

**MANAGEMENT OF
WHEAT
DISEASES**

IN THE SOUTHEASTERN UNITED STATES

**AN INTEGRATED
PEST MANAGEMENT APPROACH**



Management of Wheat Diseases in the Southeastern United States An Integrated Pest Management Approach

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The Authors

Foreword

Many state, regional and national publications have been written about wheat diseases. Each has served a specific situation or client group admirably but few, if any, have been written with an integrated approach to disease management.

This publication emphasizes the use of a total integrated management system to reduce diseases and the damage they cause in the field. The process of managing diseases begins long before soil is prepared or when seeds are placed in the soil. Likewise, it does not end at maturity of the crop or even at harvest. The overall principles and goals outlined in this publication follow an Integrated Pest Management (IPM) approach: that is, to take into account various factors that may influence pest pressure and damage and to adjust and/or initiate farming practices that reduce pest populations and associated damage. The underlying premise is that these adjustments are done with the welfare of the farm, the environment and society in mind.

Management of Wheat Diseases in the Southeastern United States: An Integrated Pest Management Approach is a compilation of wheat disease information from throughout the southeastern United States. It covers the major and minor diseases of the soft red winter wheat grown primarily in that region. The management strategies are as inclusive as possible, taking into consideration the time of disease development within the wide range of environments that occur within the region.

It is our hope that the users of this publication will find it useful in gaining an understanding of how the soft red winter wheat diseases work, their importance in the region and how to take a more holistic approach to their management. In the sections that describe the diseases caused by fungi, viruses, bacteria and nematodes, the disease management suggestions are highlighted in bold and italic lettering.

This publication is intended to be a guide for those who use it; specific recommendations for managing specific, local disease problems should be referred to the Cooperative Extension Service in each state. The mention of specific products in this publication is not intended as a recommendation.

Management of Wheat Diseases in the Southeastern United States

An Integrated Pest Management Approach

Introduction

Wheat acreage has expanded considerably in the past 15 years in much of the southeastern United States. This increase in acreage has caused some diseases to become more important than was previously the case. This is because, historically, the small acreage meant longer rotation between wheat crops. This had a positive effect in keeping many diseases at low levels. The expanded acreage in many areas meant, too, that growers who had planted little or no wheat previously had to learn management of this crop including the strategies for disease management. This process continues.

The incorporation of wheat into double cropping and reduced tillage systems also presented new disease management challenges for many producers. In some cases these cropping systems reduced some diseases but enhanced others. The warm, humid climate of the southeastern United States often favors higher levels of diseases than other parts of the country, especially diseases of the leaves and head. The mild winter often allows a low but steady increase of leaf diseases such as powdery mildew and rusts. This means spores and other infectious propagules of the various fungi and other disease agents are at higher levels early in the spring when wheat begins rapid growth. Some of the procedures needed to manage diseases efficiently in these systems still need to be worked out. In addition, continued improvements in disease diagnosis are needed.

There is often a significant gap between currently available disease management strategies and their application on the farm. An important goal of this disease management guide is to reduce this gap.

Integrated Pest Management

Integrated Pest Management (IPM) has been defined in many ways by many people. The interpretation of IPM for the purposes of this publication involves looking at every aspect of growing a crop and manipulating what can be done to reduce pests and their impact on the crop while minimizing impact on the environment and society. These options involve pre-plant decisions through post-harvest handling of the crop.

Problems that occur throughout the growing season receive most of the attention because they occur at a specific time in the presence of the grower. The IPM approach requires consideration of influences that occur before, during and after the growing season.

This publication stresses the use of an IPM approach to manage wheat diseases.

Concept of a Biotic Plant Disease

Plant disease is defined in many ways. Some definitions are simple; others are very inclusive and more complex. Disease is not a condition, but rather a result of several important factors occurring at once. Plant disease results from continuous irritation by a pathogen (infectious agent) or environmental factor (non-infectious agent) that leads to the development of symptoms.

A plant is normal, or healthy, when it is able to perform its physiological functions. But when a plant, or at least a plant part, is attacked by a disease-causing organism (pathogen), then cells and tissues of the attacked plants are weakened or destroyed. Plants then lose their ability to perform essential physiological functions, resulting in a range of possible disease symptoms or death.

Pathogens may incite disease in several ways: (1) weakening the plant by absorbing food from it, (2) disrupting the metabolism of host cells through toxins, enzymes or growth-regulating substances, (3) disrupting nutrient and water transportation and (4) consuming cell contents. For example, root rots interfere with water and nutrient

absorption. This can influence foliage infection, expressed as leaf spots, blights or mosaics that interfere with the plant's photosynthesis. Ear infections interfere with reproduction and thus, grain development.

A plant disease results when several key factors occur at the same time. The Disease Triangle is a term used to explain how these factors interact to cause a disease. One side of the Triangle is the host or plant, which must be susceptible to a specific disease

organism. A second side of the Triangle involves the pathogen, which must be capable of causing disease.

Figure 1. The disease triangle.

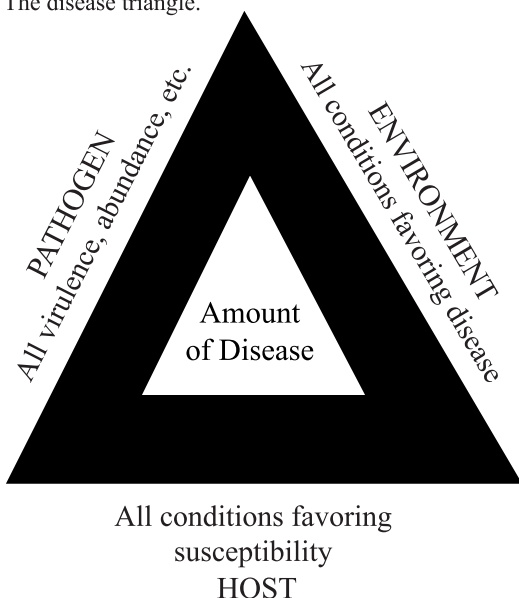
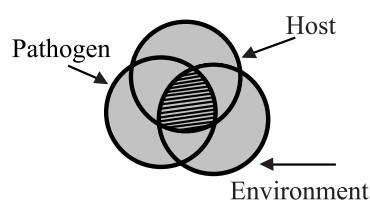
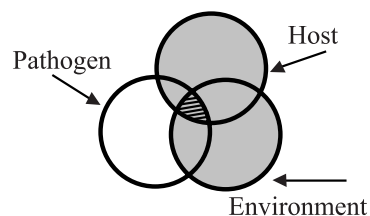


Figure 2. Dynamic interaction of plant disease.

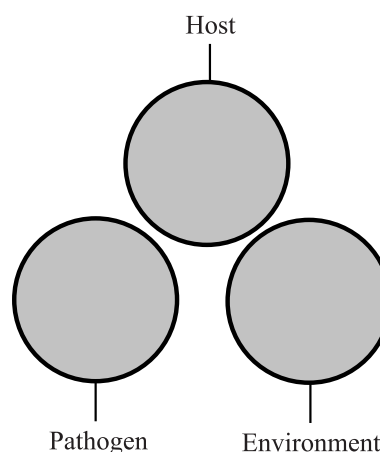
A. Severe Disease



B. Mild Disease



C. No Disease



The third side of the Triangle is a favorable environment that allows the pathogen to develop in the susceptible host and cause disease (Fig 1). All three components are necessary, but, more than that, they must occur at the same time.

The amount of disease is influenced by how closely these factors fit together. For example, if a virulent pathogen and a susceptible host are present, but the environmental factors necessary for disease development do not exist, then very little to no disease will develop (Fig. 2). If time is added to the Disease Triangle as another dimension, there exist the elements of the disease epidemic (Fig. 3). Disease, not only occurring, but increasing, over time develops into an epidemic.

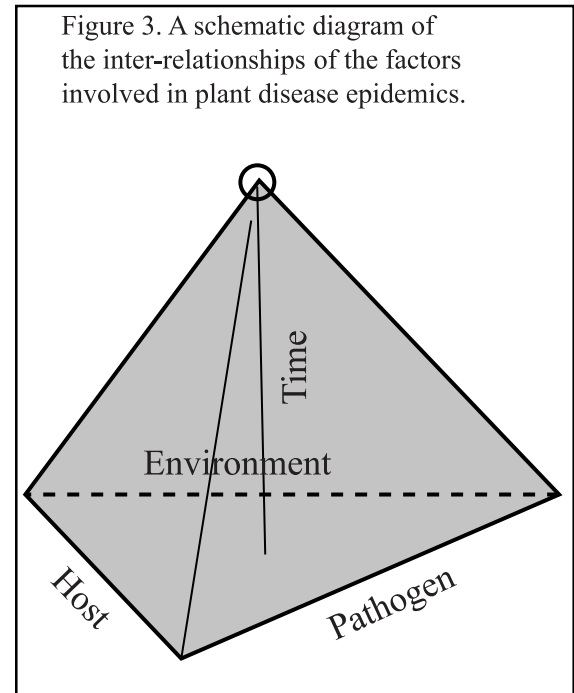


Figure 3. A schematic diagram of the inter-relationships of the factors involved in plant disease epidemics.

How Disease Develops: The Disease Cycle

Regardless of the type of disease, the host or its cause, disease development follows a certain pattern, known as the disease cycle (Fig. 4). The disease cycle varies only in the time it takes to develop. The steps in the cycle remain the same. The initial step in the cycle is inoculation. This refers to the depositing of a pathogen onto the host. This can be accomplished by wind; splashing water; insect, mite or fungal vectors; animal or human vectors or mechanically. Second, penetration occurs, which refers to the entrance of the pathogen, regardless of whether it is by passive or active means, into the host tissue. The third step is infection in which the pathogen derives nutrient from

the host. Fourth, an invasion of the host occurs, followed by with symptom expression.

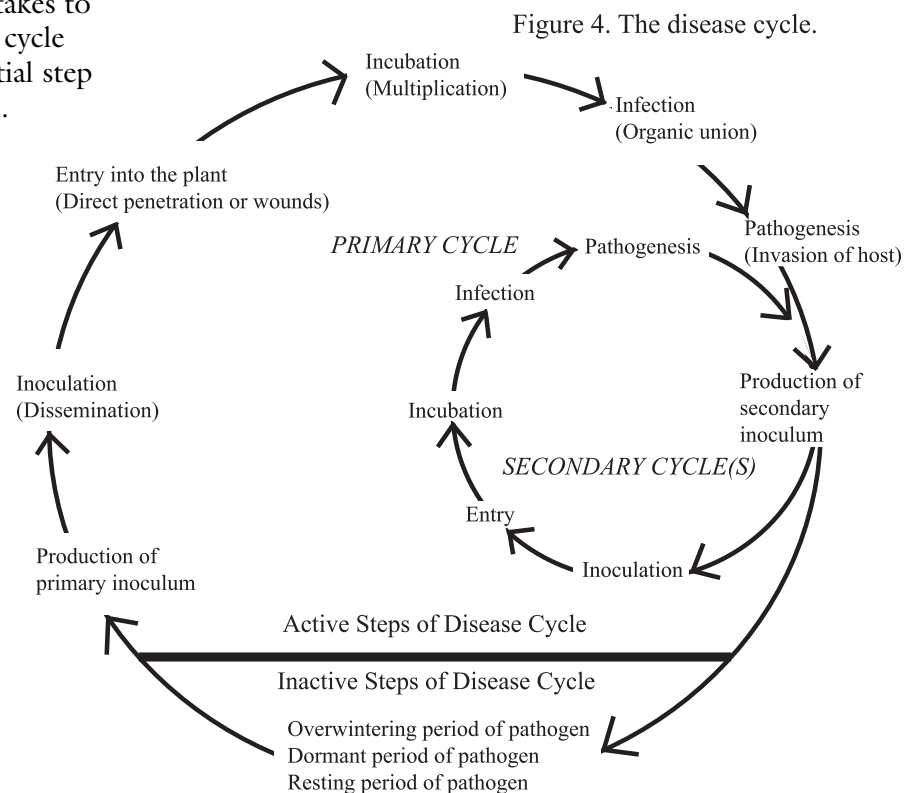


Figure 4. The disease cycle.

