Integrated Pest Management

MANAGEMENT OF SOFT RED WINTER WHEAT

Plant Protection Programs
College of Agriculture, Food and Natural Resources

Published by MU Extension, University of Missouri-Columbia

$5.00 IPM1022

This publication is part of a series of IPM Manuals prepared by the Plant Protection Programs of the University of Missouri. Topics covered in the series include an introduction to scouting, weed identification and management, plant diseases, and insects of field and horticultural crops. These IPM Manuals are available from MU Extension at the following address:

Extension Publications
2800 Maguire Blvd.
Columbia, MO 65211
1-800-292-0969

CONTENTS

Authors

Shawn Conley, Agronomy
Wayne Bailey, Entomology
William Casady, Agricultural Engineering
Fred Fishel, Agronomy
Bill Johnson, Agronomy
Ray Massey, Agricultural Economics
Peter Scharf, Agronomy
Reid Smeda, Agronomy
Laura Sweets, Plant Microbiology and Pathology
Allen Wrather, Plant Microbiology and Pathology

University of Missouri, Columbia

Note: Bill Johnson's current affiliation is the Department of Botany and Plant Pathology, Purdue University

Photo credits

Photos were provided by Wayne Bailey, Shawn Conley, Fred Fishel, Peter Scharf, Laura Sweets and Lee Jenkins Slide Collection, University of Missouri; David Buntin, University of Georgia; and Harold Gunderson, Iowa State University.

On the World Wide Web

For this and other Integrated Pest Management publications, visit http://ipm.missouri.edu

Production

MU Extension and Agricultural Information
Kathleen Kerr, editor
Dennis Murphy, designer and illustrator

College of Agriculture Food and Natural Resources

INTRODUCTION TO WHEAT MANAGEMENT


Figure 1. Wheat crop at physiological maturity.

Soft red winter wheat is the predominant class of wheat grown in Missouri. This class of wheat is characterized as having a low to medium protein content, a soft endosperm and a high yield potential. The principal use of soft red winter wheat is in the baking industry, where it is used to make cakes, pastries, flat breads and crackers.

Since 1970, Missouri continuously has been ranked as one of the top five soft red winter wheat-growing states. Currently, Missouri ranks third in total production behind Arkansas and Ohio. In 2003, Missouri growers harvested 870,000 acres of wheat with a state average yield of 61 bu/acre.

The environmental variability among the soft red winter wheat-growing regions within Missouri dictates that regionalized recommendations are needed to assess potential crop and pest management issues. Understanding the impact of crop and pest interactions at specific crop-growth stages is important in maximizing crop yield.

The goal of this publication is to provide Missouri growers information with which to make both timely and accurate crop and pest management decisions.

IDENTIFYING CROP-GROWTH STAGE

Accurate identification of crop-growth stage is important in managing winter wheat. Of the cereal grain development scales currently in use, the Feekes and Zadoks scales are the most common. One advantage of using a uniform plant identification system, such as the Feekes or Zadoks scale, is enhanced communication among growers, research and extension faculty, and consultants. These systems also aid in developing precise and timely recommendations that address crop and pest management concerns.

Both the Feekes and Zadoks scales are extremely useful. The Zadoks scale, however, is more descriptive and may prove more valuable in communicating crop-growth stage. The advantage that the Zadoks scale has over the Feekes scale is that more than one descriptive value may be assigned to each plant. For example, if a plant has four leaves and one tiller, the Feekes scale will identify that plant as a Feekes: 2, whereas the Zadoks scale will identify the same plant as Zadoks: 14, 21.

Another example would be if a plant had five leaves, three tillers and one detectable node. The Feekes scale would identify that plant as Feekes: 6, whereas the Zadoks scale would identify the same plant as Zadoks: 15, 23, 31.

The increased precision in describing crop-growth stage may improve crop and pest management recommendations. The most difficult task in describing crop-growth stage is determining leaf number and tiller number. To determine the former, position the plant so that the first true leaf is on the left. Since winter wheat has an opposite leaf arrangement, the next leaf will be on the right side of the plant. The next leaf would be counted only if that leaf were at least half the length of the preceding leaf. This method is continued up the entire stem until all the leaves are identified.

It is important that tillers be differentiated from leaves and counted separately. To distinguish tillers from leaves, look for the presence of an independent sheath called a prophyll, which is

Table 1. Soft red winter wheat crop-growth stages.

Visual description	Zadoks	Feekes
Germination		
Dry seed	00	
Start of imbibition	01	
Imbibition complete	03	
Emerged radicle	05	
Emerged coleoptile	07	
Leaf at coleoptile tip	09	
Seedling growth		
First true leaf	10	1
First leaf unfolded	11	
2 leaves unfolded	12	
3 leaves unfolded	13	
4 leaves unfolded	14	
5 leaves unfolded	15	
6 leaves unfolded	16	
7 leaves unfolded	17	
8 leaves unfolded	18	
9 or more leaves	19	
Tillering		
Main shoot only	20	
Main shoot and 1 tiller	21	2
Main shoot and 2 tillers	22	
Main shoot and 3 tillers	23	
Main shoot and 4 tillers	24	
Main shoot and 5 tillers	25	
Main shoot and 6 tillers	26	3
Main shoot and 7 tillers	27	
Main shoot and 8 tillers	28	
Main shoot and 9 or more tillers	29	
Stem elongation		
Pseudostem erection	30	4-5
1st detectable node	31	6
2nd detectable node	32	7
3rd detectable node	33	
4th detectable node	34	
5th detectable node	35	
6th detectable node	36	
Flag leaf visible	37	8
Flag leaf ligule and collar visible	39	9

Visual descripion	Zadoks	Feekes
Booting		
Flag leaf sheath extending	41	
Boot swollen	45	10
Flag leaf sheath opening	47	
First visible awns	49	
Inflorescence emergence		
First inflorescence spikelet visible	50	10.1
1/4 of inflorescence visible	53	10.2
1/2 of inflorescence visible	55	10.3
3/4 of inflorescence visible	57	10.4
Inflorescence completely emerged	59	10.5
Anthesis		
Anthesis begins	60	10.51
1/2 of anthesis complete	65	
Anthesis complete	69	
Mild development		
Kernel watery ripe	71	10.54
Early milk	73	
Medium milk	75	11.1
Late milk	77	
Dough development		
Early dough	83	
Soft dough	85	11.2
Hard dough	87	
Ripening		
Kernel hard (hard to split by thumbnail)	91	11.3
Kernel hard (cannot dent by thumbnail)	92	11.4
Kernel loosening in daytime	93	
Overripe	94	
Seed dormant	95	
Viable seed has 50% germination	96	
Seed not dormant	97	
Secondary dormancy	98	
Secondary dormancy lost	99	

Source: Adapted from J.E. Nelson, K.D. Kephart, A. Bauer, and J.E. Conner. 1988. Growth staging of wheat, barley, and wild oat. MSU Coop. Ext. Ser., Bozeman, Mont., and Univ. of Idaho Coop. Ext. Ser., Moscow, Idaho.

located at the base of each tiller. Unlike leaves, tillers are counted as soon as they emerge.

Once the leaf number and the tiller number have been identified, the subsequent key characteristics to be noted are node formation, flag leaf emergence, boot stage, head emergence, flowering and finally grain development.

To classify crop-growth stage, identify the following characteristics in order (refer to Table 1 for corresponding numerical assignment):

- Number of leaves on the main shoot.
- Number of tillers.
- Number of nodes.
- Flag leaf emergence.
- Boot stage initiated.
- Head emergence.
- Flowering or anthesis.
- Grain developmental stage.

KEY COMPONENTS OF WINTER WHEAT YIELD

To manage a winter wheat crop, it is important to know the key growth stages at which yield potential is determined. The components that directly affect wheat yield are tiller and head number, head size, kernel number and kernel size. Precise timing of crop and pest management practices at these key crop-growth stages will aid in maximizing crop yield.

- Tiller and head number: maximum number of tillers that form heads is determined by jointing (Feekes: 6; Zadoks: 31).
- Head size: head size is a function of the number of kernels per spikelet and is determined from mid to late tillering (Feekes: 3; Zadoks: 25 to 29).
- Kernel number per spikelet: the number of kernels per spikelet is determined at jointing (Feekes: 5-6; Zadoks: 30-31).
- Kernel size: kernel size is determined by resource availability (water and nutrients) and crop health beginning at flag leaf emergence and continuing through grain fill (Feekes: 8; Zadoks: 37).

AGRONOMIC PRACTICES

Variety selection

When choosing a soft red winter wheat variety, several factors must be considered. These include insect, disease and herbicide resistance characteristics and winter survival, as well as heading date, lodging, test weight and yield. Since no variety is ideal for every location, it is important to understand the crop environment and pest complex that affects a specific region in order to maximize yield.

Variety selection begins by choosing a variety that is adapted to the environmental conditions and cropping system that a grower employs. For example, in northern Missouri, it would be important to select a variety that has excellent winter survival, as well as a delayed heading date to decrease the risk of a spring frost that may affect crop yield. In central or southern Missouri, it may prove more important to select a variety that has an early heading date and early maturity date to decrease the risk of an early fall frost that may affect the double-crop soybean yield.

Crop height and lodging potential also are important varietal characteristics that may be affected based on cropping system. If the wheat crop is intended for grain only, it may be important to select a variety that is short statured and has a low potential for lodging. This may decrease yield loss due to crop spoilage and harvest loss as well as increase harvest rate. However, if the wheat crop is to be used as silage or to be harvested as both grain and straw, then selecting a taller variety may be warranted.

Select a variety that has the specific insect, disease and herbicide resistance characteristics that fit the regional needs. By selecting the appropriate resistant varieties, a producer can either reduce or avoid crop yield loss without the need of pesticides. Careful management of resistant cultivars through crop and variety rotation is required to ensure that these characteristics are not lost.

Test weight is also an important factor to consider when selecting a variety. The minimum test weight to be considered, a U.S. #2 soft red winter wheat, is 58 lb/bu. Wheat with a test weight lower than 58 pounds will be discounted.

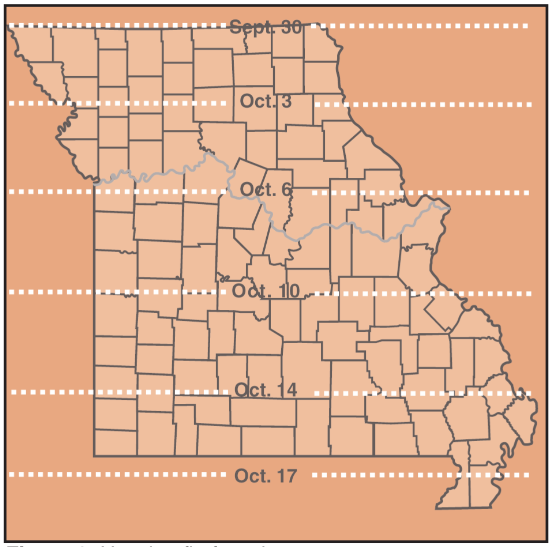


Figure 2. Hessian fly-free dates.

Both environment and pests can greatly affect test weight; therefore, selecting a variety that has a high test-weight potential in your region is critical to maximize economic gain.

Yield is based on the genetic potential and environmental conditions in which the crop is grown. Therefore, by diversifying the genetic pool that is planted, a grower will hedge against crop failure. By understanding the environment and the pest complex in a particular region, growers can make better variety selections, which will increase crop yield.

Seed quality

The next step in maximizing crop yield is to plant clean, high-quality seed that is either plant certified or private seed that is true to variety and has a high germination percentage (greater than 90 percent). Seed size is also an important factor in determining seed quality. Select varieties that have large, dense kernels and a thousand kernel weight (TKW) greater than 30 grams. Wheat seed with TKW values greater than 30 grams tends to have increased fall tiller number and increased seedling vigor.

If saved seed is to be planted, it is critical to clean the seed. Cleaning will remove weed seed, chaff and small and broken seeds, thus increasing seed quality and TKW. It is also important to perform a germination test. If the germination percentage is below 90 percent, increase the seeding rate accordingly; however, do not plant seed with a germination test below 80 percent. If it is known beforehand that seed is to be saved, scout and choose seed from fields where diseases and weeds were minimal.

Planting date

The optimal planting date for soft red winter wheat for Missouri is based on the Hessian fly-free date, which varies at regular intervals from south to north (Figure 2). Planting before this date increases the risk of yield loss associated with Hessian fly damage and also increases risk of aphid feeding and transmission of barley yellow dwarf virus. Planting significantly later than this date increases the risk of poor crop establishment and decreased tiller number, both of which may affect crop yield.

Planting rate and depth

The targeted fall stand for wheat seedlings is between 30 and 35 plants per square foot. To achieve this goal, the planting rate for soft red winter wheat is between 1,300,000 and 1,500,000 seeds per acre. Depending upon varietal seed size (thousand kernel weight), this equates to a range of between 74 and 119 pounds of seed per acre (Table 2). Growers may choose to use the lower seeding rate if planting conditions are ideal. However, increasing the seeding rate under poor planting conditions in no-till production systems or when the planting date is significantly delayed may prove beneficial.

Table 2. Wheat seeding rate in pounds per acre based on thousand kernel weight.

Pounds of seed per acre		
Thousand kernel weight	1,300,000 seeds	1,500,000 seeds
26.0 grams	74.4	85.9
28.0 grams	80.2	92.5
30.0 grams	85.9	99.1
32.0 grams	91.6	105.7
34.0 grams	97.4	112.3
36.0 grams	103.1	118.9

Wheat may be planted ½ to 1½ inches deep, depending upon soil moisture conditions. Wheat planted less than ½ inch deep may result in uneven germination due to seed exposure or dry soil condition. Wheat planted more than 1½ inches deep may result in death due to premature leaf opening or poor tiller development and winter survival. Uniform seed placement and seeding depth are important in promoting crop health in the fall.

References

J.E. Nelson, K.D. Kephart, A. Bauer, and J.E. Conner. 1988. Growth staging of wheat, barley, and wild oat. MSU Coop. Ext. Ser., Bozeman, Mont., and Univ. of Idaho Coop. Ext. Ser., Moscow, Idaho.

J. Hickman, J. Jacobsen, and D. Lyon. 1994. Best management practices for wheat. National Association of Wheat Growers Foundation.

FERTILITY MANAGEMENT

Several key goals for optimizing wheat growth and yield can be addressed, at least partly, through appropriate fertility management. The success of a fertility management program can be judged by how much it contributes to meeting these goals, which include

- Good fall growth.
- An appropriate level of tiller development.
- Rapid and vigorous stem elongation and head development.

This chapter will discuss each of these goals, and how fertility management can help you achieve them.

GOOD FALL GROWTH

Development of a vigorous root system and several healthy tillers per plant in the fall is instrumental in growing high-yield winter wheat (Figure 3). If this fall growth is not achieved, yield potential is reduced and there are no spring management practices that can restore it.

The most important management factors to promote good fall growth are the planting date and seed placement. A successful, well-managed planting operation is the most important component of a profitable wheat system. Fall weather will interact with planting variables to determine the amount of fall growth. When wheat is planted too early and fall weather is warm, excessive growth can occur and the wheat will be vulnerable to winter kill. Late planting is even more undesirable, particularly when fall weather is cold; fall development will be inadequate and the wheat crop will not be primed for rapid spring growth.

