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Barley Yellow Dwarf in Small Grains in the Southeast

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Barley yellow dwarf (BYD) is the most destructive viral disease in small grains worldwide. Several years ago, virologists discovered that BYD is caused by two viruses, barley yellow dwarf virus (BYDV) and cereal yellow dwarf virus (CYDV) (Table 1). This complex of viruses will be referred to in this publication as the yellow dwarf viruses (YDV) and the diseases that they cause will be referred to as barley yellow dwarf (BYD). Barley yellow dwarf got its name because symptoms were first described in barley. YDV infection causes barley leaves to become yellow or chlorotic, and when infection occurs in an early stage of the plant's development, it will stunt, or dwarf, the plant. In oats, the disease is commonly known as redleaf disease due to the characteristic red color of the infected oat plants.

Table 1. Current Classification of the Yellow Dwarf Viruses*

Virus	Strains	Genus
Barley yellow dwarf virus (BYDV)	MAV, PAV, PAS	*Luteovirus*
Cereal yellow dwarf virus (CYDV)	RPV, RPS	*Polerovirus*

*The virus strains SGV, RMV, GPV, and GAV have not yet been assigned to either genus.

Aphids carry yellow dwarf viruses from grasses and some crops to wheat fields. Severity of the disease varies from year to year and by location because of the complex interaction among aphids, weather, the virus, and plants. Few management tactics attack the virus directly. Instead, the disease must be managed by cultural practices and by management of the aphids that transmit YDV.

This publication was prepared by experts from Virginia, Kentucky, South Carolina, Georgia, and Alabama. The content will be most appropriate for these states but should apply to other Southeastern states.

Disease Impact

A 3-year survey in the mid-1990s showed a high incidence of BYD in Alabama wheat fields (Table 2). Certain areas in northern Alabama had fields with 100 percent infected tillers and yield losses of up to 60 percent due to YDV infection. Table 3 shows that from 1993 to 1998 the average percentage of BYD incidence in Kentucky ranged from a trace to 70 percent.

Table 2. BYD Incidence and Potential Yield Loss as Observed in a 3-Year Survey of Alabama Wheat Fields (1993–1995)

	Average Percentage	
	Infected Tillers	Yield Loss
Northern Alabama	36	39
Central Alabama	20	39
Southern Alabama	21	33

Table 3. Average Percentage YDV Infection in Noninsecticide-Treated Plots at Two Kentucky Locations in Six Harvest Years

	Location	
Harvest Year	Princeton	Keysburg
1993	59	70
1994	19	4
1995	35	23
1996	Trace	2
1997	Trace	Trace
1998	Trace	-

Host Range

Yellow dwarf viruses infect only members of the grass family (*Poaceae*), including rice, corn, and all small grains, as well as many annual and perennial lawn, weed, pasture, and range grasses. Not all show typical virus symptoms, but they may play a major role in the spread of the disease. At least five different aphid species transmit YDV in the Southeast. These aphids have an extensive plant host range that includes many of the same plant hosts as YDV. This enables both the aphids and YDV to survive in many different environments.

Several strains of the viruses have been identified (Table 1). Historically, strains were named based on their primary aphid vector. In the Southeast, surveys have found that PAV and RPV are the predominant strains.

Disease Symptoms

Symptoms of YDV infection include leaf discoloration, stiffening or curling of leaves, death of leaf tissue, stunting of the plants, reduced tillering, and even plant death (Figure 1). Leaf discolorations can range from yellow in barley, rye, and wheat; to orange or tan in oats; and to red or purple in oats and wheat. Leaf discoloration begins at the tip (Figure 2) and progresses down to the base of the leaf (Figure 3). BYD

Figure 1. A small patch of plants with barley yellow dwarf (BYD) in an otherwise healthy field.

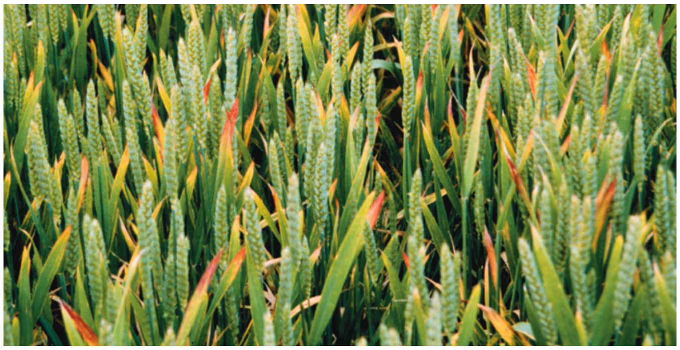

Figure 2. Symptoms of BYD in wheat. Reddening or yellowing starts at the tip of the leaf. Infected leaves are usually twisted.

can easily be mistaken for nutrient deficiency, cold injury, herbicide damage, drought, or other viral infections. Furthermore, YDV symptom expression is highly variable and dependent on factors such as the crop species and variety, virus strain, weather conditions, soil fertility, soil compaction, and stage of the plant at the time of infection. In wheat, early infections usually result in stunting and red-purple to yellow flag leaves in the spring; whereas, spring infections tend to result in discolored, usually yellowish, erect flag leaves without plant stunting. Early spring BYD infections could easily be mistaken for wheat streak mosaic virus or wheat spindle streak virus.

