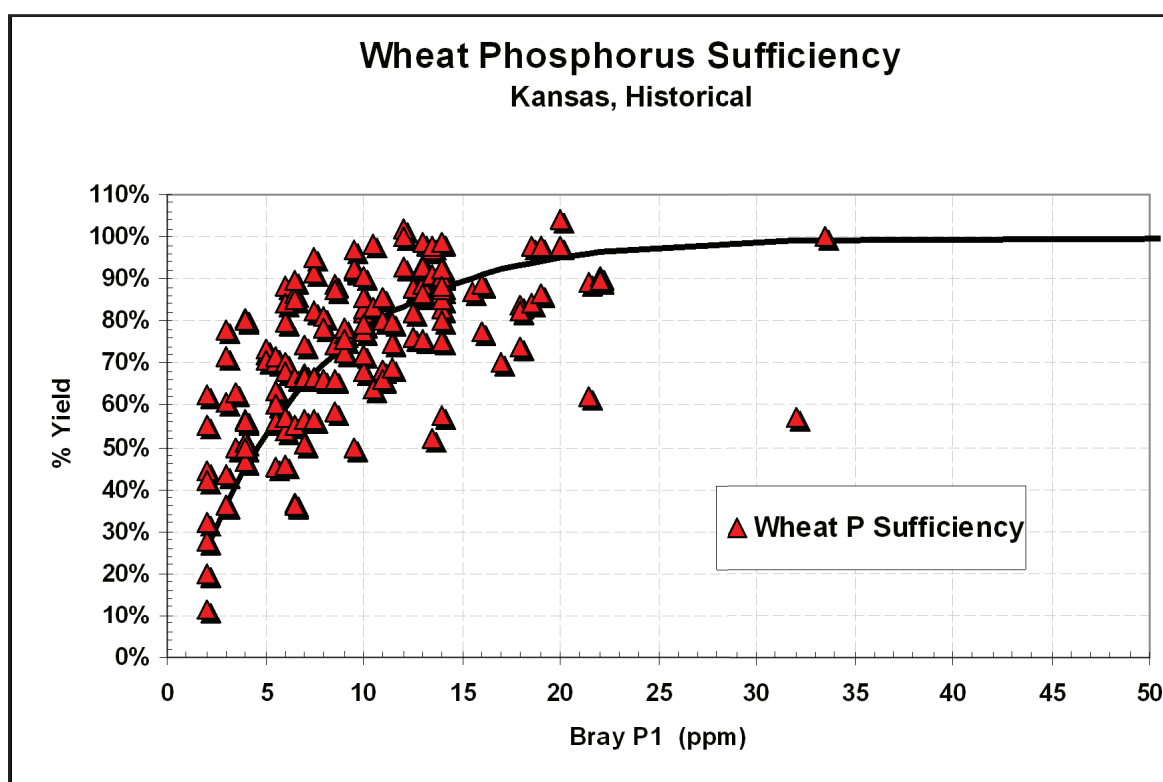
### Determining P Application Rate

Soil testing helps identify soils that are likely to limit wheat profitability due to inadequate P nutrition. However, it does not tell us how much P is “available” in the soil. Due to complex soil reactions, soil testing only provides an index value that can be used to estimate fertilizer P needs for specific conditions encountered in the field. Meaning of index values varies depending on the specific soil test procedure used, the depth the sample was collected from, and other field specific factors that affect P uptake by wheat.

P soil testing indicates the probability of obtaining a profitable response to fertilizer phosphorus. If the soil test index is low, there is a high probability that P nutrition will limit yield, while a high soil test index indicates the probability of obtaining a response is less. Additionally, soil test index values allow us to make a sound estimate of the amount of response an application of fertilizer P is likely to stimulate. Specific rate recommendations can be developed by relating soil test information to past research, specific field characteristics, other cultural practices, and the fertility goals of the individual producer.

Three soil test procedures are available to help assess a soil's ability to adequately supply P to growing wheat plants. The **Bray P-1** procedure is commonly used on soils that are neutral to acidic (pH below 7.3), but is generally less reliable on calcareous soils. The **Olsen P** soil test was developed for calcareous soils commonly found in much of the Great Plains. The **Mehlich III** procedure performs well on neutral to calcareous soils. Each test provides an index value only, extracts different amounts of P, and must be interpreted differently. The Mehlich III procedure has generally been shown to extract about 5 to 10 percent more P than the Bray P-1 procedure, while the Olsen P test extracts about 65 to 70 percent as much P as the Bray P-1 test.

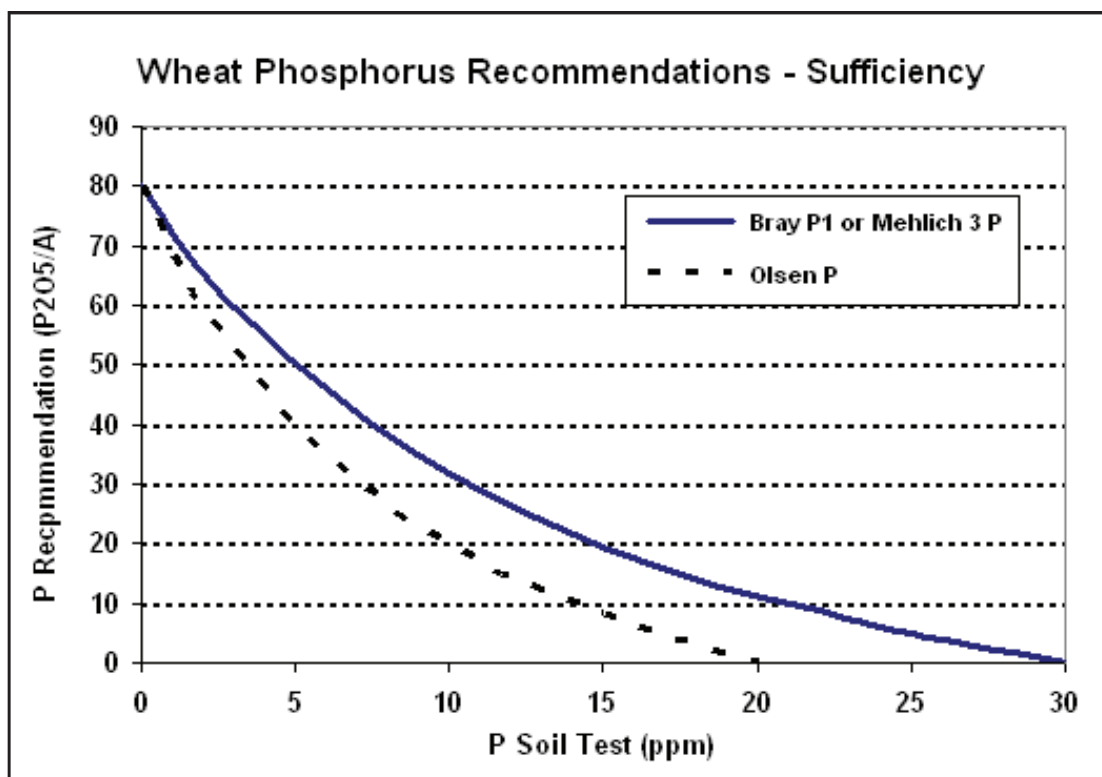
Figure 5.7 indicates the relative yield that can be expected at various P soil test indices for wheat. For example, with a Bray P-1 soil test index of 10 ppm, about 75 percent of the maximum yield can be expected if fertilizer P is not applied. Similar results have been obtained across the Great Plains. However, these are only estimates and the amount of response that actually occurs may be more or less in a specific year for a specific field.



**Figure 5.7**  
Relative  
wheat yield  
at P soil  
test values  
(Bray P-1).



**Figure 5.8**  
General Great Plains  
wheat guidelines for  
phosphorus.



#### **Sufficiency Approach**

Figure 5.8 provides some general guidelines for fertilizer P application rates. Most states in the Great Plains will have P recommendations that will be fairly close to these, although most will also include a yield potential component. This approach is called a “sufficiency” approach and on average should provide for optimum economic returns in the year of application. In some years, sufficiency recommendations may be too high, while in other years the recommendations may be too low for optimum economic results. Since these guidelines do not result in the building of P soil test index values to non-limiting levels, P fertilization cannot be skipped for a year without decreasing profitability. If the long-term P fertility goals of individual growers are to build or maintain P soil test indices at non-limiting values in order to provide for future P application flexibility, the guidelines for the build-maintain approach would be more appropriate.

#### **Build-Maintain Approach**

The build-maintain approach is to follow P application rate guidelines that are based on building soil test P index values to a point where P nutrition is not usually limiting to optimum wheat growth and development, and then maintaining these levels by annually applying the amount of P<sub>2</sub>O<sub>5</sub> removed in the harvested portion of the crop until soil test levels are high enough that no P is recommended. While these guidelines may not always provide maximum economic return in any given year, they do provide for long-term economies and flexibility. Four, six, and eight year buildup guidelines are presented, depending on the overall rotation and P management goals of the individual grower (Table 5.1).

**Table 5.1**

Wheat phosphorus guidelines.

Phosphorus Build-Maintenance Wheat Recommendations									
Bray P1	4-Year Build Time Frame Yield (bu/ac)			6-Year Build Time Frame Yield (bu/ac)			8-Year Build Time Frame Yield (bu/ac)		
Soil test	30	50	70	30	50	70	30	50	70
(ppm)	Lb P <sub>2</sub> O <sub>5</sub> /ac			Lb P <sub>2</sub> O <sub>5</sub> /ac			Lb P <sub>2</sub> O <sub>5</sub> /ac		
0-5	94	104	114	68	78	88	54	64	74
5-10	71	81	91	53	63	73	43	53	63
10-15	49	59	69	38	48	58	32	42	52
15-20	26	36	46	23	33	43	21	31	41
20-30	15	25	35	15	25	35	15	25	35
30+	0	0	0	0	0	0	0	0	0

### P Application Method

Phosphorus is immobile in soils and therefore stays where it is placed. As a result, fertilizer P applications need to be made at or before planting. The method of P fertilizer application is at least as important as application rate, especially for low P testing soils or shallow tillage. For systems that include unincorporated tillage, surface applications are generally ineffective since the fertilizer P is not placed in the root zone. In the Great Plains, where low P soil test index values and shallow/minimal tillage are common, placing the P fertilizer with the seed (drill-row) and preplant deep banding (which places fertilizer P three to eight inches deep on 15 to 18 inch spacing) are better choices than broadcast applications. Both of these methods ensure fertilizer P is placed in the root zone, while minimizing soil fertilizer contact.

If soil test levels are low and band applications are not possible, broadcast applications should be made as early in the cropping sequence as necessary to thoroughly incorporate the fertilizer P with the tillage that is used. For wheat-fallow areas, broadcast applications should be made in the spring prior to the first tillage operation. In other production sequences, broadcast applications should be made prior to the deepest tillage operation.

Broadcast applications perform well in areas with deeper tillage or higher P soil test index values. These applications should be made prior to the deepest tillage operation. However, if a producer is contemplating a move to shallower or less frequent tillage, some thought should be given to band application. Even in areas of higher P soil test index values or deeper tillage, band applications are recommended.

However, for long-term no-till systems, it is possible that surface broadcast applications will be much more effective than in traditional production systems that included tillage. Because of a change in soil moisture content and root development near the soil surface immediately below the residue, wheat root uptake of shallow P would likely be better. Band P applications are still desirable if possible, but broadcast P applications would seem to be a good complement to band P applications systems.

## Fertilizer P Sources

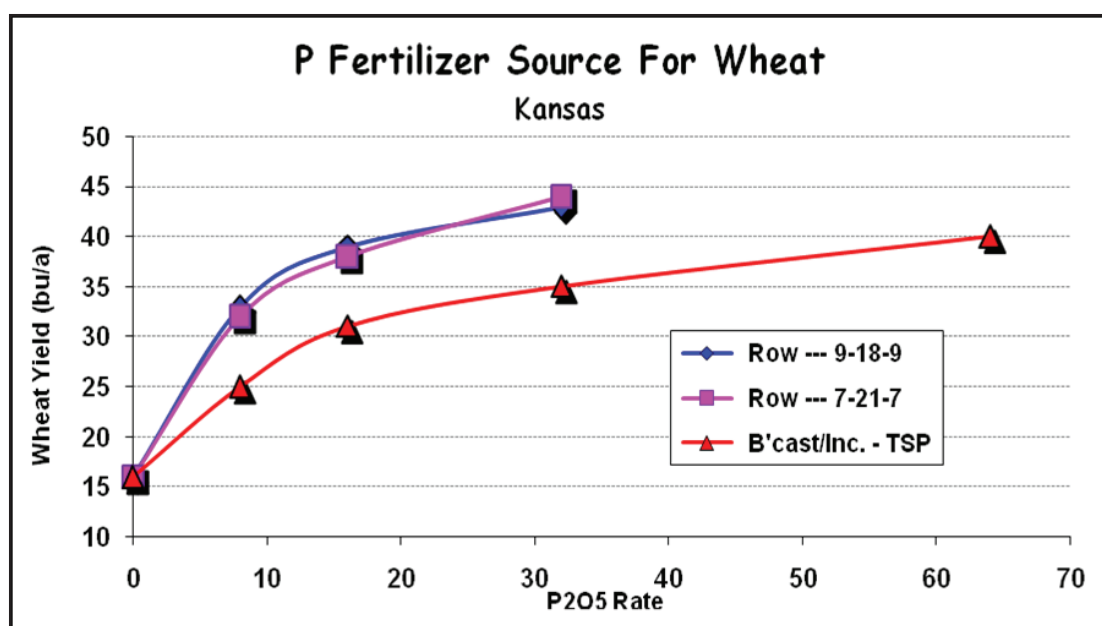
There continues to be much discussion about the agronomic performance of various P fertilizers for wheat production. The effectiveness of various P fertilizers, applied at equal amounts of available phosphate in a similar manner, is generally equal. It is often implied that monoammonium phosphate (MAP, typically 11-52-0) is superior to diammonium phosphate (DAP, 18-6-0) for wheat production, particularly if applied with the seed. Many field comparisons between row applied MAP and DAP for wheat have been conducted, with the overall results indicating no differences between the two materials. Likewise, comparisons between liquid and dry P fertilizers have generally provided similar conclusions. However, application equipment to band apply liquid P is much more common than for dry P sources. Differences between dry and liquid sources of P are generally more related to logistics, flexibility in specific placement relative to the seed/openers, and ease of fitting/retrofitting equipment for efficient fertilizer application.

## Reduced Application Rate If Banding?

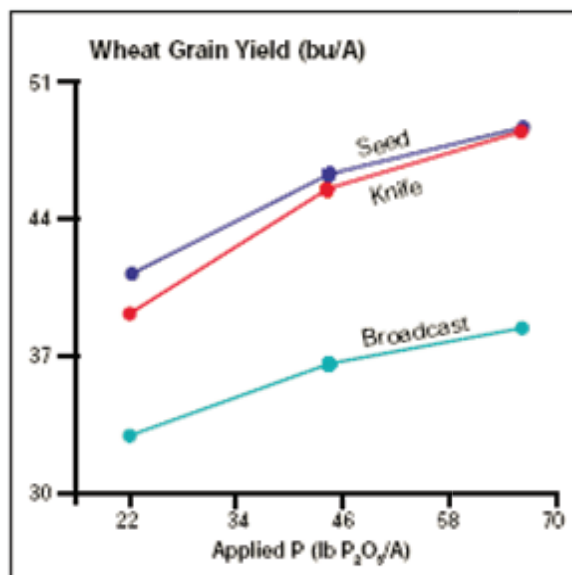
If drill-row or preplant band P applications are used instead of broadcasting, the P application rate can be reduced by 33 to 50 percent. *Figure 5.9* provides information indicating that while drill-row applications certainly were more efficient at this very low P soil site, minimally incorporated broadcast applications were inferior to banding.

While band applications are more efficient, reducing P applications when banding may cost wheat producers money. At low P soil test index values, with minimal incorporation, optimum band P application rates were actually higher than for broadcast applications since broadcast applications never resulted in yields comparable to band P applications (*Figure 5.10*). As the P soil test index increases, differences between band and broadcast P applications diminish. In addition, preplant, dual, deep band applications of P fertilizer, and ammonia or UAN solution are equal in agronomic effectiveness to drill-row applications.

**Figure 5.9**  
P application method and wheat yield (Kansas average of three years, very low P soil test index).



In general, on low P soils, comparable wheat yields can be obtained at lower band applied P rates than for broadcast P. However, these reduced rates will not optimize production efficiency and profitability since additional yield response may occur at higher, fully adequate rates. Additionally, if P application rates are consistently reduced below crop removal values, P soil test values would be expected to drop into the low (very crop responsive) category. Band P application methods should be adopted to make money—not as a way of saving money.



**Figure 5.10**  
Broadcast and band P effect on wheat yields and profitability.

### How Much P Fertilizer Can Be Placed With The Seed?

In general, it is the amount of nutrients other than P which limit the amount of fertilizer that can be safely placed in direct seed contact. When developing a fertility program which includes row applied fertilizer, N and K (K<sub>2</sub>O) should be considered—not the amount of phosphate applied with the seed. Also, as the row spacing becomes narrower, the amount of nutrients that can safely be row applied increases. As a rule of thumb, for six to eight inches row spacing, the maximum amount of N + K<sub>2</sub>O that can be safely placed in direct seed contact is 30 pounds per acre. For 10-inch spacing, do not exceed 24 pounds per acre, while 12-inch spacing should not exceed 20 pounds per acre. When seeding late, or in dry seedbeds, reduce these amounts by 25 to 30 percent (*Figure 5.11*).

Salt Index - N + K <sub>2</sub> O		
Suggested Maximum Rates of Fertilizer to be Applied Directly With Seed (Corn and Small Grains)		
Row Spacing in Inches	Pounds N +K <sub>2</sub> O* (No urea or UAN)	
	Medium to Fine Textured Soils	Sandy or Dry Soils
40	6	4
30	8	6
20	12	8
15	16	11
12	20	14
10	24	17
6-8	30	21

Reduce salt rates 30% for grain sorghum.

No seed-placed fertilizer is recommended for soybeans, sunflowers, field beans, or sugar beets.

**Figure 5.11**  
Maximum N + K<sub>2</sub>O application rates.

## **P Management Summary**

Phosphorus deficiencies are relatively widespread and result in reduced profitability across the entire wheat producing area. While the best way to identify fields likely to respond to fertilizer P applications is through a sound soil testing program, deficient fields also can be identified by visual examination. Thin, poorly tillered fields that do not seem to respond to fertilizer N are frequently P deficient. Eroded slopes and hill tops are also prime candidates, but many nearly level fields are also low in P availability. Phosphorus deficiency causes a reduction in root development, which is associated with increased winter injury. While band applications are desirable in areas with shallow or minimal tillage, broadcast P applications work well when fertilizer P is thoroughly incorporated and in long-term no-till systems. Phosphorus application rates should not be reduced if band P applications are used. It is important in profitable wheat production systems to identify fields or portions of fields likely to be low in P and to apply adequate amounts of fertilizer P in an efficient manner.

## **Potassium Fertility Management**

Wheat is less responsive to potassium than phosphorus, and deficiencies have not been an issue for most of the Great Plains. For winter wheat, potassium shortages are most likely in the eastern portion of the region (e.g., eastern Oklahoma, eastern Kansas) and on sandy soils in other areas. About 0.3 pounds of K<sub>2</sub>O are removed in each bushel of wheat. Greater amounts of potassium are removed if the wheat is pastured or if forage crops are included in the rotation.

Potassium is different from most of the essential nutrients in that it is not a part of any structural component in wheat. As a soluble ion in plant sap, potassium is required for the activation of many enzymes. Additionally, potassium plays major roles in photosynthesis, metabolism, and many other essential plant processes.

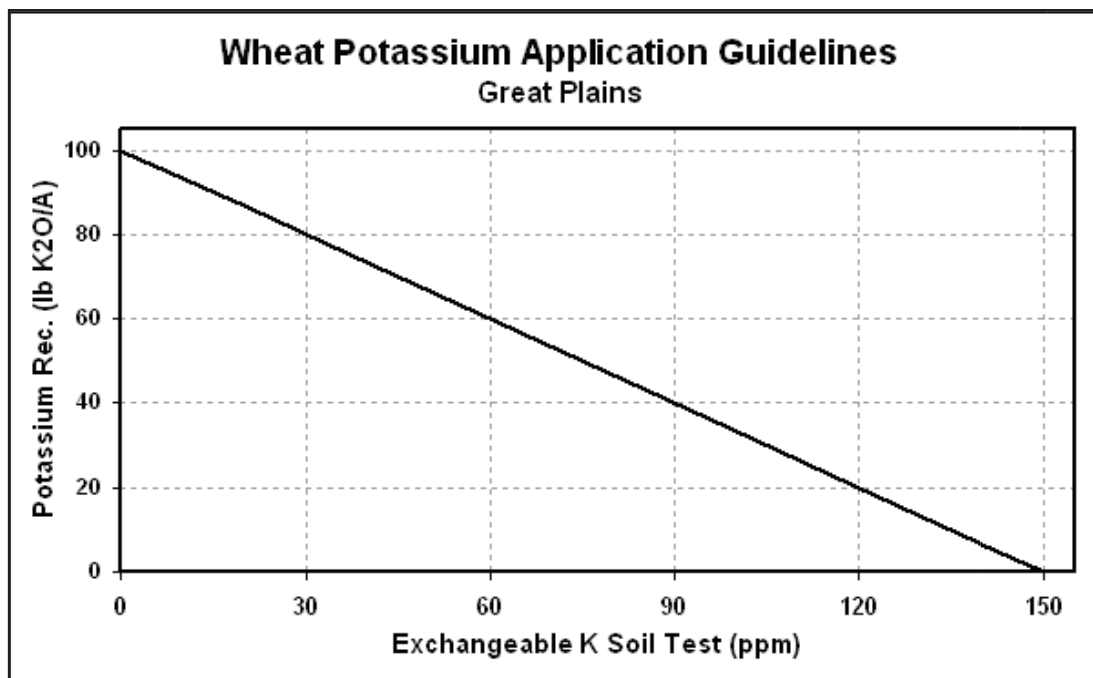
## **K Deficiency Symptoms**

The critical period for adequate potassium nutrition for wheat is during the early growth and development stages, when the wheat plant has a small root system and a relatively large need for potassium. Since potassium is involved in a host of plant processes, a deficiency of potassium results in retarded leaf development and stunted growth. Later, deficiencies of potassium in wheat result in increased susceptibility to lodging. Shortages of potassium have also been reported to increase the incidence and severity of several wheat diseases.

## **Determining K Application Rate**

A sound soil testing program is the best tool available for helping wheat producers identify areas likely to be deficient in potassium. Soil testing does not identify the amount of "available" potassium present in the soil, but provides an index value which, when properly interpreted, provides a good estimate of the soil's ability to supply potassium to the developing wheat plant. Rate recommendations are developed by relating the soil test index to research, geographic location, and other location specific factors.





**Figure 5.12**  
Fertilizer K  
recommendations.

Figure 5.12 provides general guidelines for fertilizer K recommendations for the Great Plains hard wheat region. These sufficiency approach guidelines are not exact for each state but should be close. On the average, they should generally provide for optimum economic returns in the year of application.

### K Application Method

Potassium is considered to be relatively immobile in soils and moves very little with water. As a result, fertilizer K applications should be made prior to planting and incorporated into the root zone if tillage is employed. Potassium applications should be made prior to the deepest tillage operation to allow for maximum incorporation.

There is little wheat research information available on the effectiveness of deep banding potassium prior to planting. However, it would be expected to perform as well as broadcasting and maybe better on low K soils with shallow incorporation. Potassium fertilizers can be placed in direct seed contact if the rates are kept low. Guidelines for the maximum amount of fertilizer that can normally be placed in direct seed contact are based on the amount of nitrogen and potassium in the fertilizer material (N and K<sub>2</sub>O) (Figure 5.11). If excessive amounts of these nutrients are placed with the seed, germination can be delayed or prevented.

### Sulfur Fertility Management

While sulfur is classified as a secondary nutrient, nutritional shortages of sulfur are more common than potassium in many areas. While sulfur deficiencies are not as prevalent as nitrogen and phosphorus deficiencies—on sandy, well drained, or low organic matter soils, sulfur often limits wheat production efficiency and profitability.

Sulfur is an essential constituent of several amino acids as well as other plant constituents and processes. Often, sulfur deficiency in small plants is mistakenly identified as nitrogen deficiency. Sulfur deficient wheat will exhibit a general yellowing and stunting which is also typical for a nitrogen shortage. On older plants, the lower leaves of nitrogen deficient plants will die as N is redistributed to the younger plant parts, while the lower leaves on sulfur deficient plants will remain a pale green.

### **Determining S Application Rate**

A routine soil test is available for sulfur, but it is of questionable value for determining fertilizer sulfur needs for wheat. High sulfur soil test values indicate additional sulfur is likely not needed, but low sulfur soil test values tell very little. The sulfur soil test may aid in determining sulfur needs, but factors such as soil texture, soil organic matter content, and yield potential are much more useful.

The form of sulfur used by plants is the sulfate ion ( $\text{SO}_4^{=}$ ). Since sulfate is very soluble in water, it is subject to leaching—especially in sandy soils where water moves through the soil much more freely than in medium-fine textured soils. The higher the precipitation, the greater the likelihood that sulfur may limit wheat growth and development.

Most of the sulfur in soils is present in soil organic matter. When soil microbes decompose soil organic matter, sulfate sulfur is released. As a result, sandy or low organic matter soils are most prone to sulfur deficiency. The higher precipitation areas of the soft red winter wheat area are also more prone to sulfur deficiencies.

### **Application Method / Sulfur Source**

In general, sulfur sources should perform equally if they contain sulfate sulfur. Elemental sulfur sources are generally not well suited for wheat production since they require biological oxidation to convert elemental sulfur to plant available sulfate sulfur. Since wheat is a cool season crop, growth and development largely occurs when soils are cold and microbial activity is low. As a result, only minimal oxidation of elemental sulfur typically occurs. If elemental sulfur is used, it should be broadcast and incorporated early in the fall when soils are relatively warm.

Since sulfate sulfur is mobile in soils, there are several application options available. For topdress applications, ammonium sulfate and ammonium thiosulfate are commonly used for dry and liquid programs, respectively. Band applications of liquid N-P-S products have performed well for preplant and at planting, and homogeneous products are recommended for drill-row applications. Dry bulk blended materials have the possibility of segregating as the grain drill bounces across the field.

## Chloride Fertility Management

Chloride is an essential plant nutrient and has a major role in plant water relationships, yet in the past, chloride was rarely considered when developing a fertility program. However, over the past 20 years, research in many areas of the Great Plains has demonstrated wheat yield and profit increases from chloride applications.

The beneficial effects of chloride applications are often, but not always, due to the suppression of various root and leaf diseases. It should be pointed out, however, that while the incidence or severity of these foliar diseases are reduced, fungicides often further reduce the detrimental effects of these diseases. Chloride applications on wheat do not replace the need for fungicides, especially for heavy disease pressure or susceptible varieties. Also, not all of the positive responses to chloride have been tied to disease suppression since grain yield increases have been noted in the absence of root and foliar diseases.

### Chloride Sources / Application Method

The most common source of chloride is potassium chloride (potash 0), which contains about 45 percent chloride and liquid ammonium chloride solution. Other chloride sources, such as ammonium chloride and calcium chloride, could also be used but are not readily available and have potential compatibility issues with other fertilizer products.

Since the chloride ion is soluble in water and mobile in soils, chloride containing fertilizers can be applied before or after planting. Research to date has not indicated yield differences in method of application. Often, it is not possible to apply all of the chloride in drill-row applications because of the risk of germination damage. Preplant deep banding of chloride should perform well where equipment is available. The most practical methods of chloride application would be to include potassium chloride with a preplant N or P broadcast application or with topdress dry nitrogen programs.

### Chloride Application Rate

South Dakota, North Dakota, and Kansas offer a chloride soil test based on the chloride content of the surface two feet of soil. Research generally indicates that 40 to 60 pounds of chloride per acre are required to optimize wheat production. If the soil test from the surface two feet is less than this amount, fertilizer chloride is recommended to provide the total of 40 to 60 pounds per acre. If a soil chloride analysis is not available, 20 to 30 pounds of chloride would be suggested on a trial basis. The inclusion of chloride in Great Plains wheat fertility programs should be considered since research has indicated relatively consistent and profitable wheat yield responses.

## Other Secondary and Micronutrients

In general, it is unlikely that any of the other secondary or micronutrients limit wheat growth and development to a significant degree. Iron availability limits wheat growth in certain areas, but there is little that can be done to economically correct the problem other than incorporating large quantities of manure. Wheat is known to respond to copper, but known deficiencies in the U.S. have generally been limited to the peat soils in the far north and coastal soils in the southeast. While zinc response has sometimes been reported for wheat, documented deficiencies are rare. While there have been numerous discussions about widespread and severe Cu and Zn deficiencies of wheat in recent years, there is little research supporting these claims. The same is true for the other micronutrients. Any response to these nutrients would be expected to be rare or marginal. Taking care of soil acidity (N, P, S, Cl, possibly K) and other important management practices would seem to be much more profitable than keying in on micronutrients for wheat in the Great Plains.

## Wheat Fertility Management Summary

Nutrient deficiencies often limit wheat growth and development across the wheat producing areas. As a result, production efficiency and profitability suffer. While wheat producers do not have control over some factors affecting wheat growth and development, it is important to prevent controllable factors such as wheat nutrition limit production opportunities and profitability. It is often stated that rainfall and the length of grain fill are the most limiting factors for wheat production in the Great Plains—it is important that we make sure that it is these uncontrollable factors which limit wheat production and not such easily controllable factors such as crop nutrition.

## CHAPTER 6

# Dual-Purpose Wheat Management

By Jeff Edwards

Farmers in the southern Great Plains sow over 13 million acres of wheat on an annual basis, and much of this crop is grown in the dual-purpose wheat production system. In this system wheat is typically sown in early September, grazed by cattle from mid-October until early March (*Figure 6.1*), and harvested for grain in early June. While wheat grain yields are frequently lower for dual-purpose wheat than for grain-only production, the majority of wheat producers still prefer the dual-purpose system as it provides a second source of income and spreads risk.

The dual-purpose wheat management system requires different management than a grain-only system. This system works in the southern Great Plains because most farmers are experienced with livestock production, temperatures commonly favor wheat growth well into the winter months, and there are relatively few snow-covered or ice-covered days. In this chapter, we will discuss some of the unique management strategies that apply to dual-purpose wheat production.



**Figure 6.1**

Wheat producers in the southern Great Plains diversify income by grazing dual-purpose wheat fields with stocker cattle from mid-November until early March.



## Seedbed Preparation

The mechanics of seedbed preparation for dual-purpose wheat production will be very similar to those for grain-only wheat production. Since seedbed preparation for dual-purpose wheat occurs earlier in the summer, there is generally much greater potential for moisture losses during final tillage operations. Early season moisture availability is frequently the dominant factor governing wheat forage production in the southern Great Plains. Therefore, final tillage operations should be shallow or avoided by herbicidal control of weeds as part of a stale seedbed or no-till management system.

## Variety Selection

Variety selection is important in any crop production system. A good dual-purpose wheat variety requires certain traits not needed in grain-only production systems. Perhaps one of the most unique traits a dual-purpose wheat must possess is the ability to germinate well in hot soil conditions ( $> 85^{\circ}\text{F}$  or  $29^{\circ}\text{C}$ ). Dual-purpose wheat sowing frequently begins just before Labor Day, when soil temperatures can exceed  $100^{\circ}\text{F}$  ( $38^{\circ}\text{C}$ ). Many wheat varieties have high-temperature germination sensitivity and will not germinate well in hot soil conditions.

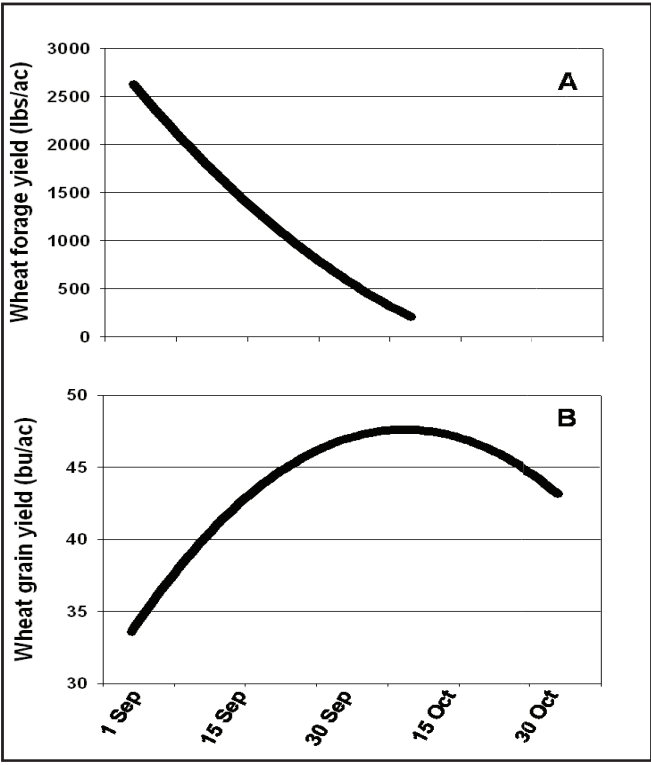
The degree to which high temperature germination sensitivity affects wheat emergence can vary by seed lot and by environment. A cool rain or irrigation treatment, for example, will often result in complete germination, even in sensitive varieties. Sow sensitive varieties later in the year when soils have cooled.

Varieties differ in their ability to grow and produce adequate forage in the fall, but very few modern wheat varieties are classified as “poor” forage producers. Breeding efforts in the southern Great Plains over the past decade have emphasized forage production as a critical trait, so wheat cultivars currently being grown in the southern Great Plains are generally good forage producers. Some varieties consistently produce more fall forage than others. This exceptional fall forage production potential can sometimes come at the cost of winter hardiness, so it is important to consider the ability to recover from grazing and yield potential after grazing as well.

The key to reliable, consistent management of high temperature germination sensitivity is to know the sensitivity ratings of varieties by checking a current variety comparison chart (variety performance guides are available through local cooperative extension offices). Data on fall forage production by wheat varieties and grain yield following grazing in the southern Great Plains is commonly available through local cooperative extension offices. It is important to view forage production data in combination with grain yield data from a grazed environment. Some wheat varieties tolerate grazing much better than others, and the “yield penalty” associated with grazing these varieties is much less.