Only minimal fertility management is needed to promote good fall growth. A small amount of available nitrogen (N) and an adequate level of soil phosphorus (P) are the main requirements. Nitrogen availability is crucial for good fall growth, but most fields in Missouri appear to have enough N in the soil at the time the wheat is planted to support good fall growth. Research across Missouri showed that only one in eight fields needed fall N fertilizer to achieve maximum yields. A small application of N in the fall, maybe 20 lb N/acre, is recommended to ensure that all fields have enough N to support good fall growth. Often, this N can be supplied as part of a fall P application before planting wheat.

Figure 3. Timely and accurate planting, normal fall weather and a modest level of N and P availability contribute to ideal fall growth.

Phosphorus availability in soil is limited in cold weather. Thus, phosphorus fertility is crucial for good fall and early spring growth in winter wheat. Wheat is thought to be more sensitive to P deficiency than most other crops. University of Missouri target levels for soil test P are set at a level that will easily supply enough P to support the maximum possible growth rate for wheat in the fall. All that is required is to maintain soil test P at an adequate level, which is somewhere near the target level of 45 lb soil test P/acre.

SUPPORTING AN APPROPRIATE LEVEL OF TILLER DEVELOPMENT

One of the most difficult aspects of successful wheat management is achieving an appropriate population. As with all other crops, the established stand density is less than the seeding rate. Unlike other crops, the harvested

Figure 4. A wheat plant with a main stem and three good-sized tillers.

population is not plants, but tillers. Each plant can develop side shoots, or tillers (Figure 4), that will bear heads nearly as large as the head on the main stem. Normal seeding rates are sufficient to produce an optimum harvest stand only if two to three vigorous tillers develop on each plant.

There are two main periods when tiller development occurs: (1) in the fall between planting and dormancy and (2) again for about a month in the spring when the wheat resumes growth until jointing and stem elongation begin. Ideally, the wheat crop should develop two to three strong tillers per plant during the fall, and then no additional tiller development is needed in the spring. Tillers formed in the fall are often more vigorous and yield more than tillers formed in the spring. However, if there are not enough tillers formed during fall growth, then formation of additional vigorous tillers in early spring is critical to attaining good yields.

Tiller development is strongly influenced by nitrogen availability. A small amount of N is needed to support the development of tillers during fall growth. As mentioned in the previous section, there is usually enough N in the soil to support fall tiller development, but it is safer to apply a small amount of N to all fields to make sure that N availability is adequate. On sandy soils, even when fall N fertilizer is applied, a heavy rain within a week or two of planting may wash the N below the root zone of the seedlings. If this occurs, responding quickly with a small additional N application, maybe 20 lb N/acre, could be beneficial. In this situation, if a small additional fall N application is not made, a small application at the beginning of a warm snap (high temperatures above 50 F) during January or February may be beneficial.

If there is a combination of late planting, cold fall weather and inadequate fall N availability, the wheat crop will enter the spring growth period with an inadequate number of tillers. It will be important then to fertilize the wheat as soon as spring growth resumes, a stage that is sometimes called greenup. This is typically around March 1 in central Missouri and somewhat earlier in southern Missouri.

Nitrogen applications at greenup will stimulate the formation of additional tillers and increase yield potential. Fields with an average tiller density below 60 per square foot should receive top priority for early spring applications. A single spring N application at this time is a reasonable management option, but splitting spring N applications is slowly becoming more widely practiced.

One reason is that N applied in early spring can be lost before the period of rapid N uptake, particularly on sandy soils with wet weather. Another reason is that for fields with moderate tiller densities — for example, 70 tillers per square foot — early spring N is needed, but a large N application may actually lead to tiller densities that are too high. Excessively lush growth in early spring can lead to lodging and can make the crop more vulnerable to disease.

When wheat is tillered well at the beginning of the spring growth period, growers should wait until near jointing to apply spring N fertilizer. Wheat leaves will become upright at this stage

Figure 5. Wheat leaves often lie fairly flat during the winter but as jointing approaches, they become more and more upright. This is a good time to apply spring N for fields that entered spring with enough tillers.

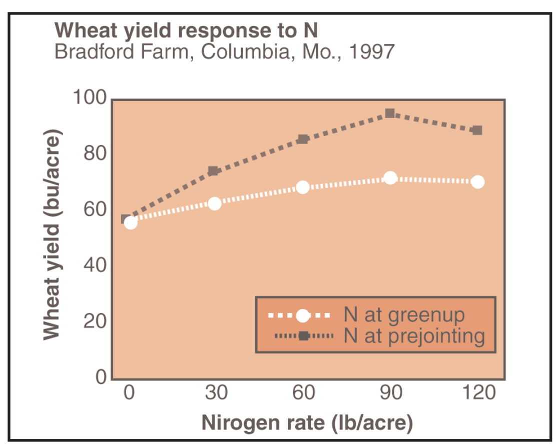


Figure 6. Delaying spring N applications until just before jointing (Figure 5) can sometimes increase yield response to N.

(Figure 5), which signals that the tillering phase has ended and jointing and stem elongation are about to begin. Early N applications can result in excessively lush growth and limit yield potential or even reduce yields. Out of six experiments with spring N timing in Missouri, yields in two experiments were higher when spring N applications were delayed until near jointing (Figure 6). In both of these experiments, fall tillering was good, and tiller density was greater than 100 tillers per square foot in early spring.

Figure 8. A spring nitrogen rate and timing experiment at the Delta Center in Portageville, Mo. Optimum N rate in this experiment was about 90 lb N/acre with no effect of spring timing (greenup vs. prejointing).

RAPID AND VIGOROUS STEM ELONGATION AND HEAD DEVELOPMENT

During the stem elongation phase of growth, nitrogen management is again the most critical element of fertility management. The highest rate of N uptake for wheat occurs between jointing and flowering (Figure 7). It is crucial that an adequate supply of N be available during this stage. This is also the time when demand for all other nutrients is highest, so a shortage of any other nutrient can also limit growth and ultimately reduce yield.

The longer the time between N application and the period of rapid N uptake, the greater the risk that N will be lost from the soil before the crop can take it up. It used to be more common for most or all nitrogen to be applied during the fall, but this practice resulted in too much yield loss from nitrogen deficiency. Potential for loss of N is greatest on sandy soils. On these soils, even N applied in early spring can be lost before the crop gets a chance to take it up. This is another reason for delaying spring N applications if tiller density is adequate at greenup.

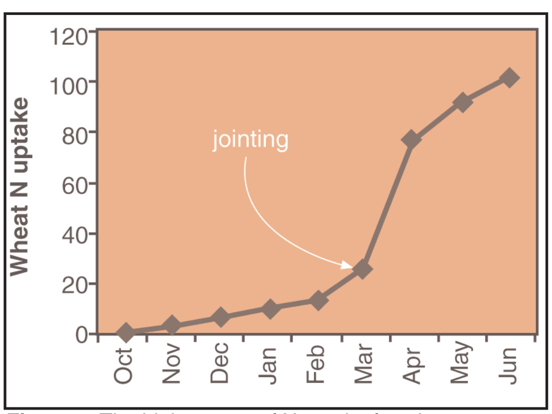


Figure 7. The highest rate of N uptake for wheat occurs between jointing and flowering

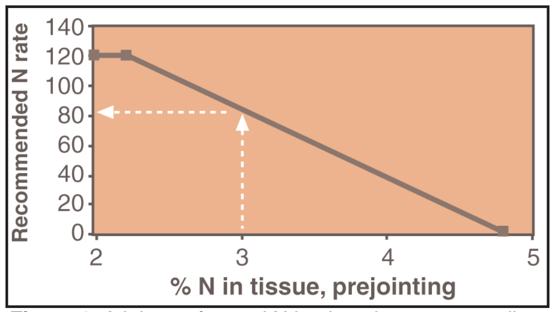


Figure 9. A lab test for total N in plant tissue can predict how much N fertilizer is needed. The dotted arrow shows how to use the line on the graph: a tissue N level of 3 percent translates to an N rate of 80 lb N/acre.

For six nitrogen rate and timing experiments conducted by the University of Missouri, optimum spring N rate was about 90 lb N/acre in four of the experiments, 120 lb N/acre in one of the experiments and 40 lb N/acre in the other experiment. One of these experiments is shown in Figure 8, and the dramatic effect of N on wheat growth is apparent. Average yield over these six experiments was 72 bu/acre. A rate of 90-100 lb N/acre in the spring is probably a good average. Most of these experiments were in wheat following soybean harvest. The amount of N needed is more variable for wheat following corn than for wheat following soybean. For wheat following corn, a tissue test can be used to diagnose whether a high rate or low rate of N is needed (Figure 9).

This tissue test measures the total N concentration in wheat tissue shortly before jointing. It is important not to take the samples too early because results will come back high and too little

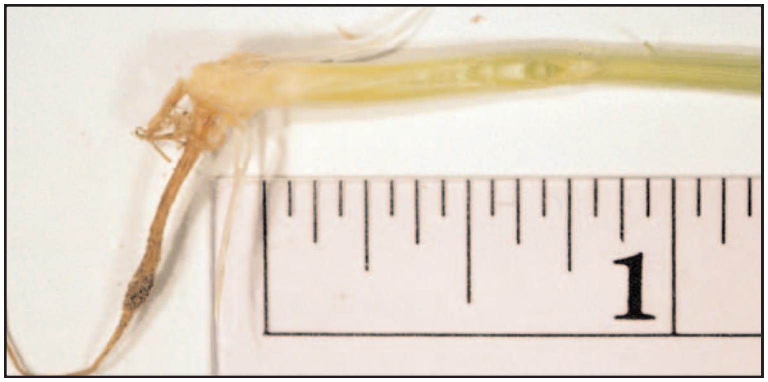


Figure 10. Just before jointing, a small hollow space will begin to form at the bottom of the wheat stem. This can be seen by splitting stems with a knife. When this stage is reached, a tissue test can be used to diagnose the amount of N needed by the crop (Figure 9).

N will be recommended. A small hollow space at the bottom of a stem split with a knife (Figure 10) indicates the wheat is at the right stage. Small handfuls of tissue should be cut at ground level from a variety of locations around the field that look typical for that field.

Arrangements should be made with a lab ahead of time to ensure a rapid turnaround time for the sample. Even so, there is some risk with this method of weather turning wet while the sample is being analyzed, which makes N applications difficult. Some producers have managed this risk by building small sprayers that can be pulled by a four-wheeler so that they can top-dress their wheat even when soils are wet.

The other nutrients that are most likely to limit winter wheat yields are phosphorus, potassium and sulfur. In eight Missouri experiments with good soil test P levels, no yield response to P was seen. Current University of Missouri soil test interpretations, if followed, should provide adequate P availability to maximize yield.

In these same experiments, wheat yield was increased 3-4 bu/acre by potassium (K) applications at the three locations with the lowest soil test K (below 230 lb K/acre). No response was seen in experiments with higher soil test K. Full yield would have been achieved in all experiments by following current University of Missouri K recommendations.

Four of the eight experiments were in southern Missouri, and wheat yield responded to sulfur (S) applications in two of those four experiments — one in southeast Missouri, and one in southwest Missouri. Including earlier experiments with S in southeast Missouri, wheat yield response to S is probably more likely in that part of the state than anywhere else, particularly on sandy soils. However, yield responses are still not common. Soil test sulfur tends to be higher in southwest Missouri than in other areas of the state, so responses there are also not likely to be common.

SUMMARY

Fertility management for winter wheat in Missouri has three main purposes:

- Provide a small amount of N and adequate P to support good fall growth.
- Provide N in early spring to stimulate tiller formation when tiller numbers are low, but avoid N applications in early spring when tiller numbers are adequate or high.
- Provide enough N, typically 90 lb N/acre in the spring, to support vigorous stem elongation and head development. The amount of N needed is more variable for wheat following corn than for wheat following soybean, and a tissue test to predict the amount of N needed may be helpful for wheat following corn.

WEED MANAGEMENT

Weeds reduce wheat yield and profit by competing with the crop for moisture, light and nutrients. Weeds also can interfere with harvest and result in dockage and lower quality grain. Yield loss and harvest problems caused by weeds in wheat will vary depending on the weed species, weed population, time of weed emergence, growing conditions and status of the wheat crop. A healthy stand of wheat that has a head start on weeds is competitive and will suppress weed growth. A thin stand of wheat that is stressed by disease, insects, nutrient deficiency or drought is not very competitive with weeds.

The timing of weed emergence relative to crop emergence has a great influence on competition and yield reduction caused by weeds. Weeds that emerge with the wheat crop or early in the fall are more competitive than weeds that emerge in the winter or spring (Table 3). Thus, winter annual weeds generally cause more yield loss in winter wheat than summer annual weeds. Summer annual weeds can interfere with harvesting and cause problems in the summer annual crop (usually soybean) planted after wheat harvest.

Table 3. Percent crop yield loss associated with common winter annual weeds found in Missouri.

Weed species	Density per 100 sq. feet	Yield loss potential (%)
Field pennycress	50	37
Wild buckwheat	50	15
Prickly lettuce	80	15

Winter annual weeds usually germinate and emerge in the fall about the time wheat is planted, and they complete their life cycles and produce seed in the spring. Winter annual weeds may also germinate and emerge during the winter or spring but are usually not as competitive with wheat as the fall-germinating weeds are. Germination depends on soil temperatures and precipitation.

Figure 11. Horseweed is a common weed in Missouri.

In Missouri, the most common weeds that emerge in the fall or winter include cheat, downy brome, annual ryegrass, wild garlic, wild onion, field pennycress, chickweed, henbit, horseweed (marestail), prickly lettuce, shepherd's-purse and wild buckwheat. Summer annual weeds present in wheat could include common lambsquarters, common ragweed, giant ragweed, redroot/smooth pigweed, smartweed and velvetleaf (see page 15 for Weed Identification).

CULTURAL WEED CONTROL PRACTICES

Establishing and maintaining a competitive wheat stand is one of the best techniques for minimizing yield loss due to weed interference. A seeding rate that results in 30 to 35 wheat seedlings per square foot is ideal for achieving optimum yields and limiting weed infestations. Applying nitrogen at recommended rates and timings (see fertility management) can promote tillering of wheat and limit the presence of weeds that affect harvest efficiency.

Crop rotation can be used to reduce weed populations. Infestation levels of wild garlic, chickweed and henbit tend to be lower following corn than following soybean, because the atrazine used in corn provides late-season, soil-residual activity on these weeds. Thus, a rotation of corn/wheat/double-crop soybean would be more favorable for managing these weeds than a soybean/wheat/soybean rotation.

Managing weeds in the fall before planting wheat, either with tillage or with burndown herbicides, is beneficial for controlling winter annual weeds. The benefits of these practices are greater if weather conditions before planting wheat are favorable for germination of the weed seed. Fall tillage practices that use both plowing and disking are effective for controlling perennial weeds such as wild garlic. Control of perennial weeds is enhanced with aggressive tillage to break up the underground reproductive structures.

Managing winter weeds in other crops in the rotation also can be beneficial by reducing the amount of weed seed in the seed bank. Using fall-applied herbicides to control winter weeds before corn and soybean planting should be considered in areas where winter weed growth is prevalent.

