Section 7

Disease Management

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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.