Importance of Wheat Diseases and Proper Disease Identification

The greatest concern producers have about wheat diseases is the effect they can have on crop yield. Diseases also can affect wheat in other ways. For example, even where yield reduction is minimal some diseases, such as leaf rust or stagonospora nodorum blotch, can reduce seed size by reducing green tissue on the upper leaves and head, which are responsible for grain filling late in the season. This reduced seed size and reduced test weights lower the price paid to the producer, and marketability of the crop may be affected. Changes in the population genetics of the powdery mildew and leaf rust fungi result in the need to change cultivars frequently. Breeding for disease resistance has always been the primary means of managing these diseases, but the breakdown of resistance three to four years after a resistant variety is developed results in the frequent turnover of cultivars and the need to develop new, resistant ones. This means considerable time must be spent in breeding programs to select disease resistant lines. In many situations, an emphasis on selecting cultivars for disease resistance hampers the development of cultivars with superior yield potential, grain quality or other traits. Therefore, incorporating types of resistance, such as partial resistance, that are long-lasting is now a goal of many wheat-breeding programs.

Diseases often influence the sequence of crops producers plant in the rotation. For example, in double-cropping systems, the choices for a winter crop are limited so producers commonly plant wheat. But, planting wheat in consecutive years with soybeans as the summer crop has caused take-all root and crown rot to become important in the southeastern states where it had previously occurred only rarely. Knowledge of diseases and their interaction with cropping sequences is an important factor in successful wheat production.

Accurate disease identification by the grower is important for several reasons. It is

necessary to make decisions about management methods aimed at specific diseases or the need to apply specific management measures in a timely fashion. Few management measures are effective against a wide range of disease organisms or over a long period. Often, a few days' delay in applying a fungicide or applying the wrong fungicide may result in poor disease management and significant yield or quality reduction. Growers often have relied on assistance from county agricultural agents or other trained specialists for disease diagnosis. It is increasingly important, however, for growers to be able to recognize common pest problems themselves.

Often, several diseases are similar in appearance and therefore must be differentiated. For example, it is not always possible to differentiate leaf diseases solely by visual inspection of the size and shape of the leaf spots, particularly those caused by fungi. Observation of the reproductive structures of the disease-causing fungi is often necessary for accurate diagnosis. They may be produced partially submerged in the diseased tissue and are difficult to recognize without magnification. In these instances, specialized training and experience may be needed to differentiate similar diseases.

Proper identification is necessary to determine the type of management needed. For example, diseases caused by viruses or bacteria will not be managed by applying a fungicide. A low severity of powdery mildew at the heading stage will not require treatment if the cultivar has moderate resistance, because powdery mildew declines as temperatures rise as the season progresses.

If fungicides are needed as part of a disease management program, their only use will be for management of leaf and head diseases caused by certain fungi. Foliar-applied fungicides can add considerably to the variable costs of production. Therefore accurate diagnosis and an understanding of the environmental factors that influence

disease increase and fungicide performance are crucial to making a decision about use of a fungicide and the time of its application.

A factor in disease diagnosis that at first may not be recognized as important is the knowledge of the cultivar grown in each field. Disease diagnosis is often aided by knowing that a cultivar is highly resistant and therefore unlikely to have a certain disease until late in the season. Conversely, a low level of severity early in the season on a susceptible cultivar can indicate the disease has the potential to increase quickly and have a serious impact on the crop yield.

The diseases that growers encounter vary in each region of the country. The range of disease encountered in the southeastern United States also varies significantly. For

example, leaf blotch caused by the fungus *Septoria tritici* is not found in Georgia and the wheat-growing areas of Florida but can be severe in eastern Arkansas. Stripe rust has caused losses in the lower Mississippi Valley, but it has not been found in other areas of the southeastern United States. Knowledge of the distribution of the various diseases in a region aids greatly in diagnosis.

Disease management is a significant part of an overall crop production program. An understanding of the important diseases in the producer's region, their identification, means of spread and response to environmental conditions will be increasingly important in the critical decision-making process necessary to produce wheat profitably and in an environmentally sound manner.

Wheat Disease Management

Disease management is a key component of high-yielding wheat. Some diseases, such as take-all disease, must be managed proactively and cannot be affected once they are established. Other diseases, such as foliar diseases caused by fungi, can often be managed by the timely application of foliar fungicides. Generally, wheat producers place too much emphasis on disease management using foliar fungicides only. Most diseases are best managed through the use of multiple tactics, both proactive (crop rotation, delayed planting, resistant varieties, proper fertility, seed treatment fungicides) and reactive (application of foliar fungicides).

Scouting for Diseases

Scouting for diseases is important for two reasons. Yearly scouting helps to build an on-farm database that can be used to select appropriate disease management tactics for future crops. Scouting also helps to determine if and when to apply fungicides. Once fields have been properly scouted, these data are helpful to determine disease management options. For help with this, contact local Extension agricultural agents or crop consult-

ants for the latest recommendations. An appropriate course of action can begin only when up-to-date, accurate information is at hand.

How Preplant Decisions Affect Diseases

Wheat producers have a significant portion of their total disease management program in place once the seed is in the ground. By that time, decisions have been made about crop and cultivar selection, method of tillage/seedbed preparation, seed quality, seed treatment, planting date, seeding method and rate and fall fertility. Individually and collectively, these decisions can play an important role in influencing which diseases develop, their severity and their effect on crop yield and test weight. Because preplant and planting decisions are so important in the management of wheat diseases, understanding how they affect disease is necessary.

Variety Selection

Decisions relating to variety selection are, perhaps, the most important decisions that

can be made in managing diseases. Every commercially available wheat variety has a unique range of reactions to diseases common in the region. Which and how many varieties are planted determine the potential for certain diseases. Failure to consider the ramifications of variety selection in managing diseases is a costly mistake. Selection of two or three varieties with the greatest amount of available resistance to the diseases most common on a farm or in the community is important. To do this, some idea about the disease history on the farm is necessary. If that information is not readily available, Extension agricultural agents or crop consultants will be of help. This information won't be as good as actual data from the grower's own 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 damage a single variety severely. When multiple varieties are planted, the risks are reduced. Planting more than one variety, especially when different maturities are represented, also can help with the logistics of harvesting and soybean planting.

Crop Rotation

Crop rotation helps to manage the wheat pathogens that survive between wheat crops in wheat residue. When a crop other than wheat is grown in a field, levels of pathogens specific to wheat decline. This occurs simultaneously as the residue of previous wheat crops deteriorates. Lower levels of pathogens can translate into less disease pressure the next time wheat is produced. Crop rotation is helpful in the management of hidden diseases, such as *Pythium* root rot, and destructive diseases, such as take-all. In fact, rotating fields out of wheat is the only practical means of controlling take-all. Rotation also can reduce infections by the fungal species *Stagonospora* and *Septoria*. The effect of rotation on these diseases can be negated by spores blowing into fields from neighboring fields, however. In some areas of the soft red winter wheat-growing region, wheat is planted following corn. Corn is generally a good non-host crop to

grow in non-wheat years. There has been some talk that planting conventionally tilled wheat behind corn increases the chances for a *Fusarium* head blight problem in wheat because the head blight fungi also can attack corn, causing stalk and ear rots. Observations have shown, however, that planting wheat behind corn, even in a no-till environment, does not increase the amount of head blight in wheat to any great extent. Thus, apparently head blight inoculum is produced and blows around readily and, as long as conditions are favorable for head blight development, the disease will be a problem regardless of the rotation.

Tillage

Tilling wheat stubble hastens the breakdown of residue that harbors certain disease organisms. This can help reduce levels of take-all and foliar diseases, such as *Septoria* leaf blotch and tan spot. "Help" is the operative word here since it is unlikely that tillage will be of much good in the absence of other management methods. For fields in a wheat/double-crop soybean/corn rotation, tillage prior to planting corn should cause a significant decline in surviving wheat stubble. The year between wheat crops in this rotation also helps, except where high levels of the take-all fungus exist. In those cases, two or more years between wheat crops may be required.

Planting no-till wheat following corn is not a problem except that this practice can slightly increase the risk for *Fusarium* head blight to occur in borderline situations. There are, however, no data to suggest that planting wheat directly into corn residue will be the difference between a serious head blight problem or a light one.

Seed Quality, Seed Fungicides, Seeding Rate and Planting Method

All of these can influence stand establishment and seedling development. To achieve the highest possible yields, sufficient stands are necessary. To achieve the desired stands, there must be excellent seed germination followed by emergence and development of seedlings. Using high-quality (certified) seed treated with a broad-spectrum fungi-

cide and good planting techniques foster good stand establishment. Excess stands, however, are undesirable because they encourage foliar and head diseases by reducing air circulation and light penetration into the canopy later in the season. Lodging of plants because of weakened stems is also a problem caused by excessively dense stands.

Planting Date

The trend in recent years has been to plant wheat earlier and earlier each year. Early-planted wheat, defined as wheat planted before the Hessian fly-free planting date, is at greater risk of damage caused by barley yellow dwarf, take-all disease and Hessian fly than is later-planted wheat. If logistic considerations cause a grower to plant some wheat acres before the fly-free date for that area, those acres should have been well rotated and planted to a variety that can tolerate some barley yellow dwarf. Planting all wheat acreage before the fly-free date is extremely risky and is not recommended.

Nitrogen Fertility

Too much nitrogen in the fall can encourage excessive fall growth that can increase problems with barley yellow dwarf and most foliar diseases caused by fungi. Increased problems with barley yellow dwarf have to do with an extended period of activity by aphids that transmit barley yellow dwarf virus when stands are dense in the fall. The same situation encourages infection and overwintering of pathogens causing foliar diseases, such as leaf 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. Lodging may increase, too, resulting in higher moisture within the canopy of fallen plants and creating favorable conditions for fungal diseases.

Fungicide Seed Treatments

Obtaining and keeping a good stand of wheat is a key component of high yields. One management strategy many wheat

producers use to attain excellent stands is to treat seed with a fungicide. Wheat seed treatment fungicides:

(a) **Encourage good stand establishment.** Wheat is planted at a time of the year that can be hostile to germinating and emerging seedlings. Excessively cool, wet or dry soils; seed planted too deep or too shallow; and no-till plantings where seed-to-soil contact is poor all slow the germination process and predispose developing seedlings to infection by seed- and soil-borne fungi. Species of *Pythium* are probably the main culprits in excessively wet and warm soils. The other conditions mentioned favor infection of seedlings by species of the fungi *Fusarium*, *Rhizoctonia*, *Septoria* and *Stagonospora*, among others. Infection can result in fewer emerged seedlings and reduced vigor of the seedlings that do emerge.

Most producers who plant wheat according to recommended guidelines, however, have little difficulty achieving dense, vigorous stands of wheat seedlings. The fact that a good percentage of the wheat seed planted in the region is treated with a fungicide probably has something to do with this situation. Routine use of high-quality, high-germ seed, however, is probably the key contributing factor. In fact, historically, most small-plot seed treatment research done has shown that treating high-quality seed with a fungicide only rarely results in stand or yield increases. Nonetheless, it is still advisable to treat seed with a good general-use fungicide to protect seedlings from adverse soil conditions if they develop after planting. In this regard, seed treatment fungicides should be seen as a form of low-cost crop insurance. Environmentally, seed treatment fungicides are desirable because of their low toxicity, low use rates, rapid breakdown and target application strategy.