CHEMICAL WEED CONTROL PRACTICES

Herbicides are a safe and effective option for control of certain weeds in wheat. However, herbicides will not solve all weed problems and should be used only as a component of an integrated weed management program. Important factors to consider when choosing which herbicide to use are (1) identification of the weed species present, (2) the stage of crop and weed development, (3) herbicide persistence in the soil and rotational crop restrictions, and (4) the risk of off-site movement.

Much of the information related to items two, three and four can be found in MU publication MP 575, *Weed Control Guide for Missouri Field Crops*. This publication is updated annually with new information on herbicides, their efficacy on various weed species, appropriate application timings based on crop and weed-growth stages and rotational crop sensitivity to these herbicides.

Herbicides should only be applied at the crop-growth stages recommended on the label to achieve the desired results. Wheat must be at the proper stage of growth to avoid crop injury. Application too early or late may result in stunting and yield reduction. Wheat is generally most tolerant of postemergence broadleaf herbicides after it is fully tillered but before jointing. Application of 2,4-D before tillering can result in stunted wheat and incomplete head formation and grain fill.

No herbicides are labeled for application when the wheat is in the early-boot to soft-dough stage. Application during this time would result in sterility, poor grain fill and reduced yield.

Postemergence herbicides are usually most effective when applied to weeds that are actively growing. Winter annual broadleaf weeds are most susceptible when in the rosette stage of growth in the fall or early spring. Winter annual weeds that have bolted and produced the flowering stalk are more herbicide tolerant than younger weeds. Only a handful of herbicides are registered for the control of broadleaf weeds in winter wheat grown in Missouri.

Phenoxy herbicides, such as 2,4-D and MCPA, control a number of annual broadleaf weeds and are the least expensive of these herbicides to use. However, proper application timing of the growth-regulating herbicides 2,4-D, MCPA and Banvel is critical to avoid crop injury and possible yield losses. These herbicides can cause substantial crop injury and yield loss in small grains if applied before tillering begins or after development of the grain heads has begun.

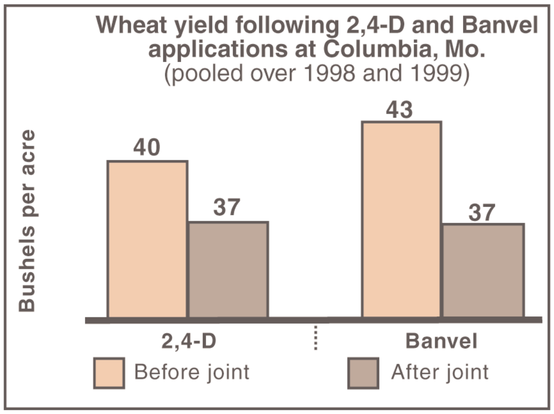


Figure 12. Wheat yield comparing herbicide application timing.

The exact time at which grain heads begin developing is not easy to determine, but this event always precedes stem elongation. The occurrence of stem elongation easily can be detected by the appearance of the first node or "joint" above the soil surface, which is commonly referred to as the "jointing stage." Pinch a wheat plant stem at the base between the thumb and forefinger and slide your fingers up the stem. The presence of a node or joint will be felt as a hard bump about an inch above the soil surface. Slicing the stem lengthwise with a sharp knife will reveal a cross section of the hollow stem and solid node.

If jointing has occurred, applications of 2,4-D, MCPA and Banvel should be avoided because crop injury and yield loss are likely (Figure 12). Research from the University of Missouri Weed Science program has shown a yield loss of 3 to 6 bu/acre from 2,4-D and Banvel applications to wheat after the jointing stage. MCPA alone at labeled rates should be applied before jointing. However, the amount of MCPA applied in Bronate, a combination of bromoxynil and MCPA, is low enough to permit later applications.

Many wheat fields in Missouri contain wild garlic and wild onion. Although not considered to be strong competitors with a wheat crop, wild garlic *(Allium vineale)* and wild onion *(Allium canadense)* are both responsible for imparting a strong odor to beef and dairy products. Wheat producers and grain elevator operators are familiar with dockages that occur with the presence of wild garlic or onion bulbs in their harvested grain. Found throughout Missouri, wild garlic is a native of Europe, while wild onion is native. Despite the fact that these perennials occur in similar habitats, wild garlic occupies the majority of small grain settings, including wheat.

Control measures for wild onion and wild garlic differ. Producers, consultants and industry personnel will want to make certain that they are able to distinguish between these two weed species. The vegetative leaves of wild garlic are linear, smooth, round and hollow (flowering stems are solid). A major difference with wild onion is that its leaves are flat in cross section and not hollow. Another varying feature is the underground bulbs. Wild garlic bulbs have a thin membranous outer coating while wild onion bulbs have a fibrous, net-veined coating.

Harmony Extra (thifensulfuron + tribenuron) is the herbicide most commonly used for control of garlic in wheat. It also controls a relatively wide spectrum of other broadleaf weeds and possesses a fairly wide application window. Harmony GT (thifensulfuron) has activity on wild garlic but is considered slightly weaker than Harmony Extra. Peak also is labeled and effective on wild garlic in wheat but it is fairly persistent in soil. The Peak label does not allow one to plant double-crop soybean following wheat harvest in Missouri. Wild onion is controlled with 2,4-D. Keep in mind that both of these weeds are perennials, and the full-labeled rate is needed for adequate control.

Harvest aid or rescue herbicide treatments

Occasionally, late-season, harvest-aid treatments are needed to burn back weed vegetation to improve harvest efficiency. These treatments should be applied no earlier than the hard-dough stage of wheat so they do not interfere with wheat grain fill.

There are three products labeled for this use: 2,4-D, Banvel/Clarity and glyphosate (Roundup/others). Keep in mind that if these treatments are needed, it is likely that the weeds are 2 feet or more in height and that the upper limit of the labeled rate will be required for effective control. Also, each product will have unique feed, forage, grazing and rotational crop restrictions. These restrictions include the following:

- If you are planning to double-crop soybean or sunflower after the wheat, do not use Banvel/Clarity, because herbicide residues remaining in the soil will not allow effective establishment of the crop.
- If you have underseeded legumes, all products will cause various degrees of injury to the underseeded legumes, with Banvel/Clarity causing the most severe injury.
- Double-crop soybean can be planted after use of 2,4-D, but the label requires a waiting period of 14-30 days before planting.

Other restrictions relate to feed, forage and grazing. Consult the manufacturer's label or MU publication MP 575 for more information.

Reference to specific trade names in this publication does not imply endorsement by the University of Missouri; discrimination is not intended against similar products.

Before using any herbicide, read and follow directions on the label accompanying that product.

Figure 13. Mouseear chickweed.

Herbicide-resistant weeds in wheat

At this time, there are no documented cases of herbicide-resistant weeds in Missouri wheat, although horseweed is suspected of resistance. Herbicide-resistant populations of the following weeds occur in adjacent states in wheat-production areas (Table 4).

Table 4. Weeds with known herbicide-resistant populations in wheat-producing adjacent states.

Weed	State	Herbicide
Perennial ryegrass	Arkansas	Diclofop (Hoelon)
Kochia	Illinois, Nebraska, Kansas	Thifensulfuron (Harmony, Harmony Extra)
Kochia	Nebraska	Dicamba (Banvel/Clarity)
Kochia	Kansas	Metribuzin (Sencor)

Figure 16. Wild garlic.

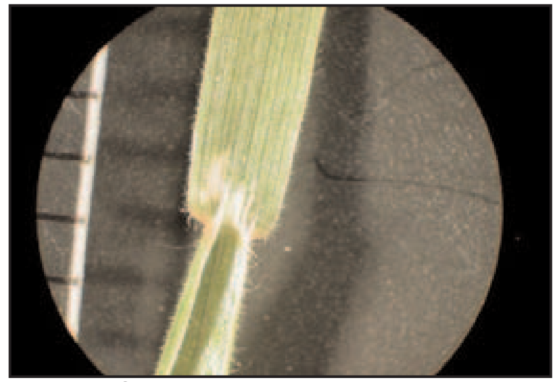


Figure 14. Cheat.

Figure 15. Henbit.

The weeds most commonly treated in Missouri wheat are henbit, chickweed, wild garlic and cheat/downy brome (Figures 13-16). Care should be taken to avoid repeated use of herbicides with the same mode of action for these weeds. In addition, weed management in other crops using different modes of action or cultural practices will slow or minimize the development of herbicide resistance in these weeds.

Herbicide-resistant wheat

Corn and soybean varieties with tolerance for nonselective herbicides became commercially available in the mid-1990s. In 2002, wheat varieties with tolerance for a specific imidazolinone herbicide (imazamox) became commercially available. The imidazolinone-resistant varieties are currently being developed and marketed by BASF under the trade name of ClearField. The trade name of the herbicide labeled for use in ClearField wheat is Beyond. Beyond can be applied in the fall or spring from the third-leaf stage of wheat until jointing. Beyond will control ryegrass, bromegrass and many winter annual weeds. Although seed supply is somewhat limited, more varieties will become available each year. Consult your seed dealer to find a variety suited to your growing conditions.

WEED IDENTIFICATION

Left: Downy brome. Similar to cheat, especially in seedling stage, but less pubescent as it matures. Sheath of both is closed to near the top of the collar. Annual.

Middle: Ryegrass. Short auricles appear to clasp stem. Blades smooth with prominent veins. Annual.

Right: Wild garlic. Bulbous perennial. Emerges in early spring and dies back in late spring. Leaves are hollow, lack hair and have a strong odor. Perennial.

Left: Wild onion. Flowers similar to wild garlic except that the leaves are flattened and not hollow. Perennial.

Middle: Star-of- Bethlehem. Similar in appearance to wild onion and wild garlic, though no odor. Leaves are grooved and dark green with a prominent white midrib. Perennial.

Right: Dandelion. Leaf margins are irregular, toothed or wavy with deep lobes. Contains a milky sap. Flower is large and yellow. Perennial.

Left: Field pennycress. Leaves along stem lack hair and petioles. Lobes at base. Small white flowers (4 petals). Fruit is flat and round. Annual.

Middle: Common chickweed. Some petioles hairy; others smooth. Upper stem has no petioles. Leaves smooth, light green. White flowers (5 petals) similar to mouseear. Perennial.

Right: Mouseear chickweed. Small leaves lack petioles and are hairy. Flowers white (5 petals). Perennial.

Left: Horseweed. Erect, columnar appearance. Stems and leaves covered with dense hairs. Leaves lack petioles and are long and narrow. Annual.

Middle: Prickly lettuce. Basal rosette of bluish green leaves, fine prickles. Prominent midrib, row of spines, milky sap. Annual/biennial.

Right: Shepherd's-purse. Leaves deep and irregular cut in rosette stage. Later, take an arrow shape. Small, white flowers (4 petals). Annual.

Left: Wild buckwheat. Leaves alternate (pointed tips and basal lobes directed backward). Flower greenish white or purple spotted. Annual.

Middle: Wild mustard. Leaves rough and variable. Lower leaves irregular lobed margins and petioles. Flowers yellow clusters (4 petals). Annual.

Right: Common lambsquarters. Young plant has small linear cotyledons. First true leaves opposite; later leaves alternate. Annual.

Left: Common ragweed. Cotyledons are small spatulas. First true leaves appear lobed and opposite. Later, true leaves appear highly dissected. Annual.

Middle: Giant ragweed. Spatula-shaped cotyledons, larger than common ragweed. First true leaves opposite but larger and 3-lobed. Annual.

Right: Redroot pigweed. Emerging plant has linear-shaped cotyledons. Later, leaves oval shaped, rough. Stems reddish and hairy. Annual.

Left: Pennsylvania smartweed. Cotyledons about 3 times as long as wide, with dark red emerging hypocotyl. First true leaves alternate. Annual.

Middle: Velvetleaf. One heart-shaped and round cotyledon. Both softly hairy. First true leaves alternate, hairy. Leaves heart shaped. Annual.

Right: Henbit. Pinkish purple. Square stem; upper leaves appear to encircle stem. Rarely over 12 inches. Annual.

WINTER WHEAT DISEASES & THEIR MANAGEMENT

Wheat diseases can and do occur each year in Missouri. Problems with germination and stand establishment that are related to seed decay, damping-off and seedling blights may be encountered in the field. Diseases may cause leaf spots or leaf blights, wilts or premature death of plants. Wheat diseases can also cause harvest losses, affect the quality of the harvested crop and cause storage losses. The extent of the damage from wheat diseases in a given season depends on a number of factors, including the susceptibility of the wheat variety to the specific diseases, the level of the pathogen inoculum present and the environmental conditions during that season.

To minimize losses due to wheat diseases, it is important to correctly identify the disease or diseases present so that appropriate management steps can be taken. The principal diseases of wheat in Missouri can be divided into seedling diseases; virus diseases; foliage diseases; root, crown and wilt diseases; and head diseases. This section covers the common diseases and management strategies in each of these wheat disease categories.

SEEDLING DISEASES

Various seedborne and soilborne pathogens can cause seedling diseases in wheat. Seed may be rotted before germination, or developing seedlings may be infected before or after emergence. Stands may be thin or uneven (Figure 17). Seedlings may be yellow and stunted. Root systems may be poorly developed with root and crown tissue that is brown to black in color and soft or rotted (Figure 18). Severely infected seedlings may yellow, wilt and die. Seedling diseases tend to be more severe if poor quality or diseased seed is used and if conditions at planting are not favorable for quick germination and stand establishment. Planting good quality, disease-free seed is the most effective means of preventing problems from seedborne pathogens. If seed contaminated with a seedborne pathogen must be used for planting, it is important to clean the seed lot thoroughly to remove as much of the small, damaged seed as possible; to have a germination test done on the cleaned seed lot; and to consider the use of a fungicide seed treatment.

A management program for wheat seedling diseases should include the following steps:

- Plant good quality, disease-free seed under good seedbed conditions.
- Use a fungicide seed treatment.

Figure 17. Thin stand due to seedling blight.

Figure 18. Seedling on right shows stunting, yellowing and poor root development from seedling blight.

VIRUS DISEASES OF WHEAT

The virus diseases most likely to occur on winter wheat in Missouri are wheat spindle streak mosaic, wheat soilborne mosaic, barley yellow dwarf and wheat streak mosaic. Symptoms of barley yellow dwarf may be evident on young wheat plants in the fall, may show up on young plants early in the spring or may be evident later in the season primarily on the flag leaves of plants. Symptoms of wheat spindle streak mosaic and wheat soilborne mosaic typically show up during spring greenup and are most pronounced when air temperatures are around 50 F. Wheat streak mosaic symptoms tend to become obvious as air temperatures increase later in the spring.

Symptoms of wheat spindle streak mosaic (also referred to as wheat yellow mosaic) appear in early spring as yellow green streaks or mottling on the dark green background of the leaves (Figure 19). These lesions usually run parallel to the leaf veins and tend to be tapered at the ends giving the lesions a spindle-shaped appearance. Foliage symptoms are most obvious when air temperatures are about 50 F. Plants may be slightly stunted, off-color and have fewer tillers than normal (Figure 20).

Wheat spindle streak mosaic tends to be more prevalent in lower, wetter areas of a field. The virus that causes this disease is soilborne, and it is spread by the soil fungus *Polymyxa graminis*. Wet falls tend to favor outbreaks of wheat spindle streak mosaic the following spring. Symptoms are most pronounced when air temperatures are 46 to 54 F and tend to fade as air temperatures increase above that range. In years with extended periods of cool, spring temperatures, wheat spindle streak mosaic may be severe and contribute to yield losses.

