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A Comprehensive Guide to

Wheat Management in Kentucky

KENTUCKY
Small Grain
GROWERS' ASSOCIATION

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Cover: *Pembroke* variety of soft red winter wheat developed by the University of Kentucky with funding from the Kentucky Small Grains Growers' Association.

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Section 1

Introduction

Chad Lee, James Herbek, and Richard L. Trimble

The soft red winter wheat (*Triticum aestivum* L.) grown in Kentucky provides flour for cookies, cakes, pastries, and crackers and is the fourth most valuable cash crop in the state (Figure 1-1). Winter wheat has been an integral part of crop rotation for Kentucky farmers. Wheat is normally harvested in June in Kentucky and provides an important source of cash flow during the summer months. Several trends should be examined when considering the economic potential of wheat production in the state (see *Section 9—Economics of the Intensively Managed Wheat Enterprise*).

Improvements in varieties and adoption of intensive wheat management practices have resulted in dramatically increased wheat yields. Prior to 1987, the highest average yield achieved in Kentucky was 42 bushels per acre; since 1987, averages have been at least 49 bushels per acre in all but two years (Figure 1-2). State average yields have been 59 bushels per acre for the past decade and 62 bushels per acre for the past five years. State averages were above 70 bushels per acre in 2006 and 2008. Continued increases in yield help to keep wheat in the crop rotation.

Figure 1-1. Kentucky crop values according to the Kentucky Agricultural Statistics Service.

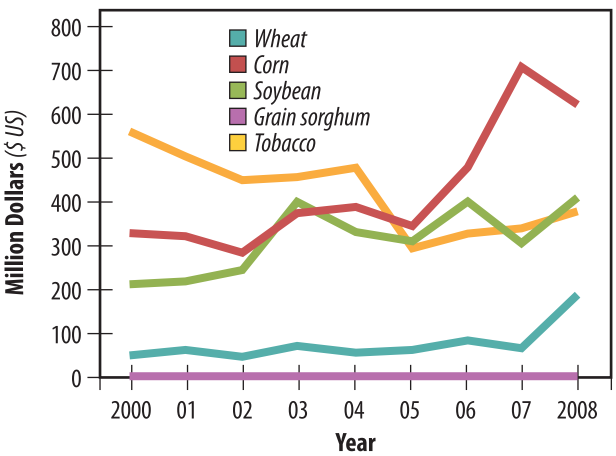


Photo 1-1. Soft red winter wheat *(Triticum aestivum)* grown in Kentucky is a valuable commodity and an important component to crop rotations. It also provides flour for cookies, cakes, pastries, and crackers, and feed for livestock.

The average yield of wheat trend has been upward, but the number of acres of wheat planted in the state has declined since 1981. Harvested acres were 680,000 in 1981 and were 460,000 in 2008 (Figure 1-3). Fluctuation in wheat acres harvested is a function of government programs, crop condition and economics.

This publication will help you use wheat management practices to improve the competitiveness of wheat in your crop rotation. There is no single best wheat management prescription for all circumstances, but this comprehensive publication explains the principles of wheat growth and management so you can make decisions appropriate to your situation. This publication also will help troubleshoot problems encountered during the growing season. If you use and adopt the following principles and practices, you should see increased yields, higher profits, and improved environmental protection from your wheat fields.

The important steps for intensive wheat management can be summarized in 18 steps. The application of these steps at the proper stage of growth and time of year is the basis for obtaining maximum and efficient wheat yields. (See *Winter Wheat Calendar* [ID-125A].)

18 Steps for Maximum Winter Wheat Yields	
1.	Test soil to determine fertility of field.
2.	Apply P, K, and lime according to soil test and University of Kentucky recommendations.
3.	Select several high-yielding, disease-resistant, winter-hardy wheat varieties.
4.	Calibrate the drill or other seeding equipment.
5.	For conventional tillage, prepare a good seedbed.
6.	For no-tillage, use a contact herbicide.
7.	Use 30 lb/A Nitrogen in fall as residual or applied.
8.	Plant from Oct. 10 to Oct. 30.
9.	Plant in 4- to 8-inch row spacings. Tramlines may be established at this time for subsequent applications.
10.	Seed 35 (up to 40 for no-till) seeds/square foot of high quality viable seed.
11.	Apply insecticide as needed for insect control (fall and spring).
12.	Check stand density near mid-February when winter survival can be rated.
	a) If stand is adequate (25 plants/square foot or more), apply 30 to 40 lb of nitrogen mid-to-late February.
	b) If stand is thin (less than 25 plants/square foot), apply 40 to 50 lb of nitrogen mid-to-late February.
13.	Apply an additional 50 to 60 lb nitrogen at Feekes 5 (mid-March).
14.	Use proper weed control measures (fall and spring).
15.	Apply fungicides as needed for disease control during the growing season.
16.	Harvest on time at optimum grain moisture (13 to 15%).
17.	Provide and prepare adequate, safe storage space.
18.	Market wisely for optimum profits.

Figure 1-2. Kentucky average wheat yields according to Kentucky Agricultural Statistics Service.

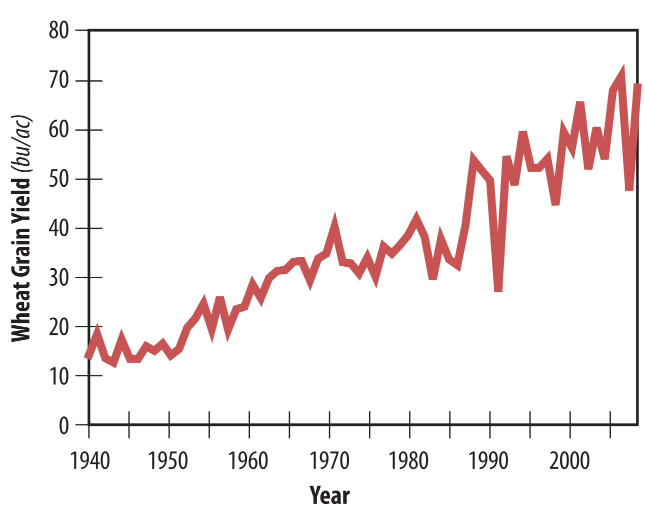
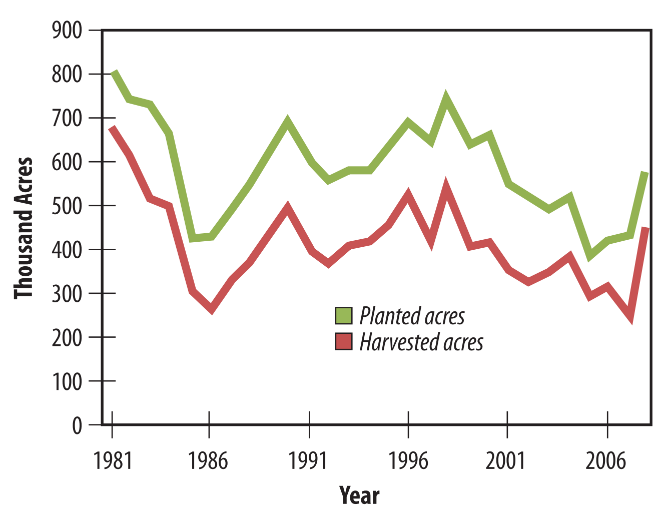


Figure 1-3. Kentucky planted and harvested wheat acres according to Kentucky Agricultural Statistics Service.



Section 2

Growth and Development

James Herbek and Chad Lee

Wheat responds best to inputs at certain stages of plant development. Therefore, it is important to understand wheat development and recognize wheat growth stages in order to properly time applications of pesticides, nitrogen, and other inputs.

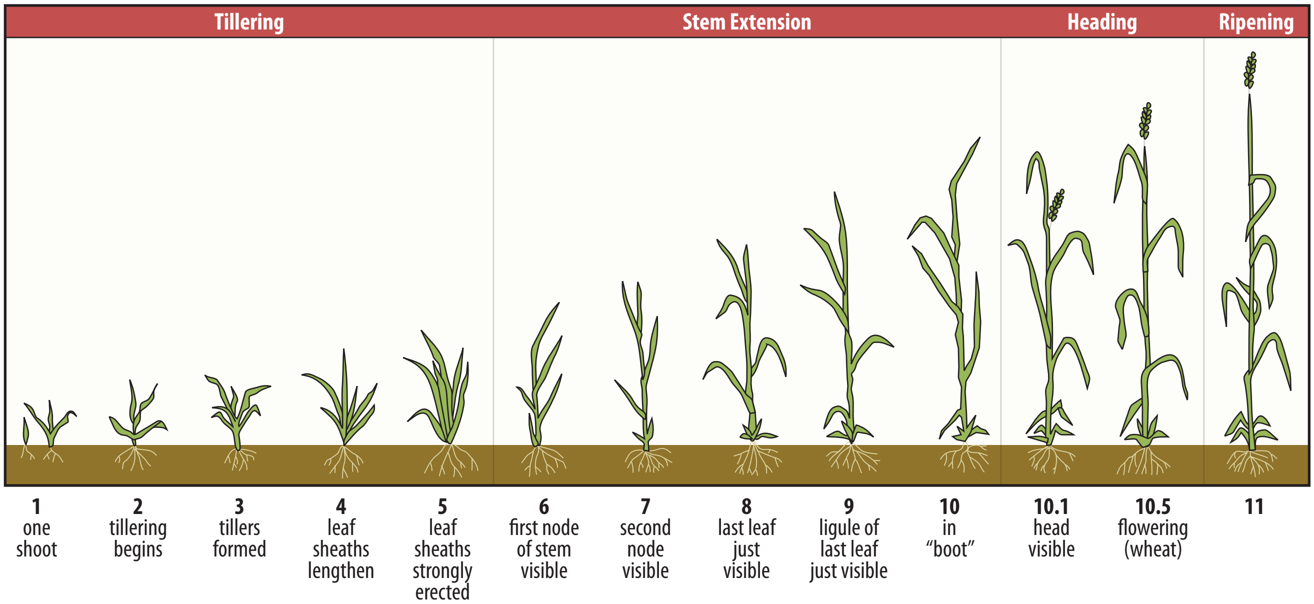
Wheat plants progress through several growth stages, which are described in terms of developmental events. Wheat plant growth and development can be broadly divided into the following progressive stages: germination/seedling emergence, tillering, stem elongation, boot, heading/anthesis, and grain-fill/ripening. Several different systems have been developed to identify wheat growth stages. These systems use a numerical designation for the development or formation of specific plant parts. The two most widely used methods for identification of wheat growth stages are the Feekes scale and the Zadoks scale. The Feekes scale is the traditional, most common scale and has been widely used by Kentucky growers. Developmental stages are designated on a scale of 1 (seedling growth) through 11 (ripening). The Zadoks scale is much more descriptive of various stages of development. It uses a two-digit system for wheat plant development, divided into 10 primary stages, each of which is divided into 10 secondary stages, for a total of 100 stages. The Zadoks scale goes from primary stage 00 (dry seed) to 90 (ripening). Both the Zadoks and Feekes scales are shown for comparison (Figure 2-1 and Table 2-1).

Germination and Seedling Growth

Adequate temperature and moisture are needed for wheat seeds to germinate. Wheat seeds germinate at temperatures of 39°F or higher; temperatures between 54° and 77°F are considered optimum for rapid germination and growth. Germination begins when the seed imbibes water from the soil and reaches 35 to 45 percent moisture on a dry weight basis. During germination, the seedling (seminal) roots, including the primary root (radicle), emerge from the seed along with the coleoptile (leaflike structure), which encloses the primary leaves and protects the first true leaf during emergence from the soil. The coleoptile extends to the soil surface, ceases growth when it emerges, and the

Photo 2-1. Wheat at about Feekes 2 (Zadoks 21) in corn residue.

Figure 2-1. The Feekes scale of wheat development.



first true leaf emerges from its tip. Under favorable conditions, seedling emergence occurs within seven days. Until the first leaf becomes functional, the seedling depends on energy and nutrients stored in the seed.

Seedling growth begins with the emergence of the first leaf above the soil surface and continues until the next stage, tillering. Normally three or more leaves develop in the seedling stage before tillering is initiated. Each new leaf can be counted when it is over one-half the length of the older leaf below it. During this phase the fibrous root system develops more completely, helping plant establishment.

The crown (a region of lower nodes whose internodes do not elongate) is located between the seed and the soil surface. It tends to develop at the same level, about one-half to one inch below the soil surface, regardless of planting depth. Leaves, tillers and roots (including the main root system) develop from the crown nodes. The growing point is located at the crown until it is elevated above the soil surface at the stem elongation stage.

Tillering

The tillering stage begins with the emergence of lateral shoots (tillers) from the axils of the true leaves at the base of the main stem of the plant. The tillers are formed from the auxiliary buds located at each crown node. Primary tillers form in the axils of the first four or more true leaves of the main stem. Secondary tillers may develop from the base of primary tillers if conditions favor tiller development. A tiller may also develop from the coleoptile node (coleoptilar tiller), but this occurs sporadically and its appearance is dependent on genotype, planting practices, and environmental conditions. At the base of each tiller is a sheath (small leaflike structure) called the prophyll, from which the tiller leaves emerge. The prophyll acts like the coleoptile and protects the auxiliary bud before it elongates its first leaf to become a tiller. Identifying the prophyll, which encloses the base of the tiller, will help differentiate tiller leaves from the leaves on the main stem and from other tillers. Tillering usually begins when the seedling plant has three or more fully developed leaves. Tillers depend on the main stem for nutrition during their development. Once a tiller has developed three or more leaves, it becomes nutritionally independent of the main stem and forms its own root system.

Tillers are an important component of wheat yield because they have the potential to develop grain-bearing heads. In Kentucky, each plant normally develops two or more tillers in the fall when planted at optimum dates. The total number of tillers eventually developed will not all produce grain-bearing heads. Under recommended plant populations, usually two or three tillers, in addition to the main shoot, will produce grain. Tiller development occurs in the fall until low temperatures stop plant growth. In Kentucky, during the tillering stage, winter wheat goes through the winter months in a dormant condition in which plant growth (including tiller production) essentially ceases due to cold temperature. Tiller production and development resumes in late winter/early spring with an increase in temperature as the plants "break" dormancy and resume growth. Due to cooler temperatures, late planted winter wheat may have little or no fall tillering because of limited seedling growth or because no wheat has emerged; late planted wheat will rely heavily on spring tiller development.

Table 2-1. Wheat Growth Stages

Stage	General Description	Scale Feekes	Scale Zadoks	Additional Comments
Germination	Dry seed		00	
	Start of imbibition		01	
	Imbibition complete		03	Seed typically at 35 to 40% moisture.
	Radicle emerged from seed (caryopsis)		05	
	Coleoptile emerged from seed (caryopsis)		07	
	Leaf just at coleoptile tip		09	
Seedling Growth	First leaf through coleoptile	1	10	
	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 unfolded		19	
Tillering	Main shoot only		20	
	Main shoot and 1 tiller	2	21	
	Main shoot and 2 tillers		22	
	Main shoot and 3 tillers		23	Many plants will only have 2 or 3 tillers per plant at recommended populations.
	Main shoot and 4 tillers		24	
	Main shoot and 5 tillers		25	
	Main shoot and 6 tillers	3	26	Leaves often twisting spirally.
	Main shoot and 7 tillers		27	
	Main shoot and 8 tillers		28	
	Main shoot and 9 tillers		29	
Stem Elongation	Pseudostem erection	4-5	30	
	1st detectable node	6	31	Jointing stage
	2nd detectable node	7	32	
	3rd detectable node		33	
	4th detectable node		34	Only 4 nodes may develop in modern varieties.
	5th detectable node		35	
	6th detectable node		36	
	Flag leaf visible	8	37	
	Flag leaf ligule and collar visible	9	39	
Booting	Flag leaf sheath extending		41	Early boot stage.
	Boot swollen	10	45	
	Flag leaf sheath opening		47	
	First visible awns		49	In awned varieties only.
Head (Inflorescence) Emergence	First spikelet of head visible	10.1	50	
	¼ of head visible	10.2	52	
	½ of head visible	10.3	54	
	¾ of head visible	10.4	56	
	Head completely emerged	10.5	58	
Pollination (Anthesis)	Beginning of flowering	10.51	60	Flowering usually begins in middle of head.
		10.52		Flowering completed at top of head.
		10.53		Flowering completed at bottom of head.
	½ of flowering complete		64	
	Flowering completed		68	
Milk Development	Kernel (caryopsis) watery ripe	10.54	71	
	Early milk		73	
	Medium milk	11.1	75	Milky ripe.
	Late milk		77	Noticeable increase in solids of liquid endosperm when crushing the kernel between fingers
Dough Development	Early dough		83	
	Soft dough	11.2	85	Mealy ripe: kernels soft but dry.
	Hard dough		87	
Ripening	Kernel hard (hard to split by thumbnail)	11.3	91	Physiological maturity. No more dry matter accumulation.
	Kernel hard (cannot split by thumbnail)	11.4	92	Ripe for harvest. Straw dead.
	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	

Sources: *Conley, et al. 2003. Management of Soft Red Winter Wheat. IPM1022. Univ. of Missouri. Alley, et al. 1993. Intensive Soft Red Winter Wheat Production: A Management Guide. Pub. 424-803. Virginia Coop. Extension. Johnson, Jr., et al. Arkansas Wheat Production and Management. MP404. Univ. of Arkansas. Coop. Ext. Serv.*

Spring tillers generally contribute less to yield potential than do fall tillers. Consequently, fall tillering is important for winter wheat to achieve maximum yield potential.

Tillers develop sequentially on a plant, resulting in a prioritization for development. The main stem and older (first-formed) tillers have priority to complete development and form a grain-bearing head. This same priority also exists regarding the size of the grain-bearing head on the main stem and subsequent tillers.

The number of tillers a plant develops is not a constant and will vary because of two factors: genetic potential and environmental conditions. Some varieties have a greater potential to develop more tillers than others. Tillering is also a means for the plant to adapt to changing environmental conditions. Plants are likely to produce more tillers when environmental conditions such as temperature, moisture, and light are favorable, when plant populations are low, or when soil fertility levels are high. Under weather stress conditions such as high temperature, drought, high plant populations, low soil fertility, or pests, plants respond by producing fewer tillers or even aborting initiated tillers. Rarely do more than five auxiliary tillers form and complete development on a plant. Although the total number of tillers formed per plant can vary considerably and be quite high, not all of the tillers remain productive. The later developing tillers usually contribute little to yield. Tillers that emerge after the fifth leaf on the main stem are likely to senesce (or die), abort, or not produce a grain head. Very few of the secondary tillers that form usually develop a head unless conditions dictate a need.

Photo 2-2. Wheat field at about Feekes 4 or 5 (Zadoks 30).

As temperatures decrease below the minimum for plant growth in late fall/winter, winter wheat will become dormant. Cooler temperatures induce cold hardiness in wheat plants to protect against cold injury and to help them survive the winter. During this period, the low temperatures initiate in the plant a physiological response called vernalization. During vernalization, the plant converts from vegetative to reproductive growth and the reproductive structures are developed. Because of this vernalization requirement, winter wheat produces only leaves for both the main stem and tillers aboveground in the fall in preparation for winter. The growing point and buds of both the main stem and tillers remain belowground, insulated against the cold winter temperatures. Once vernalization requirements are met, the growing point differentiates and develops an embryonic head. At this time, wheat head size or total number of spikelets per head is determined. Neither seedling growth nor tillering is required for vernalization to occur. This process can begin in seeds as soon as they absorb water and swell. Hence, late planted wheat that has not emerged prior to winter should be adequately vernalized. Following vernalization, exposure to progressively longer photoperiods (longer day length periods) is necessary to initiate and hasten reproductive development.

The vernalization requirement involves exposure to cooler temperatures for a required length of time. Temperatures below 50°F are needed to induce cold hardening and satisfy vernalization requirements; temperatures of 37° to 46°F are considered sufficient and most effective. The required length of low temperature exposure decreases with colder temperatures and advanced plant development. At sufficiently low temperatures, most varieties in Kentucky require three to six weeks of vernalization. Varieties also differ in their response to vernalizing temperature requirements. Generally, early-maturing varieties require less time to vernalize than later-maturing varieties.

In some varieties, vernalization is affected by photoperiod, in which exposure of the wheat plant to short days replaces the requirement for low temperatures. Exposure of wheat to temperatures above 86°F shortly following low temperatures can sometimes interrupt vernalization. Spring wheat varieties do not possess an absolute vernalization requirement. Reproductive development in most spring varieties is induced by light and accumulated heat units (growing degree days).

Stem Elongation/Jointing

Stem elongation is the next phase of growth (Feekes 4-9; Zadoks 30-39). The leaves of overwintering (dormant) wheat are generally short and lie rather flat. As temperatures increase in the spring, the wheat plants break dormancy and resume growth. The leaf sheaths grow quickly and give a strongly erect appearance known as a pseudostem (not a real stem) (Feekes 4-5; Zadoks 30). At this time, and prior to actual stem elongation, each main stem and tiller of the young plant is a succession of leaves wrapped around each other (i.e., a pseudostem). The actual stem has not elongated at this stage and the immature head (growing point) is still below ground level but has started to advance above the crown region. The growing point is only about one-eighth of an inch in length and has the appearance and shape of a very small pinecone.

As growth continues, stem elongation (jointing) occurs as a result of internode elongation. The embryonic head (growing point) in the main stem and each tiller that has formed at the base of the plant begin to move up the stem. The maximum possible number of kernels per head is determined at this time. The plant allocates nutrients to the main stem and tillers with at least three leaves. Once the plant has jointed, typically no more potential head-bearing tillers will form. However, if the growing point has been killed during stem elongation as a result of damage (physical, freeze, pests) to the immature head and/or supporting stem, that main stem or tiller will die. As a result, the wheat plant will tend to compensate for this loss by development of new shoots from the base of the plant.

During stem elongation, the stem nodes and internodes emerge above the soil surface and become visible. Nodes are areas of active plant cell division from which leaves, tillers and adventitious (crown) roots originate. Leaves originate from the stem nodes above the soil surface and emerge as the stem elongates. As jointing (stem elongation) occurs, the nodes swell, and they look and feel like bumps on the stem. This makes them easier to see or feel and easier to count. An internode is the region between two successive nodes. During stem elongation, the internodes above the soil surface elongate to form the stem. The elongated internode is hollow between the nodes. Wheat stems contain several internodes which can be described as "telescopic." Prior to stem elongation, the nodes and internodes are all formed but are sandwiched together at the growing point as alternating layers of cells destined to become the nodes and the internodes of a mature stem. When jointing is initiated, these telescoped internodes begin to elongate, nodes appear one by one, and elongation continues until head emergence. When an internode has elongated to about half its final length, the internode above it begins elongating. This sequence continues until stem elongation is complete, usually at head emergence. Each succeeding stem internode (from the base to the top of the plant) becomes progressively longer. The last elongated internode is the peduncle, which supports the head. It accounts for a good proportion of the overall stem length. Plant height continues to increase during stem elongation until the heads emerge. Plant height is influenced by both genotype (variety) and growing conditions. Generally, variation in height is due more to differences in internode length than internode number.

When stem elongation begins, the first node of the stem is swollen, becomes visible as it appears above the soil surface, and is commonly called jointing (Feekes 6; Zadoks 31). Above this node is the immature head, which is being pushed upward as internodes elongate to eventually emerge (heading stage). Usually a plant has about five to six leaves on the main shoot when jointing begins. The immature head continues to develop and enlarge during stem elongation until it becomes complete at the boot stage. As previously noted, the jointing stage will not occur prior to the onset of cold weather, as vernalization is required in winter wheat to initiate reproductive development. When the growing point moves above the soil surface and is no longer protected by the soil, the head becomes more susceptible to damage (mechanical, freeze, pests).

During stem elongation, the lower four nodes remain in the crown. The fifth node may remain in the crown or be elevated slightly. Nodes six, seven, and possible additional nodes are elevated above the soil. When stem elongation is complete, most wheat varieties usually have three nodes visible above the soil surface, but occasionally a fourth node can be found. The stem elongation stage is complete when the last leaf, commonly called the flag leaf, emerges from the whorl (Feekes 8-9, Zadoks 37-39). On most varieties, the flag leaf begins to emerge just after the third aboveground node is observed (or can be felt). To confirm that the leaf emerging is the flag leaf, split the leaf sheath above the highest node. If the head and no additional leaves are found inside, the emerging leaf is the flag leaf. The flag leaf stage is significant because the flag leaf produces a large proportion (estimates of at least 75%) of the photosynthate (carbohydrates) for filling grain. It must be protected from diseases, insects, and defoliation in order for the plant to develop its full yield potential. Flag leaf emergence is a visual indicator that the plant will soon be in the boot stage.

Boot

The boot stage (Feekes 10, Zadoks 45) occurs shortly after flag leaf emergence and indicates that the head is about to emerge. The flag leaf sheath (the tubular portion of the leaf that extends below the leaf blade and encloses the stem) and the peduncle (the internode which supports the head) elongate and the developing head is pushed up through the flag leaf sheath. As the developing head beings to swell inside the leaf sheath, the leaf sheath visually obtains a swollen appearance to form a "boot." The boot stage is rather short

Photo 2-3. Many wheat varieties have awns and are called "bearded" wheat, while other varieties are awnless.

Photo 2-4. Flowering usually begins at the middle of the head and then progresses upward and downward simultaneously.

and ends when the awns (or the heads in awnless varieties) are first visible at the flag leaf collar (junction of the leaf blade and leaf sheath) and the leaf sheath is forced open by the head.

Heading/Flowering (Anthesis)

By the time heading occurs, the development of all shoots (main stem and tillers) on the same plant is in synchronization even though there were large differences as to when the initiation of the various shoots occurred (i.e. tiller initiation occurs later than the main stem). However, throughout the pre-heading period, differences also occur in the duration of the various developmental phases among the shoots (i.e. developmental phases for tillers are shortened), which serves to synchronize tiller development with the main stem so that tiller head emergence and flowering occurs soon after the main stem has headed and flowered.

The heading stage begins when the tip of the spike (head) can be seen emerging from the flag leaf sheath (Feekes 10.1; Zadoks 50), and emergence continues until the head is completely emerged (Feekes 10.5; Zadoks 58). The heading date in most wheat varieties is determined by temperature (accumulation of heat units). In some varieties, a combination of heat accumulation and day length determines heading date.

Shortly after the wheat head has fully emerged, flowering (anthesis) occurs. However, flowering and pollination in cereals may occur either before or after head emergence, depending on plant species and variety. Thus, cereals are classified as either open-flowering or closed-flowering types. Flowering occurs in open-flowering types shortly after head emergence. Most varieties of wheat are of the open-flowering type. Generally, flowering in wheat begins within three or four days after head emergence. Open flowering is characterized by extrusion of the anther (reproductive portion of the flower which produces pollen) from each floret on the head. In contrast, closed-flowering types of varieties or cereals (i.e. barley) flower prior to head emergence and the anthers remain inside each floret.

Flowering and pollination of wheat normally begins in the center of the head and progresses to the top and bottom of the head. Pollination is normally very quick, lasting only about three to five days. Pollination occurs slightly later on tillers than on the main stem, but all heads on a plant pollinate within a few days of each other. Wheat is largely self-pollinated, and pollination and fertilization has already occurred before the pollen-bearing anthers are extruded from the florets. Kernels per head are determined by the number of flowers that are pollinated. Pollen formation and pollination are very sensitive to environmental conditions. High temperatures and drought stress during heading and flowering can reduce pollen viability and thus reduce kernel numbers.