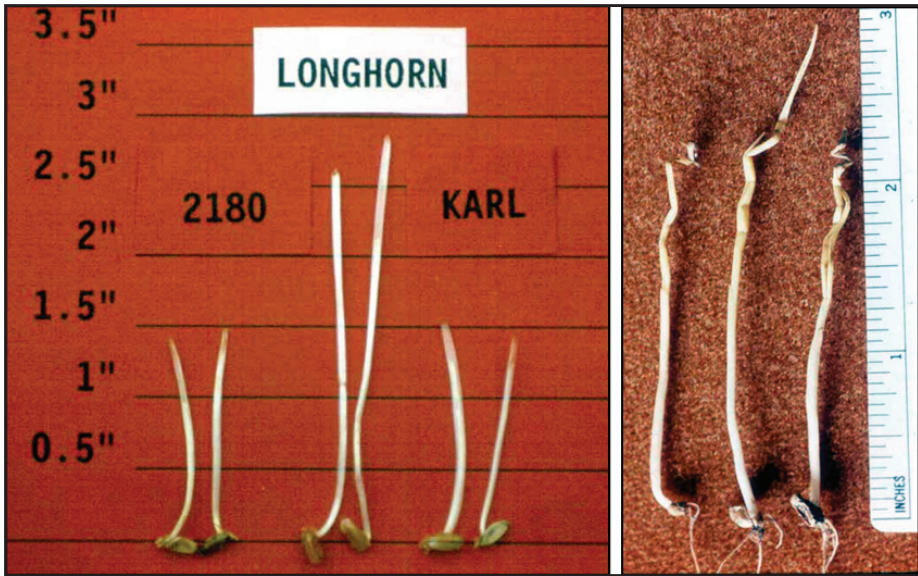
### Planting Date

Wheat planting date is a critical factor for forage production. Dual-purpose wheat farmers often plant as early as Labor Day and generally wrap up wheat sowing by the last week of September. For each two week delay in planting in September, fall forage production is reduced by about 1000 pounds per acre (*Figure 6.2a*); however, optimal wheat grain yields are associated with October plantings (*Figure 6.2b*). Because of this tradeoff between fall forage production and grain, a September 15 planting date frequently is targeted in order to maximize both.



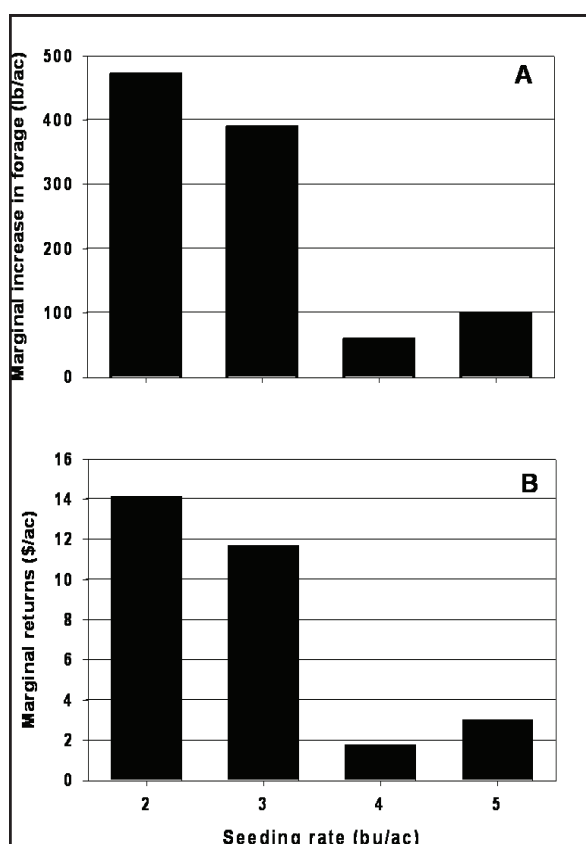
**Figure 6.2a & b** Wheat forage (A) and grain yield (B) response to planting date at Lahoma, OK from the 1991-1992 through the 1999-2000 production season.

Environmental factors frequently interfere with optimal planting dates. If moisture in the soil profile is lacking, growers choosing to sow too early run the risk of having wheat emerge and then perish due to drought stress. If moisture is not available in the top inch of the soil profile due to evaporative losses or excessive tillage, farmers are often tempted to sow wheat deep enough to reach moisture in the profile. In most circumstances, however, the better strategy is to “dust the wheat in” with the expectation that rainfall eventually will provide ample moisture for germination. Shallow sowing (one inch or shallower) is generally preferred because hot soil conditions reduce the coleoptile length of germinating wheat. Wheat seed planted deep to moisture may not produce a coleoptile long enough to break through the soil surface, resulting in poor emergence and stands (*Figure 6.3a & b*).



**Figure 6.3a & b** Coleoptile length varies by variety and soil temperature. Notice the accordion-like effect on wheat leaves that emerge below the soil surface.

**Figure 6.4**  
Marginal increases  
(i.e., increase for  
adding one addi-  
tional unit) in wheat  
forage yield (A) and  
marginal returns (B)  
for wheat seeding  
rates at Goodwell,  
OK in 2004.



## Seeding Rate

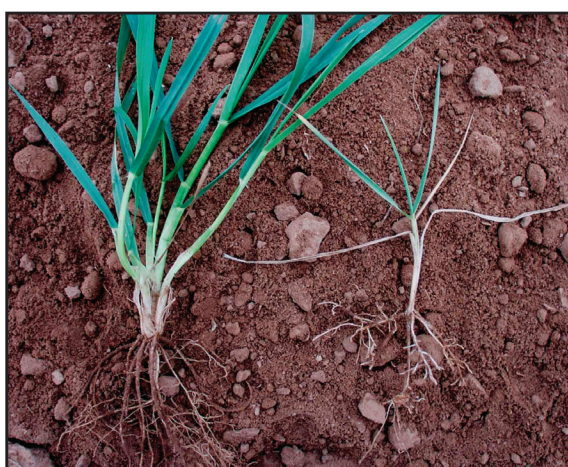
Seeding rates for dual-purpose wheat should be at least 1.5 times greater than those used for grain-only production. Many producers opt for seeding rates as high as 120 pounds per acre, and seeding rates as great as 180 pounds per acre can be beneficial to fall forage production (*Figure 6.4*). Higher seeding rates must be combined with narrower row spacing (eight inches or less). This combination reduces the amount of time required for the wheat canopy to close, which, in turn increases the amount of sunlight intercepted by the crop and daily forage production. Therefore, increased seeding rates and narrow row spacing are of even greater importance when planting is delayed and less time is available for forage production.

## Fertility

Dual-purpose wheat generally requires more fertilizer than grain-only production. It takes approximately 30 pounds per acre of nitrogen to produce 1000 pounds per acre of wheat forage. While some of this nitrogen is returned to the system via urine and manure, it is not evenly distributed and has minimal effect on subsequent grain yield. Nitrogen removed from the production system via grazing should either be accounted for by additional pre-plant nitrogen application or by top-dress applications in the spring.

Low soil pH has a greater influence on wheat forage production than grain yield. One of the primary impacts of low soil pH is reduced phosphorus availability. The wheat plant has a much shorter period of time available for root growth and interception

**Figure 6.5**  
The plant on the left  
received an in-fur-  
row application of  
phosphorus and had  
faster emergence,  
increased early-  
season root growth,  
increased tillering,  
and more forage  
growth than the  
plant on the right.



and uptake of plant nutrients for forage production than it does for grain yield (*Figure 6.5*). To overcome this limitation, 20 to 40 pounds per acre of phosphorus fertilizer should be placed in-furrow at planting. In-furrow application of P fertilizer is more efficient than broadcast application. In fact, when used in combination with an acid-tolerant wheat variety, in-furrow application of P fertilizer can be used as a “short-term” alternative to lime application on rented or marginal soils.



## Grazing Management

Grazing by cattle should not be initiated until wheat plants have developed a secondary root system. The secondary root system prevents the plants from being pulled out of the ground during the grazing process. Likewise, grazing should be avoided if wet or waterlogged soil conditions persist during the fall grazing window. Damage from hoof traffic and the associated compaction can be just as detrimental to wheat grain yield as the grazing itself (*Figure 6.6*). Some farmers plant areas of cool-season annual pasture adjacent to dual purpose wheat fields to serve as an area that can carry cattle during brief periods of wet or waterlogged soil conditions.

Cattle should be removed from wheat pasture at the first hollow stem stage of growth. Cattle weight gains after this point will not offset decreases in wheat yield caused by continued grazing. Wheat is at the first hollow stem stage of growth when  $\frac{1}{2}$  inch (about the diameter of a dime) of hollow stem is present below the developing grain head (*Figure 6.7*). Since grazing delays wheat development, growers must check for first hollow stem in a non-grazed area of the field planted at the same time to the same variety. Varieties can differ by as much as three weeks in when the first hollow stem occurs.



**Figure 6.6**  
Compaction and plant damage resulting from hoof traffic during wet or waterlogged conditions reduces head numbers at harvest and wheat grain yield.



**Figure 6.7**  
The first hollow stem stage is characterized by  $\frac{1}{2}$  inch (about the diameter of a dime) of hollow stem being present below the developing wheat head.





# Arthropod Pests of Wheat

*By Gary Hein, Gerry Michels, & Phil Sloderbeck*

Only a few arthropod species in Great Plains wheat can be considered serious pests. The Russian wheat aphid is sporadic in occurrence through most of the Great Plains, except in Colorado where growers must deal with it almost on a yearly basis. The greenbug can be a serious pest across the Great Plains, but its greatest impact is in the southern plains (Texas, Oklahoma, and southern Kansas), and it is only a sporadic problem further north. A few other pests can be found in most years, but serious infestations will only occur in limited areas. For example, wheat curl mite, which transmits wheat streak mosaic and High Plains viruses, is consistently present in the region but only becomes serious when and where conditions are favorable for its survival through the summer. Also, in most years the army cutworm will seriously impact wheat somewhere in the Great Plains, but the areas of serious infestations tend to move from year to year.

Some pests appear to be of increasing concern. The Hessian fly has increased its presence in recent years in some areas of Oklahoma, Kansas, and Nebraska. Cereal aphids, which were not thought to overwinter north of central Kansas, have been able to overwinter much further north, and the wheat stem sawfly has increased its presence in no-till areas of the high plains of Wyoming and Nebraska.

The impact of a changing climate and changes in production practices, particularly the warmer falls and winters and the increased use of no-till farming, have and will continue to impact pest species. It is likely that the spectrum of pests will change if climatic conditions and farming practices continue to change. The development of effective integrated pest management programs to manage pests will become increasingly complex and will rely on increased knowledge of pest biology and their relationships with host plants.

## Cereal Aphids

Cereal aphids represent the most damaging arthropod pests of wheat in most of the Great Plains. Russian wheat aphid and greenbug are by far the most common and most devastating aphids, but other species, such as bird cherry-oat aphid, corn leaf aphid, and English grain aphid are occasional pests in wheat. The most detailed integrated management techniques and control methods have been developed for Russian wheat aphid and greenbug because of their persistent damage in parts of the Great Plains each year. Problems stemming from infestations of the other species can be ascertained using sampling methods similar to those for Russian wheat aphid and greenbug.

When approaching cereal aphid management, it should be kept in mind that the wheat ecosystem is complex. Aphids feeding on wheat are often attacked by naturally occurring predators and parasitoids (biological control). These natural enemies suppress aphid abundance and in many years can be relied upon as effective control agents. Coupling naturally occurring biological control with host plant resistance is often a completely effective control combination that does not require additional intervention.

Economically important cereal aphid infestations usually occur when the natural balance is disrupted. These disruptions can be the result of harsh climatic conditions that negatively impact natural enemies, the selection and proliferation of aphid genotypes virulent to genetic resistance bred into wheat, or the inappropriate use of insecticides.

Scouting wheat for pest presence is paramount for management of cereal aphids in those years when nonchemical controls fail. Sampling techniques have been developed to help producers properly sample fields to determine if cereal aphids will develop into a problem that might require chemical control. Relying on chemical control as a prophylactic or insurance treatment is a poor management option. ***It is environmentally unsound and economically inefficient to “program in” chemical control.*** Efficient and easy-to-use sampling methods, in most years, result in a decision not to use chemical control. Releasing commercially available aphid predators or parasitoids can prove to be a wasteful and unsound practice, as well.

Barley yellow dwarf virus (BYDV) is a common disease problem associated with most cereal aphids (see Chapter 9—“Disease Management of Wheat”). Although a serious problem in wheat, there are no specific management strategies to control BYDV transmission by these aphids. Bird cherry-oat aphid and English grain aphid likely are the most important carriers of BYDV, but greenbug and corn leaf aphid can transmit it as well. Control methods mentioned throughout this chapter are directed at controlling damage caused by aphid feeding habits and will not reduce the incidence of BYDV.

## **Russian Wheat Aphid – *Diuraphis noxia* (Kurdjumov)**

### **Identification / Life Cycle**

This small, lime green aphid has a football-shaped body, short antennae, and very short cornicles (*Figure 7.1*). Russian wheat aphid can be found at any time in the wheat crop. Winged adults migrate into wheat fields from the south. It is also common for resident populations that over-summer on wild grass species to give rise to small infestations in wheat that may be unnoticed in the fall. Russian wheat aphid can generally survive winter in the Great Plains, with the possible exception of North Dakota. Prolonged periods below 15°F (9°C), extended snow cover, and rapid freezing and thawing are detrimental to the aphid. Most economically important infestations occur in the spring. During the vegetative stages of wheat, these aphids feed on the newest leaves of the wheat plant within rolled leaves that provide a protected microhabitat. However, they will also infest seedheads late in the season.



**Figure 7.1 (left)**  
Russian wheat aphid.



**Figure 7.2 (right)**  
Leaf damage caused by the Russian wheat aphid.

## Plant Damage and Response

Infested leaves exhibit purple, yellow, or white longitudinal streaks along the leaves and leaf sheaths (Figure 7.2). Heavily infested plants may appear flattened, with prostrate young tillers (Figure 7.3). Later in the season infested leaves can trap emerging heads, preventing good grain fill (Figure 7.4).

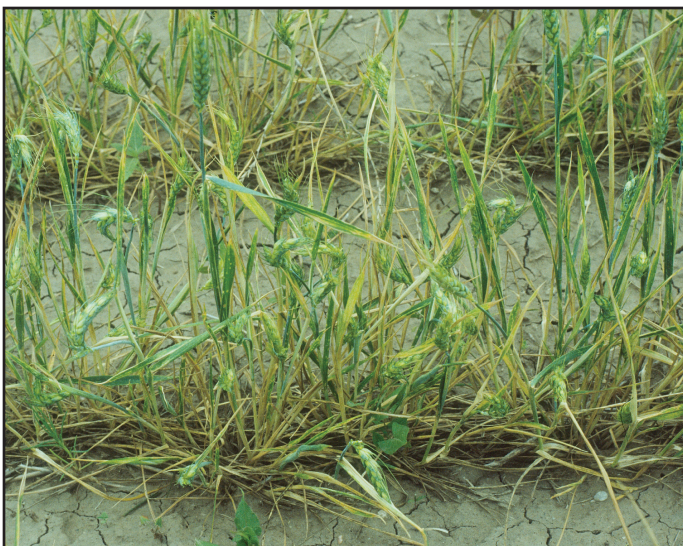
## Management

### *Establishing level of risk*

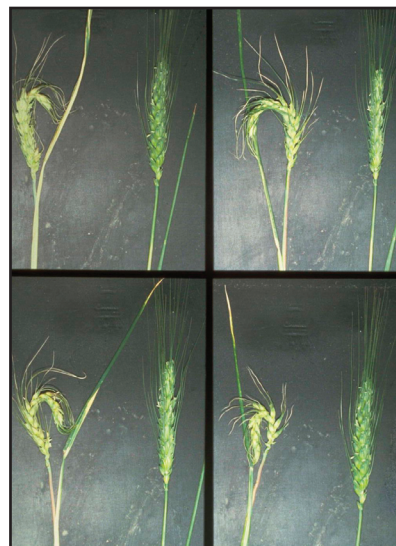
Persistently high populations of Russian wheat aphid can lead to serious yield reduction and even plant death. Risk of yield loss is highest when infestations develop in early spring. In many areas, climatic conditions and biological control by predators, especially lady beetles, are normally quite effective in keeping them below damaging levels.

### *Field Scouting*

Scouting wheat fields for infested tillers is the most effective way to determine the need to control Russian wheat aphid. Scout fields by randomly selecting tillers along a random path and examining them for the presence of live aphids and symptoms of Russian wheat aphid damage. Record the percentage of infested tillers. It is important to scout an area of the field large enough to determine the extent of the infestation. Scouting for Russian wheat aphid can be combined with scouting for greenbugs and other wheat pests as well.



**Figure 7.3 (left)**  
Plant injury caused by the Russian wheat aphid.



**Figure 7.4 (right)**  
Russian wheat aphid feeding can cause emerging heads to become trapped.

### Thresholds in Fall

Populations that develop soon after the crop emerges in early fall can also be damaging. Extensive damage by the Russian wheat aphid in the fall can set plants up for reduced vigor and poor winter survival. This is more of a concern as winters become more harsh. In Kansas, Oklahoma, and Texas fall thresholds are 20 to 30 percent infested plants, while in Colorado, Nebraska, and Wyoming infestations of 10 to 20 percent infested plants may warrant treatment.

### Thresholds in Spring

Economic thresholds for spring infestations of the Russian wheat aphid can be determined for varying treatment costs, yields, and prices by using the following formula:

$$\% \text{ Infested Tillers} = \frac{\text{Control Costs per Acre) x 200}}{\text{Expected Crop Value per Acre}}$$

If the percentage of infested tillers in the field exceeds the calculated threshold, then a treatment should be considered. After heading, use a factor of 500 rather than 200 in the numerator (see *Table 7.1* for examples). Aphids are more likely to build up and impact heads if no rainfall occurs. Also, infestations confined to late-developing secondary tillers will have less impact on yield.

### Chemical Control

It is important to only use insecticide treatments for control if the economic threshold has been reached. This will maintain effective suppression by natural enemies. Because Russian wheat aphid is well protected within curled leaves, control can be difficult. Chlorpyrifos is most effective at controlling these aphids. Other insecticides may be more effective if the aphids are exposed on the leaves or head. Also, if aphid infestations are well above the thresholds, control will be poorer and the potential for retreatment will increase.

**Table 7.1**

Calculated economic thresholds for fall and spring infestations of Russian wheat aphid.

Threshold:		Yield								
% Infested tillers		25 bu/ac			40 bu/ac			60 bu/ac		
Wheat Price (\$/bu)		\$3/bu	\$4/bu	\$5/bu	\$3/bu	\$4/bu	\$5/bu	\$3/bu	\$4/bu	\$5/bu
Spring Thresholds										
Control Cost	\$5/ac	13%	10%	8%	8%	6%	5%	5.5%	4%	3%
	\$10/ac	27%	20%	16%	17%	12%	10%	11%	8%	7%
Heading Stage Thresholds										
Control Cost	\$5/ac	33%	25%	20%	21%	16%	12%	14%	10%	8%
	\$10/ac	67%	50%	40%	42%	31%	25%	28%	21%	17%



Neonicotinoid seed treatments may provide protection through the fall. However, the cost of these treatments and the sporadic occurrence of the aphid in most areas limit the economic value of this strategy. These seed treatments may be warranted if the risk of fall infestation is high (e.g., near uncontrolled volunteer, early planted wheat, or alternate hosts for the aphid such as wheatgrasses, rangeland, or CRP).

### Cultural Control

Elimination of volunteer wheat during the summer may help break the Russian wheat aphid life cycle by removing essential grass hosts for over-summering. Depriving the aphids of wheat through the summer can lower the abundance of aphids moving into wheat fields in the fall. Healthy, well watered plants are often able to withstand more aphid feeding than weak or drought stressed plants.

### Biological Control

When the Russian wheat aphid invaded the United States an extensive program was established to import exotic parasitoids and predators in hopes of establishing new biocontrol agents. However, there has been little impact on the aphids by these agents. On the other hand, native parasitoids and predators seem to have adapted to Russian wheat aphid and now readily attack (Figure 7.5). Parasitoids that seem to be effective include the native *Aphelinus varipes* and the introduced species *A. albipodus* and *A. asychis* (Figure 7.6). Russian wheat aphid can also be parasitized by native *Diaeretiella rapae* and *Lysiphlebus testaceipes*, although parasitism rates are low. Lady-beetles (*Hippodamia* sp., *Coccinella* sp., and *Scymnus* sp.) are the primary predators of Russian wheat aphid and can effectively control infestations. However, it is possible that these predators work best when there are other aphids present in the field. Predaceous syrphid flies and nabids will prey on Russian wheat aphid but seldom have a great impact.

### Host Plant Resistance

In areas with a history of Russian wheat aphid problems, resistant varieties are a potential management option. Genetic sources of resistance developed in the late 1980s were eventually incorporated into commercial wheat varieties. One source is available in the variety Stanton (derived from PI 220350, containing the resistance gene designated *Dny*). The other resistance source is in the varieties Prowers 99, Prairie Red, Yumar, and several others (all derived from PI372129, containing the resistance gene *Dn4*) (Refer to Chapter 3—“Variety Selection” for additional information and resources).



**Figure 7.5 (left)**  
Parasitized Russian wheat aphids.

**Figure 7.6 (right)**  
Wasp parasitoid (*Aphelinus* spp.).



However, in 2003 a new biotype of the pest was detected in Colorado that was virulent to the resistance present in these varieties. This biotype is now widely distributed throughout eastern Colorado and surrounding states. The new biotype is capable of rapid population growth and can damage wheat very quickly, especially at warmer temperatures. The development of host plant resistance to Russian wheat aphid, as with most small grain aphids, is a continuing battle. New resistant cultivars and varieties will no doubt be developed over time.

## **Greenbug – *Schizaphis graminum* (Rondani)**

### **Identification / Life Cycle**

Greenbug is a pale green aphid approximately  $\frac{1}{16}$  of an inch long with a darker green stripe down the center of the back (*Figure 7.7*). Greenbug colonize wheat fields when winged females migrate from native grasses or other wheat fields. These females produce nymphs which give rise to multiple generations of parthenogenic wingless aphids. As wheat matures, winged females develop and migrate elsewhere. Males are produced in late summer and fall. Sexual reproduction does occur, but in most states, eggs are either infertile or are not subjected to sufficient cold hardening to hatch. Greenbug nymphs produced from eggs are more likely to be found in the northern states.

### **Plant Damage and Response**

Greenbug damages wheat by sucking phloem fluid from the plant and injecting toxins. Plants damaged by greenbug have yellowed leaves that turn brown and necrotic as damage increases. Moderate to heavy greenbug infestations at any time will reduce yield through direct damage to the plant and indirectly in young wheat by impacting root development. With high greenbug density, seedling to mid-sized wheat plants can be killed. Early to mid-season greenbug infestations are often noticed as circles of yellowing or brownish wheat within the field. As the season progresses, these “greenbug spots” coalesce into larger areas.

**Figure 7.7**  
Greenbug.



## Management

### *Establishing level of risk*

When greenbugs are present, careful scouting and monitoring can determine if a field is a candidate for chemical control. Various sampling methods can be used to assess the status of a wheat field in regard to greenbug infestations. An evaluation of potential greenbug control by natural enemies is encouraged before making any decisions to apply insecticides. The most important determination to make is whether or not greenbug infestation is increasing over time.

### *Field Scouting*

The *Cereal Aphid Expert System* and *Glance-N-Go* sampling system are recommended for greenbug. Glance-N-Go is a greenbug scouting system used to rapidly tell if a wheat field is at risk for economic damage from greenbug. Walking in a zigzag pattern across a wheat field, wheat tillers are sampled to see if greenbugs are present, and the findings are recorded on standardized data sheets. If greenbug density is very high, the decision to treat might be made by taking as few as five, three-tiller samples spaced 30 feet apart. If greenbug density is low or spotty, a sample of as many as 90 tillers may be needed to make a decision. Results for every 15-tiller sample are compared on the data sheet, and a decision is made whether: 1) more samples are needed, 2) sampling can be stopped and the field does not require treatment, or 3) sampling stops and a decision to treat is made. Information on the Glance-n-Go system can be found at <http://entopl.okstate.edu/gbweb/>. The most recent version of the Glance-n-Go system also incorporates the presence of parasitoids into the decision process.

### *Thresholds*

Economic thresholds for greenbugs vary depending on the time of the year, plant vigor, climatic conditions, and the presence of natural enemies. As a general guide, it is recommended that chemical control may be considered if greenbugs are found at a level of 100 to 200 per linear foot of row for plants three to six inches high, 200 to 400 aphids per linear foot of row for plants four to eight inches high, and 300 to 800 aphids per linear foot of row for plants ranging from 6 to 16 inches in height.

On the other hand, the Glance-N-Go system uses a sliding scale that depends on the season (fall or spring) and the number of aphids recorded per 15-tiller sample. The decision-making aspect of Glance-N-Go is based on multiple years of field research which determined the ratio of tiller infestation levels to actual field infestation levels. It also incorporates a preselected threshold that users can determine using the Cereal Aphid Expert System.

### *Chemical Control*

Because greenbug is more exposed on the leaves, it is generally more easily controlled than Russian wheat aphid. However, some greenbug populations have shown resistance to organophosphate insecticides, and treatments also may be ineffective when weather is cold. Thus, multiple applications of the same insecticide class during the same season should be avoided, and applications should be made when weather is expected to be favorable (highs above 50°F or 10°C and no rain) for a few days following the application.

### **Cultural Control**

As with Russian wheat aphid, a healthy and well-watered crop can endure a heavier greenbug infestation than one suffering from water or nutrient stress. Although control of volunteer wheat probably has some impact on greenbug over-summering populations, greenbugs readily infest sorghum, and some common grasses (such as Johnson grass), throughout the summer.

### **Biological Control**

Greenbug biological control by native predators and parasitoids is identical to that found for Russian wheat aphid. Conservation of naturally occurring predators and parasitoids can often preclude the need for chemical control. This aspect of the aphid's ecology is incorporated into the Glance-n-Go management system.

### **Host Plant Resistance**

Wheat varieties and cultivars resistant to greenbug have been available for many years, but the number of resistant varieties is often very limited. Currently available varieties include TAM-110 and TAM-112. Be sure to check current variety descriptions as new resistant lines are constantly under development.

## **Bird Cherry-Oat Aphid – *Rhopalosiphum padi* (L.)**

### **Identification / Life Cycle**

The bird cherry-oat aphid is dark, olive green with a reddish-brown patch on the back of the abdomen (*Figure 7.8a & b*). Under cool conditions, the color can be so dark that the reddish patch becomes difficult to see. Its antennae and cornicles are black, and it is one of the largest aphids found on wheat. They are common in the fall but also can occur in spring.

### **Plant Damage and Response**

Direct feeding damage to wheat is negligible, but populations of 50 or more per tiller at the boot to heading stage may be damaging. Heavy populations in the spring may cause the flag leaf to roll up into a corkscrew shape that can trap the awns, resulting in “fish-hooked” heads. This aphid is also a vector of barley yellow dwarf virus.

**Figure 7.8a (left)**  
Bird cherry-oat  
aphid.

**Figure 7.8b  
(right)**  
Bird cherry-oat  
aphid population.





## Management

### *Establishing level of risk*

Estimate the population based on a sample of 25 to 50 randomly selected tillers. If treatment is elected, choose products broadly labeled for aphid control on wheat.

### *Field Scouting*

Sample tillers for the aphid. No specific sampling techniques have been established. However, sampling techniques used for greenbug or Russian wheat aphid can be used in a similar manner for bird cherry-oat aphid.

### *Thresholds*

If 50 or more aphids are found per tiller as the crop approaches boot stage, control measures might be considered.

### *Chemical Control*

Conventional foliar sprays usually are not effective in reducing virus incidence; however, neonicotinoid seed treatments reduce BYDV infection by suppressing aphid colony establishment in the fall.

### *Biological Control*

Incidental predation and parasitism can occur. It is possible that bird cherry-oat aphids act as a food source for ladybeetles and therefore might help increase predator abundance in wheat fields. As an indirect effect, increased predators could attack other aphids such as the greenbug or Russian wheat aphid. No specific biocontrol agents or programs are known to control bird cherry-oat aphid infestations.

## Corn Leaf Aphid – *Rhopalosiphum maidis* (Fitch)

### Identification / Life Cycle

The oval-shaped, wingless adult is approximately  $\frac{2}{25}$  of an inch (2 mm) long. It is pale bluish-green in color with black antennae, legs, and cornicles (*Figure 7.9*). The head is marked with two longitudinal dark bands and the abdomen with a row of black spots on each side. The body often seems to have a powdery coating.

The first spring adults are winged females which fly in search of suitable host plants, and shortly thereafter give birth to live nymphs which usually develop into wingless females. Under favorable conditions, more winged females develop and migrate. Males are rarely found, and females continue to reproduce without mating (no egg stage is known for corn leaf aphid). Reproduction slows in winter and summer and is most rapid during cool weather. Therefore, corn leaf aphid tends to be a problem on winter grains in the spring.



**Figure 7.9**  
Corn leaf aphid.

## Management

### *Establishing level of risk*

The corn leaf aphid shows a preference for barley, sorghum, and corn. It also infests many other wild and cultivated grasses. An occasional pest of winter wheat, the corn leaf aphid sometimes occurs on seedling wheat in the fall. It is a vector of barley yellow dwarf virus.

### *Biological Control*

Similar to other small grain aphids, corn leaf aphid can be attacked by various predators and parasitoids that are common in wheat fields.

## English Grain Aphid – *Sitobion avenae* (F.)

**Figure 7.10**  
Adult English grain aphid and nymphs.



### Identification / Life Cycle

English grain aphid varies from yellowish-green to reddish-brown with long black legs and cornicles (Figure 7.10). They are larger than greenbugs, and their antennae are slightly longer than half the length of the body.

### Plant Damage and Response

These aphids colonize wheat in the fall and feed on the leaves, causing no discernable damage. In spring, they feed in the heads where they can cause some kernels to shrivel. They are also vectors of barley yellow dwarf virus.

### Management

Populations are normally held in check by various biological controls, and chemical treatments are rarely, if ever, justified. These aphids cause no discernable damage to wheat. The only management practice impacting English grain aphids would be one in which it was desirable to limit the spread of barley yellow dwarf virus.

## Mites

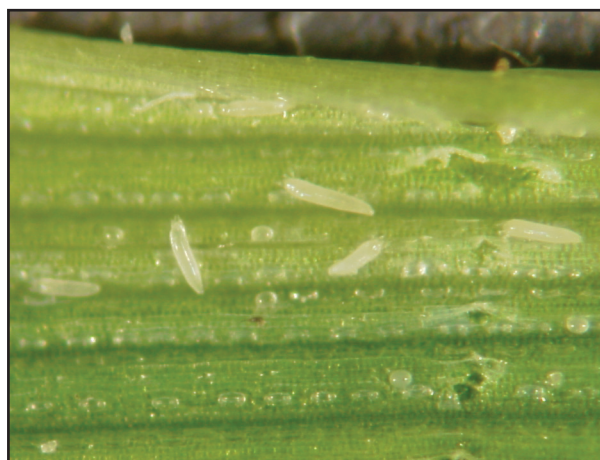
### Wheat Curl Mite – *Aceria tosichella* (Keifer)

The wheat curl mite is a major pest of winter wheat in the Great Plains from Texas to Canada because of its ability to vector three viruses. In the western Great Plains, wheat streak mosaic has been the most serious disease in winter wheat, and more recently, High Plains virus and Triticum mosaic virus also contribute to the impact of this disease complex.



## Identification / Life Cycle

The wheat curl mite is tiny (less than  $\frac{1}{100}$  of an inch long), cigar-shaped, and has only two pairs of legs (Figure 7.11). Its hosts include wheat, corn, and several other grasses. The wheat curl mite feeds on the youngest leaves and almost always is found in protected areas, such as a curled leaf or deep in the leaf whorl. It also feeds and reproduces in the protected areas of the wheat head or corn ears.



**Figure 7.11**  
The wheat curl mite.

Because of the wheat curl mite's tremendous reproductive capacity, it can increase to very large populations when conditions are favorable. Wheat curl mites go through two nymphal stages after hatching from eggs. Development from egg to adult occurs in about 8 to 10 days at 77°F (25°C). It has a continuous life cycle and overwinters in all life stages. Mites disperse among numerous hosts via air movement.

Wheat curl mite is found on winter wheat from the time it infests the plants in the fall until wheat maturity the following summer. It can survive off the green plant only a few hours to a few days depending on temperature and humidity. Under hot and dry conditions in the summer, mites likely will desiccate within 12 hours. To survive from the time of wheat maturity until emergence of the fall wheat crop, the mite must find "green bridge" hosts. The most important green bridge results when hail occurs prior to wheat harvest. Hail shatters wheat heads and kernels fall to the ground where they germinate rapidly and sprout into volunteer wheat. Wheat curl mite readily infests and transmit viruses to this preharvest volunteer.

The buildup of mite populations during the green bridge period is determined by the available bridge hosts, environmental conditions, and the length of the bridge period. In the north, a short bridge period may limit mite population increase, but the milder environmental conditions may allow for better survival. In the south, a longer bridge period may allow extensive mite buildup, but hot, dry conditions may limit mite survival.

Although not as important as volunteer wheat, corn also can serve as a green bridge host. Mite populations build up within the corn ears and exit as the corn dries down in the late summer and fall. Irrigated corn produces more mites later in the fall than dryland corn, increasing the infestation risk around irrigated corn. Several other grasses and grassy weeds contribute to background populations of mites, and under certain situations may contribute to significant mite infestations.

## Plant Damage and Response

Wheat curl mite is most often found feeding in areas of the plant with young, succulent tissues within the whorl of the plant. This causes the edges of the leaves to remain tightly curled inward (*Figure 7.12*). As the leaf curl is exposed, the mites move back into the whorl to colonize the next developing leaf. As the plant grows, subsequent leaves or awns on the head can be trapped in the previous leaf's curl causing distorted leaves or curled heads. Mite feeding damage is secondary to the vectored virus impacts; however, feeding during the heading stages, when mites can build to large populations, can reduce yields up to 15 percent.