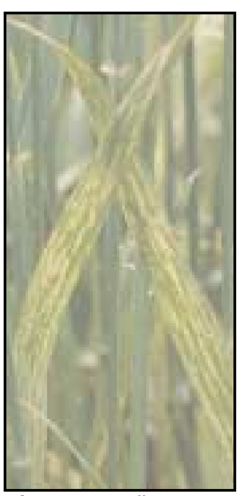


Figure 19. Foliage symptoms of wheat spindle streak mosaic.

Wheat soilborne mosaic causes light green to yellow green to bright yellow mosaic patterns in leaf tissues (Figure 21). Symptoms are most evident on early spring growth. Warmer temperatures later in the season slow disease development. Symptoms of wheat soilborne mosaic are not always distinctive and might occur as a more general yellowing, similar to that caused by nitrogen deficiency (Figure 22). Infected plants may be stunted and slow to green up in the spring (Figure 23).

This disease may be more severe in low-lying, wet areas of a field. The wheat soilborne mosaic virus survives in the soil and is spread by the soil fungus *Polymyxa graminis*. Again, wet falls tend to favor outbreaks of wheat soilborne mosaic the following spring. Symptoms of wheat soilborne mosaic are most pronounced when air temperatures are 50 to 68 F and tend to fade when air temperatures increase above that range. In years with extended periods of cool spring temperatures, wheat soilborne mosaic may be severe and contribute to yield losses.

Both wheat spindle streak mosaic and wheat soilborne mosaic are vectored or spread by the soil fungus *Polymyxa graminis*. This fungus prefers wet conditions and is most likely to infect wheat roots during wet falls. Plants infected in the fall usually show the symptoms described above the

Figure 20. Poor spring growth due to wheat spindle streak mosaic.

Figure 21. Foliage symptoms of wheat soilborne mosaic.


Figure 22. Extensive yellowing of lower leaves due to wheat soilborne mosaic.


Figure 23. Poor spring growth due to wheat soilborne mosaic.


Figure 24. Barley yellow dwarf symptoms on young plants.

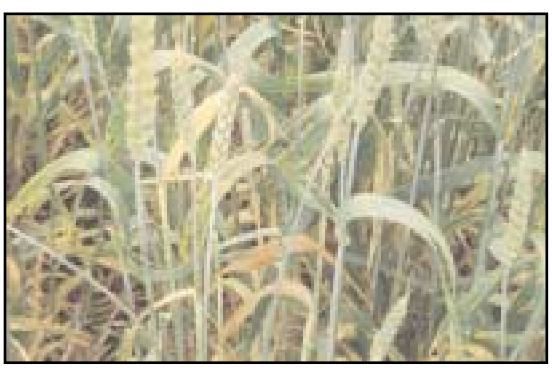


Figure 25. Discoloration of flag leaves due to barley yellow dwarf.

following spring. Spring infections may occur during wet springs, but they usually occur too late to cause significant injury. In most years, the symptoms of these two wheat virus diseases are evident as the wheat crop is greening up and tend to fade as air temperatures increase. In years with late, cool springs, symptoms may be evident much later in the season, even on plants that have headed.

Barley yellow dwarf (also called yellow dwarf and red leaf) is an extremely widespread virus disease of cereals. Symptoms include leaf discoloration ranging from a light green or yellowing to a red or purple discoloration of leaf tissue (Figures 24 and 25). Discoloration tends to be from the leaf tip down and the leaf margin in toward the center of the leaf. Plants may be stunted or may have a rigid, upright growth form. Symptoms are most pronounced when temperatures are in the range of 50 to 65 F.

The barley yellow dwarf virus persists in small grains, corn and perennial and annual weed grasses. More than 20 species of aphids can transmit the barley yellow dwarf virus. Symptoms may be more severe and yield losses higher if plants are infected in the fall or early in the spring. Infections developing in late spring or summer may cause discoloration of upper leaves but little stunting of plants or yield loss.

The other virus disease likely to occur on winter wheat in Missouri is wheat streak mosaic. Wheat streak mosaic causes a light green to yellow-green mottling and streaking of leaves (Figure 26). The leaf streaks are yellow-green with parallel margins so they appear more as streaks than spindle- or oval-shaped lesions. Symptoms may vary with variety, virus strain, stage of wheat growth when plants are infected and environmental conditions. Plants may be stunted. As temperatures increase later in the spring, yellowing of leaf tissue and stunting of plants may become more obvious (Figure 27). The heads on severely infected plants may be partially or completely sterile.

The wheat streak mosaic virus is spread by the wheat curl mite. Symptoms are frequently found along the edges of fields where the mite vector first entered the field. Both the wheat streak mosaic virus and the wheat curl mite survive in susceptible crop and weed hosts, including winter and spring wheat, barley, corn, rye, oat and a number of perennial grasses. Thus, the destruction of volunteer wheat and grass weed

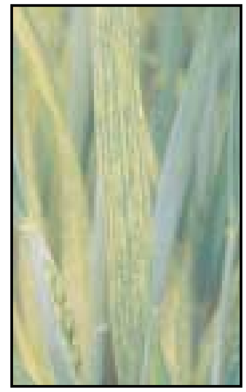


Figure 26. Wheat streak mosaic

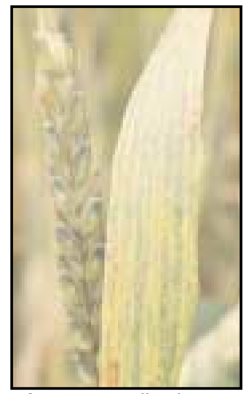


Figure 27. Yellowing and drying of leaves from wheat streak mosaic.

control are important management options for wheat streak mosaic.

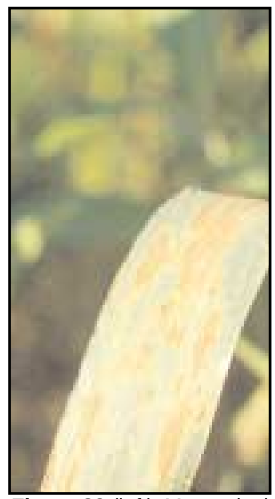
Mixed infections of wheat viruses in the same field or even the same plant are common in Missouri. When plants are infected with more than one virus disease, it may not be possible to identify the specific viruses present by symptoms. It may be necessary to submit a plant sample to a plant diagnostic laboratory for virus testing.

Most of the management options for virus diseases in wheat are preventative measures such as planting resistant or tolerant wheat varieties; avoiding continuous wheat production; destroying volunteer wheat and weed grasses near wheat production fields; delaying wheat planting until all corn is harvested; and avoiding early fall planting of wheat. Proper fertility may help reduce the impact of virus diseases on wheat.

A management program for virus diseases of wheat should include the following steps:

- Plant good quality seed of resistant varieties.
- Avoid planting too early in the fall to minimize opportunity for vectors to transmit viruses to young wheat plants.
- Destroy volunteer wheat and control weed grasses that may be hosts of the virus pathogens or insect vectors.
- Rotate crops.
- Maintain good plant vigor with adequate fertility.

Figure 28. Young lesions of Septoria leaf blotch.



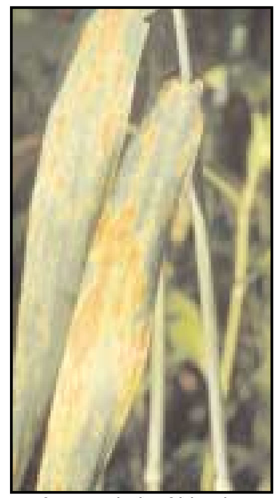


Figure 29 (left). Mature lesions of Septoria leaf blotch with pycnidia evident in the centers of lesions.
Figure 30 (right). Severe Septoria leaf blotch on flag leaves.

FOLIAGE DISEASES

Figure 31. Stagonospora glume blotch on head.

Many different fungi and bacteria can cause foliage diseases on wheat. These pathogens cause a wide range of leaf spots, leaf blights and similar symptoms on wheat. Foliage diseases that can cause significant injury to wheat in Missouri include Septoria leaf blotch, Stagonospora glume blotch, tan spot, leaf rust, stem rust, stripe rust, powdery mildew and bacterial stripe or black chaff.

Lesions of Septoria leaf blotch begin as light yellow flecks or streaks. These flecks expand into yellow to reddish brown, irregularly shaped blotches (Figure 28). As the lesions mature, the centers may turn lighter gray in color. Dark brown specks (fruiting bodies or pycnidia of the causal fungus, *Septoria tritici*) may be scattered within the centers of mature lesions (Figure 29).

Lesions may coalesce, killing larger areas of leaf tissue (Figure 30).

Stagonospora glume blotch (formerly called Septoria glume blotch) may also begin as light yellow flecks or streaks on leaves. The lesions also turn yellow to reddish brown but usually have a more oval- to lens-shaped appearance than those of Septoria leaf blotch.

Again, the dark brown specks or fungal fruiting bodies of the causal fungus, *Stagonospora nodorum* may be evident within the lesions, but they are not as conspicuous in leaf tissue as are those of *Septoria tritici*. Symptoms of Stagonospora glume blotch are more common on heads than on


Figure 32. Tan spot.

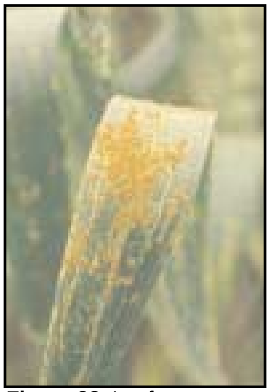


Figure 33. Leaf rust.


Figure 34. Yellowing of lower leaves from leaf rust.


Figure 35. Stem rust (with leaf rust on some leaves).


Figure 36. Stripe rust.

foliage of wheat. Infected heads will have dark blotches on the glumes (Figure 31).

The initial symptoms of tan spot are small, tan to brown flecks on the leaves. These expand into tan to light brown, elliptical lesions that often have yellow borders (Figure 32). The centers of mature tan spot lesions may have a dark brown region caused by an outgrowth of the fungus *Pyrenophora tritici-repentis*. Since the tan spot fungus does not produce pycnidia or fruiting bodies, mature tan spot lesions do not have the distinct dark brown specks scattered in the centers of the lesions as do Septoria leaf blotch lesions.

Leaf rust lesions appear primarily on the upper leaf surfaces and leaf sheaths. Initially, lesions are small, yellow to light green flecks. Eventually, leaf rust appears as small, circular to oval-shaped, orange red pustules. These pustules break open to release masses of orange red spores of *Puccinia recondita* (Figure 33). The edges of the open pustules tend to be smooth without the tattered appearance of stem rust pustules. Heavily rusted leaves may yellow and die prematurely (Figure 34).

Stem rust, caused by the fungus *Puccinia graminis* f. sp. *tritici*, is most common on stems and leaf sheaths of wheat plants but may develop on any of the aboveground portions of the plant, including both upper and lower leaf surfaces, glumes and awns. Stem rust pustules are small, oval and reddish brown (Figure 35). The ruptured pustules tend to have more ragged edges than leaf rust pustules. Frequently, both leaf rust and stem rust occur on the same plant, and both types of pustules may develop on an individual leaf.

Stripe rust, caused by the fungus *Puccinia striiformis*, has become more prevalent in Missouri over the last few years. Stripe rust may develop earlier in the season than either leaf rust or stem rust. The pustules of stripe rust are yellow or yellowish red in color and occur in obvious stripes or streaks that run lengthwise on wheat leaves (Figure 36). This disease is more commonly associated with lower temperatures (especially lower night temperatures) and intermittent rain or dew.

Powdery mildew infections begin as light green to yellow flecks on the leaf surface. As powdery mildew develops, the leaf surfaces become covered with patches of cottony white mold growth of *Erysiphe graminis* f. sp. *tritici*, the causal fungus (Figures 37 and 38). These patches eventually turn a grayish white to grayish brown


Figure 37. Young lesions of powdery mildew.


Figure 38. Powdery mildew covering leaf.


Figure 39. Bacterial stripe.

color. Small, black fungal fruiting bodies may be visible within the patches of mildew growth.

The fungi that cause most of these wheat foliage diseases survive in infested wheat residues left on the soil surface. The next growing season, spores are produced during moist periods and are carried by wind currents to susceptible wheat leaves where infection may begin. Disease problems tend to be more severe when wheat is planted in fields with infested wheat residue left on the soil surface. Eventually, spores that are produced in the initial lesions on plants are wind blown to other leaves or other plants causing secondary infection.

Leaf rust, stem rust and stripe rust are exceptions to this simplified explanation of disease development. The rust fungi do not survive in infested residue left in a field and, in fact, do not survive the winter months in this area at all. Rather, the rust fungi are reintroduced into this area each season when spores are carried up on air currents from the southern United States. Most of the foliage diseases of wheat are favored by warm, wet or humid weather. Frequently, infection begins on the lower portion of the plant.

If weather conditions are favorable for disease development, the disease may move up through the plant. Severely infected leaves may yellow and die prematurely. Yield losses tend to be highest when the flag leaves are heavily infected.

There are several fungicides labeled for use on wheat to control fungal foliage diseases. It is important to scout wheat fields and determine which leaf diseases are occurring, as well as the level of their severity, before making a decision to apply a foliar fungicide. In particular, be on the lookout for Septoria leaf blotch, Stagonospora glume blotch, tan spot and leaf rust. When scouting fields, try to identify the disease(s) that are present; determine the average percent of infection on a leaf and the number of leaves showing infection; and determine the stage of crop growth.

Generally, the profitable use of foliar fungicides on wheat depends on a number of factors, including varietal resistance, disease severity, effectiveness of the specific fungicides and timing of fungicide application. The greatest increases in yield are usually obtained when fungicides are applied to disease susceptible varieties with high yield potential at the early boot to head emergence growth stage when the flag leaf is in danger of severe infection.

Fungicide applications are seldom beneficial if applied after flowering or after the flag leaf is already severely infected.

It is also important to read the fungicide label for specific information on rates, recommended timing of application, frequency of applications, preharvest intervals and grazing restrictions.

A management program for foliage diseases of wheat should include the following steps:

- Plant disease-free seed of varieties with resistance to diseases likely to occur in your area.
- Rotate with nonhost crops.
- Manage residues (if tillage system is a conservation tillage system, particular care should be given to rotation and variety selection).
- Maintain good plant vigor with adequate fertility.
- Use foliar fungicides if warranted.


Figure 40. Black chaff.

Figure 41. Initial symptoms of Cephalosporium stripe.

Black chaff (also called bacterial stripe) is a bacterial disease that produces symptoms on both leaves and heads. Water-soaked lesions may develop on young leaves. These develop into reddish brown to brown to brownish black streaks on the leaves (Figure 39). Glumes and awns show brown-black blotches or streaks (Figure 40). The bacterium that causes this disease, *Xanthomonas campestris* pv. *translucens*, is seedborne, so the use of disease-free seed is a primary control measure. Use of resistant or tolerant varieties and crop rotation should also reduce the incidence of bacterial stripe and black chaff.

ROOT, CROWN & WILT DISEASES OF WHEAT

Several soilborne fungi can cause root and crown diseases of wheat. Affected plants may be stunted or less vigorous than healthy plants. Plants may yellow, wilt and die prematurely. Dead plants may have a bleached or white appearance. When affected plants are dug up, root systems may be poor with roots and crown tissues discolored and deteriorated.

