UNITED SORGHUM CHECKOFF PROGRAM

Mid Atlantic Production Handbook

Welcome to the United Sorghum Checkoff Program's Mid Atlantic Production Handbook. We have integrated research from various sources to produce an easy-to-use guide that can help farmers manage their crop more efficiently. Sorghum has tremendous potential to return a profit to your farm and the work of the Sorghum Checkoff will only improve that potential over time. As you manage your sorghum, keep these tips in mind:

- Make sure you are using the hybrid that works in your area and planting to get the right "plants per acre" in your field.
- Use an integrated weed management strategy.
- Most importantly, provide the crop with adequate fertilizer.

By following a few guidelines, you'll be amazed at what this crop can do for you. We strive to help you make sorghum more profitable for your operation. But remember, every situation is a bit different so contact your local county extension office, land-grant university or other area sorghum farmers to help you get the most out of this water-sipping crop.

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Growing Grain Sorghum in North Carolina, 2009
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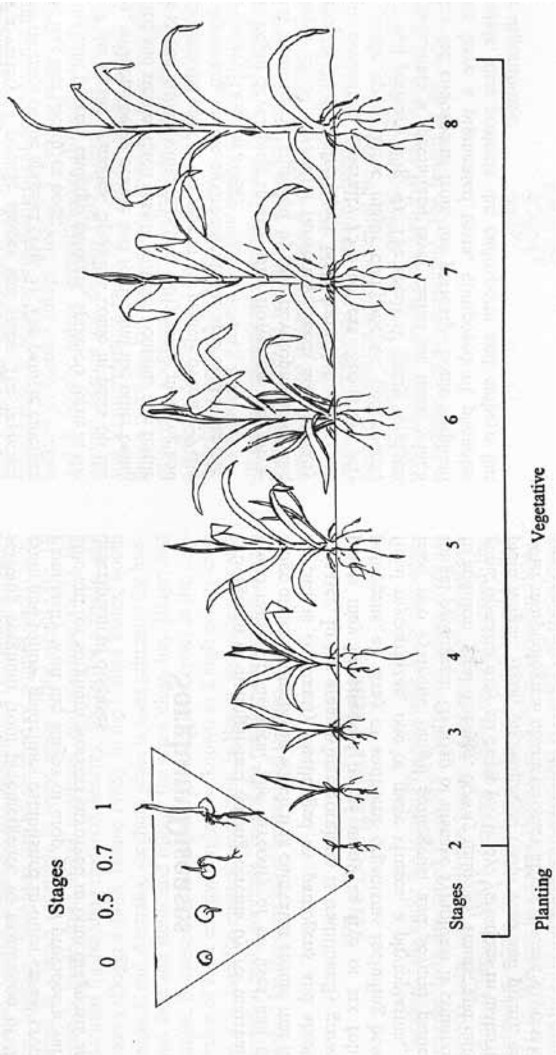
Growth Stages

It is important to understand the various developmental stages of sorghum since this understanding will assist in making irrigation and management decisions. The stages are based on key stages of sorghum growth that are used to describe sorghum from planting to maturity (Figure 1).

Another common scale that is used among sorghum researchers is a more simplified growth scale. GS1 would equate to stages 0-5 (vegetative stage) in this system. GS2 would represent from stages 5-10 (reproductive stage), and finally, GS3 would be from stage 10 to 11.5 (flowering stage).

Comprehensive grain sorghum growth and development guides are available, such as Kansas State's "How a Sorghum Plant Develops" (http://www.oznet.ksu.edu, currently being revised with your sorghum Checkoff dollars) and Texas AgriLife's "How a Sorghum Plant Grows," (http://agrilifebookstore.org). Both of these guides provide pictures of different growth stages, graphs of cumulative nutrient uptake relative to growth stages (KSU), or approximate heat unit requirements (base temperature 50°F, maximum 100°F) for attaining a particular growth stage (Texas AgriLife). Cool or wet weather early in the season or an early planting date can significantly slow growth early in the season adding a week or even two weeks to the time to half bloom.
Refer to Appendix A.


Stages
0 0.5 0.7 1
Stages 2 3 4 5 6 7 8
Planting
Vegetative

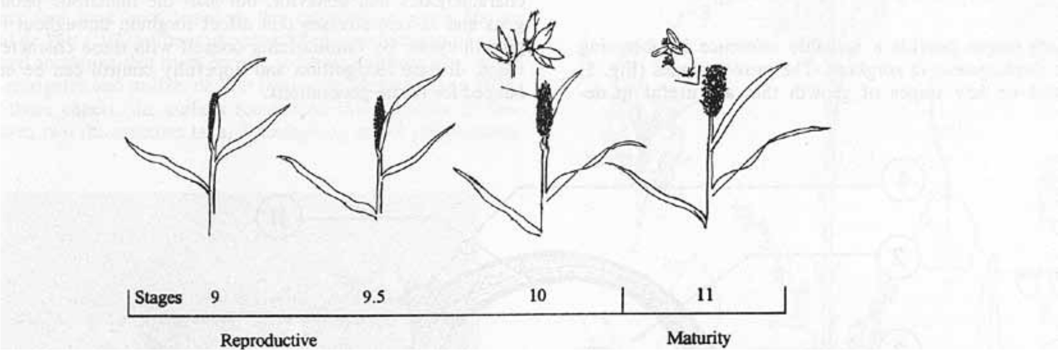
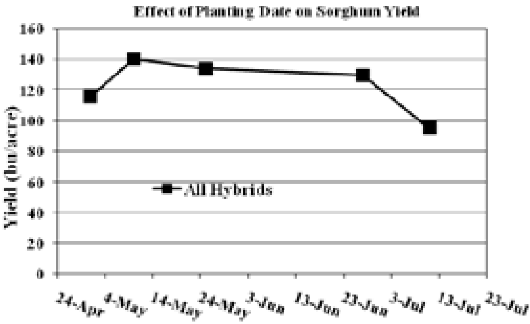


Fig. 1. Stages of sorghum growth: Stage 0: 0.0 planting; 0.1 start of imbibition; 0.5 radicle emergence from seed (caryopsis); 0.7 coleoptile emergence from seed (caryopsis); 0.9 leaf at coleoptile tip; Stage 1: emergence; Stage 2: first leaf visible; Stage 3: third leaf sheath visible; Stage 4: fifth leaf sheath visible; Stage 5: Panicle differentiation and start of tillering; 5.1 main shoot and one tiller; 5.9 main shoot and several tillers; Stage 6: stem elongation (late vegetative stage); Stage 7: flag leaf visible, whorl; Stage 8: booting (end of vegetative stage); Stage 9: panicle just showing, inflorescence emergence; Stage 10: anthesis (50% of panicle flowering); Stage 11: maturity; 11.1 grains at milk stage; 11.2 grains at early dough stage; 11.3 grains at late dough stage; 11.4 grains at physiological maturity (black layer, approximately 30% seed moisture); 11.5 mature grain (seed moisture approximately 15%). (Courtesy K. Cardwell). *For more information see Appendix A, page 163.*