(b) **Enhance germination of marginal-quality seed lots.** If seed quality is marginal because of fungi such as *Fusarium*, seed treatment can be used to bring seed germination up to acceptable levels. In many cases, seed testing laboratories can provide tests that indicate whether or not

fungicides will enhance germination of seed. Poor response of low-to-moderate germination seed lots to fungicides is indicative of a high percentage of dead seed, mechanical damage or some factor apart from disease. Seed lots of low germination are not likely to be helped by any seed treatment fungicide and should not be used where high yield is a primary goal.

(c) Control loose smut. Loose smut control is probably the main reason seed treatment fungicides are so widely accepted and used in the southeastern United States. Before seed certification, loose smut was a serious problem for both seed and grain producers. The use of seed treatment fungicides, such as carboxin, allowed seed lots to be “cleaned up” by eliminating loose smut from infected seed. Carboxin is still considered by many to be the standard for loose smut control. It is inexpensive and highly effective under most situations. But, sporadic, reduced activity of carboxin caused by poor application procedures or soil conditions that caused the active ingredient to be washed off the seed, supported the development of a new generation of seed treatment materials that are highly effective against loose smut. All of these new-generation fungicides are extremely active at low use rates. In fact, because of the excessively low use rates of these products, application can be done only by seed conditioners with the experience and equipment to do the job properly. This eliminates the option of on-farm seed treatment by producers and increases the cost in many cases.

(d) Control foliar diseases. The new generation of systemic, sterol-inhibiting seed treatment fungicides can provide fall management of several fungal diseases, including *Septoria* and *Stagonospora* leaf blotches (leaf blotch complex), leaf rust and powdery mildew. Occasionally, management of these diseases extends into early spring as a result of reduced inoculum levels of the causal fungi in fields planted to treated seed. In some cases, this activity can be quite substantial, as is the case with triadimenol and powdery mildew. Management of powdery mildew through head emergence

the following spring is not uncommon. Nonetheless, seed treatment fungicides should not be considered as a total replacement for spring-applied foliar fungicides since no seed treatment provides season-long control of foliar diseases.

In general, new-generation sterol-inhibiting seed treatments, because of their specific mode of action, are not highly effective against many common soil-borne pathogens. For this reason, most are marketed as a mixture with either thiram or captan, both of which provide at least moderate activity against a wide range of soil-borne fungi. Newer formulations may include metalaxyl to control soilborne *Pythium* spp.

When contemplating the use of wheat seed treatment fungicides, consider these factors. Costs of materials and disease control vary widely, so it is critical to assess cost-benefit ratios of the various fungicides. The main consideration is to determine why to use a seed treatment fungicide. Specifically, what diseases are to be managed and what is to be accomplished by seed treatment use? Fungicide labels should be read and followed completely. These labels refer to the specific diseases the products manage. In this regard, labels are specific. Once these determinations have been made, selection of the most appropriate material (best disease control for the money) can be accomplished. For example, triadimenol seed treatment is relatively expensive. If powdery mildew is a major problem on a farm, however, triadimenol may negate the need for an early spring foliar application of a fungicide on a mildew-susceptible variety. Taken in this context, the economics of triadimenol seed treatment become more favorable. If loose smut or general soil-borne pathogens are the main concern, and the risk of powdery mildew is minimal, triadimenol is not the most economical choice since less expensive materials are as good as triadimenol at managing these diseases.

Although fewer options are open to producers regarding on-farm treatment of seed, some hopper-box treatments are still available. If a hopper-box treatment is to be

attempted, it is important to note that coverage is essential. Poor coverage equals poor results and, perhaps, a waste of money. Even distribution can be accomplished on-farm only with considerable effort and planning. Having seed treated by a professional eliminates poor fungicide distribution and variable rates on seed as potential problems.

Foliar Fungicides

Deciding whether to apply foliar fungicides to wheat is one of the most difficult decisions a producer or crop consultant has to make, because of the many variables that influence the need for and effectiveness of foliar fungicides. First, fungicides must be applied in the early stages of a disease epidemic to be of much use. Applying fungicides too far in advance of an epidemic or waiting too long to apply results in poor disease management and little or no economic benefit. Similarly, there is no economic gain from using foliar fungicides if yield-reducing levels of disease fail to develop or if crop yield potential is too low to cover costs. Finally, foliar fungicides manage only certain foliar and head diseases caused by fungi. They do not manage diseases caused by bacteria, viruses or nematodes, and they have no effect on some fungal diseases, such as loose smut and take-all.

Below are the steps to take when making foliar fungicide use decisions:

Step 1. Commit to scouting fields.

When considering the use of foliar fungicides, you must answer certain questions. Is there a commitment to scouting fields to determine the need to apply a fungicide? (If there is uncertainty about how to answer this question, refer to steps 3 through 6, below, for specific field scouting requirements.) If there is no commitment to field scouting (whether it is done by the grower or by a consultant), there is a question as to the decision to even consider fungicide use. Ultimately, a grower will need to decide how important wheat is to the total farming operation. If wheat is important to the profitability of the farm, it is advisable to make both time and monetary commit-

ments to produce the best crop possible. If wheat is of only secondary importance relative to other farm operations, perhaps management of diseases using resistance and cultural practices should be considered.

Step 2. Determine the number of potential fungicide applications. Once the commitment has been made to scout wheat fields, the next significant determination is how many fungicide applications are you willing to make? Nearly every producer says only one; few say two. The answer to this question is important because it determines the approach to fungicide use.

If a grower is going to make only one fungicide application, timing of the application is crucial. Research and experience show that a single application made during heading performs at least as well, and usually better than, a single application made at flag leaf emergence in most situations.

The problem with single applications at flag leaf emergence (regardless of the fungicide used) is that they frequently allow late-season disease pressure to build to excessive levels. As a result, the crop is damaged even though early diseases may have been kept in check. Heading applications, on the other hand, usually limit disease buildup on the flag leaf (F), the second leaf down (F-1) and the head, even though disease is allowed to develop unchecked early in the season. Protection of the F and F-1 leaves and the head is much more important to yield and grain quality than is protection of lower leaves. The risk in making a single late application is waiting too late to apply the heading treatment. Fungicides are of little or no value once the flag leaf and head are severely diseased. The best way to limit this risk is to start scouting operations during flag leaf extension. It is unlikely that significant disease will have developed on the F and F-1 leaves by this time.

Two fungicide applications (an early application followed by a late application) often outyield even the best single application. The question, however, is whether or not the economic benefit that results from the additional treatment is greater than its

cost. As a general rule, the extra treatment at least pays for itself if early disease pressure is moderate to heavy and crop prices are good. If early disease pressure is minimal or crop prices are low, however, it probably would not be an economical treatment.

Step 3. Know the disease reaction of the wheat variety planted. Typically, foliar fungicides are not necessary on wheat varieties rated as resistant or moderately resistant to a particular fungal disease. Careful scouting and observation are the keys. Leaf rust and powdery mildew can adapt to and attack a formerly resistant variety. This can happen in a single season, so growers and consultants need to be vigilant and still scout those crops.

Step 4. Estimate crop yield potential. Does the field have sufficient yield potential to justify a foliar fungicide application? Spraying with fungicides protects only yield already built into a crop; fungicides do not increase yield. Although various techniques can be used to estimate crop yield potential, most producers can look at a crop after greenup and know, intuitively, if the crop is worth protecting. In most cases, there will be a need to harvest an additional three to eight bushels per acre (depending on grain price and chemical cost) to offset the cost of a fungicide application. The higher the yield potential of a crop, the more likely you are to benefit economically from applying a foliar fungicide if disease becomes a problem.

Step 5. Know the disease(s). As indicated earlier, fungicides manage a relatively small number of fungal diseases. Fortunately, the diseases they control are those that commonly reduce yields in the southern United States' soft red winter wheat crop -- leaf rust, powdery mildew, leaf blotch complex and glume blotch. Other diseases (except tan spot, which is rarely a problem) are not managed with foliar fungicides, so proper identification of the disease is critical.

Step 6. Scout fields. Scouting wheat fields to determine crop growth stage and current disease situation is critical to making good fungicide-use decisions. When scouting fields, observe the entire field. Decisions

should not be based on what is found along the edges or what is seen from the seat of a moving vehicle. The key is to make a decision based on the average disease situation in a field. This requires assessing disease levels in eight to 10 randomly selected sites. Once in a field, it is important to determine the growth stage of the crop for two reasons:

(a) All fungicides must be applied within specific growth-stage restrictions. Tilt, for example, legally cannot be applied once the flag leaves in a crop are fully expanded (Feekes 9 or decimal scale 39). (Some states have received exemptions that allow for heading application of Tilt fungicide.) Other fungicides, such as Dithane M-45, have well-defined days-to-harvest restrictions. (b) Fungicides provide the greatest benefit when plants are protected from disease between flag leaf emergence and soft dough stage. In much of the southeastern United States, the most critical stage is typically from mid-head emergence through flowering. This is the period in which fungicide applications are often most beneficial.

Step 7. Determine disease levels. To be effective, fungicides must be applied early in an epidemic. Too often, fungicides are applied too early, before any disease is visible. This approach results in no economic benefit if disease pressure remains low. Waiting too late to apply fungicides, although common, is equally ineffective. For leaf blotch complex including *S. nodorum*, if F-2 and lower leaves have symptoms and rain has been recent, there is a good chance the flag leaf and head are already infected (with first symptoms being seven to 12 days away). Therefore examination of symptoms on lower leaves can help determine when to apply a fungicide. Herein lies the greatest obstacle to effective, economical use of foliar fungicides: how much disease is enough disease to justify a foliar application of a fungicide? There are no absolutes, but many states have developed various threshold guidelines to help producers make fungicide use decisions. Thresholds must be used, however, along with some common sense. For example, if a specific

threshold is reached for powdery mildew, application of a fungicide would not be recommended if an extended period of hot, dry weather is predicted. The thresholds indicate that yield loss caused by one or more of the above diseases is likely; however, they do not mean losses will definitely occur. Weather can always intervene and short-circuit a disease epidemic. There is no way to develop disease thresholds appropriate for all situations.

Step 8. Select a fungicide. Product labels provide detailed use instructions and product limitations. Apply all pesticides according to label specifications!

Step 9. Understand the risks. One problem fungicide users face is the inability to determine if disease-favorable conditions will persist after a fungicide is applied. Fungicides are valuable only if yields and test weights are threatened by disease. Similarly,

fungicides are of limited value if other diseases develop that are not managed by those fungicides. Examples are all virus and bacterial diseases and fungal diseases such as take-all, loose smut and head scab. Last, fungicides may be of limited value if yields and test weights are reduced by non-disease factors such as a spring freeze, lodging, delayed harvest or poor grain fill period. Unfortunately, the above situations are always a risk to the fungicide user. Some risk can be reduced by monitoring crop development throughout the season. This might allow you to pick up on yield-limiting factors indicating that applying fungicides would not be warranted. Of course, this is a moot point once a fungicide is applied. In all instances where fungicides are used, check the response of the crop to the treatment by leaving a non-treated strip in the field for comparison.

Diseases Caused by Fungi

Seed and Seedling Diseases

Rhizoctonia spp., *Pythium spp.*, *Fusarium spp.* and Other Pathogens

Several soilborne organisms living in the upper few inches of the soil cause seedling diseases. The primary seedling disease fungi include various species of *Rhizoctonia*, *Pythium* and *Fusarium*. These organisms attack seed and immature seedlings, which are more susceptible than older plants. The period from germination through early seedling development is the most vulnerable time for the wheat plant.