Cephalosporium stripe has not been a significant problem on wheat in most of Missouri. With recent wet seasons, shorter rotations between wheat crops and reduced tillage, this disease has become more common in the northern part of the state. Foliage symptoms are most evident during jointing and heading. Light green to yellow-green, longitudinal stripes develop on the leaves of infected plants (Figure 41). The stripes run parallel to the leaf midrib and may extend the entire length of the plant. Older lesions are predominantly yellow or even brown (Figure 42). Severely infected plants may be stunted, produce few tillers and die prematurely (Figure 43). The fungus that causes this disease, *Cephalosporium gramineum*, persists in association with wheat residues and may also be soilborne. Fungicides are not effective in controlling Cephalosporium stripe and resistant varieties are not available for Missouri.

A management program for Cephalosporium stripe should include the following steps:

- Crop rotation to corn or legumes for at least two years.
- Residue management.
- Proper fertility.
- Proper weed control.

Figure 42. Cephalosporium stripe.

Figure 43. Stunting of plants due to Cephalosporium stripe.

Take-all is one of the more common root and crown rot diseases of wheat in Missouri. The fungus that causes this disease may infect seedlings in the fall.

Symptoms are usually most evident after heading as white heads on wheat plants (Figure 44). Entire heads on infected plants may be bleached (white heads) and sterile. Infected plants are also stunted and slightly yellow, have few tillers and ripen prematurely (Figure 45).

Plants with take-all usually have poorly developed root systems and roots are sparse, blackened and brittle. With sufficient soil moisture, a black-brown dry rot may extend into the crown and up the lower stem. This shiny, black discoloration of the lower stem and crown may be evident if the lowest leaf sheath is scraped off with a knife or fingernail (Figure 46).

Diseased plants may lodge and fields may appear uneven in height and irregular in maturity. At harvest, the heads on diseased plants may be darkened by "sooty" molds and may contain either no grain or shriveled grain.

Take-all of wheat is caused by the fungus *Gaeumannomyces graminis*. This fungus survives in infected host plants (wheat, barley, rye and weed grasses such as smooth bromegrass, quackgrass and bentgrass) and in infested host debris.

Infection occurs when the fungus penetrates the young roots of a living host plant. Infection can occur throughout the growing season but is more severe when the temperature is 54 to 64 F. The take-all fungus is more active in wet soils, so the disease is typically most severe in wet areas or years, or in irrigated fields. Root infections in the fall and early spring are most likely to progress to the crown and foot of the plant.

Hot, dry weather after heading increases the water stress on plants infected with take-all and may lead to the sudden development of white heads on plants that were actually infected earlier in the season or the previous fall.

Take-all is favored by continuous cropping of wheat. It is also more severe in lighter, alkaline, infertile and poorly drained soils. Plant nutrients offer increased resistance to take-all and a greater capacity to tolerate infections by producing more roots.

It is important to maintain good levels of available nitrogen, phosphorus and potassium. Soil pH also affects the development of this disease. Disease damage is usually worse as soil pH approaches 7.0.

Figure 44. White heads due to take-all.

Figure 45. Severe take-all symptoms in wheat field (field had been in wheat four out of last five years).

Figure 46. Take-all symptoms on lower stem, crown and roots.

Figure 47. Loose smut.

A management program for take-all should include the following steps:

- Plant good quality seed of adapted, disease resistant varieties.
- Plant in well-drained sites under good seedbed conditions.
- Rotate with nonhost crops for one to three years.
- Control weed-grass hosts and volunteer wheat.
- Use seed treatment fungicides.
- Maintain good plant vigor with adequate fertility.

HEAD DISEASES OF WHEAT

Diseases such as smuts, bunts and scab affect primarily the head of the wheat plant. Smut and bunt diseases, such as stinking smut or loose smut, tend to replace the normal kernels in the head with galls that contain masses of powdery black spores. The scab fungus can colonize heads producing kernels that are shrunken, shriveled and discolored.

Loose smut is obvious as heads emerge from the boot. All portions of the head except the rachis are converted to masses of dusty black spores (Figure 47). These spores are eventually dislodged by wind and rain, so later in the season the smutted stems are less evident (Figure 48).

The fungus that causes loose smut, *Ustilago tritici*, survives within the embryo of wheat seeds, so planting disease-free seed or using systemic fungicide seed treatments are important management tools.

Stinking smut (also called covered smut or common bunt) is not as obvious as loose smut. The kernels are replaced with smut galls, but the pericarp covering the smut gall remains intact and masks the smut gall.

At harvest, the pericarps are broken, releasing clouds of dark spores. Grain contaminated with stinking smut has a strong fishy odor and a darkened appearance. The fungus that causes stinking smut can survive on wheat seed and in the soil. Disease development is favored by cool, wet conditions.

A management program for smut and bunt diseases should include the following steps:

Figure 48. Bare rachis remains after smut spores are dislodged.

- Plant disease-free seed.
- Use a systemic fungicide seed treatment.

The characteristic symptom of scab on wheat is a premature bleaching of a portion of the head or the entire head (Figures 49 and 50). Superficial mold growth, usually pink or orange in color, may be evident at the base of the diseased spikelets. Bleached spikelets are usually sterile or contain shriveled or discolored seed (Figure 51).

Scab is caused by the fungus *Fusarium graminearum*. This fungus overwinters on host residues such as wheat stubble, corn stalks and grass residues. Spores are carried by wind currents from the residues on which they have survived to wheat heads.

If environmental conditions are favorably warm and moist, the spores germinate and invade flower parts, glumes and other portions of the spike. Scab infection occurs when the wheat crop is in the flowering to early grain fill stages. Infection depends on environmental conditions while wheat is in susceptible stages of growth. Moderate temperatures in the range of 77 to 86 F, frequent rain, overcast days, high humidity and prolonged dews favor infection and development of the scab fungus.

An additional concern with wheat scab is the possibility of mycotoxin production in the infected grain. Mycotoxins are naturally produced chemicals that in small amounts may be deleterious to animal or human health.

The fungus that causes wheat scab may produce several different mycotoxins, including vomitoxin (deoxynivalenol or DON) and zearalenone. This is a primary concern where grain is fed to nonruminant animals.

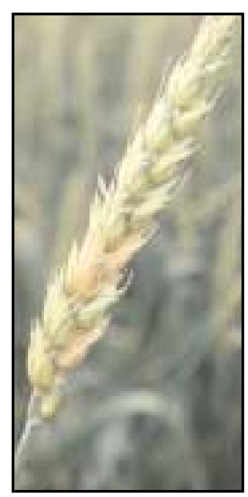


Figure 49. Scab or Fusarium head blight.

Figure 50. Scab or Fusarium head blight.

Figure 51. Scab symptoms on kernels.

Ruminants are fairly tolerant of these two mycotoxins. Swine and poultry may refuse to eat grain containing high levels of these mycotoxins. Where mycotoxin problems are suspected, a sample should be submitted to a qualified laboratory for mycotoxin analysis.

A management program for wheat scab should include the following steps:

- Plant adapted varieties with tolerance to scab.
- Rotate to nonhost crops (corn is also a host, so rotation should be to crops other than small grains or corn).
- Manage residues.
- Plant disease-free seed (If planting seed from a field that had scab, clean seed thoroughly before planting, have a germination test done on the lot and use a fungicide seed treatment to minimize seedling blight problems caused by seedborne Fusarium).

INSECT PESTS OF MISSOURI WHEAT

Several aphid species can be found infesting wheat plants in Missouri fields. The greenbug is the most important as it has the potential to cause severe damage when populations of this aphid increase to outbreak levels. Depending on the aphid species present, injury to wheat can result from the sucking of sap by large numbers of aphids, injection of a toxic saliva that discolors and destroys tissue or by transmission of the barley yellow dwarf virus (BYDV). The greenbug can cause damage to wheat through all of these actions. Other aphids of lesser importance found inhabiting wheat plants include the bird cherry-oat aphid, English grain aphid and corn leaf aphid (see Appendix).

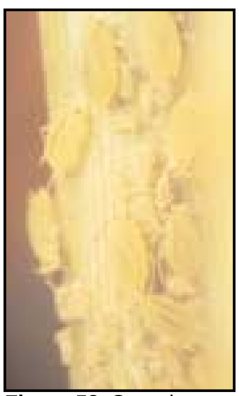


Figure 52. Greenbugs.


Figure 53. Aphid colony on wheat leaf.

Greenbug

Schizaphis graminum (Rondani)

Family Aphididae

Quick identification: Pale green to greenish yellow aphid with a darker green internal stripe running the length of its back (Figures 52 and 54). Cornicles are tipped in black and point toward the tip of the abdomen.

Status: Occasional pest. Greenbug outbreaks often occur after a mild winter followed by a cool spring.

Distribution: Statewide

Damage: The greenbug is the most destructive aphid that attacks wheat in Missouri. Host plants include wheat, oats and several species of wild and cultivated grasses. Greenbug outbreaks generally begin in states south of Missouri and move northward on prevailing winds in the spring of the year. Greenbug populations often develop during periods of cool weather when development of natural enemies and parasites is slowed. Greenbug injury to wheat may result from the sucking of plant sap by large numbers of aphids, by injection of a toxic saliva that discolors and destroys plant tissues or by transmission of the barley yellow dwarf virus. Aphid colonies may be found on upper and lower leaf surfaces and will generally increase in numbers as the crop develops grain (Figure 53). Injection of toxins during feeding by greenbugs may result in necrotic spots on leaf tissue. Other aphids frequently found on wheat do not cause this type of damage.

Pest description and life cycle: Greenbugs are about 1⁄16 inch long when mature. They are light green in color with a dark green stripe running down the center of their backs. The eyes and antennae are black with the antennae length being greater than half the length of the body. Legs and cornicles ("tailpipes") are pale green and tipped in black. Greenbugs feed and reproduce by giving birth to living young throughout the year. In more northern states, greenbugs overwinter in the egg stage and wingless females emerge in the spring. Within about two weeks of emerging, females begin to give birth and produce approximately 50 to 60 female young over a one-month period. Several generations of females are produced up until fall, when winged females and males both are produced, mate and lay overwintering eggs. Several generations are produced each year.

Scouting/Economic damage: Scout for greenbugs by examining 20 plants in five locations within the field. Greenbug colonies often develop on lower plant leaves, so inspect this area of plants first. Treatment is generally recommended if an average of 50 or more greenbugs are found per linear foot of row on small plants in the fall, or when 100 or more greenbugs are present per linear foot in the early spring before plants joint or when wheat foliage becomes discolored.

Control: In addition to insecticides, insect predators and parasites may greatly reduce numbers of this pest.


Figure 54. Greenbugs.

Bird cherry-oat aphid

***Rhopalosiphum padi* (L.)**

This aphid is most easily identified by its olive green to olive gray body color with a reddish orange area surrounding the base of the cornicles. The reddish orange coloring may fade under cool conditions. Antennae are black and more than half as long as the aphid body. Legs and cornicles are tipped in black. Bird cherry-oat aphids are common in Missouri wheat statewide but rarely require control. This aphid is an efficient vector of barley yellow dwarf virus.

English grain aphid

***Sitobion avenae* (Fabricius)**

The English grain aphid is most often found on developing heads of wheat during the spring. Body color is light to dark green, and antennae are more than half as long as the body. Cornicles are longer than those of most other aphids and solid black in color. Although it feeds directly on the heads of maturing grain and may cause shriveled kernels and yield reductions, ladybird beetle and other predators generally keep populations below economic levels and minimize impact. This aphid can be a vector of barley yellow dwarf virus.

Figure 57. Armyworm feeding damage in wheat field with defoliation of plants.

Figure 58. Armyworm feeding damage in wheat field with defoliation of plants.

Corn leaf aphid

***Rhopalosiphum maidis* (Fitch)**

This dark green to black aphid is a common pest of corn, sorghum and some weed species in Missouri but only occasionally infests wheat. When infestations occur in wheat, aphid colonies often develop in protected locations such as plant leaf sheaths, whorls and heads. Although capable of transmitting barley yellow dwarf virus, it is not considered an important Missouri wheat pest.

Armyworm (True)

***Pseudaletia unipuncta* (Haworth)**

Family Noctuidae

Quick identification: The best identifying characteristic of larvae is the presence of a dark band on the outer side and a dark tip on the inner side of each insect proleg.

Status: Common pest of wheat, fescue seed fields and grass pastures.

Distribution: Statewide

Host crops: Wheat, corn, milo, oat, barley, rye, tall fescue and many other grass species.

Timing: Damage may occur from late April through late June.

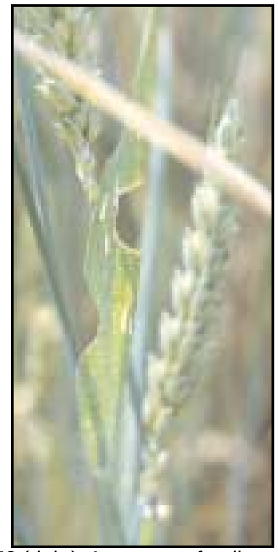


Figure 55 (left) and **Figure 56** (right). Armyworm feeding damage on wheat foliage.

Damage: Every few years the true armyworm is a serious pest in Missouri although noneconomic infestations are present in most years. During pest outbreaks, armyworm larvae can destroy grass vegetation over many hundreds of acres. Outbreaks often occur during cold, wet springs that reduce parasite populations. Damage usually starts at field margins, where worms migrate into fields as “armies” from another crop. Because small larvae hide from sunlight, initial feeding occurs on lower leaf tissue and moves upward as larvae mature (Figures 55-59). Economic damage in wheat usually results from larvae feeding on the flag leaf. In addition, severe yield loss occurs when larvae clip wheat heads from plants. Outbreak populations of this pest clip wheat heads in some years but not others. The “trigger” to initiate wheat head clipping is unknown. Small armyworms are usually found in plant debris near the soil surface during daylight hours before moving upward on plants to feed at night or on overcast days. Larvae spend greater amounts of time feeding on upper plant tissues and flag leaves as larvae approach maturity.

Disease transmission: None

Pest description and life cycle: The tan-gray moths have wingspans of about 1½ inches and can be most easily identified by the presence of a small white dot in the center of each forewing (Figure 60). Like many other species of cutworms, the true armyworm moths migrate into the state on prevailing winds and storm fronts during early spring. In some years, armyworm larvae may overwinter in Missouri. In either situation, these nocturnal moths lay egg masses on leaf blades and sheaths at night. About a week after eggs are laid, larvae emerge and begin feeding on host plants. Mature larvae may grow to 1½ inches in length and are nearly hairless and smooth. Larvae are greenish brown in color and typically have alternating dark and light stripes with two orange stripes located on each side of the body (Figures 61-63). Each proleg has a dark band on its outer side and a dark tip on the inner side, and the tan head is covered with dark lines. Large numbers of larvae can quickly consume wheat vegetation and are forced to move to new fields to feed. The name armyworm comes from the way larvae move to new sites as a group or "army" of larvae. The first generation of larvae usually is responsible for most wheat damage. There may be three generations of this pest produced in northern states and numerous generations in southern states.