Planting

The planting period for grain sorghum is very wide. Research in Virginia and North Carolina has shown that high yields can be obtained from planting dates ranging from May 1 to July 1 (Fig. 2). Optimum planting dates for consistent yields fall from May 10 to June 15. Double-cropped sorghum could be planted as late as July 10, but later dates result in a crop that will not mature until late fall and will increase the risk of an early fall frost damaging the crop. Generally, on sandy soils that are more drought prone, an early planting date (early to mid May) is the best choice. This gives the crop plenty of opportunity to reach head exertion without the risk of moisture stress. However, sorghum has been grown successfully as a double-crop behind potatoes, barley or wheat on both mineral and organic soils. The

Figure 2. Sorghum yield when planted on different dates in eastern North Carolina.



keys to acceptable yields when planting sorghum as a double-crop behind potatoes or wheat are to select an early to medium-maturing hybrid and to plant in narrow rows.

Variety Selection

Hybrid selection is critical to the success of the sorghum crop. Hybrids can be broken into three categories: early, medium, and late. Generally, early hybrids reach flowering in 45 to 55 days. Medium hybrids flower in 55 to 65 days and late hybrids take longer than 65 days to flower. Most of the hybrids available in North Carolina are late hybrids. Research trials have shown that on soils with good water holding capacity or when sorghum is grown in years with good rainfall, late hybrids work well. Good examples are AgriPro AP2838, DeKalb DKS44-41, and Pioneer 83G66. However, when planting sorghum on droughty soils or when planting as a double-crop behind Irish potatoes, wheat, or barley, early to medium hybrids work best. Early hybrids reach flowering before water stress sets in and can reach maturity before a frost.

Currently there is no official variety test for grain sorghum. Producers should rely on local tests or use on-farm comparisons to identify the best hybrids for their soils. Table 1 shows the results of a hybrid performance trail conducted in 2008. While limited to only a few hybrids this is the latest information we have for hybrid response on sandy soils.

Table 1. 2008 sorghum hybrid comparison trial. Anthracnose ratings for sorghum hybrids grown in North Carolina. 1 = poor diseases resistance; 10 = excellent resistance. Maturity refers to the number of days to flowering or mid-bloom.

Hybrid	Maturity (days)	Grain Moist	Yield bu/A	Anthracnose Rating
Monsanto MSE 532	72	15.3	123.6	Unknown
Pioneer 83G66	72	16.7	117.3	7
Pioneer 83G15	73	13.1	117.3	1
Pioneer 82G0	73	15.1	116.8	5
DeKalb DKS53-67	70	15.2	115.4	2
Pioneer 84G62	72	15.5	114.9	3
Monsanto MSE 536	75	14.5	112.7	Unknown
Pioneer 85G46	69	15.7	111.8	5
NC+ 7B51	70	14.9	106.3	Unknown
Pioneer 84G62	72	16.4	105.1	3
DeKalb DKSs54-00	72	14.7	98.5	3
DeKalb A603	72	14.9	97.	2
DeKalb DKS54-00	72	14.7	96.9	3

Additional Hybrid Selection Criteria

In addition to maturity and yield, the following hybrid parameters have a potentially major impact on sorghum performance.

- **Tillering**—Hybrids express differences in tillering. Early planting and low populations foster increased tillering. Although tillering is one important means by which sorghum hybrids may adapt to their environment, Producers should be cautious about high tillering hybrids where drought stress is expected. In contrast, low tillering hybrids reduce the possibility that early favorable conditions lead to increased tillering, only to have drought and heat increase, leaving the plant with too little moisture per head hence reducing actual yield.
- **Lodging**—Standability is important for grain sorghum. Companies rate their own hybrids for lodging resistance, but significant lodging only occasionally shows up in Texas AgriLife hybrid trials and it is often not even reported. Drought stress and limited moisture conditions can lead to charcoal and other stalk rots, which cause lodging, especially when plant populations are high. Coastal wind and storm damage can also make strong standing sorghum hybrids more valuable.
- **Weathering**—This is particularly important for grain sorghum grown along the Atlantic coast. Hybrids that 1) can better withstand storm damage, 2) do not deteriorate after maturity while they await harvest in the

event of extended rain, and 3) minimize germination in the head, etc., are a plus.

Hybrid Recommendations

The following list describes recommended sorghum hybrids based on recent information and analysis. Use this list to help identify potential sorghum hybrids.

WARNING: This list of hybrids is based on information from field trials, county variety tests, and other field observations. As such it represents the best information available. However, this is not a comprehensive list. There are several companies that have sorghum hybrids that have not been tested in North Carolina. The hybrids offered by these companies may have characteristics that are as good or better than the listing below. The grower should evaluate these hybrids by comparing the literature offered by the company to the information given below.

Early to Medium Maturing Hybrids – 70 days to bloom or less

Pioneer 86G08 – 65 days to bloom

- Early maturing hybrid
- Good standability and early season vigor
- Good drought tolerance
- Area of adaptation: coastal plain and tidewater
- Below average anthracnose resistance

Recommendation: Use this hybrid on your better soils. Does well when field conditions are good.

Pioneer 85G46 – 69 days to bloom

- Good standability and average early season vigor
- Above average drought tolerance
- Area of adaptation: coastal plain and tidewater
- Average anthracnose resistance

Recommendation: Good hybrid for a wide range of soil conditions. Yields well consistently. One of the better early hybrids for droughty soils.

DeKalb DK44 – 66 days to bloom

- Excellent standability & average early season vigor
- Average drought tolerance
- Best suited to the better mineral or organic soils
- Area of adaptation: coastal plain and tidewater
- Moderate anthracnose resistance
- Older hybrid that does best as a double crop planted late

DeKalb DK44-20 – 70 days to bloom

- Good standability and early season vigor
- Average drought tolerance
- Best suited to mineral soils
- Area of adaptation: coastal plain
- Good anthracnose resistance

Recommendation: This is a new hybrid that is best used on mineral soils. Potential for very good yields in poor growing conditions.

Late Maturing Hybrids – More than 70 days to bloom

DeKalb/Asgrow A571 – 71 days to bloom

- Good standability and poor early season vigor

- Average drought tolerance
- Suited to mineral or organic soils
- Area of adaptation: tidewater and coastal plain
- Good anthracnose resistance

Recommendation: This is an older hybrid with average yield performance. Could be used in a double crop situation.