Most root rots are favored by cool, wet conditions shortly after fall planting or in the early spring when new growth is initiated. Root rots are encouraged by imbalanced fertilization or high nitrogen and low phosphate fertilization. Both internal field drainage and, to some extent, soil fertility are influenced by soil type and should be considered.

Affected seedlings may occur singly or in groups. In the latter instance, groups of

plants are often associated with lower areas of fields. Death of the seedling or failure of the seed to germinate are the most conspicuous symptoms. Surviving seedlings have broken roots or poor root development. The lower stem may become infected and display some discoloration. Although plants may survive an attack by these organisms, they are often stunted with little root development. Tillering may also be reduced.

Management can be accomplished by using a seed treatment fungicide and planting high quality certified seed as shallow as possible to establish a stand. If a soil test indicates low levels, apply phosphate to the soil to promote rapid root growth.

Lower Stem and Root Diseases

Foot Rot (Eyespot)

(Pseudocercospora herpotrichoides)

Foot rot, also known as eyespot or strawbreaker, can be an important wheat

disease in the cooler climates of the upper southeastern United States. Wheat is more susceptible to foot rot than are barley, rye, oats and wild grasses.

Foot rot may kill entire plants outright. More commonly, however, individual tillers are weakened or killed, reducing kernel size and number, causing culms to lodge and leaving plants difficult to harvest. Mild infections normally are not noticed in dense plant populations.

Foot rot is generally assumed to be a disease of winter wheat. It is diagnosed from lesions that are most distinctive at the plant base after jointing but also may appear on younger plants. Usually restricted to the basal portions of the plant, symptoms seldom appear on roots or extend more than 4 inches above the soil line.

The disease symptoms become more obvious as the crop approaches maturity. Elliptical or eyespot lesions develop on the lowest leaf sheaths and adjacent internodes just above the soil line. Young lesions have brown elongated borders with straw-colored centers. Eventually the whole stem may be girdled. The center area of lesions darkens with age. When the culm is split open just above the crown, fluffy gray mycelium of the fungus can be seen in the hollow center of the stem beneath the eyespot lesion. Lodging usually accompanies severe attacks.

The fungus persists as mycelia on crop residue. Infection may occur from conidia produced on diseased straw or from active mycelia invading the lower leaf sheaths. The disease develops inward and laterally, eventually producing cottony mycelia in the hollow center of the stem. Conidia produced on diseased plants during the early growth stages serve as a secondary source of inoculum.

Foot rot is favored by high soil moisture, a dense crop canopy, recurrent host crops, reduced tillage, early seeding and high humidity near soil level. Mild winters and cool springs prolong sporulation and infection periods. Plants may be predisposed to infection in spring by frosts and nitrogen fertilization. In hot, dry weather, diseased culms undergo extra moisture stress.

Suggested management measures include delayed fall seeding and rotation

with crops other than cereals and tillage, especially following recurrent wheat crops, thus reducing the amount of inoculum in the soil.

Sharp Eyespot (*Rhizoctonia cerealis*)

Sharp eyespot occurs on several grain crops including wheat, barley, oats and rye. Oats are less susceptible than other cereals. Culm infections apparently originate from soilborne sclerotia or from mycelium in host debris. The disease appears on the outer leaf sheath near the base of the plant as circular, or elliptical, light brown areas surrounded by a thin, necrotic, dark brown border. Affected leaf sheath tissues rot, leaving a characteristic hole in the tissues. After invading seedling leaf sheaths, the pathogen spreads by mycelial growth within and on the plant during the growing season.

On the culms, lesions are light brown to straw-colored and are surrounded by a sharply defined, dark brown border. The lesions are similar to those of foot rot but are more superficial, less lens-shaped and more sharply defined. Normally, they develop later than foot rot lesions and can occur up to 12 inches above the soil line. On maturing culms, mycelium beneath lesions is often abundant and ash white. Sclerotia form near the end of the season and are the principal source of inoculum returned to the soil after harvest. Premature ripening and lodging occur with severely infected plants. Lodged culms frequently bend at the second or third internode.

Culm infections apparently originate from soilborne sclerotia or from mycelium in host debris. Cool, moist conditions near the base of the plant are necessary for infection. Sharp eyespot develops more rapidly on wheat growing in light, well-drained soils. The disease is usually of minor importance in the South, but it is more prevalent and severe to cereals grown continuously on the same land.

No effective and economical chemical management strategies are available. Rotation with legumes or other non-host crops is beneficial.

Take-all

(*Gaeumannomyces graminis* var. *tritici*)

Take-all disease affects a wide range of grasses but is especially severe on wheat (Fig. 5, 6). The fungus can survive on undecomposed infested stubble, but maintains itself on newly emerged grass roots. A short rotation out of cereals or grasses can reduce the fungus population dramatically. Take-all was only a minor problem in the Southeast until the late 1970s, when wheat acreage increased greatly, mainly because of annual wheat-soybean double-cropping. When wheat was grown four or more years consecutively, take-all became a serious problem in those fields.

The fungus invades the roots and lower stem portion of the plant and grows through the tissues, causing a dry rot (Fig. 7). This gray to black stem and root rot interrupts water and nutrient movement up the stem and causes the plant to die prematurely. Prematurely killed plants produce whiteheads that are evident in diseased fields. Plants may be stunted but do not lodge. The base of the stem has a shiny coal-black appearance, and the roots are decayed and blackened. The fungus grows over root and stem surfaces and from plant to plant as dark-pigmented runner hyphae (thread-like filaments). This spread of the fungus outward from infection centers produces dead patches of plants in the field.

A nitrogen, phosphorus and/or potassium deficiency will favor take-all. Therefore, maintaining balanced soil fertility is important in minimizing damage. Since the disease is usually carried on or in root and crown tissue, the destruction and decomposition of this tissue reduce disease levels.

Take-all is favored by weakly acid to alkaline soil (pH 6.5 or higher). Soil pH above 6.5 is uncommon in the acid soils of the South except when growers apply excessive lime. Take-all is influenced by the population of soil bacteria and fungi antagonistic to the take-all fungus. Fertilization with ammonium forms of nitrogen fertilizer suppress take-all by lowering the pH in the root zone, which favors the antagonistic soil microbes. Continuous cropping of wheat can lead to the decline of take-all because of

the buildup of antagonists. Since most wheat in the South is now double-cropped with a summer crop, this decline process may be upset. Research in Georgia has shown that a summer crop of soybeans maintained take-all at a high level in a continuous wheat-soybean sequence, whereas sorghum as a summer crop caused take-all to be less severe in the subsequent wheat crop. Canola and oats planted for one season in place of wheat reduces losses to take-all. Rye or barley in place of wheat does not suppress take-all in a subsequent wheat crop.

Tillage operations spread the disease by moving infected plant debris across the field. Avoid excessive tillage if a wheat crop with a low incidence of take-all is followed by wheat in the next season. In the upper Midsouth, delayed planting past fly-free date tends to reduce the incidence of take-all.

Pythium Root Rot (*Pythium* spp.)

Symptoms and damage caused by Pythium root rot are difficult to diagnose. Diseased plants tend to be more uniformly distributed in wheat fields than those affected by other diseases caused by soilborne pathogens. Pythium root rot is difficult to diagnose without comparing diseased plants to plants known to be pathogen free. Symptoms of severely infected stands include missing, stunted and poorly tillered plants. On seedlings, the first true leaf is often noticeably shorter than a normal healthy first leaf, perhaps as a result of early embryo infections in moist soil. Affected adult plants may appear stunted, chlorotic and nitrogen deficient. Often there is a delayed heading and maturity and plants develop small, poorly filled heads.

A Pythium-damaged root system is small, with brown lateral roots and root cortical tissue. Severely infected root systems result in general root death.

Pythium spp. are some of the most common soil fungi and are present in all agricultural soils to some extent. Oospores in and on residues serve as the source of infection. They can persist for years in soil or embedded in fragments of plant refuse.



FIGURES



Figure 5. Take-all (field view)



Figure 6. Take-all



Figure 7. Take-all



Figure 8. Powdery mildew



Figure 9. Powdery mildew

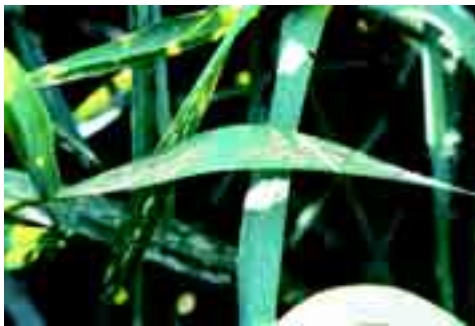


Figure 10. Powdery mildew



Figure 11. Downy mildew



Figure 12. Downy mildew



Figure 13. Leaf rust flecking



Figure 14. Leaf rust flecking



Figure 15. Early leaf rust development



Figure 16. Leaf rust



Figure 17. Leaf rust



Figure 19. Leaf rust



Figure 18. Leaf rust



Figure 22. Stem rust



Figure 20. Stem rust



Figure 21. Stem rust



Figure 23. Stem rust



Figure 24. *Stripe rust*



Figure 25. *Stripe rust*

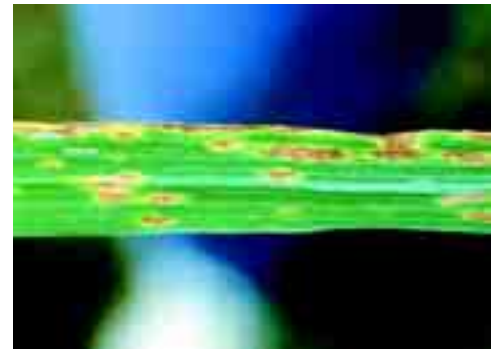


Figure 26. *Tan spot*



Figure 27. *Stagonospora nodorum* leaf lesions



Figure 28. *Stagonospora nodorum* leaf blotch



Figure 29. *Glume blotch*



Figure 30. *Fusarium head blight*



Figure 31. *Fusarium head blight*



Figure 32. *Fusarium head blight*



Figure 33. *Loose smut*



Figure 34. *Loose smut*



Figure 35. Barley yellow dwarf



Figure 36. Barley yellow dwarf



Figure 37. Barley yellow dwarf



Figure 38. Soilborne wheat mosaic

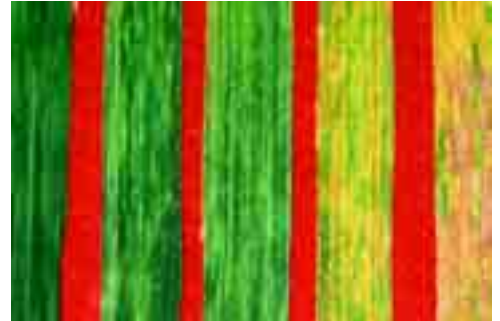


Figure 39. Wheat spindle streak



Figure 40. Bacterial streak



Figure 41. Bacterial streak



Figure 42. Bacterial streak



Figure 43. Bacterial streak



Figure 44. Peduncle lesion of black chaff



Figure 45. Peduncle lesion of black chaff



Figure 46. Black chaff



Figure 47. Black chaff

They germinate and initiate infections directly or indirectly from released zoospores. Initial infections often begin in the embryo of germinating wheat seeds a few days after seeding. Soon after, new roots, especially fine lateral roots and root hairs, become infected.

Straw left on the soil surface or incorporated only slightly favors Pythium root rot because fungus spores are concentrated in the top few inches of soil. *Planting in well-drained seedbeds is beneficial. Use high-quality seed and supplemental phosphorus where this disease is a problem. Some systemic fungicides applied as seed treatments can provide important early seedling protection.*

Foliar Diseases

Powdery Mildew **(*Erysiphe graminis* f. sp. *tritici*)**

Powdery mildew is a major problem of wheat in areas of the Southeast and upper Midsouth. The disease can reduce plant vigor, cause lodging and reduce yield, kernel size and test weight. The fungus robs the wheat plant of nutrients, reduces food production and increases water loss (transpiration) from its cereal hosts.