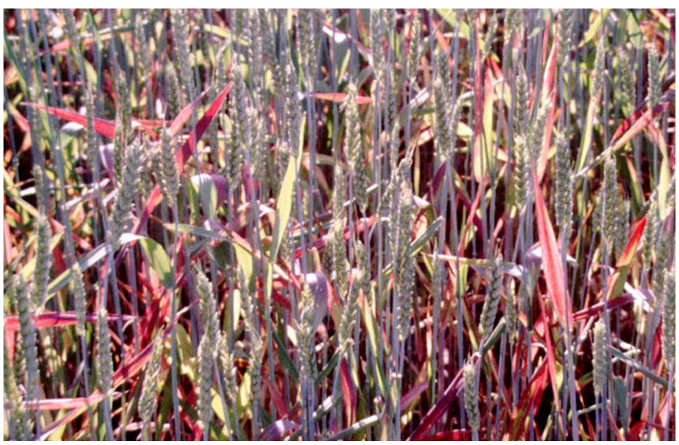

Figure 3. As the virus infection progresses, entire leaves are discolored and may die prematurely.

A reduction in root growth is a less obvious but important symptom of YDV infection. A poorly developed root system cannot provide the aboveground plant parts with sufficient water and nutrients to sustain proper growth. In the Southeast, water may become scarce toward the end of the grain-filling period; consequently, infected plants with poorly developed root systems often die before reaching physiological maturity. Ample water and nutrients will help offset the negative effect of reduced root growth. Under drought stress, field areas with soil compaction have more obvious symptoms than areas without soil compaction.

On a field scale, the formation of numerous, bowl-shaped depressions about 3 to 8 feet in diameter are another symptom of YDV infection (Figures 4 and 5). This "field signature" is especially visible at flowering (Feekes scale 10.5). Infected plants in the center of depressions are stunted and tend to have severe leaf discoloration. Plants toward the perimeter of the patches show less stunting and leaf discoloration. Research in Virginia has shown that these stunted areas yield about 30 percent less grain than nonstunted areas.

Figure 4. A wheat field with many BYD-diseased plants.

Figure 5. The bowl-shaped depression is a typical field signature of YDV.

Several laboratory-based procedures can be used to detect YDV in infected tissues. The procedures vary in technical complexity. Commercial products are available that allow detection of YDV using procedures such as an Enzyme Linked Immunosorbent Assay (ELISA).

Vectors of Yellow Dwarf Viruses

Healthy plants can become infected only after being fed upon by aphids carrying YDV. The viruses cannot be transmitted in seed and are not spread mechanically. Aphids pick up the viruses as they feed on the sap of infected plants, a process that takes from 1 to 48 hours. Before the viruses can be transmitted by an aphid to other plants, they have to travel through the aphid's body to the salivary accessory gland, a process that can take up to 4 days. Once infective, aphids carry the viruses for the rest of their lives, about 21 days under normal conditions. The viruses are not transmitted to the offspring of the aphids. Newborn aphids have to acquire the viruses by feeding on an infected host plant.

Transmission takes place when virus-carrying aphids penetrate a plant with their mouthparts. To enhance penetration, aphids excrete saliva from the salivary canal to soften the plant tissue, which is how the virus is transmitted into the plant. When the viruses are transmitted into a cell other than the phloem cells, they can multiply, but no systemic infection takes place. Only when the aphid releases the viruses into the phloem can a systemic infection take place and the disease develop.

Figure 7. Yellowing symptom in a barley plant infected early in the season. This symptom can resemble normal senescence of older leaves.

Method of Transmission

YDV is moved into wheat fields by winged aphids (Figure 6). These flights of winged aphids can occur any time the weather is warm enough. When virus-carrying aphids land in a field, they feed on plants and transmit the viruses in the process. This is called primary infection. The aphid offspring that feed on these primary infected plants will acquire the virus. When these aphids move from plant to plant, they spread the viruses. This is referred to as secondary infection. Most of the aphids that cause secondary spread are wingless and spread the infection to neighboring plants in the field. Winged aphids that develop on the primary infected plants can also cause secondary spread of YDV.

Figure 6. Winged aphids can colonize the small grain as soon as it emerges.

Aphids that infest the crop in the fall transmit the viruses when plants are in an early stage of development. This early infection (Figure 7) is more damaging than infection in the spring, when plants are more mature. In cold winters, the viruses are likely to be spread only by wingless aphids and movement is limited to neighboring plants, resulting in the bowl-shaped depressions. In mild winters, winged aphids also spread the virus in a scattered infection pattern across the field.

Aphid Biology

Aphids are small insects with soft, pear-shaped bodies and piercing sucking mouthparts. Once aphids find a suitable host, they tend to remain on that plant, reproducing and forming large colonies. Different aphid species can be identified by four structures: the antennae, the feet (tarsi), the knee (joint between two segments of the leg), and the "tail pipes" (cornicles, which are used to secrete alarm chemicals) (Figure 8).

Aphid movement can be categorized as flying, flitting, or walking. Each type benefits the aphid in specific ways and also results in a characteristic spatial pattern of BYD.

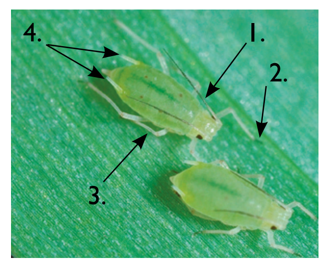

Figure 8. Greenbugs *(Schizaphis graminum);* (1) antennae, (2) tarsi or feet, (3) knee, (4) cornicles or tail pipes (Photo by Jack Kelly Clark; used with permission of the University of California Statewide IPM Project.)