DeKalb DKS54-00 – 72 days to bloom

- Good standability and early season vigor
- Above average drought tolerance
- Best suited to mineral soils
- Area of adaptation: coastal plain
- Below average anthracnose resistance

Recommendation: This is an older hybrid that is best used on mineral soils. Best performance when planted in May. Is not well suited for double crop.

DeKalb/Asgrow A603 – 72 days to bloom

- Good standability and early season vigor
- Average drought tolerance
- Best suited to mineral or mineral-organic soils
- Area of adaptation: coastal plain and parts of tidewater
- Poor anthracnose resistance

Recommendation: This is an older hybrid that is best when planted early. Potential for good yields when grown in good conditions.

DeKalb DKS54-03 – 72 days to bloom

- Good standability and early season vigor
- Good drought tolerance

- Best suited to mineral or mineral-organic soils
- Area of adaptation: coastal plain and tidewater
- Good anthracnose resistance

Recommendation: This is a new hybrid that has increased disease resistance. Potential for good yields when grown in average to good conditions.

Pioneer 84G62– 72 days to bloom

- Good standability and early season vigor
- Good drought tolerance
- Best suited to mineral or mineral-organic soils
- Area of adaptation: coastal plain and tidewater
- Poor anthracnose resistance

Recommendation: This is a hybrid with good consistent performance. May not always be the best hybrid but will perform above average across a range of conditions.

Pioneer 83G66 – 72 days to bloom

- Good standability and early season vigor
- Good drought tolerance
- Best suited to mineral or mineral-organic soils
- Area of adaptation: coastal plain and tidewater
- Very Good anthracnose resistance

Recommendation: This is the top hybrid in North Carolina for the past five years. Good disease resistance combined with excellent yield potential.

Pioneer 83G15 – 73 days to bloom

- Good standability and early season vigor
- Good drought tolerance
- Best suited to mineral soils
- Area of adaptation: coastal plain

- Very poor anthracnose resistance

Recommendation: This hybrid has high yield potential across a range of conditions but does not have good anthracnose resistance. Use in areas where sorghum has not been grown for several years.

Pioneer 84G77 – 71 days to bloom

- Good standability and early season vigor
- Good drought tolerance
- Best suited to mineral or mineral-organic soils
- Area of adaptation: coastal plain and tidewater
- Below average anthracnose resistance

Recommendation: This hybrid has excellent yield potential. Best when planted early.

Seeding Rate and Row Spacing

Seeding should be done in seeds per acre NOT POUNDS PER ACRE. Like wheat, sorghum seed varies greatly in the number of seeds per pound and this can impact the number of plants seeded. In most cases, sorghum should be planted to achieve final plant populations of 100,000 to 120,000 plants per acre (Figure 3). At 75% emergence this would require 130,000 to 160,000 seeds planted per acre (Table 2). However, when planting on droughty or sandy soils seeding rates should be reduced to achieve final a plant population of 90,000 plants per acre. Emerging sorghum seedlings are fragile and can be easily destroyed by insect feeding or soil drying. Percent emergence will often be less than 75% when planting in cool, wet soils or when planting using no-till practices. When planting early or when planting under no-till conditions use of an in-furrow insecticide or Gaucho® or Cruiser® seed treatment is recommended.

When planting between May 1 and June 1, row widths from 10 to 20 inches yield the best (Figure 4). Row spacings of 30- or 36-inch rows have less yield potential. However, on extremely droughty soils, 30-inch rows can give more consistent yield results from year to year. This is due to the fact that water can be stored in the middle of the interrow area and is available during heading and flowering when the sorghum plant's need for water is the greatest. When planting after June 1, sorghum yield tends to be greater when drilled at spacings less than 15 inches.

Figure 3. Sorghum yield at two different plant populations on an organic soil in eastern North Carolina.

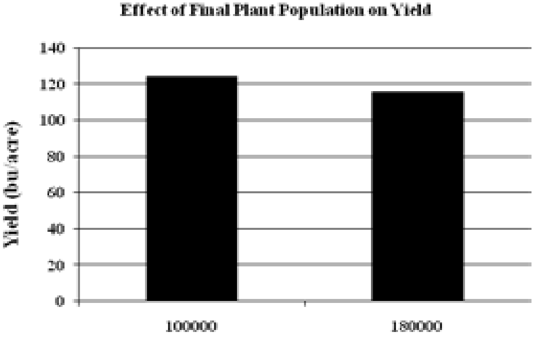
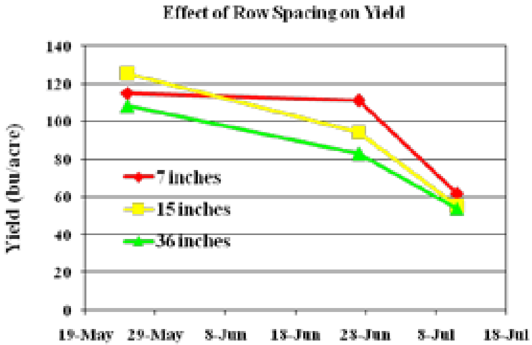


Table 2. Suggested Sorghum Seed Spacing (inches) in Row at Different Row Spacings

	Soil Type					
	Sandy		Organic or Piedmont Soils		Irrigation	
	Target Plant Populations (plants/A)					
Row Width	80,000	90,000	100,000	120,000	120,000	150,000
10	5.5	4.9	4.4	3.7	3.7	2.9
15	3.7	3.3	2.9	2.4	2.4	2.0
20	2.7	2.4	2.2	1.8	1.8	1.5
30	1.8	1.6	1.5	1.2	1.2	1.0
36	1.5	1.4	1.2	1.0	Not Recommended	
40	1.4	1.2	1.1	0.9	Not Recommended	

When Planting after June 15th increase seeding rates by 20,000 seeds per acre. When Planting after June 15th increase seeding rates by 20,000 seeds per acre

Figure 4. Effect of row spacing on grain sorghum yields at three different planting dates in North Carolina.

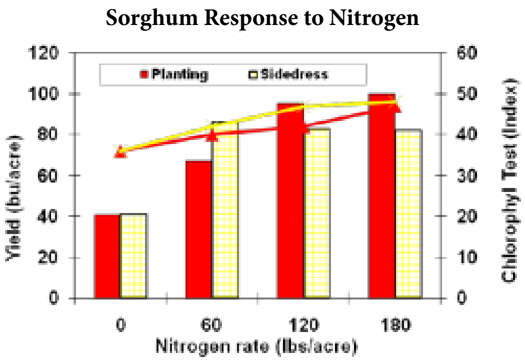


Fertilization

Grain sorghum requires less nitrogen than corn, but has similar requirements for P and K. Between 30 to 50 lbs of P2O5 per acre and 50 to 70 lbs or K2O are recommended for sorghum based on soil test levels. Sorghum does not respond well to starter fertilizer with P and K. It is better to have sufficient levels of P and K in the soil prior to planting than to supplement

Nitrogen rates for optimum sorghum yields range from 80 to 125 lbs of N per acre (Figure 5). In heavy residue or when little or no nitrogen is available from the previous crop, some nitrogen applied in a band at planting can be beneficial. Otherwise, the best time to apply nitrogen to grain sorghum is at sidedress (sorghum is 10 to 12 inches tall). On most soils 120 lbs of N per acre applied at sidedress will produce excellent results. Nitrogen fertility is important for high sorghum yields. Nitrogen must be available from 12 inches to flowering for a good sorghum crop. Lack of nitrogen at heading can result in failure to set seed (head blasting).