Powdery mildew is characterized by a white-to-light gray, powdery fungal growth on the leaves, leaf sheaths, culms and floral bracts (Fig. 8, 9). The lower leaves may be completely covered.

In areas where powdery mildew is severe, losses up to 40 percent may occur. Heavily infected leaves and even entire plants may be killed prematurely. Damage is most severe if heavy infection occurs during periods of rapid growth, tillering, stem elongation and head development. Powdery mildew is associated with dense plant growth and cool, moist conditions (Fig. 10). Therefore it is usually one of the first foliar diseases seen in the field. Excessive nitrogen fertilizer produces dense growth of young tissue that creates an ideal environment for development of disease. Excessive rain may slow disease development.

The best way to manage powdery mildew is to grow mildew-resistant cultivars.

Because the fungus survives only on living plants, crop rotation and deep plowing to destroy volunteer wheat will reduce the chance of severe infection by removing overwintering sources of the fungus. Maintain balanced soil fertility based on a soil test to avoid conditions of excess nitrogen in relation to phosphorus and potassium in which the fungus thrives. Fungicide sprays are of benefit in some seasons on susceptible cultivars. The population of powdery mildew can undergo rapid changes. Therefore, resistant cultivars can become susceptible in one season if a new race develops. It is important to consult the latest recommendations for wheat cultivars in your region. Unless cultivars are very susceptible, powdery mildew declines after flowering stage as temperatures rise. This is especially important for timing of fungicide applications.

Downy Mildew (*Sclerospora macrospora*)

Downy mildew, common in the lower Midsouth and South, is usually associated with wheat plants grown in poorly drained areas (Fig. 11). Plant symptoms produced by downy mildew are variable. Some diseased plants tiller excessively and are severely dwarfed, with many tillers growing only a few inches tall. Other plants have thickened leaves that are yellow striped, fleshy, twisted, curled and stiff. These plants rarely produce heads. Those heads that are produced are distorted (Fig. 12) and abnormally large. The stem below the affected heads may be thick and deformed. In bearded varieties, the beards are distorted and abnormally long. Diseased heads produce no viable grain.

Proper soil preparation to improve surface drainage and remove debris will reduce disease incidence. Using clean seed provides some control. Usually other management measures are not available.

Leaf Rust (*Puccinia recondita* f. sp. *tritici*)

Leaf rust is the most important foliar disease in the Southeast. Rusts have a short disease cycle and therefore can increase very rapidly. Infection can be initiated from fall to early spring from spores produced locally

on leaves of volunteer or early-planted wheat. Spores also are wind-blown into the South from wheat grown in Mexico and volunteered along the Gulf Coast. Spores then move northward as the season progresses.

Conditions necessary for infection include the presence of rust spores of a virulent race, a susceptible wheat plant, several hours of moisture on the leaves (six to eight hours of dew or rain) and proper temperatures (60 - 80 degrees F). Relatively cool nights combined with warm days are excellent conditions for disease development.

When a rust spore lands on a susceptible wheat leaf under favorable conditions, it will germinate, penetrate the leaf and infect the host. The difference between a resistant and susceptible wheat plant becomes evident a few days after the first penetration. If the variety is resistant, the fungus quickly kills a small amount of plant tissue, which then causes the fungus to die. This response, called the hypersensitive reaction, stops the infection. This reaction results in yellowish-white flecks on the leaf (Fig. 13). If the variety is susceptible, numerous reddish-orange pustules are formed seven to 10 days after spores infect leaves (Fig. 14-19). Each pustule produces about 2,000 spores daily, each capable of reinfecting wheat. Because of this 10-day repeating cycle forming a large number of spores during the growing season, coupled with the ability of the spores to move great distances by wind currents, leaf rust has the potential to cause severe losses quickly.

For example, four of these 10-day repeating cycles are all that is necessary for rust to develop from a few pustules to an epidemic when susceptible varieties are grown and weather conditions are favorable for rust development. The rate at which leaf rust develops throughout the spring, particularly in the southernmost areas of the region, determines rust severity for that year. The rate of development differs for each variety from year to year.

The disease reduces the size and number of kernels per head. Grain from severely rusted plants is lower in test weight and

protein content. Losses from leaf rust may be underestimated because the disease never destroys an entire crop and seldom causes severe shriveling of the grain.

There are several types of management measures. Using resistant varieties is usually the best and least expensive method. The hypersensitive type of resistance has been used most widely, but this resistance is also the type that can be quickly overcome by new races of the fungus. Breeders are now making more use of partial resistance or "slow-rusting," in which the plant is infected, but the disease proceeds more slowly and economic loss is avoided. This type of resistance is likely to be longer-lasting. Leaf rust-resistant varieties adapted to your locality are recommended.

Cultural methods may be used to reduce disease severity. Follow recommended planting dates and fertilize fields based on a soil test. Following the recommendations given in the soil test may make it possible to increase yield without increasing the susceptibility of the crop to leaf rust.

The use of foliar fungicides, while not needed or appropriate in all instances, is a very effective means of controlling leaf rust development. Fungicide applications may be warranted if: (a) the yield potential and value of the crop is high, (b) the wheat variety is susceptible to leaf rust, (c) rust has an early start and (d) the long-range weather forecast is for continued moist weather. The most important aspect of fungicide application is to protect the flag leaf from infection until after the kernels have filled. Also, it is important to evaluate each field separately because of the variability among fields.

Stem Rust (*Puccinia graminis* f. sp. *tritici*)

Stem rust, like leaf rust, is a disease caused by a fungus. Although stem rust is found in southeastern wheat fields nearly every year, significant damage occurs only to a few isolated late-maturing fields. This disease is usually severe following winters milder than normal, which permits the disease to build up very early in the season. The early maturing winter wheat varieties grown in the region

usually escape serious losses caused by stem rust. The significance of stem rust along the Gulf Coast is that the locally produced inoculum blows northward and infects wheat fields there. Elimination of the most susceptible cultivars in this environment from recommendation lists provides some genetic protection against stem rust epidemics.

As the name implies, stem rust can be found on the stem but is not confined there. It also may be found on leaves, sheaths, peduncles and the heads (Fig. 20). The infection first appears on wheat as reddish-brown elongated pustules that produce urediospores (Fig. 21).

Urediospores are the repeating spores that can be easily transported by the wind and continue to reinfect wheat. The pustules of stem rust are usually larger than those of leaf rust. Also, the epidermis of the leaves and stems is ruptured and pushed back around the pustule (Fig. 22, 23). This rupture aids in excessive water loss from the plant. As the wheat plant matures, the pustules begin to produce the black spores known as teliospores.

On the alternate host (barberry), infection occurs from germinating teliospores from wheat and the disease appears first on the upper surface of the barberry leaf as an orange pustule. Later yellow-orange, horn-like projections develop on the lower surface of the leaf. Spores produced from the barberry are blown into nearby wheat fields, where the uredial stage redevelops.

Since the barberry is involved in the complete life cycle of the fungus, destruction of the barberry, where possible, is one method of management. Elimination of the barberry reduces the chance of new physiological races being developed. Because varieties are replaced every few years to maintain resistance from powdery mildew, leaf rust or other pests, most southeastern wheats are susceptible to stem rust. Early-maturing varieties, although susceptible, will escape damage. Stem rust is seen every season in the Deep South. Fungicides may be used to manage stem rust when economically feasible. Feasibility is determined by evaluating yield

potential, crop value, varietal susceptibility, earliness of disease and long-range forecast for wet weather.

Stripe Rust (*Puccinia striiformis*)

Stripe rust, also known as yellow rust and glume rust, is normally confined to higher elevations and cool climates, such as the Pacific Northwest. It can, however, be found in more temperate areas during persistent cool weather. Although previously rarely found in the southern United States, stripe rust has caused light to moderate economic loss in the lower Mississippi Valley region in recent years.

Symptoms of stripe rust vary but are most severe during cool, wet, spring weather. Stripe rust occurs early in the spring before other rusts, especially in areas with mild winters. Yellow uredia appear on foliage then coalesce to produce long stripes between veins of the leaf and sheath (Fig. 24, 25). Small, linear lesions occur on floral bracts. Telia develop as narrow, linear dark brown pustules covered by the epidermis.

The stripe rust fungus overwinters as urediospores on volunteer cereals and grasses during the period between harvest and emergence of wheat planted in the fall. Mycelium, and occasionally urediospores, remain viable over the winter in or on various cereals. Urediospores are formed during cool, wet weather and are wind-borne to healthy plants to cause infection. Disease development is most rapid between 40 and 59 degrees F, with little infection occurring above 59 degrees F. Warmer than normal winters and cooler spring weather favor stripe rust epidemics.

Disease management is accomplished by using resistant cultivars, maintaining well-fertilized soils, especially with potassium, and using foliar fungicides.

Tan Spot (*Pyrenophora tritici-repentis*)

Tan spot can be serious by itself or it can contribute to leaf spotting complexes in which several diseases are involved. The disease occurs on wheat, brome grass, wheatgrass and rye. Symptoms first appear in spring on lower leaves and progress to

the upper leaves in late spring and early summer. Symptom development is favored by frequent rains and cool, cloudy, humid weather. At first, tan flecks appear on both sides of the leaf. The flecks eventually become diamond-shaped lesions up to 1/2 inch long, with a yellow border and a dark brown spot in the center that is caused by sporulation of the pathogen (Fig. 26). Lesions may coalesce causing large areas of the leaf to die, usually from the tip inward. Tiny raised, black sexual fruiting bodies called pseudothecia will eventually develop on the straw.

After wheat harvest, the pathogen persists on plant debris. It has increased substantially in the Midwest and Plains states, where debris remains on the soil surface in conservation tillage systems. It has not been as much of a problem in similar cropping systems in the Southeast, perhaps because of a more rapid rate of debris decomposition, but incidence has increased in Louisiana recently. The sexual fruiting bodies mature on wheat straw during fall and winter and release ascospores (sexual spores) as primary inoculum throughout the growing season. Sexual spores of the *Pyrenophora* stage are dispersed by wind, as are conidia (asexual spores) of the *Drechslera* stage, which appear from jointing stage to crop maturity. Wheat infections are most numerous near host residues. Infections, which require at least six hours and as long as 48 hours of leaf wetness, occur throughout the growing season. Yield losses are most severe when infections develop during heading and damage flag leaves. Conidia produced in older leaves serve as secondary inoculum and are wind-borne to hosts. Seed-borne inoculum appears to be insignificant.

The decomposition of wheat stubble and crop residues limits multiplication and primary inoculum of the pathogen. Crop rotation with non-hosts also is advised.

Septoria tritici Blotch (*Septoria tritici*)

Septoria tritici causes a leaf blotch in many parts of the eastern and southern wheat-growing regions. It is not found in

the warmest areas in the region, however, such as the piedmont and coastal plain area of Georgia, Alabama and Florida or the coastal region of Louisiana and Mississippi.

The first symptom of leaf blotch is the appearance of small, light green or yellow areas between the veins of the lower leaves. These areas elongate rapidly to form light brown to reddish-brown irregular lesions often partly surrounded by a yellowish band. As the lesions age, they turn light brown to ash-white, with many black specks in the centers. These specks are pycnidia, and their presence is the most reliable criterion for identifying the disease. As the lesions increase in size and number, they interrupt the water supply to the leaf tips and result in a progressive dying of leaf tissue. *Septoria tritici* blotch infections also may occur on the leaf sheaths and stems of wheat.