Most adult aphids in a colony are wingless, but a small number in each generation has wings to allow for continual population migration to new host plants. Environmental factors such as poor weather, overcrowding, and reduction in food quality cause more aphids to develop wings, allowing movement away from unfavorable local conditions.

Large populations of winged aphids can travel hundreds of miles in prevailing winds and storm cells. Little is known about the impact of these long-distance immigrants in the Southeast. Locally, individual winged aphids can move from one field to another or from a weed host to a crop field. In the fall, grain aphids move from drying summer grasses to young fall grasses, including small grains, which may introduce YDV into grain fields. Some aphids will make short flights (flitting), a few feet to a few yards, which allow the viruses to move to new spots within a field. Aphids often walk from plant to plant. This gradually expands the area of an existing population and produces near-circular spots of infected plants. The plants infected earliest are near the center and the most recently infected ones are near the edges. The spots expand in size over time.

Aphid life cycles are complicated and vary considerably among species, climatic regions, and even between individual populations of the same species. Within the wheat fields, most of the aphids are females that do not need to mate before producing offspring. These aphids give birth to live offspring, baby aphids instead of eggs. In the South, aphids overwinter as juveniles and adults, but they overwinter as eggs in northern areas of the United States. Temperature determines the extent of winter survival of juveniles and adults. In general, the warmer the temperature, the more aphids can survive, move, and reproduce. Conversely, colder temperatures result in lower survival rates, fewer offspring, and less movement. As a rule of thumb, it needs to be about 50 degrees F for aphids to be active; temperatures below 30 degrees F result in increased aphid mortality. However, some aphids survive even at very low temperatures. A warm, dry winter aids aphid survival and virus spread; whereas, a cold, wet winter reduces aphid survival and movement.

Identification of Aphids That Colonize Small Grains in the Southeast

Six aphid species typically colonize small grains in the Southeast: greenbug, bird cherry-oat aphid, English grain aphid, rice root aphid, corn leaf aphid, and yellow sugarcane aphid. Several of these aphids infest fields at specific stages of plant development.

The greenbug, *Schizaphis graminum,* is bright green with a dark green stripe running down its back and a black ring at the tip of its tail pipes (Figure 8). The mostly black antennae are shorter than the body. Legs are green with black feet. Greenbugs feed on a variety of wild grasses, pasture grasses, small grains, and sorghum. Their feeding causes the leaf cells to redden around the feeding site (Figure 9) and can kill seedling wheat or cause severe yield losses. This is the result of a toxin in the saliva of the aphid. Greenbugs usually can be found in winter wheat from emergence until shortly after flag leaf emergence. Occasionally, they remain in the field until heading. Greenbugs frequently build to damaging levels in Alabama and Georgia; they are less common in Kentucky, South Carolina, and Virginia. Greenbugs are also major pests in winter wheat in the southern Great Plains Region. Greenbugs are only a minor vector of YDV in South Carolina because only a small percentage of greenbugs can transmit YDV.

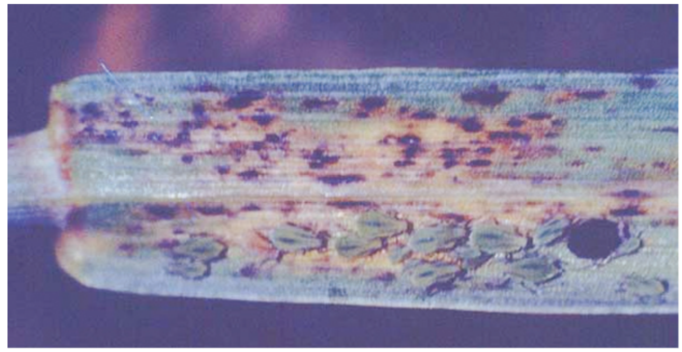

Figure 9. Direct feeding damage by the greenbug on wheat. Note the discoloration on the leaves.

Bird cherry-oat aphids, *Rhopalosiphum padi,* are small, dark green to brown aphids with a reddish orange spot at the tail end and black at the tip of the tail pipes (Figure 10). Bird cherry-oat aphids feed on various grasses. They feed on the leaves, at the base of the plant (Figure 11), and even below ground, where they are easily overlooked. Later in the season, they can also be found in the leaf sheaths. They feed throughout the season, although less often at heading. Bird cherry-oat aphids are important vectors of YDV. In South Carolina (the only state in the Southeast in which the epidemiology of BYD has been thoroughly studied and documented), bird cherry-oat aphids are more commonly associated with yield losses from BYD than any other aphid species.

Figure 10. Bird cherry-oat aphids (*Rhopalosiphum padi*). (Photo by Jack Kelley Clark; used with permission of the University of California Statewide IPM Project.)

Figure 11. Bird cherry-oat aphids often found near the base of the plant.