**Figure 7.12**  
Wheat curl mite feeding causes edges of leaves to curl inwards.



The greatest impact from the wheat curl mite is virus transmission. Loss estimates indicate that wheat streak mosaic causes an average of two percent per year loss in wheat. This yearly average includes a range from near zero to 13 percent, indicating a wide variance in its impact from year to year. Damage can also be quite variable from field to field. This estimate is likely representative of much of the western Great Plains. In addition, High

Plains virus and Triticum mosaic virus have been found to be vectored by the mite. These viruses are widely present throughout the Great Plains, but their impact is very difficult to determine as they are almost always found with wheat streak mosaic.

## Management

### *Establishing Risk*

The most effective management practice is to control green bridge hosts to reduce the number of mites available to infest fall planted wheat. High risk bridge hosts should be controlled completely before the emergence of the fall wheat crop. If mite infested bridge hosts are not completely destroyed before the next wheat crop emerges in the fall, the mites will move from the green bridge to the new wheat crop and transmit viruses.

Preharvest volunteer arising from hail has, by far, the greatest risk of serious mite and virus presence. Volunteer wheat growing in summer crops (e.g. sunflower, corn, millet) that emerges before wheat harvest can also be a threat if left uncontrolled. After harvest, mite activity drops to very low levels, and post-harvest volunteer will be infested slowly. The risk from postharvest volunteer will be greater in the southern plains because the green bridge period is much longer than further north, and there is more time for mites and viruses to build to significant levels.

Corn also can serve as a green bridge host. Mites move into corn just prior to wheat harvest. They build up in corn as the ears develop, and they move off corn as the ears are drying down. Dryland corn often dries down before wheat planting in the fall and carries a lower risk for virus problems. Irrigated corn stays green longer, and if wheat emergence overlaps with green corn, the risk of disease development increases.

Other potential green bridge hosts include several other grasses. The ability of mites to reproduce on these hosts is much less than wheat; so the risk from their presence is much lower than that for volunteer wheat.

### ***Planting Dates***

Avoid early planting of winter wheat. Early planting increases the risk for green bridge crossover and mite population and disease buildup during the fall. Later planting will reduce the risk levels of developing WSMV in high risk situations (e.g., next to preharvest volunteer) or low-moderate risk situations (e.g., next to growing irrigated corn).

### ***Plant Resistance***

Commercial wheat varieties resistant to the wheat curl mite (e.g., TAM 107) are available. However, mite biotypes have developed in the region that can overcome this resistance. There are several sources of resistance to the mites in wheat and closely related grasses, but the optimum use of these resistant genes in wheat varieties has not been determined due to the biotype issues. Currently, new wheat varieties are being developed with much higher levels of resistance to WSMV than previously available. However, these varieties are not immune to the disease and some may require additional management (e.g., adjusting planting date) to maximize their effectiveness in the field. Check with local extension sources for availability and other recommendations.

## **Brown Wheat Mite – *Petrobia latens* (Müller)**

The brown wheat mite is a sporadic pest of winter wheat in the western plains. Mite impact is most severe when drought conditions persist through the winter and spring. Cropping practices can increase incidence, but impact on wheat will largely depend on the moisture status of the wheat. In the northern Great Plains, the brown wheat mite also can transmit barley yellow streak mosaic virus.

### **Identification / Life Cycle**

The brown wheat mite is about  $\frac{1}{50}$  of an inch (0.5 mm) in length with a dark brown to black body and lighter colored legs (*Figure 7.13*). The front legs are about twice as long as the others and are often held straight in front of the body. Brown wheat mites are parthenogenic (all females) and over-summer as dormant white eggs (*Figure 8.14*). In the fall, when they are exposed to lower temperatures and rainfall, white eggs will hatch. Multiple generations occur from fall through spring. Eggs laid from the fall through early spring will be red in color (*Figure 7.14*) and will hatch in about 7 days at 72°F (22°C). Mite populations increase more rapidly under dry conditions. Populations peak in early spring (April) then decline with the onset of continuous warm weather. The final spring generation produces dormant white eggs.



**Figure 7.13 (left)**  
Brown wheat mite.

**Figure 7.14  
(right)**  
Brown wheat mite  
eggs.



### **Plant Damage and Response**

The mites spend nights in the soil and among the leaves near the soil, and move up to feed on the leaves during the day. Feeding causes stippling or yellowing of the leaves, especially at the leaf tips. Extensive damage will result in bronzed or brown plants that appear drought stressed. The impact of brown wheat mite feeding will be most severe when plants are stressed by drought.

### **Management**

#### ***Establishing Risk***

The greatest risk of brown wheat mite infestation occurs in continuous winter wheat or when volunteer wheat was present the previous spring. These situations can result in large populations of over-summering white eggs that hatch and infest the new crop in the fall. Control volunteer wheat and avoid continuous winter wheat to reduce the risk of large mite populations.

#### ***Chemical Control***

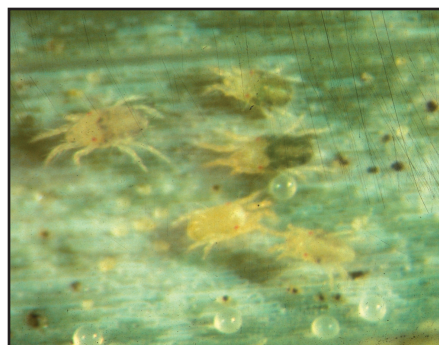
Decisions on the need to control brown wheat mite infestations are difficult because infestations mostly occur when the wheat is severely drought stressed. If no rainfall is received, mites remain active and plant damage increases, but yield potential will be reduced due to drought stress. However, if rainfall greater than  $\frac{1}{4}$  to  $\frac{1}{2}$  inch is received, mite populations will be reduced along with plant stress. Treatments may only buy time for the plant to catch a critical rainfall event. Treatments should only be considered if mite populations exceed several hundred mites per row foot, damage symptoms are evident, and females are still depositing primarily red eggs. When sampling, mites are most active on the foliage in the early afternoon of warm days. As the proportion of white eggs increases, adult population densities begin to decline.

## Banks Grass Mite – *Oligonychus pratensis* (Banks)

The Banks grass mite is a major pest of corn throughout the western Great Plains, but is only a sporadic pest of winter wheat. Severe infestations occur when plants are under drought stress.

### Identification / Life Cycle

Banks grass mites are straw to tan colored, and adults have a deep green color concentrated on either side of the posterior  $\frac{2}{3}$  of the body (Figure 7.15). Adult females can be up to  $\frac{1}{50}$  inch (0.5 mm) in length, and in the fall, overwintering females are bright orange. Mite colonies produced on the leaves will contain heavy webbing that collects dust and dirt granules. Damaged leaves are folded over longitudinally with the mites inside.



**Figure 7.15**  
Banks grass mite.

Banks grass mite populations can build up through the summer in cornfields. As corn dries down in the fall, overwintering females move from corn to adjacent winter wheat or other grass hosts. They feed on the crown of these plants through the fall and winter. In the spring, mites move up on the plant to feed and establish colonies on the leaves. During periods of little rainfall in the spring, populations can build on wheat plants and cause significant damage to leaves. As wheat plants mature, mites will move to alternate hosts adjacent to the wheat (e.g., corn).

### Plant Damage / Response

Banks grass mite sucks plant juices causing leaf stippling and yellowing. Severely damaged leaves will brown, especially at the leaf tips, and plants will become brownish yellow. Mites build up to severe levels on the leaves in the spring only when very little rain occurs and wheat is under drought stress. Banks grass mites can also damage winter wheat in the fall if large populations of overwintering females feed on the crown of the plants.

### Management

#### *Establishing Risk*

Wheat fields adjacent to infested corn and sorghum are at greatest risk for infestations as the overwintering females seek winter feeding sites. Severe damage is only likely to occur in combination with dry growing conditions, both in the fall and through the spring.

#### *Chemical Control*

Fall treatment of areas bordering severely infested field corn may be warranted. Treatment of spring infestations is difficult to justify because drought conditions that allow increases in mite populations will severely limit wheat yields. Rainfall will reduce mite populations and eliminate plant stress. Treatment may provide benefit if rainfall is eventually received.



## Winter Grain Mite – *Penthaleus major* (Dugès)

**Figure 7.16**  
Winter grain mite.



The winter grain mite, also known as blue oat or pea mite, is most prevalent from south-central Kansas through central Texas. Its host preferences are cereals and grasses, but it will feed on a wide range of broadleaf hosts as well. Recent taxonomic work in Australia with this mite has revealed the presence of two additional species, casting question on the true identity of this species in North America.

### Identification / Life Cycle

Winter grain mites are about  $\frac{1}{25}$  inch (1 mm) in length with dark brown bodies (Figure 7.16). Their legs are reddish orange, and their front legs are only slightly longer than the others. Winter grain mite feeds at night or on cloudy days and readily drops from the plant when disturbed. When not on plants, mites may be found several inches down in the soil.

Winter grain mite spends the summer as dormant eggs. In the fall, these eggs hatch when soil moisture conditions are optimum, and a first generation peaks during early winter (December-January). A second generation occurs and peaks in early spring (March-April). Mites are most active between temperatures of 40 to 70°F (4-21°C), and they move into the soil during periods of warm, dry weather. The second generation produces the over-summering eggs that remain dormant until fall. The egg types (winter and summer) are difficult to distinguish because the summer eggs are only slightly larger. Both types of eggs are laid in the soil and on plant material, and when dried are wrinkled and tan.

### Plant Damage / Response

Winter grain mites feed nocturnally, but remain near the plants during the day. Their feeding cause the leaves to become grayish or silvery in appearance as opposed to the typical yellowing caused by spider mite feeding. Extensive feeding can result in brown leaf tips and stunted or dead plants. Stunting will reduce potential forage in areas where wheat is grazed through the winter. Damage from the winter grain mite will be greatest during early winter (first generation) and again in early spring (second generation).

### Management

Winter grain mites are most severe in continuous winter cereals; therefore, rotation away from continuous winter cereals will reduce the risk of damage. If high mite numbers are present along with leaf damage and stunting, treatments may be warranted. Inspections for mite presence on the plants must be done when the mites are active (nights or cloudy days).

## Caterpillars

### Army Cutworm – *Euxoa auxiliaris* (Grote)

The army cutworm is a regular pest that is distributed throughout the Great Plains because its life cycle ties it closely to the regions just east of the Rocky Mountains. In most years it reaches economic infestations in some areas of the Great Plains, but these areas shift unpredictably from year to year. It can feed on an array of crops and weeds, but most of its economic impact is limited to winter wheat and alfalfa because these are the vulnerable crops growing in the early spring when larval feeding activity occurs.



**Figure 7.17**  
Adult army cutworm.

### Identification / Life Cycle

The army cutworm moth has a wing span of about 1¾ inches and is typical of the “miller moths” that are commonly observed in the region (Figure 7.17). The moth has five color forms, ranging from a lighter form with fairly distinct wing markings to a darker form with less distinct wing markings. Female army cutworm moths lay their eggs directly in loose soil. They seem to be attracted to bare areas such as overgrazed pastures, alfalfa stubble, stressed grassy areas, and newly planted or tilled cropland. Females lay from 1000 to 3000 eggs from late August through late October. The result of this extended egg laying period is a great variation in larval size within fields.

The eggs hatch shortly after they have been exposed to moisture (i.e., rainfall). Larvae continue to feed as long as temperatures are favorable and can be found actively feeding through the winter when temperatures are warm enough. During cold conditions, the partially grown larvae overwinter in the soil. Larval feeding activity resumes in late winter or early spring when soil temperatures increase. Army cutworms become active at relatively cool temperatures, possibly even below 40°F (4°C), because solar heating warms soil temperatures well above the air temperature. Feeding continues through the spring, when fully grown larvae burrow into the soil, create an earthen chamber, and pupate. Adults begin to emerge from the soil in late April (Oklahoma and Texas) or May (Nebraska and Wyoming).

Generally, larvae of the army cutworm have a pale grayish body color that is splotched with variable white or light markings (Figure 7.18). The upper surface is lighter with a pale stripe along the center of the back. There is a lighter band along the side of the larvae below the spiracles. Larvae can attain lengths of 1½ to 2 inches when fully grown.

**Figure 7.18 (left)**  
Army cutworm  
larva.



**Figure 7.19  
(right)**  
Under high larval  
densities, stand  
losses can occur due  
to army cutworm  
feeding habits.



The most prominent trait of the army cutworm moth is its migration pattern. Adults emerge from April through early June and feed locally on a variety of nectar bearing, flowering plants. These moths gradually migrate westward toward the Rocky Mountains and continue to feed on available nectar sources as they ascend in elevation. As they move westward, they rest during the day in dense vegetation or sheltered areas. They are attracted to lights, and during outbreak years, tremendous numbers of army cutworms can congregate in towns and around residential areas. Moths may remain in these areas for several days, feeding on local nectar sources, especially trees. However, when temperatures begin to warm consistently and flowering of major trees in the area has ceased, the moths will move westward to higher elevations offering cooler temperatures and new sources of food. The moths spend the summer in the Rocky Mountains, and in late August and September they return to the plains to mate and deposit eggs.

### Plant Damage / Response

The army cutworm has a wide host range that includes alfalfa, barley, corn, oats, potato, sugar beet, wheat, many vegetables, and a number of grasses. The army cutworm is a climbing cutworm that “grazes” on the leaves of its host plants. In the early spring, when wheat plants are just breaking dormancy and leaf area is limited, the army cutworm may keep the new plant growth completely clipped back. This results in delayed green-up of wheat, and if feeding continues, stand losses will occur (*Figure 7.19*). Under high populations larvae tend to migrate, all moving in the same direction in large numbers, often devouring any green vegetation in their path. This behavior has resulted in the name ‘army’ cutworm. The leading edge of this ‘army’ can contain 20 to 30 larvae or more per square foot.

### Management

There are few management options available to reduce the severity or damage potential of the army cutworm. The primary management option is to scout the field to assess cutworm populations and treat if infestation levels reach the economic threshold.

***Establishing Risk***

Moth populations in the fall can be determined by using pheromone traps to monitor moth flights. This information can be used to predict the risk of serious infestations the following spring. Pheromone traps are easy to use and monitor the army cutworm because the lure is specific to the army cutworm. Traps should be set up by late August and monitored through October. High risk situations would result from trapping a total of more than 800 army cutworm adults for this 8 to 10 week trapping period. Other environmental factors will influence risk levels as well. If trapping indicates a high risk situation, further field scouting should be done in these areas during the spring green-up of wheat to determine the extent of the risk for individual fields.

***Field Scouting***

Wheat fields should be monitored periodically during late winter and early spring just as the winter wheat is breaking dormancy. Army cutworms are not always easy to detect. Larvae hide in loose soil at the base of plants or under soil clods during the day, and can be found feeding on plants only in the evenings and on cloudy days. Early on, small feeding holes in the wheat leaves are an indication that cutworms are present and feeding. Serious infestations will result in extreme defoliation and minimal or no regrowth. The density of cutworms (number per square foot), the condition of the wheat, and the extent of regrowth are important considerations in determining the need for treatment. Healthy growing wheat can withstand substantial defoliation. However, if plant growth is limited due to stress (e.g., drought stress, cool temperatures), the cutworms may feed down to and injure the crown of the wheat plants.

***Thresholds***

Treatment thresholds depend on how vigorously the wheat is growing. If wheat is slowly coming out of dormancy due to stress or cool temperatures (e.g., drought, no-till situations), the effects of army cutworm feeding damage will be increased. Under these conditions, two or more cutworms per square foot may cause economic damage. If wheat appears to be growing well, four or more larvae per square foot may be needed to cause significant damage. Pyrethroid insecticides are particularly effective in controlling these cutworms in wheat.

***Biological Control***

A number of parasites, predators, and diseases are important influences on army cutworm populations. The impact that these natural enemies have on damage potential is not well understood, but their presence increases during high infestation periods. Perhaps the most effective predators are the various types of birds that feed on these insects when they are abundant.



## Pale Western Cutworm – *Agrotis orthogonia* (Morrison)

The pale western cutworm is a sporadic pest that is distributed throughout the western Great Plains. It reaches damaging populations, primarily during dry periods. Pale western cutworm can feed on a vast array of crops and weeds, but its major economic impact is limited to winter wheat.

### Identification / Life Cycle

The pale western cutworm moth is gray to brownish white with a body length of just under  $\frac{3}{4}$  inch and wingspan of  $1\frac{3}{8}$  inches. The distinctive characteristic of these moths is the white undersurface of the wings. Moths begin to emerge in late August and quickly increase in numbers, peaking by mid September. They are attracted to areas with loose soil to deposit their eggs, and in areas where it is most severe, the moth flight coincides with tillage and planting of winter wheat. Each female lays 250 to 300 eggs in the upper  $\frac{1}{2}$  inch of soil. Moth activity decreases by early October. Some eggs may hatch during a warm spell in the fall or winter, but most hatch early in the spring when temperatures at the soil surface reach 70°F (21°C). This may occur from February through March.

Young larvae are small and very difficult to find. Larvae pass through six to eight stages before they cease feeding and pupate. Until they are about  $\frac{1}{2}$  inch long, they are grayish white in color. As they get bigger they become a grayish-green color. The pale western cutworm is pale with no distinct markings on its body (*Figure 7.20*). When fully grown, the pale western cutworm is about  $1\frac{1}{4}$  inches long. The only other cutworm likely to be present in fields at this time is the army cutworm, which generally is larger because it begins development in the fall. Also, pale western cutworm larvae are lighter in color than the army cutworm, which has distinct striping on the body (*Figure 7.21*). Pale western cutworm feed through the spring and mature in May and early June. The larvae are capable of surviving extended periods (up to a month or more) without food. They then burrow into the soil and form earthen cells where they pass most of the summer, pupating in early August shortly before they emerge as adults.

**Figure 7.20 (left)**

Pale western cutworm larva.

**Figure 7.21 (right)**

Army cutworm (bottom) as compared to pale western cutworm (top).



## Plant Damage / Response

The pale western cutworm has a very broad host range, including many weed species. It is a subterranean cutworm in that it primarily feeds below the soil surface. The depth at which it feeds is regulated by the moisture line in the soil. These cutworms avoid moisture and stay just above this moisture line. Under wet conditions the cutworms actually will come to the surface and feed on the above-ground part of plants. This activity increases the rate of predation by birds and other insects, and parasitization. Increased moisture levels at the surface also increases disease incidence in the population.

Because of the feeding habits of the pale western cutworm, fewer larvae than army cutworm are necessary for severe damage. These cutworms cut the plant off below the soil surface by notching or completely severing the stem. This damage appears in winter wheat as dead or wilted tillers. Pale western cutworm damage is likely if these tillers can be easily pulled from the ground and no roots are attached. Since the cutworms eat only a small portion of the plants they cut, their potential for significant damage is greatly increased.

Damage often continues along a row or expands in patches until few tillers are left. Severe infestations can completely destroy a stand. Infestations within a field are usually spotty and are first evident in the lighter soils on knolls or hills, or areas with southern exposure (*Figure 7.22*). Later, the cutworms move out into the surrounding areas. Early feeding by small larvae appears as shotholes or ragged edges on the leaves.



**Figure 7.22**  
Damage in fields occurs along rows or in patches and expands outwards.

**Figure 7.23**  
Cutworm pheromone trap; plastic milk jug trap.



## Management

### *Establishing Risk*

The first step in managing the pale western cutworm is to determine the potential for outbreaks. Several factors influence the population growth of this insect. During wet springs, pressure from parasites, predators, and disease cause populations to decline sharply. The number of days with at least  $\frac{1}{4}$  inch of rainfall (“wet days”) is used to determine the potential impact of rainfall on the pale western cutworm population. If 12 or more “wet days” occur during the spring (March-June), the pale western cutworm population likely will be reduced to the point that it will take two or more dry springs for the population to rebuild to significant levels. If there are 10 or fewer “wet days,” the pale western cutworm population is likely to increase, and the potential for damage the next year is increased.

Moth populations in the fall can be determined by using light or pheromone traps to monitor flights. This information can be used to predict the risk of serious infestations the following spring. Pheromone traps (plastic milk jug trap, *Figure 7.23*) are easily used to monitor the pale western cutworm because the lures are specific to this cutworm. Traps should be set up in mid to late August and monitored weekly through September into early October. Pheromone trapping totals of more than 200 pale western adults for this trapping period indicate high risk. Other environmental factors will influence risk levels.

### *Scouting*

Estimating the severity of an infestation of pale western cutworms in wheat is difficult. Infestations tend to be spotty throughout the field, so scouting should be done early to avoid severe damage in localized areas. When scouting, look for early leaf damage. Another indication is the presence of a few dead or wilting tillers in wheat. Population density can be assessed by digging and screening the soil from one foot of row. The sample should be dug to a depth of at least three inches and extend from row center to row center. Several samples at different sites should be dug for a reliable estimate of population density and area of infestation. Often an area of severe infestation may not be extensive, and such areas could be spot treated to avoid the cost of a complete field application.

### *Thresholds*

The threshold for insecticide treatment is one to two pale western cutworms per foot of row. If the wheat has a high yield potential, the threshold would be closer to one. On the other hand, the higher threshold should be used if wheat has a low yield potential. Pyrethroid insecticides are particularly effective in controlling pale western cutworms in wheat.



## Fall Armyworm – *Spodoptera frugiperda* ( J.E. Smith)

The fall armyworm is thought to be a native pest of the western hemisphere but does not overwinter in the High Plains and must migrate northward annually from southern states. It is a sporadic pest that can damage early planted wheat in the fall. Fall armyworm populations are a more common problem in the southern plains.

### Identification / Life Cycle

The hind wings of fall armyworm moths are grayish white, and the front wings are marked with distinctive dark gray, brown, and white splotches (*Figure 7.24*). Eggs are deposited in masses on the undersides of foliage, and the masses are fuzzy with scales from the female's body. Fall armyworm larvae are usually brown, but color variations occur ranging from green to nearly black. They have four distinct spots arranged in a square on top of the 8<sup>th</sup> abdominal segment (*Figure 7.25*). The front and sides of the head have distinct reticulations, and the front of the head is marked with a pale, but prominent, inverted Y. Larvae are 1½ inches long when mature.

Moths usually arrive in late summer and lay eggs on corn, sorghum, and other summer crops. Reproduction may continue through August and into September, putting early planted wheat at greatest risk.

### Plant Damage and Response

The first sign of damage is “windowpane” injury caused by tiny larvae chewing on seedling leaves. The larvae, which are usually too small to be easily observed at this time, hide in or around the base of seedlings. Within a few days the larvae are large enough to destroy entire leaves. Larvae increase in size at an exponential rate and so do their food requirements. Later instars do the most damage, sometimes destroying entire stands, and are the least susceptible to insecticides.



**Figure 7.24**  
(left)  
Adult fall armyworm.

**Figure 7.25**  
(right)  
Fall armyworm larva.



## Management

Since this insect generally is an early fall pest, later planted fields are less likely to become infested. Early planted fields should be inspected frequently during the first few weeks following emergence. Without treatment, problems can continue until larvae reach maturity or until there is a killing frost. Fields with 25 to 30 percent of plants with windowpane injury should be reexamined daily and treated immediately if stand establishment appears threatened. Several insecticides are currently labeled for fall armyworm control and should be effective if treatments are applied when larvae are small.

## Armyworm – *Pseudaletia unipuncta* (Haworth)

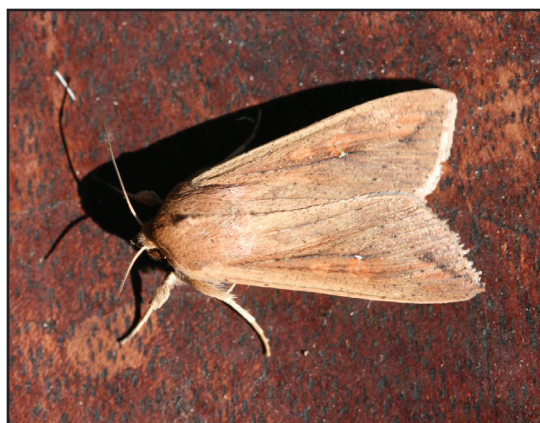
The armyworm, or “true” armyworm, feeds on a variety of plants, preferring grasses. It is a sporadic pest that can be found throughout the Great Plains, but significant infestations in wheat are most likely to occur in the southern plains (Kansas to Texas). Most damage occurs during warm, moist periods in late spring, but there also is a danger of migration out of maturing grain fields and into adjacent fields of corn and sorghum.

## Identification / Life Cycle

Armyworm moths are tan to light brown with a tiny white spot centered on each forewing (*Figure 7.26*). Adults lay their eggs in large clusters on lush vegetation. The larvae are green to black with stripes of various colors (*Figure 7.27*). The head capsule is medium brown with dark markings. Armyworms pupate in a brown earthen shell just below the soil surface.

**Figure 7.26 (left)**  
Adult armyworm  
moth.

**Figure 7.27  
(right)**  
Armyworm larva.



## Plant Damage and Response

Each larva, feeding mostly at night, can consume 43 linear inches of wheat leaf, or the equivalent of three whole plants, in the course of its development. However, 80 percent of this damage occurs during the last three to five days of larval feeding. Wheat is likely to suffer yield loss if the flag leaf is destroyed before the soft dough stage is completed. Head clipping in barley is serious and should be prevented, and while it is less likely in wheat, worms should be watched closely if present after heading. As wheat plants mature, armyworms may feed on beards and clip heads to complete their food requirements.

## Management

When leaf feeding is observed, look for larvae curled up on the ground under litter, especially in patches of lodged plants. Treatment is usually not necessary below levels of four or five larvae per foot, but may be justified at infestations of five to eight per foot depending upon larval maturity in relation to crop maturity.

## Wheat Head Armyworm – *Faronta diffusa* (Walker)

The wheat head armyworm is a minor pest of wheat in most years but occasionally can cause noticeable crop injury. Unfortunately, the first indication of a wheat head armyworm problem is often when wheat is downgraded at harvest because of insect damaged kernels, or when larvae are noticed on grain screens at elevators. Infestations are usually too sporadic and isolated to justify any type of scouting or treatment program.

## Identification / Life Cycle

The adult moth is yellowish brown with a chocolate colored stripe down the length of each forewing (Figure 7.28). The larvae vary in coloration from greenish to cream colored, depending on the maturity of the grain they have consumed, but all have longitudinal white and brown lines down each side of the body (Figure 7.29a & b). The larvae will grow to about one inch in length and are slightly tapered to the rear end. Larvae feed on the wheat heads from evening to early morning, typically hanging onto the awns upside down and hollowing out kernels. They rest in the soil at the base of the plant during the day.



**Figure 7.28 (left)**  
Adult wheat head armyworm moth.

**Figure 7.29a & b (right top and bottom)**  
Wheat head armyworm larvae.

The insect passes the winter as a pupa in the soil, emerging as an adult in the spring to lay eggs on a wide variety of grasses, although wheat is highly preferred. Unlike the true armyworm, there is more than one generation per year, but it is the first generation of larvae that feeds on maturing wheat heads and causes direct damage to kernels (Figure 7.30). Second generation moths emerge over an extended period in summer months and lay eggs on warm season grasses. Fall flights can be observed well into October, and it is not clear if a portion of these represent a third generation, late-developing second generation individuals, or some combination of both. Larvae that complete feeding on maturing warm season grasses in the fall pupate in the ground but remain dormant until the following spring.

**Figure 7.30**

Wheat head armyworm larvae feeding on a maturing wheat head.



**Figure 7.31**

Damaged kernels due to wheat head armyworm feeding.



## Plant Damage and Response

Damaged kernels appear partially hollowed (*Figure 7.31*). Kernel damage will vary from slight to severe, and many of the most severely damaged kernels are likely to be blown out through the combine. Damage to kernels is difficult to distinguish from that of certain stored product pests and can be classified 'IDK' (insect damaged kernels).

## Management

There are no established management plans for this pest. Infestations are usually concentrated around field margins so scouting efforts for this pest would need to include interior transects to obtain a representative estimate of population levels. In addition, no economic threshold has been determined. There are no materials specifically labeled for this pest, but materials registered for other armyworms in wheat would likely provide control if applied sufficiently early. However, unless detected well in advance of crop maturity, treatment would be impractical because the preharvest interval requirement of most insecticides would cause even greater losses due to delayed harvest. Larvae arriving in storage bins with harvested wheat either die or emerge as moths, and they are not a concern in stored grain.

## Grasshoppers

Grasshoppers can be found across the Great Plains, but most damage occurs in areas with less than 25 inches of annual rainfall. In most years, the western Great Plains falls into this higher risk category and is susceptible to grasshopper outbreaks. Grasshopper damage to winter wheat occurs 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.

### Identification / Life Cycle

Four grasshopper species—the migratory, differential, two-striped, and red-legged—cause nearly all the damage to cultivated crops (*Figure 7.32-7.35*). They prefer habitats with a variety of host plants, including both grasses and broadleaf weeds. As a result, they prefer cropland settings with nearby undisturbed areas such as roadside ditches, crop borders, abandoned cropland, and overgrazed pastures or rangeland. Field crop problems usually do not arise from neighboring well managed rangeland or pasture.





**Figure 7.32**  
(upper left)  
Migratory  
grasshopper.



**Figure 7.33**  
(lower left)  
Differential  
grasshopper.



**Figure 7.34**  
(upper right)  
Twostriped  
grasshopper.



**Figure 7.35**  
(lower right)  
Redlegged  
grasshopper.

Female grasshoppers lay their eggs in pods, laying 8 to 30 eggs per pod and a total of about 100 eggs during the summer and fall. The potential for outbreak increases when females produce more eggs as a result of better food quality or an extended fall which allows more time to lay them. Egg pods are deposited in the upper few inches of undisturbed soil in grasslands, pastures, ditches, and field borders. No-till fields also may have increased risk due to potential egg laying throughout the field. Eggs are well insulated by the pod and soil and can survive extremely cold temperatures as they overwinter.

Hatching time is strongly influenced by temperature, with earlier hatching occurring after a warm spring. The twostriped grasshopper is the earliest hatching grasshopper of concern in cropland with eggs beginning to hatch from mid to late May. Eggs from the remaining species begin to hatch from one to three weeks later. Hatching will continue well into June.

Nymphs start feeding immediately after hatching and usually feed on the same plants as adults. Because of limited fat reserves, nymphs are very vulnerable to adverse weather just after hatching, and extended cool temperatures (less than 65°F or 18°C) and rainy weather can result in extreme nymphal mortality due to starvation. Grasshopper nymphs go through five developmental stages or instars. After each instar, they shed their cuticle and grow larger, developing into adults in five to six weeks. In most years, adult grasshoppers are present by late June and early July. Adult grasshoppers, the only instar with wings, can readily move out of hatching areas.

### Plant Damage / Response

Grasshoppers cause defoliation as they consume and also clip foliage. In the fall, early seeded winter wheat is more vulnerable to injury than later plantings because the plants emerge while adult grasshoppers are still actively feeding. Newly emerged wheat can be severely damaged by grasshopper feeding, resulting in stand loss. Increased grasshopper pressure also may occur after a light fall frost that kills broadleaf weeds, such as sunflowers, in areas adjacent to winter wheat. Grasshoppers losing this forage source may move quickly into winter wheat and cause damage; however, a heavy frost will reduce or eliminate local grasshopper infestations.



**Figure 7.36**  
Grasshopper feeding habits cause heads and stems to fall to the ground.



In the spring and early summer, grasshopper damage to small grains can seriously damage maturing small grains. They will defoliate wheat, but the greatest impact will occur when grasshoppers clip the stems, causing entire heads to fall to the ground (*Figure 7.36*). This damage is most likely to occur when grasshoppers move into wheat fields while the wheat is maturing and the stems below the heads is the only remaining green tissue.

### Management

Because grasshoppers move into crop production fields from hatching beds around field borders, grasshopper surveys should be conducted in adjacent untilled areas early in the season (late May and June) to determine the potential for problems. If timely rains keep the vegetation in and around hatching beds green, the grasshoppers may not move into the maturing wheat crop.

Sweep net sampling is useful in determining the stage (instar) and species makeup of grasshopper populations. A standard 15-inch diameter sweep net, equipped with a heavy cloth net, should be used. Information from sweep net samples is particularly valuable early in the season for determining the stage of grasshopper development to optimize treatment timing and to assess the potential for damaging infestations.

***The best method for determining grasshopper density in field borders or hatching areas is to count the number of grasshoppers by using the square-foot method.*** With practice, this approach can provide good estimates of hopper density. To use this method, randomly select a point several feet away and visualize a one square foot area around that point. When first learning this method, practice with a measured square foot area to improve your ability to visualize the counting area. Walk toward this point while watching this square foot area, and count the number of grasshoppers in or jumping out of the area. Repeat this procedure 18 times, and divide the total number of grasshoppers by two. This will give you the number of grasshoppers per square yard (9 square feet). Counting sites should be 50 to 75 feet apart and randomly chosen. Just after hatching, when grasshoppers are small, they will be difficult to see, and underestimating the true hopper density is common. Vary the vegetation in the count area, and sample both north and south facing slopes.

### Thresholds

When the number of grasshoppers per square yard has been estimated, use *Table 7.2* and *Table 7.3* to determine if treatment is necessary. Adult grasshoppers can consume a great deal of plant material in a short time. Due to the small amount of vegetation available in emerging wheat and the life stage of the grasshoppers, light to moderate infestations in the field and borders can cause considerable stand loss along borders.

### Cultural Control

A long term solution to reduce grasshopper potential is to **reduce the attractiveness of abandoned or weedy areas to cropland grasshoppers** by establishing a dense grass cover that includes few broadleaf plants. For winter wheat, delayed seeding in high risk fields also can reduce the potential for grasshopper damage but may not be practical, especially during a warm fall when grasshopper survival is extended.

If severe infestations are anticipated, field margins can be planted at a higher (double) wheat density to allow for some plant loss. Planting at increased density would only be needed on field edges in the first one or two passes with the drill.

**Table 7.2**

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

	Nymphs/yd <sup>2</sup>			Adults/yd <sup>2</sup>		
Rating <sup>1</sup>	Adjacent	Crop	Treat?	Adjacent	Crop	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
Threatening	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.

<sup>1</sup>This is a general rating used in all crops.

**Table 7.3**

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

	Adults/yd <sup>2</sup>		
Rating <sup>1</sup>	Adjacent	Crop	Treat?
Nonthreatening	<10	<3	No
Light	10-20	3-7	Yes
Threatening	21-40	8-14	Yes, consider wider border treatments
Severe	41+	15+	Yes, use wider border treatments and monitor for retreatment.