Flowering is the transition between two broadly categorized growth stages in wheat. In the first stage, vegetative growth, reproductive initiation, and reproductive development occur and determine the final yield potential of the crop and also provide the photosynthetic factory necessary for maximum yield. The second stage is the grain-filling period in which the potential yield created in the first stage is realized. The extent to which the potential yield is realized will depend on the environment and on management inputs prior to and after anthesis.

Grain Filling/Ripening

Grain filling follows anthesis and refers to the period during which the kernel matures or ripens. Within a few hours of pollination, the embryo (rudimentary, undeveloped plant in a seed) and endosperm (area of starch and protein storage in the seed) begin to form and photosynthates (products of photosynthesis) are transported to the developing grain from leaves (primarily the flag leaf). In addition, starches, proteins, and other compounds previously produced and stored in leaves, stems, and roots are also transferred to the developing grain. The grain filling period is critical for producing high yields because kernel size and weight are determined during this stage. Yields will be reduced by any stress (high temperatures, low soil moisture, nutrient deficiencies, and diseases) occurring during grain fill. Environmental factors affect the rate and duration of the grain filling period. The longer this filling period lasts, the greater is the probability for higher yields. If this period is shortened, yields will usually be lower. In Kentucky, the average length of the grain filling period is one month. The grain fill period can be as few as 25 days or less in high stress environments (hot and dry weather, heavy disease, and nutrient deficiencies) and may exceed 35 days in high yield, low stress environments (disease-free, high soil moisture, and moderate/cooler temperatures).

The grain development stages are listed in Table 2-1 (Feekes 10.54 to 11.4; Zadoks 70 to 92). A brief description and comments of the grain filling and ripening stages follows below.

Watery ripe stage. Kernel length and width are established during this stage. The kernel rapidly increases in size but does not accumulate much dry matter. A clear fluid can be squeezed from the developing kernel.

Milk stage. During this stage there is a noticeable increase in solids of the liquid endosperm as nutrients in the plant are redistributed to the developing kernels. During the milk stage a white, milk-like fluid can be squeezed from the kernel when crushed between fingers. By the end of the milk stage, the embryo is fully formed.

Soft dough stage. The kernels are soft but dry. The water concentration of the kernel has decreased so that the material squeezed out of the kernel is no longer a liquid but has the consistency of meal or dough. The kernel rapidly accumulates starch and nutrients and by the end of this stage the green color begins to fade. Most of the kernel dry weight is accumulated in this stage.

Hard dough stage. The kernel has become firm and hard and is difficult to crush between fingers. It can be dented with a thumbnail. Kernel moisture content decreases from a level of 40 percent to 30 percent. At the end of the hard dough stage (Feekes 11.3; Zadoks 87-91), the kernel reaches its maximum dry weight and the wheat is said to be physiologically mature (no more weight is added to the grain). Physiological maturity often corresponds to kernel moisture content between 30 and 40 percent. Previous wheat swathing research at the University of Kentucky at various kernel moisture contents indicated physiological maturity occurred at a kernel moisture content of 38 to 42 percent (with no reduction in yield or test weight if cut at this stage). Harvesting can occur anytime after physiological maturity but often does not occur because of high kernel moisture.

Table 2-2. Key growth stages in Wheat for Yield Determination.

Critical Yield Component	Determined by:
Tiller and head number	Jointing (Feekes 6, Zadoks 31)
Head Size	Mid to late tillering (Feekes 3; Zadoks 23 to 29)
Kernel number per head	Jointing (Feekes 6; Zadoks 31)
Kernel Size	Beginning at flag leaf (Feekes 8; Zadoks 37) and continuing through grain fill

Ripening stage. Kernel moisture content is still high, usually ranging from 25 to 35 percent, when wheat begins to ripen but decreases rapidly with good weather. The plant turns to a straw color and the kernel becomes very hard. The kernel becomes difficult to divide with a thumbnail, cannot be crushed between fingernails, and can no longer be dented by a thumbnail. Harvest can begin when the grain has reached a suitable moisture level (usually less than 20%). Often harvest does not occur until grain moisture content is close to 15 percent, unless drying facilities are available.

It is important for grain quality that the harvest begins as soon as possible. Test weight (and hence grain yield) may be reduced during the ripening process. Decreased test weight results from the alternate wetting (rains or heavy dews) and drying of the grain after the wheat has physiologically matured.

Wheat yield components

Critical yield components include tiller and head number, head size, kernel number per head and kernel size. Table 2-2 highlights the key growth stages that affect yield determination. For maximum wheat yields, proper management and favorable weather are necessary during these key growth stages. The final yield of a wheat crop is a function of the yield components in the following formula:

number of heads/acre
x number of seeds/head
x weight/seed
= **grain yield/acre**

Section 3

Cultural Practices

Chad Lee, James Herbek, David Van Sanford, and William Bruening

Wheat grows best on well-drained soils. Since wheat does not tolerate waterlogged conditions well, yields and stands are reduced in fields prone to standing water, flooding, or poor drainage. Wheat can be grown successfully on moderately and somewhat poorly drained soils, but the long-term yields are usually reduced by five to ten bushels per acre due to stress placed on the wheat during wet springs, increased winterkill, higher nitrogen losses, and inability to access fields with application equipment. During springs with normal or below normal rainfall, yields on poorly drained soils approach those on well-drained soils.

Crop Rotation

Most of the wheat in Kentucky harvested for grain is grown in a cropping system of three crops in two years (corn/wheat/double-crop soybeans). Wheat following soybean generally yields more than wheat following corn (Figure 3-1). However, when wheat yields are high, the previous crop has less influence on wheat yield. Wheat is suited to the corn/wheat/double-crop soybean rotation system and offers both economic and agronomic advantages. Yields of all three crops in the rotation are increased over growing any crop without rotation.

Wheat is planted in the fall after summer annual crops are harvested and can be harvested early enough in the summer for a second crop to be planted (double-cropped). Double-cropping is an important economic component of the wheat enterprise in Kentucky. More than 85 percent of the harvested wheat acreage is double-cropped, primarily with soybeans.

Variety Selection

Choosing a wheat variety is one of the most important management decisions that Kentucky wheat producers make. Yield potential is clearly important, but the decision is complicated by such factors as the need for disease resistance; the double-cropping system, which requires early maturity; the extreme year to year climatic varia-

Photo 3-1. Wheat variety trials are conducted across the state to compare relative performances of varieties. Each variety is planted mulitiple times at each location to minimize field variability and to better predict performance potential.

tion in Kentucky, and the need to spread out the harvest maturity date so every variety is not ready to harvest at once. It makes sense to minimize risks by planting several varieties with good yield and test weight potential that complement one another in terms of disease resistance, maturity, and resistance to spring freeze damage.

Proper use of variety test performance data is the first step in making this important decision. The University of Kentucky Small Grain Variety Performance Tests provide the most comprehensive source of information on varieties tested under a broad range of environments. Results of the variety tests are published annually and are available at Cooperative Extension Service offices and online at www.uky.edu/ag/WheatVarietyTest. The best use of University of Kentucky variety performance data for variety selection can be achieved by applying the following basic principles.

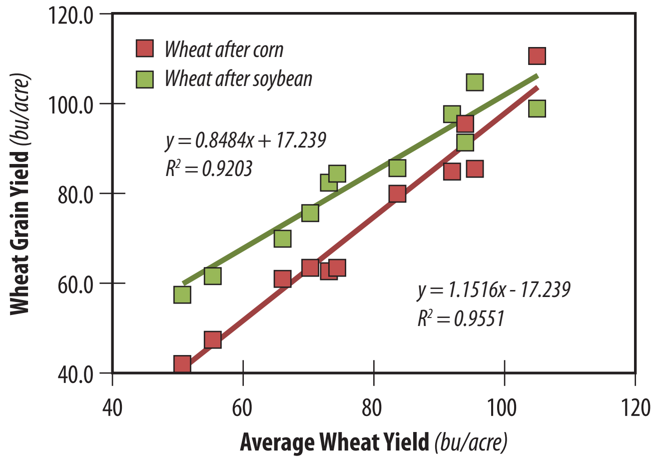


Figure 3-1. Wheat is commonly grown following corn in Kentucky. As overall wheat yield potential increases, the previous crop has less effect on wheat yield. (1998 through 2008 at Lexington, Kentucky, data provided by John Grove)

Conventional vs. No-till Testing

Based on 10 years of conventional vs. no-till data from the University of Kentucky variety testing program, variety performance can be assessed independently of the tillage system used. This fact enables growers to identify superior varieties based on performance regardless of the tillage system used.

Multi-year/Multi-location Data

While many growers ask about the variety that looked best in this year's test, it is more useful to know which varieties have performed well over a range of conditions. When interpreting the results in the variety performance report, it is important to note that variety yield is relative. This means that comparisons among varieties should only be made among those varieties in the same test or within the same analysis averaged across locations. The state summary table provides performance data averaged across test locations and years. It provides the best estimate of varietal performance, particularly the 2 and 3 year averages. When selecting varieties, growers should first utilize data from the state summary table. Once several candidate varieties have been selected, the grower should examine their performance in the closest regional test. After identifying a group of varieties with high grain yield potential, varietal selection can be based on secondary characteristics such as test weight, disease resistance, lodging, height, maturity and straw yield potential.

Wheat varieties that have performed well under diverse conditions are likely to perform well again. For growers who want to try a new variety, it is best to choose one that has been evaluated for at least one year. If a variety has been tested for one year only, it is best to use the state summary table, rather than using single year data from a single (regional) test. Depending on a grower's location, additional variety performance data may be useful from other (bordering) state variety testing programs. The University of Kentucky Small Grain Variety Testing Program website has links to these programs.

Economic Analysis of Varieties

Farmers are always interested in high yields, but the highest yielding variety may not always be the most profitable. One needs to consider other economic factors such as disease susceptibility (may require fungicides), lodging

Photo 3-2. While most wheat in Kentucky is grown for grain, some is grown for forages. The University of Kentucky tests wheat varieties for performance both in forage yields and grain yields.

(costs more to harvest), late maturity (delays soybean planting), potential straw yield as a secondary commodity, low test weight (discounts at the elevator) and seed cost. All of these factors require study and evaluation to determine the most profitable varieties for a particular operation. Maximum productivity and profitability begin with careful variety selection. Once varieties have been selected, the best guarantee of obtaining the quality seed necessary for the highest yields is to use certified seed or seed of proven high quality from an established, reputable dealer.

Table 3-1. Recommended number of wheat seeds to plant per square foot or per drill-row foot.

Row Width (in)	Row Length Needed for 1 sq ft (in)	Seeds/sq ft 30	Seeds/sq ft 35
		Seeds/row ft Needed[a]	
4	36.0	10	12
6	24.0	15	18
7	20.6	17	20
7.5	19.2	19	22
8	18.0	20	23
10	14.4	25	29

a If planting time is delayed, increase seeding rates by two to three seeds/sq ft (one to two seeds/row foot) for every two-week delay beyond the optimum planting date.

Table 3-2. Number of pounds of wheat seed needed, depending on seed size and seeding rate.

	Seeds/sq ft[a]	
	30	35
Seeds/lb	lbs/acre	
10,000	131	152
12,000	109	127
14,000	93	109
16,000	82	95
18,000	73	85
20,000	65	76

a Based on 90 percent or greater germination.

Planting Practices

The target population for planting wheat is a uniform stand of 25 plants per square foot (225 plants per square yard) (Table 3-1). Usually planting 30 to 35 seeds per square foot (1,524,600 seeds/A) will result in the desired plant population. Planting methods include seedbed preparation or no-tillage planting (see *Section 4—Planting Methods*), planting date, seed placement, seeding rate, row width, and use of tramlines.

Planting Date. The recommended planting date for most of Kentucky is October 10 through October 30. This window is a compromise between early planting to ensure adequate fall growth and winter survival and later planting to decrease disease and insect infestations. Typically, these dates will fall within a period of one week before to one week after the expected date of the first fall frost. Soil temperatures are usually high enough during this window for the crop to emerge in seven to ten days or less. Also, the length of time between the first frost and winter dormancy for growth is critical for the development of an adequate number of tillers. Tillers developed in the fall are essential to producing high yields. A longer period of growth in the spring and more extensive root systems mean that fall tillers account for most of the grain produced in an intensively managed crop.

Late-planted wheat misses much of the critical fall growing period, generally suffers more winter damage, is more prone to heaving (uplifting of the plant and root system due to alternate freezing and thawing of soil), tillers less, has reduced yields, and matures later than wheat planted at the recommended time. It is difficult, if not impossible, to make up for late planting by management practices employed at later growth stages.

Planting too early, on the other hand, can result in excessive fall growth and create the potential for more winter injury (growth stages too advanced), greater risk of spring freeze injury, fall disease infection, and increased problems with aphids (which vector barley yellow dwarf) and Hessian fly infestations. Delaying planting until October 10 in northern Kentucky and October 15 in southern Kentucky generally averts Hessian fly damage. These dates are known as the fly-free planting dates. The Hessian fly-free date is based partly on the first fall freeze date, so if air temperatures are warmer in the fall, the effective fly-free date would actually be delayed that season.

Seed Placement. Plant seeds 1 to 1½ inches deep when soil moisture levels are adequate, slightly deeper if moisture is deficient. Do not plant wheat seed more than 2 inches deep. Rapid emergence and good root development start with good seed-soil contact.

Many wheat varieties have small seed, and when seed is planted deeper than 2 inches, emergence is delayed. Some semi-dwarf varieties with short coleoptiles might open the first leaf below ground and die. Deep seed placement delays emergence and reduces stand, resulting in plants with less vigor, less initial vegetative growth, and reduced tillering.

The other problem is not planting seed deep enough. Planting seed less than ½-inch deep can result in uneven germination and emergence because of dry soil. Shallow seed placement also can result in more winter injury and greater susceptibility to heaving. If seed is planted shallow and timely rains accompany planting, then adequate stands can be achieved.

Seed placement is especially critical for no-till planting. Seed must be placed in the soil at the proper depth and below all the plant residue or mulch. The mulch should be distributed evenly on the soil surface to help drills successfully slice through the mulch and place the seed in the soil. Poor seed placement is a major problem in no-tillage planting. Fast, uniform seedling emergence provides quick ground cover and erosion protection.

Seeding Rate. Wheat seed size varies dramatically among varieties and can be influenced by production environment and degree of conditioning. Using seeding rates expressed in terms of volume or weight (bushels or pounds) per acre—

Photo 3-3. Seeding wheat rows at a diagonal to the old corn rows is generally a good practice in no-till fields.

Photo 3-4. Corn residue that piles in the field can prevent the drill from placing the wheat seed under the soil surface. Seeds either fail to germinate or seedlings are killed during winter, leaving blank spaces in the field.

without consideration of seed size—can result in stands that are too low or too high. Proper stand establishment requires that the seeding rate be determined in terms of number of seeds per unit area (per square foot or linear row foot). Seeding rates below optimum may reduce yield potential, while excessive seeding rates increase lodging, create a greater potential for disease, and increase seed costs. The optimum planting rate is 35 seeds per square foot (1,524,600 seeds/A) with an objective of obtaining at least 25 plants per square foot. The seed rate and seed size should be determined to calculate how many pounds of seed per acre are needed. Seed sizes and the pounds needed can vary widely (Table 3-2).

For precise seeding, calibrate your planting equipment. Seeding rate charts on drills may not be precise and size and shape of seed can affect seed delivery. (See *Section 4—Planting Methods* for a five-step procedure for proper grain-drill calibration.)

Row Width. The most practical wheat row widths are normally 7 to 8 inches, combining the higher yield potential of narrow rows with the effective movement of planting equipment through the field. Research throughout the growing region of soft red winter wheat has shown 5 percent to 10 percent higher yields when wheat is planted in 4-inch rows versus 8-inch rows. Likewise, research has shown significant yield decreases for wheat grown in row spacings greater than 10 inches. Wheat must be planted at a uniform rate and depth, and conservation requirements must be met.

Drills with units 4 inches apart are likely to clog due to excessive surface residue or clods. Typically, drills with units about 7 to 8 inches apart have minimal clogging, but relatively high yield potential. Some farmers are choosing to use modified planters with units spaced 15 inches apart. These planters are normally used in soybean and corn. The cost of modifying the equipment is less than purchasing a drill, but the yield loss associated with the wider row spacings may not justify 15-inch rows.

Based on limited research in Kentucky, wheat in 15-inch rows will yield about 15 percent to 20 percent less than wheat planted in 7.5-inch rows. For wheat normally yielding 70 bushels per acre, that is a yield loss of 10.5 bushels per acre, or $63 per acre for wheat being sold at $6.00 per bushel. Based on these numbers, not very many acres are needed before a drill becomes more economical than a planter.

Tramlines and/or GPS. Tramlines are roadways placed in the wheat field at planting and used by equipment for applying pesticides and fertilizers. Tramlines should match the width of the applicator tires and be spaced to match the width of the applicator boom. Tramlines allow timely application of input and more uniform applications of nutrients and pesticides with no skips or overlaps.

Tramlines can be formed by blocking drill spouts and not planting wheat seed in specific rows. Tramlines can also be formed by planting wheat in all rows and then running over the same tracks each time an application is made. Tramlines formed by blocking seeding spouts will allow wheat plants in rows beside the tramlines to compensate some for the unplanted area. There is no compensation for plants that have been run over past jointing (Feekes 6, Zadoks 31).

When blocking drill spouts, using tractors with narrow tires so only one drill row needs to be blocked is a recommended practice. Devices that automatically close the selected drill spouts on the appropriate planting pass through the field are available for most grain drills. Fertilizer and spray booms should be at least 40 feet wide to be economical. The distance from the first tramline to the edge of the field should be one-half the width of the sprayer.

When running over wheat to form tramlines, use the same track for each application and do the first track (application) prior to jointing (Feekes 6, Zadoks 31) to allow plants in adjacent rows to compensate for the tramlines. Lightbars enabled with GPS (global positioning system) receivers can be very useful in helping to establish tramlines. Lightbars limit the amount of overlap and skips for nutrient and pesticide applications.

Photo 3-5. Wheat heads that are bleached white are a clear indication that heads were killed by a freeze event.

Photo 3-6. Wheat is regrowing after a freeze event. Normally, development of this regrowth will be delayed, pushing harvest to later in the season.

Winterkill and Freeze Injury

Wheat is subjected to adverse weather conditions during much of its growth period. Autumn frosts and cool temperatures actually help by hardening plants for the months of cold winter weather ahead.

Expect winterkill on poorly drained soils, with extreme temperature fluctuations, where poor fall root development occurred, and with sustained low temperatures (particularly with no snow cover). Extremely cold winters tend to cause more winterkill in varieties developed in more southerly locations because they have less winter hardiness. Heaving is a major cause of late winter or early spring damage to small plants due to extreme temperature fluctuations, especially on poorly drained soils.

Wheat seeded close to the recommended dates typically will receive little damage from a spring freeze. Spring freeze injury can occur when low temperatures coincide with sensitive plant growth stages (Table 3-3). The risk of spring freeze injury is greater when conditions cause wheat to break winter dormancy (greenup) and begin growing and those conditions are followed by freezing temperatures. These scenarios occur with unusually warm temperatures in February or March or from unusually late freeze events in April or May. Injury can occur across large areas of the field but usually is most severe in low areas or depressions in the field where cold air settles. A late spring freeze can reduce yield because of damage to the head and stem. Usually, a week to ten days of good warm temperatures and adequate sunlight are required before head and stem damage from a freeze event becomes visible. If cool, cloudy days persist, then more time may be needed to assess the damage. If the plants are damaged from the freeze, then the wheat stems will likely be damaged close to the ground. Heavy rainfall will knock over the damaged wheat and severely reduce yields.

Table 3-3. Freeze injury in wheat.[a]

Growth Stage	Feekes	Zadoks	Approx. Injurious Temp. (2 hrs)	Primary Symptoms	Yield Effect
Tillering[b]	1-5	20-29	12°F	Leaf chlorosis; burning of leaf tips; silage odor; blue cast to fields	Slight to moderate
Jointing	6-7	31-32	24°F	Death of growing point; leaf yellowing or burning; lesions, splitting, or bending of lower stem; odor	Moderate to severe
Boot	10	41-49	28°F	Floret sterility; spike trapped in boot; damage to lower stem; leaf discoloration; odor	Moderate to severe
Heading	10.1-.5	50-58	30°F	Floret sterility; white awns or white spikes; damage to lower stem; leaf discoloration	Severe
Flowering	10.51-.54	60-71	30°F	Floret sterility; white awns or white spikes; damage to lower stem; leaf discoloration	Severe
Milk	11.1	75	28°F	White awns or white spikes; damage to lower stems; leaf discoloration; shrunken, roughened, or discolored kernels	Moderate to severe
Dough	11.2	85	28°F	Shriveled, discolored kernels; poor germination	Slight to moderate

a Information in this table assumes timely rainfall events occurring after the freeze event.
b See Section 2 for more information about growth stages.

To check for damage to an unemerged wheat head, cut into the stem to find the growing point (developing head). An undamaged head normally appears light green, glossy, and turgid. A killed head is pale white or tan, limp, shrunken, and not developing in size. Spikelets within a single head can be damaged as well. Growing tissue of plants that have been frozen is dry, bleached, and shrunken. See the *Supplement* section for more pictures of freeze damage.

The temperatures and growth stages listed in Table 3-3 work well in most situations as a general guideline; however adequate yields may still be produced.

There is some evidence that timing of nitrogen fertilizer application in relation to the freeze event may help reduce the damage from a freeze event. The theory is that for a short period of time, as wheat takes up nitrogen the concentration of nitrogen in the plant cell will be high enough to act as a kind of anti-freeze agent. The problem is that there is no sound recommendation for applying nitrogen to help with this.

In addition, some wheat varieties may be a little more tolerant to spring freezes based on the mechanisms that determine flowering in wheat. Flowering in some wheat varieties seems to be controlled more by day length while flowering in others may be controlled more by temperature. Unusually warm temperatures could accelerate crop development in varieties more responsive to temperature more so than in varieties more responsive to day length. In these cases, varieties more sensitive to temperature would be at a greater risk for spring freeze. Assessing wheat damage from a freeze event can be difficult. In addition to evaluating the stems and heads for freeze damage, one also must look at extended forecasts. If rain is not in the forecast, farmers may be less likely to destroy a damaged wheat crop.

Photo 3-7. Using a hand lens or microscope to examine the growing point of wheat can help determine if the crop survived a freeze event.

Photo 3-8. A dowel road with specific lengths marked on it can be used to count plants and tillers on a square-foot-basis.

Determining Plant Populations, Tiller, and Head Counts

Plant Populations. After the wheat has emerged, make a stand count to determine if your target population was achieved and if the final stand is acceptable for maximum yield potential. Make fall stand counts one to two weeks after emergence. Make spring stand counts before greenup of the plants occurs to determine if winter damage has reduced the initial plant population obtained in the fall. Count only whole plants, not tillers. Fields with stand counts below 15 plants per square foot have less than 75 percent yield potential (Table 3-4) and probably should not be kept but used instead for planting corn or soybeans. If stand counts are adequate to keep but somewhat reduced from optimum, consider an early nitrogen application.

To determine the number of plants per square foot:

- Use a yardstick, or cut a dowel rod to a 3-foot length.
- Place the measuring stick next to an average-looking row, and count all plants in the 3-foot length of the row. Record the number.
- Repeat the counting process in at least five other locations well spaced around the field. Record all numbers.
- Average all of the stand counts from the field.

Table 3-4. Wheat yield potential based on plants per square foot.

Final Stand (%)	Plants per:		Potential Yield[a] (%)
	sq ft	sq yd	
100	30 - 35	270 - 315	100
80	24 - 28	216 - 252	100
60	18 - 21	162 - 189	90 - 95
50	15 - 18	135 - 162	75 - 80
40	12 - 14	108 - 126	60 - 70
20	6 - 7	54 - 63	40 - 50

a This provides an estimate of the relationship of wheat stand to yield potential and is only a guide. Many factors (plant vigor, weather, disease, fertility management, planting date, and variety) influence how a wheat stand ultimately responds to achieve its final yield potential.

Table 3-5. Length of row needed for 1 sq ft.

Row Width (in)	Row Length for 1 sq ft	
	(ft)	(in)
6	2.0	24.0
7	1.7	20.6
7.5	1.6	19.2
8	1.5	18.0
10	1.2	14.4
15	0.8	9.6

Table 3-6. Wheat stand count table.

Row Width (in)	Row Length (ft)	Area (sq ft)	Plants (or tillers) per counted area											
			10	15	20	25	30	40	60	80	100	120	140	160
			Plants (or tillers) per sq ft											
7	1	0.58	17	26	34	43	51	69	103	137	.	.	.	.
	2	1.17	9	13	17	21	26	34	51	69	86	103	120	137
	3	1.75	6	9	11	14	17	23	34	46	57	69	80	91
7.5	1	0.63	16	24	32	40	48	64	96	128	.	.	.	.
	2	1.25	8	12	16	20	24	32	48	64	80	96	112	128
	3	1.88	5	8	11	13	16	21	32	43	53	64	75	85
8	1	0.67	15	23	30	38	45	60	90	120	.	.	.	.
	2	1.33	8	11	15	19	23	30	45	60	75	90	105	120
	3	2.00	5	8	10	13	15	20	30	40	50	60	70	80
10	1	0.83	12	18	24	30	36	48	72	96	120	.	.	.
	2	1.67	6	9	12	15	18	24	36	48	60	72	84	96
	3	2.50	4	6	8	10	12	16	24	32	40	48	56	64
15	1	1.25	8	12	16	20	24	32	48	64	80	96	112	128
	2	2.50	4	6	8	10	12	16	24	32	40	48	56	64
	3	3.75	3	4	5	7	8	11	16	21	27	32	37	43

- Calculate plants per square foot with the following equation:

plant number =
(average plant count × 4)/row width in inches

A second method to counting stands is to determine the length of row needed to equal one square foot (Table 3-5). Mark the needed length on a dowel rod or stick and then count the plants in a row.

A third method is to count the plants, or tillers in 1, 2 or 3 feet of row and use Table 3-6 to determine stands.

Tiller and Head Counts. Taking a tiller count which includes main shoot and tillers at Feekes 3 (roughly Zadoks 22 through 26) is the first step in all fields for determining nitrogen needs in late winter or early spring. To determine tiller numbers, count all stems with three or more leaves. Tiller counts below 70 per square foot indicate the need for nitrogen at Feekes 3. At recommended populations, many plants will have only three to four stems (main shoot plus two to three tillers, Zadoks 22 or 23). Thus, 70 to 100-plus tillers (stems) per square foot at Feekes 3 are considered adequate.

Head counts can be taken late in the season after heads have fully emerged (Feekes 10.5, Zadoks 58 or later) to help estimate yield potential. An ideal count for maximum yields is 60 to 70 heads per square foot (540 to 630 per square yard) with 35 kernels per head and 16 to 18 spikelets per head. For adequate yields, 55 heads per square foot (500 per square yard) are needed. If the number of heads per square foot is too high (90 to 100), severe lodging can occur and seeding rates were probably too high. Use the same procedure to count tillers or heads as outlined above for plant populations.

Lodging Control and Plant Growth Regulators

Lodging can be a problem when too much fertilizer nitrogen is used, too thick of a stand is established and/or growing conditions favor excessive growth. Lodged wheat can result in decreased combine speed because of the amount of straw that must be processed through the combine, decreased grain recovery, delayed harvesting after rainfall and heavy dew, and more difficult planting conditions for double-crop soybeans that follow wheat.