English grain aphids, *Sitobion avenae,* are large, green aphids that have black feet, knees, and antennae; and long, shiny black tail pipes (Figure 12). Their antennae are longer than their bodies. They are often found in the heads of wheat during grain filling time and can reduce wheat yield by feeding on the wheat heads from head emergence through milk stage. They are commonly seen in the spring from flag leaf emergence to ripening and can build up large numbers. Feeding injury can discolor leaves when aphid numbers are high. In South Carolina, these aphids are primarily late-season (April) vectors of YDV and, therefore, less significant than bird cherry-oat aphid.

Figure 12. English grain aphid (*Sitobion avenae*). (Photo courtesy of Martin Spellman, University of Delaware.)

Rice root aphids, *Rhopalosiphum rufiabdominalis,* are similar in appearance to bird cherry-oat aphids. They have hairy, curved antennae and a black-green to brown-reddish appearance (Figure 13). Winged adults are abundant only in November and December, but wingless forms can be found all season long. Rice root aphids are the aphids most often overlooked because they usually feed on the underground stem and roots of the plant. This may be a serious oversight because these aphids transmit YDV. In South Carolina, rice root aphids are excellent vectors of YDV in laboratory studies, but their abundance was not correlated with field infections, demonstrating that, in South Carolina, this aphid is less economically significant than the bird cherry-oat aphid.

Figure 13. Rice root aphid *(Rhopalosiphum rufiabdominalis)*

Corn leaf aphids, *Rhopalosiphum maidis,* are blue-green aphids with short, black tail pipes (Figure 14). The body is flatter and longer than the bird cherry-oat aphid. The black antennae are about one-third as long as the body. They prefer to feed on corn and sorghum but will colonize wheat (and potentially spread virus) in the fall. These aphids are more cold sensitive than other grain infesting species and disappear as temperatures drop in the fall.

Yellow sugarcane aphids, *Sipha flava,* are sometimes found on wheat, particularly in south Alabama. They are hairy aphids with short tail pipes and an overall yellowish appearance (Figure 15). Sugarcane aphids feed exclusively on grasses, including sorghum, sugarcane, wheat, barley, johnsongrass, and dallisgrass. They are uncommon in small grains in Georgia and South Carolina but are known to infest orchardgrass pastures in Virginia. They have not been found in Kentucky. These aphids, like greenbugs, secrete a toxin into the plant with their saliva. They are not a vector of YDV.

Figure 14. Corn leaf aphids *(Rhopalosiphum maidis).* (Photo by Jack Kelly Clark; used with permission of the University of California Statewide IPM Project.)

Figure 15. Yellow sugarcane aphids (*Sipha flava*). (Photo courtesy of George Teetes).

BYD Control Tactics

Three primary management tactics minimize yield losses to BYD, but none gives 100 percent control. Under the right conditions, a very small number of aphids can have a major impact on BYD incidence and crop yield. It would be easier to manage BYD if the proportion of invading aphids carrying YDV in a given year were known, but this cannot be easily determined.

Factors that usually reduce the risk to BYD

- Avoiding early planting
- Aphid numbers remain below treatment guidelines
- High seeding rate and plant population
- Cold winter with little snow cover
- Late, cool spring
- Hot, dry preceding summer (Kentucky)

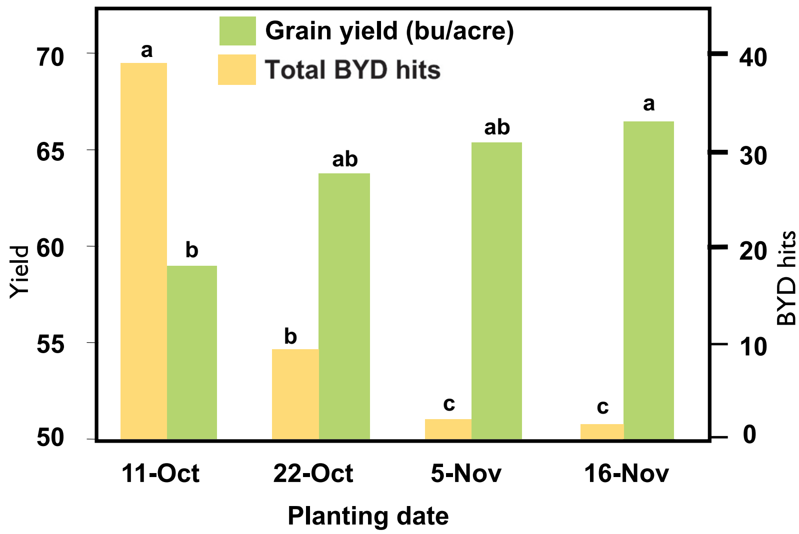

Figure 16. Effect of planting date on wheat yield and BYD incidence, Davis Farm, New Kent Co., Virginia, 2001–2002.

The first, and possibly the most effective, tactic is to avoid early planting (Figure 16). Research shows that fields planted later in the fall have lower aphid populations, which take longer to grow and spread (Figure 17) than do earlier planted fields. Delaying planting until after the first hard freeze, which kills many soft-bodied insects including aphids, leaves fewer aphids to fly into crop fields. In addition, temperatures are generally cool enough to greatly reduce movement and reproduction of the aphids that do arrive in the field.

Planting after the first hard freeze generally minimizes BYD incidence in Kentucky, Tennessee, Virginia, the Carolinas, north Georgia, and north Alabama. However, in the most southerly regions, such as the Coastal Plain, the first hard freeze generally occurs well after the recommended planting date. Keep in mind that planting too long after the recommended agronomic planting interval will reduce yield potential. For planting date recommendations, consult the appropriate wheat production guide for your state.