<sup>1</sup>This is a general rating used in all crops.

### **Chemical Control**

Grasshoppers are easiest to control as nymphs. If a range of rates is listed for a given insecticide, the higher rates generally should be used to control adults. Grasshoppers can be controlled by using sprays or baits. ***Read the label thoroughly before any insecticide application, and follow safety instructions and precautions.*** When spraying borders adjoining cropland, be sure to read and follow label restrictions on grazing. The treatments discussed here should provide adequate control of low to moderate grasshopper infestations. If grasshopper counts are high, control will be difficult.

- **Baits.** One option for grasshopper control is a bait formulation. Carbaryl-based bran bait is available as a two percent or five percent formulation. This method can provide good control when applied just before winter wheat emergence, when crops are only a few inches tall, or in areas with short, dry vegetation. Success depends on uniform distribution of the bait and reapplication if the bait is no longer attractive to grasshoppers. Moisture (rain or heavy dew) will reduce the bait's attractiveness substantially.
- **Border Treatments.** In most years, treating the crop margin or the border area surrounding the crop is adequate for control. A border treatment of 150 feet beyond the crop edge should be adequate in most situations, depending on the size of the grasshopper source area, but season long control may require up to a ¼ mile border treatment when the population source is large. With large infestations, control may be difficult, and multiple border treatments may be required. Using insecticides with the longest residual activity would be most effective. The residual activity of the treatments will vary with the chemical and environmental conditions. It is important to monitor the border areas and crop margins after treatment to make sure grasshoppers do not reenter the field.

Timing of 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 too quickly. If it is applied too late, some of the earliest emerging wheat may already be damaged.

Planting insecticide treated seed can help control grasshoppers in emerging wheat. Imidacloprid (Gaucho) and thiomethoxam (Cruiser) seed treatment can be effective when hoppers are present at moderate levels. These seed treatments can only be purchased on pretreated seed. Once in the soil, the chemical is taken up by the germinating seed and seedling and is ingested by feeding grasshoppers. Grasshoppers can still damage the wheat, but damage will be slowed considerably as they are affected by the insecticide. As with all control methods at this time of year, this method will not be completely effective if grasshopper infestations are high.

## Wheat Stem Sawfly – *Cephus cinctus* (Norton)

The wheat stem sawfly has long been a severe pest of spring wheat in North Dakota and Montana. 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 before harvest. However, in recent years, winter wheat in the northern plains has seen increased damage from the sawfly. In the central High Plains, the wheat stem sawfly was not a pest of significance, presumably because of the predominance of winter wheat and lack of spring wheat. However, over the last two decades serious infestations have begun to occur and spread in southeastern Wyoming and in adjoining counties in Nebraska. It is unclear why the sawfly is becoming more prevalent in winter wheat, but its increasing presence in this region is worth noting and watching. Serious infestations are most often associated with no-till wheat production.

### Identification / Life Cycle

The adult wheat stem sawfly is a wasp-like insect about  $\frac{3}{4}$  inch in length (Figure 7.37). 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 (10°C) and when conditions are calm. They are not strong fliers and usually only fly until they find wheat plants suitable for egg laying. Because of this, areas most impacted by the sawfly tend to be field margins closest to the adult emergence site. In western Nebraska, adults begin to emerge in May and can still be present in early June. The females begin to oviposit five days after they emerge. They will select the largest stems and insert a single egg just below the node. If populations are high, smaller stems will be selected and multiple eggs per stem will be laid. However, only one larva will survive in each stem.



**Figure 7.37**  
Wheat stem  
sawfly.



**Figure 7.38**  
Life cycle of the  
wheat stem sawfly.



Sawfly larvae feed within the stem after hatching and gradually move down the stem, feeding as they move for about 30 days. The larvae are cream colored,  $\frac{1}{2}$  to  $\frac{3}{4}$  inch in length, with a broad head. They will always be found within the stem and will assume an S-shaped posture when taken out of the stem. When mature, the larvae move to the area in the stem near the soil line and cut a V-shaped notch around the stem, weakening it at that point. The larvae then plug the stem at the notch and move down near the crown where it remains until it pupates the next spring (Figure 7.38). It produces a clear protective covering around it that protects it from excess moisture or moisture loss.

The presence of wheat stem sawfly can be verified by splitting the suspected stem from top to bottom and examining the interior. If the stem is packed with a sawdust-like material, it was infested with a wheat stem sawfly larva. The sawfly larva will likely be in the stem in a chamber just above the crown. Darkened areas on the stem just below the nodes is another clue of sawfly presence. These areas result 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, damaged stems lodge near the soil line. 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.

### Plant Damage / Response

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. In addition to losses from lodging, sawfly larvae cause physiological damage of 10 to 15 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. Other cereal crops (barley, oats, rye) 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.

## Management

### *Cultural Controls*

Tillage will reduce wheat stem sawfly larval survival through the winter and spring. The objective of summer and fall tillage is to bring the stubs containing the larvae to the surface, so they will be maximally exposed to the dry conditions in the late summer and the cold through the winter. Blading after harvest or before winter will accomplish this by lifting the crowns and loosening or removing the soil around them. This can result in about a 50 percent reduction in sawfly emergence the following year. In contrast, spring tillage should bury the stubble so that the adult sawflies will have a problem emerging from deeper soil levels.

The use of a trap crop (barley, oats, rye, or solid stem wheat) along the edge of winter wheat strips may be effective, especially when populations are low to moderate. These trap crops will be attractive to the sawflies for oviposition, but the larvae will not be able to complete development. However, if sawfly populations are heavy, trap crops may not be enough to satisfactorily reduce damage because significant numbers of sawfly adults will move past the trap crops to infest the wheat.

Another cultural practice that will reduce sawfly potential is the use of larger acreages in block plantings rather than planting in narrow strips. Strip planting maximizes the ability of the sawfly to move from the old stubble into the wheat crop. Reducing the amount of border in the fields reduces the potential for damage throughout the field. Soil erosion issues come into play when considering this option, but it may be feasible in a no-till cropping system.

### *Host Plant Resistance*

Solid stem varieties of spring wheat have been successful at reducing the amount of damage from the wheat stem sawfly. However, the effectiveness of this resistance is influenced by environmental conditions. No winter wheat varieties adapted to the central High Plains region have solid stems; however, Montana has developed two winter wheat varieties (Rampart and Vanguard) that are solid-stemmed. Yield data indicates these varieties are almost competitive in yield with commonly used adapted varieties.

### *Biological Control*

Several natural enemies of the wheat stem sawfly have been noted in the northern plains, but in most years none of these have been identified as a major factor in reducing the population. The presence and effectiveness of natural enemies in the central High Plains has not been determined.

### *Chemical Control*

Insecticide control has proven to be an ineffective option because of the extended period that the adults are present and control is needed. Effective control efforts would require close monitoring to determine the timing of sawfly presence and repeated applications for most of the period adults are active.

## Hessian Fly - *Mayetiola destructor* (Say)

The Hessian fly is often cited as an example of an introduced pest that rapidly spread and caused serious damage to cultivated crops in its new environment. Thought to have been introduced during the Revolutionary War the pest now occurs throughout much of the eastern two thirds of the United States and in some of the wheat producing areas of the west coast. It is considered a major pest of wheat and occasionally infests barley, rye, and triticale and may survive on wild grasses. The Hessian fly has the capacity to cause devastating injury to wheat during periods that are favorable for its development. In many areas the Hessian fly has been managed fairly effectively using host plant resistance and a variety of cultural controls, however recent changes in cropping practices appear to be allowing this pest to reemerge as a wheat pest in some areas of the High Plains.

### Identification/Life Cycle

The adult Hessian fly is a tiny insect about  $\frac{1}{8}$  inch long, dark colored, and resembles a gnat in appearance (*Figure 7.39*). On warm days during the fall, often following a rain, these tiny fragile flies emerge and females begin to seek the young leaves of fall-seeded wheat on which to lay their eggs. The period of adult activity is short, flies live for only a few days, and during this time, the females will deposit their eggs in the grooves on the upper surface of wheat leaves. Seedling wheat seems to be preferred.

The eggs, although very tiny, can be seen with the unaided eye and tend to resemble wheat leaf rust in its early stages (*Figure 7.40*). Within three to ten days the reddish, oblong eggs will hatch into tiny larvae or maggots. This is the stage that injures the plant. Eggs generally hatch in the evening and larvae migrate downward during the night when humidity is high. Larvae cannot survive in the exposed condition on the leaf surface during hot dry weather. The larvae move downward on the plant between the sheath and the stem and finally stop just above the crown at a site generally just below the soil surface. Larvae feed by withdrawing sap from the plant for a period of eight to 30 days. The rate of development is influenced primarily by temperature. Most complete their development before the onset of cold weather. Mature larvae are shiny, whitish, legless, and headless maggots about  $\frac{3}{16}$  inch in length (*Figure 7.41*). Full grown larvae gradually form  $\frac{1}{8}$  inch long, brownish, elongated, capsule-like cases (puparia) commonly called “flaxseeds” due to their resemblance to real flax seed (*Figure 7.42*). The insects pass the winter as flaxseeds.

Emergence of adults that produce the spring brood begins around the same time as wheat begins jointing in the spring. Females prefer young leaf blades for egg deposition. The point of attack by the spring maggots may be at the base of the plant, below the surface of the soil, or just above any of the nodes higher up on the stem. The generalized seasonal cycle includes the occurrence of a main spring brood, followed by flaxseed that lie dormant in the stubble until they emerge to produce the main fall brood.





**Figure 7.39**  
(top left)  
Adult Hessian fly.



**Figure 7.40**  
(bottom left)  
Hessian fly eggs  
can resemble  
early stages of  
leaf rust.



**Figure 7.41**  
(top right)  
Hessian fly lar-  
vae.



**Figure 7.42**  
(bottom right)  
Full grown Hes-  
sian fly larvae on  
flaxseeds.

It is important, however, to recognize that a portion of the population fail to emerge as adults at any one period. Some of the flaxseeds survive in a dormant stage for weeks, months, or in some cases even years. Hence, the exact source of a given infestation may be difficult to document. This also allows for additional broods to develop. The presence of volunteer wheat in or adjacent to infested fields allow for the development of a summer brood when weather conditions are favorable.

### Plant Damage and Response

Beginning signs of fall infestations may or may not be conspicuous. Infested shoots are stunted, but leaves of infested tillers become thicker and darker green than the un-infested tillers. Early infestations can easily be overlooked; however, infested tillers eventually begin to die. In severe infestations large patches or entire stands may be lost, especially if heavy infestation occurs shortly after emergence while the plants are in the seedling stage. If tillering has begun at the time of infestation, some tillers may be killed while others survive.

With spring infestations, the tissue of the stem near where the larva begins feeding appears to cease growth while the surrounding tissue continues to develop. This forms a niche just large enough for the maggot to develop in along the side of the stem. The injury may not be enough to kill the tiller, but the stem is usually weakened. This results in partially filled heads and stems that are prone to breakage just above the infested node. If infestation is severe, the stem may be killed outright. Low levels of infestation are not obvious and are frequently overlooked.



## Management

### *Cultural Controls*

- **Tillage.** The fly population passes the period following harvest as flaxseeds in the stubble. Undisturbed stubble will favor the survival of the insects. Research has shown that thorough incorporation of the stubble can greatly reduce Hessian fly emergence. However, recent trends have been toward reduced or no-till planting, allowing increased survival of Hessian fly populations.
- **Destruction of volunteer wheat.** Volunteer wheat that is allowed to grow for a period of two to three weeks, especially in wet summers, can enable the fly to produce an extra brood and thus increase the number of flies available to infest fall planted wheat. Volunteer wheat not only serves to increase the population, it may also render other practices, such as planting after the fly-free date, less effective, by producing flies that are active later in the fall. Volunteer wheat left to grow through the fall and into the spring can serve as host to the fall generation, and subsequently, initiate spring infestations.
- **Delaying Planting.** The risk of fall infestation is almost always greater when wheat is planted in early fall. In many areas of the county researchers established “fly-free” dates by conducting a series of planting date studies to determine planting dates that would reduce the chance of Hessian fly damage. The goal is to allow the main fall brood of adult Hessian flies to emerge and die before the new crop wheat emerges. Without live wheat plants available, the emerging female flies are deprived of a place to lay their eggs, and the wheat is therefore able to avoid fall infestation. There is still some risk if the main brood emerges later than normal or if for some reason a secondary fall brood develops. Therefore, delayed planting will reduce the infestation potential, but may not totally eliminate the risk of infestation. The fly-free date may be used locally on a field by field basis; however, they would probably be more effective where it is practiced on an areawide or community-wide basis.

### *Host Plant Resistance*

Planting resistant varieties is often considered to be one of the best ways to reduce potential damage from the Hessian fly. However, currently, the availability of resistant varieties is more limited than we would prefer. To date, several resistance genes have been identified and have been or are being used in various wheat cultivars. However, depending on the predominate biotype of Hessian fly in a location, many of these genes no longer ensure an effective level of resistance, because virulence to these genes may be abundant in the local insect population. Thus, monitoring biotypes and altering resistance genes in locally adapted wheat varieties is an ongoing struggle. Yet growers should consider this option carefully during times when fly populations appear to be on the increase. It deserves special consideration where growers plan to plant early for fall pasture, and where the usefulness of other management options is limited.

### **Biological Controls**

While there are several species of tiny wasps that parasitize the Hessian fly, their impact and importance is often overlooked and little is known about how to conserve or increase their effectiveness to help manage Hessian fly populations.

### **Monitoring and Thresholds**

Monitoring for Hessian fly should be done in both the fall and spring, especially if damage symptoms are noticed or if Hessian fly has been noted to be a problem in the area in previous years. In the fall or winter, search for Hessian fly larvae or pupae at the base of the plants if abnormal growth occurs (as mentioned above) or if dead plants or tillers are observed. Examination of an infested plant will usually reveal an undeveloped central shoot with an unusually broad and thickened dark green leaf. To confirm the diagnosis, carefully remove the plant along with the roots from the soil and look closely for maggots or flaxseeds by gently pulling the leaf sheath away from the stem and inspecting carefully in the crown area. In the spring, check for Hessian fly anytime white heads or lodging is noticed prior to harvest.

If 10 to 20 percent of tillers are infested with multiple larvae in the fall, then spring infestations are likely to be heavy if weather conditions are favorable. However, if spring weather is hot and dry then damage could be less. Noticeable spring damage from Hessian fly should trigger adoption of special efforts to reduce the potential for Hessian fly the next season (destruction of volunteer, selection of resistant varieties, and delayed planting), in a effort to reduce the build up of Hessian fly populations.

### **Chemical Controls**

There are no chemical controls available once plants become infested. However, some of the newer systemic seed treatments do provide some protection from fall infestations of Hessian fly and may be useful in fly-prone areas when planting susceptible varieties early in the season.

## **Wheat Stem Maggot – *Meromyza americana* (Fitch)**

The wheat stem maggot can be found throughout the region in host grasses and occasionally wheat. The damage from the maggot is very noticeable, and even low levels of infestation can appear dramatic. Severe damage is rare, and this insect remains only a minor pest of wheat in the region.

### **Identification / Life Cycle**

The wheat stem maggot overwinters within the lower portions of its host grass stems. The greenish maggot is  $\frac{1}{4}$  inch long. In the spring the maggot will pupate, and later, the adults will emerge. The adults will lay eggs on the leaves and stems of hosts that are in the late jointing to early heading stages. The small larvae will move to and bore into the upper stem, normally above the top node, where they will feed and develop. From spring to early fall, there are three generations of stem maggots. During each of these generations they utilize host grasses that are at the proper stage for development. Wheat, rye, and barley all serve as hosts, but wheat is preferred. Grass hosts include bluegrass, millet, timothy, foxtail, wheatgrasses, bluestem, and a few other grasses.

## Plant Response / Damage

Wheat stem maggot larvae tunnel into the upper portions of the wheat stem just above the upper node, resulting in the severing of stems at this point. Subsequently, the wheat head will die and turn white. The appearance of these damaged heads is dramatic, and infestations of only one to two percent will be very apparent. Damage from this insect in some years is much more apparent than in other years, but the reasons for this are not known. In most years, damage is limited to less than one to two percent infested stems. Damage is more likely to occur in field margins next to wild grasses where the insect will be present. Wheat stem maggot populations may increase in no-till situations because larvae survive better in the undisturbed stems; however, the fly population is probably limited by its survival in host grasses during the mid-summer generation when wheat is not present.

## Management

There are few options available for managing the wheat stem maggot. No-till production practices may increase damage potential, but rotations that include non-host (non-grass) crops will reduce the potential for the buildup of wheat stem maggot populations. Also, control of volunteer wheat eliminates this host for insect buildup. Where practical, planting after the Hessian fly 'fly-free' dates will also reduce damage potential by avoiding the fly activity period in the early fall. Insecticidal control is impractical because of the difficulty in determining the optimum timing for control.

## Black Grass Bug – *Labops hesperius* Uhler

The black grass bug, or 'Labops,' rarely causes serious problems in wheat; however, infestations can occur along field margins adjacent to wheatgrass pastures or borders. Infestations can also develop throughout fields grown in continuous wheat rotations using no-till practices.

## Identification / Life Cycle

There are several species of grass bugs found in the region, but the most common is the black grass bug. Labops is about ¼ inch long and black with buff colored edges on the wings and whitish markings on the head (*Figure 7.43*). The wings of the adult females are shorter than the abdomen, and those of the males extend beyond the end of the abdomen. Immature stages are similar in appearance to the adults but do not have wings.

**Figure 7.43**  
Black grass bug.



Black grass bug has a single generation each year with the active period confined to the spring. It overwinters as eggs in the stems of the host, hatch in the spring (April), and begin feeding on the host. Throughout a four to five week period, the insect develops through three immature stages before becoming an adult. When mature (May), the females mate and lay eggs in the stems of their grass hosts. Their preferred hosts include wheatgrasses, especially crested wheatgrass. The short wings of the females limit their mobility, so their infestations are most often limited to field margins.

### Plant Damage / Response

Black grass bug has piercing-sucking mouthparts, and feeding results in yellow to white spotting at the feeding site. As feeding damage increases, the leaves show extensive white speckling (*Figure 7.44a & b*). Extreme damage results in a nearly white or frosted appearance of the plants. The greatest impact of this insect in wheat occurs when the flag leaf is extensively damaged because the leaves do not replace the chlorophyll lost through feeding. Extensive damage will result in reduced seed yields and reduced forage quality.

### Management

#### *Establishing Risk*

Black grass bug problems in wheat seldom become serious. High risk situations include areas where wheat is planted next to wheatgrass pastures or ditches. In these areas black grass bugs will be restricted to the field margins. Because it survives the summer and winter as eggs in the stem, this insect can also build up throughout the field in no-till continuous wheat.

#### *Cultural Controls*

The infestation potential for the black grass bug can be substantially reduced by haying or grazing wheatgrass areas that serve as breeding sites. Eggs present in the grass stems are removed and the subsequent population is reduced.



**Figure 7.44a (left)**

White speckling occurs at black grass bugs' feeding sites.

**Figure 7.44b (right)**

Leaf damage due to black grass bug's feeding habits.



### **Chemical Controls**

Where wheat is planted next to wheatgrasses, black grass bug populations should be monitored to determine the potential for bugs to move into the adjoining wheat. Treatment of the margin of wheat fields can be done to control black grass bugs if infestations warrant. It is important to time the control of black grass bugs early enough to prevent extensive damage because wheat plants do not recover after they have been damaged. No thresholds have been developed for these situations, but monitoring black grass bug presence would be important where damage had been noticed the year before.

### **Say Stink Bug – *Chlorochroa sayi* (Stål)**

Say stink bug is a minor pest of wheat. They are seldom numerous enough during the susceptible stages of wheat to warrant control measures. However, they may be more numerous in wheat fields during the late heading stages when their impact is substantially reduced.

### **Identification / Life Cycle**

Adults are green, shield-shaped, and about ½ inch long (*Figure 7.45a & b*). They have yellow to orange spots on their back in the triangular area between their wings. Females lay small, barrel-shaped eggs in clusters or rows on plant stems or surfaces. The small nymphs are dark and more oval shaped. The larger nymphs are green and similar in shape to the adults. They will take about six weeks to go from egg to the adult stage. They feed actively in the morning and late afternoon. Say stink bug overwinters as adults within plant debris in fields and field borders. They undergo one to three generations per year, depending on the length of the growing season.

### **Plant Response / Damage**

Say stink bug feeds on weeds, especially Russian thistle, and other wild hosts in the spring before dispersing into cereal grain fields during heading and grain fill. Both adults and nymphs have piercing-sucking mouthparts, and their preferred food source is developing seeds. Say stink bugs are attracted to wheat starting in boot stage, and the bugs will continue to feed on maturing grains until they begin to harden (hard to soft dough). Feeding during the boot stage can destroy the entire head and result in

**Figure 7.45a  
(left) & b (right)**  
Say stink bug.



sterile, sun bleached heads. Feeding during the early heading stages can reduce both grain number and weight. Yield losses of 75 percent or more can result from feeding by one or more stink bugs per head between late boot and milk stage. Feeding during the later heading stages reduces only grain weight. Shriveled, deformed, and light grains are symptomatic of Say stink bug feeding. Damage potential falls rapidly after milk stage, and small reductions in test weight can occur from feeding during the dough stages.

## Management

Specific management for the Say stink bug is seldom necessary. Controlling weed hosts in and around wheat fields during the spring reduces the risk of problems because the overwintering adults will not be attracted to the area.

Use a sweep net and sample weeds and wheat in the field margins to determine populations. For wheat in the boot to milk stage, consider treatment if infestations exceed three to four adult stink bugs per 100 sweeps with a standard insect sweep net. Stink bugs are highly mobile, and they may readily move out of an area. Also, stink bugs present late in the season may be attracted to secondary tillers that contribute little to yield.

## Wireworms – Elateridae (Click beetles)

Several species of wireworms can be found Great Plains:

- *Agriotes mancus* Say – Wheat wireworm
- *Agriotes lineatus* L. – Lined click beetle
- *Alaus oculatus* L. – Eyed click beetle
- *Ctenicera glauca* Germar – Dryland wireworm
- *Ctenicera aeripennis destructor* Brown – Prairie grain wireworm
- *Ctenicera pruinina* Horn – Great Basin wireworm
- *Limonius infuscatus* Motschulsky – Western field wireworm

The biology of these species are not well known, but they vary in the length of life cycles, their attractiveness to crops and soil conditions, and their geographic distribution. Generally, wireworms are a sporadic pest because they do not feed extensively through the fall when wheat root mass is most limited.

## Identification / Life Cycle

Wireworms are long, slender, and yellowish in color, with wirelike hard-bodies. They have three pairs of legs behind the head, and the last abdominal segment is flattened (Figure 7.46). Full-grown larvae may reach a length of 0.4-1.5 inches (1 to 4 centimeters).

**Figure 7.46**  
Wireworm  
larva.



**Figure 7.47a**  
Adult wireworm  
(*Agriotes lineatus*  
L.).



**Figure 7.47b**  
Adult wireworm  
(*Alaus oculatus* L.).



Adult beetles emerge from the soil in the spring (*Figure 7.47a & b*). From late May through June, the female beetles lay 200 to 1400 eggs in loose or cracked soil and under lumps of soil. Females of many species are attracted to lay eggs around grasses. The young wireworms hatch and begin feeding on roots or germinating seeds.

The larval stage lasts anywhere from 1 to 5 years, depending on the species involved. When full grown, usually in July, the larvae pupate in the soil. The adults do not emerge until the following spring. Wireworms overwinter as larvae deep in the soil. When soil temperatures warm in the spring, the larvae move to the surface to feed. Due to their long life cycle, the larvae can damage several successive crops, feeding on the roots of weeds, grasses, and crop plants. Once soil temperatures become warm and soil moisture decreases, the larvae migrate downward and may be difficult to find later in the season. When it is time to become adults, the larvae migrate back to the surface and pupate, and the adult emerges to mate and lay eggs in grasslands or weedy areas.

## Plant Damage and Response

Wireworms feed on germinating seeds and roots of young seedlings, killing the seedlings and reducing stand. Wireworms are most active during the months of April through June and occur most often in fields that have little disturbance. Nonuniform growth or gaps in the stand may be due to wireworm feeding on germinating seeds. Wireworms are rarely a problem in fall planted wheat. They are generally more prevalent in sandier soils.

## Management

### *Establishing level of risk*

Wireworm infestations are difficult to detect prior to visible plant injury. They are most likely to be found following a long-term grass (native or pasture) or legume crop.



**Field Scouting**

Sieve soil samples to find wireworms present in the field. Samples should be taken to a depth of six inches from several areas of the field prior to planting. An alternative method is to place bait stations in the field to monitor wireworm activity a couple of weeks prior to planting. Dig a hole approximately six inches wide and two to three inches deep and bury a nylon mesh bag with one cup equal parts untreated and soaked corn and wheat or freshly cut potatoes. Mound the soil over the bait to prevent standing water. Return to the stations a few days before planting to sift through the bag contents and surrounding soil, and record the number of larvae found per station.

**Thresholds**

An action threshold of about three to four wireworms per square foot is often recommended. If wireworms are found at this density or higher, seed treatment is usually warranted.

**Chemical Control**

Neonicotinoid seed treatments will provide some control from wireworm damage. Seed treatments are primarily a protective measure and do not necessarily result in eliminating the wireworm problem from a field.

**Cultural Control**

In fields known to contain wireworm larvae, fallow during summer with frequent tillage will lessen their impact. Damage from wireworm infestations during the seedling stage can sometimes be reduced by replanting, if replanting occurs before existing plants begin to tiller. Rotation with non-host crops is also effective.

**False Wireworm – *Elodes* spp.**

False wireworms are beetle larvae that are similar in appearance to wireworms, but they belong to a different family of beetles. They are predominantly pests in semiarid regions.

**Identification / Life Cycle**

There are several species of false wireworms that can damage wheat seedlings. The beetles are generally dark colored, long legged beetles that cannot fly. Eggs are deposited in loose soil. Larvae are very similar to the true wireworms but have longer legs and antennae. Larvae pupate in the spring and adults emerge in early summer.

**Plant Damage and Response**

Plant damage is similar to that caused by wireworms. With wheat, they usually attack the seed before germination. In dry soils, one larva may follow the drill row and destroy several seeds by eating out the germ, causing bare patches in the field.

**Management*****Establishing level of risk***

Since the beetles cannot fly, populations tend to build up in areas of continuous wheat production.



### **Field Scouting**

Some indication of false wireworm activity can be obtained by monitoring fields during the summer. High numbers of false wireworm beetles in the summer would signal the potential of problems in the fall if weather remains hot and dry. In addition, soil samples can be sifted prior to planting.

### **Thresholds**

An average of one larva per three square feet suggests an infestation of economic importance.

### **Chemical Control**

In the past, lindane seed treatments offered protection from this pest, but more recently has been withdrawn from the market. Neonicotinoid seed treatments are not highly effective against false wireworm larvae.

### **Cultural Control**

Piles of decomposing straw and vegetation provide attractive shelter for adults and should be avoided when possible. In addition, crop rotation may also be an important method to reduce damage.

## **White Grubs – *Cyclocephala* spp., *Phyllophaga* spp.**

White grubs are very sporadic in occurrence and seldom cause serious damage to winter wheat in the Great Plains. White grubs may be cause for concern in the same rotations where wireworms are found. Larval infestations are greatly influenced by crop rotation and soil type or texture. Infestations by *Phyllophaga* spp. are reported to be more common in light, sandy soils that are well drained.

**Figure 7.48**  
White grub.



### **Identification / Life Cycle**

It is likely that several species of *Cyclocephala* (annual life cycle) or *Phyllophaga* (three-year life cycle) can be found in wheat fields in the Great Plains. White grubs are the immature stage of scarab beetles (*Cyclocephala*—chafer beetles; *Phyllophaga*—May or June beetles). White grubs are recognized by their white body color, brown head capsule, and C-shaped body (Figure 7.48).

Annual white grubs complete their life cycle in a single year. Beetles lay eggs in late June and early July. After hatching in July the larvae feed on roots and decaying organic matter in the soil. The larvae normally mature by early fall and feeding ceases. They overwinter as larvae, pupate, and emerge as adults the following spring.

A common species in the Great Plains, *Phyllophaga implicita*, normally takes three years to complete its life cycle. During the spring of the first year, beetles emerge and at night fly to trees to feed. After mating, females return to the fields from which they emerged and deposit eggs in the soil during the day. The highest density of eggs will be found in the soil near the adult food source, such as shelterbelts (densities decline with increasing distance from the trees). First instar larvae begin feeding on organic matter after hatching, later feeding on plant roots. Most larvae reach the second instar stage before soil temperatures begin to decline in the fall. At this time, larvae dig deep into the soil where they spend the winter below the frost line.

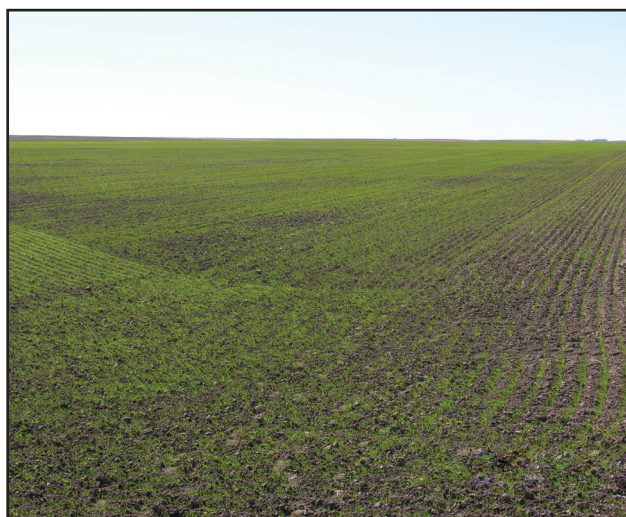
In the spring of the second year, larvae move upward as soil temperatures increase. Second year larvae cause the greatest level of feeding injury. Larvae molt to the third instar by July and continue feeding into the fall when they burrow deeper into the soil to overwinter.

In the third year, larvae feed on seedling roots but seldom cause significant losses. By early August, pupae and adults can be found at depths of 6 to 18 inches in the soil. Adults emerge the following spring.

During soil sampling in the late summer and fall, all larval instars, pupae, and adults can be found. However, one brood usually dominates, representing the greatest proportion of the population all three years. If so, significant feeding injury is expected only in one year out of three. The year of greatest injury should correspond with the second year of the life cycle, when second instars are the most numerous in the spring.

### Plant Damage / Response

Larvae of white grubs feed on roots, severing plants at or above the crown (Figure 7.49a & b). Plants are most vulnerable to this feeding when they are seedlings and have limited root mass. Associated damage may result from vertebrate predators aggressively digging up grubs and destroying plant stands. Damage is most often limited to spotty areas where populations are high or where soil conditions were optimum for egg laying and larval development.



**Figure 7.49a  
(left)**

Wheat tillers damaged by white grub feeding habits.

**Figure 7.49b  
(right)**

White grub damage to wheat field.

## **Management**

### ***Establishing level of risk***

An assessment of specific fields is usually necessary to determine risk levels for white grub damage. White grubs stop feeding in the fall and move deeper in the soil. Early planting increases risk because plants will be growing longer during the white grub feeding period.

### ***Field Scouting***

Larvae are present in the upper six inches of soil and begin moving down in the soil in the fall. In the spring, larvae return to the upper soil layers, but the damage potential for wheat in the spring is low because wheat plants have extensive root systems at this time and root feeding can be tolerated. Sampling during late summer and early fall is recommended.

### ***Thresholds***

Some areas use a threshold of four to five grubs per square foot, but thresholds can vary by region. These differences may result from different species of insects being found in different regions.

### ***Chemical Control***

Serious infestations of white grubs are difficult to control, but neonicotinoid seed treatments may suppress populations.

## **Resources**

For details on a time saving scouting procedure, see *Sampling Russian Wheat Aphid on the Western High Plains* (Colorado State University Cooperative Extension/ Great Plains Agricultural Council Bulletin GPAC 138, available through the Morgan Library).

Information on the Greenbug Management Decision Support System, Glance-n-Go can be found at: [<http://entoplp.okstate.edu/gbweb/>].

Recommendations and guidelines for chemical control change quickly. There are often federal, state, and local restrictions that make broad statements regarding pesticide usage of little value. The use of specific insecticides or rates is at times restricted to certain areas or times of the year. It is strongly suggested to check with state and local information guides and the pesticides label when chemical control is being considered. Listed below are selected websites, electronic documents, and books on wheat pest management.

### **High Plains Integrated Pest Management Guide:**

[[www.highplainsipm.org](http://www.highplainsipm.org)]

### **The Colorado Environmental and Pesticide Education Program (CEPEP):**

[<http://www.cepep.colostate.edu/>]

**Kansas State University Directory of Wheat Pests:**

[<http://www.entomology.k-state.edu/DesktopDefault.aspx?tabid=405>]

**Oklahoma State University Information of Insects/Arthropods and Plant Diseases:**

[<http://www.entopl.okstate.edu/ddd/>]

**University of Nebraska—Lincoln, Crop Watch:**

[<http://cropwatch.unl.edu/web/wheat/insects>]

**NebGuide - Cereal Aphids:**

[<http://www.ianrpubs.unl.edu/epublic/pages/publicationD.jsp?publicationId=341>]

**North Dakota—Entomology Updates:**

[<http://www.ag.ndsu.nodak.edu/aginfo/entomology/>]

**NDSU Cereal Grain Insects:**

[[http://www.ag.ndsu.nodak.edu/aginfo/entomology/entupdates/ICG\\_07/05\\_CerealGrainInsects07.pdf](http://www.ag.ndsu.nodak.edu/aginfo/entomology/entupdates/ICG_07/05_CerealGrainInsects07.pdf)]

**North Central IPM Center—South Dakota:**

[<http://www.ncipmc.org/state.cfm?state=SD>]

**“Pest Management Strategic Plan for Northern Wheat”:**

[<http://www.ipmcenters.org/pmsp/pdf/NorthernWheatPMSP.pdf>]

**Texas AgriLife Extension Service:**

[[http://insects.tamu.edu/extension/publications/results\\_all.cfm](http://insects.tamu.edu/extension/publications/results_all.cfm)]

**University of Wyoming—Cooperative Extension Service:**

[<http://ces.uwyo.edu/Entomology.asp>]

**Colorado State University Extension Program:**

[[http://www.ext.colostate.edu/menu\\_insect.html](http://www.ext.colostate.edu/menu_insect.html)]

**National Pesticide Information Center:**

[<http://npic.orst.edu/index.html>]

**“Wheat Diseases and Pests: a guide for field identification”:**

[<http://wheat.pw.usda.gov/ggpages/wheatpests.html>]

Buntin et al. 2007. *Handbook of Small Grain Insects*. ESA.