Risk of wheat lodging can be reduced by choosing good varieties, establishing the correct stand and using the recommended amount of fertilizer nitrogen. Situations do occur, however, in which there is a large carryover of residual soil nitrogen or weather conditions produce very lush crops and the potential for lodging is high.

When the potential for lodging is high, consider using the growth regulator such as Cerone. Cerone prevents lodging by shortening the wheat plant and strengthening the straw. It does not increase yields if no lodging occurs. Correct application is critical and should be made between Feekes 8 and 10 (Zadoks 37 and 45). Never apply Cerone to crops with exposed heads. Research at the University of Kentucky showed best results when Cerone was applied at Feekes 8 or 9 (Zadoks 37 or 39). Carefully read the label, and follow all directions.

Section 4

Planting and Drill Calibration

James Herbek and Lloyd Murdock

The objective when planting wheat is to establish a uniform stand of at least 25 plants per square foot with adequate fall growth for tiller development and an established root system for winter survival. Planting methods include drilling, broadcast seeding, and aerial seeding. Each has advantages and disadvantages. A planting method should be based on planting equipment, time and labor availability, seeding costs, planting date opportunity, weather, crop usage, yield goals, and stand establishment risks associated with each method. In addition, calibration of planting equipment is critical to getting the correct number of seeds in the soil. Methods for drill calibration are included at the end of this section.

As machinery moves across a field, soil compaction is a concern. Compaction causes the soil to waterlog easily, reduces air movement through the soil, puts the wheat crop under stress, and can reduce the yield. Fields should be tested for compaction by using a penetrometer or similar device when there is ample water in the soil. If soil compaction exists in the field, it should be alleviated before wheat is seeded, when the field is relatively dry. Subsoiling equipment can alleviate deep compaction while a field cultivator can alleviate shallow compaction. These tillage operations should only be conducted when the field is dry. If the field is wet, then these operations could actually worsen compaction. Some types of subsoilers leave most of the residue on the surface and other types cause considerable soil disturbance which would require additional tillage. Once the compaction is remedied and is the field is managed in a complete no-tillage system, the field usually will remain free of compaction.

Drilling

The best results in wheat stand establishment and yield are obtained by seeding with a grain drill. A drill ensures good seed-to-soil contact, promotes rapid germination, results in more uniform and optimum stands, reduces winter injury, and increases yields over broadcast seeding and aerial seeding. (For calibration of a drill, see the end of this section.)

Photo 4-1. Proper seeding techniques are critical for an excellent stand of wheat.


Photo 4-2. Wheat can be seeded into heavy corn residue with modern no-tillage drills.

Drills can be used for conventional tillage, reduced tillage, and no-tillage field conditions. Conventional/full tillage provides a level, smooth seedbed for drilling and results in a more uniform planting depth. Drills with additional coulters and more down pressure on the planter units can establish a good stand of wheat in reduced tillage and no-tillage fields. Leaving crop residue on the soil surface protects the soil from erosion until the wheat crop becomes established. About half of the wheat crop in Kentucky is currently planted into no-till conditions with a drill. For fields that still receive tillage, disking is probably the most common method.

No-tillage conditions provide several advantages over tillage conditions, including reduced soil erosion, reduced equipment requirements, reduced labor costs and reduced fuel costs. No-tillage conditions also allow more timely management, such as spring applications of nitrogen (N) fertilizer. On the other hand, no-till wheat can result in variable planting depths and uneven stands, especially if equipment is not properly adjusted for no-tillage fields. In the early stages of no-tillage adoption by a producer, yields can be a reduced in a high-yield environment. However, management experience seems to eliminate most of these disadvantages. Yield comparisons from many research and on-farm trials over the last 25 years show little or no difference in yield between no-tillage and tillage. The small increase in yields of soybean and corn in a true no-tillage system for wheat, double-cropped soybean and corn is attractive to producers, also.

Residue management varies with the previous crop. Planting into no-tillage conditions after soybeans is ideal but may not be the most economical crop rotation. Planting into corn residue requires proper management of that residue in order to get uniform seed depth and uniform emergence. Combines should have residue choppers and spreaders to distribute the corn residue evenly. In many fields, wheat seeding occurs very soon after corn harvest. Normally, stalk shredding or mowing prior to seeding is not necessary if cornstalks are moist and firmly in the soil. However, if two or three weeks will elapse between stalk shredding and wheat seeding, then shredding the corn residue can improve drill coulter penetration. A rotary mower may have a tendency to “windrow” the residue. A flail mower is a better tool and distributes the residue more evenly for a more uniform seeding depth. Drilling wheat at an angle to the corn stalk row is also helpful because a drill unit is not continually in a row of corn stalks.

Winterkill is a problem about every four or five years in Kentucky. It can be more pronounced in no-till plantings if the planting depth is ½ inch or less. To remove this increased risk, use the proper planting methods and adjustments to plant 1 to 1½ inches deep. Also, be sure to plant a winter hardy variety.

Drills should be adjusted to target 30 to 35 live seeds per square foot for conventional tillage systems and 35 to 40 live seeds per square foot for no-tillage systems.

Broadcasting

Wheat seed can be broadcast as either a planned or emergency seeding method. The wheat seed is broadcast on the soil surface with a fertilizer spreader and incorporated into the soil with light tillage (usually disk or field cultivator). Broadcasting is a fast method of seeding wheat and is an acceptable option if corn or soybean harvest is delayed or weather delays push planting dates to the end of or beyond the optimum planting period.

When broadcast seeding into corn stubble, tillage is often conducted before broadcasting. Once broadcasting occurs, then a light tillage operation incorporates the seed into the soil. When broadcasting wheat into a field of soybean stubble, generally a light tillage operation after broadcasting is necessary.

Broadcast seeding often results in uneven seed placement in the soil, which results in uneven emergence and stands. Seeds may be placed as deep as 3 to 4 inches, where many seeds will germinate but will not emerge through the soil surface. Other seeds may be placed very shallow or on the soil surface. These seeds often do not survive due to dry soil or winter damage. The uneven stands from broadcasting often result in lower yields comparing with drilling.

One method of improving stand uniformity is to broadcast seed in two passes across the field, with a half seeding rate for each pass. The second pass is made perpendicular to the first pass. While this method should improve stand uniformity, it also increases time required to seed the field.

Because plant establishment potential is reduced and seed placement is not uniform, seeding rates should be increased for broadcast seeding. Increase broadcast seeding rates by 30 percent to 35 percent over drilled seeding rates. This equates to seeding rates of 45 to 47 seeds per square foot (or approximately 2½ bushels per acre at average seed size). Soil moisture, crop residue and accuracy of seed incorporation into the soil are crucial to stand establishment.

Broadcasting wheat with fertilizer is a fast way to seed after harvest. Take precautions to ensure that the seed is uniformly blended with the fertilizer and that the fertilizer-seed mixture is uniformly applied. Seed should be mixed with fertilizer as close to the time of application as possible and applied immediately after blending. Allowing the fertilizer-seed mixture to sit after blending (longer than eight hours), particularly with triple super phosphate (0-46-0) or diammonium phosphate (18-46-0), results in seed damage (reduced germination) and, subsequently, a poor stand.

In summary, broadcast seeding is a faster method of seeding and can save time during corn or soybean harvest. The time saved may offset some of the greater costs and potential yield loss associated with broadcast wheat. Disadvantages include inconsistent seed depth and emergence, nonuniform stands, potential for reduced stands, usually lower yields, increased chances of winter injury and higher seed costs.

Aerial Seeding

Aerial seeding is a risky method for establishing wheat and is not very common. It may be considered as an option when harvest of the summer crop is delayed well into the optimum time for planting wheat. An airplane or helicopter drops a high rate of wheat seed onto the soil surface through the canopy of an established summer crop such as corn or soybean. The wheat seed is not incorporated into the soil, making successful germinate and stand establishment heavily dependent on adequate and timely rainfall. Depending on the weather during stand establishments, yields from aerial seeding can be very high or the crop can be a complete failure.

Aerial seeding normally works best when the summer crop of corn or soybean is turning yellow and leaves are dropping to the ground. This leaf drop can provide a mulch cover and improve the environment for germination. Even in the best conditions, aerial seeding will result in wheat plants with crowns at or above the soil surface, making the wheat crop extremely vulnerable to winterkill.

Historically, aerial seeding was conducting in September prior to the Hessian fly free date. This practice is not recommended, because rainfall is usually low during this period, and there is a greater risk of damage from Hessian fly, aphids, take-all and wheat spindle streak mosaic virus. Aerial seeding is not recommended for late October or November plantings, either. Normally, wheat growth from late aerial seedings will be inadequate for winter survival.

Seeding rates should be 50 to 55 seeds per square foot for aerial seeding, nearly 40 to 50 percent greater than those used for drill seeding. Expected stand establishment will be about 50 to 75 percent of the seeding rate.

In summary, aerial seeding is a high-risk venture and should only be considered for the early window of wheat seeding dates when harvest of the summer crop is delayed. Even in these cases, seeding wheat late with a drill may have better odds of surviving than aerial-seeded wheat.

Grain Drill Calibration

Several methods for calibrating drills are presented below. For any of these methods, ensure that all units are properly delivering seed before conducting any calibration. Look for any loose hoses or chains, gears, etc. that might affect seed delivery.

For all target recommendations, we are expecting a germination rate of 90 percent. For example, when 30 to 35 seeds/sq ft is recommended, we are expecting 27 to 32 plants to emerge. Seeding rates for no-tillage are slightly higher than conventional tillage, because we anticipate slightly lower emergence rates.

When calibrating a drill, make note of the standard germination of seed as marked on the seed tag. That number can be used with the desired live seeding rate to calculate how many total seeds to drop. For example, if the targeted live seeding rate is 35 live seeds per sq ft and the standard germination is 80 percent, then the total seeds needed are 38 seeds per sq ft (30 ÷ 0.8 = 38). Table 4-1 can help with calculations of standard germination and adjusted seeding rate.

Table 4-1. Adjusted seeding rate needed based on standard germination and desired live seeding rate.

Live Seeding Rate (seeds/sq ft)	Standard Germination Rate				
	95%	90%	85%	80%	75%
	Adjusted Seeding Rate (seeds/sq ft)				
25	26	28	29	31	33
30	32	33	35	38	40
35	37	39	41	44	47

Once desired seeding rate has been determined, based on field conditions and standard germination of the seed, then the following methods can be used.

Method 1. (most accurate) A five-step process for proper grain-drill calibration follows:

Step 1. Use Table 4-2 as a guide for seeding rates at various row widths when the seed germination test is 90 percent or higher. Table 4-3 gives estimates of the pounds of seed needed per acre at seeding rates of 30 and 35 seeds per square foot for a known seed size.

Step 2. Calculate the number of seeds required in 50 drill-row feet. For example, with 7-inch wide rows and on-time planting, an appropriate seeding rate would be 20 seeds per drill-row foot multiplied by 50 feet, which equals 1,000 seeds planted every 50 feet of row. Count 1,000 seeds of each variety and put them in a graduated tube, such as a rain gauge, or other clear tube or cylinder. Mark the level of the 1,000 seeds on the tube. Or, if you have scales, weigh the 1,000 seeds of each variety.

Step 3. Hook a tractor to the grain drill so that the drive wheels of the drill can be raised off the ground and the drive gears can be engaged. Jack up the drive wheel so it clears the ground and turn the wheel several revolutions to be certain all working parts are turning freely. Check all drill spouts for blockages.

Step 4. Determine the number of revolutions the drive wheel must make to travel 50 feet. Measure the distance around the drive wheel. This distance can be measured directly with a tape measure or calculated by measuring the diameter or distance across the tire and multiplying that distance by a factor of 3.2. For example, if the drive wheel measures 30 inches from tread to tread (diameter), the distance around the tire should measure 96 inches (30 x 3.2). The number of tire revolutions per 50 feet (50 x 12 inches) equals 600 inches. Divide 600 inches by 96 inches to get 6.25 revolutions of the tire per 50 feet of travel. Make a mark on the wheel so the number of revolutions can be conveniently determined when the wheel is turned.

Photo 4-3. Drill calibration takes time, but the final results are worth the effort.

Table 4-2. Recommended number of wheat seeds to plant per 50 drill-row feet.

Row Width (in)	Row Length Needed for 1 sq ft (in)	Seeds/sq ft 30	Seeds/sq ft 35
		Seeds/50 drill-row ft needed[a]	
4	36.0	500	600
6	24.0	750	900
7	20.6	850	1000
7.5	19.2	950	1100
8	18.0	1000	1150
10	14.4	1250	1450

a Assumes 90 percent germination rate.

Table 4-3. Number of pounds of wheat seed needed, depending on seed size and seeding rate.

Seeds/lb	Seeds/sq ft[a] 30	Seeds/sq ft[a] 35
	lb/acre	
10,000	131	152
12,000	109	127
14,000	93	109
16,000	82	95
18,000	73	85
20,000	65	76

a Based on 90 percent or greater germination.

Step 5. Calibrate the drill.

- Put at least a quart of seed of the variety to be calibrated over at least two drill spouts. (You get better accuracy if you use more than one drill spout.)
- Set the drill on a rate setting expected to be close to that desired, and turn the wheel the number of revolutions needed for 50 feet (as determined in step 4) while catching the seed from each spout in a separate container. Pour the seed caught into the precalibrated tube (as determined in step 2), and check the level. Repeat for each of the drill spouts.
- Change settings as needed, and repeat until you get the appropriate number of seeds (level marked on the tube). Repeat the above steps for each variety.

Option: The above procedure also can be used under actual field conditions by catching seed while the drill is traveling a distance of 50 feet. Use Table 4-4 to determine how much seed should be collected from each row unit.

Method 2. (less accurate) Put the wheat seed in the hopper of the drill to cover two or three drill spouts. Keep the seed tag for reference.

- Pull one or more hoses off of the planter units and attach bags to the bottom of the hoses using either zip ties or duct tape.
- With the drill engaged, drive the drill for 50 feet.
- Pull the bags off of the row units and weigh the seed.
- Use Table 4-4 to determine how much seed should be collected from each row unit. Use the seed tag to identify how many wheat seeds are in a pound. Each variety and possibly each seed lot of wheat will be a different seed size.
- Adjust the settings on the drill if necessary.

Method 3. (least accurate) Calculate out how many pounds of seed should be planted for each acre. For example, a target of 35 seeds per square foot is 1,524,600 seeds per acre. If the seed size is 10,000 seeds per pound, the total pounds per acre needed is 152 pounds per acre (Table 4-3).

- Put a specific amount of wheat seed into the drill hopper (either fill to a certain line inside the hopper or fill the hopper to the top).
- Plant a specified area, either one acre or one-half acre.
- Weigh out 200 pounds of seed. Put seed into the hopper until you have filled the hopper back to the specified height.
- Weigh the remaining seed to determine how many pounds were added back to the hopper.

Table 4-4. Weight of seed needed for one row unit and 50 feet of row, depending on seed size, target seeding rate and spacing between row units (assuming 90% seed germination).

30 seeds/sq ft (target seeding rate)

Seed Size (seeds/lb)	Row Width (in)					
	7	7.5	8	7	7.5	8
	Seed collected from one unit in 50 ft of row					
	ounces			grams		
10,000	1.55	1.67	1.78	44.1	47.2	50.3
12,000	1.30	1.39	1.48	36.7	39.4	42.0
14,000	1.11	1.19	1.27	31.5	33.7	36.0
16,000	0.97	1.04	1.11	27.5	29.5	31.5
18,000	0.86	0.93	0.99	24.5	26.2	28.0
20,000	0.78	0.83	0.89	22.0	23.6	25.2

35 seeds/sq ft (target seeding rate)

Seed Size (seeds/lb)	Row Width (in)					
	7	7.5	8	7	7.5	8
	Seed collected from one unit in 50 ft of row					
	ounces			grams		
10,000	1.81	1.94	2.07	51.4	55.1	58.7
12,000	1.51	1.62	1.73	42.8	45.9	49.0
14,000	1.30	1.39	1.48	36.7	39.4	42.0
16,000	1.13	1.22	1.30	32.1	34.5	36.7
18,000	1.01	1.08	1.15	28.6	30.6	32.6
20,000	0.91	0.97	1.04	25.7	27.6	29.4

40 seeds/sq ft (target seeding rate)

Seed Size (seeds/lb)	Row Width (in)					
	7	7.5	8	7	7.5	8
	Seed collected from one unit in 50 ft of row					
	ounces			grams		
10,000	2.07	2.22	2.37	58.8	63.0	67.1
12,000	1.73	1.85	1.97	49.0	52.5	55.9
14,000	1.48	1.59	1.69	42.0	45.0	48.0
16,000	1.30	1.39	1.48	36.7	39.4	42.0
18,000	1.15	1.23	1.32	32.6	35.0	37.3
20,000	1.04	1.11	1.18	29.4	31.5	33.6

Calculation to determine seeds needed:

Ounces of seed needed = [seeds per sq ft x (50 ft x row width in ft) ÷ seeds per pound) x 16 ounces per pound]/0.9

Where seeding rate is seeds per sq ft, row width is in feet, and 0.9 is 90% germination.

Section 5

Fertilizer Management

Lloyd Murdock, John Grove, and Greg Schwab

The most important first step in your fertilizer management program is to take a soil sample. Except for nitrogen (N), your fertilizer and lime decisions will be based on the soil test results. It is advantageous to take the sample as soon as possible after harvest of the previous crop to supply the necessary phosphorus (P) and potassium (K) for the seedling wheat plant. However, in drought years, soil testing at this time can result in soil pH and K test values that are artificially low due to extremely dry soil conditions during August and September. Extension publication AGR-189 gives recommendations on taking soil samples under such conditions. Refer to Extension publication AGR-1, *Lime and Fertilizer Recommendations,* for specific recommendations based on soil tests.

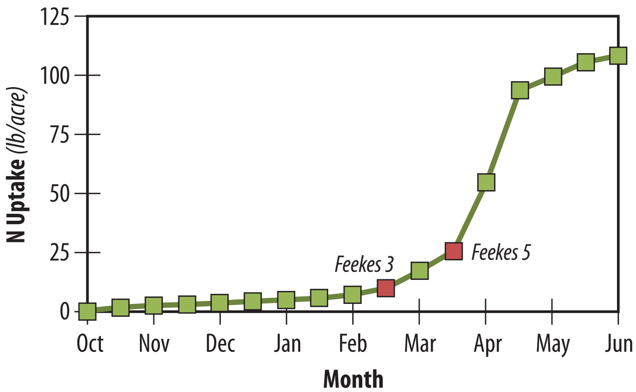
Nitrogen

Nitrogen is the nutrient requiring the most management. Proper N rate and timing are important for high tiller numbers and yield (Figure 5-1). Nitrogen deficiency symptoms consist of pale green (chlorotic) plants that are poorly tillered (Photos 5-2 and 5-3). Excessive N can cause lodging, increased disease incidence and severity, and lower yield. Additionally, excessive N may result in increased levels of N in ground and surface waters, with negative environmental (and economic) consequences.

Rates and Timing. Wheat requires a small, but important, amount of N in the fall. This requirement can almost always be met by soil N remaining after the preceding corn or soybean crop. Producers needing additional P may select P fertilizer sources containing N (for example, diammonium phosphate, DAP, 18-46-0). In the unusual event where and when corn yields greatly exceed (by at least 30 bu/acre) the expectations built in to the corn crop's nutrient management plan, residual N for the succeeding wheat crop will likely be low. If the corn yield exceeds expectations, then 20 to 40 lb N/acre should be added at or near planting. Fall N fertilization becomes more important with late planting (after the first week of November) in a wet fall season

Photo 5-1. The wheat is at about Feekes 2 (Zadoks 21). Stand counts at this stage can help determine how much N to apply for the first application.

Figure 5-1. Nitrogen uptake during the growth of winter wheat.

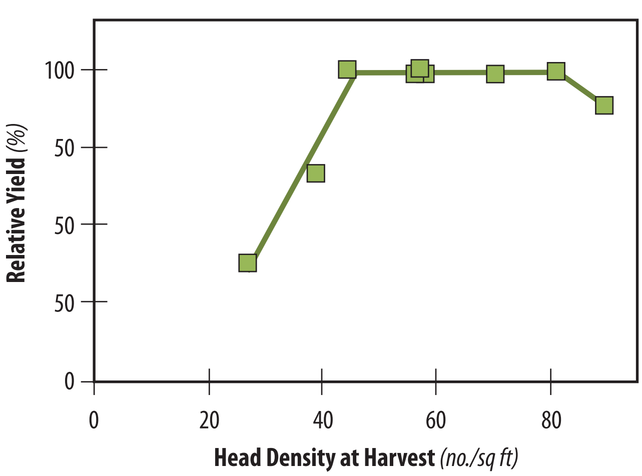


and poor initial emergence (less than 25 plants per square foot). Sufficient fall N stimulates early tillering, which is important for high yields. The fall N rate should not exceed 40 lb N/acre.

Nitrogen applied in late winter-early spring is most effective for yield. There are two approaches that can be used for spring N applications: a single application or a split spring application. Research indicates that a split spring application of N can increase yield by 3 bu/acre (although this varies from year to year), and split N applications reduce lodging potential. Split spring N applications are recommended when possible, but equipment and logistic problems cause some growers to make a single application.

When using the split N strategy, the first application should be made in late winter (mid-February to early March, Feekes 2-3, Zadoks 20-29) at a rate between 30 and 50 lb N/acre. Nitrogen applied at this time encourages further tillering and maintains current tillers. Fields with thin stands or little fall tillering should receive higher early N rates, while those with high tiller counts (above 70 tillers per square foot) should receive lower early N rates (Figure 5-2). Excessive N applied in late winter can increase the potential for lodging, disease, and late spring freeze damage. The second N application should be made to no-till fields in mid to late March (Feekes 5.6, Zadoks 30-31) at a rate sufficient to bring the total amount of spring N to 80 to 110 lb N/acre. In no-till fields with yield potential greater than 70 bu/acre, spring N should total 100 to 120 lb N/acre. If there is some freeze damage or excessively high rainfall in February and March, then the higher N rates should be targeted. For tilled plantings the total should be decreased by 20 lb N/acre because N fertilizers are more efficient with tillage and N loss potential is slightly lower. Higher rates of N application than those recommended here increase lodging potential and do not increase yield potential, unless specific conditions that require more N nutrition are identified.

Figure 5-2. Tillering influences on relative yield of wheat (average of three varieties in two tillage systems over three years).



When making a single N fertilizer application, the best time is when the crop growth stage is Feekes 4-5 (Zadoks 30, usually mid-March), just before the first joint appears on the main stem and, when wheat starts growing rapidly. Rapid growth causes a large demand for N. The rate of N fertilizer for a single application should be between 60 and 90 lb N/acre for fields with a yield potential less than 70 bu/acre and 90 to 100 lb N/acre for fields with greater yield potential. An early (late February) single N application is recommended only when the field's stand or tiller density is low. Earlier N applications are at increased risk of denitrification loss (N loss during extended wet periods). Early single applications increase the risk of spring freeze damage because they encourage earlier heading. Single applications made too early generally result in lower yields and encourage the growth of succulent plants with lush canopies susceptible to diseases like powdery mildew.

Single applications made too late are equally problematic. Nitrogen must be applied in a timely manner to maximize yield potential. Delaying N application after Feekes 6 (Zadoks 31, appearance of the first joint on the main stem) to an N-deficient crop will result in decreased yield potential most years. As plant development advances, yield response to added N progressively declines. After Feekes 9 (Zadoks 39, flag leaf fully developed), there is usually little yield return to added N. However, N applied after Feekes 9 will increase the grain protein concentration.

Fertilizer N Sources. Fertilizer N sources for wheat include ammonium nitrate (33-34% N), urea (45-46% N), and urea-ammonium nitrate solutions (28-32% N). All are equally good sources of wheat N nutrition, when properly managed, in all tillage systems and regardless of previous crop residue. Slow release N is now available for use on wheat. It is a polyurethane (plastic polymer) coated urea prill. The

Photo 5-2. Streaks in this field were caused from anhydrous ammonia applications made before corn where some knife slits were closed and others were not. Where the knife slits were closed, more N was in the soil (for the corn and then for the wheat), resulting in greener wheat.

Photo 5-3. Streaks in a field are common at field entrances where sprayers overlaps and skips in N application are more likely to occur.

trade name is ESN®. This product should be used at the same rate of N as recommended for other N sources. Since ESN releases N slowly, there is no advantage to split N applications with this source. Research results show that ESN applications between January 15 and February 15 produce wheat yields equal to those observed with uncoated urea applied at Feekes 5 (Zadoks 30). Applying ESN after March 1 increases the risk that too little N will be made available for plant uptake during the critical early growth period.

Distribution of Fertilizer N and Leaf Burn. Since the difference between enough and too much N is small, distribution in the field is important. The best distribution will be achieved using liquid N sources or, for solid N sources, an airflow delivery truck. Spinner systems delivering solid materials are less accurate. Distribution of a solid N material that contains a lot of fine material can be improved by double spreading (reducing the distance between passes by half and spreading half the desired rate on each pass). If evenly distributed, N from liquid and solid sources perform equally well in February and March.

Leaf burn can be a concern with liquid N sources, but you can eliminate this concern by using streamjet or flood nozzle application, mixing the liquid N with additional water, applying less than 60 lb N/acre per application, and avoiding applications on cold, windy days. Although wheat fertilizer burn is visually disturbing, research indicates no yield reduction occurs when N is applied late winter-early spring (February and March). Leaf burn after flag leaf emergence (Feekes 9) can cause yield reductions.

Methods to Fine-Tune Wheat Fertilizer N Application Rates. When the amount of fertilizer N to apply in March is in question, a plant sample collected at Feekes 5 (Zadoks 30) might be helpful. Cut a handful of wheat about ½ inch above the ground at 20 to 30 places in the field, and place a subsample of the total plant material collected in a paper bag. Send the sample to a laboratory with a quick turnaround time so fertilizer N application will not be delayed. Table 5-1 shows guidelines for fertilizer N rates recommended at various tissue N concentrations.

Table 5-1. Guidelines for fertilizer N application using wheat tissue N concentrations at Feekes 5.

Plant N Concentration *(%)*	Recommended Fertilizer N Rate *(lb N/acre)*
2.3	100
2.7	80
3.2	60
3.6	40
4.0	20

Murdock (unpublished data)

A chlorophyll meter is a hand-held, non-destructive, field diagnostic tool that actually measures plant leaf greenness. Chlorophyll measurements can provide additional information to help predict the amount of N fertilizer that needs to be added at Feekes 5 or 6 (Zadoks 30 or 31, usually in March). To help calibrate the chlorophyll meter, large amounts of fertilizer N (150 pounds per acre) are added to two or three small areas or strips in the field, in early to mid February. At Feekes 5, chlorophyll readings are taken on 10 to 20 plants in the high N areas and then on 20 to 30 plants in the rest of the field. The measurements are made on the first fully expanded leaf (leaf with a leaf collar) from the top of the plant. Measurements are made about halfway between the tip and

Photo 5-4. Wheat varieties at Feekes 5 (Zadoks 30) ready for a second application of fertilizer N.

Photo 5-5. Variations in green color within a field can be due to application methods as well as weather and soil conditions.

base of the leaf. The following formula is used to make the March fertilizer N rate recommendation:

N = 6 + (7 x D)

N = N (lb N/acre) needed for optimum growth at Feekes 5 (March).
D = difference between chlorophyll reading in the bulk of the field and that found in the small areas/strips with high N rates added in February.