The fungus overwinters either as mycelium in living wheat plants or as pycnidia on dead plant refuse. The overwintering fungus produces an abundance of spores in the early spring. Fall-sown wheat is usually infected during late fall in cool, wet weather. If an extended period of cool, wet weather occurs, the fungus spreads rapidly by rain-splashed spores that germinate and infect the higher leaves.

Temperatures are optimum for germination and infection of *Septoria tritici* between 59 and 68 degrees F. A minimum six-hour period of leaf wetness is needed for infection. Occasionally, all the leaves on a plant are infected, causing premature ripening and defoliation.

The fungus survives the summer on infected plant refuse and in volunteer wheat. It then infects winter wheat seedlings after they emerge in the fall. Infections continue to increase and spread until stopped by winter temperatures that are consistently below 40 degrees F.

Cultural management of Septoria tritici blotch can be obtained through deep plowing of infested wheat stubble as soon as possible after harvesting and by destroying all volunteer wheat and wild grasses before seeding. Foliar fungicides may be beneficial when applied properly.

Stagonospora nodorum Leaf and Glume Blotch (*Stagonospora nodorum*)

Stagonospora nodorum is a fungus that attacks the glumes, stems, leaf sheaths and leaves of the wheat plant. *Stagonospora nodorum* blotch occurs throughout the eastern and southern growing areas of the United States.

Leaf lesions begin as brown or yellow flecks that become more or less elliptical in shape with a brown center and narrow yellow border (Fig. 27). If lesions are numerous, they join to produce an irregular pattern of spots on the leaf (Fig. 28). The fruiting bodies (pycnidia), which develop in the center of the spots, appear as small, dark brown specks partly sunken into the leaf tissue. They are much less conspicuous than the fruiting bodies of *Septoria tritici*. On the glumes, the lesions appear as irregular, chocolate brown spots with pycnidia (Fig. 29). These spots expand quickly and, if disease is severe, the entire head is blighted. The premature loss of green tissue results in shriveled grain. Even 10 percent to 15 percent disease severity on the head can reduce seed weight significantly.

Unlike *septoria tritici* blotch, *stagonospora nodorum* blotch is more adapted to warm conditions. The optimum temperatures for *Stagonospora nodorum* spore germination and infection are between 68 and 80 degrees F. Epidemics of glume blotch occur on wheat when there is excessive rainfall between flowering time and harvest. The fungus survives in wheat straw and chaff and internally in seed. Infected seed may be an important source of primary infection since they often produce infected seedlings. Infected seed is a source of inoculum when wheat is planted in a field rotated out of wheat for several years. Seed-borne inoculum is less important if wheat follows wheat because of inoculum from host debris. *Planting seed from fields with little or no glume blotch and fungicide seed treatment will reduce seed-borne inoculum to very low levels.*

The same cultural practices that manage septoria tritici blotch will help prevent stagonospora nodorum blotch.

Head Diseases

Black (Sooty) Head Molds (several fungi)

Several dark-spored fungi, including species of *Alternaria*, *Cladosporium*, *Epicoccum*, *Sporobolomyces* and *Stemphyllium*, are associated with senescing tissue of wheat plants throughout the life span. Black head molds can be severe if wet weather occurs during maturation, especially if harvest is delayed. Black molds can lower seed quality. Damage from these fungi becomes more severe on heads of plants that are damaged from other diseases such as take-all and *stagonospora nodorum* blotch, nutrient deficiency or lodging. *No practical disease management measures are known beyond a timely crop harvest.*

Fusarium Head Blight (Scab) (*Fusarium graminearum*)

The scab fungus causes seedling blight, crown rot, root rot, stem blight and head blight or “scab” in wheat. This fungus also causes a stalk and ear rot of corn. Therefore, scab tends to be slightly more severe when wheat follows corn in a rotation. Wheat often follows soybeans in doublecropping systems in the Southeast, and scab is less serious in these situations. Damage to wheat from scab varies greatly from year to year and is associated with favorable environmental conditions that occur during flowering. Infection occurs via the anthers, the part of the flower that bears the pollen. Therefore, if the weather is dry when the heads are in flower, little damage will result from head blight. If high humidity occurs during an extended period when anthers are present, however, invasion by the fungus increases and chances are good that mature wheat heads will be seriously damaged by head blight.

Infected spikelets turn light yellow in contrast to the green of healthy spikelets. As the wheat ripens, the infected spikelets turn white. This whitening of the head is the most recognizable symptom of scab. The entire head is usually not involved. In wet weather, a pink or salmon color appears at the base of the spikelets or

along the edge of the glumes (Fig. 30). Scab-infected heads are usually scattered randomly throughout the wheat field (Fig. 31, 32). At harvest, infected spikelets become speckled with small black dots, which are the spore-bearing structures of the sexual or *Gibberella* stage of the scab fungus. Severely diseased seeds are light, pinkish-white and often referred to as "tombstones."

The pathogen survives either on living wheat or on crop residue. In the fall, masses of spore-producing bodies are found on wheat residue. *Fusarium* spp. spores from the residues infect the wheat heads during blossom, and freshly produced spores from infected spikelets can be blown by wind and rain to infect other heads.

The scab fungus also survives as spores on the surface of grain from infected heads. This grain, when used for seed, can result in seedling blight. Wheat seedlings attacked by *F. graminearum* are stunted, yellow and usually die. Diseased roots have a reddish-brown rot and are often covered with a gray to pink mold. Infected seedlings that survive have abnormal tillering or produce a single stem with a small head containing shriveled grain.

Occasionally, the scab fungus will cause a root or crown rot as wheat approaches maturity. Sometimes it will attack wheat plants at the stem joints or leaf sheath, causing the plant parts above the infected joints to die or produce empty, bleached heads. This stem blight is often mistaken for insect damage.

Scab damage can be somewhat reduced by plowing under infected wheat stubble, corn stalks and rotted corn ears. If possible, do not follow corn with wheat. Use only thoroughly cleaned, treated seed.

Loose Smut (*Ustilago tritici*)

The disease is easily recognized at the time of heading by the characteristic dusty black appearance of diseased heads that emerge from the boot slightly earlier than those of healthy plants. Usually all the floral structures in a head are completely transformed to black powder (Fig. 33, 34). This sooty mass is composed almost

entirely of millions of microscopic smut spores. The smutted heads disintegrate easily and, by harvest, only a bare rachis remains.

Infection of the wheat plant takes place from shortly before until two days after the flowering period. Maximum infection occurs during flowering. Wind, rain and insects carry the spores from a smutted head to the flowers of a healthy head. The spores germinate quickly under moist conditions and grow down the stigma and pistil (female parts of the flower) to infect the young embryo (seed). Infection also may occur by direct penetration of the embryo wall. After establishing itself in the developing kernel, the smut fungus becomes dormant. Smut-infected seed look normal, and there is no effect on germination. When an infected kernel is sown and begins to sprout, the smut fungus becomes active again and grows systematically into the young shoots to the growing point. The fungus develops with the wheat plant and invades the developing floral tissues. By heading, the mass of smut spores has completely replaced the tissue and only a black, smutty head appears. Consequently, the amount of the infection that occurs in any one year is the result of infection taking place the previous year.

Since loose smut is not surface-borne on the seed, contact fungicide treatments are not effective. An effective control must kill the fungus inside the seed without injuring the germ of the seed. Most southern states recommend the use of systemic seed treatments to control loose smut. Loose smut is a potentially serious disease each year throughout the southern United States. Other smut diseases of wheat, such as common bunt, do not occur except when infested, untreated seed from other parts of the United States are planted.

Certified seed is inspected for loose smut, and only a very low level is tolerated. Grower-saved seed that has not been treated is the most likely situation where loose smut and common bunt will be found.

Diseases Caused by Viruses

Barley Yellow Dwarf (barley yellow dwarf virus) (BYDV)

Susceptible grain cultivars are susceptible to attack by the virus in all stages of growth. This disease can be severe on barley, oats and wheat. Infected barley usually has bright yellow leaves, whereas oat leaves turn red when the disease first appears. On wheat, symptoms are much more variable. There may be varying degrees of yellowing and purpling (Fig. 35, 36), depending on the cultivar, which is often difficult to differentiate from cold injury early in the spring or the onset of senescence later.

New growth of wheat plants infected in the seedling stage is chlorotic, whereas the older leaves of these plants are darker green and smaller than those of healthier plants. Diseased plants may be severely dwarfed, sparsely tillered and produce few heads, or heads with little or no seed. Plants that become infected after the tillering stage are not dwarfed but are a little shorter than healthy plants.

Affected plants may have a 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 symptomatic plants. Infected plants frequently occur in random, small groups (Fig. 37). Large portions of fields or entire fields can be affected.

Barley yellow dwarf virus (BYDV) is transmitted from infected grasses into wheat and barley by several species of aphids. The bird-cherry oat aphid and, to a much lesser extent, the corn leaf aphid are the most important vectors in the fall. In the spring, overwintered bird-cherry oat aphids and migrating English grain aphids are the most important vectors. Regardless of the aphid species, winged adults migrate into wheat fields from neighboring and distant sites, feed and deposit live young on plants. Typically, they develop into wingless adults

that produce more offspring over several generations. Wingless aphids spread gradually in fields by crawling from plant to plant, leaving behind their young.

BYDV is transmitted into wheat by the feeding activities of both winged and wingless aphids. Aphids acquire the virus by feeding on diseased plants for as little as 30 minutes. 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.

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 crop emergence. Normal or higher rainfall during the summer usually means an adequate amount and quality of host crops (some infected by BYDV) for aphids during the summer. During a drier than normal summer, fewer aphids are produced because of reduced host plant quality. For the same reasons, a larger proportion of BYDV-infected host plants die because of the extra stress.

Crops that emerge long before a hard freeze have more 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.

Aphids arriving in the field during the fall continue to move, feed and reproduce as long as temperatures remain above about 48 degrees F. Mild temperatures or some insulating snow cover during cold spells usually results in significant survival of the aphids during the winter. Harsher weather results in higher mortality. BYDV-infested

aphids that survive the winter are a primary source of BYDV increase in the spring.

The English grain aphid has a spring flight and arrives around spring greenup time. The numbers of these winged aphids 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 into fields.

Plant after the Hessian fly-free date. Plant wheat varieties tolerant to BYDV. Limiting BYDV infection by controlling aphids with insecticides can be successful, but the results are erratic. The greatest probability for the successful use of insecticides exists when the following criteria are met: the crop is planted before the fly-free date or first killing frost; crops were not drought-stressed during the previous summer; 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 10 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 10-aphids-per-row-foot level is reached in the fall or spring, 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 apply an insecticide. If it turns cold after the application, wait and scout again in the spring. If the fall is mild and winged aphids continue to arrive in the field, 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 of 10 aphids per row foot is reached before flag leaf emergence. Failure to make the necessary spring applications may negate any gains associated with fall applications.

The above aphid treatment guideline is not chiseled in stone. In some years, 10 aphids 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. But, until our understanding of BYD epidemiology and aphid biology is en-

hanced by new research, the 10-aphids-per-row-foot treatment guideline is the only one available with any experimental basis.

Wheat Streak Mosaic (wheat streak mosaic virus)

Development of wheat streak mosaic virus disease depends on three factors: (1) the population level of the tiny wheat curl mite, *Aceria tulipae*, which is the vector of the virus from infected plants (wheat, corn, grass, etc.) to virus-free wheat plants, (2) the closeness of virus-infected plants, especially volunteer wheat, to newly emerging wheat and (3) moisture to keep the wheat in a vigorous growing condition where mites attain maximum reproduction.