Bockus. 2010. *Compendium of Wheat Diseases and Pests*. APS Press.





# Managing Weeds in Winter Wheat

By Drew Lyon & Case Medlin

Weeds compete with winter wheat for water, light, space, and nutrients. Weed competition reduces wheat yields and profitability, and also slows harvest and increases combine repair costs. Growers may be docked at the elevator for having excessive moisture or weed seeds in their grain. Weeds also may serve as hosts for insects or diseases that can harm winter wheat plants and reduce yields. An effective weed control program considers all aspects of the cropping system, including tillage program, rotational crops, rotation of herbicides used, soil fertility, disease and insect management programs, and the complex of weeds targeted.

**Integrated Weed Management** uses a combination of different practices to manage weeds. By reducing the reliance on one or two specific weed control techniques (for example, relying solely on the use of herbicides), weeds are less likely to adapt to these methods. The objective of integrated weed management is to maintain weed densities at manageable levels while preventing weed shifts to more difficult-to-control species. This objective is met by preventing weed problems before they start, helping the crop gain the competitive advantage over weeds, and making it difficult for weeds to adapt to a cropping system. All of these factors contribute to a healthy, competitive crop.

## Preventive Weed Control

The best way to control weeds is to keep them out of fields in the first place. Prevention, or stopping the advancement of weed infestations, is an important part of an integrated weed management program. It requires time and diligence from the grower, but offers an effective, low cost control.

## Quality Seed

Planting crop seeds contaminated with weed seeds has been the most common method of spreading weeds for centuries. Drill box surveys in Kansas, Nebraska, and Oklahoma have shown that many growers are planting unacceptable levels of weed seeds with their crop. Using trashy wheat seed will not only increase the weediness of a field, but it also reduces the seeding rate, resulting in a lower wheat population and a less competitive crop. At the very least, farmers should have their seed cleaned at certified seed conditioners. To ensure you are planting high quality, weed-free seed, purchase certified seed. The benefits, which include increased forage and grain yields, far outweigh the cost.

## Other Preventive Control Methods

Clean tractors, implements, trucks, and combines before moving them from weed-infested fields to clean fields. This should include inspecting equipment of hired contractual operators before they enter your fields, especially harvesting equipment that may introduce weed seed from other counties or states.

Keep uncropped areas (fence lines and field borders) weed-free by establishing a good stand of a perennial grass or spraying annually with herbicides. A typical 20-foot long fence surrounding a section of wheat amounts to less than 10 acres. Compare the cost of preventing weed establishment on the 10-acre border (with relatively low-cost options) versus the long-term control of weeds on 630 acres of cropland (with typically more expensive measures).

Do not allow livestock to move directly from infested to clean areas. It can take 7 to 10 days for ingested weed seeds to pass through most livestock.

Prevent weed seed production in all areas. To control annual and biennial weeds, you must control their seed production, while to control perennial weeds you must control both seed production and vegetative reproduction structures.

## Cultural Weed Control

Cultural weed control involves manipulating the crop-weed environment so that conditions are more favorable for crop plants than weeds. Crop rotation and crop competitiveness are important cultural control practices in winter wheat production.

### Crop Rotation

Crop rotation is an important component of integrated weed management. The use of diverse crops with different life cycles, seeding dates, herbicide options, and competitive abilities will prevent weeds from adapting and thriving in fields and will help prevent weed shifts as well.

Since growing conditions vary across regions, crop rotations also vary across regions (refer to Chapter 4—“Diversified Cropping”). Common crop rotation sequences used when growing winter wheat in the northern Great Plains include winter wheat-fallow, winter wheat-corn-fallow, winter wheat-grain sorghum-fallow, winter wheat-corn-soybean, and continuous winter wheat. Proso millet and sunflower also are used commonly in rotations with winter wheat. On the other hand, the most common crop rotation in the southern Great Plains is continuous winter wheat, although rotations of wheat with canola, corn, sorghum, and soybean do occur. Continuous winter wheat (monoculture) is problematic for weed control because too often the same class of herbicide is continually used, often resulting in weed resistance and/or species shifts.

Weeds with the same life cycle as the crop tend to increase under monoculture. Winter annual weeds, particularly the grasses, tend to be the most common weeds in winter wheat. Downy brome, hairy chess, cheat, jointed goatgrass, feral rye, Italian ryegrass, and volunteer wheat are most troublesome when winter wheat is grown continuously or every other year on the same land. Winter annual broadleaf weeds also increase but can be readily controlled in the growing winter wheat with herbicides.

Inserting a warm-season crop such as corn, grain sorghum, proso millet, soybean, or sunflower into a winter wheat-fallow rotation can break the life cycle of these economically important winter annual weeds. Any regionally adapted, warm season crop will suffice and serve as an important weed management tactic. Inserting a cool season spring crop such as spring wheat or oat is not as effective as a warm season crop at disrupting the life cycle of winter annual weeds. These weeds can emerge as late as mid-April, after the cool season crops are established and still have enough time to produce seed. A rotation of winter wheat-corn-fallow is excellent for the management of winter annual weeds in winter wheat and for improving wheat yield.

A reduction in the duration of the pre-wheat fallow period (for example, by planting winter wheat immediately after a summer annual crop like corn for silage or soybean), often results in wheat stands of reduced vigor due to limited soil water or late planting. This winter wheat is less competitive, resulting in increased weed growth (Table 8.1). However, this is less of a problem in the southern Great Plains where planting dates are more flexible.

**Table 8.1**

Effect of crop rotations on winter wheat yield and weed density following winter wheat harvest in 174 Nebraska fields.<sup>1</sup>

Rotation	Weed Density				
	Fallow Duration (months)	Wheat yield (bu/ac)	Green foxtail (no./yd. <sup>2</sup> )	Longspine sandbur (no./yd. <sup>2</sup> )	Kochia (no./yd. <sup>2</sup> )
Wheat-fallow	14	62	0.2	1.7	<0.1
Wheat-corn-fallow	11	63	1.1	0.8	<0.1
Continuous wheat	2	48	2.3	<0.1	<0.1
Wheat-corn-spring sm. grain	1	40	6.7*	1.7	0.3
Wheat-corn-soybean	0	47	1.5	<0.1	0.4
Wheat-corn or sorghum	0	39	0.9	3.8	2.4*

<sup>1</sup>Adapted from Wicks et al., Weed Technology 17:467-474.

\*Indicates value is significantly different from the value for wheat-fallow at the 5% level.



Continuous winter wheat has been the dominate crop rotation in the southern Great Plains since the 1930s. Much of this is dual purpose wheat grown for both grazing and grain production (see also Chapter 6—“Dual Purpose Wheat”). However, continuous, dual purpose wheat rotation has led to major winter annual weed infestations. In the southern Great Plains (Oklahoma and northern Texas), successful summer crop production is difficult due to high temperatures and limited rainfall. A winter broadleaf crop, such as winter canola, would be a better fit for rotation with winter wheat. This crop would allow application of several different herbicide modes of action that are not typically used in wheat. Other benefits may include the breaking of disease cycles that normally plague continuous winter wheat and improving certain soil characteristics with the deep tap-rooted crop.

An important reason for rotating winter annual and summer annual crops is to deplete the soil weed seed bank. With two or more years between winter wheat crops, soil weed seed banks decline to levels of low competition and may be more easily managed. However, for this to occur weeds must be managed during the fallow season.

### **Fallow Weed Management**

Weed management during fallow is critical to preserve soil water, eliminate weed seed production, and disrupt insect and disease pests. Herbicides and tillage may be used to achieve weed control during the fallow period. Herbicides maintain greater residue cover than tillage, which helps to reduce soil erosion and increase soil water storage (see also Chapter 5—“Wheat Fertility Management”). If tillage is used, it should preserve as much residue on the soil surface as possible.

Volunteer wheat is host to the wheat curl mite (which is the vector of a complex of three wheat diseases), the Russian wheat aphid, and several other pest problems. Volunteer wheat should be controlled throughout the fallow period and must be completely eliminated at least a 10-day period between wheat harvest and wheat seeding. This is known as “breaking the green bridge,” which prevents the carryover of these insects from one wheat crop to the next by depriving the insects of a key host. Controlling these insects and disease pests will improve wheat health, which results in a more vigorous wheat stand.

High temperatures during July and August often stress volunteer wheat and weeds, and reduce the efficacy of herbicides. Additionally, broadleaf weeds that have had their tops cut off by the combine are difficult to control with herbicides. Although tillage can work well at this time of year, it must commence shortly after harvest, or soils may become too hard for tillage equipment to be effective. The number of tillage operations needed depends on precipitation, weed species present, slope, susceptibility to erosion, and the amount of crop residue the drill can handle. Sweep tillage maintains crop residues on the soil surface and can provide very effective weed control when soils are dry and air temperatures are warm enough to cause rapid desiccation of weeds. More aggressive tillage (for example a tandem disk), may be needed when soils are moist. Herbicides are typically a better option for weed control than tillage when soils are moist.

### Seedbeds

A firm seedbed enhances wheat seed germination and seedling growth. Residues should be maintained on the soil at seeding to help prevent wind and water from silting under the winter wheat seedlings or burying the seeds too deep. If tillage was used during the previous fallow periods, a rodweeder should be used to control weeds and create a firm seedbed during the final two to four weeks before seeding. In areas where winter annual weeds are a problem, rainfall prior to wheat seeding can cause weed seeds to germinate. Following rain, rodweeding and wheat seeding should be delayed at least one week to aid in controlling winter annual weeds. This delay, followed by a burndown herbicide prior to planting, effectively controls the winter annual weeds and leads to lower infestation levels during the cropping season. Research indicates a 69 percent yield savings by using this technique for downy brome control prior to seeding winter wheat. Downy brome is more of a problem in early planted fields than in later planted fields. However, it is important not to delay wheat seeding much beyond the optimum planting date or yields will be reduced.

### Variety Selection

Select adapted competitive winter wheat varieties. Research and field surveys have shown a large difference in weed suppression characteristics of winter wheat varieties (Table 8.2). Tall varieties competed with weeds better than short varieties in two out of three years. Other factors that may improve wheat's competitiveness with weeds include rapid early fall growth, good tillering, winter hardiness, and extensive leaf display. The same weed suppression characteristics have been observed in wheat varieties commonly grown in Oklahoma in studies conducted with feral rye (Table 8.3).

**Table 8.2**

Effect of winter wheat varieties on summer annual weed density at North Platte, Nebraska.<sup>1</sup>

Variety Stature	Plants (per yd. <sup>2</sup> )		
	1983	1984	1985
Medium tall	33	48	8
Medium	37	46	10
Medium short	365	93	12
Short	403	102	4
LSD <sub>0.05</sub>	133	38	NS <sup>2</sup>

<sup>1</sup>Adapted from Wicks et al., Weed Science 42:27-34.

<sup>2</sup>Not shown

**Table 8.3**

Effect of wheat cultivar on percent wheat yield loss due to feral rye infestations in four experiments during the 1997-1998 and 1998-1999 wheat growing seasons in Chickasha, Perkins, and Orlando, Oklahoma.<sup>1</sup>

Variety	Wheat yield loss (%) due to feral rye			
	1998		1999	
	Chickasha	Perkins	Orlando	Perkins
2163	47	57	58	78
2180*	45	58	—	—
Agseco 7853	40	56	53	73
Jagger	28	45	42	50
Karl 92*	40	55	—	—
Longhorn	36	49	52	81
TAM107	48	59	49	54
TAM202	52	33	53	78
Triumph 64	38	49	33	68
LSD <sub>0.05</sub>	11	9	14	8

<sup>1</sup>Adapted from Roberts et al., Weed Technology 15:19-25.

\*Cultivars 2180 and Karl 92 were not included in the 1998-1999 experiments.

**Table 8.4**

Effect of winter wheat planting date on density of summer annual grasses in wheat and the following grain sorghum crop at North Platte, Nebraska.<sup>1</sup>

Planting date	Wheat yield (bu/ac)	Summer annual grasses (per yd <sup>2</sup> )	
		In wheat	In sorghum
September 1	18	12	225
September 15	37	6	117
September 25	39	7	83
LSD <sub>0.05</sub>	5	4	100

<sup>1</sup>Adapted from Wicks et al., Weed Science 43:434-444. and yield may be reduced.

**Table 8.5**

The effects of wheat seeding rate, row spacing, and seeding date on the density and biomass of cheatgrass in April at Lahoma, Oklahoma.<sup>1</sup>

Wheat seed- ing rate (kg/ha)	Row width (in)	Month seeded			
		Cheatgrass plants (per yd. <sup>2</sup> )		Cheatgrass biomass (kg/ha)	
		September	October	September	October
67	3.0	492	233	1230	930
	6.0	308	67	970	520
	9.0	475	125	1280	740
101	3.0	300	117	730	380
	6.0	433	142	1040	550
	9.0	250	125	540	470
134	3.0	183	58	1080	170
	6.0	308	67	670	280
	9.0	117	83	390	280
LSD <sub>0.05</sub>		158		440	

<sup>1</sup>Adapted from Koscelny et al. 1991, Weed Technology 5:707-712.

### Seeding Period

Seed at the optimum time to ensure the most advantageous growing conditions for wheat and a healthier wheat stand. For example, at North Platte, Nebraska, the optimum seeding period is September 15 to 25. In the southern Great Plains the optimum planting date typically ranges from September 15 to October 30 when the intended use of the crop is wheat grain production; however, seeding generally occurs two to four weeks earlier when it will be used as a forage crop for grazing cattle.

Planting wheat earlier than the optimum seeding date may result in lower winter wheat yield because it is more vulnerable to crown and root rot infection. Additionally, weeds are more prevalent in wheat that is seeded before the optimum date. Even the following summer crop, for example grain sorghum, was found to have more weeds when it was planted into early seeded winter wheat residues rather than winter wheat seeded near the optimum date (*Table 8.4*). Similarly, winter wheat seeded too late may not tiller enough to suppress weeds in the spring, and yield may be reduced.

If one cannot seed at the optimum seeding time, the competitive edge can still be achieved by altering other factors such as seeding rate and row spacing (*Table 8.5*). By increasing seeding rate and decreasing row spacing, wheat competitiveness can be improved even when seeding date is less than optimum.



**Table 8.6**

Optimal wheat seeding rate (pounds per acre) derived for alternative wheat seed and grain prices for three levels of cheat infestations.<sup>1</sup>

Seed Price (\$/lb)	Cheatgrass seed (lb/ac)	Wheat price (\$/bu)			
		2.50	3.00	3.50	4.00
0.075	0	86	89	90	92
0.100	0	81	85	87	89
0.125	0	77	81	84	86
0.150	0	72	87	80	83
0.075	60	107	110	111	113
0.100	60	102	106	108	110
0.125	60	97	101	104	107
0.150	60	97	97	101	103
0.075	120	128	130	132	133
0.100	120	123	126	129	130
0.125	120	118	122	125	127
0.150	120	113	118	122	124

<sup>1</sup>Adapted from Epplin et al. 1996, J. Prod. Agric. 9:265-270.

**Table 8.7**

Effect of row direction on weed density when an 11 to 14-month fallow period precedes winter wheat.<sup>1,2</sup>

Row direction	Stinkgrass plants (per yd. <sup>2</sup> )	Tumble pigweed plants (per yd. <sup>2</sup> )
North-South	0.70 <sup>b</sup>	0.25 <sup>b</sup>
East-West	3.75 <sup>a</sup>	1.40 <sup>a</sup>

<sup>1</sup>Adapted from Wicks et al., Weed Technology 17:467-474.

<sup>2</sup>Numbers in columns followed by the same letter are not significantly different at the 5% level.

## Seeding Rate

Adjust seeding rates to improve weed control. In the northern Great Plains, winter wheat is seeded at 45 to 120 pounds per acre depending on location and planting date. The 45 lb/ac rate is more common in the west while 60 to 75 lb/ac is more common in the east. When winter wheat is planted at the optimum time, the appropriate seeding rate is 18 seeds per foot of row. This is about 60 lb/ac with average seed size. Planting fewer seeds may result in increased weed growth. Generally, seeding rates need to be increased when seeding is delayed beyond the optimum dates to compensate for reduced tillering. Higher seeding rates are used when winter wheat is planted late, such as after soybean harvest, or when wheat is irrigated. Seed treatments should be considered to control seedling diseases.

In the southern Great Plains, winter wheat seeding rates range from 30 to 150 lb/ac depending on location, planting date, availability of irrigation, and whether or not the crop will be used for forage production. A 60 lb/ac seeding rate is common for dryland, grain-only wheat, while 90 lb/ac is a minimum for wheat that is intended for grazing or where irrigation will be used. Under intense grazing pressure, seeding rates of 120 to 150 lb/ac are still economically viable and will improve weed control by helping the crop canopy fill back in after grazing.

Seeding rates should also be optimized based on seed costs, expected weed infestations, and the potential selling price of the harvested grain (*Table 8.6*). These effects are possible due to the improved weed suppression, crop yield, and reduced weed seed production brought about by increased seeding rate.

## Row Spacing

Row spacing affects competition with weeds. Winter wheat is planted in row widths from 6 to 14 inches. Generally, row spacings are wider in the west, where soil moisture is more limited. Wide rows are advantageous when soil moisture is limited because hoe openers can move dry soil to the inter-row without excessive seed coverage. The wheat seeds then are placed into firm moist soil, thereby improving wheat germination, seedling vigor, and crop competitiveness with weeds.

When moisture is not a limiting factor, however, narrow rows and increased crop density help with weed control by shading the ground and suppressing further weed germination and development. Narrow row spacing can improve weed control during the fallow periods because weeds are smaller and more easily controlled with herbicides than they are in wide row spacings.

## Row Direction

Row direction may influence weed densities. In fields where rows run in a north-south direction, weed control following wheat harvest is better than where rows run in an east-west direction (*Table 8.7*). It is hypothesized that the north-south rows shade the ground better than east-west rows and reduce weed emergence. In fields where soil erosion is not a concern, north-south rows also are preferred.

**Table 8.8**

Effect of fertilizer application timing on wheat yield, tiller density, and weed density in three regions of Nebraska.<sup>1,2</sup>

Fertilizer application	Wheat yield (bu/ac)	Tillers (per yd. <sup>2</sup> )	Weeds (per yd. <sup>2</sup> )
Western Region			
Fall	60a	542a	3.5b
Spring	59a	550a	6.3a
South-central Region			
Fall	62a	508a	0.4b
Spring	51b	342b	3.7a
Southeastern Region			
Fall	59a	525a	6.8a
Spring	43b	392b	13.3a

<sup>1</sup>Adapted from Wicks et al., Weed Technology 17:467-474.

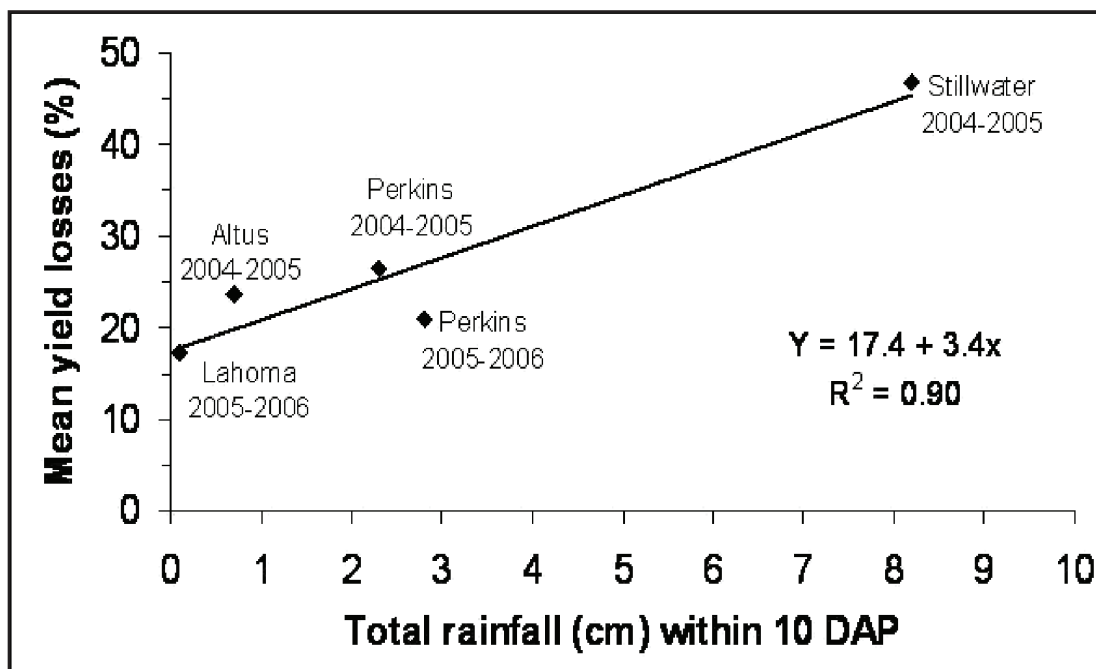
<sup>2</sup>Within a region, numbers in columns followed by the same letter are statistically similar ( $\alpha = 0.05$ ).

**Table 8.9**

Influence of phosphorus on winter wheat yield, stem density, and weed density when banded in a farmer's field at winter wheat seeding time in west central Nebraska.<sup>1</sup>

Crop and Weed Effects	Phosphorus Application	
	No	Yes
Winter wheat yield (bu/ac)	48	58
Winter wheat stems (per yd. <sup>2</sup> )	500	608
Witchgrass (per yd. <sup>2</sup> )	1.7	0.0
Stinkgrass (per yd. <sup>2</sup> )	3.6	.25
Pigweed (per yd. <sup>2</sup> )	2.3	0.0
Russian thistle (per yd. <sup>2</sup> )	.25	.25
Common purslane (per yd. <sup>2</sup> )	0.8	0.0
Total weeds (per yd. <sup>2</sup> )	8.6	0.5

<sup>1</sup>Adapted from Wicks et al., Weed Technology 3:244-254.

**Figure 8.1**

Wheat grain yield loss due to weed competition as a function of rainfall received during the first 10 days after planting across Oklahoma (data pooled over five winter annual grasses seeded at five densities).

### Seeding Depth

Seeding at an optimum soil depth can result in earlier germination, better stand establishment, and, thus, a more competitive crop. Establishment conditions within the first two weeks after planting are very important for weed management throughout the growing season. Ideally, the crop will emerge and establish itself before weeds emerge. Depth of planting should vary based on soil texture, soil moisture at the time of planting, and anticipated rainfall soon after planting (*Figure 8.1*). Clean-tilled, fine-textured soils tend to crust under warm conditions following rainfall. Under these conditions, using a higher seeding rate may help the wheat seedlings push through the crust.

Ideal wheat planting depths range from ½ inch to 2 inches, but a general rule of thumb is 1 to 1.5 inches in medium to fine textured soils and 2 inches in coarse textured soils. If one must seed deeper to reach soil moisture, a long coleoptile wheat variety must be used. Never cover wheat seed with more than 3 inches of soil. If the top 2 to 4 inches of soil is dry at planting, a hoe drill is preferred over a disk drill to place the winter wheat seeds into firm moist soil. The openers must have proper tension to ensure the wheat is planted deep enough, especially in the tractor wheel tracks. Weed density is often greater in wheel tracks because the wheat does not emerge well due to improper seeding depth.

### Fertilization

Fertilize to increase crop competitiveness with weeds. A good fertilizer program based on soil tests and appropriate application timing will increase the vigor and competitiveness of the winter wheat crop. In general, weed control is better when nitrogen is applied in the fall rather than in the spring (*Table 8.8*). Fall fertilization improves the competitiveness of winter wheat and reduces summer annual weed growth. However, nitrogen applied in the fall is more susceptible to leaching than spring-applied nitrogen, especially in areas of higher rainfall and courser soils.



Spring-applied nitrogen requires adequate and timely rain to be moved into the root zone. If rainfall is not adequate and timely, late germinating weeds can take advantage of the nitrogen. Weeds may be larger after harvest and more difficult to control where nitrogen was applied late in the spring. The excess weed growth is due to incomplete utilization of nitrogen by the wheat as a result of late application. Spring applications of nitrogen are best applied as early in the spring as possible. Do not wait to apply nitrogen until the optimum time for herbicide application, or some of the potential yield benefits may be lost. When nitrogen is to be applied in spring, apply phosphorus in a band at planting to stimulate crop growth.

Fertilizer placement is very important with phosphorus. Phosphorus applied as a band when wheat is seeded can increase early season forage production which increases the wheat's competition with weeds, increase wheat yield, and reduce weed density after wheat harvest (*Table 8.9*). Row-applied phosphorus is very beneficial to wheat seeded after the optimum planting date, even for soils containing high levels of phosphorus. ***Never put ammonium thiosulfate (12-0-0-26) with the seed.***

### **Pest Management**

Managing insect and disease pests throughout the growing season improves the vigor of the wheat stand. This results in a more competitive wheat stand that is more likely to compete with weeds (reference Chapter 7—"Arthropod Pests of Wheat" and Chapter 9—"Disease Management of Wheat").

### **Chemical Weed Control**

Herbicides have provided excellent control of broadleaf weeds in winter wheat for many years. In more recent years, herbicides have been developed to selectively control winter annual grasses in winter wheat. In order to get the best weed control with the least crop injury, be sure to:

1. Correctly identify the problem weed(s).
2. Apply herbicides when weeds are small and actively growing.
3. Use proper spray equipment that is in good condition and not contaminated with previously used herbicides.
4. Calibrate the sprayer to ensure application accuracy.
5. Read and follow directions on the herbicide label.
6. Know your rotational plans to avoid herbicide carryover problems to sensitive crops. Be aware that crop disasters such as winter injury, hail, or disease occur, and previously applied herbicides may limit the choices for recropping.
7. Check current local weed management recommendations for options in addition to those mentioned, because new herbicides are continually entering the market.

## Winter Annual Grass Weeds

Only in the last few years has it been possible to selectively control winter annual grass weeds in winter wheat. Control of these weeds is best when herbicides are applied in the fall, shortly after emergence, when plants are growing rapidly but before they become well tillered. Winter wheat fields that look like a lawn probably have winter annual grassy weeds filling in between the rows of wheat.

### *Downy Brome*

Maverick®, Olympus®, and Olympus®Flex herbicides provide selective control of downy brome and other *Bromus* species in winter wheat. Maverick and Olympus provide very similar control of downy brome when applied in the fall. Downy brome control with both of these products when applied in the fall has ranged from about 70 to 95 percent control in University of Nebraska trials. Spring applications have been less consistent, ranging from 35 to 85 percent control. Plant growth rate and stage of development at the time of application, and weather conditions following application, influence the level of control.

All three products have important rotation restrictions. Olympus Flex has a little less soil residual than Olympus, which allows a few rotational crops, such as soybean, to be planted a little sooner than is the case with Olympus. However, the differences are small and may be of little practical significance in non-soybean production regions.

### *Clearfield Wheat*

Growers who have seeded a Clearfield® wheat variety can use Beyond® or ClearMax™ herbicide to selectively control downy brome, jointed goatgrass, feral rye, cheat, wild oat, and minor populations of Italian ryegrass. Of these weeds, feral rye control has proven to be the most difficult and least consistent. The best control of feral rye has been achieved by applying five ounces per acre of Beyond in the early fall before rye plants have formed a tiller. It is recommended that UAN and surfactant be added to the spray mixture for improved control. Fall control of feral rye with Beyond has ranged from 70 to 90 percent, while spring applications of Beyond have been very inconsistent and are not advised in most situations.

Unlike feral rye, the control of jointed goatgrass with Beyond has been very effective and consistent. Fall and spring applications of Beyond at 4 ounces per acre have generally ranged from 85 to 100 percent control. Surfactant and UAN should be added to the spray mixture. Herbicide resistance is a concern with jointed goatgrass, so growers should be careful not to overuse this technology or it may soon lose its usefulness. We do not recommend that growers use Beyond herbicide more than twice in six years. Although downy brome control with Beyond is usually good, downy brome can be controlled more economically with the previously discussed herbicides.

## Winter Annual Broadleaf Weeds

Common broadleaf winter annual weeds in winter wheat include blue mustard, tansy mustard, tumble mustard, field pennycress, and shepherd's-purse. Unfortunately, many growers are unaware of these weeds in their fields until they start to bloom in the spring. By this time, control is difficult and most crop damage has already occurred. The sulfonyleurea herbicides Ally<sup>®</sup>XP, Amber<sup>™</sup>, Finesse<sup>™</sup>, or Peak<sup>™</sup> can be applied alone, without 2,4-D, in the fall to control winter annual broadleaf weeds. Herbicide applications made in late winter or early spring must be applied before weeds begin to bolt, or stems elongate, for effective control.

Blue mustard is perhaps the most difficult of the winter annual broadleaf weeds to control because it bolts very early. If timed correctly, 2,4-D (8 oz/ac of LV4 ester or 16 oz/ac of 4 lb/gal amine) provides low cost and effective control of winter annual broadleaf weeds. Wheat should have at least four tillers before applying 2,4-D or serious crop injury may occur. The addition of a sulfonyleurea herbicide, such as Ally<sup>®</sup>Extra or Amber to 2,4-D, may improve control, particularly after these plants have bolted. If the sulfonyleurea herbicide is used after bolting, but prior to weed seed production, it may be useful to reduce the amount of weed seed produced, but such late control may not prevent yield loss.

## Warm Season Broadleaf Weeds

Many broadleaf weeds in winter wheat can be controlled at a modest price with amine or ester formulations of 2,4-D. Generally, ester formulations of 2,4-D provide better broadleaf weed control than amine formulations because they are oil soluble and readily penetrate plant foliage. Amine formulations are water soluble and do not penetrate foliage as easily, resulting in reduced control of weeds such as kochia and Russian thistle. However, amine formulations provide greater crop safety than ester formulations.

To reduce injury with 2,4-D, use low rates and apply in early spring to fully tillered wheat, prior to stem elongation (jointing). Winter wheat is considered fully tillered when it has six to nine tillers; however, the number of tillers depends on the seeding rate and date. Wheat injury and yield loss can be significant if 2,4-D or other herbicides are misapplied.

Dicamba (Banvel<sup>™</sup>, Clarity<sup>™</sup>, Sterling<sup>™</sup>, etc.) and 2,4-D are combined to control a wider spectrum of broadleaf weeds, including wild buckwheat, which is not controlled by 2,4-D alone. Dicamba plus 2,4-D must be applied to well tillered wheat, but before jointing, to avoid crop injury.

Sulfonyleurea herbicides have soil persistence and will control germinating broadleaf weeds for about four weeks after application. A surfactant (at 0.25 % v/v) should be added to the spray solution whenever the sulfonyleurea herbicides are used, unless liquid fertilizer is being combined with the herbicide.

Among the weeds that may or have become resistant to the sulfonylurea herbicides are kochia, Russian thistle, and prickly lettuce. The use of 2,4-D (4 lb/gal) at ½ pint per acre applied with one of the sulfonylurea herbicides and a surfactant improves weed control and helps prevent resistant weed development. Higher rates of 2,4-D and surfactant may injure the wheat.

The sulfonylurea herbicides have rotational restrictions of one to 36 months that limit their use in areas where susceptible crops are grown in rotation with wheat. This is especially important when the crop is lost to hail or other crop failures. The degradation of sulfonylurea herbicides in soil is slowed by high soil pH. Some of the sulfonylurea herbicides should not be applied to soils with a pH greater than 7.2 to avoid the risk of rotational crop injury. Growers should follow label directions carefully and determine rotational plans before using these products.

Wild buckwheat has become an increasing problem in winter wheat fields. Wild buckwheat is best controlled when herbicides are applied before it produces vines. Herbicides with short residuals applied before wild buckwheat germinates will not provide adequate control. Dicamba and aminopyralid (Cleanwave™) can be combined with 2,4-D for improved control of wild buckwheat.

Weed control in winter wheat requires an integrated system that relies on numerous management decisions related to maximizing crop growth and minimizing weed growth. The use of multiple cultural practices for weed control frequently provides synergistic benefits greater than the added effects of using just one or two cultural practices. Timely field scouting is essential in good weed management.





# Disease Management in Wheat

By Roberta Armenta

Great Plains wheat production can be affected by a number of diseases caused by viruses, fungi, and bacteria. While many of these were once of great concern to Great Plains producers, varietal resistance, cultural practices and effective pesticides have decreased the severity and incidence of disease. Those still of economic concern across the Great Plains include take-all, barley yellow dwarf virus, wheat streak mosaic virus, High Plains virus, Triticum mosaic virus, wheat soilborne mosaic virus, root rots, bunts and smuts, and rust diseases.

## Bunts and Smuts

Bunts and smuts are a group of similar fungal diseases that attack developing kernels, replacing them with spore masses. In addition to reducing grain yield and quality, spore clouds are flammable and can be a hazard during threshing. In the Great Plains region, those of economic importance include common bunt or stinking smut, dwarf bunt, and loose smut.

### Common Bunt / Stinking Smut (*Tilletia foetida* & *T. caries*)

#### Disease Cycle

Common bunt and stinking smut are most commonly seed-borne diseases, but they can be soilborne and wind-borne as well. Seeds become contaminated during harvest, when smut spores from diseased plants stick to healthy kernels. Smut spores can survive in the soil for at least ten years, and seeds and young seedlings also may become infected when they are sown near these spores (soilborne).

Smut spores and wheat seeds germinate at the same time, allowing the fungus to penetrate the seed before seedling emergence. The fungus continues to grow in its host until it has invaded the head and developing ovaries. The healthy plant tissue is replaced by the fungus, and the kernels are converted into spores by the time the plant reaches maturity.

Hosts include wheat, rye, triticale, barley, and grassy weeds. These diseases are favored by cool, moist soil conditions (40-60°F or 4-16°C), so they are more prevalent and severe in fall sown wheat than in spring-sown wheat.

**Figure 9.1a**  
Winter wheat head  
infected with com-  
mon bunt.



### Symptoms

The symptoms of common bunt and stinking smut generally are not apparent until heading. Diseased plants may be stunted, and bunted heads may be a darker color of green and may stay green longer than normal plants (*Figure 9.1a & b*). Heads of infected plants may also be smaller and their numbers reduced. After heading, diseased heads can appear slightly open due to the expansion of infected kernels causing the glumes to spread apart. In infected heads, diseased kernels, or bunt balls (*Figure 9.2*), are dull, grayish-brown in color and are filled with dark brown spore masses. The heads rupture at harvest and release spores that have a fishy odor due to the chemical trimethylamine.