Example: Small areas or strips with high N (150 lbs/ac) added at Feekes 3 (Zadoks 26) read an average of 52 at Feekes 5 (Zadoks 30).

Bulk of field reads an average of 45.

52 – 45 = 7.

6 + (7 x 7) = 55 lb N/acre recommended fertilizer N rate.

A soil nitrate (NO_3) test usually is not helpful unless there are unusual conditions that might cause high N levels in the soil, such as high N carryover due to a very poor corn crop or heavy manure applications. Take soil samples to a depth of 3 feet in February, and place them on brown paper for drying. The NO_3-N measured in the samples will be reported in parts per million (ppm), which should be multiplied by 12 to get pounds per acre. If 120 pounds per acre of NO_3-N are found, no fertilizer N needs to be added. If the soil test indicates less than 120 pounds per acre of NO_3-N, then fertilizer N should be applied.

Phosphorus and Potassium

Phosphorus is essential for root development, tillering, early heading, grain fill, timely maturity, and winterkill resistance. Wheat takes up about 0.67 pounds of P_2O_5 for each bushel produced, and 80 percent of this ends up in the grain. A soil test is necessary in order to determine the proper rate of P fertilizer. Apply P fertilizer in the fall, prior to seeding, for best results. See Table 5-2 for the P_2O_5 concentrations of wheat in grain and straw.

Potassium helps to lower the incidence of some diseases and increases straw strength, which helps reduce lodging. Wheat takes up about 2 pounds of K_2O for each bushel produced, but only about 20 percent of this is removed with the grain. A soil test is required in order to determine the proper rate of K fertilizer. Potassium fertilizer should be applied in the fall, but can be applied in the spring if necessary. See Table 5-2 for the K_2O concentrations of wheat in grain and straw.

Other Nutrients

Calcium (Ca), magnesium (Mg), and sulfur (S) deficiencies have not been observed on wheat in Kentucky. Calcium and Mg will generally be adequate if the proper soil pH is maintained using agricultural lime. Additional Mg should

Table 5-2. Nutrients in wheat grain and straw.

Crop Part	Yield Unit	Nutrient Concentration (lb)		
		N	P_2O_5	K_2O
Grain	Bu	1.2	0.5	0.3
Straw	Ton	12	4	20

Photo 5-6. Scientists are constantly working with equipment to improve N application, N timing and N use by the wheat crop.

be added only if soil test Mg is below 60 pounds per acre. Sulfur deficiencies are best determined by analysis of plant tissue sampled at Feekes 5 (Zadoks 30). If the N:S ratio is greater than 15:1, S should be added at a rate of 20 to 40 lb S/acre. Only water-soluble sources that contain sulfate-S (-SO_4), such as spray grade ammonium sulfate, should be used at this stage of growth.

Micronutrient deficiencies have not been found on wheat grown in Kentucky. The best way to determine micronutrient needs is through plant tissue analysis. See AGR-92 *(Sampling Plant Tissue for Nutrient Analysis)* for additional sampling instructions and interpretation. Micronutrient deficiencies generally occur when the soil pH is too high or too low. A soil pH between 6.0 and 7.0, with a target pH of 6.4, should provide excellent conditions for micronutrient availability and wheat growth. Lime should be applied prior to planting, in the fall.

Burning of Wheat Straw

Burning wheat straw in the field will cause loss of some of the nutrients with the vapor and smoke. Research indicates that losses of carbon (C), N, P and K are as follows:

C - 90 to 100%
N - 90 to 100%
P - 20 to 40%
K - 20 to 40%

Photo 5-7. Most nitrogen fertilizer is applied as a liquid urea ammonium nitrate (UAN) and 28 or 32% N. By using stream bars or stream jet style nozzles, leaf burn from the UAN is minimized. Granular nitrogen (usually urea) can also be applied.

Photo 5-8. Nitrogen test strips in a field with tram lines.

Section 6

Weed Management

James R. Martin and J.D. Green

The crop rotation system typically used in Kentucky can contribute to the control of certain weed species. Practices used in the establishment of no-till corn often break the life cycle of cool-season weeds such as common chickweed, purple deadnettle, or henbit before plants mature and produce seeds. A competitive wheat stand can help weed control in double-cropped soybeans by preventing or delaying emergence of warm-season weeds including crabgrass, cocklebur, and morningglories.

One drawback with this rotation system is that it may perpetuate certain problems. For example, Italian ryegrass often begins in wheat where its seed are easily spread during wheat harvest with combines. Ryegrass seedlings that develop from the scattered seeds during the fall after wheat harvest are able to overwinter and compete the following spring during the establishment of no-till corn. Heavy ryegrass infestations limit no-till corn stands by direct competition as well as harbor voles that feed on corn seed. Studies have shown that if ryegrass is not completely controlled in corn, escaped plants will produce seed and perpetuate the problem in wheat after corn harvest.

Another unique feature about growing wheat in a rotation with corn and double-crop soybeans is associated with the risk of crop injury caused by carryover of herbicide residues. Growers must use caution in selecting herbicides that do not persist in soil for long periods and cause injury to rotational crops.

The spectrum of weeds in conventional and no-tillage plantings of wheat is similar; however, there are some species that tend to be more troublesome where no-tillage practices are used. Wild garlic populations tend to be greater in no-tillage programs compared with programs that use plowing and disking for seedbed preparation. The infestation level of common chickweed, purple deadnettle, and henbit tend to be greater in no-till plantings than in conventional till plantings.

Photo 6-1. Italian or annual ryegrass *(Lolium rigidum)* is a problematic weed in wheat and must be aggressively managed.

Photo 6-2. Common Chickweed, *Stellaria media*

Common chickweed is a cool-season annual with white flowers that grows prostrate and is sparsely hairy. Mouseear chickweed (*Cerastium vulgatum*) is a similar species but has no leaf petiole, is very pubescent, and grows as a perennial.

Why Control Weeds in Small Grains?

The ability of weeds to compete and limit wheat yield will vary depending on the weed species. Italian ryegrass is the most competitive weed in wheat in Kentucky. One ryegrass plant per square foot can reduce wheat yield by approximately 4 percent. As much as 90 bu/A of yield loss of wheat has been measured in research trials on ryegrass. Common chickweed has a prostrate growth habit that forms dense mats and tends to be more competitive than purple deadnettle or henbit. In no-till plantings infestations of common chickweed can reduce potential wheat yield by 14 percent. However, the impact of these weeds is less where preplant tillage is used for preparing the seedbed.

Weeds can also affect the quality of harvested grain and harvesting efficiency. The aerial bulblets of wild garlic contaminate the grain during the harvesting process. Dockage due to bulblet contamination can vary due to a number of factors determined at the grain elevator. In some cases aerial bulblet contamination may be severe enough to render the grain unfit for sale at the elevator. Giant ragweed, common ragweed, johnsongrass, and marestail are examples of warm-season weeds that produce sufficient amounts of green vegetation in the spring that can reduce harvesting efficiency. The green vegetation may also lead to dockage due to increased moisture and foreign matter. Once wheat has been harvested, the clipped stubble of these weeds may survive and be difficult to control with burndown applications in double-cropped soybeans.

Weed Scouting

Periodically monitoring fields helps detect problems before weedy plants become too large to control effectively. Critical periods for monitoring weeds are:

- **Early October.** Near the time of planting, especially in no-tillage plantings, watch for cool-season weed species that cause problems in wheat.
- **Mid- to late November** (about one month after planting). Once wheat has emerged, watch for cool-season annuals, such as common chickweed, henbit, purple deadnettle, or Italian ryegrass. These weeds initiate growth during early fall and sometimes grow too large to control effectively with spring applications of herbicides.
- **Early March to early April.** Begin monitoring soon after wheat recovers from winter dormancy, but before plants are jointing, because some herbicides need to be applied after tillering but before the jointing stage.

Photo 6-3. Shepherd's-purse, *Capsella bursa-pastoris*

Shepard's purse is a cool-season annual that grows 12 to 18 inches tall when mature. Rosette leaves are deeply lobed, and stem leaves are arrow-shaped with clasping leaf bases. Its flowers are white with four petals, and its triangular- or heart-shaped fruit is about ¼ inch long.

Photo 6-4. Field Pennycress, *Thlaspi arvense*

Field pennycress is a cool-season annual with four-petal white flowers. Its basal leaves are egg-shaped and have petioles, while middle and upper leaves are without petioles and have clasping leaf bases. Seed capsules are oval and notched at the tip. Mature plant grows 4 to 20 inches tall.

Photo 6-5. Marestail—also referred to as horseweed, *Conyza canadensis*

Marestail is an annual that grows 1 to 6 feet tall when mature. Seedlings normally grow as rosettes in fall or late winter and bolt (develop elongated stems) in early to late spring. Stems are hairy and are erect unless damaged from herbicides or mowing. Leaves are hairy with entire or slightly toothed margins. Seed are small achenes that are attached to a pappus or group of hairs.

Photo 6-6. Purple Deadnettle *(Lamium purpureum)*, left, and Henbit *(Lamium amplexicaule)*, right.

Both are cool-season annuals with square stems and reddish to purple flowers. Mature plants grow about 4 to 16 inches tall. Purple deadnettle has uppermost leaves that tend to be reflexed (turned downward) and all leaves occur on petioles. Henbit leaves are not reflexed and its lower leaves have petioles while mid- to upper leaves have no petioles.

- **Late May to early June.** After wheat has headed, watch for emerging warm-season weeds. A preharvest treatment after the hard-dough stage may be needed to control weeds and improve harvesting efficiency of wheat, especially where wheat stands are poor and weed infestations are heavy.

Scouting Procedures for Weeds in Wheat

Pertinent weed information can be recorded on paper or digitally on hand-held recording devices such as a PDA (Personal Data Accessory) or a PC tablet. An advantage for using the computer devices is that they can be equipped with GPS technology or connected to a separate GPS unit to help develop field maps and facilitate keeping permanent records of problem weeds for each field.

Step 1. Randomly select survey sites so they are representative of the entire field. Do not survey within 100 feet of a fence or roadway. As Table 6-1 indicates, the minimum number of sites varies according to field size. At each survey site, walk forward 60 feet (approximately 20 steps) and observe for weeds occurring within 5 feet on either side (see Figure 6-1). Each site should be approximately 600 square feet.

Step 2. Infestation levels of weeds can be recorded as estimates of the percentage of ground cover occupied by each species or plant counts within a given area.

Table 6-1. Minimum number of survey sites based on field size.

Field Size (ac)	Number of Survey Sites
1-20	3
20-30	4
30-40	5
40-50[a]	6

a For fields larger than 50 acres, increase number of sites by 1 for each additional 10 acres.

For broadleaf weeds and weedy grasses, estimate the percent ground cover at each survey site. A general guideline for categorizing ground cover is: light (<5%), moderate (5% to 30%), and severe (>30%). It might help to visualize the total percentage occupied by all weeds, then estimate the percentage occupied by each weed species so that the sum of all species equals the total. For example, at the first site you visit, you estimate that the total ground cover occupied by all

Figure 6-1. Survey diagram.

weeds is approximately 20 percent. You then determine that common chickweed occupies about half of the weed cover, with henbit and Italian ryegrass accounting for the remaining space in equal proportions. Based on these observations, common chickweed accounts for 10 percent of the ground cover (i.e., moderate infestation) and henbit and ryegrass each account for 5 percent of the ground cover (i.e., light infestation).

Use plant counts for describing infestation levels for wild garlic. Estimate the infestation of wild garlic at each site as light (one plant per 600 square feet), moderate (two to five plants per 600 square feet), or severe (more than five plants per 600 square feet). It is not necessary to count all wild garlic that occurs in clusters of small plants because only a few, if any, of the small plants occurring in groups develop aerial bulblets. Focus primarily on single plants, and count each cluster of small plants as a single plant.

Step 3. Record the average size or growth stage of each weed species present in the field. The size of cool-season broadleaf weeds that have a low or spreading growth habit is often based on diameter instead of height of plant. Cool-season grasses are defined by growth stage (number of leaves on main stem of seedlings or number of tillers on established plants). This information can help you select herbicide options and determine when to treat.

Step 4. A field map can be used to show general locations of survey sites and problem areas not included in the survey sites. A weed map helps chart special weed problems and may isolate areas of the field that need treatments. The map can also be a useful reference for planning future weed control programs. Figure 6-2 is a sample weed map of a wheat field.

Economic Thresholds

Economic thresholds for weeds in wheat are not well defined; consequently, growers need to rely on their personal experience to determine if a herbicide treatment is warranted. General treatment guidelines are in Table 6-2 and vary depending on several factors including weed species, cost of treatment, and price of wheat.

Photo 6-7. Yellow Rocket, *Barbarea vulgaris*

Yellow rocket is a cool-season annual or biennial that grows 1 to 2 feet tall when mature. Rosette leaves have large terminal lobes and one to four lateral lobes. Upper leaves become progressively smaller and are less deeply lobed. Flowers are yellow with four petals. Seed pods are cylindrical, about 1 inch long and nearly square in cross section.

Figure 6-2. Sample weed map.

Table 6-2. Treatment guidelines for wheat.

	Infestation level[a]		
	Weed Cover	Wild garlic counts/600 sq ft	Treatment Guideline[b]
Light	<5%	1	Probably no economic benefit to treat
Moderate	5 to 30%	2 to 5 plants	Treatment may or may not be justified
Severe	>30%	>5 plants	Treatment may be justified if implemented in a timely manner.

a The infestation level is the total weed cover (in the fall) or wild garlic counts (in the spring) averaged across survey sites. In some instances the average infestation level may suggest no need for treating, yet a few sites may be heavily infested and warrant control. It may be feasible to spot-treat portions of a field where severe infestations occur based on a weed map.

b Light infestations of problem weeds such as Italian ryegrass may still warrant treatment in order to limit spread of weed seed.

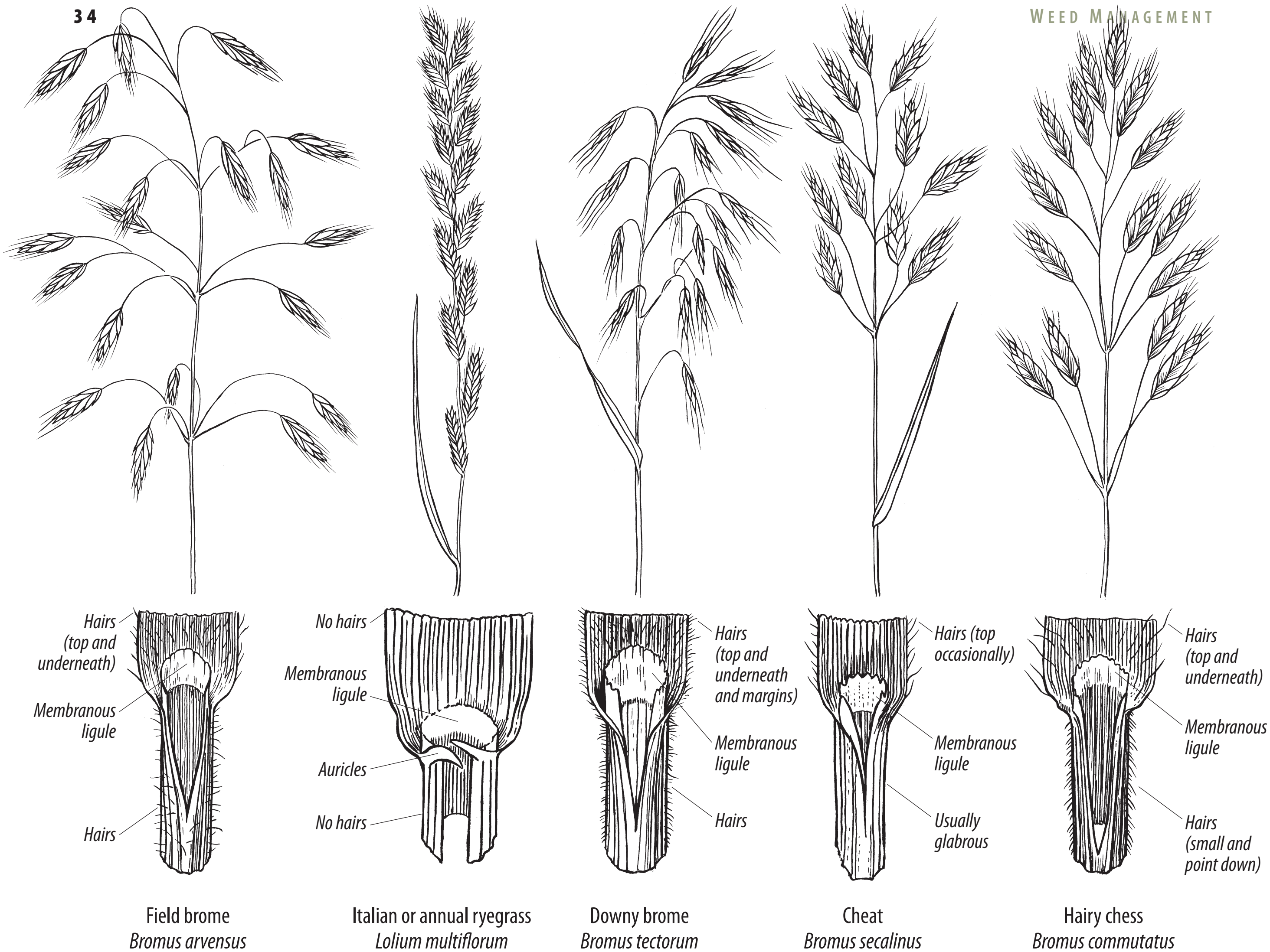
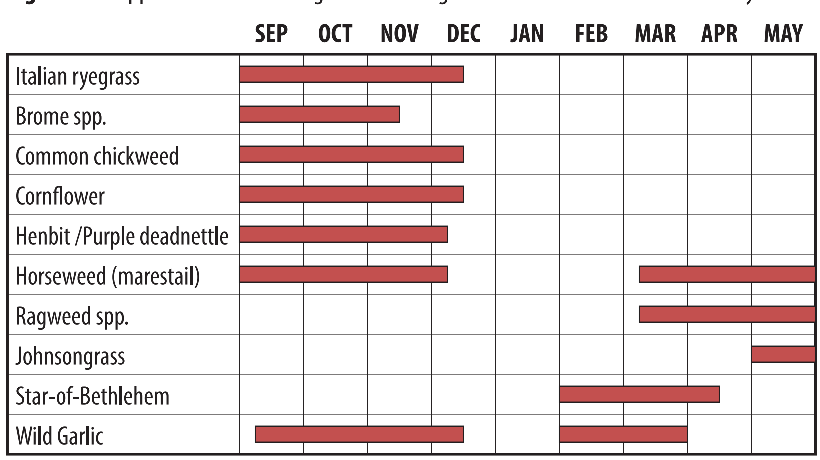


Figure 6-3. Drawings of grass species that occur as weeds in wheat in Kentucky.

Weed Identification

Correctly identifying weeds during their early stages of development is important to help select and initiate successful control strategies. Many weed species look similar during early stages of development. Vegetative characteristics such as shape, color, arrangement of leaves, and location of pubescence (hairs) can aid in identification; providing these characteristics remain consistent under a wide variety of conditions. However, it is not unusual for these vegetative characteristics to vary for some weed species, so they are not always reliable for identification. See the illustrations in this section for descriptions and visual aids to be used in identifying weed species.

Figure 6-4. Approximate Time of Significant Emergence of Weeds in Wheat in Kentucky.*



*Some cool-season species, particularly ryegrass, may continue to emerge sporadically throughout winter and early spring when conditions are favorable for emergence.

Photo 6-8. Corn Speedwell, *Veronica arvensis*

Corn speedwell is a cool-season annual that grows prostrate. Its lower leaves are opposite, have petioles and are rounded at the base. Upper leaves may be alternate and do not have petioles. Leaves and stems have fine hairs. Ivyleaf speedwell (Veronica hederifolia) looks similar, but its leaves have larger toothed margins and more flat or truncated leaf bases.

Photo 6-9. Wild Garlic, *Allium vineale*

Wild garlic is a perennial that grows 1 to 3 feet tall when mature. It has hollow round stem-like leaves and underground bulbs. Aerial bulblets occur in cluster(s) at the top of the plant. Wild onion (Allium canadense) looks similar, but its stem-like leaves are flat and are not hollow. Star-of-Bethlehem (Ornithogalum umbellatum) also looks similar, but it does not have the garlic odor and its leaves are somewhat flat with a pale midrib.

Weed Control—An Ongoing Process

The timeline for emergence of various weed species in wheat (Figure 6-4) illustrates why weed management can be an ongoing process beginning prior to planting up through wheat maturity.

An effective overall weed management program for Kentucky wheat involves a combination of cultural and chemical practices.

Cultural Practices

Establishing and maintaining a competitive wheat stand contributes to weed control. A seeding rate that results in a minimum of 25 wheat seedlings per square foot is ideal for achieving optimum wheat yields and often limits the amount of weedy vegetation. Planting wheat in narrow rows increases the likelihood for achieving early-season shading and competition to weeds compared with wheat planted in wide rows. Applying nitrogen at recommended rates and times can promote tillering of wheat and limit the presence of warm-season weeds that affect harvest.

Crop rotation often reduces weed populations. For example, infestation levels of wild garlic, common chickweed, and henbit tend to be lower following corn than soybeans. A rotation of corn/wheat/double-crop soybeans is common in Kentucky and is often more favorable for managing weeds in wheat than a soybean/wheat/soybean rotation.

Preplant tillage was once the only option for managing such weeds as wild garlic and certain cool-season weedy grasses in wheat. There are a number of drawbacks with tillage including added fuel, time, and erosion. Unless wheat is organically grown, herbicides have often replaced the need for using tillage for weed control.

Growing wheat in rotation with corn and soybeans can be beneficial in controlling broadleaf weeds, such as common chickweed or henbit. The timely use of burndown herbicides or preplant tillage in corn or soybeans limits production of weed seed by destroying cool-season weeds before they mature.

Sanitation is an effective preventative option for limiting the spread of Italian ryegrass. Clipping infested field borders and waterways ahead of wheat harvest can limit the spread of ryegrass seed; however, it is critical to clean equipment after mowing infested areas. Harvest infested fields last. Cleaning combines after harvesting infested areas is especially important. In instances where a portion of wheat seed is being saved for next season's crop, care should be taken to avoid using crop seed harvested from ryegrass infested areas. Also, cleaning the harvested wheat seed is important in limiting the spread of seed in future crops.

Chemical Control

Herbicides play a major role in managing weeds in wheat. Herbicide recommendations for wheat production are discussed in the Cooperative Extension bulletin *Chemical Control of Weeds in Kentucky Farm Crops* (AGR-6). Always read and follow the restrictions and precautions stated on the label of herbicide products.

Winter Wheat Calendar

Wheat Growth Stages | One Shoot | Tillering | Tillerin

Dormancy

Month | August | September | October | Nov/Dec/Jan | February

Production Practices

- Purchase seed
- Clean, treat seed
- Soil test
- Prepare drill for planting
- Calibrate drill
- Soil probe for compaction
- Fertilize (lime, P, K)
- Tillage (if any)
- Plant seed
- Assess stands
- Early nitrogen appl
- Sin
- Tak

Insect and Disease Management

- Scout for aphids and fall armyworms
- Scout for aphids

Weed Management

- No-till weed control
- Scout for weeds
- Spray for grasses or broadleaf weeds
- Spray for wild chickweed, ar

Stored Grain Management and Marketing

- Inspect grain bins
- Aerate to cool grain
- Aerate to maintain grain temperatu

ng Completed | Jointing | Boot | Heading | Ripening

March | April | May | June | July

Apply PGR

Prepare combine for harvest

lication

Start harvest

gle nitrogen application

Start variety selection

ke stand counts

Plant double-crop soybeans

Assess winter injury

Plan for next crop

Finish harvest

s and armyworms

Scout for aphids, armyworms, cereal leaf beetle

Scout for diseases: spray if needed

garlic, henbit,
nd other weeds

Clean and spray storage bins, prepare dryer

re

Aerate to warm grain

Prepare a marketing plan

Treat grain for long-term storage

Summarize and analyze
Enterprise Costs and Returns (past and present)

Photo 6-10. Hairy Chess *(Bromus commutatus),* left, and Italian Ryegrass/Annual Ryegrass *(Lolium multiflorum)*

Hairy chess is a cool-season annual that grows 1 to 3 feet tall. The leaf blade has hairs, and the leaf sheath has hairs pointed downward. There are no auricles. Cheat, downy brome, and field brome are similar in appearance to hairy chess.

Ryegrass is a cool-season annual that grows 1 to 3 feet tall. The leaf blade is glabrous (no hairs), and the leaf sheath is glabrous and shiny. Clasping auricles are present at the leaf collar.

Examples of issues that need to be considered when using herbicides for weed control in wheat are: 1) application timing, 2) compatibility with other chemicals, 3) varietal sensitivity, 4) herbicide-resistant weeds, 5) herbicide carryover, 6) harvesting restrictions for grain or forage, and 7) cleaning spray equipment.

Application timing. The four periods of time when wheat herbicides are applied are: 1) before wheat emergence, 2) postemergence in the fall, 3) postemergence in late winter or early spring, and 4) preharvest. Important issues associated with each timing and some of the factors that determine when treatments should be applied are discussed below.

Before wheat emergence. Fields planted to no-till wheat often require a foliar-applied burndown herbicide such as glyphosate or paraquat. These herbicides will control grasses and broadleaf weeds and can be applied before or after wheat planting but before wheat emerges. Paraquat is a contact herbicide that is labeled to control annual weeds up to six inches in height. It is usually applied in 20 to 40 gallons of clean water or clear liquid fertilizers per acre. Glyphosate is a translocated herbicide used to control annual and perennial weeds. It is often applied in 10 to 20 gallons of water per acre

The use of soil-residual herbicides ahead of wheat emergence is not widely adopted in Kentucky, yet there are occasions where they can help prolong early-season control of some weeds. For example the premix of chlorsulfuron plus metsulfuron (Finesse) can be applied prior to wheat to help suppress emergence of Italian ryegrass. When applied at the high labeled rate, diclofop (Hoelon) offers both premergence and postemergence ryegrass control prior to wheat emergence. Diclofop can also be applied after wheat emergence because of its foliar activity to grassy weeds and safety to wheat. A strategy that growers use to limit expenses with diclofop is to apply preemergence treatments around field borders or areas of heavy infestations where Italian ryegrass problems often begin.

Fall postemergence applications. The likelihood of achieving optimum wheat yield tends to be greater when cool-season broadleaf weeds such as common chickweed, henbit, or purple deadnettle are controlled in the fall rather than in the spring. This is particularly true for no-till plantings. The level of control of these broadleaf weeds is essentially the same regardless of whether treatments are applied in the fall or spring; however, fall tends to be a more favorable timing for optimum control of such weeds as cornflower, annual bluegrass, Italian ryegrass, and certain Brome species.

Fall postemergence sprays can be made soon after wheat emergence and continue though late fall, providing weather conditions are favorable for plant growth. Most postemergence herbicides used in wheat rely on foliar absorption to control weeds; consequently, plants should be actively growing in order to achieve optimum weed control and crop safety. Dry conditions can delay weed emergence, particularly Italian ryegrass. Cold and dry conditions may also delay herbicide activity and in some cases limit weed control. Heavy rainfall, prolonged cold temperatures, or widely fluctuating day/night temperatures before, during, and shortly after application may lead to crop injury, particularly with Acetolactate Synthase (ALS) inhibitor herbicides such as thifensulfuron (Harmony) and mesosulfuron (Osprey).