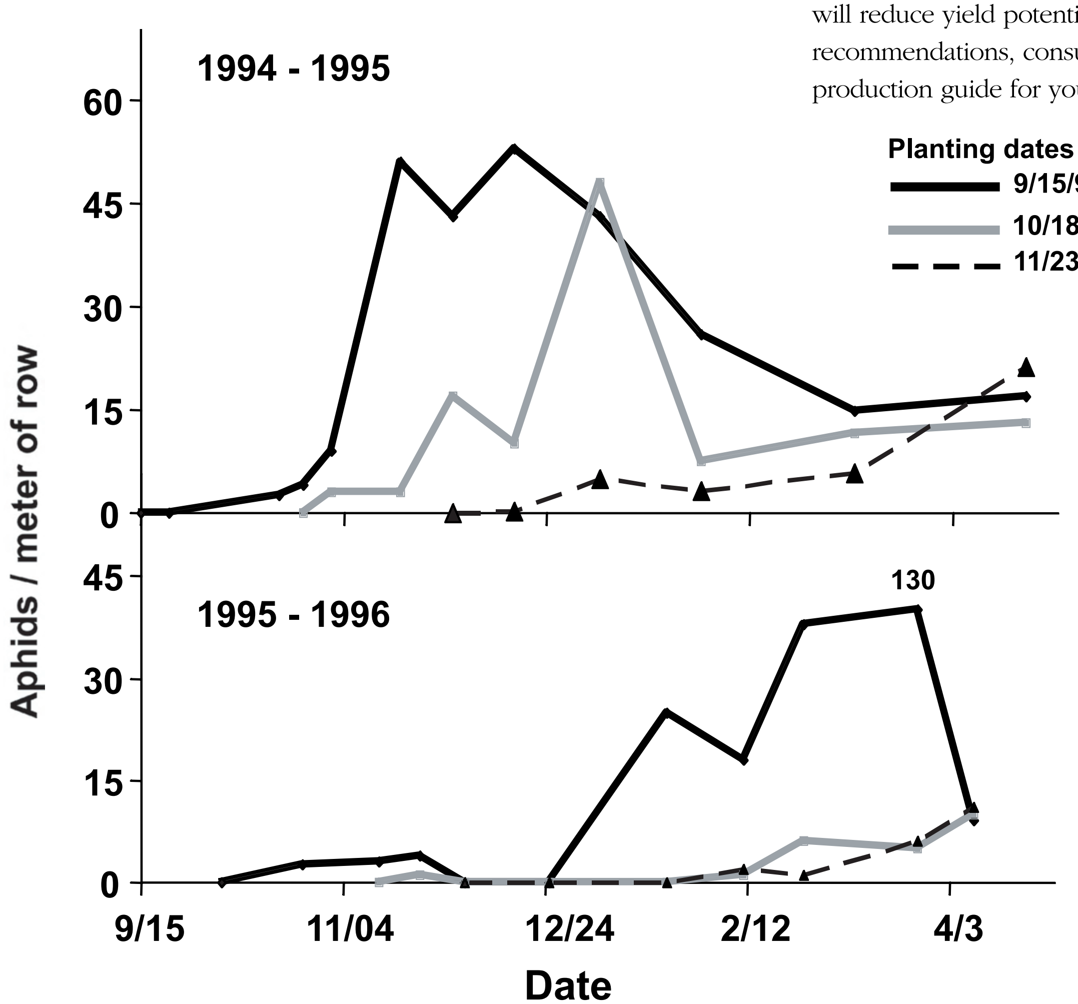

Figure 17. Effect of planting date on aphid numbers in winter wheat, Griffin, Georgia, 1994–1996.

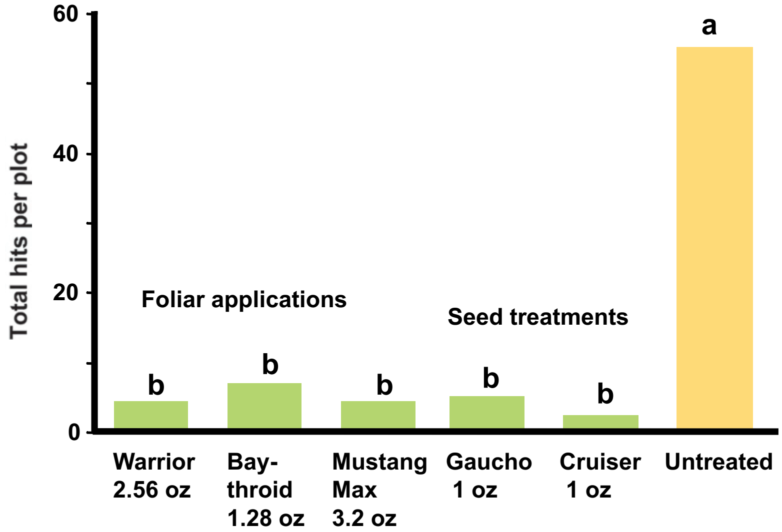

Figure 18. Effect of seed treatments and foliar insecticides applied at 3-leaf stage on BYD in winter wheat, Aigner Farm, Henrico County, Virginia, 2003–2004.