### Management

Stinking smut and common bunt are controlled through seed certification and seed treatment.

**Figure 9.1b (left)**  
Wheat plants in-  
fected with common  
bunt (right) exhib-  
iting stunting and  
extended greening.



**Figure 9.2 (right)**  
Winter wheat spike,  
with glumes re-  
moved to reveal  
smut balls.



## Loose Smut (*Ustilago tritici*)

### Disease Cycle

Loose smut is a seed and wind-borne fungal disease. The pathogen survives in the wheat seed until germination and then grows up the shoot and infects the head. Healthy wheat plants can be infected during the first two days of flowering by wind-borne spores from infected plants. Rain and insects can also help spread the fungus. Humid weather, including light rain and heavy dew, and cool to moderate temperatures, between 60 and 71°F (16-22°C), promote infection. When spores land on healthy flowers, they germinate and become dormant within the ovary until seeds germinate. Yield loss is in direct proportion to the number of smutted heads present.

## Symptoms

Disease symptoms usually are not apparent until heading. However, diseased heads tend to emerge earlier than normal plants from the boot stage (approximately 1-3 days). Brown to black fungal spore masses develop in the diseased heads of the plants. The membrane ruptures during flowering and smut spores are dispersed leaving only the dark, bare rachis (Figure 9.3).

## Management

It is not possible to visibly tell the difference between infected seed and healthy seed. Plant high quality, certified seed treated with an effective fungicide.



**Figure 9.3**

Wheat infected with loose smut exhibits typical symptoms—after flowering the spores are dispersed and only a bare rachis remains.

## Common Root and Foot Rot

### Dryland Foot Rot (*Fusarium culmorum* and *F. graminearum*)

Also known as Fusarium foot rot, dryland foot rot is a soilborne disease that can survive and multiply on crop residues. The occurrence of dryland foot rot has increased with reduced tillage practices. Hosts of dryland foot rot include many cereals, especially barley, and grasses. The primary causes of this disease are the fungi *Fusarium culmorum* and *F. graminearum*. *F. culmorum* the northern Great Plains and interior northwest, while *F. graminearum* is more important in the southern Great Plains.

## Disease Cycle

Dryland foot rot infects the roots and crowns of wheat plants and is more prevalent in loose, dry soil. Areas with low annual precipitation (below 16-18 inches) are susceptible to the disease. Stress, including drought, can increase the damage. Associated with areas of high fall soil temperatures and low fall soil moisture, dryland foot rot is most common in dryland winter wheat and no-till spring cereals. Spring wheat usually is not affected. Stressed or droughty areas, such as hilltops, sandy areas, slopes, and ridges, tend to experience the most severe damage.

## Symptoms

In the late fall and early spring, discolored root and crown tissue, appearing brown to reddish-brown and rotted, is the most apparent sign. The stem may also be brown to reddish-brown several nodes up the plant (about 4 to 5 inches) (Figure 9.4). During the final stages of development water stress due to root damage causes the plant to ripen prematurely resulting in white heads (Figure 9.5). Heads may either be void of kernels or contain shriveled kernels.



**Figure 9.4 (left)**

The browning of wheat stems is a common symptom of dryland foot rot.



**Figure 9.5 (right)**

Infected plants produce white heads.



### Management

Control methods include crop rotations, seed treatments, and water conservation practices. Crop rotation with broadleaf crops, corn, millet, or oats can decrease the incidence of dryland root rot. At least two years between cereal crops is recommended to reduce the risk of infection. Avoid plant stress by implementing water conservation practices and applying fertilizers effectively. Chisel plowing can improve infiltration and decrease runoff. In addition, early seeding can result in bigger, more water-stressed plants, so plant seeds when soil is below 60°F (16°C) at seed depth. Plant seeds at shallower depths in warmer soil.

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

The common root rot fungus survives as spores in crop residue, but unlike many other root rots, it can also survive several years in the soil. Because of this and because the fungus infects many grasses, it is not practical to rid a field entirely of common root rot.

### Disease Cycle

Common root rot is most common between September and June, during moist, warm weather. Root and crown tissues are infected, and flower parts also may be infected if spores are splashed onto spikes that will remain wet for several days. Water stress after infection can worsen damage.

## Symptoms

Common root rot mainly affects the roots and crown. Roots may be poorly developed and spotted with brown to black lesions. The crown is affected later in the season with similar symptoms—poor development and areas of brown discoloration. The infection is especially noticeable on the subcrown internode and coleoptiles where symptoms mirror those of the roots and crown. Diseased spikes turn white before healthy plants mature. Plants may be stunted and produce fewer tillers, and infected heads turn white and contain shriveled kernels.

## Management

Control common root rot with good cultural practices, good weed control, crop rotation, and seed treatments. Plant high quality wheat seed late in the fall into firm seedbeds, since loose seedbeds and warm soil conditions promote disease. Do not over fertilize, especially with nitrogen.

## Take-all (*Gaeumannomyces graminis* var. *tritici*)

Take-all got its name over 100 years ago in Australia when a severe seedling blight emerged killing entire fields, destroying entire stands of wheat, and “taking-all” seedlings it infected. The disease affects the root, crown, and stem base of wheat and interrupts plant development. Cool, damp conditions and alkaline soils promote infection, and irrigation increases damage.

## Disease Cycle

Take-all is caused by a soilborne fungus that survives year-to-year in wheat residues and on volunteer wheat and grassy weeds such as brome grass, quack grass, and bent grass. Wheat becomes infected when plant roots come in contact with infested residues or infected plants. The fungus moves to its new host via the growth of runner hyphae through the soil. Spores are produced, but are not important in spreading the disease.

Soil conditions affect the severity of the disease. Sandy, light, poorly drained soils promote take-all severity as do soils with low fertility and a high pH and heavy, poorly drained soils. Wet weather, particularly in the second half of the growing season, promotes take-all fungal growth. Increased damage occurs when soil temperatures are between 54 and 68°F (12-20°C). Usually, damage is worse the earlier plants are infected.

Nutritional stress also plays a part in determining the severity of take-all in wheat plants. Take-all incidence is decreased with adequate soil fertility, particularly with nitrogen. Spring nitrogen application in a deficient wheat crops can reduce take-all development.

Wheat plants can endure mild to moderate infection with no apparent symptoms and minimal yield loss. However, when weather and soil conditions favor the disease, symptoms may be severe and yield losses as high as 50 percent may occur.

## Symptoms

Symptoms of take-all are most noticeable near heading and include plant stunting and early maturation. Circular patches of stunted, yellow plants may appear during the early growth stages, commonly occurring in wetter areas of the field. Infected plants tend to be yellow in color and produce fewer tillers (*Figure 9.6*). Because plants are killed prematurely, bleached and sterile heads are produced (“white heads”). The white heads may be void of grain or produce only a few shriveled kernels. Wet weather promotes fungal growth that blackens the dead, white heads.

**Figure 9.6**

Wheat plants infected with take-all root disease tend to be yellow in color and infection usually occurs in circular patches.



**Figure 9.7**

Root rot is common in plants affected by take-all; Roots may appear blackened and brittle compare to healthy roots.



Root rot is another take-all symptom, resulting in blackened, and brittle roots (*Figure 9.7*). Diseased plants can be easily pulled out of the ground or may break off near the soil line. Under prolonged wet soil conditions, take-all extends into the crown and stem base. An infected stem will be covered with black, shiny fungal growth.

## Management

Rotation with crops not affected by take-all, e.g., corn or sunflower, is an effective management strategy. Eliminate volunteer wheat and grassy weeds, such as downy brome, for these may serve as take-all hosts and allow the fungus to persist from year to year. If tillage is used, till as late in the year as possible. Early planting promotes take-all, so plant wheat after the Hessian fly-safe date for your area.



## Barley Yellow Dwarf Virus (BYDV)

### Disease Cycle

Hosts of barley yellow dwarf virus, a Luteovirus, include wheat, barley, oats, triticale, and over 150 grass species. Aphids feed on infected plants and transmit barley yellow dwarf to healthy plants in subsequent feedings. It is vectored by all the cereal aphids except Russian wheat aphid (*Figures 9.8-9.11*) (Reference Chapter 7—“Arthropod Pests of Wheat”). Each aphid species transmits specific virus strains, but some strains can be vectored by multiple aphid species. There are five strains of the disease common to the United States including MAV, PAV, SGV, RMV, and cereal yellow dwarf. BYDV cannot be transmitted through seed or soil.

The barley yellow dwarf virus survives year to year in wild grass hosts and volunteer small grains or is introduced to the field by virus-carrying aphids. Winged aphid migrations can be either localized or occur over several miles with favorable winds. BYDV is often associated with environmental conditions that favor the buildup of aphid populations including wet, cool summers, warm falls, and mild winter conditions. Irrigated areas also support aphid populations.

Severity of disease depends on many factors including efficiency with which the aphids transmit the virus, the source and strain of the virus, aphid mobility and feeding habits, environmental conditions, and the age and susceptibility of wheat plants when infected. There is increased injury in early-seeded winter wheat, and fall infections tend to be more damaging than those in the spring and leave plants more vulnerable to winterkilling. However, even though plants may become infected in the fall, symptoms may not be apparent until the spring. Losses attributed to barley yellow dwarf are usually between 5 and 25 percent.



**Figure 9.8 (left)**

Adult bird cherry-oat aphids.

**Figure 9.9 (right)**

The corn leaf aphid in both the adult and nymph stages.

**Figure 9.10 (left)**

Adult greenbug.

**Figure 9.11 (right)**

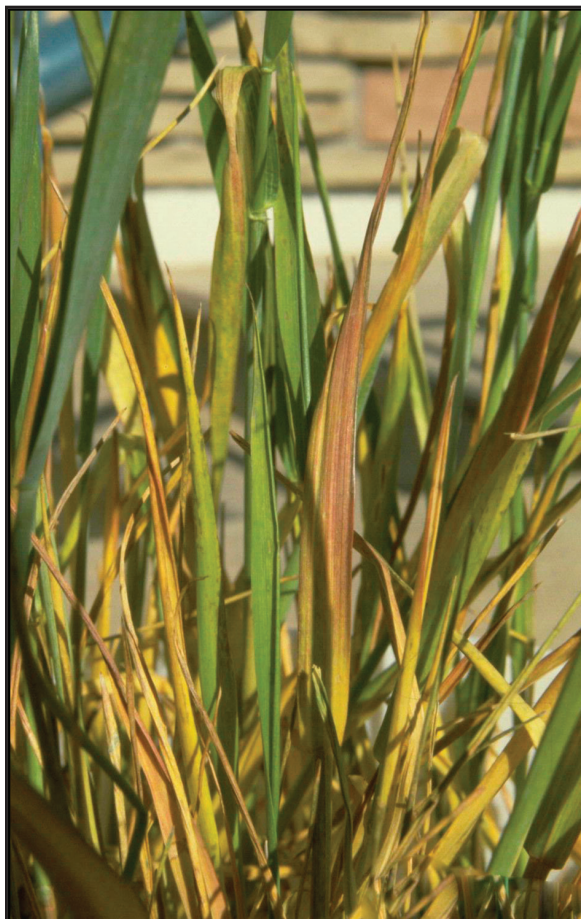
Adult English grain aphid and nymphs.



**Figure 9.12**  
Winter wheat  
exhibiting barley  
yellow dwarf virus  
symptoms, includ-  
ing stunting and leaf  
discoloration.



**Figure 9.13**  
Infection is apparent  
due to the yellow  
and purple discol-  
oration of wheat  
leaves.



## Symptoms

Symptoms of BYDV become obvious by jointing and include plant stunting and slight to severe leaf discoloration (*Figure 9.12*). However, BYDV symptoms can closely resemble those of environmental stress, nutritional stress, wheat streak mosaic virus, and crown and root diseases, so it is important to have samples tested in a lab to confirm disease. Plant leaves begin to yellow and sometimes turn red or purple beginning at the leaf tips or margins, and discoloration progresses towards the base (*Figure 9.13*). Serration may also occur at the leaf margin, and diseased leaves can have a more erect appearance compared to healthy leaves (*Figure 9.13*). Infection occurring at early growth stages results in increased injury. Severely infected plants exhibit stunting, poorly developed tillers, reddening of flag leaves, delayed maturity resulting in poorly developed heads, shriveled grains, and reduced yields. Infection often occurs in small patches due to localized aphid feeding, and these patches tend to occur in a row due to aphid feeding along rows of plants or may also be associated with field margins. Symptoms become apparent two weeks after a plant becomes infected at 68°F (20°C) and four weeks at 77°F (25°C); bright, sunny weather favors symptom expression. If temperatures exceed 86°F (30°C) the virus will be suppressed, and symptom development will cease.

## Management

See Chapter 7—“Arthropod Pests of Wheat” for details on managing aphids in wheat.

## Wheat Streak Mosaic Virus (WSMV), High Plains Virus (HPV), and Triticum Mosaic Virus

Wheat streak mosaic virus, High Plains virus, and Triticum mosaic virus are very similar wheat diseases, with the same vector, wheat curl mite, *Aceria tosichella* Keifer. They are common in the Great Plains and have similar disease cycles, symptoms, and management approaches. In addition, the three diseases often occur in conjunction with one another, making it hard to distinguish which disease is the cause of infection without sending samples to a virus lab.

The virus complex can cause serious losses in wheat, especially in fields planted next to or near volunteer wheat. HPV was identified in the Great Plains in 1993. It is now reported to be widespread in this area from Nebraska and the Texas Panhandle, to Colorado and Kansas. Triticum mosaic virus was first identified in 2006, and it has since been found accross most of the Great Plains. The impact of these viruses in combination are not well known.

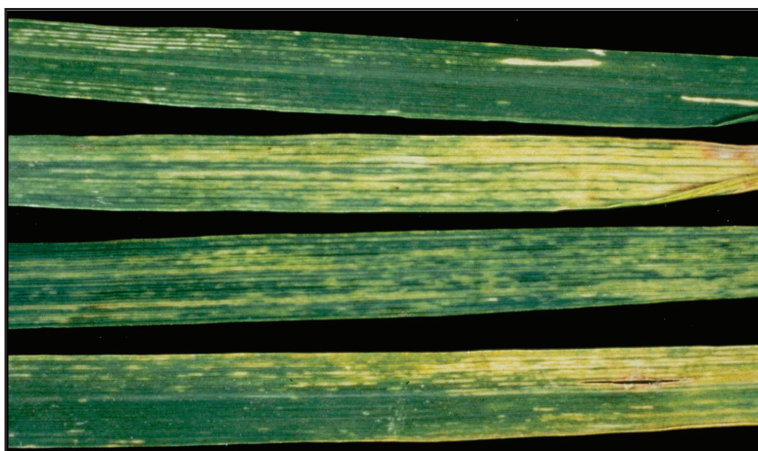
Hosts of WSMV include wheat, oats, barley, corn, triticale, rye, and several annual and perennial grasses (green foxtail, giant foxtail, sandbur, crabgrass, barnyard grass, stinkgrass, witchgrass, hairy grama, Canada wild rye, Virginia wild rye, and Bermuda grass), while HPV hosts include wheat, corn, barley, yellow and green foxtail, and witchgrass. While virus hosts are not always the same as vector hosts, many of them tend to overlap.

For details on the cycle of these diseases and their vector, the wheat curl mite, reference Chapter 7—“Arthropod Pests of Wheat.”

### Symptoms

#### *High Plains Virus*

Infection caused only by the High Plains virus occurs in mid-May through July and also in September and October. Disease symptoms are apparent when leaves exhibit a mosaic pattern of yellow, chlorotic spots and streaks (*Figure 9.14*). Leaf symptoms also may be similar to those of WSMV, with green or yellow stripes near the leaf tips, or wheat soilborne mosaic virus, with green spots on a light green background. Laboratory testing is needed to reliably diagnose High Plains virus.



**Figure 9.14**  
High Plains Virus  
disease symptoms  
on three leaves of  
winter wheat.



**Figure 9.15a  
(left)**

Yellowing of winter wheat.

**Figure 9.15b  
(right)**

Patches of diseased winter wheat appear yellow and stunted when compared to healthy plants.



#### ***Wheat streak mosaic virus***

Symptoms of WSMV first appear in the spring when temperatures begin to warm. They are often most noticeable on the edge of fields or in areas near volunteer wheat. Severe infections occur in the fall but may not show symptoms until the spring when warmer temperatures favor disease development.

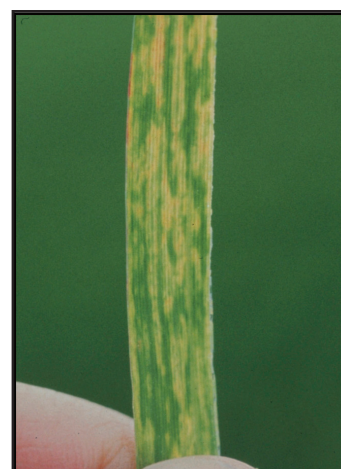
Diseased plants have a general appearance of being yellow and stunted (*Figure 9.15a & b*). Infected leaves are mottled and exhibit light green-yellow, parallel, and discontinuous streaking (*Figure 9.16a & b*). As infection worsens, infected leaves turn brown and die. In addition, infected plants develop fewer tillers than normal, some of which may lie on the ground (*Figure 9.17a & b*). Time of infection is a very important factor in determining how great losses will be. Plants infected early in the season, before early tillering, exhibit severe stunting, and produce few, if any, heads. If plants are not infected until the spring, there is little impact. Losses also tend to be more severe in dry years.

**Figure 9.16a  
(left)**

Diseased wheat leaves exhibit discontinuous streaking.

**Figure 9.16b  
(right)**

Light yellow-green, parallel streaking due to wheat streak mosaic virus.







**Figure 9.17a (left)**

Infected wheat plants develop fewer tillers, some of which may lie prostrate on the ground.

**Figure 9.17b (right)**

Diseased leaves fail to unfurl due to the feeding habits of the wheat curl mite.

### HPV & WSMV

Plants infected with both High Plains virus and wheat streak mosaic virus will exhibit severe chlorosis and stunting, strong mosaic patterns, and premature death.

### Management

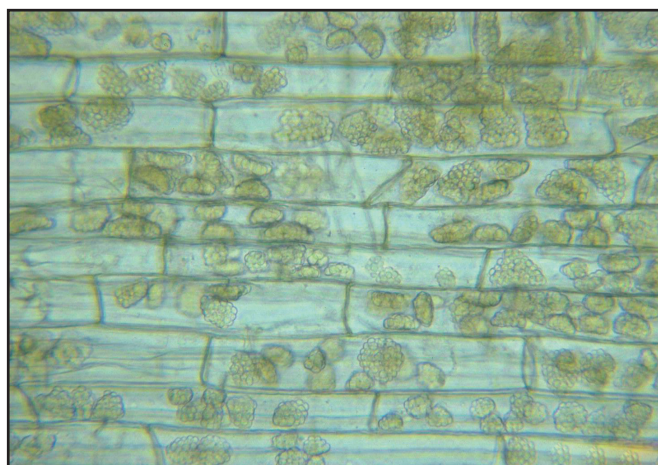
See the section on wheat curl mite in Chapter 7—“Arthropod Pests of Wheat” for details.

## Wheat Soilborne Mosaic Virus (WSBMV)

Wheat soilborne mosaic virus is carried by the soilborne fungal vector *Polymyxa graminis* which is found in cool, wet soils. The symptoms, life cycle, and disease pattern of WSBMV are very similar to those of wheat spindle streak mosaic virus, but with two distinct differences. WSBMV causes greater yield losses and disease symptoms persist longer into the spring.

### Disease Cycle

WSBMV is carried into roots by fungal zoospores (Figure 9.18). In cool, wet soil conditions resting spores produce these zoospores which swim to young wheat roots and enter through root hairs or epidermal cells. When infected roots decay, resting spores are released into the soil where they, and the virus, can survive for many years. The virus also persists for as many as 10 years in dry plant tissue. WSBMV is spread only through infested soil. Infection is spread when infested soil is dispersed by wind, water, or contaminated equipment.



**Figure 9.18**

Fungal zoospores carrying the vector *Polymyxa graminis*.



Favorable conditions for WSBMV include prolonged cool temperatures, below 65°F (18°C), soil temperatures between 50 and 60°F (10-16°C), and short day lengths. Therefore, root infections occurring in the fall are most important. Wet soil conditions and low-lying areas of fields also promote disease.

Losses caused by wheat soilborne mosaic virus are variable and depend on the area, weather, and wheat variety. The earlier a plant is infected, the greater the injury is. Temperatures below 60°F (16°C) promote fungal development, but as the season warms and temperatures exceed 68°F (20°C), fungal development ceases. Therefore, a long cool spring promotes the disease and may result in yield losses of 30 to 50 percent, while a warm spring hinders disease development and results losses of only 10 to 20 percent. Reduced yields are associated with fewer kernels per spike and reduced test weights.

**Figure 9.19**  
Wheat infected with wheat soil-borne mosaic virus exhibits stunting and yellowing.



**Figure 9.20**  
Irregular patches of yellow, stunted wheat may be due to wheat soil-borne mosaic virus.







**Figure 9.21  
(left)**

Leaves infected with wheat soil-borne mosaic virus exhibit mottling and discoloration.



**Figure 9.22  
(right)**

Reddish streaking may occur at leaf tips.

## Symptoms

Symptoms are most apparent in the early spring, right after green up and include plant stunting and leaf mottling and streaking (*Figure 9.19*). Leaf mosaic symptoms diminish by the time of jointing, but stunting tends to persist through maturity. Wheat soilborne mosaic virus is first evident by the presence of large, irregular patches of yellow, stunted wheat (*Figure 9.20*). Unlike many other diseases, the infected patches do not grow in size throughout the season; instead field patterns follow drainage or irrigation patterns because the zoospore vector needs water in order to spread the disease. Leaf mosaic symptoms include mottling and light green spots or dashes against a yellow background (*Figure 9.21*), often referred to as a mosaic of “green islands.” Reddish streaking and necrosis may sometimes occur on the tips of leaves, and infected plants may produce a reduced number of tillers and heads (*Figure 9.22*).

## Management

Because the virus can survive in the soil and in crop residues for up to 10 years, crop rotation is not an effective control method. Planting resistant varieties is the most effective control strategy for wheat soilborne mosaic virus. Late planting may reduce the risk of infection but is not always successful. Plant winter wheat after the Hessian fly safe date for your area to reduce the incidence of WSBMV and other viral diseases.

## Rust Diseases of Wheat

Rust diseases occur worldwide and are of economic importance due to their capacity to rapidly develop new races, making previously resistant varieties susceptible. In addition, rust diseases are capable of disseminating over long distances and develop rapidly under favorable conditions. Leaf rust, stem rust, and stripe rust all affect wheat, but in the Great Plains leaf and stripe rust are of the greatest importance.

### Leaf Rust

Leaf rust is a worldwide disease of wheat caused by the fungus *Puccinia recondita* f. sp. *tritici*. There are many races of the leaf rust fungus, and no variety is resistant to all of them. New races emerge frequently, making the lifespan of a resistant variety only a few years.

### Disease Cycle

The severity of leaf rust is affected by the growth stage at the time of infection, weather conditions, and the amount of rust inoculum present. Damage is greater when plants are infected before flowering, especially when the flag leaf becomes infected. Late-maturing varieties of wheat and cool (60-75°F or 16-24°C), wet weather, including rain and dew, also promote the disease. However, heavy rain washes spores off of the plant, and dry, windy conditions favor spore dispersal. Losses due to leaf rust are caused by a reduced number of kernels per head, reduced size of kernels, lowered test weights, and reduced protein content of the grain.

### Symptoms

Leaf rust pustules form on infected wheat and are small (.04-.08 mm in length), reddish-orange oval fruiting bodies (uredinia) on the leaf surface (*Figure 9.23*). Pustules can be either scattered or clustered. Each pustule contains thousands of orange, powdery rust spores that rupture the epidermis of the leaf surface as the fungus matures and then are disseminated by the wind and rain. Pustules are usually surrounded by orange dust, and sometimes also a narrow, yellow or white border or “halo” (*Figure 9.24*). Unlike other rusts, the orange spores will rub off of your finger and, if infection is severe, field scouts may find the orange dust on their hands and clothing.

As plants mature, pustules begin producing black spores. These pustules resemble tar spots and are most noticeable on lower leaves and leaf sheaths. Orange spots (not pustules) may also form on the heads and culms of diseased plants. Leaf rust, unlike stem rust, does not form pustules on these organs.

Leaf rust infection occurs uniformly across fields, usually from mid May through early July and again in September and October. When leaf rust overwinters in a field, disease is more severe on the lower leaves because the fungus develops here first before advancing up the plant to the flag leaf. Disease is more severe in the upper part of the plant when spores are blown in from adjacent areas. Severity of disease increases exponentially, and during favorable weather pustules development can result in 30 to 50 percent coverage of the leaf surface.



**Figure 9.23  
(left)**  
Leaf rust pustules occur randomly across the leaf surface and are ellipsoidal in shape.



**Figure 9.24  
(right)**  
Leaf rust pustules surrounded by a yellow or white "halo."

## Management

Plant varieties with at least moderate resistance to leaf rust. Planting varieties that vary in parentage, maturity, and disease reaction can reduce the chances of leaf rust taking out entire fields. Some varieties are susceptible to disease, but tolerate infection better than other varieties. Early maturing varieties may escape late season rust problems.

Susceptible varieties can be protected with foliar fungicides. However, fungicide treatment is recommended only after consideration of the following risk factors:

1. Yield potential in a field (at least 45 bu/ac dryland and 75 bu/ac irrigated)
2. Wheat variety susceptibility to leaf rust
3. Time of infection (early rust increases damage)
4. Dryland or irrigated wheat (irrigated wheat more vulnerable to injury)
5. Planting dates of winter wheat crops (late seeded crops more at risk due to delayed development)
6. Current and 30-day weather forecasts from mid-May to mid-June (wet weather conditions favor disease development)

Seed treatments can control fall infections but may not persist through to spring.

Plant winter wheat after the Hessian fly-safe date for your area to reduce fall infections, but keep in mind that delayed maturity can lead to increased injury in the spring. In addition, control volunteer wheat in the summer because it is an important source of infield inoculum in the fall, from over-seasoning uredinia, but this does not prevent infection from windborne spores.



## Stripe Rust (yellow rust)

Stripe rust is caused by the fungus *Puccinia striiformis*. Stripe rust incidence was once rare in the High Plains due to the hot, dry climate. The development of new strains tolerant of a wider range of temperatures has led to increasing stripe rust problems in the central Great Plains.

### Disease Cycle

Stripe rust develops in cooler temperatures (55-75°F or 13-24°C) than other rust diseases, allowing it to develop earlier in the season. Stripe rust develops most rapidly between 50 and 60°F (10-16°C), and development slows when temperatures exceed 75°F (24°C). Cool, wet falls, mild, open winters, and long, cool, and wet springs all promote disease development.

Stripe rust over-summers on volunteer wheat and perennial grasses. It also develops in the fall and winter in the southern United States, and then spores are carried north into the central Great Plains in the spring. The fungus can persist through cold climates (as low as 23°F or -5°C), overwintering on wheat and grassy weeds or as dormant mycelium under snow cover.

### Symptoms

Infected wheat leaves develop long, narrow stripes, usually about  $\frac{1}{16}$  of an inch wide and irregular in length, of yellowish-orange pustules (*Figure 9.25*). Pustules are small ( $\frac{1}{100}$  of an inch) and round, contain masses of rust spores, and develop on the head as well as leaf sheaths. Stem rust spores are lighter in color than those of leaf and stem rust. In moderately resistant varieties pustules may be absent or hard to see, resulting in symptoms similar to those of black chaff. As diseased plants mature or become stressed, tissues appear dry and brown, giving plants an overall scorched appearance (*Figure 9.26*).

### Management

The most effective control method for stripe rust in wheat is to plant resistant varieties (see Chapter 3—“Variety Selection” for resources on current varieties). However, a new race of stripe rust is currently emerging, and previous management practices may be ineffective.

Cultural practices also can help decrease disease incidences. Control grassy weeds and volunteer wheat at least three weeks prior to fall seeding to reduce the risk of disease transmission by “green bridge.” Avoid early planting of winter wheat to reduce this risk as well. Scout fields for infected perennial grasses, because these are an important reservoir of disease.



**Figure 9.25  
(left)**

Long, narrow stripes of yellowish-orange pustules are indicative to the stripe rust fungus.



**Figure 9.26  
(right)**

As diseased wheat plants mature, they turn brown and dry out giving plants a scorched appearance.

Fungicides may control stripe rust effectively and economically after taking into account the following risk factors:

1. Susceptibility of wheat varieties to stripe rust.
2. Current and 30-day weather forecasts from mid-May to mid-June (cool, wet weather conditions favor disease development).
3. Dryland or irrigated wheat (irrigated wheat more vulnerable to injury).
4. Yield potential in a field (at least 45 bu/A dryland and 75 bu/ac irrigated).
5. Development of rust on lower leaves (early infection increases losses).
6. Incidence of rust on local wheat.

## Stem Rust (black rust)

Stem rust, caused by the fungus *Puccinia graminis* f. sp. *tritici*, is the most damaging of all rusts, capable of causing complete crop loss. Stem rust outbreaks have been rare for several decades, but a new race, Ug99, is spreading from East Africa. Little resistance is available to Ug99, and the potential for severe epidemics is greater than it has been in many years.



**Figure 9.27a**  
European barberry  
serves as an alter-  
nate host for the  
stem rust fungus.



**Figure 9.27b**  
Aecia of stem rust  
on barberry.



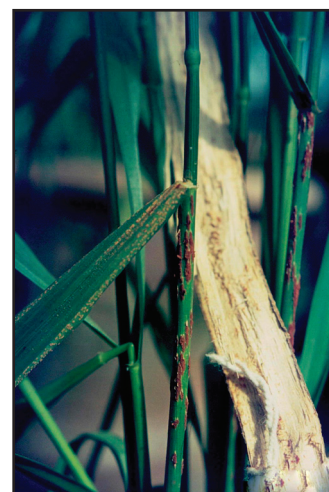
**Figure 9.28**  
Telia of wheat stem  
rust overwintering  
on stubble and plant  
residue.



**Figure 9.29 (left)**  
Stem rust pustules  
develop on infected  
plant parts includ-  
ing leaf sheaths,  
stems, spikes, and  
occasionally leaves  
as well.



**Figure 9.30a**  
(right)  
Stem rust pustules.



## Disease Cycle

The stem rust fungus requires two hosts to complete its life cycle. Telial stage hosts include wheat, barley, and several grasses, and aecial hosts, or alternate hosts, include European barberry such as *Berberis vulgaris* (Figure 9.27a & b), *B. fendleri*, and *B. canadensis*.

The fungus overwinters as teliospores on plant residue (Figure 9.28) or in the soil in colder climates and as urediospores on winter wheat grown in warmer climates. Wind-borne urediospores from southern states are the primary inoculum for disease in the Great Plains. Diseased plants produce more urediospores, creating a second inoculum.

Stem rust occurs worldwide, and is especially important in areas exhibiting warm, humid conditions (65-85°F or 18-29°C). Losses tend to be greatest when severe infection occurs before grain fill. Diseased plants produce shriveled grain and lodging results in loss of spikes.

## Symptoms

Fruiting bodies (uredinia) develop on diseased leaf sheaths, stems, spikes and occasionally on leaves as well (Figure 9.29). The brick red, oval-shaped pustules (Figure 10.9a & b) eventually turn dark brown or black (Figure 9.31) and rupture the epidermis of its host.



**Figure 9.30b  
(left)**

A close-up view of stem rust pustules.

**Figure 9.31  
(right)**

Pustules turn black as plants mature.

## Management

The most effective control method for stripe rust in wheat is to plant resistant varieties. See chapter 3—“Variety Selection” for sources of information on current varieties. Early maturing varieties also reduce the risk of injury because plants have time to ripen before becoming severely infected.

Eradicating barberry, the alternate host, may help control local buildup of disease causing spores. However, Great Plains wheat is most commonly infected when wind-borne spores are dispersed in the area from southern states and Mexico. Fungicides are usually not necessary when resistant cultivars are planted.

## Tan Spot (*Pyrenophora tritici-repentis*)

Tan spot, caused by the fungus *Pyrenophora tritici-repentis*, is an important leaf spot disease in the Great Plains region. Tan spot often occurs in conjunction with leaf rust and Septoria leaf blotch and is associated with reduced tillage. Losses due to tan spot are reflected in reduced yields and grain weight.

## Disease Cycle

The tan spot fungus overwinters as pseudothecia on wheat stubbles (either standing, buried, or lying down). Spores produced in the pseudothecia are disseminated by wind and rain and are the primary source of infection. Secondary infection is spread through a field or to adjacent fields by spores produced by the tan spot lesions, also disseminated by wind and rain. Fungal development is favored by wet weather conditions, especially in May and June.

## Symptoms

Symptoms of tan spot appear in the spring as oval to diamond-shaped, elongated brown leaf spots that are often darker in the center and yellow around the outside (Figure 9.32). The earlier the plant is infected, the more distinct the yellow border usually becomes, creating an “eye-spot” appearance. As the disease progresses, more spots develop on the leaves and start to coalesce, producing large areas of dead tissue. In addition, tan spot may kill leaves after heading, resulting in the early death of plants. In the late summer (August), characteristic, small, black fruiting bodies called pseudothecia appear on the stubble.



**Figure 9.32**  
Infected wheat  
plants develop  
brown spots with a  
yellow halo.



## Management

Crop rotation at least one year out of wheat is the best option for controlling tan spot. In addition, there are many tan spot resistant varieties available. See chapter reference for information on tan spot resistance sources. Foliar fungicide applications are recommended to protect the flag leaf in high risk situations.

## Powdery Mildew

Powdery mildew is caused by *Blumeria graminis* f. sp. *tritici* and is common in humid or semi-arid wheat growing regions. Factors that favor powdery mildew problems include mild temperatures (59-71°F or 15-22°C), high humidity (between 85 and 100 percent), dense stands, high nitrogen fertilization, and varietal susceptibility. Varieties are most susceptible to injury from jointing to flag-leaf emergence, and plants sustain the most damage when infected early in the spring. Damage increases as the mildew develops further up the plant before flowering, and severe losses occur when the flag leaf becomes diseased before heading. Severe infections may result in lodging, early death of leaves, reduced kernel size and test weight, failure to produce heads, and yield losses of up to 40 percent.