Figure 5. Grain sorghum yields at four different nitrogen rates applied either at planting or as a sidedress application in North Carolina.



Weed Control

The best option for weed control on organic or mineral organic soils is to use Concept treated seed (safened seed) and a mixture of Dual and atrazine at 1 to 1.33 pt of Dual and 1 to 1.5 qt atrazine. Another alternative is to use safened seed and Lasso (Harness) and atrazine. On organic or mineral-organic soils a post-emergence application of atrazine + Clarity is very effective in controlling most broadleaf weeds but is limited in grass control. On sandy soils with less than 1% organic matter the only alternative is to use safened seed with Lasso (Harness) or concept treated seed with Dual and then follow with a post emergence application of 2,4-D + Clarity. Post emergence applications of 2,4-D and Clarity can be very effective. Sorghum should be treated after it is 4 to 6 inches tall but before it reaches 12 inches. The chemical manual states that sorghum is more sensitive to 2,4-D or Clarity than corn. This is true if 2,4-D or Clarity is applied after sorghum is 12 inches tall. Before this stage, sorghum is actually more tolerant to these chemicals than corn.

For grass control Buctril can also be applied post emergence up to 14 inches tall. Unfortunately, Buctril is not effective against common grass species such as nutsedge, bermudagrass, and goosegrass. In severe cases, Lorox could be applied using drop nozzles to clean up a grass problem. Some damage to the sorghum crop will occur when using these products.

Insect Management

The two main pest problems in grain sorghum are birds and corn earworm. Bird damage can be avoided by planting large areas and avoiding planting small fields near heavily wooded areas. There are no easy methods of getting rid of birds. Bird-resistant sorghum hybrids are available but have less desirable feeding characteristics and are usually discounted at the market. Corn earworms can be a significant problem. Earworms attack the flowers and kernels of sorghum. In early August, earworm moths move from maturing corn fields and attack sorghum that flowers from August through early September. The damaging pest is the hairy caterpillar that is usually light green, tan, or yellow with a broad lighter strip down the side. It has small black spots, an orange head, and curls up when disturbed. Sorghum, particularly sorghum planted after June 1, should be scouted for corn earworms from flowering to maturity. Earworms can be easily controlled through the use of insecticides such as Warrior®. However, significant damage often occurs before the problem is recognized and treated.

There are few other significant insect pests that effect grain sorghum in North Carolina. Billbugs do not reproduce on grain sorghum. However, they have been known to feed on small sorghum plants. It is rare to find significant billbug damage to sorghum.

There are several diseases that can affect sorghum such as Fusarium head blight. Probably the most damaging disease is anthracnose. This is a common disease in cereal crops in North Carolina. The most common way to manage this disease is through variety resistance. Unfortunately, there are only a few sorghum hybrids with good resistance to this disease. Growers who are growing sorghum after corn or a previous sorghum crop should choose sorghum hybrids with good resistance to anthracnose.

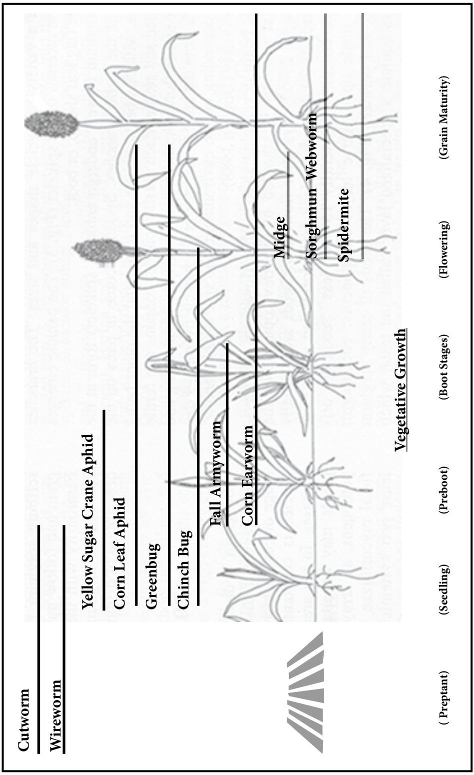


Fig. 6. Consists of data compiled by the University of Arkansas Extension Service which outlines the timeframe (shown in darkened line) when common insect pests are more likely to occur during the sorghum growing season.

Diseases

Anthracnose Leaf Blight and Stalk Rot of Sorghum

Anthracnose is caused by the fungus Colletotrichum graminicola (Ces.) G.W. Wils., teleomorph Glomerella graminicola Politis. When this disease occurs on sorghum it is commonly divided into three categories based on where symptoms develop on the plant. The three categories are: leaf anthracnose, panicle and grain anthracnose and anthracnose stalk rot. Cultivated hosts include sorghum, sudan grass, wheat, oats, rye and barley. The fungus also has several grass hosts. Those hosts of importance in North Carolina are crabgrass, Johnson grass, orchard grass and red fescue. While *C. graminicola* has a wide host range, isolates from small grains do not infect corn and sorghum. However, corn isolates have been shown to infect sorghum and Johnson grass. The fungus survives readily as mycelium and spores on plant debris that remains on the soil surface. Fungal viability is diminished when debris is buried. The fungus also survives between seasons in seed. It is suspected that it overwinters as hyphae and/or stroma in the endosperm. Primary infection of leaves occurs when conidia are windblown or splashed from debris to leaves. Conidia germinate and infection occurs directly through the epidermis or through stomata. The infection process takes place readily when warm wet weather conditions prevail. Primary infection is not as clearly understood in the stalk rot phase of the disease. The confusion is partially due to the fact that stalk rot can occur in fields with very little leaf blight and little or not crop residue from the previous year. The infection may spread from leaf sheaths to stalk tissue or the disease may progress from the roots up the plant. In the latter case, the source of inoculum is suspected to be resting spores that have overwintered in buried stalk debris. In addition, the fungus may enter stalk tissue through insect feeding wounds.