There are a few soil-residual herbicides that can be applied after wheat emergence. It is unlikely these will provide season-long weed control, yet they can be helpful if conditions are conducive for activity. Extremely dry conditions,

Photo 6-11. 2,4-D or Banvel (dicamba) injury. Wheat treatment during boot stage of growth with auxin-type herbicides result in trapped heads, missing florets, or twisted awns.

Photo 6-12. Atrazine or Princep (simazine) carryover. Wheat plants emerge, then dieback from leaf tips of oldest leaves.

Photo 6-13. Command (clomazone) carryover. Wheat plants emerge and often have chlorotic or bleached appearance. Plants may recover from early-season injury.

or a seedbed that is cloddy or has a lot of surface residue from the previous crop, may limit control from certain soil-residual herbicides. The premix of flufenacet + metribuzin (Axiom) is an example of a soil-residual herbicide that also offers limited foliar activity for seedling weeds present at the time of application. However, pendimethalin (Prowl H_2O) is an example of a soil-residual herbicide that has no foliar activity and may need a foliar-applied herbicide as a tank-mix partner for managing weeds that are emerged at the time of application.

Late winter—early spring postemergence applications. Wild garlic emerges during the fall and early spring months. Achieving optimum control of this weed is important; therefore, growers tend to delay herbicide applications until late winter or early spring to ensure that most of the population of wild garlic plants has emerged. It is not unusual for growers to apply postemergence herbicides during this time for managing cool-season broadleaf weeds and grasses, especially if conditions in the fall were not favorable for weed emergence and growth.

Several postemergence herbicides can be applied when wheat is coming out of dormancy and in Feekes growth stage 5 (Zadoks 30). This timing usually occurs in March and will vary depending on environmental conditions. Some postemergence herbicides may also be applied up to boot stage, yet growers seldom wait this late to make applications.

Crop injury from 2,4-D is associated with such factors as rate, formulation, and wheat growth stage. Injury may be a risk with the high labeled rate, particularly with ester formulations. The risk of injury from 2,4-D is least when crop plants are fully tillered (Feekes 5, Zadoks 30) but before jointing (Feekes 6, Zadoks 31). Although some 2,4-D labels do not prohibit applications after initiation of the first joint, they do prohibit applying to plants that are in the boot (Feekes 8, Zadoks 37) to dough stage (Feekes 11.2, Zadoks 85). Research has shown that applications of 2,4-D in the fall before wheat is fully tillered can injure wheat and reduce yield by as much as one-third.

Dicamba (Banvel or Clarity) is a growth regulator herbicide that is similar to 2,4-D. While dicamba may be applied in the fall or early spring; it is important that treatments be made prior to jointing (i.e. Feekes 6, Zadoks 31) in order to avoid crop injury. See Photo 6-11 for injury symptoms when 2,4-D or dicamba is applied during the boot stage.

Preharvest treatments. Preharvest treatments are not a part of a planned weed control program but are often used as salvage treatments to help prevent such weeds as Pennsylvania smartweed, ragweeds (common and giant), and johnsongrass from impeding wheat harvest and competing for soil moisture in double-crop soybeans. However, research has shown preharvest treatments are not effective in preventing production of viable seed of such weeds as Italian ryegrass.

Glyphosate and certain formulations of 2,4-D are examples of herbicides registered for preharvest weed control in wheat. The response of weeds to these herbicides is slow and does not occur as rapidly as with certain harvest-aid applications used in other crops. Drift to nearby sensitive crops is a concern when using these treatments. Preharvest treatments can injure wheat or reduce seed germination or seedling vigor and are not recommended for wheat grown for seed production.

Herbicide compatibility with other chemicals. Herbicides can interact with other chemicals when tank mixed with one another or applied near the same time. These interactions can occur between herbicides or other pesticides (especially organophosphate insecticides) as well as fertilizers or additives. Consult the label(s) for potential problems


Photo 6-14. Wheat with no injury symptoms (left). Wheat injured by Opsrey herbicide (mesosulfuron-methyl) (right). Leaf burn is more likely to occur when fertilzer N is applied within 14 days of the Opsrey application.

with physical compatibility of the mixtures as well as the potential for crop injury or poor weed control. Also, be certain the application timing is within the recommended period for all chemicals involved.

The following are examples of problems associated with compatibility issues:

Osprey and nitrogen fertilizer. Liquid nitrogen fertilizer is often used at low rates as a spray adjuvant with foliar-applied herbicides. However, applying herbicides near the time of topdressing nitrogen fertilizer can lead to crop injury from certain ALS inhibitor herbicides. For example the label for Osprey indicates topdress applications of liquid nitrogen fertilizer may occasionally cause transient leaf burn and stunting when applied within 14 days of an Osprey application (see Photo 6-14). Research has shown that applying Osprey and topdressing nitrogen fertilizer within a few hours of one another on the same day can limit wheat grain yield by 12.6 bu/A. It is important to consult the herbicide label for any precautions regarding timing for topdressing nitrogen fertilizer.

Harmony Extra + liquid fertilizer + nonionic surfactant. Stunting and yellowing of wheat can occur when liquid nitrogen fertilizer is used as the carrier in place of water. Injury associated with this mixture sometimes can be reduced by using the lowest recommended rate of nonionic surfactant and applying the mixture during favorable weather conditions.

Harmony Extra + diclofop (Hoelon). This mixture can reduce ryegrass control with Hoelon. Applying these products separately, approximately seven days apart helps prevent antagonism associated with this mixture.

Harmony Extra + 2,4-D. Theses two herbicides are frequently applied together as a tank mix combination, yet the application timing of 2,4-D is not always compatible with Harmony Extra. This mixture should be applied in the spring after wheat has fully tillered and before jointing. Fall sprays of this mixture can limit tillering and cause other growth regulator symptoms to appear during later stages of wheat development.

Varietal Sensitivity. Wheat varieties may vary in their susceptibility to certain herbicides. Metribuzin is an example of a wheat herbicide that can vary in its ability to cause crop injury based on variety. The labels of products containing metribuzin list wheat varieties sensitive to metribuzin. Testing of varietal response to herbicides is not an ongoing process, which limits the ability to know sensitivity of newly released varieties. When information on varietal sensitivity is not known, treat only a small area until sensitivity is established before treating large acreages.

Herbicide-resistant weeds. Herbicide resistance is the ability of certain biotypes within a weed species to survive a herbicide that would normally control it. A biotype is a naturally occurring individual of a species that often looks the same but has a different genetic makeup than other individuals of the species. The difference in genetics among biotypes within a species accounts for the presence of herbicide-resistant weeds.

There are isolated populations of Italian ryegrass in Kentucky that are resistant to the ACCase inhibitor herbicide diclofop (Hoelon). Scientists have shown that the resistance of Italian ryegrass to ACCase inhibitor herbicides is not well defined. For example, pinoxaden (Axial XL), another ACCase inhibitor, may control certain biotypes resistant to Hoelon, yet not other Hoelon-resistant biotypes. This inconsistent response to Axial XL makes it difficult in identifying resistant problems for this species.

Resistance to ALS inhibitor herbicides has been reported as a major problem in other wheat production regions of the United States, but not in Kentucky or neighboring states. The fact that sulfonylurea herbicides, which are ALS inhibitors, are widely used in Kentucky makes it important that growers be on the lookout for problems with ALS resistance.

The potential for weed resistance to develop increases with repeated use of herbicides that have the same site or mode of action. Therefore, monitor herbicides used in all rotational crops and use production practices that prevent or reduce the potential for the development of herbicide-resistant weedy biotypes.

Herbicide carryover. Injury due to carryover of herbicide residues is a concern when growing wheat in rotation with corn and double-crop soybeans. Growers must use caution in selecting herbicides that do not persist in soil for long periods and cause injury to rotational crops. While wheat injury due to carryover of atrazine residues has not been a widespread problem in Kentucky, the atrazine label warns that the risk of injury may occur. Simazine is chemically similar to atrazine, but may pose a greater threat to carryover injury to wheat than atrazine. There is a significant risk of injuring wheat where clomazone (Command) was used the previous spring in other crops. See Photos 6-11, 6-12, and 6-13 for injury symptoms due to herbicide carryover.

Certain ALS inhibitor wheat herbicides persist in soil and injure double-cropped soybeans. Dry weather and high soil pH are conditions that prolong the persistence of many ALS inhibitor herbicides. Products that contain such active ingredients as chlorsulfuron (Finesse or Finesse Grass & Broadleaf), metsulfuron (Finesse), propoxycarbazone (Olympus Flex), or sulfosulfuron (Maverick) have potential to injure double-cropped soybean. It is important that growers consult labels for the required rotational interval and any recommendation on planting a Sylfonylurea Tolerant Soybean (STS) variety.

Harvesting restrictions. Most herbicides used in wheat have label restrictions regarding use of the crop as grain or for forage purposes. The EPA has established these restrictions to prevent illegal residues in the harvested grain or forage for livestock feed. When more than one product is included in the spray tank mixture, follow the label that is most restrictive.

Cleaning spray equipment. If spray equipment is not rinsed properly, herbicide residues can accumulate in the spraying system and dislodge in subsequent applications, causing injury to susceptible crops. Check the herbicide label for recommended procedures for cleaning equipment. The procedures may appear cumbersome but are often necessary to remove small amounts of herbicide that could injure other crops.

Section 7

Disease Management

Donald E. Hershman and Douglas Johnson

Disease management is a key component of high-yielding wheat production. In many years, it simply is not possible to produce high wheat yields without paying attention to matters related to disease control. Some diseases, such as take-all disease, barley yellow dwarf, and Fusarium head blight, must be managed proactively, before disease symptoms are evident. Other diseases, such as speckled leaf blotch, leaf rust, stripe rust, stem rust, and powdery mildew, can be managed successfully after initial disease symptoms have become evident. Generally, Kentucky producers place too much emphasis on disease control using foliar fungicides only. As a consequence, little attention is paid to implementing helpful non-fungicide disease control tactics. Most diseases are best managed through the use of multiple tactics, both proactive (e.g., crop rotation, delayed and/or staggered planting plates, use of resistant varieties of varying maturities, proper fertility, and application of seed treatment fungicides) and reactive (e.g., application of foliar fungicides and timely harvest). Leaving disease control to chance is a highly risky approach to producing high-yielding wheat.

Scouting for Diseases

For a variety of reasons, few Kentucky wheat producers place much emphasis on scouting their wheat diseases. Time and labor constraints (for do-it-yourselfers), the cost of hiring a crop consultant, and indifference to the need for scouting rank among the top reasons why this is the case. However, scouting is essential for an integrated approach to managing diseases. First, scouting helps build an on-farm database that can be used to select appropriate disease management tactics for future crops. Second, scouting helps you make the best possible fungicide use decisions, which frequently results in the decision NOT to spray a fungicide.

Research and experience over the past 20 years suggest that fungicides are not helpful or needed in about two out of every five or six years. Low disease years are most often associated with extremely dry and hot weather following flag leaf emergence. Applying fungicides in low disease years is a waste of time and money and is not good for the environment. Effective crop scouting can help you avoid

Photo 7-1. Fusarium head blight (head scab) is caused by *Fusarium graminearum* and must be managed in Kentucky.

making unnecessary fungicide applications and will make your wheat operation more profitable and sustainable in the long haul.

Effective crop scouting takes time, experience, and patience, but is not difficult. The Kentucky Integrated Pest Management (IPM) Program offers annual scout trainings, as well as multiple scouting resources (http://www.uky.edu/Ag/IPM/ipm.htm). In addition, there are numerous other training opportunities held throughout the year, and there is an inexhaustible supply of wheat disease and scouting information available on the Internet. Take advantage of all opportunities to learn how to scout for, and identify, the most common wheat diseases on your farm. At first, scouting for diseases may seem daunting, but only a few diseases have the potential to seriously reduce crop yield, and these tend to occur at specific times during the season, not all at once. The University of Kentucky operates two Plant Disease Diagnostic Laboratories to help with disease identification. Pest problems must be identified accurately before embarking on any pest management program, especially those that involve the use of a pesticide. For more information on submitting samples for diagnosis, contact your local county Extension office.

How Pre-plant Decisions Affect Diseases

Most Kentucky wheat producers have their total disease management program in place once the seed is in the ground. By that time, decisions have been made regarding the length of time since the last wheat crop (crop sequence), tillage method and seedbed preparation, variety selection (maturity, disease package, yield potential, etc.), seed quality (germination, vigor), seed treatment, planting date, seeding rate, seeding method, and fall fertility. Individually and collectively, these decisions play an important role in determining which diseases might develop, their severity, and their potential impact on crop yield, test weight, and grain quality. Because pre-plant and planting decisions are so important in the management of wheat diseases, you need to understand how they influence disease development.

Variety Selection

Decisions relating to variety selection are possibly the most important decisions you can make in managing diseases. Every commercially available wheat variety has a unique “disease package” and this information is usually very easy to come by for most soft red winter wheat varieties. Excellent resistance is not available to manage some diseases, and it is hard to find high-yielding varieties that have decent resistance to all disease threats. Nonetheless, which and how many varieties are planted on your farm will determine the potential for certain diseases to develop. Failure to consider the ramifications of variety selection in managing diseases is a costly mistake made by many producers. It is best to select two or three high-yielding varieties with the greatest level of available resistance to the most common diseases on your farm. To do this, you must have some idea about the disease history of your farm (see above section on scouting). If you don’t have access to historical disease information for your farm, talk with your county Extension agent, farm supply dealers, local crop advisor, and/or neighbors. This information may not be as good as actual data from your farm, but it is far better than basing decisions on no information. It is important to plant more than one variety for this key reason: it is common for a single disease to severely damage a single variety. However, when multiple varieties are planted, the risk that a disease will wreak havoc on all your wheat acres is significantly diminished. In addition, planting more than one variety, especially when different maturities are represented, can help with the logistics of harvesting and planting doublecrop soybean.

Crop Rotation

Few wheat producers in Kentucky give much thought to the influence of crop rotation on diseases. Our normal production systems rarely include planting wheat in the same field in consecutive years. This is good in that planting wheat in alternate years (or even less often) helps in the management of wheat pathogens that survive between wheat crops in wheat residue and/or are short-lived in the soil in the absence of a host crop. One such disease is take-all. In fact, crop rotation is the only practical way to control take-all disease. Rotating crops also can reduce infections by certain windborne foliar diseases, such as the diseases that make up the leaf blotch complex (speckled leaf blotch, Stagonospora leaf blotch, and tan spot). It should be noted, however, that favorable effects are frequently compromised, or even negated, by spores blowing into fields from neighboring fields or from fields that are many miles away.

Most wheat in Kentucky is planted no-till following corn. Corn is generally considered to be a good non-host crop to grow in rotation with wheat because the two crops have few diseases in common. However, there has been some concern that planting no-till wheat where corn was planted the previous season, significantly increases the risk to Fusarium head blight (FHB, head scab). FHB also attacks corn (causes stalk and ear rot) and readily survives between seasons in corn stubble. Planting wheat behind corn does not significantly enhance the FHB threat in Kentucky. Results of multi-year research trials, disease surveys, plus many years of observations, all point to the same conclusion: weather, not local tillage regime, determines if FHB will be serious enough to reduce yields and grain quality or not. This is because when weather conditions favor FHB, so many FHB spores are produced and blow into fields from both local and distant sources, that the role of in-field spore production is relatively unimportant. Under conditions favorable for FHB, disease severity can be slightly elevated in no-till fields. As a result, levels of deoxynivalenol (DON), an undesirable mycotoxin usually associated with FHB, can also be elevated. Nonetheless, tillage regime will never be the factor that determines whether FHB will be severe in a particular field or not.

Tillage

In continuous wheat systems such as are common in the Great Plains Region, tillage hastens the breakdown of residue that harbors certain wheat pathogens. This can help reduce levels of some soil-borne and foliar diseases caused by fungi. However, in southern states, like Kentucky, where wheat is planted every second or third year in a field and soil conditions favor residue breakdown, most of the residue is deteriorated by the time the next wheat crop is planted. Thus, local tillage regime has little impact on diseases that develop from one wheat crop to the next. Implementing community-wide or regional tillage programs might be beneficial, but this approach is impractical.

See the above section on crop rotation for a discussion on the limited impact of tillage on FHB.

Seed Quality, Seeding Rate, and Planting Method

Seed quality, seeding rate, and planting method can each affect stand establishment and development. Excellent seed germination and seedling growth are required for sufficient stands and maximum yields. High-quality seed treated with a broad-spectrum fungicide and good planting techniques (especially depth) foster good stand establishment. Excess stands, however, encourage foliar and head diseases by reducing air circulation and light penetration into the canopy later in the season. Calibrate your equipment to achieve sufficient, but not excessive, stands (see *Section 3—Cultural Practices* for more information).

Planting Date

The trend in recent years has been to plant wheat earlier than is recommended for a given area. The desire to achieve high yields and the logistics of planting large acreages appear to be the main factors behind this trend. The problem is that early-planted wheat (defined as wheat planted prior to the "Hessian fly-free" planting date) is at greater risk of damage caused by barley yellow dwarf (BYD), wheat streak mosaic (WSM), take-all disease, and Hessian fly than is later-planted wheat. In addition, early planted wheat may also encourage leaf rust and stripe rust infection in the fall and this can increase the risk that one or both disease will carry through a mild winter and into the spring. If logistical considerations cause you to plant some of your wheat acres prior to the fly-free date for your area, make sure those acres have been well-rotated, that volunteer corn (which is "green bridge" for WSM) in and around the field has been killed, and plant a variety that can tolerate some BYD. You might also target these acres for a seed applied or fall foliar insecticide treatment (See *Section 8—Insect Pests.*). Finally, make sure you scout your early-planted acres for signs of leaf rust and/or stripe rust in the spring so as to not miss hotspots which could lead to a more general infection later in the season.

Planting all your wheat acreage prior to the fly-free date is extremely risky and is not recommended under any circumstances.

Nitrogen Fertility

Too much nitrogen in the fall can encourage excessive fall growth that can increase your problems with BYD and most foliar diseases caused by fungi, but especially powdery mildew. Increased problems with BYD are often the result of an extended period of aphid activity (aphids transmit BYD virus) when stands are dense in the fall. The same situation encourages infection and overwintering of foliar fungal diseases, such as leaf and stripe rust, powdery mildew, and leaf blotch complex. Excessive spring nitrogen results in lush stands that promote disease in a manner similar to that associated with excessive seeding rates.

Fungicide Seed Treatments

Seed treatment fungicides are used on nearly all wheat seed purchased in Kentucky. Stands and yields are not always improved when fungicide treated seed is planted, but the cost of fungicide and treating is relatively low compared to the potential benefits. Think of seed treatments as a form of low cost crop insurance; it is there when you need it.

Getting and keeping a good stand is a key component of high-yielding wheat. Typically, achieving excellent stands is not that difficult in Kentucky as long has high quality seed is used, and planting date and planting method are consistent with University of Kentucky recommendations. We have conducted a great many seed treatment fungicide tests over the years, and we rarely see a significant impact on spring stands, tiller counts, disease control, or yield. Occasionally, we see significant stand improvements in the fall, but these rarely carry over into the spring.

Seed treatment fungicides play a significant role in Kentucky wheat production. Many times, one or more factors are compromised at planting and in the absence of a seed treatment fungicide, yield and quality could be compromised. For example, dry soil conditions in early fall frequently cause a delay in planting as producers wait for soil moisture conditions to improve. Under these circumstances, it is not uncommon for wheat to be planted well after the recommended planting date for an area. Often soil conditions in November become hostile to germinating wheat and young seedlings. Under these conditions, germinating seed and young seedlings need the benefit of a seed fungicide. Even when planting date is optimal, stands can be compromised if seed are planted too deep or too shallow, if planting equipment is not properly calibrated and functioning, or if soil conditions turn cool and wet earlier in the fall than normal. In these cases, seed treatment fungicide may help you attain and retain acceptable stands that can produce a high yield.

Another significant role of seed treatment fungicides is to assist with stand establishment when seed planted has reduced percent germination and/or vigor. For example,

Table 7-1. Activity of Common Seed Treatment Fungicide Active Ingredients.[a]

Fungicide	Activity
Carboxin	Modest control of general seed- and soil-borne pathogens; excellent control of loose smut.
Difenoconazole	Moderate control of general seed- and soil-borne pathogens, very good control of Fusarium seed rot and seedling blight, and excellent control of loose smut. Minor control of early powdery mildew and rust and good control of seedling blights caused by Stagonospora and Septoria.
Fludioxonil	Provides excellent control seed borne Fusarium as well as several soil borne pathogens, with the exception of Pythium.
Imazalil and Thiabendazole	Similar to thiram and captan except for much improved control of Fusarium seed rot and seedling blight.
Mefenoxamand Metalaxyl	Provides protection from Pythium for a limited time following seeding. Other classes of seed and soil-borne pathogens are not controlled.
Pentachloronitrobenzene	Provides protection from Rhizoctonia for a limited time following seeding.
Tebuconazole	Similar to difenoconazole, except provides no control of fall powdery mildew.
Captan, Maneb, Thiram	Moderate activity against many common seed- and soil-borne fungi.
Triadimenol	Similar to difenoconazole, but provides excellent control of fall powdery mildew and very good control of fall infections of leaf rust or stripe rust. In high mildew areas, can often be used as a replacement for foliar fungicide sprays for mildew in early spring (up to head emergence). Very good control of Fusarium seed rots and seedling blights. Excellent control of loose smut.
Triticonazole	Provides excellent control of smuts and very good control of seed borne Fusarium and several soil borne pathogens with the exception of Pythium.

a Consult with your chemical salesperson and/or ag supply dealer for product trade names. Most commercially-available seed treatment products are comprised of multiple active ingredients.

stocks of high germination seed are usually very limited in the fall following a big FHB year. In these years, growers frequently have to settle for seed with lower than desired germination rates (e.g., 70%). As long as seed is within acceptable tolerances for both germination and vigor, certain fungicide seed treatments can be the difference between achieving acceptable stands or not. This does not apply to severely damaged seed that may contain a lot of tombstones (dead seed) or has suffered serious mechanical damage.

Historically, diseases like loose smut used to be serious disease problems in both wheat and barley, but this is no longer the case. Like near eradication of polio in the human population, it is now very rare for smuts and related diseases to cause significant damage in most wheat producing states. Good seed production practices and certification standards have played a major role in helping to achieve this status. However, the regular use of certain seed treatment fungicides capable of eradicating the smut fungus in seed, has also been extremely important. The increase in occurrence of smuts would be all but certain if growers quit using seed treatment fungicides, many of which are highly effective against smut.

There is currently a very long list of seed treatment fungicides available for use on wheat. The vast majority of newer products are effective at very low use rates and consequently can only be applied by certified applicators. Hopper box treatments are still available, but their use has been considerably reduced in recent years. Some fungicides have a broad spectrum of disease control activity and others have very specific uses. Table 7-1 lists some of the most commonly used products and the diseases they control. Contact your local farm supply dealer for more specific information.

Foliar Fungicides

The role of modern foliar fungicides is to manage certain common diseases caused by fungi. Target diseases include leaf rust, stripe rust, stem rust, powdery mildew, speckled leaf blotch, Stagonospora leaf and glume blotch, and tan spot. Certain fungicides also suppress FHB. Other diseases, like take-all and all diseases caused by viruses or bacteria, are not controlled by fungicides.

Since the first printing of this publication 1996, foliar fungicide use in Kentucky has gone mainstream. By 1996, only 30 percent of producers had ever applied a foliar fungicide to wheat. At present, fungicides are used by most producers interested in achieving high yields. There is no doubt that producers will at least recover the cost of fungicide and application in most years. However, fungicides are not needed every year. Unfortunately, the current trend is to apply fungicides on a calendar or growth stage basis and not according to actual need. Scheduled applications, while easier to plan for and implement, are in direct opposition to established good farming practices. Fungicides should certainly be used when needed, but there are many good reasons to keep the sprayer in the barn in some years. The best and most sustainable approach is to base fungicide spray decisions on results of field scouting and after considering other production practices that impinge on a crop's risk for disease.

Regardless of how fungicide use decisions are made, it is important to understand what fungicides do and do not do. Their main role is to protect crop yield potential from losses caused by specific fungal diseases. Fungicides vary in their effectiveness against these target diseases (Tables 7-2 and 7-3). Fungicides do NOT give a "yield bump". Rather, they protect yield potential that is already built into the crop. This may seem like a minor point, but it is actually quite important. If you understand this principle, you will appreciate why fungicides do not always result in higher yields compared to untreated crops.

The bottom line is this: If disease pressure is great enough to reduce crop yields, then fungicides may help protect the crop from potential losses. However, if disease conditions are light such that no or nominal yield loss is possible, than applying a fungicide would not result in either a yield or economic advantage.

Deciding whether or not to apply foliar fungicide should involve a couple of steps. First, catalog your use of production practices that favor disease development (or not). Do-

Table 7-2. Fungicide Efficacy for Control of Wheat Diseases.

The North Central Regional Committee on Management of Small Grain Diseases (NCERA-184) has developed the following information on fungicide efficacy for control of certain foliar diseases of wheat for use by the grain production industry in the U.S. Efficacy ratings for each fungicide listed in the table were determined by field testing the materials over multiple years and locations by the members of the committee. Efficacy is based on proper application timing to achieve optimum effectiveness of the fungicide as determined by labeled instructions and overall level of disease in the field at the time of application. Differences in efficacy among fungicide products were determined by direct comparisons among products in field tests and are based on a single application of the labeled rate as listed in the table. Table includes most widely marketed products labeled products, and is not intended to be a list of all labeled products.

Efficacy of fungicides for wheat disease control based on appropriate application timing.

Fungicide(s)			Powdery mildew	Stagonospora leaf/glume blotch	Septoria leaf blotch	Tan spot	Stripe rust	Leaf rust	Head scab	Harvest Restriction
Class Active ingredient	**Product**	**Rate/A (fl. oz)**								
Strobilurin										
Azoxystrobin 22.9%	Quadris 2.08 SC	6.2 - 10.8	F(G)[a]	VG	VG	E	E[b]	E	NR	45 days
Pyraclostrobin 3.6%	Headline 2.09 EC	6.0 - 9.0	G	VG	VG	E	E[b]	E	NR	Feekes 10.5
Triazole										
Metconazole 8.6%	Caramba	10.0 - 17.0	--[c]	--[c]	--[c]	--[c]	E	E	G	30 days
Propiconazole 41.8%	Tilt 3.6 EC PropiMax 3.6 EC Bumper 41.8 EC	4.0	VG	VG	VG	VG	VG	VG	P	40 days
Prothioconazole 41%	Proline 480 SC	5.0 - 5.7	--[c]	VG	VG	VG	--[c]	VG	G	30 days
Tebuconazole 38.7%	Folicur 3.6 F[d] Embrace 3.6 L Monsoon Muscle 3.6 F Orius 3.6 F Tebucon 3.6 F Tebustar 3.6 F Tebuzol 3.6 F Tegrol Toledo	4.0	G	VG	VG	VG	E	E	F	30 days
Prothioconazole19% Tebuconazole 19%	Prosaro 421 SC	6.5 - 8.5	G	VG	VG	VG	E	E	G	30 days
Mixed mode of action										
Metconazole 7.4% Pyraclostrobin 12%	Multiva TwinLine	6.0 - 11.0	G	VG	VG	E	E	E	NR	Feekes 10.5 and 30 days
Propiconazole 11.7% Azoxystrobin 7.0%	Quilt 200 SC	14.0	VG	VG	VG	VG	E	E	NR	45 days[e]
Propiconazole 11.4% Trifloxystrobin 11.4%	Stratego 250 EC	10.0	G	VG	VG	VG	VG	VG	NR	35 days

a Efficacy categories: E=Excellent; F=Fair; G=Good; NR=Not Recommended; P=Poor; VG=Very Good. Efficacy designation with a second rating in parenthesis indicates greater efficacy at higher application rates.
b Efficacy may be significantly reduced if solo strobilurin products are applied after stripe rust infection has occurred
c Insufficient data to make statement about efficacy of this product
d Generic products containing tebuconazole may not be labeled in all states
e The pre-harvest interval for Quilt is under review by EPA and may be adjusted to consider a growth stage restriction.
This information is provided only as a guide. It is the responsibility of the pesticide applicator by law to read and follow all current label directions. No endorsement is intended for products listed, nor is criticism meant for products not listed. Members or participants in the NCERA-184 committee assume no liability resulting from the use of these products.