### Disease Cycle

Fall infections of newly planted wheat occur when spores develop on volunteer wheat or within cleistothecia. The powdery mildew fungus overwinters as cleistothecia on plant debris or as mycelium on infected plants. Conidia form on infected winter wheat plants and serve as the primary means of inoculum. Conidia are wind dispersed and germinate under cool, humid conditions. Under favorable conditions the disease can complete a life cycle in 7 to 10 days. Development ceases at around 77°F (25°C).

**Figure 9.33**  
Powdery mildew on  
winter wheat.



## Symptoms

Symptoms of powdery mildew include patches of powdery white or grey fungal growth on leaves, stems, and heads (*Figure 9.33*). Infection usually occurs on the lowest leaves of plants first and eventually works its way up the plant. The opposite sides of infected leaves become chlorotic and turn yellow and brown in color. As plants mature, the fungus changes color, getting darker grey and brown. Small, round, black fruiting bodies form on leaves in June.

## Management

Growing resistant varieties is the easiest way to control powdery mildew. However, new races are constantly developing, so it is important to stay informed about current varieties and resistance (reference Chapter 3—“Variety Selection” or your local university extension office).

Utilize crop rotation, destroy volunteer wheat, and use a balanced nitrogen fertilization program to reduce the likelihood of inoculum.

## Other Wheat Diseases

### Agropyron mosaic

Similar to wheat streak mosaic virus, agropyron mosaic virus in wheat is transmitted by the cereal rust mite (*Abacarus hystrix*). Symptoms of this disease are also similar in appearance to those of wheat streak mosaic, but they are not as severe. Agropyron mosaic is often associated with quack grass, and is usually found in patches or along grassy field borders. Management practices are similar to that of wheat streak mosaic virus.

### Black Chaff

#### *Disease Cycle*

Black chaff is a bacterial disease caused by the bacterium *Xanthomonas translucens*. The bacterium survives in and on seeds and may also persist on crop residue and in soil. Because it can also survive on plants during the growing season, it can be transmitted by splashing water, plant to plant contact, and insects. However, the most important source of inoculum is contaminated seed. Volunteer and grassy weeds also are sources of inoculums. Black chaff is promoted by irrigation and plentiful rainfall. Losses of up to 40 percent have been attributed to black chaff.

#### *Symptoms*

Black chaff gets its name from the dark discoloration of the glumes characteristic of diseased plants. Brown to black interveinal streaks develop on infected glumes and leaves, and stripes of alternating healthy and necrotic tissues on awns create a “barber’s pole” appearance. Cream to yellow colored slime or droplets appear in wet weather.

Dried droplets are light in color and scale-like. Infected stems, below the head and above the flag leaf, may develop a brown to purple discoloration and leaves may produce irregularly shaped lesions that first appear as water spots. These spots turn brown as infection progresses, giving diseased plants an overall orange appearance.

#### *Management*

Plant high quality, disease-free seed. Control volunteer and grassy weeds and do not over-irrigate.

### **Cephalosporium stripe** (*Cephalosporium gramineum*)

The fungus causing Cephalosporium stripe is soil and residue-borne and often associated with minimum tillage. Low, wet areas of fields favor disease as do heavy, wet, low pH soils.

#### **Symptoms**

Symptoms of cephalosporium stripe are first noticeable in the spring, in jointing and heading, as yellow, chlorotic stripes on leaves, blades, and stems. Sometimes brown necrotic tissue can be seen inside the yellow stripes. Plants are stunted and nodes are darker in color than normal. Diseased plants occur randomly, and heads are white and sterile.

#### **Management**

Control cephalosporium stripe with crop rotations, tillage, and tolerant cultivars. Destroying straw reduces inoculum since the cephalosporium stripe fungus can survive for several years on straw.

### **Ergot** (*Claviceps purpurea*)

Ergot, caused by the fungus *Claviceps purpurea*, can result in significant loss in yield and quality. However, mycotoxins produced by the fungus are of greatest concern. These cause ergotism in livestock and humans, resulting in constriction of blood vessels, muscle contractions, gangrene, convulsions, and hyperexcitability.

#### **Disease Cycle**

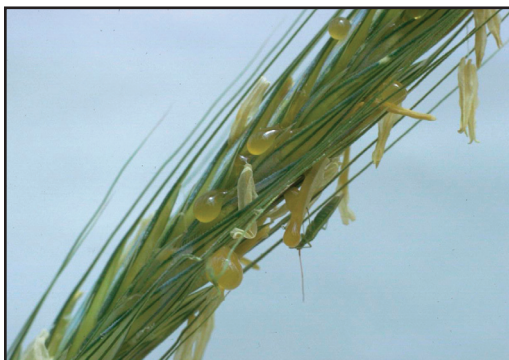
Initial infection occurs when wind-borne sexual spores that land on open flowers and germinate, causing infection. The infected flowers produce cloudy, sticky honeydew that contains fungus spores that are disseminated with the help of insects, splashing water, and plant-to-plant contact. The fungus is favored by wet, cool conditions during flowering, and susceptibility to disease increases with prolonged flowering periods.

#### **Symptoms**

Diseased plants produce hard, purplish-black sclerotia about ¼ to ½ inch in length, called ergot bodies, in place of healthy kernels. The ergots are similar in size to healthy wheat kernels and are tannish-white internally. In addition, a yellowish, sugary honeydew (Figure 9.34) forms on infected heads during flowering and prior to the development of ergots. This honeydew may be present on other infected plant parts as well.

**Figure 9.34**

The honeydew stage of the ergot fungus.



## Management

Plant clean seed, free of sclerotia, to avoid introducing disease into a field. Sclerotia will not germinate at a depth greater than one inch, so deeper planting may help reduce disease incidence. Varieties with shorter flowering periods may decrease initial infection. Rotate with non-host crops such as legumes or corn. Control grass and weeds in and around the field to reduce disease reservoirs.

## Resources

*Compendium of Wheat Diseases and Pests*. 3rd Edition. 2010, APS Press.

### **UNL Plant Disease Control:**

[<http://pdc.unl.edu/agriculturecrops/wheat>]





# Freeze Injury and Other Environmental Stresses

By James P. Shroyer

## Cold Injury

Cold injury symptoms of winter wheat can be observed at most stages of development. Newly emerged seedlings may show a white to yellow or purplish color band on leaves when warm days are followed by much cooler nights. Usually, neighboring seedlings will show similar symptoms at the same location on the plants. Symptoms will fade as seedlings become cold hardened. After plants are hardened by declining autumn temperatures, wheat can survive very low temperatures with few harmful effects. However, even cold-hardened plants can be injured when soil temperatures at the crown depth approach 10°F (-12°C). Wheat in dry, loose soils is more subject to cold injury than in moist soils because the cold penetrates more rapidly. Also, winter injury is more common on terrace tops and north-facing slopes. Generally, winter injury symptoms are most noticeable as uninjured plants begin to green up in late winter. Injured plants either never green up or slowly die during green-up as the vascular tissue deteriorates and microorganisms invade the damaged tissue. Cold injury also occurs after green-up when cold hardiness has been lost, followed by a rapid drop in temperatures.

Soil heaving, which often occurs in fine-textured soils, can leave plants with exposed crowns and roots. These may green up but will eventually die. Soil heaving occurs as the soil freezes and thaws during the winter, and ice lenses form under a dry soil surface. As an ice lens expands, moisture migrates toward the lens causing further expansion. If expansion occurs at or below the crown of the wheat plant, the crown is pushed out of the soil (*Figure 10.1*).



**Figure 10.1**

Plant crowns and roots are pushed above the surface due to soil freezing and thawing.

**Figure 10.2 (left)**  
Freeze injury to  
leaves.



**Figure 10.3  
(right)**  
Freeze injury to  
stems.



Freezing temperatures may cause leaf tips to yellow and die back from the tip on actively growing plants. This type of injury, which resembles topdress nitrogen burn, is minor and plants will grow out of it. As jointing occurs, low temperatures can cause damage to leaves, nodes, and stems. Initially, leaves may darken and appear water-soaked (*Figure 10.2*). The damaged area of the stem may be bleached, water-soaked, and soft and eventually will become rough and dark. This area may bend or kink causing the stem to lodge (*Figure 10.3*). If the stem is not killed, it will bend at the node and begin to grow upright. If the growing point is killed, a chlorotic leaf will appear in the whorl (*Figure 10.4a & b*).

**Figure 10.4a  
(left)**

A chlorotic leaf  
whorl indicates  
freeze damage to  
the growing point.  
There may be no  
other apparent dam-  
age.



**Figure 11.4b  
(right)**

With time chlorotic  
leaves will be more  
obvious.







**Figure 10.5  
(left)**

New tillers develop after freeze damage to older tillers.

**Figure 10.6 (top  
right)**

Freeze-damaged growing point.

**Figure 10.7  
(bottom right)**

Healthy growing point.

New tillers will form because the apical dominance of the primary tillers is now gone (Figure 10.5). Split stems, due to ice forming internally, generally die as temperatures rise or when the stems lodge. A damaged head appears off white, dried out, and fluffy (Figure 10.6). It will eventually turn whitish-brown and shrivel. However, a healthy head has a whitish-green, turgid appearance (Figure 10.7). Undamaged plants develop normally, while damaged plants will not grow and leaves will become chlorotic. The general appearance of the field will be yellow and ragged, with healthy plants taller than damaged plants (Figure 10.8).



**Figure 10.8**

Freeze damage is most pronounced in the low areas of the field, near the center of the photo.



**Figure 10.9 (left)**

A wheat head suffering from freeze injury as compared to a healthy one at right.

**Figure 10.10 (right)**

*Left*—floral parts prior to pollination  
*Middle*—anthers shedding pollen  
*Right*—fertilized ovule (1-2 day old kernel).



Freezing temperatures during boot stage may damage the head, stem, and leaves of wheat. The base of the head may emerge first, or the head may emerge from the side of the boot. Damaged spikelets will have a yellowish, water-soaked appearance instead of the normal crisp, green color (*Figure 10.9*). A light freeze may bleach exposed awns.

Temperatures near 32°F (0°C) can cause damage as the head emerges from the boot and initiates flowering. It takes three to five days for the head to fully extend above the flag leaf before flowering begins. Flowering will begin in the spikelets, about  $\frac{2}{3}$  up the head, and will progress up and down the head over a three to five day period. Each spikelet contains two to five florets. Three lime-green anthers and a stigma, with two fluffy, white branches, are contained in each floret. Pollen is released as the anthers are pushed upwards and the pollen lands on the stigma (*Figure 10.10*). The yellow to white anthers eventually push outside the floret. Within ten days after flowering, kernels should nearly be full length. Each spikelet generally produces two to three kernels.

When freezing temperatures occur at this stage there are several things that can occur. Temperatures at or below 32°F (0°C) damage the anthers, which are more sensitive to cold than the stigma, causing floret sterility. Anthers will become shriveled and twisted while they still have their lime-green color. This can be detected with a hand lens within 24 hours after the freeze. Over several days, the anthers will not elongate, and they will continue to shrivel and turn whitish-yellow. In this situation, anthers will not shed pollen, but if the stigma is undamaged it may still be receptive to pollen from undamaged anthers in other florets. However, if the stigma was damaged, it will not open to expose its two fluffy branches, and it will become shriveled and whitish-brown. If temperatures remain cool after a freeze event, symptoms will be slow to develop, but as time passes kernels should continue to develop if there was no damage. Lack of kernel development indicates some form of freeze injury occurred.

Freezing temperatures can damage kernels well into the dough stage. Undamaged kernels have a light-green appearance while injured kernels will be rough, shriveled, and whitish-gray. Freeze symptoms on kernels in the dough stage include shriveled, chalky kernels and lower test weights. Also, the small structure that attaches the spikelet to the head, called the rachilla, can be damaged by freezing temperatures. Kernels will cease to develop, and eventually the spikelet may fall from the head causing grain-shattering losses.

## Plant Lodging

Plant lodging can be caused by a number of factors (*Figure 10.11*). The most common reasons for lodging are high seeding rates, high nitrogen or fertilizer rates, and excessive irrigation or high rainfall. Lodging often occurs first in low areas of the field. There are differences among wheat varieties in their lodging resistance. Tall varieties tend to lodge more than semi-dwarf varieties. There are some pest problems, such as strawbreaker and Hessian fly, that cause lodging. Also, strong winds with heavy rainfall cause plants to lean or lodge. Immature plants that have lodged likely will recover, but plants that have lodged during later grain-fill stages will often remain lodged, causing harvest difficulties. If lodging occurs early, yield reductions can occur. Freeze damage on the lower stems can cause lodging as well.



**Figure 10.11** Plant lodging can be caused by a number of environmental, chemical, biological, and varietal factors.

**Figure 10.12**  
Problems with head emergence occur due to hail stone impact (note the mark halfway down the stem from hail impact).



## Hail Damage

Generally, hail prior to jointing rips or shreds leaves causing little permanent damage. However, hail events in later stages can cause minor to severe yield losses. The most serious hail damage occurs when the stem below the head or boot is struck by hail stones, causing severing or kinking of the stem. Also, direct hits by hail stones to the head can damage the whole head or parts of the head. This can cause severe grain shattering. Direct hits by hail stones while in the boot stage can damage the head, causing it to get trapped inside the boot (*Figure 10.12*). Damaged heads tend to be gnarled and misshapen as they emerge. Hail stones hitting the stem will result in bruising. The leaf sheath may become chlorotic, and the stem eventually lodges much later as grain fill causes the head to become heavier.

## Soil Crusting

If a packing rain occurs soon after planting, the soil crusts and the elongating coleoptile cannot penetrate the soil surface. When this occurs the coleoptile will bend, the first leaf will emerge under the soil surface, and the seedling will not emerge.

## Resources

### “Spring Freeze Injury”:

[<http://www.ksre.ksu.edu/library/crpsl2/C646.pdf>]



## CHAPTER 11

# Harvesting Practices

By John A. Smith, Mark D. Schrock, Randal K. Taylor, and Randy R. Price

The productivity of wheat harvest and the role of wheat harvest within the larger picture of multi-year cropping systems are being improved through new technologies. Refinements such as header height control, automated threshing and cleaning adjustments, auto-steer, uniform spreading of straw and chaff, and yield mapping have increased machine capacity, increased operator efficiency, reduced grain damage, and improved productivity of the overall cropping system. The following sections describe some of these technologies available with today's combine harvesters.

### General Combine Types and Selection

The two basic types of combines are “conventional cylinder” and “rotary.” **Conventional cylinder combines** use a cylinder-concave threshing mechanism located near the front of the combine, with its axis perpendicular to the direction of material flow and combine travel. Because the cylinder is positioned transversely within the combine, the cylinder can only be as wide as the inflow of material. This cylinder-concave combination threshes the crop using an impact and rubbing type action. The concaves and grates located at the bottom of the cylinder drum allow seed and chaff to exit the cylinder area and drop into the grain cleaning system, which consists of a set of sieves where the seed is cleaned with air. A tailings auger is used to catch any remaining unthreshed heads and return them to the cylinder for rethreshing. Straw exits at the top, rear of the cylinder onto straw walkers, which use a vibrating action to move the straw through the combine and to separate out any remaining seed or chaff. Rotational speed of the cylinder is an important factor in breaking of kernels and threshing efficiency.



**Figure 11.1**  
Combine with rigid header harvesting winter wheat.



The **rotary combine** uses a rotating, threshing, separating mechanism with its axis parallel to the direction of combine travel. Because of this orientation, the threshing mechanism can be much longer than that of the conventional combine. Material moves through the combine in a helical, spiraling type path, first through the threshing section and then through the separation section. A fan and sieve combination is used to separate the chaff from the seed. The rotary separation mechanism eliminates the need for straw walkers.

Rotary combines tend to be gentler to the seed because they contain fewer moving parts and have higher throughputs than conventional cylinder machines. However, rotary combines also tend to require more engine power and break straw into shorter lengths so that baling the straw is more difficult. A conventional combine is recommended if baling is desired (for haying or bedding).

Combine size and capacity have increased dramatically through the years. There is not currently a consistent criterion available for designating or comparing combine capacity. Before rotary combines became popular, conventional combines were according to the number of individual sections of the straw walker. Engine power, grain tank size, and grain tank unloading rate were added as additional descriptive measures of combine ‘size.’ Today, this classification is used only to report combine sales and is based solely on advertised engine power. Current reporting classes include:

• <b>Class 5</b>	under 200 kw (268 hp)
• <b>Class 6</b>	200 kw (268 hp) to under 240 kw (322 hp)
• <b>Class 7</b>	240 kw (322 hp) to under 280 kw (375 hp)
• <b>Classes 8 &amp; 9</b>	over 280 kw (375 hp)

The size and capacity of combines continues to increase as evidenced by the recent introduction of a nearly 500 horsepower class 9 machine. Increases in size of combines and associated headers offers increased field capacity but also necessitates an increase in the level of system management.

## Header Types

For decades, rigid headers (*Figure 11.1*) using an auger to convey the crop to the feeder house have been the standard of wheat harvest. Recently, however, two new wheat header concepts have gained popularity.

### Stripper Headers

The stripper concept of harvesting wheat offers many advantages (*Figure 11.2*). The stripper header does not cut the wheat stalk but rather engages wheat spikes with plastic-backed stainless steel combs attached to a transverse rotor. The rotor rotates in the opposite direction of the combine wheels, so the spikes are combed with a forward and upward motion. Most of the kernels are threshed from the spike and enter the combine as loose grain. Depending on crop conditions, part of the grain may enter as unthreshed spikes and spike fragments.

The stripper header reduces the amount of material other than grain (MOG) entering the combine by 80 to 90 percent. Because the stem is not cut, straw remains in the field, and the combine processes very little MOG when compared to conventional rigid headers. The low amount of MOG eases the separation and cleaning processes and increases the capacity of conventional cylinder combines by 30 to 100 percent. Rotary combine capacity is more limited by factors affecting ground speed, such as terrain roughness, than by separation capacity (with either type of header). Wheat separation and cleaning losses from a combine equipped with a stripper header are usually quite low.

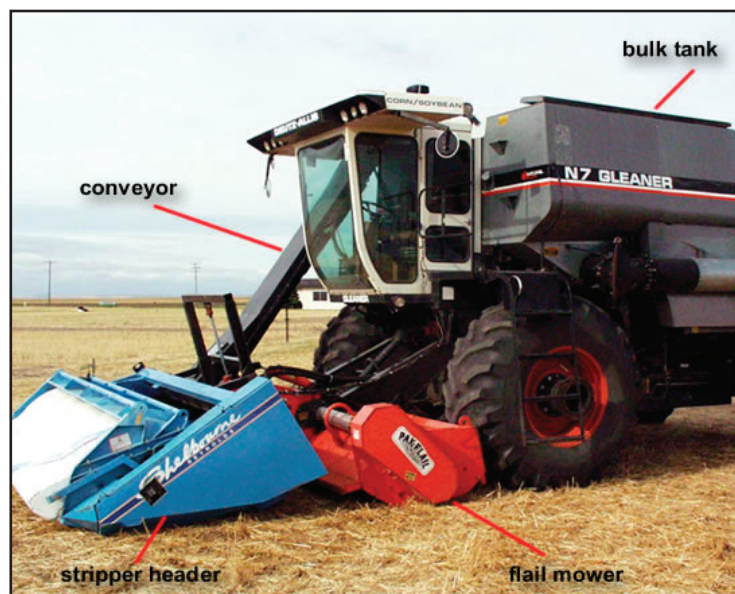


Figure 11.2  
Stripper header on a  
wheat combine.

Stripper heads also improve crop residue management. Because the straw is never gathered into the combine, the combine straw discharge does not have to be chopped and spread as with a conventional header. This reduces combine power requirements and eliminates the need for optional equipment to handle the residue, although chaff and fines may still need to be spread. Furthermore, the tall, stripped stubble has positive implications for subsequent no-till planting, as well as favorable evaporation and snow catch characteristics for fallow cropping systems.

Stripper headers work best in a high yielding crop. In thick wheat, the incoming crop retards movement of loose grain and gives the rotor a second chance to deliver it into the header. Percentage of grain losses are higher in short, thin, droughty wheat. At four miles per hour ground speed, increasing wheat yield from 30 to 90 bushels per acre can reduce losses from about 5.5 percent to just under 3 percent. The greater header loss from stripper headers, relative to conventional headers, is offset by lower separation and cleaning losses and larger combine capacity.

Losses from a stripper header are usually reduced by *increasing* the ground speed. Increasing ground speed from 2.3 to 5.4 miles per hour can reduce losses from about 7 percent to just over 4 percent. Most new operators of stripper headers require a day or two of experience to accept this counterintuitive trend (higher speeds producing *less* grain loss).

### Draper Headers

Draper swathers have always been popular in the northern plains because they gently swath wheat, but more recently they have become popular for combines. There are several advantages of draper headers over auger headers in wheat.

First of all, wider models are available in draper configuration. Auger headers over 30 feet wide are rare due to problems with auger runout and thermal warping. Because draper headers eliminate the table auger, they can be substantially wider than flex or rigid headers. This is important because the 30 foot header size limit has become a limiting factor, given the recent increase in combine threshing, separation, and cleaning capacities. Unacceptably high ground speeds may be needed to compensate for the limitations of a 30 foot header on a large combine in typical Great Plains wheat.

Draper headers feed the crop more uniformly than auger headers. With an auger header, there is a space just behind the cutterbar and in front of the auger where the crop is not in contact with either the reel or the auger. Also, the orientation of the crop entering the feeder house is random. In contrast, a draper header reel delivers the cut crop directly onto the draper which moves it laterally onto a center draper. The center draper then moves rearward into the feeder house. Draper headers tend to feed the wheat plant head first into the threshing element of the combine, resulting in smooth feeding that increases the degree of capacity 20 to 30 percent.

The wider models of draper headers commonly incorporate suspended outrigger wheels and an integral means of transport. In some cases, the conversion to transport mode involves changing the wheels from field position to transport position and repositioning a hitch tongue. The rapid, easy conversion from field to transport is an important feature for custom harvesters.

## **Combine Sensors and Control Systems**

Today's combines are more complex than those from just a few years ago. Although general combine design and processes have changed little, there have been many recent advances in sensors and control systems. Steering and speed control systems are relatively new. Yield monitors and protein sensors to gather data regarding crop production are also newly available. The industry will continue to see such advances as we attempt to automate repetitive harvest tasks.

### **Header Control**

Some of the earliest control systems for grain combines were developed for the header. Automatic reel speed control systems adjust reel speed relative to ground speed to maintain uniform crop flow into the header. Proper reel speed adjustment will reduce potential shattering of grain and header loss. These automated systems maintain the reel speed to ground speed ratio as the combine operator makes ground speed adjustments.

Header height control systems are common in soybean production and are gaining popularity in wheat as grain platforms have become wider. These systems maintain the header at constant height from the ground. In severely sloped terrain, the standard system may keep one end of the header from hitting the ground while raising the opposite end out of the wheat crop. In combines equipped with a tilting feeder house, the operator also can control header tilt, which maintains the entire header at the desired height across rolling terrain.

## Automatic Steering Systems

Guidance systems for tractors and sprayers that use Differential Global Positioning System (DGPS) receivers to reduce skips and overlaps are becoming more common in the Great Plains. Reducing operator fatigue is the primary benefit of these systems on combines. Removing the need to steer reduces stress and frees the operator for other tasks. Generally, DGPS guidance systems are limited to straight lines, but recent advances in laser scanning guidance may be applicable in wheat harvesting. A laser scanner would examine the crop ahead of the combine and make steering adjustments to keep the header full even if this requires an irregular path. This should result in increased productivity and reduced operator fatigue in solid seeded crops like wheat.

## Speed Control Systems

Similar to cruise control on cars, combine speed control systems adjust ground speed to maintain the desired material flow through the combine. Good combine operators do this intuitively, but it can be challenging to adjust speed in response to subtle changes in crop density. A speed control system uses sensors in the combine to measure capacity or load. When engaged, it will control ground speed to keep the combine fully loaded, increasing potential capacity by 5 to 15 percent.

## Yield Monitors

Yield monitors are common in the Corn Belt but are used less in wheat producing areas. Basic yield monitor components are flow, moisture and field speed sensors, a DGPS receiver, a processor, and a display. **Flow sensors** measure the mass or volume of grain flowing through the clean grain system. The most common design in wheat producing regions is an impact flow sensor mounted in the clean grain elevator. An initial calibration for wheat is required in the first season, but then can be simply checked in following seasons. To calibrate, compare the yield monitor reading for one load to the measured mass from a reference scale, which can be a weigh wagon or the scale at a local elevator. Some yield monitors may require multiple loads for accurate calibration, which should be at different flow rates. The yield monitor also will require separate calibrations for other crops.

The **moisture sensor**, a popular yield monitor component, also requires initial calibration. Compare the sensor moisture reading to that from a reliable moisture meter, and apply an offset so that they match. The combine operator can now assess grain moisture instantaneously. This facilitates decisions such as whether to keep harvesting and whether the grain needs more time to dry.

Sensor data are used to calculate yield, which the **DGPS receiver** allows us to map. Major uses for yield maps include diagnosing crop production problems, conducting on-farm research, and determining spatial yield potential. Most producers know where the good and bad spots are in their fields, but the yield monitor allows them to measure and map problem areas. The producer who uses custom harvesters does not get to ride the combine and see the yield variation, so the yield map may be the only available feedback on production problems.



Most farmers have conducted some type of on-farm research by measuring yields with a weigh wagon or by sending partially loaded trucks to the elevator, which can seem overwhelming in the rush of harvest. Yield monitors allow seamless yield data collection without impeding harvest. Farmers can develop yield potential maps from multiple years of yield monitor data, which can be used to guide input decisions for future crops.

Data from the yield monitor, moisture sensor, and DGPS receiver can be integrated into maps, showing specific yield and grain moisture performance of different sections of the field. These maps can be combined with soil type maps and fertilizer application maps to improve management of the crop. In addition, most field mapping systems allow the combine operator to insert notes (map 'flags') in the map, which can be used to locate particular weed infestations, broken terraces, drainage problems, or other visible areas of interest.

### **Protein Sensors**

The development of accurate combine mounted protein sensors, used to create grain protein maps, is ongoing. Protein sensors could be used to segregate grain based on protein content or to establish nitrogen management zones. While protein measured with combine mounted sensors is correlated with laboratory measurements, sometimes the correlation is not strong enough to allow grain segregation. However, there was sufficient correlation to delineate nitrogen management zones. As with any sensor, calibration is a necessity.

Sensor and control system technology for combines continues to advance. More sophisticated control systems will evolve as more sensors are developed and improved. These systems will ease the workload on combine operators but will likely alter, if not increase, the skill required to operate a wheat combine.

### **Straw and Chaff Spreading and Chopping**

The question of whether to windrow or spread the straw and chaff that is discharged from the combine is answered by the goals of the overall cropping system. In some systems, the straw is simply a nuisance in the field and provides income if packaged and removed from the field. In other systems, the residue provides soil surface cover, reducing soil erosion and improving conservation of soil water. In either case, the success of the overall system often depends on how uniformly the straw and chaff are distributed behind the combine or how well the windrows are made to accommodate complete pickup by a baler or other pickup equipment.

Most experienced no-till or conservation tillage producers will say that their production system begins with uniform distribution of both the straw and chaff behind the combine. Problems associated with uneven residue distribution can include:

- Plugging of tillage equipment and bunching of residue (if tillage is used).
- Plugging of planting equipment.
- “Hair pinning” of residue into the seed furrow and inadequate seed-soil contact.
- Too much residue in one area shielding soil from the sun, or too little residue in another area exposing the soil to water evaporation and erosion.
- Concentrations of residue shielding the soil and weeds from herbicide application.
- Weed and volunteer wheat control difficulties in concentrated windrows.

Generally, chaff and fines are more of a problem to spread uniformly than the long straw. Straw tends to be “heavier” and is easier to move mechanically or with air. The quantity of chaff and fines can be significant and pose a large problem if not spread.

Approximately 10 bushels per acre of wheat is associated with about 1000 pounds per acre of above ground residue. Of this residue, approximately half is cut by and taken into the combine. Of the material that passes through the combine, 30 to 70 percent drops from the sieves as “chaff” and never reaches the straw spreader. For example, if we assume a 40 bushels per acre grain yield and 50 percent of the material passing through the combine is chaff, then there will be approximately 1000 pounds per acre of chaff discharged by the combine. If that is distributed over half the combine header width, there would be 2000 pounds per acre chaff cover where the chaff lands. If the chaff is only distributed over  $\frac{1}{4}$  the width of the header (8 ft. windrow behind 35 ft. head), then the concentration of chaff would be 4000 pounds per acre. This is an excessive residue concentration.

Roughly 2000 pounds per acre of residue can provide significant benefits in reducing soil erosion and soil water evaporation. However, if this residue amount covers the planted row of an emerging crop it can have negative effects, such as reducing soil temperature or causing an allelopathic effect that hinders normal development of the crop seedling. ***Uniform distribution of the residue behind the combine can contribute significantly to the success of no-till and conservation tillage systems.***

Complete, uniform distribution of straw and chaff behind the combine can be very difficult to achieve, but perfect distribution is not necessary. Several practices can help:

- Leave stubble as tall as possible. Less material going through the combine means less material to spread uniformly.
- Avoid stopping the combine in one spot. If you need to stop the forward motion of the combine, keep the combine moving in reverse or in a circle over the harvested stubble until it cleans out. This will avoid a large pile of residue.
- If wind prevents good side-to-side distribution, change combine directions if possible.
- Experiment with any adjustments, such as to deflectors, to the side and to the rear that might help residue distribution, particularly in windy situations.
- Examine the spreader mechanism for wear (including bats, spinning disks, and flails).
- Try any options for speed of rotation of the spreader mechanism.
- Consider a stripper header which will leave all the straw attached to the soil and will reduce the amount of chaff and fines that need to be distributed.

If removing the wheat straw from the field is the goal of the cropping system, then attention must be given to making a windrow that will best accommodate the baling or packaging equipment. Avoid aggressive threshing to minimize breaking the straw into short pieces, which do not maintain good bale shape. Rotary combines generally break the straw into much shorter pieces than conventional cylinder machines. Some producers who focus on baling wheat straw choose custom combiners with conventional cylinder machines. Certain adjustments, particularly close concave settings, tend to break straw into small pieces in combines with rotary threshing systems. Rotor cage vanes can be adjusted in some machines to move the straw through the rotor more quickly to increase straw length, but at the risk of increased rotor grain loss.

Keep windrows as narrow as possible to match the pickup headers on balers. Some of the fines and chaff from the sieves will be picked up by the baler but much will often be too fine to be picked up. What is left may create a dense residue that can create problems in the following crop. To avoid this problem, producers may need to windrow the straw but spread the chaff and fines.

Some producers do not want windrow or distributed long straw left behind the combine, and it is preferred to chop the straw into fine pieces and spread over a wide area. Straw choppers are now available that can chop the straw into very fine pieces and spread this material uniformly over a 30 foot width (in the absence of wind) to allow the straw to break down rapidly.

## Estimating Wheat Harvest Losses

Check the combine frequently to ensure efficient harvesting. During a single afternoon, conditions can change enough to require resetting some of the machine's components. Ground counts are based on the general rule that it takes about 20 kernels of wheat per square foot to equal one bushel per acre when spread evenly across the field.

Although ground counts are a simple concept, finding all the loose kernels lying in stubble can be tedious, particularly if heavy residues remain from the previous crop. Many producers train a truck or cart driver to perform initial ground counts, so the combine can keep harvesting during the count. The only equipment needed to check losses is a one square foot frame. Follow these steps to determine losses:

1. Cut through a typical area at the usual speed, then stop the combine and back up about 20 feet.
2. In the area behind the separator discharge, lay the one foot square frame down three times and take ground counts, including both loose and unthreshed kernels. Average the three counts to get the **separator count**.
3. In the area between the cutter bar and the standing wheat, take three more ground counts and average them. Do not forget to look for heads. This is the **header count**.
4. Take a final three ground counts in the standing wheat and average them. This is the **preharvest count**.
5. Calculate **header loss** in bushels per acre.

$$\text{Header loss} = \frac{\text{Header count} - \text{Preharvest count}}{20}$$

6. Calculate the **separator loss** in bushels per acre.

$$\text{Separator loss} = \frac{\text{Separator count} - \text{Header count}}{80}$$

Since header width for most combines is about four times as wide as the separator, it takes about 80 kernels per square foot behind the separator discharge to equal one bushel per acre if no spreading devices are being used. If your combine has a bat type spreader, use 65 kernels per square foot instead of 80. If you have a straw chopper, use 50 and if you also have a chaff spreader, use 25.

**What are acceptable losses?** This depends on the operator and the condition of the crop. However, for standing wheat under good harvesting conditions, machine losses can usually be held to two percent of the total yield. Higher losses will have to be tolerated in downed or damaged wheat.



## Combine Settings

The best source of information on combine adjustment is the operator's manual for the specific combine model being used. With the intent of reinforcing and supplementing the manual, the following adjustment principals and guidelines are offered.

### Header Height

Height of cut is a frequent adjustment during wheat harvest and has a substantial impact on harvest loss, combine capacity, operating cost, and even subsequent crop yields. In general, the cutter bar height should be set as high as possible without missing more than a few of the lowest heads. Uniformity of head height varies with variety and growing conditions, but a three year study of nine varieties in Fort Collins, Colorado suggested that a cutting height of  $\frac{2}{3}$  the average head height would result in a loss of less than 0.5 percent. Low heads usually contain less grain than average.

In wheat, material other than grain (MOG) usually drives separator loss, so taller stubble will increase combine capacity and reduce fuel consumption per acre. Fuel savings of up to 30 percent can result from higher height of cut, while staying within permissible loss limits. In addition, taller stubble reduces straw-handling problems for subsequent cropping systems, particularly if a double crop is planted immediately after wheat harvest.

Taller stubble reduces evaporation. Increasing stubble height from 4 to 20 inches can reduce potential evaporation by about 40 percent, at a stem density of 170 stems per square yard. Increasing wheat stubble height from 4 inches to 10 inches can increase subsequent no-till corn yield from 40 bushels per acre to nearly 65 bushels per acre. Corn and grain sorghum can yield five bushels per acre more following stripped wheat.