Symptoms

Colletotrichum graminicola produces a wide range of symptoms on sorghum. Leaf blight symptoms progress from lower to upper leaves and vary in size and color with host genotype. Typical symptoms on a susceptible hybrid appear as small, water soaked spots that are semitransparent and oval to elongate in shape. Spots enlarge and become tan with a wide border that is varies in shade from red or orange to purple or tan. The entire leaf may become blighted if lesions coalesce, resulting in a "fired" appearance. Dark fruiting bodies called acervuli develop on dead host tissue. When large numbers of acervuli form, they may be present in concentric rings. Black hairlike structures (setae) and conidiospores form in the acervulus. Conidiospores appear creamy to pinkish color when they are present in large numbers and serve as the source of inoculum for secondary infection. Leaf infection may also appear as a midrib infection. This type of infection is characterized by elongated elliptical lesions that vary in color from red to purple to black. Acervuli may also be present in these lesions. Leaf and midrib infections may occur independently of each other or together in which case yield loss increases. Leaf anthracnose generally occurs at half-bloom or later. If plants are infected early in the growing season, damping off may occur or plants may be stunted, yellow and tiller poorly.

Panicle and grain anthracnose occurs on mature plants. Spores of *C. graminicola* produced from the leaf blight stage are splashed by rain or irrigation water to the panicle (inflorescence) and initiate infection. Initial lesions are water-soaked and turn tan or purple with age. They are elliptical or bar shaped and occur just below the epidermis. If the panicle is split lengthwise, areas of red discolored infected tissue can be seen interspersed with healthy white tissue. Black acervuli may be produced in infected tissue and extend on to seed produced on the panicle. Infected panicles are lightweight, may exhibit some degree of sterility and mature early. Infected seed is discolored, germinates poorly and may produce plants that succumb to seedling blight.

The stalk rot phase of anthracnose is very similar to the panicle infection phase. Infection may occur at anytime during the growing season but symptom development is most common on mature plants. Infection occurs when conidia from the leaf blight stage are splashed or wind blown to the stalks. The initial symptom of stalk infection is a water-soaked discoloration of rind tissue in the lower internodes. Lesions take on a reddish discoloration and infected tissue is interspersed with healthy tissue. External infections are characterized by irregular bleached areas that are surrounded by a red border (host pigmentation).

Plant Health Management

Resistant Hybrids

Resistance is available for both the leaf blight and stalk rot phases. However, hybrids showing resistance to anthracnose stalk rot often do not show resistance to stalk rots caused by other fungi.

Residue Management

Anthracnose is generally more severe on continuously cropped corn where residue remains on the surface between seasons. Burial of residue has been shown to be effective in reducing inoculum. Residue burial would be most effective when rotating to a nonhost crop such as soybeans. In a conservation tillage system with continuously cropped corn, destruction and burial of residue is not possible so selection of a resistant hybrid would be necessary.

Seed Treatment

Seed protectant fungicide, thiram is labeled for control of seedling blight on sorghum. Trials have indicated that seed treatments are effective at preventing early infections and can help reduce the incidence of the stalk rot phase of anthracnose.

Harvesting

Ideally, sorghum should be harvested at 16-18% moisture and dried down to 13.5%. This gives an excellent quality grain with less potential for lodging. However, if drying facilities are not available, sorghum can be left to dry in the field. Sorghum should be stored below 13.5% moisture. Careful attention should be given to checking stored grain sorghum regularly. The small kernels leave less air pores in the bin and can lead to trapped moisture and "hot spots" where stored-grain insects will multiply rapidly.

Minimizing Harvest Losses

An efficient harvest is the result of attention to management throughout production and harvest seasons. Decisions, such as the selection of hybrids that mature at a time when labor and equipment can be devoted to harvest can ensure that the sorghum produced in the field makes it to the bin. Since sorghum is a perennial it has the potential to produce tillers in the fall that are generally undesirable. Therefore, sorghum producers should select hybrids that will mature just prior to the first killing frost with the goal of harvesting the crop as soon as it dries to 18% moisture. Estimates have put average sorghum harvest losses in North Carolina anywhere from 5 to 10 bushels per acre, with expert operators and managers reducing this to about 1 to 2 bushels per acre. The added income from an efficient harvest is almost pure profit, so a timely harvest and the few minutes spent on careful combine adjustment can be extremely profitable.

The key to maximizing sorghum quantity and quality is timely harvest.

Three factors make timely harvest attractive. 1) Timely harvest reduces the potential losses to bird feeding, 2) reduces the chance of lodging from a hurricane or tropical storm, and 3) improves grain quality by reducing losses resulting from grain sprouting in the panicle or from immature grain from late developing tillers that are produced in the fall. Under favorable conditions following black layer formation, sorghum should be ready to harvest in 14 days or less at moisture levels below 18%. If harvest occurs before a killing frost the plant will have significant green leaf area that may make harvest difficult. In these cases growers may want to consider using gramoxone, defol, or other harvest aids to kill the plant and associated weeds prior to harvest. These harvest aids can help reduce grain moisture and ensure a timely harvest.

Drying Sorghum

One of the reasons often cited for not harvesting in a timely manner is the cost of drying corn to the proper moisture levels for storage. If the crop is to be stored for any given period and if fungal growth is to be stopped or reduced, moisture content in sorghum should not exceed

13.5%. Because early harvest is done when grain moisture often exceeds 17%, drying is necessary. Grain drying costs can be estimated by the following equations:

Energy cost ($/dry bushel) = [(LP gas price X 0.02) + (Electricity price X 0.01)] X (initial moisture – 13.5)

Energy cost ($/wet bushel) = Energy cost per dry bushel X (100 – initial moisture)/86.5

These calculations are based on the fact that it takes 0.02 gal of LP gas and 0.01 KWH of electricity to remove 1% moisture per bushel.

Keep in mind these costs do not cover the cost of the drying equipment, extra labor involved in operating a dryer, or in grain shrinkage (weight loss caused by removing moisture and handling). Sorghum has a small seed with less pore space in the grain. Therefore, air does not move through the grain as easily as it does with a large seeded crop such as corn or soybean. When using bin, batch or peanut driers growers should keep the depth of the grain being dried to a maximum of 24". This will improve drying efficiency and help avoid spots in the grain mass that are not dried to the target moisture. Maximum drying temperatures for grain sorghum are from 10 to 20˚ F less than those used for drying corn. This means that the time required to dry a batch of sorghum will be longer compared to corn. Bin aeration systems will require higher flow capacities compared to those used in corn and soybean in order to move air through the bin in a reasonable time period. Sorghum grain should be monitored more frequently than other grains to control moisture migration and to ensure that hot spots don't occur.

Grain Storage

There is one primary reason to store grain – to increase net return. If the net return cannot be increased by storing grain, storage is a waste of time and effort, and becomes a risk. The major drawback to grain storage can be summed up by the following. The returns from storage are measured in pennies, the losses from losing just one bin to insects or mold are measured in dollars. If grain is to be stored for a long period of time, if frequent monitoring of the grain is not possible, or if the labor and time required to move grain to the marketplace is not available when needed, then commercial storage may be a better alternative.