Table 7-3. Preliminary estimates of fungicide efficacy for stem rust of wheat and barley.

Preliminary estimates are based on available data. We have more data for Tebuconazole and Propiconazole than for other products. When products have only been evaluated in a few studies the efficacy ratings are based in part on product efficacy against other cereal rust diseases.

Fungicide(s)			Stem rust
Class Active ingredient	**Product**	**Rate/A (fl. oz)**	
Strobilurin			
Azoxystrobin 22.9%	Quadris 2.08 SC	6.2 - 10.8	E[a]
Pyraclostrobin 3.6%	Headline 2.09 EC	6.0 - 9.0	E
Triazole			
Metconazole 8.6%	Caramba	10.0 - 17.0	E
Propiconazole 41.8%	Tilt 3.6 EC PropiMax 3.6 EC Bumper 41.8 EC	4.0	VG
Prothioconazole 41%	Proline 480 SC	5.0 - 5.7	VG
Tebuconazole 38.7%	Folicur 3.6 F	4.0	E
Prothioconazole19% Tebuconazole 19%	Prosaro 421 SC	6.5 - 8.5	E
Mixed mode of action			
Metconazole 7.4% Pyraclostrobin 12%	Multiva TwinLine	6.0 - 11.0	E
Propiconazole 11.7% Azoxystrobin 7.0%	Quilt 200 SC	14.0	E
Propiconazole 11.4% Trifloxystrobin 11.4%	Stratego 250 EC	10.0	VG

a Efficacy categories: E=Excellent; VG=Very Good. Efficacy designation with a second rating in parenthesis indicates greater efficacy at higher application rates. This information is provided only as a guide. It is the responsibility of the pesticide applicator by law to read and follow all current label directions. No endorsement is intended for products listed, nor is criticism meant for products not listed. Members or participants in the NCERA-184 committee assume no liability resulting from the use of these products.

ing this gives you a way to assess your disease risk and the concurrent potential for a fungicide to give an economic result. Carefully consider the following:

- Variety disease package (more resistant varieties are less likely to respond to a fungicide application).
- Dense canopy (thick crops have reduced light penetration and air circulation in the canopy, and both of these favor development of foliar and head diseases).
- Early planting date, later maturing variety, mild fall and/or winter (favors the survival and earlier appearance of some fungal diseases in the spring).
- High N fertility (enhanced plant susceptibility).
- Disease-favorable weather forecast
- No-till (following corn)
- Field history of disease
- Diseases in current crop

Scout the wheat at critical stages for 1) incidence and severity of fungal diseases targeted by foliar fungicides, 2) crop yield potential, and 3) to determine if some other pest or disease has compromised crop health to the point where apply a fungicide is not prudent. For obvious reasons, crops with low yield potential are not good candidates for fungicide application. Typically, fungicides applied during or immediately following head emergence give the best yield response when disease pressure is sufficient to reduce yield. Fungicides applied for FHB suppression, however, must be applied at early anthesis (beginning of flowering) for best results. This can create a tension if other diseases, such as leaf blotch complex, threaten the crop. Most of the time, this is not a serious issue and applications made for FHB also do an excellent job against other late-season fungal diseases. But the occasional situation develops when a producer may need to decide which target disease is the highest priority. Depending on the decision made, either FHB suppression or control of other leaf and head diseases could be compromised.

Periodically, fungicide manufactures probe the market to see if ultra-early to early applications of fungicides (i.e., stem elongation to flag leaf emergence) will be accepted and used by producers. Part of the lure in this approach is that many producers already apply herbicides and/or insecticides at early growth stages, so adding the fungicide is relatively inexpensive. In many cases, fungicide manufacturers recommend reduced fungicide rates when their products are applied early, so this sweetens the pot. In most soft red winter wheat states, early applications are not sold as a replacement for later applications, but, rather, in addition to later applications. In some parts of the country, like the Pacific Northwest, this strategy can pay off, as wheat frequently does have significant disease pressure prior to flag leaf extension. However, this is a rare situation in Kentucky. We tested early applications during the late 1980's, and again during 2007 - 2008, with little success. In most cases, disease pressure did not build up well until well after the fungicide was applied. In these instances, the fungicide was not there when it was needed. In other cases, disease never did build up, so the applications were not needed in the first place. Fungicide manufacturers frequently market early applications as a way to "short circuit" a disease epidemic before it gets started. This sounds good, but in most instances, things it don't pan out the way the early application programs are sold. All things considered, there appears to be little justification for applying any foliar fungicide prior to flag leaf extension in all but the most rare cases in Kentucky.

Finally, the relatively new strobilurin class of fungicides is being sold by some fungicide manufacturers as a means of reducing the impact of certain crop stresses, in addition to disease control. While it is true that there is considerable laboratory and greenhouse evidence that this is true, how this translates to field conditions is less clear. Strobilurin fungicides do frequently elicit and effect called the "green-

Photo 7-2. Barley yellow dwarf yellow reaction.

Photo 7-3. Barley yellow dwarf purple reaction.

ing" or "stay-green effect". This so-called greening effect is pointed to by some as visual evidence that plant health is being improved. This is debatable. In fact, the greening effect is often not associated with higher yields. Furthermore, many wheat growers have taken to experimenting with various combinations of triazoles and reduced rates of strobilurins as a way to avoid, or at least reduce, the greening effect. The effect tends to delay harvest, which also results in doublecrop soybeans being planted later—up to a week later. If the crop is harvested sooner, harvest must proceed at a slower pace and grain drying is often necessary, which increases the cost of production. The bottom line is that there is a mixed response to the greening effect and it should not be assumed that the greening effect is necessarily a good thing.

Disease Descriptions

The following are general descriptions of the wheat diseases most common in Kentucky. Diseases are listed seasonally. More specific information on each disease is available through your county Extension office. If you are using picture sheets to help identify a disease, be aware that many diseases look similar and can be confused with one another. The University of Kentucky staffs two plant disease diagnostic laboratories to assist you, at no charge, in identifying plant diseases.

Diseases Caused by Viruses

Barley Yellow Dwarf (BYD)

Occurrence. Greenup through late milk.

Symptoms. Primary symptoms include plant stunting, reduced tillering, and yellow to red-purple discoloration of leaf tips and margins. Affected plants may have a unusually erect, "spiked", appearance. Symptoms can occur in the fall or spring, but are most common in the spring on the top two leaves of the plants. Foliar symptoms are frequently accompanied by secondary bacterial infections. These infections are visible as brown spots and streaks on BYD-symptomatic plants. Infected plants frequently occur in random, small groups. Large portions of fields or entire fields can be affected in severe cases.

Damage. BYD reduces grain yield and test weight.

Key features of disease cycle. Barley yellow dwarf virus (BYDV) is transmitted from infected grasses into wheat and barley by several species of aphids. In Kentucky, the bird cherry-oat aphid and, to a lesser extent, the corn leaf aphid are the most important vectors in the fall. In the spring, overwintered bird cherry-oat aphids and English grain aphids are the most important vectors. Regardless of the aphid species, winged adults immigrate into wheat fields from neighboring and distant sites, feed, and deposit live young on plants. The migratory behavior of winged vectors is the reason why initial BYD symptoms are often seen along field edges and in randomly occurring spots. Typically, the young aphids deposited by winged migrant adults develop into wingless adults that produce more offspring over several generations. These wingless aphids, in turn, producer a small number of winged aphids which fly locally and a larger number of unwinged offspring that gradually spread in fields by crawling from plant to plant.

BYDV is transmitted to wheat through the feeding activities of both winged and wingless aphids. Aphids acquire the virus by feeding on diseased plants for as little as 30 minutes. BYDV cannot be transmitted from adult to young aphids. For this reason, the percentage of winged aphids originally carrying the virus into a field is an important piece of the picture. This percentage can vary greatly from field to field and from season to season. Although you can never tell which aphids are carrying BYDV and which are not, having knowledge of seasonal aphid activities can help you assess the potential for BYDV to occur.

Fall infestation. The numbers of aphids arriving in the fall depend largely on two factors: general growing conditions the preceding summer and when the first hard frost occurs in relation to wheat seedling emergence in the fall. Normal or greater rainfall during the summer usually benefits the aphid population. In drier summers, fewer aphids are produced due to reduced host plant quality. For the same reasons, a greater proportion of BYDV-infected host plants die due to the extra stress.

Crops that emerge long before a hard freeze have a greater potential for aphid infestation (and exposure to BYDV) than those emerging after a hard freeze. The fly-free date, which is used to control Hessian fly infestation, is based on that principle and works well as long as the freeze occurs when expected.

Winter survival. Aphids arriving in the field during the fall continue to move, feed, and reproduce as long as temperatures remain above about 48°F. Mild temperatures or insulating snow cover during cold spells, usually results in significant survival of the aphids during the winter. Harsher weather results in greater mortality. BYDV-infested aphids that survive the winter months are a primary source of BYD increase in the spring.

Spring infestation. The English grain aphid has a spring flight and arrives about the same time that winter wheat is greening up and the overwintering bird cherry-oat aphid becomes active, in early spring. The numbers of winged adults of the English grain aphid depend on the same factors that determine survival of the bird cherry-oat aphid. Good conditions for survival should produce larger spring flights and, possibly, increase the movement of BYDV within and among wheat fields. Because of this timing the English grain aphid is less likely to be important in the movement of BYDV.

Management. Plant after the Hessian fly-free date. Plant wheat varieties tolerant or moderately resistant to BYDV. Limit BYDV infection by controlling aphids with insecticides if aphids reach treatment threshold within 30 days after planting in the fall, or in early spring (See aphid threshold levels in *Section 8—Insect Pests.*). The greatest probability for the successful use of insecticides exists when the following criteria are met: the crop is planted prior to the fly-free date or first killing frost; drought stress the previous summer was not widespread; there is an extended period of mild weather in the fall; there is a mild winter or good snow cover during cold periods; there is an early, mild spring; at least ten aphids per row foot are observed in the crop; the crop is at the stage prior to flag leaf emergence; and there is high crop yield potential.

If the aphids-per-row-foot level is reached in the fall or spring, it is an indication that at least some of the above criteria have been met. If this aphid level is reached in the fall especially within 30 days of seedling emergence, it may be advisable to make an insecticide application. If it turns cold after the application, wait and scout again in the spring. If the fall and / or winter is mild and winged aphids continue to arrive in the field, continue to scout. It is possible that a second fall application might be needed to achieve acceptable BYD control. Regardless of what was done in the fall, a spring application may be needed if greenup is early and the aphid treatment guideline is reached prior to flag leaf emergence. Failure to make the necessary spring applications may negate any gains associated with fall applications.

Keep in mind that the above aphid treatment guideline is not chiseled in stone. In some years, the aphid thresholds may be too low and in other years too high. Herein lies the difficulty when attempting to control BYD indirectly using insecticides; the system is not perfect. However, until our understanding of BYD epidemiology and aphid biology is enhanced by new research, aphids-per-row-foot treatment guideline is the only one available with any experimental basis.

Diseases Caused by Viruses

Wheat Soil-borne Mosaic

Occurrence. Symptoms are most prominent from green-up through stem erection, but plants may remain permanently stunted.

Symptoms. Leaves of infected plants exhibit a mild green to prominent yellow mosaic. Small green islands and short streaks may be evident on an otherwise yellowed leaf. Infected leaves may be somewhat elongated and have rolled edges; tillering of plants is commonly reduced. Wheat soil-borne mosaic can occur throughout fields, but is usually most severe in poorly drained or low areas in fields. Symptoms are most prominent early to mid season when day temperatures are between 55°F and 70°F. Symptoms tend to fade somewhat as the weather warms up, but in severe cases, plants can remain permanently stunted.

Damage. Yield is reduced.

Key features of disease cycle. Virus is transmitted by a soil fungus, *P. graminis*, that is common throughout Kentucky. Infection can occur in the fall, winter, or spring, but autumn infections lead to the most serious problems. High soil moisture favors infection.

Management. Plant resistant wheat varieties. Delay fall planting operations past the Hessian fly-free date to limit fall infections. Improve internal and surface drainage of fields where problems exist. Avoid crop production practices that encourage soil compaction.

Diseases Caused by Viruses

Wheat Spindle Streak Mosaic

Occurrence. Greenup through flowering.

Symptoms. Symptoms are highly variable, depending on the wheat variety and growing conditions. Foliar symptoms appear as random, yellow to light green dashes running parallel with the leaf veins. Early in the spring, the dashes may have a nondescript appearance. With age, however, some dashes are pointed at one or both ends, hence the name spindle streak. Spindles may have an island of green tissue in their centers. Plant stunting and reduced tillering can be associated with severe infection by the virus. Symptoms usually appear during the period the crop should be greening up in early spring. Symptoms are frequently uniformly distributed across fields and usually fade as temperatures warm in mid spring. During cool springs, symptoms may be evident throughout the season.

Damage. Yield is reduced.

Key features of disease cycle. The virus is transmitted to wheat in the fall, winter, or early spring by the soil fungus *Polymyxa graminis.* The onset and degree of symptom expression can be highly variable in a field from one year to the next, even though *P. graminis* and the virus are present at relatively constant levels. This is related to the time of year wheat becomes infected and the range and consistency of winter and early spring temperatures. Disease is favored in wet soils, although excessive moisture is not required for severe disease to occur.

Management. Same as wheat soil-borne mosaic.

Photo 7-4. Wheat spindle streak mosaic.

Photo 7-5. Wheat streak mosaic.

Diseases Caused by Viruses

Wheat Streak Mosaic (WSM)

Occurrence. Greenup through late milk. Infections evident before heading will have the greatest impact on crop yield. Severe infections, however, are rather rare in Kentucky and usually only occur in the year following drought conditions when abandoned corn and or soybean fields exist in the vicinity of emerging wheat (fall).

Symptoms. Leaves turn pale green to yellow and leaves exhibit white to cream colored parallel streaks of varying lengths. Plants may appear flaccid when symptoms develop during stem elongation to flag leaf extension. Severe infections can be evident across an entire field, or symptoms may be evident in hot spots, especially near field edges. Symptoms are frequently confused with those associated with barley yellow dwarf (because of leaf yellowing) or wheat spindle streak (WSSM) or wheat soil-borne mosaic (WSBM; because of the streaks which are produced). However, a side by side comparison of these diseases indicates notable unique features associated with each disease. Specifically, BYD does not show streaks, and WSSM and WSBM do not show characteristic yellowing of leaf tissue.

Damage. Yield and test weight are reduced. Fields showing extensive foliar symptoms prior to flag leaf extension are frequently destroyed and replanted to either corn or soybean. Plants exhibiting symptoms after flag leaf extension may not have full yield potential, but an acceptable yield can often be produced as long as other stress and diseases are not a factor.

Key features of disease cycle. WSM virus (WSMV) is transmitted through the feeding of wheat curl mites. This pest is not an insect but a mite, more closely related to ticks and spiders. The mite (and therefore the virus) requires a "green bridge" of volunteer wheat or corn (another host crop) that grows in late summer allowing the mite to survive in large numbers until the next wheat crop emerges in the fall. Mites are deposited from near or distant sources into wheat during the fall or spring. Mites that carry the virus feed on plants and spread the virus.

Management. Varieties differ in susceptibility to WSMV, but because the virus occurs so infrequently that seed companies usually cannot provide reliable WSM ratings. Thus, it is best to assume that all soft red winter wheat varieties are susceptible to WSMV. The best and most reliable means of managing WSM is to eliminate volunteer wheat and corn from your farm for a period of 30 days before wheat emerges in the fall. This break in the green bridge will greatly reduce the potential for WSM to occur. However, in years where volunteer wheat and/or corn are common on a regional basis, be aware that mites can be spread from distant fields and deposited on your farm, sometime in significant quantities. See Entfact-117 for more information.

Diseases Caused by Bacteria

Bacterial Streak/Black Chaff

Occurrence. Flag emergence through grain fill.

Symptoms. Leaves will develop water-soaked streaks of varying lengths that eventually turn necrotic (brown). Severely diseased leaves can die, but this is not typical in Kentucky. Infected heads will have glumes with black streaks that follow the glume veins. Black chaff is easily confused with a genetic discoloration of glume veins that is typical for a small number of varieties. Genetic "symptoms" will be very uni-

Photo 7-6. Bacterial streak.

Photo 7-7. Wheat head scab.

form, whereas black chaff will have a more random occurrence and will almost never involve all the heads in a field.

Damage. Test weight reduction.

Key features of disease cycle. Xantomonas translucens is seed and probably soil-borne in Kentucky. The disease is rather rare in Kentucky, but when it does occur it is usually seen along field margins where leaves receive more wounding from dirt blowing, or in patches where "dust devils" may have occurred. In some cases, bacterial streak is seen after leaves sustain some freeze damage. The causal bacterium is unable to directly infect plants and requires a wound in order to gain entrance into tissue.

Management. None.

Diseases Caused by Fungi

Fusarium Head Blight (FHB, Head Scab)

Occurrence. Early milk through maturity.

Symptoms. Individual spikelets or groups of spikelets turn cream to white on otherwise green heads. Entire heads may become diseased when extended periods of warm, wet weather occur during flowering and early grain fill. Salmon-colored patches of fungal growth frequently can be seen at the base of infected spikelets. Infected spikelets often fail to develop grain, or grain is extremely shriveled and of low test weight. Shriveled grain may have a pinkish discoloration.

Damage. Low test weight, shriveled grain is produced in diseased heads. Germination and viability of seed and milling qualities of grain are also reduced. "Scabby" grain is usually contaminated with mycotoxins, especially deoxynivalenol (DON), which affects feed and food uses. Grain with extremely high DON levels (>5ppm) may not be marketable in some regions.

Key features of disease cycle. In Kentucky, the FHB fungus, *Fusarium graminearum*, overwinters primarily in corn stubble. Spores are produced in stubble when temperature and moisture requirements are met. When conditions favor spore production and release, spores blown into fields from remote or local sources and/or are splashed onto nearby heads. If spores are deposited on heads when conditions are warm and moist and wheat is in the early flowering to early grain fill stages, heads can become infected and the characteristic disease symptoms will be evident after a 5-7 day latent period. Most fields, in most years, escape serious infection because conditions do not favor spore production and/or flowering and grain fill do not occur during warm, wet weather. Epidemics occur when extended periods of disease-favorable weather occur while much of the Kentucky wheat crop is in flower.

Management. Nature provides the best management by limiting disease-favorable conditions during crop flowering. Moderately resistant varieties are now available and these will perform reasonably well as long as disease pressure is limited. Certain triazole fungicides (see Table 7-2), applied when the crop is in early flowering, can provide additional suppression of FHB and DON. However, do not expect greater than 40-50 percent control compared to a non-treated crop. Crop rotation and tillage have little effect on FHB because of the widespread occurrence of the causal fungus in Kentucky. This is related to the nature of corn production in Kentucky. Specifically, corn is grown in relatively small, widely-scattered fields across most grain-producing regions of the state. Consequently, when conditions favor spore production and dispersal, there are so many spores of the FHB fungus blowing around, that anything that is done on an individual field basis has only a minor impact on FHB/DON. Planting different varieties that flower at different times may reduce the overall incidence of FHB in a moderate to light disease year.

Diseases Caused by Fungi

Glume Blotch

Occurrence. Early milk through maturity.

Symptoms. Infected glumes and awns develop gray-brown blotches, usually starting at the tips of glumes.

Damage. Infected heads develop low-test-weight, shriveled grain. Seed quality can also be reduced and this can result in problems with stand establishment if a high percentage of diseased or infested seed are planted.

Key features of disease cycle. Spores of *Stagonospora nodorum* blow to or are splashed onto wheat heads. Spores originate from diseased foliage (see leaf blotch complex) or infested wheat stubble. Infections occur during periods of extended wetness, especially when nighttime temperatures are warmer than normal.

Management. No highly resistant varieties are available. Plant moderately resistant varieties and high-quality, well-cleaned, disease-free (e.g., certified) seed. Control foliar and head infections on susceptible varieties with fungicides applied prior to the appearance of widespread symptoms. Avoid nitrogen excesses and deficiencies, which encourage glume blotch.

Photo 7-8. FHB effect on seed.

Photo 7-9. Stagonospora leaf and glume blotch.

Diseases Caused by Fungi

Leaf Blotch Complex

(Stagonospora leaf blotch, speckled leaf blotch, and tan spot)

Occurrence. Stem erection through late dough.

Symptoms. Foliar symptoms of speckled leaf blotch, caused by *Septoria tritici* infection include brown, elongated rectangular lesions with irregular margins. Lesions have numerous pinpoint, black specks (pycnidia) throughout. Pycnidia are most evident in the morning following heavy dew or after rain. Symptoms usually start in the lower leaves and move upward. Lesions are often first found at the tips of leaves.

Stagonospora leaf botch, caused by *Stagonospora nodorum*, is evident as lens-shaped, tan-brown lesions of varying sizes with regular borders that are frequently surrounded by a yellow halo. Young lesions have a dark brown center. Lesions of various ages contain light brown pycnidia, but these are difficult to see without the aid of a hand lens. Infections can occur very early in the season, but are most evident just prior to and after heading. Infections start in the lower leaves and move to the upper leaves and heads (see glume blotch). Symptoms become evident seven to ten days following infection.

Tan spot, caused by the fungus *Pyrenophora tritici-repentis,* looks very similar to Stagonospora leaf blotch, except that lesions do not coalesce as readily, so they tend to remain more discrete and are frequently very numerous. They are lens-shaped like Stagonospora leaf blotch, but they lack pycnidia. Instead you will usually see (with a 20 x hand lens) a weft of fungal growth. These are called conidiophores and are the structures on which new fungal spores are produced.

Damage. Yield and test weight are reduced.

Key features of disease cycle. *S. tritici*and, *S. nodorum,* and *P. tritici-repentis* overwinter in wheat stubble of previously diseased crops or on infested seed. Spores are produced during wet weather and are either splashed or wind-blown onto leaf surfaces. Infection of plants by *S. tritici* is greatest during cool to moderate temperatures. Infection by *S. nodorum* and *P. tritici-repentis* can occur over a wide range of temperatures, but are favored in the mid to late stages of

Photo 7-10. Speckled leaf blotch.

Photo 7-11. Wheat leaf rust.

Photo 7-12. Wheat stripe rust.

Photo 7-13. Loose smut.

crop development. The fungi that cause leaf blotch complex can occur individually in a crop or at the same time, even on the same leaves.

Management. Plant resistant varieties and high-quality, well-cleaned, disease-free seed that is treated with a fungicide (e.g., certified seed). Avoid excessive seeding rates as well as nitrogen deficiencies and excesses. Protect the upper two leaves and heads of susceptible varieties with fungicides. Crop rotation and tillage of infested wheat stubble may help in leaf blotch management, but neither provides a high degree of control.

Diseases Caused by Fungi

Leaf and Stripe Rust

Occurrence. Seedling emergence through late dough.

Symptoms. Leaf rust is initially evident as pinpoint, yellow flecks on upper leaf surfaces. After about one week, flecks develop into orange pustules, each containing many thousands of spores. Many things can cause wheat leaves to fleck, so flecks are a good indicator of leaf rust only when at least some mature pustules are also visible. Leaf rust pustules usually form in random patterns, primarily on the upper surfaces of leaves. Stripe rust appears in linear rows, of varying lengths, of bright yellow-orange pustules that are oriented with leaf veins. Symptoms can also develop on glumes.

Damage. Yield and test weight are reduced. Indirect losses associated with crop lodging can occur when rust is severe.

Key features of disease cycle. Both rust fungi can overwinter in Kentucky, but more commonly spores are blown into Kentucky from the south. With leaf rust, spores blow in and infect foliage during moderate to warm temperatures, and six or more hours of continuous leaf wetness. Leaf rust is a potentially explosive disease and requires just a short time to go from low to epidemic levels on a susceptible variety. Stripe rust has the ability to develop at lower temperatures than leaf rust, so it frequently can be found prior to head emergence. Symptoms are often first evident in hot spots 5-10 ft in diameter. From a distance, these affected areas will appear yellow. Close inspection of plants will reveal characteristic stripe rust lesions, with pustules. If left to develop unchecked, leaf or stripe rust can develop to the point where entire fields are involved.

Management. For leaf rust, plant resistant or moderately resistant wheat varieties. About half the soft red winter wheat varieties grown in the U.S. are susceptible to stripe rust. Unfortunately, many seed companies do not have good information on how their varieties will perform against stripe rust. Thus, it may be difficult to find varieties with known, acceptable resistance to stripe rust. For both rusts, avoid excessive stands, which tend to decrease air circulation and light penetration into the crop canopy. Protect the upper two leaves of susceptible varieties with foliar fungicides. Most modern foliar fungicides do an excellent job with managing rust diseases, but they must be applied BEFORE significant infection has occurred to perform acceptably. Crop scouting, thus, plays a central role in rust management.

Diseases Caused by Fungi

Loose Smut

Occurrence. Head emergence through maturity.

Symptoms. Floral parts of infected plants are transformed into a mass of black, powdery spores. Diseased tillers usually head out in advance of healthy tillers.

Damage. Seed infected with the smut fungus will produce smutted heads, with 100 percent grain loss being experienced by those heads.

Key features of disease cycle. Spores produced by diseased heads blow to and infect the flowers of healthy heads during rainy weather. Infected flowers give rise to infected grain. Infected grain develops normally, but harbors the loose smut fungus. The fungus remains dormant until the


Photo 7-14. Powdery mildew.


Photo 7-15. Take-all crown symptoms.


Photo 7-16. Early take-all.

seed is planted and germinates. Infected plants appear to be normal, but develop smutted heads.

Management. Plant certified or otherwise high-quality, disease-free seed. Infections in seed can be eradicated by treating seed with various systemic fungicides. Many older and most new seed treatment fungicides are highly effective in controlling seed-borne smut diseases (see Table 7-1).

Diseases Caused by Fungi

Powdery Mildew

Occurrence. Stem erection through maturity.

Symptoms. White, powdery patches form on upper leaf surfaces of lower leaves and eventually can spread to all aboveground portions of plants. Patches turn dull gray-brown with age.

Damage. Yield and test weight are reduced, directly due to infection and indirectly due to harvest losses associated with lodging.

Key features of disease cycle. Fungus persists between seasons in infested wheat stubble and in overwintering wheat. Spores infect plants during periods of high moisture (not necessarily rain) and cool to moderate temperatures.

Management. Plant resistant or moderately resistant varieties, and avoid farming practices that favor excessively dense, lush stands. If necessary, protect upper leaves and heads of susceptible varieties by using foliar fungicides.