The largest losses occur in fields with early-seeded, fall-infected plants. Infected plants that survive may head, but the heads are mostly sterile. Plants that become infected in the early spring develop leaf symptoms, but generally yield loss is low.

In some fields a severe reduction in yield and grade of grain often results from complete or partial sterility and shriveled kernels. If infection occurs early with a severe strain of the virus, the plants may die before maturity. Synergistic effects are suspected between wheat streak mosaic and other cereal viruses, for example, barley yellow dwarf and certain leafhopper-borne viruses. This makes field identification of these diseases very difficult. Inoculation of indicator test plants are helpful in positive diagnosis. The ELISA test is most accurate. The symptoms also vary, depending on the virus or virus strain, variety of wheat, temperature, time of infection, level of plant nutrition, soil temperature and other factors.

Although winter wheat is commonly infected in the fall, symptoms of wheat streak mosaic do not normally appear until the onset of warm weather or the following spring. The first symptoms consist of light-green to faint yellow blotches or streaks in the leaves, parallel to the veins. Later, affected plants appear stunted and show general yellow mottling, except for a few green streaks or blotches in the leaves. Diseased plants are usually yellowed and moderately to severely stunted; they tend to spread out more than normal and frequently

develop an abnormally large number of tillers. Tillers in the same plant may vary considerably in height. It is not uncommon to find stunted plants with sterile heads still standing after harvest, just the height of or shorter than the stubble. As infected plants mature, the yellow striped leaves turn brown and die.

Management measures for wheat streak mosaic are aimed at destroying the populations of mites that transmit it and other sources of the virus. This is best done by destroying all volunteer wheat, old wheat stubble and weed grasses in fields two weeks before planting in adjoining fields and three to four weeks before sowing in the field to be seeded. The best management results when all wheat farmers in a community cooperate in destroying volunteer wheat and removing old stubble before planting. Avoid fields near tree lines since grasses in these areas can harbor mites and low levels of the virus.

Soilborne Wheat Mosaic (soilborne wheat mosaic virus)

Soilborne wheat mosaic (Fig. 38) occurs throughout the United States. Normally, only fall-sown wheat develops symptoms, although spring wheat also is susceptible. Symptoms also develop on barley, rye and hairy bromegrass. Other names for this disease include eastern wheat mosaic, green mosaic, yellow mosaic and mosaic rosette. Losses to soilborne mosaic vary with cultivar, virus strain and environment.

Soilborne wheat mosaic virus survives in the soilborne fungus *Polymyxa graminis*, a parasite in the roots of many plants. The fungus enters the roots when the soil is water-saturated and cool (50 - 68 degrees F). The virus is spread by any method that disseminates infested soil.

Soilborne wheat mosaic-infected plants first appear in the early spring as yellow or light green areas within a field. The size of the infected area varies, and the infestation usually occurs in low spots in the field. The wheat in the diseased area may be severely stunted in the early spring and recover later. Under unfavorable growing conditions, infected plants will remain dwarfed to maturity.

Some cultivars exhibit rosetting if infection occurs in the fall. Such plants are bluish-green and remain so throughout the growing season. At other times, rosetted plants die early without developing much green color.

*Management may be accomplished by rotating wheat with non-cereal crops and by planting cultivars that are resistant to *Polymyxa graminis*. Since the disease is seen in poorly drained areas of fields, enhancing drainage will help.*

Wheat Spindle Streak Mosaic (wheat spindle streak mosaic virus)

Wheat spindle streak mosaic, also known as wheat yellow mosaic and Ontario soil-borne wheat mosaic, initially occurs on lower, older leaves during cool weather in the spring in areas such as Tennessee and Kentucky, but may be seen much earlier farther south. Symptoms tend to be uniformly distributed throughout a field. Temperatures above 64 degrees F prevent symptom development on younger leaves. The first leaves produced in spring have yellow-green mottled streaks or dashes. Streaks are oriented parallel with leaf veins and have tapered ends resembling spindles (Fig. 39). As leaves mature, yellow-green areas may be replaced with brown ones, depending on the wheat cultivar. Severely diseased plants remain slightly stunted and have fewer tillers, reducing yield. In moderately to slightly infected wheat, yields are affected very little if at all. Symptoms go into remission as the season progresses and temperatures rise.

The virus that causes the disease is transmitted by the fungus *Polymyxa graminis*. It may survive for years in soil apart from wheat culture or it may also survive at low levels in roots of resistant wheats. Autumn infections are most important and account for symptoms produced in late winter and early spring. Winter temperatures in the Southeast are similar to temperatures of early spring when the disease occurs in the Midwest and eastern Canada. Severe symptoms were observed in Georgia as early as late January. Yellowing and stunted growth, resulting in fewer tillers

and reduced root growth, make these plants susceptible to winter-kill. Since both soil-borne wheat mosaic and wheat spindle streak mosaic are transmitted by the same vector, mixed infections may occur. Any practice that will disseminate infested soil

will spread *Polymyxa graminis* and the virus.

Many cultivars are resistant. Delaying fall planting and avoiding consecutive susceptible cultivars are effective management practices.

Diseases Caused by Bacteria

Bacterial Streak and Black Chaff (*Xanthomonas campestris* pv. *translucens*)

Bacterial streak is the most common bacterial disease of cereal crops in the Southeast. The pathogen attacks wheat and other grasses. All of the above-ground parts of the plant may be affected, but the disease occurs most commonly on the leaves and glumes. Wheat is invaded through natural openings and wounds and supports the bacterium intercellularly. It is spread by splashing rain, overhead irrigation, plant contact and possibly by insects. Bacterial streak has become important in recent years in the lower Mississippi Valley area.

The early symptoms appear as small, light-brown water-soaked spots or streaks (Fig. 40, 41). The lesions tend to develop between the veins early, but eventually expand and coalesce, producing irregular gray-brown blotches (Fig. 42, 43). Under high humidity such as heavy morning dews, droplets of yellow bacterial slime exude from the lesions. Small yellowish granules or thin shiny scales form on the surfaces of leaf blades when the exudate dries. As the disease progresses to the leaf sheaths and adjacent culms, the stems have a dark, stained appearance and become weakened. Wheat grazed or cut early in the season for forage may exhibit more leaf streak because the bacte-

rium easily invades leaf wounds. The bacterium is spread mechanically by forage-cutting machinery.

The name black chaff is used to describe the disease on the head of the wheat plant. The neck (peduncle) also is often diseased (Fig. 44, 45). Black chaff is recognized by the dark, linear, water-soaked streaks on the glumes (Fig. 46, 47). Usually the symptoms appear first on the upper parts of the glumes. As the disease develops, the lesions merge, darkening the glumes and peduncle. When the disease appears early and is severe, infected heads are dwarfed, spikelets fail to develop, heads are twisted, discolored and badly blackened. The disease may sometimes be difficult to recognize because it may occur together with stagonospora nodorum blotch or other leafspot diseases caused by fungi. At later stages of disease development, watersoaking and bacterial exudate may not be readily apparent.

When wheat matures, the bacterium is returned to soil in crop residues. As a result, crop rotation and deep plowing are the best methods available to manage the disease. Seed is an important means for carryover of the bacterium to the next crop. Seed stored six months or more before planting is not an important source of inoculum.

Diseases Caused by Nematodes

Root-knot nematode (*Meloidogyne* spp.)

Root-knot nematodes are common pests of wheat throughout the United States.

Three species of root-knot nematode are found within the growing range of soft red winter wheat. These are the southern root-knot (*Meloidogyne incognita*), the Javanese

root-knot (*M. javonica*) and the peanut root-knot (*M. arenaria*) nematode. Their host range is fairly wide, with implications not only for wheat, but subsequent crops.

Root-knot nematodes attack the roots of wheat, forming small galls in the area around where they begin feeding. Typically, these galls are not visible until late in the spring and may be associated with chlorotic and stunted plants. Most of the time when root-knot nematode is present, there are no noticeable foliar symptoms.

The three species of root-knot nematodes that attack wheat prefer warm or hot conditions. They do best when soil temperatures are above 59-65 degrees F. There is only a short time in the fall and late in the spring when soil temperatures are favorable for these nematodes to be active. Under favorable conditions, the nematodes move into the roots within a few days after emergence. The life cycle is fairly long during this winter phase, taking several months to complete. Usually there is only one life cycle on wheat, compared to four to five on a crop grown during the summer.

Differences have been observed in the reaction of root-knot species or within species on varieties of wheat. The Javanese root-knot reproduces slightly better on wheat than the other species. There are four races of the southern root-knot nematode. Race 2 of southern root-knot nematode has a much higher reproduction on wheat than other races, but fortunately is not nearly as common as some of the others.

Although most southeastern states report only minimal losses of wheat to root-knot nematode, the greatest problem may be with the subsequent crop. Root-knot nematodes decline dramatically during the winter; only about 5 percent to 10 percent of the fall population survives to attack the next crop. Although root-knot nematode may increase on wheat, population levels are still much reduced from the initial fall levels. The root-knot population will be higher after wheat than on fallow ground. The increased population in the spring may cause more serious injury to any susceptible crops that are planted next. Soybeans are one of the primary crops grown in associa-

tion with soft red winter wheat and are readily damaged by these nematodes.

Management of root-knot nematodes usually is limited to cultural methods. Because of the temperature influence on root-knot development, planting date appears to be the best method of limiting problems. Delaying planting until the near the end of the planting season will prevent any infection by the nematodes during the fall. Since the wheat crop will be almost mature before soil is warm enough again for nematode development, little if any damage will occur in the spring. At present, little research is conducted to develop wheat varieties with strong resistance against root-knot nematode.

Lesion nematode (*Pratylenchulus* spp.)

Lesion nematodes are another type of nematode. They occur throughout the wheat-growing regions. Lesion nematodes have been reported to cause stunting, chlorotic foliage or even stand loss. These nematodes are endoparasites that tunnel through the wheat roots. Typical symptoms of damage on the roots are lesions ranging from light to dark areas. When damage is severe enough, considerable rot and decay may be evident on the root systems. Lesion nematodes prefer to attack young roots rather than the older roots.

Several species of the lesion nematode occur where soft red winter wheat is produced. Species such as *Pratylenchulus neglectus*, *P. scribneri* and *P. penetrans* are fairly common within our region. Like many nematodes, these lesion species can attack not only wheat but a wide variety of crops as well, making crop rotation very difficult as a management option.

Very few options are available to manage lesion nematodes. The wide host range of most of the lesion species includes many field crops such as cotton, corn, tobacco, soybeans and vegetables. Since some differences in crop response have been observed with lesion nematodes, at least changing crops or crop types (grasses vs. broadleaves) may help. Nematicides are simply not available to use or, in the case of the only

pre-plant fumigant Telone, too expensive to justify the cost.

Other nematodes

Several other types of nematodes have been associated with wheat. In the past, the wheat gall nematode (*Anguina tritici*) was an important pest of wheat. The wheat gall nematode is unusual in that, instead of attacking the roots of plants like the previous nematode, it attacks the growing point and particularly the flower buds. As soon as the nematode attacks the flower, it develops a gall instead of normal seed. These dark, black galls may contain 10,000-90,000 juveniles. The juveniles remain in a dried state after harvest until the galls are planted with the next wheat crop, starting the nematode cycle again. The nematodes in these galls have survived for 25 or more years. Modern harvesting and cleaning systems have practically eliminated this nematode pest in the United States.