The second tactic for reducing yield losses to BYD is to reduce the number of aphids in the crop. The insecticides imidacloprid (Gaucho, Gaucho XT) and thiomethoxam (Cruiser), applied as a seed treatment, reduce BYD incidence (Figure 18) and result in significantly higher wheat yields than wheat not treated with insecticides (Figure 19). These insecticides have been shown to be effective up to 90 days after planting. Plant back restrictions may be an issue with some seed treatments.

Studies in Georgia and Alabama have found that seed treatments do not provide consistent returns in the more southern locations (Tifton, Plains, Fairhope, Prattville, Tallassee), but positive marginal returns are observed consistently in the northern parts of each state (Crossville, Blairsville,

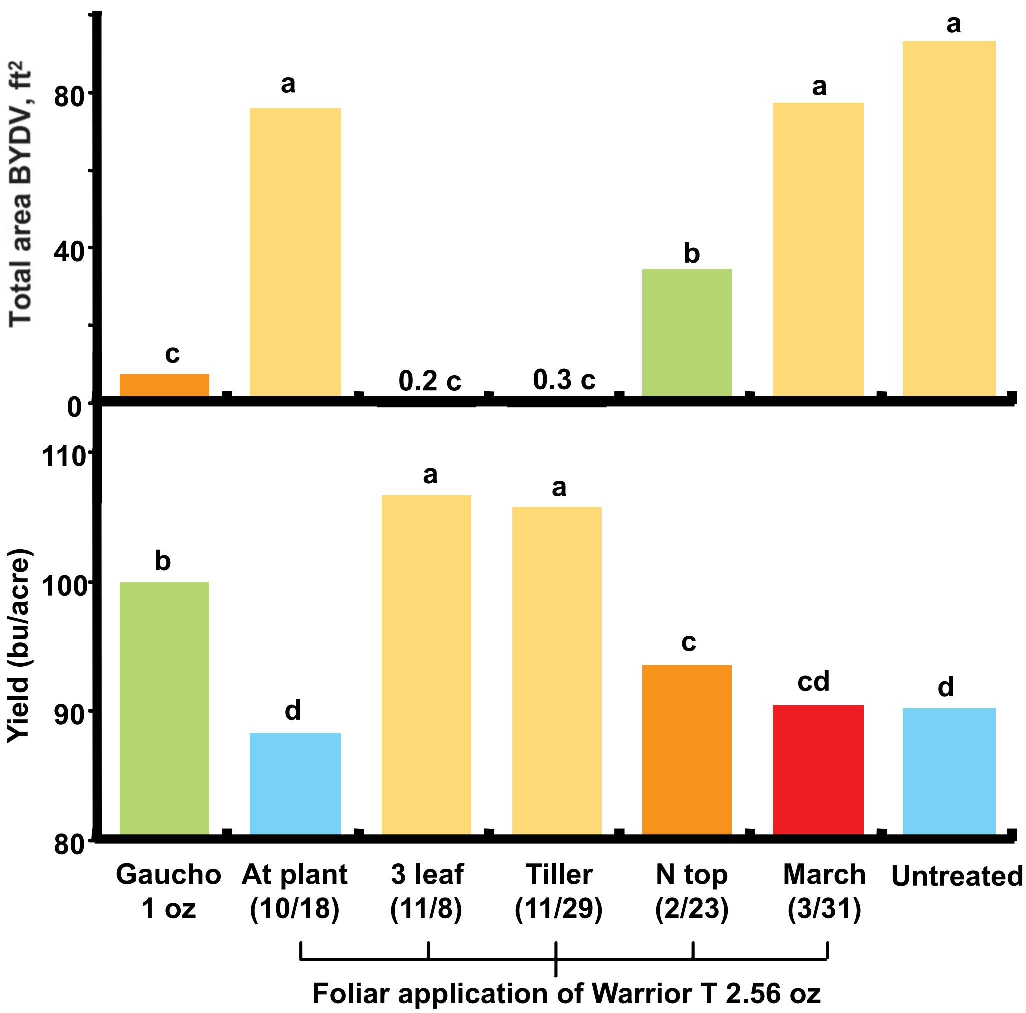

Figure 19. Incidence of BYD and yield in winter wheat plots treated with insecticides, Aigner Farm, Henrico County, Virginia, 1999–2000.

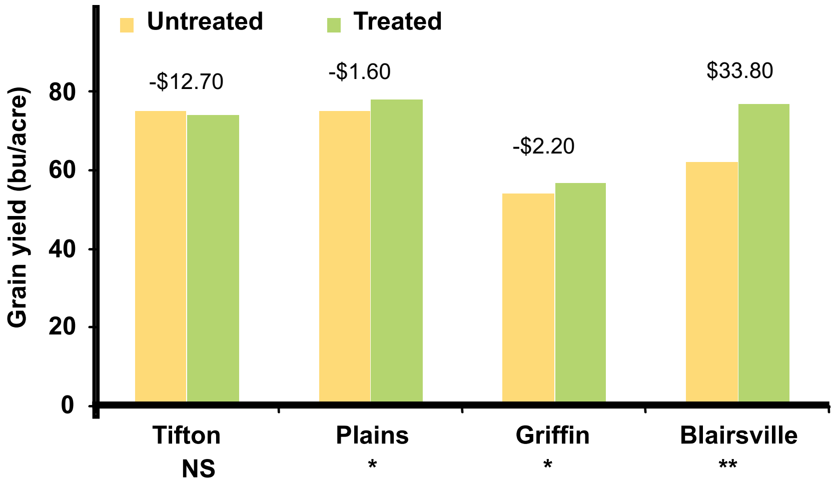

Figure 20. Effect of Gaucho ST seed treatment on grain yield of winter wheat at four Georgia locations, 2004–2005, including marginal return from using the seed treatment based on $10 per acre cost of treatment and crop value of $3.50 per bushel. (NS = no significant difference between treated and untreated; * = significant difference.)