Diseases Caused by Fungi

Take-all

Occurrence. Stem erection through maturity.

Symptoms. Infected plants appear normal through crop greenup, but eventually become stunted and uneven in height, with some premature death of tillers. Tillers that head out are sterile and turn white or buff colored. Affected plants easily can be pulled out of the soil because of extensive root rotting. A shiny black discoloration is evident under the leaf sheaths at the bases of diseased plants. Infected plants can occur individually, but more typically occur in small to large groups. Entire fields or large portions of fields can be diseased in severe situations.

Damage. Diseased plants yield little or no grain.

Key features of disease cycle. The take-all fungus survives from season to season in infested wheat and barley stubble and residue of grassy weeds. Infections are favored in neutral to alkaline, infertile, poorly drained soils.

Management. Allow at least one year (preferably two years) between wheat (or barley) crops. Soybeans, corn, grain sorghum, and oats are acceptable alternative crops. Maintain excellent control of grassy weeds and volunteer wheat in fields that are part of your farm's wheat operation. Fertilize fields and lime fields according to soil test recommendations. Do not allow fall or spring nitrogen deficiencies in the small grain crops. Improve surface and internal drainage of fields.

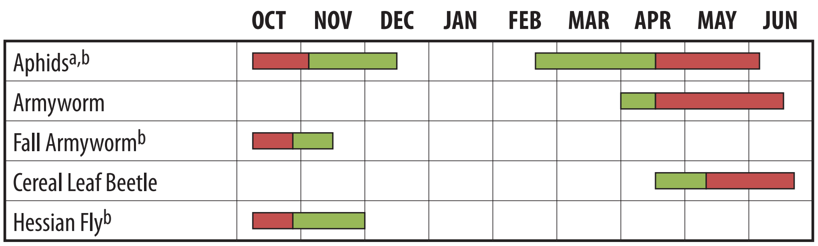
Section 8

Insect Pests

Douglas W. Johnson and Lee Townsend

Under favorable conditions, several insects can cause significant yield loss in wheat. They can reduce plant vigor by removing sap or lower yields indirectly by feeding on leaf tissue. Some feed directly on grain heads or clip plant stems so that the grain falls to the ground. Fortunately, the probability of severe infestations is relatively low if sound management practices (crop rotation, planting after the fly-free planting date, and judicious nitrogen use) are followed. Early detection, correct identification, and assessment of pest problems allow appropriate management decisions to be made. Regular field monitoring is the best means of having the information needed to follow the recommended treatment guidelines. The small grain insect scouting calendar (Figure 8-1) indicates when pests are most likely to be present in a field.

Figure 8-1. Small grain insect scouting calendar.



The red portion of the bars above indicate periods of possible economic populations.
a Early planting and warm fall weather increases potential for aphids and barley yellow dwarf virus.
b Wheat planted before October 15 is subject to attack by this insect.

Photo 8-1. Lady beetle C-7 is a beneficial insect that feeds on aphids. Proper identification of insects is critical to pest management.

Field Scouting

Field scouting procedures differ among the key pests. However, look at three sites in fields up to 20 acres in size, and add one site for each additional 10 acres. For example, there would be five locations in a 50-acre field—three sites for the first 20 acres and two more for the additional 20. The samples should be collected from randomly selected sites away from field edges and waterways.

Use the appropriate sampling method to collect information that can be compared directly to the treatment guideline for that specific pest. For example, the need for cereal leaf beetle control is determined by the average number of adults and/or larvae per stem. In some cases, methods for a pest may change during crop development. For example, aphid control prior to emergence of the flag leaf is based on the average number of aphids per foot of row. A rating system is used for these insects after the head emerges. (See IPM-4).

Photo 8-2. A greenbug (left) and a bird-cherry oat aphid (right). Bird-cherry oat aphids, common in the fall, are dark green with a red band across the end of the abdomen.

Photo 8-3. Parasitized aphids. Note the tan color compared to the gre3n healthy aphids also in the picture. Tiny wasps emerge from these "mummified" aphids and sting healthy ones.

Key Factors

Planting date, weather, particularly temperature, and nearby sources are key factors that influence pest activity. Planting after the Hessian fly-free date reduces the potential for damage from cereal aphids, fall armyworm, Hessian fly and wheat curl mite in the fall. A killing frost before or soon after planting eliminates large numbers of these pests so that they are not present to move into the fields once the plants emerge. Nevertheless, abnormally long, warm falls or early springs favor aphid reproduction and can allow damaging numbers to develop from just a few individuals. The third key factor is volunteer or cover crop small grains that emerge well before recommended planting dates. These early plants can serve as a source of aphids, Hessian fly and wheat curl mite.

Insecticide Management

Insecticide applications are valuable in quickly reducing pest infestations that could reduce yield or quality. Read the label before purchasing and applying any pesticide. Use the lowest rates consistent with the severity of the infestation and size of the insects present. The label may recommend low rates for light to moderate infestations or for insects in the early stages of development; high rates may be needed for severe infestations or pests in later, more damaging stages.

Use selective insecticides when possible to minimize the effect on beneficial species that may be present. If using tank mixes, read the labels of all products in the combination. For example, sulfonylurea herbicides should not be applied with or near to the time that organophosphate insecticides are used. This combination can cause a variety of problems from temporary plant injury to yield reduction. (See ENT- 47).

Major Pests

Aphids

Corn leaf aphids and bird cherry-oat aphids are the most common fall species. Adults and nymphs can appear any time after plant emergence and can move barley and cereal yellows viruses into the crop, resulting in Barley Yellow Dwarf disease. The bird cherry-oat aphid is the most important vector.

English grain aphids are most abundant during spring and early summer. Infestations in grain heads can cause shriveled, lightweight kernels. Occasionally greenbugs can be found; fortunately this destructive species is relatively rare in Kentucky. (See Entfact-121 and Entfact-150).

Occurrence. Aphids may be found any time after plant emergence.

Description. Aphids are small, soft-bodied, pear-shaped insects. Color varies from green to blue to yellow. Their piercing-sucking mouthpart looks like a small tube arising from under the head.

Damage. Aphids can cause two types of damage. 1) direct damage by sap removal and 2) indirect damage by injecting a virus (primarily barley yellow dwarf virus) into the plants. Damage due to direct feeding is usually confined to the "head filling" stage and causes low test weights. Fall BYDV infections cause stunting and yellowing to purpling of the plants and can result in severe yield loss.

Always be on the lookout for new aphid pests. Currently, feeding by aphids in Kentucky produces little visible damage. If you see aphid-infested plants that are dead or dying, or that have tightly rolled leaves and/or severe yellowing, collect the aphids and have them identified. The yellow sugarcane aphid and Russian wheat aphid currently are not present in Kentucky but are potential major pests.

When to scout. In the fall until temperatures remain below 45°F and again in the spring when temperatures regularly exceed 45°F.

How to scout. Scout in the fall and in the spring before leaf emergence (Feekes 8, Zadoks 37). Examine three separate 1-foot lengths of row at each location. Look over the entire plant, especially near the soil line. Count and record the number of aphids on each 1-foot section of row, then calculate the average. This sampling is for making decisions relative to movement of BYDV. Label these records as "Counts."

Table 8-1. Rating based on number of aphids per head.

Rating	No. Aphids
0—none	none
1—slight	<50
2—moderate	50 - 100
3—severe	>100

This examination is for direct damage done by aphids to grain test weights. Label these records as "Ratings."

After heads have emerged in the spring, examine 10 grain heads at each scouting location for aphids. Record a rating of infestation based on the number of aphids per head (Table 8-1).

Economic threshold. In the fall when estimating risk of BYDV, consider a control if aphid "counts" average three (3) or more per row foot during the first 30 days post planting. An average of six (6) or more aphids per row foot from 30 to 60 days after planting, or ten (10) or more aphids per row foot thereafter, may justify a treatment (see Entfact-121). In the spring during "head fill" when using the rating scale for direct aphid damage, consider a control if an average rating of 2 (moderate) or greater is recorded.

Wheat Curl Mite

Wheat curl mite is important only because it is the only known vector for Wheat Streak Mosaic virus. The mite (and therefore the virus) requires a "green bridge" of volunteer wheat that grows in late summer and allows large numbers of mites to survive until the next production wheat crop emerges. (See Entfact-117).

Occurrence. Wheat curl mite can infest plants any time before frost. The pest is especially important in very early plantings and/or in the presence of volunteer wheat, known as a "Green Bridge".

Description. Wheat curl mite is microscopic so it cannot be seen by the naked eye. Feeding causes leaves to roll up, giving an "onion leaf" appearance. Mites can be seen by carefully unrolling the leaves, and examining it with a 10X hand lens.

Damage. Feeding by wheat curl mite produces indirect damage resulting from movement of wheat streak mosaic virus into the plant.

When to scout. There are no standardized scouting procedures for this pest.

Comments. There are no rescue treatments for this pest. All control is preventative.

Armyworm and Fall Armyworm

Most armyworm feeding occurs from late May through early June. Damage starts at the leaf edge and progresses inward, giving a scalloped appearance. While this can reduce yields, the most serious losses occur when armyworms chew through stems and clip off the grain heads. (See Entfact-111).

In some years, fall armyworms can damage emerging stands of small grains in the fall. Damage is possible from early September until the first heavy freeze.

Annual and historic progression of both of these populations can be tracked on the IPM web page. (See UK-IPM).

Occurrence. Mid April to late May. Luxuriant or lodged vegetation in low, wet areas is especially susceptible to attack. Cool, wet springs favor armyworms.

Description. Larvae are greenish brown with a narrow stripe down the middle of the back and two orange stripes along each side. The yellowish head is honeycombed with dark lines. Armyworms are about 1½ inches long when full grown.

Damage. Armyworms are primarily leaf feeders but they will feed on awns and tender kernels or clip off the seed heads. Infestations are more common in barley than in wheat. Armyworms may feed on oats, rye, and some forages.

When to scout. Mid April through maturity.

How to scout. Visit each field at least once a week.

First, check field margins and lodged grain. If armyworms are present, begin surveying in the standing grain. Armyworms feed during late afternoon, night, and early morning. They may be hidden under debris on the ground when you are in the field during the day.

Photo 8-4. Fall armyworms feed on emerging tillers.

Photo 8-5. True armyworms feed on the leaves and may clip awns.

Sample 4-square-foot areas at locations throughout the field using the number of sites determined by the "Field Scouting" section. Walk at least 30 paces into the field before sampling. Pick spots randomly and look at the leaves for signs of chewing damage. Armyworms feed from the edge of the leaf in toward the mid rib. Examine the ground for dark fecal droppings and look for the larvae under surface litter or in soil cracks. Note average larval length. Walk to the remaining locations, and repeat the process.
Record. Record the number of worms present in each sample. Note the average length of the armyworms in each area.
Economic threshold. An average of 16 ½- to ¾-inch-long armyworms per 4-square-foot sample.
Comments. Armyworms longer than 1¼ inch may have completed most of their feeding. If the grain is nearly mature and no head clipping has occurred, controls are not advised. Warm spring weather favors parasites and diseases that attack armyworms. Note on your scouting report the percentage of worms parasitized or diseased.

Photo 8-6. Cereal leaf beetle larvae produce long white streaks on the upper leaf surface. The light yellow, grub-like larvae are covered with brown waste material.

Photo 8-7. Larvae of cereal leaf beetle and leaf damage from cereal leaf beetle feeding.

Cereal Leaf Beetle

More of a problem on oats than wheat, overwintering adults can be seen on the leaves from early April until mid-May. Their distinct yellow eggs are laid from mid-April until late May; the larvae are active and feeding from late April through mid-June. Both adults and larvae remove long, narrow strips of tissue from the upper surface of plant leaves, producing a distinct symptom of long, white scars. (See Entfact-107)
Occurrence. April to maturity.
Description. A shiny black beetle with red legs and thorax, approximately ½ inch long. Larvae are pale yellow and soft bodied. They "glue" pieces of trash and leaf on their backs as camouflage.
Damage. Adults and larvae chew long, narrow strips of tissue between veins.
When to scout. April until maturity.
How to scout. Check 10 stems per sample site for larvae or adults.
Record. Record the total number of larvae and adults found on the 10 stems examined at each sample site. Calculate and note the average number per stem.
Economic threshold. Controls may be warranted when there is an average of more than one larva and/or adult per stem.

Hessian Fly

In the past, fall infestations of this pest have severely damaged wheat by causing stand reduction. Both stand loss and lodging of the plants can be seen in the spring. You can reduce losses greatly by following the recommended fly-free planting date for your area and using resistant varieties. Check for the overwintering (flaxseed) stage on weakened seedlings (October through March) or for the small, white, maggot-like larvae in leaf sheaths during May. (See Entfact-101).
Occurrence. Fall and spring.
Description. The Hessian fly adult is a small, fragile gnat. The larva is a very small, white, legless maggot. The larval stage is damaging and may be found between the leaf sheath and stalk. About two weeks after egg hatch larval maturity occurs, and feeding ends. The outer skin darkens and hardens as the larvae enters its overwintering stage. This overwintering larvae (flaxseed) is the stage most often found if an infestation has occurred. This is a small, brown, seed-like case, usually found at the base of the plant between the leaf sheath and stalk.
Damage. A fall infestation can result in stand loss and broken (lodged) plants. Spring infestations usually result in plants of reduced vigor and bad color. There are two generations per year.
When to scout. Survey fields one time after the first frost and from early spring until June.
How to scout. Look for thin, stunted, chlorotic patches in the field. Examine the base of these plants for presence of the flaxseed.
Record. Record the number of flaxseed found per 10 stems examined at each sample site. Note the presence of adults or larvae.
Economic threshold. There is no rescue treatment; however, preventive measures may be used to avoid future infestations.

Photo 8-8. Hessian fly-infested plants (center) appear stunted. There is no stem elongation and the leaves are usually broad and green.

Photo 8-9. The "flaxseed" or pupal stage of the Hessian fly can be found behind lower leaf sheaths of infested plants or below the soil line.

Photo 8-10. Hessian fly adult.

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Section 9

Economics of the Intensively Managed Wheat Enterprise

Richard L. Trimble

Winter wheat is an important part of many Kentucky farmers' crop rotations. As discussed earlier, wheat yields have increased greatly over the past half century (see Figure 1-1 in *Section 1—Introduction*). Likewise, as with other crops, wheat has experienced annual variability in yields. Yields have declined in some years, but this was due to some type of environmental problem or conditions that favored extensive insect or disease development. The greatest decline in the past 10 years was caused by the devastating freeze of 2007. This freeze resulted in a dramatic decrease in state average wheat yields of 22 bushels per acre as reflected in Table 9-1 which shows the Kentucky annual state average wheat yields as well as

Table 9-1. Comparative wheat yields by geographical area, 1999-2008.

Area	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	9 Year Avg. 99-07
	(bushels/acre)										
Kentucky[a]	60	57	66	52	62	54	68	71	49	71	59.9
KFBM State Avg[b]	74	64	78	60	69	58	79	81	35	NA	66.4
Purchase Area[b]	50	56	57	45	61	56	82	72	50	NA	58.8
Pennyroyal Area[b]	77	64	81	62	70	58	79	83	31	NA	67.2
Ohio Valley Area[b]	71	75	75	50	68	58	74	75	35	NA	64.6

a Source: Kentucky Agricultural Statistics, various years.
b Source: Kentucky Farm Business Management Program (KFBM), Annual Summary Data, Various years, University of Kentucky, Department of Agricultural Economics.

Photo 9-1. Grain bin storage can be a valuable component to a farming operation, allowing a producer more flexibility in marketing grain.

the annual yields achieved by cooperators in the Kentucky Farm Business Management (KFBM) program at the state level as well as for three areas of the state.

This yield variability, both over time and across geographical areas, is shown in Table 9-1. The statewide differences over time are attributable to general growing conditions throughout the growing season. However, the yield differences between geographical areas can be attributed to the general wheat production potential of the different soil types across the Commonwealth. A comparison of yields achieved by KFBM cooperators in the Purchase[1], Pennyroyal[2], and Ohio Valley[3] areas indicate that the Pennyroyal and Ohio Valley are more adapted to wheat production than is the Purchase area. Consistently, wheat yields in these areas have been greater than state average yields or yields in other areas of the state.

Table 9-2. Management returns by enterprise, Kentucky Farm Business Management Program cooperators, 2001-2005.

Enterprise	2001	2002	2003	2004	2005	5 Yr. Avg.
	(dollars)					
Corn	-26.60	-71.99	-11.81	-21.07	-103.50	-46.99
Soybeans	-51.57	-63.92	24.33	-33.00	-35.40	-31.91
Wheat	12.53	-35.56	3.40	-86.64	-25.08	-26.27
Double crop soybeans	-20.78	30.55	109.91	30.85	-19.62	26.18
Wheat & double crop soybeans	-8.25	-5.01	113.31	-55.79	-44.70	-0.09

Source: Rogers, Jennifer and Craig Gibson, 2005 Enterprise Analysis: Snapshots of Selected Crops, Kentucky Farm Business Management Program, Department of Agricultural Economics, University of Kentucky, Agricultural Economics—Extension No. 2007-12, May 2007.

The Competitive Position of Intensive Wheat Enterprise in Kentucky

Historically, the wheat enterprise has been looked upon as one of the more profitability challenged enterprises in the Kentucky crop complex. The discussion of the wheat enterprise in our previous version of this manual suggested this view was often warranted.

However, it appears that this era may be at an end! The dramatic improvement in wheat yields has helped to increase the potential profitability of the intensively managed wheat enterprise. Table 9-2 presents a comparison of the relative profitability of the major crop enterprises (corn, soybeans, and wheat) over the period 2001 to 2005 as experienced by KFBM cooperators.

The measurement of profitability used in Table 9-2 is Management Returns. Management return is essentially the amount that remains after all costs of the enterprise, including a return to equity capital investment and unpaid family and operator labor, are deducted. It is the residual after a charge for unpaid operator labor is deducted from operator's labor and management income from the enterprise.

Management returns are most often negative numbers for agricultural enterprises as reflected in Table 9-2 since it is describing a situation where all costs of production have been paid. Therefore, there is seldom room in the margins for any agricultural enterprise to generate positive management returns. If the returns are positive for any period of time, the operators in the relatively free market will bid the price of inputs up to the point where there are no positive management returns. Therefore, one should not be skeptical of the numbers in this table. They are simply a method of comparing agricultural enterprises on an equal footing.

Looking at the management returns experienced by KFBM cooperators during the period 2001 to 2005 shown in Table 9-2, most were negative. However, they can easily be used to compare the relative performance of the enterprises over the period. Wheat performed very well over the period. Only Double Crop Soybeans (DCSB) generated a better average over the five years than did wheat. Wheat performed better than either corn or soybeans during the five years. The five year average performance suggests that wheat is quite competitive when compared to either the corn or soybean enterprises that have been the historically dominant crops across the commonwealth.

Further, when wheat is combined with DCSB, as is the standard practice, the wheat-double crop soybean combination would be even better. This performance also suggests there may be a problem about how the costs of production are accounted for between wheat and DCSB when the returns are computed. Why did DCSB outperform full season soybeans (FSSB)? It is assumed that DCSB yields are consistently less than FSSB. Therefore, why did DCSB provide a higher management return over the five years than did FSSB? If there is a problem with the allocation of costs between the wheat and DCSB enterprises, maybe wheat is doing better? Possibly, the DCSB enterprise is not paying its "fair share" of the combined cost of production.

Regardless of these potential cost allocation problems, it should be readily apparent that the combination of wheat and DCSB deserve serious consideration as being a viable part of the standard crop rotation of Kentucky crop producers. This combination performed the best in three of the five years and resulted in a superior performance over the five years when the average results are compared.

The combination of wheat and DCSB provides a more accurate accounting for all costs of production for the combination. It also provides for a more intensive use of farm resources since it produces two crops in one production period. This also provides additional risk protection since two crops are being produced in two different time periods.

Wheat Enterprise Economics

To examine the economics of the Kentucky intensive wheat enterprise, an intensively managed wheat enterprise budget for 2009 was adapted from an existing wheat budget developed by Dr. Greg Halich[4] which is shown in Table 9-3. It reflects the intensively managed wheat production situation in Kentucky using the most appropriate agronomic recommendations.

The enterprise budget assumes the use of intensive management in the wheat enterprise, meaning all inputs are used on an as-needed basis in a timely manner and reflecting the need for Kentucky wheat producers to achieve above-average yields to remain competitive. This assumption results in an expected wheat yield that is above the state's historical average yield over the past 10 years as shown in Table 9-1. The budget also assumes that the intensively managed wheat enterprise is part of a double cropping system with a similarly managed double crop soybean enterprise. This results in a sharing of common inputs such as fertilizer, lime, and the land resource which should lower these costs for both enterprises.

It should be noted that this budget was developed using the best information available at the time it was developed. However, it is immediately out of date when it is finished. Further, it reflects the situation of the typical producer, and does not reflect the conditions that you and your farm business may face. To download a budget, visit http://www.ca.uky.edu/agecon/index.php?p=29 on the University of Kentucky Department of Agricultural Economics website.

Table 9-3. Intensively managed wheat enterprise, no-tillage, estimated enterprise costs and returns for 2008 - 2009.

	Qty	Unit	Price			Total
Gross Returns Per Acre						
Wheat	70	bu	$4.25			$297.50
Direct Gov't Payment	1	acre	$20.00			$20.00
Total Revenue						$317.50
Variable Costs Per Acre						
Seed	120	lbs	$0.35			$42.00
Nitrogen[a]	100	lbs	$0.85			$85.00
Phosphorous (P_2O_5)	35	lbs	$1.00			$35.00
Potassium (K_2O)	20	lbs	$0.75			$15.00
Other Fertilizer	0	lbs	$0.00			$0.00
Lime - Spread	0.20	ton	$20.00			$4.00
Herbicides	1	acre	$20.00			$20.00
Insecticides[b]	1	acre	$0.00			$0.00
Fungicides[b]	1	acre	$0.00			$0.00
Fuel and Lube	1	acre	$13.34	Calculate Machinery Related Costs?	Y	$13.34
Repairs	1	acre	$16.42			$16.42
Hired Labor	1	acre	$0.00			$0.00
Operator Labor (Var. Only)	1	acre	$15.62			$15.62
Machinery Rental	1	acre	$0.00			$0.00
Custom Work	1	acre	$0.00			$0.00
Drying: LP, Elec, M & L	1	gal. LP	$2.30	Pts Removed	1.0	$3.30
Crop Insurance[c]	1	acre	$12.00			$12.00
Cash Rent (Pro Rate if DC)[d]	1	acre	$0.00			$0.00
Other Variable Costs	1	acre	$5.00			$5.00
Operating Interest	$246	dollars	8.0%	# Months	8	$13.10
Total Variable Costs Per Acre						**$279.78**
Return Above Variable Costs Per Acre						**$38**
Budgeted Fixed Costs Per Acre						
Operator Labor (Fixed Only)			$0.00	See Question Above		$0.00
Machinery Depreciation and Overhead			$23.96			$23.96
Taxes and Insurance	1	acre	$5.00			$5.00
Other Fixed Costs	1	acre	$5.00			$5.00
Return Above All Specified Costs						**$4**
Breakeven Yield at $4.25 /bu	66	bu per acre to cover variable costs				
Breakeven Cost at 70 bu/acre	$4.00	per bu to cover variable costs				
Breakeven Cost at 70 bu/acre	$4.48	per bu to cover all specified costs				

a Assumes urea (NH2). Adjust as needed for other forms of nitrogen.
b Scout to detect any insect or disease problems and control as required.
c Crop insurance varies substantially by policy type and coverage level.
d Cash rent varies substantially by productivity level and region in Kentucky.

The budget was developed using the Excel spreadsheet program. If you have the Excel program, you can load the wheat budget spreadsheet to your computer and change most of the numbers to more accurately reflect your actual conditions. You can use your experience and actual records to produce a more accurate wheat budget for your situation. You can also update the budget to reflect changing conditions as you get closer to seeding time.

Looking at the budget in Table 9-3 one can see that the potential profitability of the wheat enterprise for 2009 did not look good. In fact, it looked dismal! This budget does not include any land cost. The Return Above All Specified Costs of $4.00 per acre would include a return to land as the budget stands. It must be noted that this budget was developed during a very volatile time for both input and output markets in agriculture. Wheat prices had just hit historic highs earlier in the year and had fallen by more than 50 percent when this budget was developed. Also, input costs had risen in a similar fashion during the early part of 2008. They had not come down when this budget was developed. Fuel costs had declined a bit, but fertilizer prices had not. Therefore, wheat producers were looking at a dismal outlook for the wheat enterprise as depicted by this budget.

Again, this points out the need for every producer to develop a budget to fit their exact situation. Some producers may have been fortunate to forward contract some of their 2009 wheat crop at a relatively good price. Others may have a less costly source of fertilizer for use on their crop. If any of these conditions were true, then your wheat budget may look much better than the situation depicted in Table 9-3. Also, if you develop your own wheat budget and it does not look favorable, you may be able to avoid a bad experience in the real world. If plans do not seem to work with the enterprise budget you are considering, then they are not likely to be any better in the real world. You can avoid those "real losses" by making the decision to not produce before you actually make the commitment in the real world.

To reflect an attempt to "better manage" the wheat enterprises in the risky environment we seem to be experiencing, this budget includes provision for the use of crop insurance and integrated pest management (IPM) crop scouting. While use of these risk management tools is the decision of the farm business manager, they are included here as a reminder that the risk environment in agriculture has changed and producers need to strongly consider the use of these tools in the future.

The economic results for the intensively managed wheat enterprise budget shown in Table 9-3 indicated that total specified variable costs of $279.78 per acre can be covered, leaving a return above variable costs (RAVC) of $38 per acre as a contribution to all fixed costs. Deducting $34.00 to cover depreciation, housing, and other such costs leaves a return to land, capital and management of $4 per acre.

Historical Reference Note. This level of variable costs of $280 per acre is about 224 percent higher than the same cost of $125 per acre when our original Kentucky wheat manual was developed in 1997. This should indicate the extreme difficulty wheat producers are facing when they are making the decision to produce wheat.

In this budget, all specified costs of production have been covered, with $4 per acre remaining to cover the unspecified costs. This $4 could be considered a return to land, capital and management. As such, it may seem low, but one must remember that the intensively managed wheat enterprise is assumed to be part of a double crop system with soybeans. Therefore, when this $4 per acre is combined with the returns from the soybean enterprise, the combination has a greater chance of being profitable for Kentucky producers than wheat alone.

Table 9-4 provides some insights as to what would happen with various wheat prices and yields while the costs of production are held constant. It depicts the per-acre RAVC for various combinations of wheat yields and prices resulting from the budget shown in Table 9-3. This table is useful for examining "what if" situations concerning various levels of prices and yields.

A particular concern that could be addressed by Table 9-4, for example, is the need for a greater return to land to help justify the production of wheat on your farm. Assum-

Table 9-4. Per acre returns above variable costs at various prices and yields, intensively managed wheat enterprise, 2009.

	Yield, Bushels Per Acre						
	40	50	60	70	80	90	100
$/Bu	$/acre						
3.50	-118	-84	-49	-15	20	54	89
3.75	-108	-71	-34	3	40	77	114
4.00	-98	-59	-19	20	60	99	139
4.25	-88	-46	-4	38	80	122	164
4.50	-78	-34	11	55	100	144	189
4.75	-68	-21	26	73	120	167	214
5.00	-58	-9	41	90	140	189	239
5.25	-48	4	56	108	160	212	264
5.50	-38	16	71	125	180	234	289

ing you are looking at the base budget situation described in Table 9-3, which shows a return to land of $4, if you can improve your yield to 80 bushels per acre, the return to land jumps to $80. Moving up the yield chart each 10 bushels, at the price of $4.25 per bushel, adds $42.50 to your return to land, assuming your variable costs of production do not increase.