Stunt nematodes (*Merlinius brevidens* and *Quinisulcius acutus*) are frequently found in wheat, but only *M. brevidens* causes significant losses on wheat. Stunt nematodes feed as ectoparasites on root hairs and epidermal cells. *There are very few management options available for this nematode since, like many other nematodes, it has a wide host range and nematicides are not readily available.*

Two other nematode types on wheat have been reported from Florida. These are sting nematode (*Belonolaimus longicaudatus*) and stubby-root nematode (*Paratrichodorus* sp.). Both prefer sandy soil and are common throughout the southeastern United States. Sting and stubby-root have long stylets and feed on the growing tips of roots, causing extensive damage. *Management options for either of these nematodes are limited. Rotations are not very useful because of the wide host range of both nematodes. Nematicides are not available.*

Summary

Wheat plants are treated as populations and not as individuals; thus, disease management is attempted for the entire plant population. Diseases of wheat are managed through the manipulation of the plant disease triangle to disrupt the conditions necessary for establishment and development.

Disease resistance is the most economical and most widely used method for management. Unfortunately it is not always available for use against all pathogens, but some instances it is the only available method.

Resistance may be lost rapidly, especially to pathogens that develop new strains in a short time such as rusts and powdery mildew. There are measures that can be used to prolong resistance, however. Cultivars with "slow rusting," in which resistance is controlled by several genes rather than one, is an example. Any management strategy that reduces inoculum pressure on the variety is likely to increase the useful life span of the variety.

Cultural management methods limit the occurrence and severity of some wheat diseases. These methods should be used with other management methods to reduce inoculum levels.

The use of clean, disease-free seed to establish a wheat stand is essential. Seed quality is one of many factors affecting yield. Good quality seed is true to variety, free of other crop seeds, weeds, foreign material, diseases, insects and has plump kernels of high germination.

Seed that is damaged or shriveled will come in contact with soilborne organisms when planted, giving rise to damping-off or seedling blight problems. Many states suggest that seed be chemically treated to control specific seedborne or soilborne diseases. The best way to ensure high quality seed is to plant certified seed produced under the direction of a state crop improvement association or similar agency.

The date of seeding influences, to some degree, the amount of disease experienced

within a growing season. For example, early sowing influences the amount of seedling blight and increases the risk of take-all and many virus diseases. Leaf rust, powdery mildew and Septoria diseases and insect-vectored and fungal-transmitted viruses may be reduced or avoided by delaying fall seeding.

Disease losses can be minimized by a balanced fertility program that allows for the vigorous, but not excessively lush, growth of the wheat plant. Certain elements will influence the amount of disease. For example, high nitrogen levels enhance powdery mildew, strawbreaker foot rot, Septoria diseases and take-all.

Tillage often benefits disease control by promoting the destruction of crop residues that provide a source of food and habitat for many wheat pathogens. Reduced tillage or no-tillage may increase the severity of most soilborne diseases. Deep tillage has been suggested as a good cultural practice to reduce some foliar diseases such as septoria tritici blotch or tan spot, but this form of management is extremely limited on highly erodible soils.

Crop rotation does much to manage certain soilborne wheat pathogens. Continuous cropping results in buildup in the soil and crop residues of populations of wheat pathogens. All other things being equal, the higher the pathogen population, the greater the crop loss. By rotation, the continuity of favorable hosts is broken and the destructive potential is reduced. Rotation also helps to diversify the population of pathogens in the soil. Windblown pathogens like rusts or soilborne pathogens with wide host ranges or long periods of dormancy are not controlled by crop rotation.

Chemical management may be used in conjunction with cultural and genetic management measures or when cultural and genetic management are limited or do not exist. Fungicide recommendations vary from state to state. Local cooperative extension offices have the latest recommendations. Growers should also know the resistance level of the cultivar they plant before they decide to use fungicides. Some fungicides have a broad spectrum of

effectiveness against the major foliar diseases; others may be effective only against certain specific diseases.

Fungicide seed treatment is good insurance against potential damping-off and other seedling diseases and smuts. Seed saved from the previous year should have a high test weight and should be cleaned and tested for germination before planting. In most instances, sowing only certified seed is the best choice. To ensure the establishment of a stand, seed should be treated, especially if wheat is planted early for grazing. Many producers will find seed treatment is the least expensive method of chemical disease management.

Protectants manage seed decay, and systemic fungicides move into plant tissues and are needed for management of internally seedborne diseases such as loose smut. Drill box treatments are generally less effective than commercially treated seed because of uneven coverage. Some of the newer systemic fungicides applied to the seed may provide some protection against fall infection of rusts, powdery mildew and other leafspot fungi.

Fungicides may be used to manage many foliar and head diseases of wheat including powdery mildew, the rusts, tan spot and Septoria diseases.

In general, there are two types of wheat fungicides, the protectants and the systemics. Protectants must be in place before infection to achieve adequate management, while the systemics are able to move into the plant tissue to some degree. Systemics may have both protectant and/or eradivative activity. Those that have eradivative properties can stop disease development even though infection has occurred but give limitation to this activity. Any symptoms present at the time of application will remain, although spore production in some lesions (rust) may be affected. Timing, choice of fungicides and expected return in relation to the cost are critical in deciding whether to apply a fungicide. Consult the local extension service office for recommendations.

The annual cost of crop damage by plant diseases in the United States is in the

billions of dollars. More than half of this loss could be prevented by the proper use of management methods.

An understanding of the life history of the disease organisms, its method of injury, its means of dissemination and conditions favorable for its development and spread is essential when choosing the proper measures for management of any disease. Recommendations for management or prevention of plant diseases are based upon

a knowledge of causal organisms.

Because of difference in the life histories and habits of disease-producing organisms, no set of management measures apply to all diseases. The measures a grower uses should be determined from a knowledge of the number and severity of diseases in her/his locality, their habits of spread and infection, local soil and climatic conditions and, particularly, the prevalence of diseases on the farm.

Glossary

- Antagonistic** - a counteraction between organisms or groups of organisms.
- Anther** - the pollen-bearing portion of a flower.
- Ascospore** - a sexual spore formed inside an ascus by “free cell formation” after the union of two nuclei.
- Bacterium** (plural, **bacteria**) - microscopic, generally one-celled organism that lacks chlorophyll, exists mostly as a parasite or saprophyte and increases by binary fission.
- Blight** - general term for sudden, severe withering and/or killing of leaves, flowers, shoots, fruit or entire plant.
- Coalesce** - to grow or join together into one body or spot.
- Conidium** (plural, **conidia**) - an asexual fungus spore that develops at the end of a conidiophore.
- Crop Residue** - portion of crop plants remaining after harvest.
- Crown** - compacted series of nodes from which shoots and roots arise at the base of the stems.
- Culm** - stem of grasses and cereals.
- Decimal (or Zadoks) Scale** - a system for describing the growth stages of wheat using a scale of 0-100.
- Disease** - any disturbance of a plant that interferes with its normal growth and development and leads to development of symptoms.
- Disease Management** - an attempt to use all available methods to manage diseases for the best results with the least cost and the least damage to the environment.
- Double Cropping** - growing and harvesting two different crops on the same land within a year.
- Ear** - the head of a cereal plant.
- Endoparasite** - a parasite that enters and infects its host.
- Epidemic** - a widespread and rapidly developing outbreak of a infectious disease.
- Epidermis** - the outermost layer of cells of leaves, young stems, roots, flowers, fruits and seeds.
- Feekes' Growth Stages** - numerical system associated with specific stages of growth of wheat.
- Flag Leaf** - uppermost leaf of cereals.
- Flag Leaf - 1** - the leaf below the flag leaf of cereals.
- Fleck** - a white or tan minute lesion often translucent and visible through the leaf.
- Floral Bract** - a reduced leaf associated with a flower.
- Fly-free Date** - the fall date when the average temperature inhibits reproduction of the Hessian fly.
- Fungicide** - a chemical or physical agent that kills fungi.
- Fungus** (plural, **fungi**) - a single- to many-celled eukaryotic organism that lacks chlorophyll, usually with a chitinous wall, reproducing by sexual or asexual spores and commonly producing mycelia.
- Germinate** - to begin growth of a seed, spore or other reproductive body.
- Germination** - the process of germinating.
- Head** - a type of inflorescence.
- Hypersensitive** - an extreme reaction to infection.
- Hypha** (plural, **hyphae**) - a largely microscopic tubular filament that increases in length by growth at its tip.
- Infection** - the process of a pathogen entering and establishing a parasitic relationship with a host plant.

Infectious - capable of infection and spreading disease from plant to plant.

Inoculation - the process by which a pathogen is introduced to a host.

Inoculum - a pathogen or its parts which initiates a disease.

Intercellular - between or among cells.

Integrated Pest Management (IPM) - an attempt to use all available methods to manage diseases and pests of a crop plant for best management results but with the least cost and the least damage to the environment.

Internode - the region between two adjacent nodes on a stem.

Leaf Sheath - lower tubular part of a grass leaf that clasps the culm.

Leaf Spot - a self-limiting lesion of a leaf.

Lesion - a well-marked, localized, often sunken area of diseased tissue.

Lodging - lying down or falling over, usually to a weakening of stem tissue.

Metabolism - the process by which organisms use nutrients to build structural components and break down cellular material to obtain energy and simple substances for special functions.

Mosaic - disease symptom characterized by variegated patterns of dark and light green to yellow.

Mycelium (plural, **mycelia**) - the strands of hyphae making up the vegetative body of a true fungus.

Necrotic - dead.

Nematode - an unsegmented, wormlike animal with some types parasitic in or on plants or animals.

Node - enlarged joint on a stem that is usually solid.

Non-infectious - cannot be transmitted from a diseased plant to a healthy plant.

Oospore - thick-walled resting spore in the fungus class Oomycetes.

Partial Resistance - a form of genetic resistance in which the plant becomes infected but symptom expression and production of spores or other propagules is much slower than the fully susceptible response.

Pathogen - an organism or agent capable of causing a disease.

Peduncle - stalk or a main stem of an inflorescence between the uppermost leaf and the head.

Penetration - entrance of a host by a pathogen.

Photosynthesis - the fundamental process by which green plants make sugar from water and carbon dioxide in the presence of chlorophyll using light energy.

Propagule - any part of an organism capable of initiating independent growth when separated from the parent body.

Pycnidium - an asexual usually flask-shaped fruiting body of a fungus.

Reduced Tillage Systems - several tillage methods that leave some crop residue on the soil surface for erosion control.

Resistant - possessing qualities that hinder the development of a particular pathogen.

Rosette - disease symptom characterized by a short, bunchy growth habit.

Sclerotium (plural, **sclerotia**) - a hard vegetative resting structure of a fungus.

Scouting - to look carefully for disease symptoms and signs within a field.

Seed - the mature ovule of a flowering plant.

Seedling - the growth stage of a plant just after germination of a seed.

Slow Rusting - a type of partial resistance in which the period of time between penetration of the plant by a rust spore until a new generation of spores appears (latent period) is much longer than for a susceptible cultivar.

Soft Red Winter Wheat - a wheat grown primarily in the southern and eastern states of the United States that is used for cookies, crackers and crumbly breads.

Soilborne - lives in or originates from soil.

Spore - a one- to many-celled, microscopic reproductive unit in bacteria or a fungus.

Susceptible - lacking resistance or having poor resistance.

Symptom - reaction of a plant to infection and development by a disease organism.
Synergistic - two or more organisms acting at one time and eliciting a host response that one alone could not make.
Telium (plural, **telia**) - pustule of a rust fungus producing teliospores.
Teliospore - sexual spore produced in a telium.
Toxin - poisonous secretion produced by a living organism.
Transpiration - normal loss of water vapor from aerial parts of plants.
Uredium (plural, **uredia**) - the fruiting body of a fungus that produces urediospores.
Urediospore - repeating spore of rust fungi produced in a uredium.
Vigor - the ability to emerge and grow well.
Virulent - highly pathogenic.
Virus - a submicroscopic agent made of nucleic acid and a protein coat that causes disease.



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