The following questions should be used to determine if on-farm storage is necessary:

1. Are there sufficient commercial grain storage facilities?
2. During harvest, is transportation or storage a problem?
3. In the months following harvest, is it common for corn prices to increase sufficiently to cover storage cost?
4. Can weekly checks of stored grain be made

and actions taken if necessary?
5. Can the grain be moved to the marketplace at any time of the year?

Handling Stored Grain

Stored-grain management is a long-term approach to maintaining post-harvest grain quality, minimizing chemical control inputs, and preserving the integrity of the grain storage system. To implement an effective management program, operators must understand the ecology of the storage system.

Storage management must focus on the following factor:

1. grain temperature
2. grain moisture
3. storage air relative humidity
4. storage time

An excellent preventive post-harvest grain management approach is the SLAM system (Sanitize/seal, Load, Aerate, Monitor).

These stored grain management strategies should include the following steps.

Sanitize/Seal

- Housekeeping – clean bin, aeration ducts, and auger trenches where insects thrive on dust and foreign material
- Cleanup – clean up around the bin removing weeds, trash, and moldy grain.

- Disinfect – pesticide sprays or fumigation is important to remove all insects and molds.
- Seal bin – seal all openings to provide barrier protection again insect entry all locations below the roof eaves.

Load

- Load clean, dry grain – High levels of grain moisture increase the potential for high populations of stored-grain insects and molds. In North Carolina, corn that will be stored for more than six months should be dried to 13.5% moisture. Table 3 shows the estimated storage times for shelled corn based on temperature and moisture content.
- Core the grain – this involves operating the unload auger to pull the peak down and remove the center core of the bin that contains most fines and small foreign matter.
- Spreading/Leveling grain – a level grain surface is easier to manage and less likely to change temperature during storage.

Aerate

- Maintain grain temperature – Grain temperature should be below 60˚F to control insects and mold. Grain temperatures should be reduced to the optimum storage level as early as possible following harvest and grain temperature should be managed by aeration of grain in the fall, winter, and early spring. The aeration time necessary to achieve 60˚F will vary due to the airflow rates of the equipment used and ambient temperatures. Aeration can also reduce grain moisture content from ¼ to ½ percent during one aeration cycle.

- Use aeration to prevent moisture migration – In most grain bins, moisture migration occurs due to significant temperature differences that develop within the grain mass. These temperature differences are caused by changes in outside temperatures and humidity throughout the year and result in changes in the equilibrim moiture of the grain. Operators must constantly monitor grain condition particularly during periods of temperature change (fall or spring) to determine how temperature differences are effecting moisture migration in the bin. Aeration can be used to equalize grain temperature and moisture throughout the bin.

Monitor

- Use a grain thermometer to track grain temperature.
- Schedule regular grain sampling and monitoring.
- Fumigation as needed based on economic thresholds.
- Aeration/turning of hot spots when detected.

Budget

Sorghum Production Information NC Sorghum Budget

Variable Costs/A	Unit	Price	Qty	Value
Labor	hr	10.00	2.5	25.00
Seed	lbs	1.00	8	8.00
Pre-Emergence Herbicide (Bicep II)	qt	5.00	2.5	12.50
Post-Emergence Herbicide (Atrazine + Clarity)				9.00
Insecticide (Warrior) (ground application)				12.50
Fertilizer (120 lbs N + 20 lbs P)				
Nitrogen	lbs N	0.50/ lb N	120 lbs N	60.00
Phosphorus	Lbs P2O5	0.60/lb P	35 lbs P	21.00
Potash	Lbs K2O	0.52/ lb K	50 lbs K	26.00
Machiery Expense (Fuel, repairs, maintenance)				40.22
Drying Costs				15.50
Miscellaneous				3.00
Interest on Variable Expenses		6.25%		12.68
Total Variable Costs				245.40
Fixed Costs (interest on machinery, taxes, depreciation and insurance)				57.50
Total Cost/A				302.90
Income				
Yield	bu		100.0	100.0
Price per bushel	$	6.00		6.00
Total Income per Acre				$600.00
Per Acre Return Over Variable Costs				$354.60
Per Acre Return Over Total Costs				$297.10

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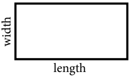
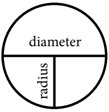
4. Heiniger, Ron. "Information for North Carolina Sorghum Growers: Anthracnose in Grain Sorghum." North Carolina State University, No. 4. 2006.

5. Heiniger, Ron. "Sorghum Production Information: North Carolina Sorghum Budget." Plymouth: North Carolina State University. Print.

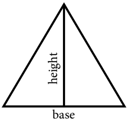
Calculations & Conversions



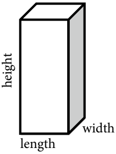
Area of a rectangle or square = length x width



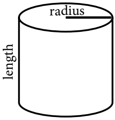
Area of a circle = 3.1416 x radius squared; or 0.7854 x diameter squared
Circumference of a circle = 3.1416 x diameter; or 6.2832 x radius



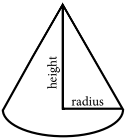
Area of triangle = base x height ÷ 2



Volume of rectangle box or cube = length x width x height

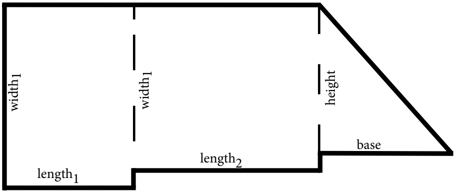


Volume of a cylinder = 3.1416 x radius squared x length



Volume of cone = 1.0472 x radius squared x height

Reduce irregularly shaped areas to a combination of rectangles, circles and triangles. Calculate the area of each and add them together to get the total area.



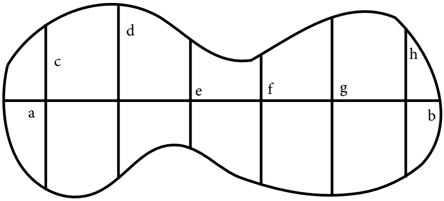
Example: If b = 25', h = 25', L_1 = 30', W_1 = 42', L_2 = 33', W_2 = 31', then the equation is:

Area = ((b x h) ÷2) + (L_1 x W_1) +(L_2 x W_2)

= ((25 x 25) ÷2) + (30 x 42) + (31 x 33)

= 2595 sq. ft.

Another way is to draw a line down the middle of the property for length. Measure from side to side at several points along this line. Use the average of these values as the width. Calculate the area as a rectangle.