Table 9-4 can also be used to examine the risk inherent in most agricultural enterprises. This is reflected in yields and prices that are less than those expected in the budgeted situation in Table 9-3. For instance, should your yield prove to be only 40 bushels per acre, rather than the 70 forecast in Table 9-3, the enterprise would not cover variable costs. In fact, it would cost you $88 per acre for the experience of growing wheat. If the wheat price was $3.50 per bushel rather than the $4.25 projected in the base budget and the yield was only 40 bushels per acre, then the returns fall $118.00 per acre short of covering all variable costs. Again, these possible outcomes reflect the need for improving management in the intensively managed wheat enterprise of the future.

As indicated by Table 9-4, many outcomes are possible with a wheat enterprise. The possibilities cover a wide range and are highly dependent on land production capabilities, weather and general growing conditions, and the level of management devoted to the enterprise. As shown in Table 9-4, the expected return above variable costs might be expected to range from -$118.00 to $289 per acre. The more favorable outcomes shown in Table 9-4 certainly could be used to justify the production of wheat in Kentucky. The main emphasis must be placed on intensive management of the enterprise to achieve higher than average yields while maintaining close control of production costs.

Growing Wheat on Rental Land

One question that may be of interest to wheat producers is: "Can wheat be profitably produced on rented land?" Based on the results presented earlier, it would seem that it may be difficult to justify growing wheat on rented land. The return of $38 per acre above variable costs would not seem to make it feasible to pay much cash land rent under current conditions. However, as stressed earlier, this depends on yields, prices, costs of production, rental arrangements, the level of management devoted to the enterprise, and many other factors. This is particularly true when the intensively managed wheat enterprise is combined with a soybean enterprise and the land rental cost is shared between the two enterprises.

According to the National Agricultural Statistics Service, USDA[5] the Kentucky state average crop land cash rental rate for 2008 was $82 per acre. Using this as a reference point, results for an $80 per acre cash rent (with $40 allocated to the intensively managed wheat enterprise) situation is investigated in Table 9-5. Results indicate that at the projected price of $4.25 per bushel, the yield would have to be at least 80 bushels per acre to be a feasible option for Kentucky producers with the production costs shown in Table 9-3. If the situation depicted in Table 9-3 is correct, the wheat price would have to be at least $5 for the $80.00 per acre cash rent (with $40 allocated to the wheat enterprise) option to be feasible.

A survey of land values and rental rates across Kentucky during October 2007[6] indicated the average crop land rental rate in West Kentucky was $108 per acre. Using this as an additional reference point, results for a $120 per acre cash rental rate (with $60 allocated to the intensively managed wheat enterprise) situation is investigated in Table

Table 9-5. Per acre returns above all budgeted costs, various prices and yields, intensively managed wheat enterprise, $40/ac cash rent allocated to wheat enterprise 2009.

	Yield, Bushels Per Acre						
	40	50	60	70	80	90	100
$/Bu	$/acre						
3.50	-194	-160	-125	-91	-56	-22	13
3.75	-184	-147	-110	-73	-36	1	38
4.00	-174	-135	-95	-56	-16	23	63
4.25	-164	-122	-80	-38	4	46	88
4.50	-154	-110	-65	-21	24	68	113
4.75	-144	-97	-50	-3	44	91	138
5.00	-134	-85	-35	14	64	113	163
5.25	-124	-72	-20	32	84	136	188
5.50	-114	-60	-5	49	104	158	213

Table 9-6. Per acre returns above all budgeted costs, various prices and yields, intensively managed wheat enterprise, $60/ac cash rent allocated to wheat enterprise 2009.

	Yield Per Acre						
	40	50	60	70	80	90	100
$/Bu	$/acre						
3.50	-216	-181	-146	-112	-77	-43	-8
3.75	-206	-168	-131	-94	-57	-20	17
4.00	-196	-156	-116	-77	-37	2	42
4.25	-186	-143	-101	-59	-17	25	67
4.50	-176	-131	-86	-42	3	47	92
4.75	-166	-118	-71	-24	23	70	117
5.00	-156	-106	-56	-7	43	92	142
5.25	-146	-93	-41	11	63	115	167
5.50	-136	-81	-26	28	83	137	192

9-6. Table 9-6 indicates how difficult it is to profitably grow wheat under current conditions. Both of these tables indicate that it is feasible to rent land for wheat production in both situations, but only with higher yields and prices.

Summary and Conclusion

Winter wheat has been an important part of the crop rotation for Kentucky farmers and will continue to be part of the crop mix. As indicated by the intensively managed wheat enterprise budget and an investigation of various yield and price scenarios based on it, there are opportunities to make profitable levels of return with an intensive wheat enterprise in Kentucky.

Historically, wheat and the wheat-double crop soybean combination proved to be quite competitive with other crop enterprises in Kentucky. However, most producers will have to improve management of their enterprises, in terms of both production and marketing to be able to earn these returns in the current economic environment.

Notes

1. Includes Ballard, McCracken, Marshal, Calloway, Graves, Carlisle, Hickman, and Fulton counties.
2. Includes Livingston, Lyon, Trigg, Crittenden, Caldwell, Christian, Todd, Muhlenberg, Logan, Butler, Warren, Simpson, Edmonson, Allen, Barren, Metcalf, and Monroe counties.
3. Includes Union, Webster, Hopkins, Henderson, McLean, Daviess, Ohio, and Hancock counties.
4. Halich, Greg, Wheat and Wheat Double-Crop Soybean Budgets 2008-2009, Department of Agricultural Economics, University of Kentucky, October 22, 2008.
5. Land Values and Cash Rents—2008 Summary, National Agricultural Statistics Service, United States Department of Agriculture, August 2008.
6. Trimble, Richard L., "Kentucky's Land Values, Fall 2008", Agricultural Situation and Outlook—Fall 2008, Department of Agricultural Economics, University of Kentucky, ESM-34, October 2008.

Section 10

Harvesting, Drying and Storing Wheat

Sam McNeill, Doug Overhults and Mike Montross

Harvesting wheat grain in the 18 to 24 percent moisture content range has not been widely practiced by farmers in Kentucky. In a double cropping system, however, significant profit potential exists for earlier wheat harvesting because of the increased yields of the second crop. Many years of agronomy research in Kentucky have shown that in general, after June 7th, a week delay in planting soybeans decreases yields between 4 and 7 bushels per acre. For economic conditions in 2007, with average yields in both crops and moderate field drying conditions, total costs of the double-crop enterprise decreased about $1 per acre before the June 7 harvest date but increased about $5 per acre afterwards (Figure 10-1). This difference is largely due to soybean yield, which provides a large incentive to dry high moisture wheat. Other advantages for harvesting wheat early are fewer weather related delays and increased yields due to higher test weight and less shatter loss at the header during combining. A spreadsheet decision tool is available on the BAE website (www.bae.uky.edu) for calculating operating costs as crop and fuel prices change from year to year.

Figure 10-1. Cost trade-offs between drying wheat/planting soybeans early versus field drying/delayed planting with 2007 grain and energy prices ($7.25 for beans, $4.17 for wheat and $1.40 for LP gas).

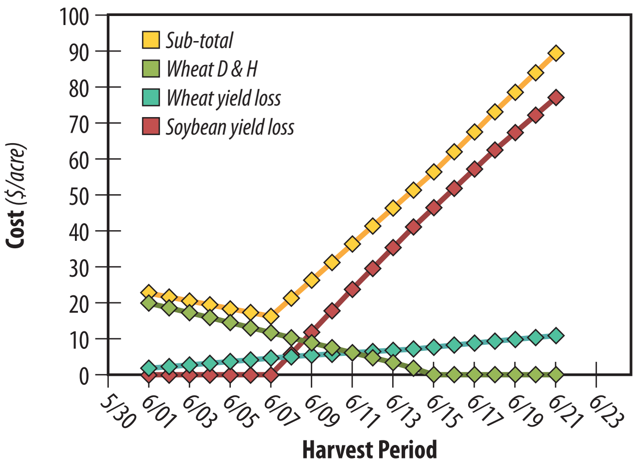


Photo 10-1. Wheat harvest is normally a very exciting stage of the wheat production process. (submitted by Joe Nichols, Seven Springs Farms)

Harvesting

Although wheat is typically harvested in the 13 to 15 percent moisture content range in Kentucky, it can be successfully harvested at higher moisture contents, provided it is dried quickly enough to prevent spoilage and/or sprouting. The moisture content at which harvest begins will depend heavily on the drying system available. Each farmer's goal should be to harvest as early as possible provided the grain can be dried safely. Some guidelines for matching the beginning harvest moisture content to the drying system are given in Table 10-1. If this is your first time to harvest high moisture wheat, start at a low moisture content and gradually increase it as you gain experience.

Table 10-1. Guidelines for matching harvest moisture content to drying system.

Drying System	Moisture Content (%)
High speed dryer	21 - 24
Bin dryers with heat/ stirring equipment	17 - 20
Bin dryers without heat	< 17

When to Start?

Wheat harvest should begin as soon as the crop has field dried enough that it can be handled safely. A moisture meter is very useful to give a quick determination of crop condition. Most hand held meters are calibrated for corn or soybeans and have charts for converting readings to other crops. If a meter is not available, weigh a ¼-½ lb sample, dry it on a cookie sheet in a 260° F oven overnight (about 10 hrs), and re-weigh the sample. Calculate the moisture content by the following formula:

(wet weight – dry weight)/wet weight × 100 = seed moisture (%)

For example, if a 0.5 lb sample weighs 0.4 lb after drying, seed moisture is 20%:

(0.5 – 0.4)/0.5 × 100 = 20%

Operating the Combine

The most important combine adjustments for harvesting wheat are cylinder speed, concave clearance, screen openings, and fan speed. Set the combine according to the manufacturer's recommendations before entering the field. Then, if necessary, adjust cylinder or fan speed in the field to improve threshing and cleaning. Lower cylinder speeds will reduce kernel damage. Increased fan speed will clean wet chaff more easily, but more grain may be blown out with the chaff. Be willing to dry some chaff if your drying system has adequate air flow.

Shatter at the header is the major source of wheat harvest loss regardless of the type of header that is used. One USDA study with a conventional cutter bar header showed that shatter losses were reduced in high moisture wheat. Researchers have observed that header losses increase as much as 1.7 bushels per acre as wheat dries in the field from 23 percent to 13 percent.

Header Choices

Limited studies have been conducted to compare the performance of rotor stripper headers and conventional cutter bars for soft red winter wheat. However, a recent report from the Northwestern United States for different types of wheat indicates that ground speed has more influence on header losses than the speed of the header rotor. Compared to a conventional cutter bar header, the stripper header had higher losses at low ground speeds but comparable losses as ground speed increased (Figure 10-2). Average losses for all ground speeds were 10.1 percent of total yield for the stripper header but only 5.8 percent for the cutter bar. As ground speed increased, header losses were nearly equal for both units.

Losses for the stripper header were also determined for various yield levels in this study and are shown in Figure 10-3. Losses generally decreased as yields and ground speed increased. Ground speeds that resulted in the lowest header losses for the stripper header were 2 to 5 times higher than those observed for the combine with the conventional cutter bar.

Check Harvest Losses

Measure field losses by counting loose kernels on the ground. Look in front of the combine in standing wheat to measure pre-harvest losses. Wheat kernels found under the combine are both pre-harvest losses and header losses. Count kernels behind the combine to measure total losses (pre-harvest, header, threshing, and separating losses). About 20 kernels found in a square foot area represent 1 bushel

Figure 10-2. Effect of combine and header rotor speed on wheat losses at the header.

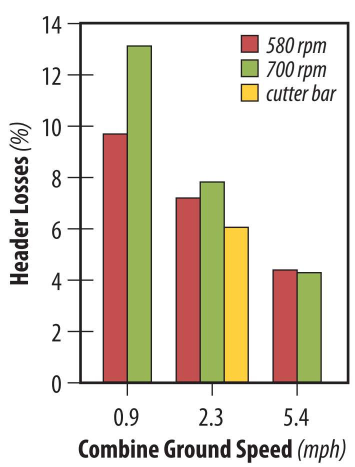
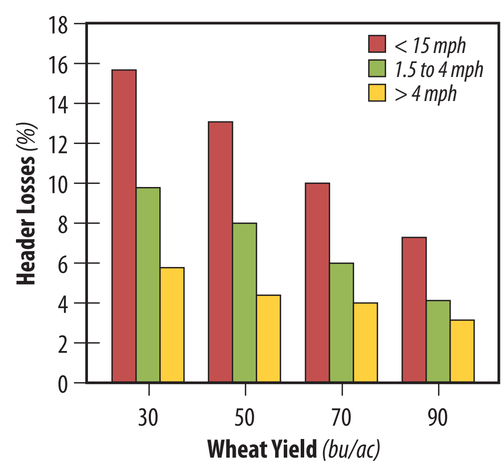


Figure 10-3. Effect of yield and combine speed on wheat losses at the header.



per acre loss. A good goal is to limit harvest losses to no more than 5 percent of the crop yield. Adjust ground speed, header height, reel speed and reel position to minimize harvest losses. Also, inspect cutter bars for sharp knives and replace dull ones when necessary.

Table 10-2. Amount of water in a bushel of corn and wheat at various moisture levels (lb/bu).[a]

	Moisture Content (% wb)														
Grain	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Corn	5.3	5.9	6.5	7.1	7.8	8.4	9.1	9.8	10.5	11.2	11.9	12.7	13.4	14.2	15.0
Wheat	5.8	6.4	7.1	7.8	8.5	9.2	9.9	10.6	11.4	12.2	12.2	13.8	14.6	15.5	16.4

a Using a base moisture level and test weight of 15.0% and 56 lb/bu for corn and 13.5% and 60 lb/bu for wheat.

Table 10-3. Airflow and static pressure (SP) at different grain depths in a 30-ft diameter bin of wheat with a full perforated floor using 1-, 2- and 3- 15 hp centrifugal fans.

Depth (ft)	Bu.	1-15 hp fans Airflow (cfm)	(cfm/bu)	SP (in H_2O)	2-15 hp fans Airflow (cfm)	(cfm/bu)	SP (in H_2O)	3-15 hp fans Airflow (cfm)	(cfm/bu)	SP (in H_2O)
2	1,131	17,282	15.28	1.80	30,651	27.10	3.87	40,426	35.74	5.72
4	2,262	15,955	7.05	3.24	25,913	11.46	6.15	29,886	13.21	7.48
6	3,393	14,784	4.36	4.42	21,617	6.37	7.23	23,436	6.91	8.06
8	4,524	13,801	3.05	5.40	18,264	4.04	7.73	19,229	4.25	8.26
10	5,655	12,888	2.28	6.19	15,846	2.80	8.04	16,399	2.90	8.40
12	6,786	11,960	1.76	6.78	13,915	2.05	8.18	14,344	2.11	8.50
14	7,917	11,041	1.39	7.16	12,431	1.57	8.29	12,777	1.61	8.58
16	9,048	10,180	1.13	7.42	11,250	1.24	8.38	11,535	1.27	8.64
18	10,179	9,453	0.93	7.63	10,285	1.01	8.45	10,525	1.03	8.69
20	11,310	8,830	0.78	7.81	9,480	0.84	8.51	9,686	0.86	8.73

Source: FANS software from the University of Minnesota Department of Bioproducts and Biosystems Engineering (bbe.umn.edu/Post-arvest_Handling_of_Crops.html).

Drying

Freshly harvested wheat grain should be dried to a moisture content of 14 percent or less within 48 hours to prevent sprouting and spoilage. High moisture wheat (>17%) can be dried with both high-speed and bin drying equipment. Corn drying systems can be used to dry wheat if some adjustments are made to maintain adequate air flow. The amount of water in a bushel of corn and wheat at different moisture levels is shown in Table 10-2.

Wheat has a higher resistance to air flow than corn, but there are usually fewer bushels to be dried. For commercial wheat, drying air temperatures should be below 140° F to avoid damage to milling quality. Seed wheat should be dried at 110° F or lower.

In-Bin Drying. Bin drying methods are easily adapted for wheat if adjustments are made to compensate for the increased resistance to air flow (measured as static pressure in inches of water). A rule of thumb is to limit wheat depth to half that used for corn. Centrifugal fans may be used to deliver higher airflow rates under higher static pressures. However, as shown in Table 10-3 for a 30-ft bin, wheat depths greater than 20 feet will generally reduce airflow rates to less than 1 cubic feet per minute for each bushel (cfm/bu) in the bin, even with up to three 15-hp fans.

Heat is required if bin drying wheat over 17 percent moisture content, as shown in Table 10-1. Stirring devices, recirculators, or automatic unloading augers can be used to increase capacities. Generally moderate air flows (2-5 cubic feet of air per bushel) and temperature rise (less than 20° F) are used. Excess heat can cause severe overdrying.

If high moisture wheat is to be dried and stored in the same bin, extra care is advised. If the initial moisture is 20-24 percent, use heat to dry the top layer below 17 percent before adding more grain. Several bins may be needed to dry a large crop. After drying to 17 percent, use unheated air to dry the wheat grain to about 15 percent. During this period, run the fan continuously to provide a uniform moisture content. Run the fan only during low humidity hours to finish drying to around 13 percent moisture. This management scheme minimizes the amount of over-dried grain in the bottom of the bin. Table 10-4 shows the moisture content that soft red winter wheat will approach when exposed to the temperature and relative humidity levels shown. Moisture levels decrease with lower humidity and higher temperature conditions.

High-Speed Dryers. High temperature batch or continuous-flow dryers usually have excess capacity for wheat drying. These units typically have very high air flow rates, so supplemental heat may not be required for daytime drying when harvesting in the 18-20 percent moisture range. If heat is used, the drying air temperature can be limited by cycling the burner on and off or by changing the gas burner orifices.

A Word of Caution. Some in-bin corn drying systems are operated by filling the bin completely full within 2-5 days. Under no circumstances should you attempt to follow this practice in drying high-moisture wheat. Rapid bin filling works for corn only when temperatures and moisture contents are low enough to prevent spoilage. Outside air temperatures (and grain temperatures) are 20 to 40 degrees higher when harvesting wheat than during the fall corn harvest. In-bin drying of high moisture wheat should only be done as a layer-fill, batch, or continuous flow process.

Table 10-4. Equilibrium moisture content (EMC) of soft red winter wheat at different temperature and relative humidity levels.

	Relative Humidity (%)									
	10	20	30	40	50	60	65	70	80	90
Temp. °F	Equilibrium Grain Moisture Content (%)									
35	7.3	8.9	10.2	11.3	12.3	13.4	14.0	14.7	16.1	18.2
40	7.1	8.7	10.0	11.1	12.1	13.2	13.8	14.4	15.9	18.0
50	6.8	8.4	9.6	10.7	11.8	12.9	13.4	14.1	15.5	17.6
60	6.5	8.1	9.3	10.4	11.4	12.5	13.1	13.7	15.1	17.2
70	6.2	7.8	9.0	10.1	11.1	12.2	12.8	13.4	14.8	16.9
80	6.0	7.5	8.7	9.8	10.8	11.9	12.5	13.1	14.5	16.6
90	5.8	7.3	8.5	9.6	10.6	11.6	12.2	12.8	14.2	16.3
100	5.6	7.1	8.3	9.3	10.3	11.4	12.0	12.6	14.0	16.0

Source: American Society of Agricultural and Biological Engineers Standard D245.4.

Rapidly filling an entire bin with high moisture wheat is a sure route to spoilage.

Avoid Overdrying when Possible. Drying wheat grain below the base market level of 13.5 percent wet basis should be avoided if the crop is sold at harvest. An estimate of overdrying costs for wheat (at $4.00/bu) are shown in Figure 10-4. However, if the crop is held through the summer when average temperatures approach 80° F, wheat should be dried to 12.5 to 13.0 percent to keep conditions dry in the bin (<65% RH) and thereby prevent problems with mycotoxins and sprouting during storage (Figure 10-5). Consequently, this additional cost should be considered as a cost of storage and not directly attributed to drying, since it is usually recovered when the crop is sold.

Storage

Sanitation, aeration and monitoring are the watchwords to remember when storing grain during the summer months. Totally remove the old crop before placing newly harvested wheat into a bin. Thoroughly sweep the bin wall and floor (including under aeration ducts, if possible) to remove grain kernels that may contain insect larvae and mold spores. Apply an approved insecticide both inside and outside the bin to delay insect population development before placing wheat in the bin.

Aeration should be used to cool wheat after drying with heated air. To a small degree, aeration will control grain temperature if it starts heating during storage, but this may only be a short term solution to avoid further damage to grain quality. If heating cannot be controlled by running the fan, the crop should be moved to another bin (if possible) to break up hot spots in the bin that usually cause the problem. Consider adding temperature cables to monitor conditions during storage and an automated controller for aeration fans to start cooling stored wheat below 60° F as soon as possible in late summer.

Check the condition of stored wheat once a week during warm weather to guard against deterioration from molds or insects. Run the fan for a few minutes to check for off odors from the grain pile. Lock out unloading auger motor switches before looking inside any bin to check for wet spots on the grain surface. Feel the top 6 to 12 inches of wheat to monitor temperatures and insect and mold activity. Insert plastic insect traps below the grain surface (being sure to secure them to a ladder or other structural member of the bin) to monitor insect activity and check them during weekly inspections to stay ahead of damaging populations. Always wear dust protection masks when cleaning bins as well as during an inspection. References from the UK Entomology Department are updated annually and provide more specific information on approved insecticide and fumigation recommendations for controlling insects in stored wheat (http://www.ca.uky.edu/entomology/entfacts/ef145.asp).

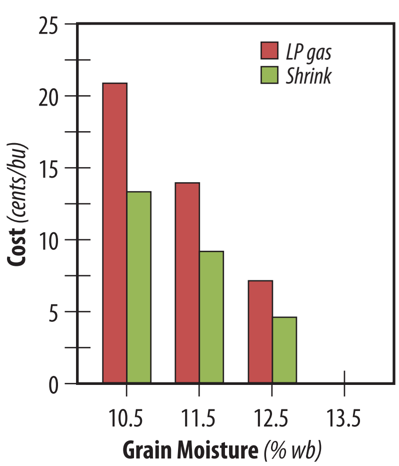
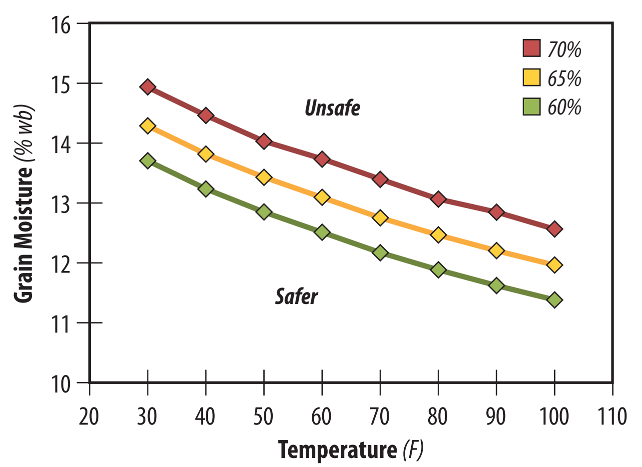


Figure 10-4. Cost of storing wheat below market moisture level (at $4.00 per bushel and $1.40 per gallon for liquid propane (LP).

Figure 10-5. Equilibrium moisture content (EMC) for soft red winter wheat at various temperature and relative humidity levels.



Section 11

Supplemental Materials

Freeze Damage

Photo 11-1. Varietal differences in spring freeze injury have been observed, but differences are mostly caused by variations in plant growth stages when freezes occur. The variety on the left has more leaf burn than the variety on the right.

Photo 11-2. Leaf burn is a symptom of freeze damage to wheat that has broken dormancy and has had prolonged exposure to low temperatures (24°F or lower) during lush, rapid growth.

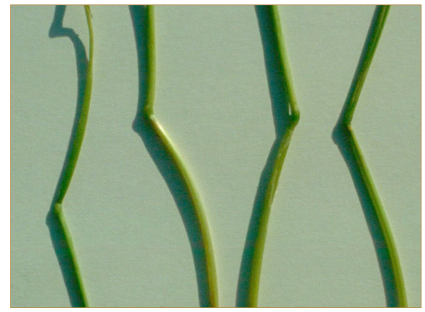


Photo 11-3. Bent elbow (bending of the stem at the lowest node forming an elbow) is another symptom of freeze damage to the stem. Bent stems usually resume an upright position but lodging can be a problem with the added weight of the grain as heads begin to fill.

Photo 11-4. The pollination (flowering) stage is the most freeze-sensitive stage. Exposure to temperatures of 30°F at pollination can kill the male parts (anthers) of the flower and cause sterility without any symptoms appearing on plant vegetative parts. The head on the right is sterile due to freeze damage at pollination. No kernels developed in the florets because the anthers and pollen were killed. The undamaged head on the left has a developing kernel in each floret.

Photo 11-5. Growing point damage. After the jointing stage, the growing point (developing wheat head) is susceptible to freeze damage. To check for damage, cut into the stem. A normal, uninjured head (two plants on the left) is glossy, turgid, and yellow-green. A freeze damaged (killed) head (three plants on the right) is pale white or tan, limp, shrunken, and not developed in size. Plants were collected 13 days after the freeze.

Photo 11-6. Freeze injury to the head at the boot, heading, or flowering stage can result in death of the heads or floret sterility. The most obvious symptom is a white head color. Due to differences in maturity of the florets along the length of the head at the time the freeze occurred, there is a range in the location of the injury to the head. The center or one or both ends of the head may be sterile. In some cases, the whole head may be sterile.

Photo 11-7. Stem freeze damage can occur after the jointing stage and usually occurs to the lower stem. Symptoms include discoloration, lesions, splitting, collapse of internodes, and enlargement of nodes. Damaged stems usually deteriorate further by breaking or rotting. The four stems on the left show freeze damage.

Other Problems

Photo 11-8. Color banding (purple or yellow banding on young leaves at emergence) is an environmental problem caused by warm days with cool nights. Seedlings will become cold-tolerant, and symptoms will fade.

Photo 11-9. Poor stands can be caused by a number of factors, such as drill problems, poor seed quality, dry soil, deep planting, soil crusting, low seeding rates, diseases, and insects. Close examination of the situation helps determine the causes of poor stands.

Photo 11-10. Deep planting (past the depth to which the coleoptile can elongate) can slow emergence or cause stand establishment problems. The coleoptile is the embryonic leaf that penetrates the soil so the seedling can reach the surface. Varieties differ in their coleoptile lengths.

Photo 11-11. A healthy wheat head has green anthers and white stigmas, as in the lower left floret. The yellow anthers of the middle floret indicate pollen has recently been shed. The developing kernel in the upper floret indicates fertilization has occurred and there has been no freeze damage.

Photo 11-12. Lodging can be caused by many factors. Heavy winds and rains at the heading stage are largely responsible for most lodging problems. Lodging tends to occur in low field areas or when high nitrogen rates, tall varieties, or high seeding rates are used.

Photo 11-13. Heaving results in plants being uplifted from the soil with the crowns above the soil surface and only a few roots attached into the soil. This is a common problem with frequent, alternate freezing and thawing of the soil, particularly with shallow plantings. As wheat begins its spring green-up, some plants begin to die.

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