Taller stubble improves wildlife habitat. Increasing the stubble height from 9 inches to 18 inches produced a nearly nine-fold increase in winter pheasant populations in western High Plains wheat.

### Combine Speed

Travel speed is another frequent operator adjustment. With conventional cylinder combines, the straw walkers are usually the first component of the separator to overload. This becomes evident only if a loss monitor is used correctly. Grain yields have large spatial variations, so frequent changes in combine travel speed are needed for best performance. Generally, rotary combines are less susceptible to separator overload caused by excessive speed or MOG input.

### Combine Adjustments

Adjust table auger finger timing to achieve smooth feeding into the feeder house. Fingers should be adjusted to extend later when harvesting light droughty wheat. Finger timing is usually adjusted by rotating a plate on the undriven end of the table auger (see owner's manual).

Adjust table auger strippers as close as practical to the auger flighting. Care must be taken to allow clearance for auger run out, including the transient thermal warping that can be caused by direct sunlight. Wider headers require more clearance between auger and strippers. Floor strippers are recommended when available.

Set cylinder or rotor speed and clearance to thresh the crop no more than needed to dislodge the grain and separate it efficiently. Overthreshing wastes power and can crack grain, overload the cleaning shoe, impede baling the combine discharge, and lead to rapid wear of concaves, bars, and drive systems. Cracked grain usually is caused by excessive cylinder speed rather than insufficient cylinder-concave clearance.

Most combines sold in the Great Plains are “corn-soybean” models, because the penalty for using such a combine in wheat is less than the penalty of using a wheat combine in corn and beans. However, wheat growers may find it advantageous to exchange the 1½ inch louvered corn-bean chaffer for a 1¼ inch wheat chaffer. Fixed air-foil and adjustable Peterson chaffers are also available for most machines and should be considered, especially if the combine is also used in canola.

### Harvesting Infested Crops

Winter annual grasses are best managed by herbicides and crop rotations, but to harvest an infested crop, the following practices are suggested:

1. Harvest heavily infested wheat fields last to give the weedy grasses time to dry.
2. Set the chaffer toward the open end of the recommended range.
3. Set the cleaning sieve toward the closed end of the recommended range.
4. Set the fan toward the high end of its recommended range.
5. Be watchful for excessive return and make adjustments as needed.
6. Manage combine traffic patterns. The combine can carry weed seed for over a minute, potentially spreading seed from an isolated infestation over a wide area.

### Moisture Docks

Be prepared to take a modest moisture dock at the beginning of harvest. Many farmers wait until wheat dries to the point that it is accepted into commercial channels with zero moisture dockage before beginning harvest. If the wheat harvest is long, this can result in very dry (less than 10 percent) wheat during the last days of harvest. Over dry wheat represents lost income as surely as the moisture dockage that would have occurred with an earlier start date. A balanced approach, accepting a modest moisture dock at the start of harvest, results in earlier harvest completion, less weather exposure, and improved double-cropping potential.

## Soil Compaction from Combines and Grain Carts

Combines and grain carts are usually the heaviest equipment items on a field. Large combines with wide headers and 300 plus bushel grain tanks can have total loaded weights approaching 60,000 pounds. Grain carts are now as large as 1400 bushels and can have loaded weights of nearly 100,000 pounds. If not equipped with properly designed tire or track systems, these high loads can potentially cause serious soil compaction, which will negatively affect future crops.

Combine or grain cart weights as high as 60,000 pounds or even 100,000 pounds do not necessarily cause soil compaction. There are several factors which will determine whether these, or even much lower implement weights, will cause soil compaction.

### ***Soil moisture content***

As soil moisture content increases, the ability of the soil to resist mechanical deformation or alteration in structural integrity decreases, making soil compaction more likely. When the soil is “too wet,” it is best to simply stay out of the field.

### ***Repeat traffic***

Soil compaction can accumulate with repeat passes of a tractor or implement. One pass might be sufficient to create only a low or moderate level of soil compaction. Repeated traffic by the same implement over the same path will increase the level of soil compaction. Avoid repeat traffic where possible, or intentionally designate a driveway to limit the area of soil compaction. Generally, most soil compaction below the soil surface will occur on the first pass.

### ***Soil-to-tire or soil-to-track pressure***

It is not necessarily the total weight of an implement or the axle load that can cause soil compaction. Instead, it is the pressure of the tire or track surface to the soil. This soil contact pressure can be managed to avoid soil compaction by using “enough” tire or track to support the axle or implement load.

## **Avoiding Soil Compaction**

Contact pressures between the tire or track and the soil of less than about 10 or 12 pounds per square inch (psi) rarely will cause soil compaction in most field conditions, unless the soil is very wet or very loose. In contrast, contact pressures above 30 or 40 psi will often cause some level of soil compaction, again depending on several factors. Whether soil compaction will be caused by contact pressures between these two general pressure levels will depend on many factors, primarily soil water content and tillage condition.

We can address the soil pressure problem by having enough supported, rubber track on the implement or by having “enough tire” on the implement. For example, a 36 inch wide rubber track with appropriate support idlers and 12 feet of contact length has 36 square feet (5,184 square inches) of contact surface. One track of this size could support 40,000 pounds with an average soil contact pressure of 7.7 psi, which should be acceptable to avoid soil compaction in most cases.

***The effective soil-to-tire contact pressure of a correctly inflated radial tire will be approximately 2 psi higher than the inflation pressure.*** Most modern radial tractor and combine drive tires, and some implement load bearing tires, are designed to operate as low as 6 psi with a designated maximum axle load. To apply this rule, we must consult a tire handbook (available at tire dealers or on the tire manufacturers’ websites) and specify enough tires and large enough tires to maintain a recommended inflation pressure below 8 or 10 psi (or at least as low as practical) for the actual axle load. In reality, with very high axle loads possible with the largest combines and grain carts, it is difficult to specify enough large tires to achieve the desired low inflation pressures. Large belted track systems may offer better floatation.

Avoiding soil compaction with very large combines and grain carts is a real issue with wheat harvest. A combination of management tools can prevent soil compaction in almost all cases:

- Stay off very wet fields when possible—allow a day or so to dry.
- Avoid repeat traffic, or create a small area for designated traffic.
- Keep tire or track-to-soil contact pressure below 10 psi or at least below 15 psi.
- Use wide belted tracks or large radial tires with low inflation pressure to achieve needed floatation.
- If the soil is too wet or other conditions suggest soil compaction may be occurring, only load the combine grain tank or grain cart half full to reduce axle weight and track or tire-to-soil contact pressure.
- Judicious ‘spotting’ of trucks, providing multiple field access points and unloading prematurely when the combine is close to the truck, can often reduce combine and cart travel.
- Local band radios enhance management of grain carts to avoid unnecessary travel of both grain carts and combines for unloading.

New technologies in the various forms of machine design, sensors, controls, and management techniques allow the wheat producer to maximize wheat yield, reduce input costs, and conserve natural resources as the wheat crop is harvested. These new harvest technologies will continue to evolve and allow the wheat producer to maximize productivity, profitability, and sustainability.





## CHAPTER 12

# Storage Practices

*By Tom Phillips*

The majority of wheat harvested in the Great Plains is managed through a network of grain elevators from which it is either processed, exported, or stored. Only about 20 percent of the crop is stored on farm. Grain is in its best condition at the point of harvest, but the impacts of harvesting, moving, and storing will ultimately lower the quality and marketability of grain. The objective of stored grain management is to slow or deter this loss of quality so that grain can attain its highest potential market value.

### IPM and Safe Grain Storage

An integrated pest management (IPM) approach can be adopted for storage of wheat just as it is being adopted for production. IPM of stored wheat requires the grain elevator, or producer with on-farm storage, to be knowledgeable about the pests of stored grain, the conditions of the grain, and the storage structures. The key to safe storage of grain is to store clean, dry grain in insect-free structures and maintain grain temperatures as cool as possible. Such ideal conditions are difficult to achieve in some Great Plain regions, such as Oklahoma. However, we are fortunate that the climate in Oklahoma facilitates proper drying in the field before harvest in most years, since wheat moisture content should be below 13 percent for safe storage. The practice of stored grain IPM integrates the use of preventive measures to avoid pest problems by monitoring insect levels and grain condition, cooling grain with aeration to slow infestations, and using effective chemical pesticides when needed to avoid economic impacts due to infestation.



**Figure 12.1**  
Small grain storage  
bins in Fort Collins,  
Colorado.

**Figure 12.2a**  
(left)

The lesser grain borer.

**Figure 12.2b**  
(right)

Damage to kernels caused by the lesser grain borer's feeding habits.



## Storage Pests

Insect pests infesting stored wheat fall into one of two categories based on their feeding habits—internal or external feeders. Internal feeders are those whose larvae feed on the inside of grain kernels and bore holes through grain, such as the lesser grain borer (*Figure 12.2a & b*) and the rice weevil (*Figure 12.3*). Because these two species contribute to the grading factor of “insect damaged kernels,” or IDK, they are considered serious economic pests. In fact, the lesser grain borer is the most serious pest of stored wheat in the Great Plains.

**Figure 12.3**

The rice weevil.



**Figure 12.4**

The rusty grain beetle.



On the other hand, external feeders are unable to penetrate the seed coat, either as adults or larvae, and make their living by feeding on broken kernels, grain dust, fungi, and most forms of milled grain products (such as flour and feed). Although external feeders do not contribute to IDK, grain will be designated “infested” if two or more live specimens are found in a sample when graded (discovery of dead insects does not result in the designation “infested”). One of the most common external grain feeders in the Great Plains region is the rusty grain beetle (*Figure 12.4*), which is relatively small compared to the next most common insect, the red flour beetle (*Figure 12.5*). Other external grain feeders of importance include the sawtoothed grain beetle (*Figure 12.6*), the hairy fungus beetle (*Figure 12.7*), and the Indianmeal moth (*Figure 12.8*). The worm-like larvae of the Indianmeal moth can cause problems when high populations deposit large amounts of silk on the top of grain, which in turn blocks aeration and causes grain heating and molding.





**Figure 12.5 (left)**  
The red flour beetle.



**Figure 12.6 (right)**  
The sawtoothed grain beetle.

However, not all insects in grain are pests, since all those previously mentioned may be attacked and killed by various species of predators and parasites that may also occur in the grain. These natural enemies actually help to regulate, and sometimes reduce, populations of pest insects. If an unknown insect is found in grain, the specimen should be directed to your local cooperative extension office for identification.

Problems with non-insect pests can also occur, but most are not as prevalent or persistent as those with insects. Some species of fungi (mold) can build up on high moisture grain and may cause problems with the production of mycotoxins. However, the hot, dry conditions in most Great Plains wheat storage facilities preclude serious problems with fungi. In addition, vertebrate pests such as birds, mice, and rats pose a constant problem for most grain managers because they eat the grain and also contaminate it with hair, feces, and urine.



**Figure 12.7 (left)**  
The hairy fungus beetle.



**Figure 12.8 (right)**  
The Indianmeal moth (adult and larvae stages).



## Sanitation and Structural Maintenance

Maintaining storage structures that are clean and secure is the cornerstone of pest prevention in stored grain IPM. The primary source of new infestation is insect breeding in grain from a previous storage season. Storage pests must have dried grain or grain debris in which to live and reproduce. Spilled grain, grain trash, or carryover grain left in a bin can serve as breeding material for insects and a source of infestation on new grain. Since stored grain pests do not breed on wheat growing in the field, they do not enter storage facilities with the new crop when it is stored. However, most grain pests are good fliers and can move from bin to bin and farm to farm, and enter grain bins or silos through any number of small openings.

Harvesting and transportation equipment must be cleaned prior to harvest because residues of old grain and grain pests can contaminate the new grain before reaching the bin. All empty bins, silos, and flat storage structures should be completely free of old grain before the new crop is stored. Prior to storage, grain managers need to go inside round steel bins and flat storages and thoroughly sweep and remove as much old grain and debris from floors and side-walls as possible. Old grain in concrete silos should also be removed and structures similarly cleaned if access is available.

Since it is impossible to clean every last bit of grain from empty bins, additional protection can be achieved by spraying the inside surfaces of bins with an appropriate residual insecticide. If substantial carryover grain exists (that from a previous crop), it should be consolidated into one or more bins and monitored carefully or treated appropriately. ***Never store new grain on top of old.*** Loose grain around the outside of bins, and on floors in the basements and galleries of concrete houses, should be cleaned immediately after it is spilled. Volunteer wheat and other vegetation growing around bins should be removed because it can harbor insects and rodents.

All grain-moving equipment, including bin walls, roofs, doors, and hatches, should be in a good state of repair. Once a bin is full it is extremely difficult to perform repairs on load-out augers or conveyors. Holes in roofs leave grain susceptible to rain water, and wet grain can sour readily and support high levels of mold and insect infestation. Large openings from inoperable doors or hatches can allow entry of more immigrating insects than would typically occur through smaller openings. Additionally, closures should be made as tight as possible so they can be properly sealed in the event of a fumigation treatment to the structure.

## Monitoring

Monitoring, also referred to as “scouting” when discussing field crop production, is very important in IPM because it is the only way to gain valuable information that will facilitate control or management decisions. Once new grain is safely stored in a relatively insect-free structure, it must be monitored regularly for pest problems, or the potential for pest problems. Three factors that should be monitored in stored grain are grain temperature, grain quality, and insect density.

## Grain Temperature

Temperature is important because cool grain, that which is less than 60°F (16°C), will prevent excessive growth of insect populations, while increasingly higher temperatures will allow populations to flourish. Large commercial storage structures—whether flat storage buildings, round steel bins, or concrete silos—should be equipped with temperature monitoring cables that can provide the manager with a profile of grain temperatures throughout a grain mass. Temperature information is transmitted electronically from each thermocouple to a reading device that allows the user to record temperatures and thus keep records over time.

Whether grain temperatures are high or low at a given time, it is desirable to maintain fairly uniform temperatures throughout a grain mass and to observe only small changes from week to week. When a thermocouple, or two or more closely situated thermocouples, read five or more degrees higher than the others in a bin for two or more consecutive weeks, the manager has reason to suspect grain heating from some pest or moisture problem. Such grain temperature “warning signs” suggest that managers should turn the grain or treat the grain to break up the hot spot(s).

It is also important to monitor the change in grain temperature during the course of aeration cooling or through passive seasonal cooling or warming. In the absence of temperature cables, a grain manager can check grain temperatures directly by manual inspection. A protected mercury thermometer mounted on a probe can be inserted into grain, or an inspector can determine temperature in the top three to four feet of the mass by simply touching the grain with the hand and arm.

## Grain Quality and Insect Density

Direct inspection of grain samples, as with remote sensing of grain temperature, is an important monitoring activity because additional information for pest management decision-making can be gathered. Grain samples should be taken from several locations throughout a storage structure at monthly intervals to count the number and species of insects, if any are present, and to assess grain quality. Grain samples can be collected from standing grain using either a deep cup probe sampler or a long, spear-like grain trier. A kilogram or more (over two pounds) of grain from each sampling point is adequate for making an assessment; and as many samples as possible should be taken from each structure.

Steel bins and flat storages allow access to the top of a grain mass where samples can be taken. Take appropriate safety measures when entering a confined space such as a grain bin; do not work alone. Concrete silos present problems for collecting grain samples, although samples from the bottom of the silo can be taken in most facilities by accessing grain at the hopper bottom. Some silos are full enough to allow for deep cup or probe samples to be taken from the top. Once obtained, a grain sample should be sieved thoroughly to remove any insects. Any insects found should be identified, counted, and recorded to observe monthly trends. Presence of external feeding insects in dry, otherwise sound wheat, are not cause for serious alarm. However, the presence of the grain-damaging internal feeders should warrant further inspection.

Insects can also be monitored using grain probe traps. Probe traps should be inserted into the top of a grain mass and checked weekly or biweekly. Probe traps do not use attractants, but simply capture insects that are moving through the grain. Capture will depend on the species of insect, the total number of insects in the grain, and the grain temperature. Numbers of insects caught in grain probe traps can not be converted into insect densities, such as the number of insects per bushel that can be determined from grain samples, but probe-trapped insects can inform the manager about the species present and population trends over time. It is possible to capture hundreds of non-grain damaging, external feeding insects in probe traps over a one to two week period in the summer without need for a control action, provided that other indicators suggest the grain is in good condition. However, the capture of one or more grain damaging insects, particularly the lesser grain borer, should alert the manager toward further investigation and possible control.

Grain quality should be assessed from samples with the best methods available. Dampness, off-odor, or moldy appearance are immediate signs of wet, deteriorating grain. Other quality factors include moisture content, test weight, dockage, and presence of IDK. Test weight and dockage information from in-bin grain samples will aid the manager in marketing decisions, while the presence of high moisture grain and any level of IDK can signal a pest problem. Consistent findings of grain damaging insects (borers and weevils) and IDK should be a trigger for a control action, such as fumigation.

## Aeration

Aeration fans should be used to cool grain with outside air once the air temperature drops considerably below that of the grain temperature. Cooling grain will not kill insects outright, but it will substantially slow their growth and development. For example, grain insects held at temperatures below 65°F (18°C) will feed and grow very little, and their eggs will take months to hatch.

Aeration fans at the base of bins should be directed to blow out and draw cool air down (suction mode) through the grain mass from vents in the roof. Intake aeration from the bottom, or blowing mode, is appropriate only if an adequate number of roof vents, some equipped with exhaust fans, are in place and operating to carry moisture out of the bin. Air flow rates of 0.1 to 0.5 cubic feet per minute per bushel (cfm/bu) are recommended for wheat at normal moisture contents and can be achieved by matching fan motor power with the depth of grain being aerated (*Table 12.1*).

In some Great Plains regions, the most effective grain cooling by aeration occurs in the late summer and early fall, when nighttime temperatures fall below 60°F (16°C). At this time fans should only be left on at night and not during the day when air temperatures may still be in the high 80s and 90s. Aeration fans need to run for several consecutive nights in order to cause a significant lowering of grain temperature. The exact number of accumulative hours will depend on the amount of grain being aerated, the depth of the grain in the bin, airflow rates of the fans, and the difference between grain and air temperatures. Automatic aeration controllers can be installed on fan motors that will turn fans on when the outdoor temperature goes below a given

**Table 12.1**Approximate aeration fan horsepower required per 100 bushels of wheat.<sup>1</sup>

Grain Depth (ft)	Cfm/bu <sup>2</sup>		
	½	¼	1/10
15	.47	.11	.04
20	.79	.20	.05
25	1.26	.30	.07
30	1.92	.45	.08
35	2.79	.65	.01
40	3.68	.87	.14
45	5.16	1.16	.16
50	6.33	1.34	.19
60	9.55	2.06	.28
70		2.82	.39
80		3.64	.50
90		4.95	.66
100			.79
110			1.04
120			1.27

<sup>1</sup>Total horsepower for all fans on a single bin.<sup>2</sup>Air flow rate in cubic feet per minute per bushel of wheat.

set point, and will turn the fans off when the outdoor temperature exceeds the set point. Controllers can also record the number of hours fans are turned on so that the progress of the cooling front can be estimated. Automatic controllers may also allow managers to begin grain cooling earlier in the summer than they might otherwise begin if they were controlling fans manually during the fall.

Winter aeration of grain in the cool months of November, December, or January can be performed both night and day for several days in order to achieve a very cool and safe storage temperature. Such cool temperatures can sometimes be maintained well into the next storage season. Implementation of proper grain cooling with aeration requires several economic and technical considerations by the manager. Consult OSU publications E-912, F-7180, and No. 1100 for details of proper grain aeration.

## Chemical Prevention, Control, and Alternatives

The practice of IPM instructs the manager that the cost of controls, such as application of pesticides, and the cost of pest preventive measures, such as the electrical cost of cooling grain with aeration, must be outweighed by the return in value of the commodity that is protected. In stored grain it is sometimes difficult to determine if an expenditure for pest management will be cost-effective, especially if it is made several months before the grain is sold.



## Residual Insecticides

Residual insecticide sprays for treating grain bins and sprays for direct treatment of new grain while it is loaded into bins are available. For information on insecticides registered for direct application to grain, refer to Kansas State University's "Stored Grain Management Options" found at [www.entomology.ksu.edu](http://www.entomology.ksu.edu).

The use of residual grain protectants is typically limited to high value raw commodities that need protection during several months of storage and for which it is cost-effective to use such material. The decision to use a residual insecticide on stored wheat is an important one that will require information about costs, benefits, and risks. There are very few cases in the Great Plains in which the use of residual insecticides are warranted for direct application to stored wheat.

However, residual sprays can be effective for treating empty grain storage structures. As previously discussed, steel bins, silos, and flat storage structures should be emptied and thoroughly cleaned prior to treatment. The residual spray serves to kill insects that are hiding in the structure and those that enter the bin from outside. Thus, a spray to the inside surface of a grain bin should act like a protective envelope around the grain.

## Fumigants

Fumigation is used to kill insects and stop infestations when insect populations reach undesirably high levels or grain damage is unacceptable. For example, a grain manager may choose to fumigate if grain samples reveal the presence of IDK and probe traps, or other monitoring activities, detect lesser grain borers. Fumigation in this case will stop infestation and grain degradation from getting worse and will allow the manager to then either blend the damaged grain to reduce total IDK or take other action. However, many commercial grain elevators will fumigate grain just before it is sold, whether grain-damaging insects or IDK are present or not, to ensure that no live insects are present when the grain is evaluated by the buyer. Such fumigations can be cost-effective because discounts for infested grain are avoided. Similarly, fumigation at the end of the summer will suppress insect populations in grain stored through the fall and winter. When fumigations are effectively conducted in August or September and are followed by fall and winter aeration, pest populations can be greatly reduced.

Fumigants registered for use on stored wheat are phosphine gas, generated from either aluminum or magnesium phosphide, and methyl bromide. Methyl bromide is expensive, difficult to use properly on raw grain, and is not recommended for stored grain. The fumigant used nearly universally for stored wheat is aluminum phosphide in the form of pellets or tablets. It is sold under the trade names of Weevilcide, Fumitoxin, or Phostoxin. These materials are potentially very dangerous if improperly used or handled. Strict safety guidelines are in place to protect those applying phosphine and those working in areas where phosphine is being used. ***Fumigations must be conducted by licensed applicators who have received specific training in grain fumigation and fumigation safety.***

Phopshine gas requires up to a week to kill eggs, larvae, pupae, and adults of grain insect pests. Effective fumigation treatment requires:

1. A sufficient number of pellets or tablets distributed throughout stored grain to generate an adequate level of gas.
2. Optimal grain moisture and temperature for gas generation.
3. Minimization of leaks in a structure so that gas can be held on the grain for the required time.

Aluminum phosphide generates phosphine gas after it is exposed to moisture in the air. In concrete houses, aluminum phosphide pellets can be added to infested grain as it is being transferred from one location to another. When infested grain cannot easily be moved or turned, such as in large steel bins or flat storages, pellets or tablets should be probed as deeply into the mass as possible, and also distributed on or near the top surface. Phosphine gas is as light as air and moves easily through grain and out of leaks in structures just as smoke would move. Since small amounts of gas are being released from each pellet or tablet, it is important that these point sources be well-distributed throughout a grain mass. However, since the gas has a tendency to move passively upward with convection currents, a larger distribution of pellets in the bottom of a mass is recommended.

For steel bins or flat storages a re-circulation system known as closed-loop fumigation (CLF) should be employed. CLF utilizes a light-duty blower fan with an array of PVC pipes to draw phosphine gas from the top headspace and re-circulate it down to the bottom aeration system of the bin. Gas that returns to the bottom of the bin can then rise through the grain mass and achieve a uniform distribution.

Leaky bins and silos contribute to most of the fumigation failures in stored wheat. Many steel bins and flat storages have numerous leaks and would not meet the minimum levels of gas-tightness for a good fumigation treatment. Concrete silos have potential for being low-leak structures, but they can easily lose substantial amounts of gas before kill is achieved if inter-vents between silos and outside vents are not sealed during fumigation. Phosphine fumigation is a technical operation that should be undertaken only by skilled professionals. Ineffective fumigation can lead to poor insect control and pest resistance to phosphine.

Many other materials and practices are registered for use in killing stored grain pests, but they are not considered here because they are either not widely used or are considered ineffective or inappropriate for most stored wheat situations in the Great Plains region. Research is ongoing worldwide to find safe and effective alternatives to dangerous chemical pesticides and to develop efficient and cost-effective pest management methods. Much of IPM in stored grain involves application of common sense once the manager has a good understanding of the pests and the commodity being managed. Grain managers should maintain a disciplined watch over their grain while it is in storage because it represents a substantial financial investment for them and their customers.

## Resources

**Oklahoma State University Stored Products and Research Education Center (SPREC):**

[<http://entopl.okstate.edu/sprec/>]

**OSU Stored Product Management**—Circular Number E-912.

**Purdue University Post Harvest Grain Quality:**

[<http://extension.entm.purdue.edu/grainlab/>]

**USDA ARS Stored Product Insect Research Unit:**

[www.ars.usda.gov/npa/cgahr/spiru](http://www.ars.usda.gov/npa/cgahr/spiru)

**SmallGrains.Org:**

[[www.smallgrains.org](http://www.smallgrains.org)]

# Winter Wheat Markets

*By Paul Bergener*

The marketing system for winter wheat in the High Plains is well developed and has been in place for more than a century. Hard red winter wheat is a non-differentiated commodity crop that offers the producer very little opportunity to exercise any market power. With little market power, the ability to time sales of the crop—through forward contracting or by using storage and post-harvest sales opportunities—is critical to capturing above average market prices. This chapter will outline the keys to understanding winter wheat markets and lay out a plan for development of a winter wheat marketing plan.

The market for winter wheat in this region is extensive and active in most communities. There are a large number of small communities throughout the High Plains, and in most of them, the grain elevator is the most prominent landmark. Producers have the opportunity to store wheat on the farm or at any number of these area elevators. With the development of increasingly better roadways and the ownership of trucks capable of making longer hauls, farmers are able to market wheat through several elevators within a reasonable hauling distance. For farms with adequate on-farm storage, the market opportunities increase.

Hard red winter wheat is the staple of the dryland farmer throughout the High Plains and is the key crop used in bread making in the United States and many other countries. The crop produced in this region is recognized world wide for its consistency and quality for baking. The United States is the world's largest exporter of wheat, supplying from 20 to 30 percent of the wheat exports in the world. This global market has a significant influence on local High Plains markets, since more than 30 percent of the hard red winter wheat produced in this region is shipped overseas each year.

## Local Elevators

The local elevator remains the key source of price information for many of the wheat producers in the region. Producers can contact the elevator throughout the year for opportunities to market wheat, evaluate storage options, and to set cash prices for wheat. The producer has the options of cash forward contracting or spot pricing on the cash market with wheat that is in storage, either at the elevator or on the farm.

The region continues to have a number of farmers who are uncomfortable with forward marketing wheat and will only sell wheat post harvest. These producers will either sell wheat at harvest time upon delivery, or store the crop and sell later in the year. They will watch the market throughout the year making sales at predetermined dates or as the market presents an attractive price.



Most area elevators have allowed producers to forward price wheat under a cash forward contracting arrangement for delivery at harvest. Typically these arrangements price wheat off the July futures contract and have historically been available for up to two years out. In the spring of 2008, the opportunity to price more than one crop away was taken from producers and has yet to return to most elevators. The cash forward contract is not without risk, as the farmer is committed to deliver wheat at the agreed upon price despite potential crop failure. Most producers who enter into these arrangements will have crop insurance in place to mitigate crop loss from drought, hail, or other unforeseen circumstances that would make it impossible to deliver the wheat under contract.

## **Futures Markets**

Hard red winter wheat is priced off the Kansas City Board of Trade wheat futures market and offers another option for producers attempting to market wheat as long as two years prior to harvest. The futures market is traded daily in Kansas City and allows the farm to hedge wheat that is being produced without the risk of having to deliver a crop if environmental issues cause crop failure. However, there is risk involved with entry into futures market, and this should not be done unless the farmer, his lender, and anyone else involved in the production fully understands the markets and how they work. For those who are willing and able to use these tools, the opportunity to manage market risk with futures and options contracts can help a farm avoid the lowest prices in the market in most years. It is the liquidity that the market offers through the Kansas City Board of Trade that allows the producer the opportunity to sell at any time during the year.

The futures markets also are used by local elevators to offset any cash forward sales that their farmers might make during the year. Once the farmer makes the sale to the elevator, the elevator then will offset that trade by selling a futures contract in the same expected delivery month. This allows the elevator to pass the risk into the market and to offer the opportunity to the farmer to make the sale and pass the risk to the elevator.

## **Marketing Plans**

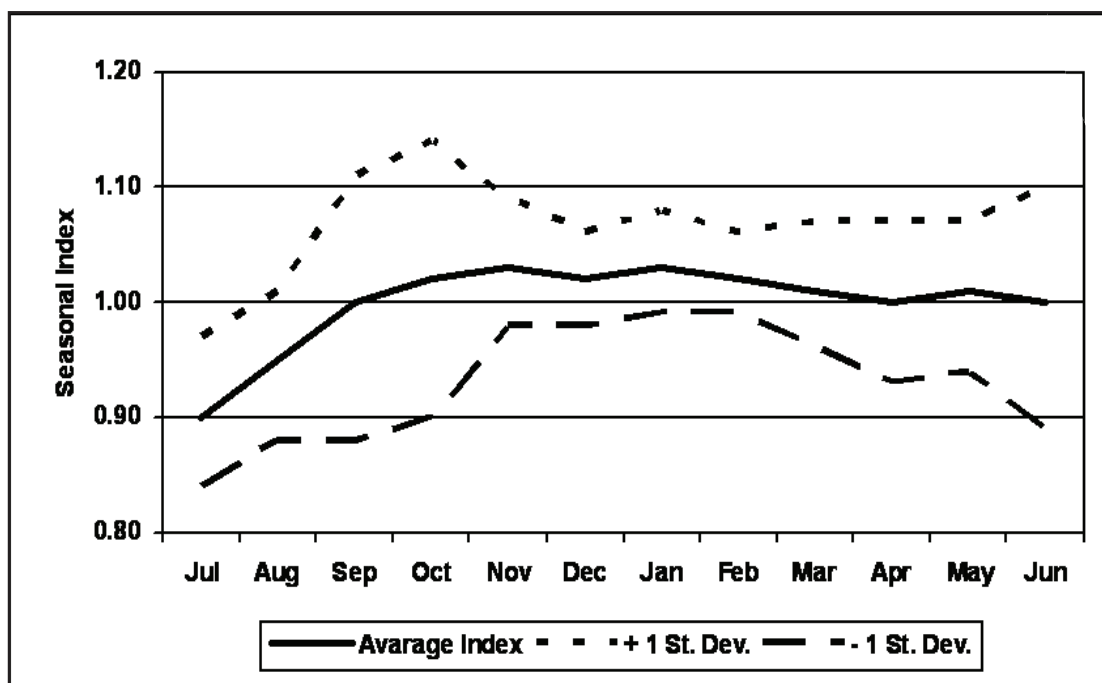
The development of an on-farm wheat marketing plan is a critical part of annual farming strategic plans. There are several critical components to the marketing plan, and it should be reviewed regularly as the year moves along. The development of the marketing plan is only as good as the willingness to follow it and to make sales at the proper times.

The first component of the marketing plan is to determine the cost of production for a bushel of wheat on the farm. It is critical to know both the cash cost and the total cost of producing a bushel of wheat. However, it is possible that in some years knowledge of cash costs is all that can reasonably be expected. In other years, total cost can be determined, and decisions will need to reflect this. Nearly all university extension services in the High Plains have enterprise budgets for winter wheat. These can be used as a guide, but it is critical to understand the actual costs for the farm and use these in the development of a marketing plan.

Once the cost structure is developed, the next step is to decide on how marketing will be completed. Are we willing to sell before harvest? Do I want to get all of the wheat in the bin before selling? Can I store all of my wheat on-farm, or do I need to arrange for elevator storage?

For producers interested in storing wheat and making all marketing decisions post harvest, knowledge of the typical wheat price patterns will be critical. *Figure 13.1* shows the typical annual wheat price index for the region. Selling wheat when the market is typically higher is one strategy used by many producers who store wheat. The key to using this strategy is reaching high enough prices to cover the cost of storage over time. If the storage cost exceeds the price increase, the farm would have been better off to sell wheat at harvest. As noted in *Figure 13.1*, the market for wheat is typically lowest in July as harvest in the southern states finishes up and harvest in the northern states is in full swing. Prices typically rise through the fall and into winter before beginning to taper off in the spring as winter wheat breaks dormancy. The key to marketing stored wheat is to try to find opportunities to market wheat on a daily rally at the seasonal peak, remembering to cover the cost of storage.

Knowing intended sell dates of wheat is critical to the decision-making process, especially when considering crop insurance. If the plan is to sell wheat prior to harvest, then the use of some type of individual crop revenue insurance (Crop Revenue Coverage or Revenue Assurance with the Harvest Price Option) is critical for producers in this high risk production area. These products allow farmers coverage to protect the forward contract commitment. The key to cash forward contracting wheat is to limit exposure to the amount of wheat that is insured (e.g., the crop insurance actual production history (APH) is 40 bushels per acre and the insurance level chosen is 75 percent). Forward contracted wheat should not exceed the coverage of 30 bushels per acre. Producers who intend to sell most of their crop ahead of harvest may actually insure up to the maximum level of 85 percent of the APH.



**Figure 13.1**

The seasonal price index for winter wheat in the High Plains. An index of one suggests average annual price while values above or below one are percentage difference from average (an index value of .90 would be 10% below average). The standard deviation values show the potential variation in the index.

With the timing decision made, the key is to watch the markets closely for opportunities to make sales throughout the year that meet the trigger points in the marketing plan. Typically, the first trigger point will be at break even, either with cash costs or total costs depending upon the range that wheat markets have been trading. Determining the mechanism to use in making sales can be a combination of education, comfort with the markets, risk preferences, lender support, and other factors related to time and knowledge that are individual to each farmer. Futures markets can offer significant opportunities to mitigate risk, but only if used properly with the support of lenders and the assistance of a broker with the best interest of the farm in mind.

Watching the markets closely throughout the year is critical to successful marketing. Knowing what is happening in terms of export markets, world wheat production, exchange rates, and other key indicators will increase the knowledge base and improve marketing abilities.

# Wheat Production and Pest Management

*for the Great Plains Region*

## Technical Editor

Frank B. Peairs

## Copy Editor

Roberta Armenta

## Layout

Roberta Armenta

## Cover Design

Roberta Armenta

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