Example: If ab = 45', c = 19', d = 22', e = 15', f = 17', g = 21', h = 22', then the equation is:

Area = (ab) x (c + d + e + f + g + h) ÷ 6

= (45) x (19 + 22 + 15 + 17 + 21 + 22) ÷ 6

= 870 sq. ft.

Conversion Factors

Acres (A)	x0.405	Hectares
Acres	x43,560	Square feet
Acres	x4047	Square Meters
Acres	x160	Square rods
Acres	x4840	Square yards
Bushels (bu)	x2150.42	Cubic inches
Bushels	x1.24	Cubic feet
Bushels	x35.24	Liters
Bushels	x4	Pecks
Bushels	x64	Pints
Bushels	x32	Quarts
Bushel Sorghum		56 pounds
$CaCO_3$	x0.40	Calcium
$CaCO_3$	x0.84	$MgCO_3$
Calcium (ca)	x2.50	$CaCO_3$
Centimeters (cm)	x0.3937	Inches
Centimeters	x0.01	Meters
Cord (4'x4'x8')	x8	Cord feet
Cord foot (4'x4'1')	x16	Cubic feet
Cubic centimeter (cm^3)	x0.061	Cubic inch
Cubit feet (ft^3)	x1728	Cubic inches
Cubic feet	x0.03704	Cubic yards
Cubic feet	x7.4805	Gallons
Cubic feet	x59.84	Pints (liq.)
Cubic feet	x29.92	Quarts (liq.)
Cubic feet	x25.71	Quarts (dry)
Cubic feet	x0.084	Bushels
Cubic feet	x28.32	Liters
Cubic inches (in^3)	x16.39	Cubic cms
Cubic meters (m^3)	x1,000,000	Cubic cms
Cubic meters	x35.31	Cubic feet
Cubic meters	x61,023	Cubic inches
Cubic meters	x1.308	Cubic yards
Cubic meters	x264.2	Gallons
Cubic meters	x2113	Pints (liq.)
Cubic meters	x1057	Quarts (liq.)
Cubic yards (yd^3)	x27	Cubic feet
Cubic yards	x46,656	Cubic inches
Cubic yards	x0.7646	Cubic meters
Cubic yards	x21.71	Bushels
Cubic yards	x202	Gallons
Cubic yards	x1616	Pints (liq.)
Cubic yards	x807.9	Quarts (liq.)

Cup	x8	Fluid ounces
Cup	x236.5	Milliliters
Cup	x0.5	Pint
Cup	x0.25	Quart
Cup	x16	Tablespoons
Cup	x48	Teaspoons
ºCelsius (ºC)	(+17.98)x1.8	Fahrenheit
ºFahrenheit (ºF)	(-32)x0.5555	Celsius
Fathom	x6	Feet
Feet (ft)	x30.48	Centimeters
Feet	x12	Inches
Feet	x0.3048	Meters
Feet	x0.33333	Yards
Feet/minute	x0.01667	Feet/second
Feet/minute	x0.01136	Miles/hour
Fluid ounce	x1.805	Cubic inches
Fluid ounce	x2	Tablespoons
Fluid ounce	x6	Teaspoons
Fluid ounce	x29.57	Milliliters
Furlong	x40	Rods
Gallons (gal)	x269	Cubic in. (dry)
Gallons	x231	Cubic in. (liq.)
Gallons	x3785	Cubic cms
Gallons	x0.1337	Cubic feet
Gallons	x231	Cubic inches
Gallons	x3.785	Liters
Gallons	x128	Ounces (liq.)
Gallons	x8	Pints (liq.)
Gallons	x4	Quarts (liq.)
Gallons of Water	x8.3453	Pounds of Wa
Grains	x0.0648	Grams
Grams (g)	x15.43	Grains
Grams	x0.001	Kilograms
Grams	x1000	Milligrams
Grams	x0.0353	Ounces
Grams/liter	x1000	Parts/million
Hectares (ha)	x2.471	Acres
Hundred wt (cwt)	x100	Pounds
Inches (in)	x2.54	Centimenters
Inches	x0.08333	Feet
Inches	x0.02778	Yards
K_2O	x0.83	Potassium (K)
Kilogram (kg)	x1000	Grams (g)
Kilogram	x2.205	Pounds

Kilograms/hectare	x0.8929	Pounds/acre
Kilometers (K)	x3281	Feet
Kilometers	x1000	Meters
Kilometers	x0.6214	Miles
Kilometers	x1094	Yards
Knot	x6086	Feet
Liters (l)	x1000	Milliliters
Liters	x1000	Cubic cms
Liters	x0.0353	Cubic Feet
Liters	x61.02	Cubic inches
Liters	x0.001	Cubic meters
Liters	x0.2642	Gallons
Liters	x2.113	Pints (liq.)
Liters	x1.057	Quarts (liq.)
Liters	x0.908	U.S. dry quart
Magnesium (mg)	x3.48	$MgCO^3$
Meters (m)	x100	Centimeters
Meters	x3.281	Feet
Meters	x39.37	Inches
Meters	x0.001	Kilometers
Meters	x1000	Millimeters
Meters	x1.094	Yards
$MgCO^3$	x0.29	Magnesium (Mg)
$MgCO^3$	x1.18	$CaCO^3$
Miles	x5280	Feet
Miles	x1.69093	Kilometers
Miles	x320	Rods
Miles	x1760	Yards
Miles/hour	x88	Feet/minute
Miles/hour	x1.467	Feet/second
Miles/minute	x88	Feet/second
Miles/minute	x60	Miles/hour
Milliliter (ml)	x0.034	Fluid ounces
Ounces (dry)	x437.5	Grains
Ounces (dry)	x28.3495	Grams
Ounces (dry)	x0.0625	Pounds
Ounces (liq.)	x1.805	Cubic inches
Ounces (liq.)	x0.0078125	Gallons
Ounces (liq.)	x29.573	Cubic cms
Ounces (liq.)	x0.0625	Pints (liq.)
Ounces (liq.)	x0.03125	Quarts (liq.)
Ounces (oz.)	x16	Drams
P_2O_5	x0.44	Phosphorus (P)
Parts per million (ppm)	x0.0584	Grains/gallon