Scouting/Economic thresholds: Small larvae are nocturnal feeders, whereas larger larvae spend more time feeding on wheat foliage and heads during the day. Scouting for this pest is done by examining three linear feet of row in five or more areas. Check plants for feeding on the edge of leaves when larvae are small or for the presence of feeding on the flag leaf or head cutting when larvae are approaching maturity. Treatment is justified when there is an average of six or more ¾- to 1¼-inch long nonparasitized larvae present per linear foot of row or before head clipping is noted. If a square foot measure is taken, the threshold is reached when an average of four or more nonparasitized half-grown or larger larvae per square foot are present, or before 2-3 percent of the heads are clipped from stems. To determine if larvae are parasitized, look for small white egg or eggshells of parasites attached behind the heads of armyworm larvae.

Figure 59. Almost complete defoliation of plants from armyworm feeding.

Control: Several insecticides are labeled for control of armyworm in wheat. In addition, parasites, insect predators, various diseases and several other organisms help keep the armyworm under control in small grains. The effectiveness of these natural control agents is reduced during cool, wet springs and during growing seasons that follow drought years.

Figure 60. Armyworm moth with small white dot in the center of each forewing.

Figure 61. Armyworm larva on the ground in a wheat field.

Figure 62. Armyworm larvae on the ground in a wheat field.

Figure 63. Armyworm larva on a wheat head. The black bands on the prolegs help identify this insect.

Cereal leaf beetle (CLB)
Oulema melanopus (L.)
Family Chrysomelidae

Quick identification: “Sluglike” larvae appear brown in color because of a covering of fecal material spread over their bodies (Figure 64). Removal of the covering reveals pale yellow larvae with brown heads and feet (Figure 65). Small larvae are usually found on the upper side of leaf surfaces, especially the flag leaf.

Status: Occasional pest of cereal grain crops, especially oats and wheat.

Timing: Economic damage may occur from pre-boot through grain fill when larvae feed on flag leaf of wheat or foliage of oats. Often a pest in years lacking heavy spring rains.

Distribution: Statewide

The cereal leaf beetle is native to Europe and was first found in Michigan in 1962. Within 10 years, it expanded its range and appeared in the St. Louis area in 1972. In the mid-1980s, this pest expanded its range throughout Missouri.

Figure 64. Cereal leaf beetle larvae and feeding damage on wheat flag leaf.

Figure 65. Pale yellow cereal leaf beetle larva with fecal covering scrapped to the side.

Host crops: Although oat and wheat are preferred hosts, this insect feeds on many cereal grains and grasses, including barley, rye, corn, timothy, reeds canarygrass, quackgrass and some ornamental grasses.

Damage: Larval feeding on flag leaves may result in economic damage of wheat, although both adults and larvae feed on plant tissues. Adult beetles chew holes through plant leaves but rarely cause economic damage. Larvae feed on the flag leaf by removing the green layer from the upper leaf surface while moving up and down the length of the leaf. The translucent lower leaf surface is left intact and produces a "window pane" type of damage, which is seen as long strips of translucent leaf tissue running parallel to leaf veins (Figures 64, 66 and 67). The tips of damaged leaves often turn white and dry, producing a “frosted” appearance in heavily damaged fields. Because the flag leaf converts much of the energy needed for grain production, damage to the flag leaf may result in substantial yield loss.

Disease transmission: None in wheat but may vector maize chlorotic mottle virus (MCMV), resulting in lethal necrosis of corn.

Pest description and life cycle: Adults are slender, 3⁄16 inch long beetles with metallic blue wing covers and head and reddish orange prothorax (neck region) and legs (Figure 68). Adult beetles overwinter in woods and field borders and move into wheat fields in early spring to feed and lay eggs. Larvae emerge in about five days, depending on temperature, and begin feeding. Larvae are yellow but appear brown in the field because their bodies are covered in fecal material, which helps repel parasites and predators (Figure 64). Removing this fecal covering will reveal pale yellow larvae with brown heads and feet (Figure 65). Larvae typically feed for about 10 days and then move to the upper two inches of soil to pupate. Adults emerge in about three weeks and briefly feed before entering summer diapause. In the fall, beetles move to overwintering sites. One generation is produced annually.

Scouting/Economic thresholds: Scouting is best accomplished by examining 20 plants each at five locations randomly selected in the field. The economic threshold is based on the average number of tillers or flag leaves infested by cereal leaf beetle larvae. If an average of one or more larva is present per wheat tiller or flag leaf, the economic threshold has been reached and implementation of control measures is justified. Yield reductions of up to 30 percent may result if flag leaves are severely damaged by larval feeding.

Control: Cereal leaf beetle infestations occur in most years in Missouri, but they typically do not reach economic threshold levels. In many cases, heavy spring rains cause significant larval

Figure 66. Cereal leaf beetle feeding damage on wheat leaf.

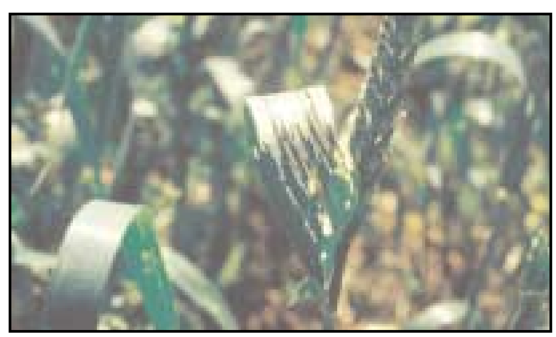


Figure 67. Cereal leaf beetle feeding damage on wheat leaf.

mortality when larvae are washed from host plants. Occasionally, wheat and oat fields will require an insecticide application, but damage to corn and other host plants is minimal. Several insecticides are labeled for control of this pest. Natural enemies such as egg and larval parasites may help reduce cereal leaf beetle numbers, although their impact on pest populations are thought to be minimal at this time. Predatory insects, including several lady beetle species and a fungal pathogen, are important natural enemies of cereal leaf beetle larvae.

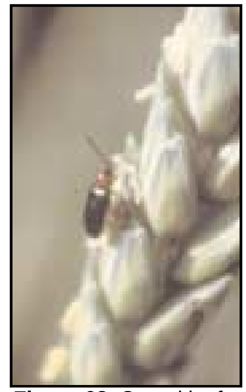


Figure 68. Cereal leaf beetle adult on wheat head.

Hessian fly

Mayetiola destructor (Say)
Family Cecidomyiidae

Quick identification: Legless small white maggots found feeding on leaf sheath tissue of wheat crown at or just below the soil surface (Figure 69).

Status: Occasional pest of wheat and cereal grains in Missouri. An important worldwide pest introduced into the United States in straw bedding used by Hessian mercenary troops during the Revolutionary War. Hessian fly was first reported in Missouri in 1870.

Distribution: Statewide

Host crops: Mainly wheat but to a lesser extent rye, barley and several species of grasses.

Damage: Winter wheat is most often damaged by the fall (second) generation of this pest in Missouri. Damage results when maggots emerge in early September to feed on newly emerged wheat; feeding may continue through mid-October. Maggots feed on the base of leaf sheaths, resulting in weakened plants that fail to tiller properly and may die during the winter. (Figures 70 and 71). If damaged plants survive the winter, they may produce reduced yields or be barren of grain the following spring. The maggots produced by the spring (first) generation of Hessian fly are usually heavily parasitized and cause minimal reductions in grain yield.

Disease transmission: None

Pest description and life cycle: The Hessian fly adult is less than 1/8 inch long and resembles a small mosquito or midge (Figure 72). Adults emerge during April (first generation) to use their 2-3 day life cycles to mate and lay eggs on wheat plants. Maggots feed at the first and

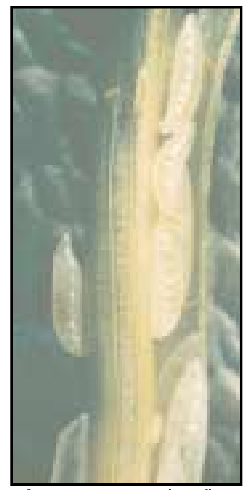


Figure 69. Hessian fly maggots on wheat crown.

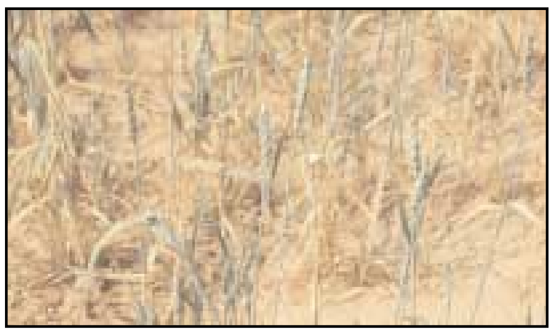


Figure 70. Thin stand with weakened plants from Hessian fly damage.

Figure 71. Field trial showing difference in damage from Hessian fly between resistant (on left) and susceptible (on right) wheat varieties.

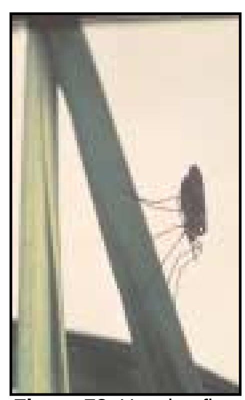


Figure 72. Hessian fly adult on wheat plant.

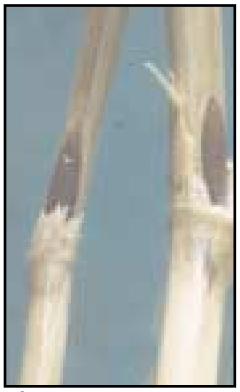


Figure 73. Overwintering puparia or flaxseeds of Hessian fly on wheat.

Figure 74. Yellow-green, parallel edged streaks on leaves from wheat streak mosaic vectored by wheat curl mite.

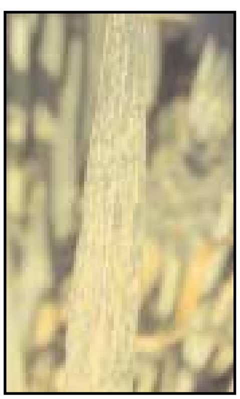


Figure 75. Yellowing and drying of leaves from wheat curl mite feeding damage and wheat streak mosaic vectored by the wheat curl mite.

second nodes of developing wheat plants for 4-6 weeks. They then change into puparia and remain in this stage until August and September when adult flies emerge and lay eggs for the fall (second) generation. Maggots emerge from eggs in 3-10 days and begin feeding at the base of leave sheaths. They feed by rasping leaf surfaces and sucking up plant juices oozing from the wounds. Feeding continues for 4-6 weeks after which Hessian flies overwinter as full-grown maggots inside puparia that resemble the seed of flax (Figure 73). The overwintering puparia are often referred to as "flaxseed." In the spring, pupation is completed and adult flies emerge to become the first of two generations produced annually.

Scouting/Economic thresholds: Scouting for the presence of Hessian fly is best accomplished by examining the base of the leaf sheath and the first and second nodes of several plants at several locations in the field. Look for the presence of maggots or puparia. Areas of reduced wheat stands and the presence of stunted plants may indicate a Hessian fly infestation.

Control/Timing: Hessian fly populations are difficult to manage with “rescue” insecticide applications. Management of this pest is best achieved by cultural methods of pest management that prevent the development of economic infestations of the Hessian fly. Cultural methods include destruction of wheat stubble and volunteer wheat throughout summer and fall months; planting of pest-resistant wheat varieties; and planting winter wheat after the fly-free date, when Hessian fly adults die in late summer. Fly-free planting dates range from Sept. 28 in northern Missouri to Oct. 16 in southeastern counties (Figure 2). After the fly-free date, adult Hessian flies are no longer present to lay eggs on emerging wheat plants. In addition to cultural control methods, several species of parasitic wasps provide some control of Hessian fly, especially the spring generation of this pest.

Wheat curl mite

Eriophyes tulipae keifer (Acari)

Family Eriophyidae

Quick identification: Tiny, white, cigar-shaped mite with four forward-directed legs located near the head. Difficult to see with the naked eye, as mites are about 1/100 inch long.

Status: Occasional pest of wheat and cereal grains in Missouri.

Distribution: Statewide

Host crops: Mainly wheat but to a lesser extent proso millet, corn, Canada wild rye and a few species of weedy grasses.

Damage: Plants infested with wheat curl mites are normally stunted with mottled and streaked leaves. Streaks on leaves are characterized by discontinuous, yellow-green streaks possessing parallel sides and may be a result of wheat curl mite damage or wheat steak mosaic (Figure 74). Infested leaves remain erect with lateral margins of leaves curled (rolled) inward toward their midribs. Infested leaves may have a dry or desiccated appearance.

Disease transmission: Wheat streak mosaic virus (WSMV) is thought to be transmitted only by the wheat curl mite (Figure 75).

Pest description and life cycle: This microscopic plant-feeding pest goes through the life stages of egg, two larval stages and adult. This mite is capable of producing a new generation every 7-10 days when temperatures range between 75 to 85 F. During the winter, this mite can survive freezing temperatures for several months. Normal summer temperatures and mild winters favor mite reproduction, whereas harsh winters and hot dry summers hinder reproduction. Eggs are laid in rows along leaf veins. Emerging larvae feed between leaf veins, generally on terminal leaves. Mites rapidly mature and reproduce during summer months, but they also may reproduce during periods of warm, winter weather. All life stages can be found on wheat and perennial grasses throughout most months of the year. Mites are wingless but often crawl to wheat heads, where they are picked up by the wind and transported to new locations. Mites may be moved several miles when winds reach or exceed 15 mph and temperatures are mild.

Scouting/Economic thresholds/Control: Scouting for wheat curl mites is difficult because of their microscopic size. Stunted plants, curled leaves and leaf streak injury are characteristics of wheat curl mite damage. Economic thresholds for curl mite in wheat have not been developed. Management of this pest using foliar acaricides traditionally has been difficult to achieve. Recommended management options include late planting of wheat; elimination of volunteer wheat and alternate host grasses around field borders; and use of resistant wheat varieties.

WHEAT HARVEST, DRYING AND STORAGE

Most wheat is harvested during a 4-6 week period in Missouri beginning in late May in the south and ending in early July in the north. The timing of the wheat harvest is highly dependent on the weather. A warm, early spring can push wheat harvest up by as much as two weeks, while damp cool weather at maturity can cause delays of two weeks or more in completing the harvest.

Most Missouri wheat growers do not hold wheat on-farm unless it is for a short period of time to let the market stabilize or to remove moisture. Many farmers endeavor to harvest wheat at a moisture content that is suitable to transport the grain directly from the field to a local elevator.

Wheat should be harvested without delay when it reaches maturity and begins to dry down to market moisture contents. After wheat begins to dry in the field, repeated precipitation and drying begins to decrease quality and test weight. It is often true that harvesting wheat while it is still somewhat wet and using artificial drying produces the highest quality wheat.

An early harvest also extends the available growing period for a double crop of soybean. Double cropping soybean after wheat is particularly suitable in the south and becomes relatively risky in the north due to the shorter growing season.

There are several advantages to harvesting wheat early and using artificial drying to remove the last points of moisture.

An early harvest reduces the risk of catastrophic damage to the crop from high winds or hail. An early harvest also may prevent the mature crop from drying and rewetting due to rain, which results in more harvested bushels and a higher quality product with higher test weights.

Finally, an early wheat harvest extends the growing season for a double crop of soybean. Length of the growing season is a primary limiting factor for soybean double cropping, especially in northern Missouri.