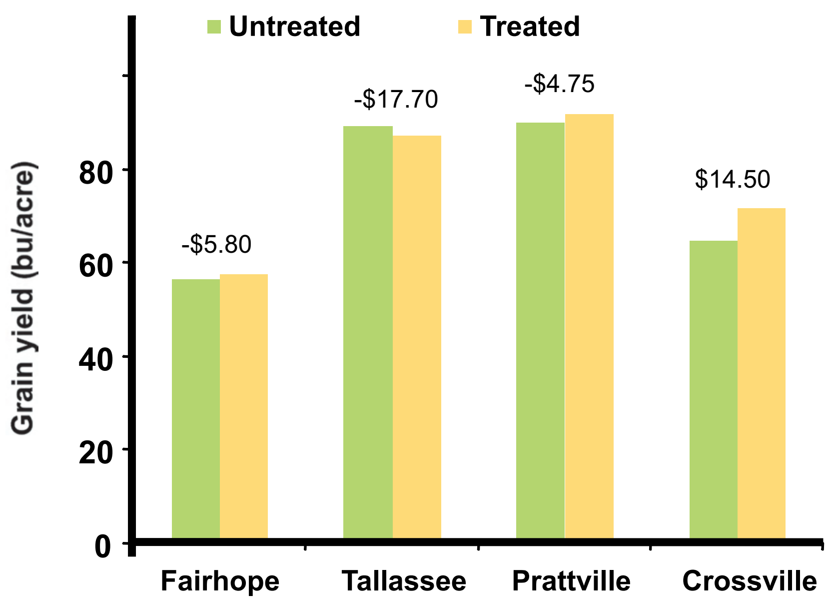

Figure 21. Effects of Cruiser seed treatment on grain yield of winter wheat at four Alabama locations, 2003–2004. Data are averages over three cultivars and two foliar insecticide treatments.

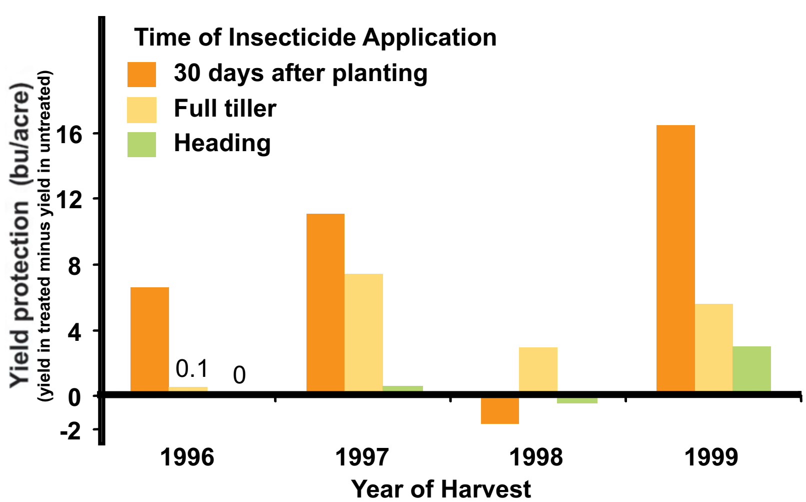

Figure 22. Yield protection resulting from treatment with Warrior Insecticide at three stages in Griffin, Georgia. Wheat was planted in late October each year.

Figures 20 and 21). Research conducted in northern Alabama, using Gaucho at the rate of 1.5 fl. oz. per hundredweight of seed, had a high net return in 2 out of 3 years and paid for itself during the other year of the 3-year study.

Foliar insecticides are another way to control aphids and reduce incidence of BYD (Figure 18). Studies throughout the region have found that organophosphate insecticides kill aphids but do not effectively suppress BYD, whereas pyrethroid insecticides control aphids and are usually effective at suppressing BYD. The most important time for controlling aphids varies from north to south within the Southeast. For example, in Virginia, spraying any time in autumn between the 2-leaf stage and tillering has been shown to be the best time to control aphids (Figure 19). In Kentucky, the timing of autumn applications produces variable results but is more important than late winter or spring applications. In central Georgia (Griffin), an autumn application (30 days after planting) is also best for effective control of aphid populations (Figure 22). In the Coastal Plain region of South Carolina, Georgia, and Alabama, the best time to apply insecticides is with top-dress nitrogen application in early to mid-February (Figure 23). If bird cherry-oat aphids are present at economically damaging levels at these times, a large yield increase can result from insecticide treatment. If they are not present, an insecticide application will be a waste of money and can have the adverse consequence of removing beneficial insects.