HARVESTING

Prepare for the wheat harvest by performing routine maintenance early and then equipping and adjusting the combine according to the operator's manual. Most modern combines will perform adequately simply by setting them according to the operator's manual. Develop a harvest plan based on the quality of the wheat and weed control. Harvest high-quality wheat first. Schedule weedy fields last because yield and quality are likely to be poorer as well. Harvest the weediest areas of those fields using a pattern that minimizes the chances of spreading weed seed to clean areas of the field.

When making adjustments to the combine, it is important to keep in mind that the crop passes through five distinct systems respectively: (1) cutting and feeding, (2) threshing, (3) separating, (4) cleaning and (5) materials handling. The performance of a particular system depends on the performance of any systems that precede it. Hence, adjustments to combine performance should begin by optimizing cutting and feeding and end with an analysis of the final cleaning operation by observing how much grain is left on the ground and by inspecting the materials-handling systems.

Cutting and feeding

The objective for setting the header for wheat should be to gather all of the grain while minimizing the volume of straw that must be handled by the rest of the combine.

Before beginning harvest, make sure the sickle is in good operating condition. Sharp sickle sections cut straw quickly and cleanly for peak performance. Dull sickle sections that tear at the stalk transmit some of the aggressive motion of the sickle to the head and can cause shattering.

Since wheat produces heads only at the top of the stem, cutting height for wheat should be relatively high to limit the amount of straw that must be handled by the combine. The combine operator should constantly be aware and ready to change header height as the terrain or the height of the crop changes. The goal always should be to harvest approximately the same length of stem to maximize feeding and cutting performance.

The reel should be adjusted just slightly ahead of the cutter bar and low enough to make good contact with the top of the stems. Reel speed should be adjusted relative to ground speed so that the bats begin to lay the stems over just before they are cut. Combines, like most other machinery, are designed to operate best at some moderate ground speed.

When ground speed is too high, some wheat may be poorly cut or knocked down. When ground speeds are excessively slow, some stems may not drop over into the header properly and fall to the ground underneath the cutter bar.

Threshing and separating

Setting the combine for maximum performance almost always involves some kind of tradeoff between maximizing the volume of grain harvested and the quality of the grain. This is particularly true for the threshing system. The same adjustments that improve threshing can damage grain and increase the amount of foreign material in the sample.

Threshing is completed with the rotor or cylinder turning at high speeds and with narrow clearances inside the concaves. The concaves confine material to a small space and allow threshed seeds and other small debris to pass through where they are collected below on the grain pan. The primary threshing action for combines equipped with a cylinder is from high-velocity impacts created as the cylinder spins at several hundred rpm. Threshing also takes place in part from the rubbing action against the plant material, especially for combines equipped with a rotor.

The aggressive action of threshing is the primary cause of physically damaged seeds. Damage is especially high for overly dry seeds (below 13 percent moisture content), which become cracked or broken during threshing. Excessive damage can also be caused to the seed coat of very wet seeds (above 22 percent) when harvest begins too early.

Seed damage is minimized by harvesting seed with moderate moisture contents and by reducing cylinder or rotor speed to the minimum level necessary for good threshing. Cylinder or rotor speeds and clearances should be changed throughout the day to match the requirements of the crop.

Under moderate operating conditions and when the amount of straw that is fed into the combine is minimized, most separation will occur through the concaves during threshing. At high feed rates or when a lot of material is fed through the combine, more grain will reach the straw walkers or the separation stage of the rotor, which results in higher separator losses as more grain is carried out the back of the combine with the straw.

Fine tuning cylinder or rotor speed and clearance is a balance between achieving complete threshing and minimizing damage to grain. It is sometimes advisable to err on the side of leaving a little grain in the heads to minimize the amount of chaff and damaged grain that is produced.

Damaged grain and grain with high amounts of foreign material reduce profits when marketed and are more difficult to store. Broken and damaged grain is more susceptible to damage by insects and storage molds. The smaller fragments from damaged kernels and foreign material further reduce storability by restricting airflow during storage.

Cleaning

Grain, partially threshed heads and chaff are sorted in the cleaning shoe. The cleaning shoe consists of two oscillating sieves. The top sieve is known as the chaffer, while the lower sieve is known as the cleaning sieve. The fan blows air through the chaffer to remove lightweight material or chaff.

Ideally, only grain and small, unthreshed seed heads fall through the chaffer sieve down to the cleaning sieve. Large unthreshed heads are propelled to the rear of the chaffer, where they may fall through the chaffer extension and drop into the tailings auger. Any material that does not pass through the cleaning sieve is propelled to the rear of the sieve, where it is collected in the tailings auger as well. Materials with intermediate aerodynamic properties, such as straw, are both floated and mechanically propelled over the chaffer and the chaffer extension, where they are expelled.

Overloading the shoe is a common problem and ultimately limits overall combine capacity. Overly aggressive threshing can pulverize straw into finer pieces and show up as excess amounts of straw at the shoe. Here, the excess straw can overload the sieves and result in carrying grain over the back of the shoe.

Similar shoe losses can be caused by setting the chaffer openings too narrow or by setting the fan speed too low. Setting the fan speed too high can result in blowing lighter kernels right out the back of the shoe. If the chaffer is set too wide, excess straw and unthreshed heads may pass through and overload the cleaning sieve, which causes excessive amounts of threshed grain to be recycled.

DRYING AND STORAGE

Wheat is often a relatively small crop for many Missouri farmers, and many elevators are only equipped to receive wheat during a period of several weeks at harvest. For these reasons, many farmers often plan on selling wheat directly from the field. Hence, much wheat is allowed to dry naturally in the field. When grain is stored on-farm, a grower must remember that quality never improves during storage. Store only the highest quality grain.

Storage facilities

If wheat is dried or stored on-farm, use a properly designed and constructed storage structure to minimize handling losses and quality deterioration during storage. A cylindrical metal bin has many distinct advantages over any other structure that might be used to store grain. Cylindrical metal bins are designed, and should be installed, to

- Contain grain in a controlled atmosphere away from livestock.
- Provide weather-tight shelter to protect grain from precipitation.
- Provide barriers to pests.
- Provide for aeration.
- Permit effective treatment to prevent or control insect infestation.
- Provide suitable access and safety for those managing the grain during storage.
- Provide easy and complete cleanout.

Prepare the storage bin before harvest by emptying the bin and removing all traces of the previous crop. Good sanitation practices eliminate sources of food for rodents as well as host locations for disease and insect pests. A thorough cleanup involves cleaning pits, augers and transitions as well as any other locations in the grain-handling system where grain can accumulate. For best results, follow the physical cleanup process with an approved insecticide to get ahead of insects before harvest begins. Thorough cleaning and pest control before bins are filled will help protect new crop grain from old crop pests.

When building new facilities, do not skimp on installing access doors and don't miss any chances to install self-cleaning components. Accessibility and ease of cleaning should be high-priority considerations in the final design of any new grain-handling system. These features can quickly pay for themselves if they help avoid even a few docked loads from a little extra mold, insect damage or sprouts from grain exposed to the elements in a hard-to-clean place. Building in the ability to thoroughly clean the grain-handling system also prepares these facilities to preserve identity and capture a premium on grain that has some relatively "highly valued" property.

Drying

Drying wheat during the summer months requires more attention than drying corn during the fall. Although the principles are the same, the rules of thumb are not. Wheat restricts airflow more than corn, so fans that can provide just enough air in a full bin of corn will fail to do so in wheat. Wheat is also harvested at the onset of some of the highest temperatures of the year, while corn is harvested at the onset of cooler temperatures. Therefore, wheat must be dried quickly to prevent spoilage.

Table 5. Minimum recommended airflow rates for drying wheat with natural air.

Initial harvest moisture content (% wet basis)	Minimum recommended airflow rate (cfm/bu)
Up to 16%	1.0
Up to 18%	2.0
Up to 20%	3.0

Wheat should be dried with natural air whenever possible to obtain the highest quality grain. Natural-air drying also reduces the tendency to overdry wheat. Wheat should be dried in shallow layers to maximize the airflow. Minimum airflow rates for drying wheat with natural air are listed in Table 5. Wheat should be dried to 13.5 percent for immediate sale since overdrying reduces the total weight of grain to be sold. However, if wheat is to be stored for any period of time during a warm Missouri summer, dry to 12 to 12.5 percent moisture content to prevent spoilage.

For most in-bin systems with properly sized drying fans, natural-air drying works best when initial wheat moisture content i less than about 18 percent and the depth of wheat is kept below about 9 or 10 feet. Remember that the higher the initial moisture content, the more quickly the wheat must be dried to prevent the top layer from spoiling. The corollary to this rule is that wetter wheat must be dried in shallower layers.

Do not attempt to dry wheat with a fan sized for aeration. High-speed dryers are the best choice for drying wet wheat because they generally provide maximum airflow. A small amount of heat may be required on only high-humidity days.

Soft red winter wheat dried with natural air at constant conditions will eventually reach the equilibrium moisture contents shown in Table 6. In practice, the relative humidity and temperature of ambient air vary throughout the day, and the final moisture content will be a function of the average conditions of the air. For example, during daytime hours with a full sun, suppose the temperature and relative humidity of the air reached 90 F and 50 percent humidity. Under these conditions, the wheat would eventually dry to a final moisture content of about 10.8 percent.

During the night as air temperatures drop, the relative humidity also tends to increase. Suppose the nighttime air reached a temperature of 60 F and relative humidity of 90 percent. The equilibrium moisture content at this condition is about 17.2 percent. If drying fans were running continuously, the final moisture content of the grain would fall somewhere between 10.8 percent and 17.2 percent.

When drying wet wheat with natural air, fans should be run day and night until the moisture content drops to about 15 percent. Wheat on the bottom of the bin is the first to dry, especially during hotter and drier daytime hours. As the air passes through the lower layers, it removes moisture from the wheat on the bottom layers and eventually becomes saturated so that it can't hold any more moisture. Hence, the wheat on the top layers does not dry until the wheat in the bottom layers is relatively dry.

During the night, the drier wheat on the bottom absorbs some moisture from the air and increases the depth of the drying front by removing moisture from grain above.

Run the fan selectively after the moisture content of the wheat reaches about 15 percent to remove the last percentage point or two of moisture. The best drying air occurs from about 10:00 a.m. to 8:00 p.m. on normal days when temperatures are high and humidity is low.

Heat should be used sparingly when necessary to improve drying efficiency. Supplemental heat shifts the properties of the drying air toward the lower left corner of Table 6, which increases the drying potential of the air and the tendency to overdry wheat.

Stirring devices and recirculating systems improve success when using supplemental heat. Supplemental heat increases the chances of spoiled grain at the top of the bin because the wheat at the top remains wet until the wheat at the

Table 6. Equilibrium moisture content for soft red winter wheat.

	Relative humidity %								
Temp F	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
35	6.3	8.3	9.8	11.1	12.3	13.5	14.8	16.3	18.3
40	6.2	8.1	9.6	10.9	12.1	13.3	14.6	16.1	18.1
50	6.0	7.9	9.4	10.6	11.8	13.0	14.2	15.7	17.6
60	5.9	7.7	9.1	10.4	11.5	12.7	13.9	15.3	17.2
70	5.7	7.5	8.9	10.1	11.3	12.4	13.6	15.0	16.9
80	5.6	7.4	8.7	9.9	11.0	12.1	13.3	14.7	16.5
90	5.5	7.2	8.5	9.7	10.8	11.9	13.0	14.4	16.2
100	5.4	7.1	8.4	9.5	10.6	11.7	12.8	14.1	15.9

bottom is dry and the higher temperatures from the added heat increase the rate of dry matter loss.

MONITORING AND AERATION

Wheat should be cooled as weather permits to reduce the activity of insects, to inhibit the growth of storage molds and to prevent moisture migration. As outside air temperatures drop, the grain against the wall of the bin begins to cool. The cooler air in the grain at the walls is relatively dense compared with the warm air in the center of the bin. This dense air at the walls moves downward and displaces air in the warm core of the bin. As this natural air current moves through the grain, it picks up moisture. When the air reaches the cooler surface grain at the top of the bin, the moisture condenses on that grain and causes spoilage. Regular aeration intervals prevent moisture migration by keeping the average grain temperature more similar to outside temperatures.

If using an aeration fan designed to provide a relatively small airflow rate on the order of 0.1 to 0.2 cfm/bu, begin cooling wheat when the average air temperature drops by about 10 F. Run the fan continuously until the exhaust air temperature drops to the new level. When using a drying fan that can provide an airflow rate of ½ to 1 cfm or more, begin aerating when the average air temperature drops by about 15 F.

Monitor stored wheat on a regular basis, at least weekly until wheat is cooled to 50 F and then at least monthly until the grain is sold. Good monitoring practices require checking the moisture content and temperature of the wheat throughout the grain mass. Aeration fans should be run immediately if musty smells or crusted grain are detected. Continue running fans until the problem is solved or until the wheat is sold.

SUMMARY

- Prepare the combine, storage and drying facilities well before harvest.
- Harvest wheat without delay after maturity and when moisture content is low enough to store or to dry quickly.
- Adjust the combine and pay particular attention to the header to minimize harvest losses.
- Set threshing characteristics of the combine to produce the highest quality wheat.
- Use natural air to finish drying wheat if necessary. Use heat sparingly to improve drying performance.
- Cool wheat as the weather permits to improve storability. Monitor bins periodically to catch small storage problems before they become large problems.

WHEAT ECONOMICS

Estimating net income from wheat production is a process of considering all of the sources of revenue and subtracting all of the expenses. The onerous part of estimating net income comes from determining what yields, prices and other items to include in the estimates of revenue and expense.

The following wheat budget is given for a typical Missouri wheat-production system. Yield and prices will vary from year to year and farm to farm. The items included in the budget are not the same for every farm but are typical of many. The format allows for individual producers to substitute their own estimates to arrive at costs and returns that they believe are more in line with their situation.

Income per acre

Returns per acre are highly dependent on yield per acre. The budget provides three columns for three different yield levels. The 50-bushel yield is the five-year average yield for Missouri wheat harvested. The 30-bushel column indicates a poorer yield that would receive a crop insurance indemnity payment only if the producer purchased greater than 60 percent yield coverage. The 70-bushel yield column is attainable in Missouri.

Price per bushel varies with time and is influenced by farm policy. Figure 76 presents average annual market prices for Missouri winter wheat for the last 10 years. The average price has fluctuated from just over $2.00/bu to just over $4.00/bu. Wheat producers can plan on receiving whichever is higher, the market price or 85 percent of the target price established by the U.S. Department of Agriculture.

The budget at the end of this section assumes a market price of $2.73/bu, the national wheat price estimated by the Food and Agriculture Policy Research Institute less $.30 for a soft red winter wheat price differential. This cash price would produce an estimated government countercyclical payment of $.67/bu of program yield (assumed to be 85 percent of average, 50 bushel, yield in the table). Miscellaneous income would be income from such things as straw sales.

The target price is multiplied by 85 percent because the Farm Bill pays only on a percentage of program yield. When the market price is below the target price, the government will pay wheat farmers a countercyclical payment approximately equal to the difference between the market price and the target price times 85 percent of the farmer's established program yield. The 2002 Farm Bill specified that the target price at $3.86 for the 2002 through 2003 marketing years, and at $3.92 for the 2004 through 2007 marketing years.