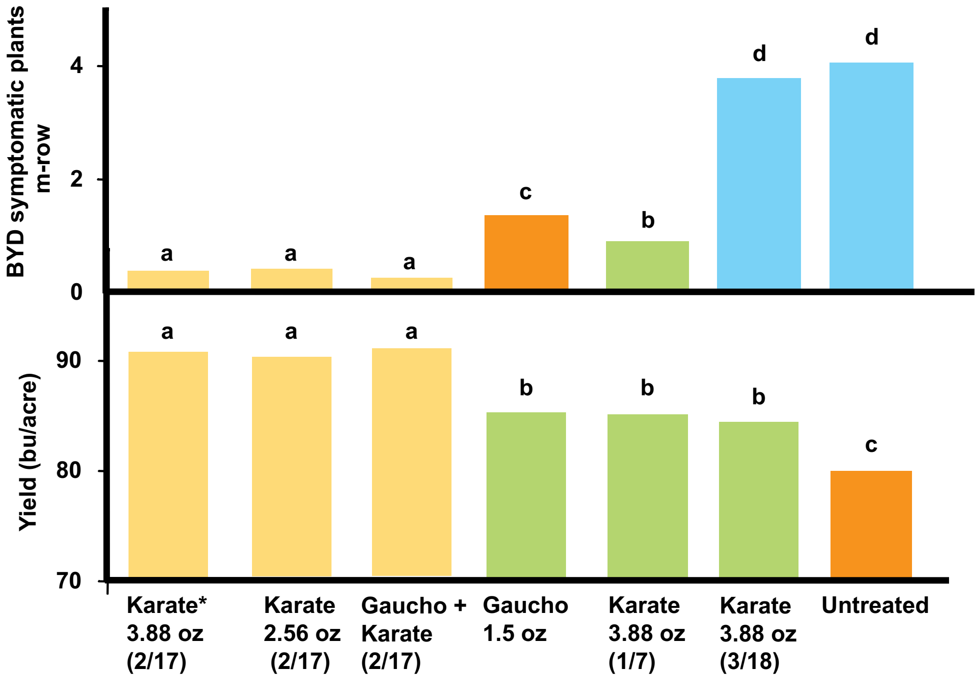

Figure 23. Effect of insecticide treatment and timing on BYD incidence and yield of winter wheat in Blackville, South Carolina, 1997 (wheat planted November 20, 1996) (*Karate 1EC = Warrior T, data for two other nonpyrethroid insecticides omitted).

Positive returns for insecticide use are more likely under intensive management conditions and favorable commodity prices. Low commodity prices and low yield potential limit the value of insecticides for aphid and BYD control. For more information on specific insecticide recommendations and aphid action thresholds, check with your county Extension office.

The third management tactic is to select a small grain variety that is less prone to sustain losses from a YDV infection. Currently, no commercial varieties are resistant and variety selection is not recommended to control BYD. However, several resistance genes have been identified that reduce virus levels in the plant. In the future, plant resistance is likely to become an important part of the BYD control program.

Factors that usually increase the risk of BYD

- Early planting
- Aphid numbers greater than treatment guidelines
- Low seeding rate and plant population
- Late, warm fall
- Mild winter or snow cover
- Early, warm spring
- Normal summer temperatures with adequate rainfall (Kentucky)
- Hot, dry preceding summer (Alabama)

Barley Yellow Dwarf Management Plan

The best practices for managing BYD vary according to region. The Southeast can be roughly divided into two BYD management areas. The northern area is that in which the recommended planting time for wheat is mid-October to early November, winter conditions are more distinct, and the first hard freeze can occur as early as mid-October. In this region, cold temperatures and repeated freezes limit aphid activity. In the southern area, the recommended planting times are in mid- to late November where winter conditions are less distinct and hard freezes may not occur. Aphids may be active during warm periods throughout the season.

Northern Area: Avoid early plantings, but do not plant after the recommended planting interval for your region. For high-input wheat, consider using a systemic seed treatment or apply a foliar insecticide spray at about 30 days after planting (from 2-leaf through fall tillering). Check for aphids at greenup in the spring and scout for them at heading to prevent direct feeding damage. Economic thresholds for grain aphids have been developed for the Southeast (Table 4). Research in Virginia, however, has shown that aphid thresholds are not appropriate for that state.

Southern Area: In this area, aphid activity can occur during warm periods throughout the season. Systemic seed treatments and foliar insecticide applications in the first 30 days after planting do not consistently reduce BYD. Wheat should be scouted throughout winter and treated if needed. The most consistent method for control of BYD in this region is to spray aphids with a foliar pyrethroid insecticide in January or early to mid-February before stem elongation (Table 4). In some places, this application may coincide with the nitrogen top-dress application. Check aphids at heading up to soft dough stage to prevent direct feeding injury.

Table 4. Number of Aphids Required to Support an Insecticide Application for Management of BYD or Direct Damage From Aphids in Alabama and Georgia

Growth Stage	North	Coastal Plain
Seedling (to 30 days after planting)	1 to 2 bird cherry-oat aphids per row-foot 10 greenbugs or sugarcane aphids per row-foot	n/a
6- to 10-inch tall plants	6 aphids per row-foot	6 aphids per row-foot
Stem elongation	2 aphids per stem	2 aphids per stem
Boot/flag leaf	5 aphids per stem	5 aphids per stem
Head emergence	10 aphids per head	10 aphids per head
Soft/hard dough	Do not treat	Do not treat

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For more information, call your county Extension office. Look in your telephone directory under your county's name to find the number.

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