In addition to the countercyclical payment, farmers receive a direct payment for wheat acres. The direct payment has been set at $.52/bu for 85 percent of program yields. Although the direct payments are for wheat base acres, the farmer is not obligated to grow wheat on those base acres. The direct payment is paid regardless of what mix of crops is grown on the land. The budget does not include direct payments for wheat acres.

The 2002 Farm Bill differentiates between classes of wheat in determining loan rates. Soft red winter wheat no longer has the same loan rate as the other four classes of wheat (hard amber durum, hard red spring, hard red winter and soft white wheat). The average loan rate in Missouri for soft red winter wheat is $2.57/bu; for hard red winter wheat the loan rate is $2.90. The loan rate affects the counter cyclical payment that farmers receive so that soft red winter wheat producers can expect to get about $.33/bu less than the national target price.

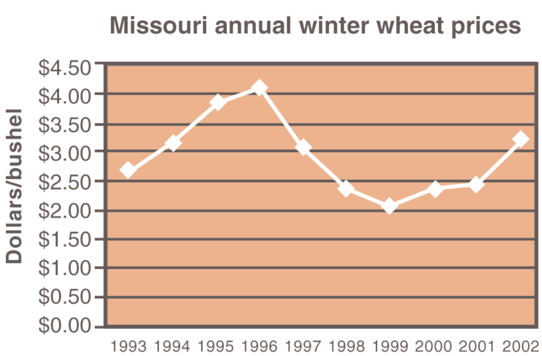


Figure 76. Historical winter wheat annual prices (1993-2002).

Costs

Cost of production will vary with assorted choices of the farmer. Whether bin-run seed or new seed is purchased, whether no-till or conventional tillage is used, and whether the seed is harvested dry or dried in storage join to affect the cost of production.

Seed expense is estimated at $10, assuming that 100 pounds of wheat seed costing $5.00 per 50-pound bag are used. Fertilizer cost includes nitrogen, phosphorus, potassium and sulfur product costs. Fertilizer application charges are listed under machinery expense. Lime cost includes the annualized price of the product delivered.

Herbicide costs are variable depending on the herbicides used. The budgeted herbicide cost of $7.25 approximates a standard herbicide program for wheat in Missouri. Again, spraying charges are included under machinery expense. No insecticide or fungicide is included in the budget, though it may be necessary depending on the pest pressure on the crop.

Custom hire and machinery expense approximates the cost of owning and operating (including labor) machinery for fieldwork and hiring services such as crop spraying. This estimate will vary depending on whether old or new equipment is used and on how many acres owned equipment is used.

Nonmachinery labor is an estimate of all labor expense not directly associated with operating equipment. It takes into account that work outside the field is important to efficient production. Miscellaneous costs include overhead and other small costs such as utilities and phone.

Land charge is reported as the average cash rental rate for dryland wheat cropland reported in 2003. Rental rates are expected to be close to the value of the land multiplied by a reasonable return on investment. The rental rate is consistent for all yield levels because the yield differences are expected to be due to growing conditions rather than land quality.

Interest in nonland costs approximates the interest that would be paid on a line of credit for purchased inputs. The interest reported is nonland costs times an interest rate of 8 percent times a half year for the term of the line of credit.

Total costs range from $193 to $206 because of the effect that yield has on fertilizer and equipment costs. Total cost/bu varies from $6.44 to $2.95 depending on the yield. This shows the influence of yield on per bushel cost of production. Time spent on marketing may profit a farmer $.10/bu, but a single bushel increase in yield will return more than twice that. Yield is the major determinant of wheat production profitability. Returns over all costs are negative for the average yield in Missouri. Farmers planning to profit from growing wheat need to manage their production to maximize yield.

DOUBLE CROP WHEAT-SOYBEAN

About half of Missouri wheat acres are double cropped with soybean in any one year. While the number of acres of wheat has been decreasing over the last decade, the percentage of acres double cropped has been increasing. Southeast Missouri has the highest percentage of double-cropped acres in the state. The number of acres put into double-crop soybean varies with year, due presumably to field conditions at wheat harvest.

Soybean double cropping permits the harvest of a second cash crop in a single year and saves on land, liming and machinery costs, which already have been either partially or fully charged to wheat.

Income per acre

Double-crop soybean typically yields less than single-crop soybean. The yield average for northern Missouri double-crop soybean is used in the budget (Table 7) along with a minimum and maximum. The soybean loan rate is used as a price estimate.

If there is a historical record of double-cropping on the farm between 1998 and 2001, both wheat and soybean bases may be established. Payments may be earned on both crops. The calculation of government payments is cumbersome. Readers are encouraged to use the "Base and Yield Analyzer" provided by the USDA at http://www.fsa.usda.gov/pas/farmbill/tools.asp to estimate government payments on double-crop soybean. No government payment is included in the budget at the end of this chapter for soybean.

Costs per acre

Seed expense is estimated as 1.5 bags of Roundup Ready® seed at $26.00 per bag. The seeding rate is held constant regardless of the yield shown on the budget because the yield variations are assumed due to growing conditions rather than management factors.

Fertilizer cost includes only the phosphorus and potassium removed due to harvest of seed. It does not include fertilizer application charges. No lime expense is attributed to the soybean plants grown on this ground.

Herbicide costs are variable depending on the herbicides used. The budgeted herbicide cost of $17.00 provides for a glyphosate burndown at planting followed by a second application to clean up late-emerging weeds. It does not include application charges. No insecticide or fungicide is included in the budget, though it may be necessary depending on the pest pressure on the crop.

Custom hire and machinery expense approximates the cost of owning and operating (including labor) machinery for fieldwork and hiring services such as crop spraying. This estimate will vary depending on whether old or new equipment is used and on how many acres the owned equipment is used on. Given that the machinery is used on two crops on the same acre, machinery costs might decrease if owned equipment is used rather than custom harvest and spraying.

Nonmachinery, labor and miscellaneous costs and interest in nonland costs are explained in the section on wheat.

No land charge is reported since the wheat budget was charged this cost. Double-crop soybean can use the same land without additional land charge.

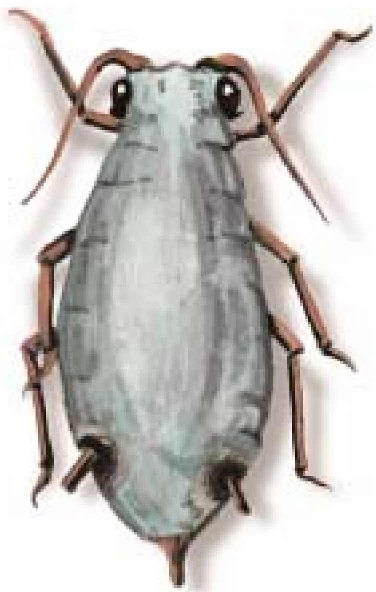
Total costs range from $115 to $122 because of the impact of yield on fertilizer costs. Total cost per bushel varies from $7.72 to $3.81 depending on the yield. At average yield, double-crop soybean does not have a positive net income. An additional 2 bu/acre yield causes income to exceed expenses — so growing conditions that indicate a successful crop are important before planting double-crop soybean.

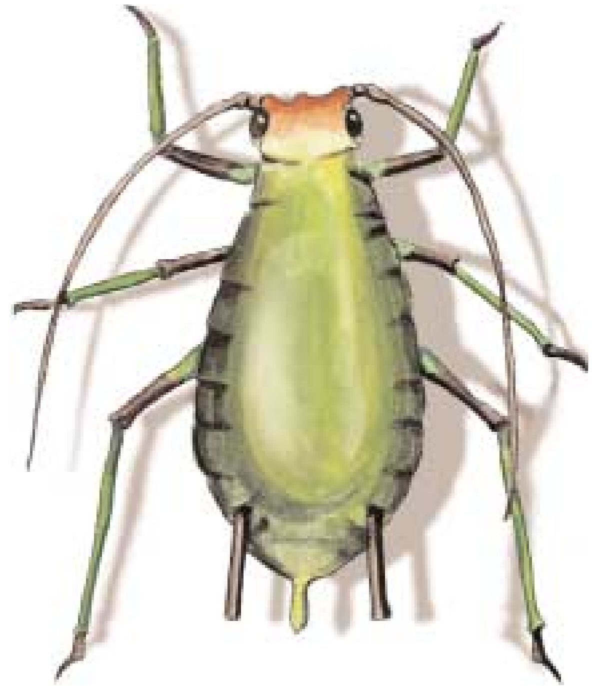
Table 7. Budget for wheat and double-crop soybean production.

	Wheat			Double-crop soybean		
Income						
Yield, bu/acre	30	50	70	15	22	32
Price/bushel	$2.73	$2.73	$2.73	$5.00	$5.00	$5.00
Government deficiency payments/acre	33.50	33.50	33.50	—	—	—
Miscellaneous income/acre	—	—	—	—	—	—
Income/acre	115.40	170.00	224.60	75.00	110.00	$160.00
Income/bushel	3.85	3.40	3.21	5.00	5.00	5.00
Costs/acre						
Seed	$10.00	$10.00	$10.00	$39.00	$39.00	$39.00
Fertilizer	38.00	41.60	44.80	5.40	7.70	11.30
Lime	5.00	5.00	5.00	—	—	—
Herbicide, insecticide and fungicide	7.25	7.25	7.25	17.00	17.00	17.00
Custom hire and machinery expenses	49.00	52.00	55.00	40.00	40.00	40.00
Nonmachinery labor	10.00	10.00	10.00	5.00	5.00	5.00
Miscellaneous	8.00	8.00	8.00	5.00	5.00	5.00
Land charge/rent	62.00	62.00	62.00	—	—	—
Interest on nonland costs	5.09	5.35	5.60	4.46	4.55	4.69
Total costs	$194.34	$201.20	$207.65	$115.86	$118.25	$121.99
Total cost/bushel	$6.48	$4.02	$2.97	$7.72	$5.38	$3.81
Returns over costs	$(78.94)	$(31.20)	$16.95	$(40.86)	$(8.25)	$38.01

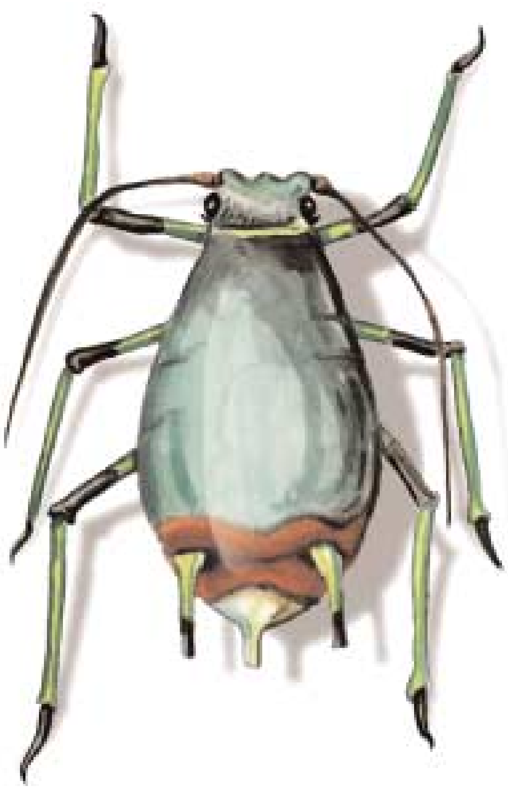
Note: No government direct payment is included in this budget.

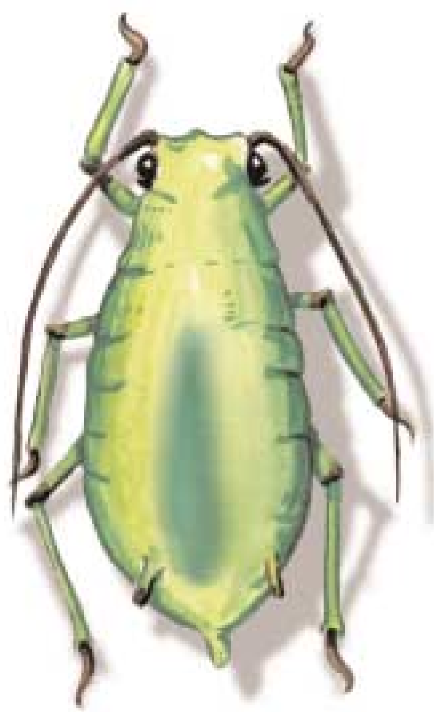
APPENDIX: APHIDS IN MISSOURI WHEAT





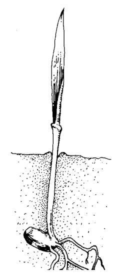
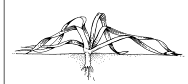
Left: Corn leaf aphid.
Right: English grain aphid.





Left: Bird cherry-oat aphid.
Right: Greenbug.

Soft red winter wheat integrated crop and pest management schedule

	Pre-plant	One-leaf	Fall tillering	Winter dormancy
				
Month	**Sept. to Oct.**	**October**	**Nov. to Dec.**	**Jan. to Feb.**
Crop management	Germination test	Planting		Spring nitrogen
	Assess seed quality			
	Soil test			
	Fall fertility			
	Seedbed preparation			
Insect managment		Aphid complex	Aphid complex	Aphid complex
		Wheat curl mite	Wheat curl mite	Wheat curl mite
	Hessian fly adult	Hessian fly adult / Hessian fly larvae	Hessian fly larvae	Hessian fly larvae
Disease management		Seedling blights	Seedling blights	
	Seed treatment fungicide (check)			
		Evaluate stand		
		Scout for barley yellow dwarf	Scout for barley yellow dwarf	
	Select resistant varieties			
Weed mangement		Winter annual weeds	Winter annual weeds	Winter annual weeds

Soft red winter wheat integrated crop and pest management schedule

	Spring tillering	Jointing	Boot	Anthesis	Harvest
Month	**Feb. to March**	**March to April**	**April**	**April to May**	**June to July**
Crop management	Spring nitrogen				Harvest
Insect mangement	Aphid complex				
	Cereal leaf beetle adults			Cereal leaf beetle overwintering adults	
		Cereal leaf beetle larvae			
	True armyworm moths (egg laying)				
		True armyworm larvae (foliage & head clipping)			
	Wheat curl mite				
	Hessian fly adult	Hessian fly larvae	Hessian fly adult		
Disease management	Scout for barley yellow dwarf			Scout for wheat streak mosaic	
	Scout for wheat spindle streak mosaic			Scout for take-all	
	Scout for wheat soilborne mosaic			Scout for scab & other head disease	
		Scout for foliage diseases			
Weed management	Winter annual weeds				
		Scout for summer annual weeds			

OUTREACH & EXTENSION
UNIVERSITY OF MISSOURI
COLUMBIA

■ Issued in furtherance of Cooperative Extension Work Acts of May 8 and June 30, 1914, in cooperation with the United States Department of Agriculture. Ronald J. Turner, Director, Cooperative Extension, University of Missouri and Lincoln University, Columbia, MO 65211. ■ University Outreach and Extension does not discriminate on the basis of race, color, national origin, sex, religion, age, disability or status as a Vietnam era veteran in employment or programs. ■ If you have special needs as addressed by the Americans with Disabilities Act and need this publication in an alternative format, write ADA Officer, Extension and Agricultural Information, 1-98 Agriculture Building, Columbia, MO 65211, or call (573) 882-7216. Reasonable efforts will be made to accommodate your special needs.

IPM 1022 New 10/03/5M