Parts per million	x0.001	Grams/liter
Parts per million	x0.0001	Percent
Parts per million	x1	Milligram/kg
Parts per million	x1	Milligram/liter
Pecks	x0.25	Bushels
Pecks	x537.605	Cubic inches
Pecks	x16	Pints (dry)
Pecks	x8	Quarts (dry)
Phosphorus (P)	x2.29	P_2O_5
Pints (p)	x28.875	Cubic inches
Pints	x2	Cups
Pints	x0.125	Gallon
Pints	x473	Milliliters
Pints	x32	Tablespoons
Pints (dry)	x0.015625	Bushels
Pints (dry)	x33.6003	Cubic inches
Pints (dry)	x0.0625	Pecks
Pints (dry)	x0.5	Quarts (dry)
Pints (liq.)	x28.875	Cubic inches
Pints (liq.)	x0.125	Gallons
Pints (liq.)	x0.4732	Liters
Pints (liq.)	x16	Ounces (liq.)
Pints (liq.)	x0.5	Quarts (liq.)
Potash (K_2O)	x0.83	Potassium (K)
Potassium (K)	x1.20	Potash (K_2O)
Pounds (lb)	x7000	Grains
Pounds	x453.5924	Grams
Pounds	x16	Ounces
Pounds	x0.0005	Tons
Pounds	x0.45369	Kilograms (kg)
Pounds of water	x0.01602	Cubic feet
Pounds of water	x27.68	Cubic inches
Pounds of water	x0.1198	Gallons
Pounds/acre	x1.12	Kilograms/ha
Quarts (qt)	x946	Milliliters
Quarts (dry)	x0.03125	Bushels
Quarts (dry)	x67.20	Cubic inches
Quarts (dry)	x0.125	Pecks
Quarts (dry)	x2	Pints (dry)
Quarts (liq.)	x57.75	Cubic inches
Quarts (liq.)	x0.25	Gallons
Quarts (liq.)	x0.9463	Liters
Quarts (liq.)	x32	Ounces (liq.)
Quarts (liq.)	x2	Pints (liq.)

Rods	x16.5	Feet
Square feet (ft^2)	x0.000247	Acres
Square feet	x144	Square inches
Square feet	x0.11111	Square yards
Square inches (in^2)	x0.00694	Square feet
Square meters (m^2)	x0.0001	Hectares (ha)
Square miles (mi^2)	x640	Acres
Square miles	x28,878,400	Square feet
Square miles	x3,097,600	Square yards
Square yards (yd^2)	x0.0002066	Acres
Square yards	x9	Square feet
Square yards	x1296	Square inches
Tablespoons (Tbsp)	x15	Milliliters
Tablespoons	x3	Teaspoons
Tablespoons	x0.5	Fluid ounces
Teaspoons (tsp)	x0.17	Fluid ounces
Teaspoons	x0.333	Tablespoons
Teaspoons	x5	Milliliters
Ton	x907.1849	Kilograms
Ton	x32,000	Ounces
Ton (long)	x2240	Pounds
Ton (short)	x2000	Pounds
U.S. bushel	x0.3524	Hectoliters
U.S. dry quart	x1.101	Liters
U.S. gallon	x3.785	Liters
Yards (yd)	x3	Feet
Yards	x36	Inches
Yards	x0.9144	Meters
Yards	x0.000568	Miles

Appendices

a. The Sorghum Plant

Sorghum grain is found on the panicle, commonly referred to as the head. The panicle consists of a central axis with whorls of main branches, each of which contains secondary and at times, tertiary branching. The length of the branches allows for a wide range of shapes and sizes in sorghum and for sorghums with very open panicles or sorghums with very compact panicles. The branches carry the racemes of the spikelets where the grain is found (see Figure 1). The panicle emerges at boot from the flag leaf sheath.

Seeds begin developing shortly after flowering and reach physiological maturity when the black layer is formed between the germ and the endosperm, some 25-40 days after flowering. Seeds are normally harvested 10-20 days after black layer when moisture content is generally 15 percent or less. Black layer can be seen at the base of the grain where it attaches to the rachis branch and indicates that the grain is physiologically mature. Seeds are made up of three major components, the endosperm, embryo, and pericarp (Figure 4). All sorghums contain a testa, which separates the pericarp from the endosperm. If the testa is pigmented, sorghum will contain tannins, if not, the grain is free of tannins. None of the commercial U.S. grain sorghums have a pigmented testa and all are said to be free of tannins.

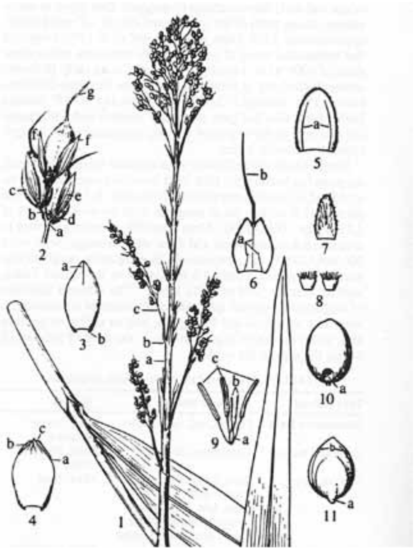


Fig. 5. The panicle of *Sorghum bicolor* subsp. *bicolor* which consists of the inflorescence and spikelets. 1. Part of panicle: a = internode of rachis; b = node with branches; c = branch with several racemes. 2. Raceme: a = node; b = internode; c = sessile spikelet; d = pedicel; e = pedicelled spikelet; f = terminal pedicelled spikelets; g = awn. 3. Upper glume: a = keel; b = incurved margin. 4. Lower glume: a = keel; b = keel wing; c = minute tooth terminating keel. 5 Lower lemma: a = nerves. 6. Upper lemma: a = nerves; b = awn. 7. Palea. 8. Lodicules. 9. Flower: a = ovary; b = stigma; c = anthers. 10. Grain: a = hilum. 11. Grain: a = embryon-mark; b = lateral lines. (Drawing by G. Atkinson. Reprinted, with permission, from J. D. Snowden, 1936, The Cultivated Races of sorghum, Adlard and Son, London. Copyright Bentham - Moxon Trust - Royal Botanical Gardens, Kew, England.

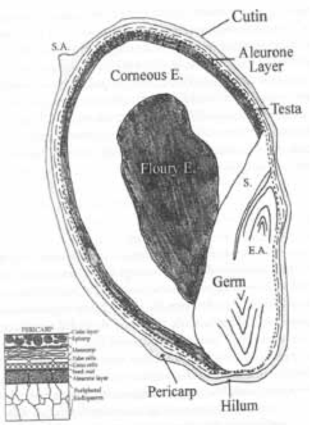


Fig. 6. Sorghum grain, showing the pericarp (cutin, epicarp, mesocarp, cross cells, tube cells, testa, pedicel, and stylar area (SA)), endosperm (aleurone layer, corneous and floury), and the germ (scutellum (S) and embryonic axis (EA). Adapted from L. W. Rooney and Miller, 1982).

b. Photos

Photo 1. Greenbug

Photo 2. Corn Leaf Aphid

*Photo 3. Yellow Sugarcane Aphid**

*Photo 4. Corn Earworm***

*Photo 5. Fall Armyworm**

*Photo 6. Sorghum Midge**

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Sorghum Facts

Sorghum is the fifth most important cereal crop in the world. It is used in a wide range of applications, such as ethanol production, animal feed, pet food, food products, building material, brooms and other industrial uses. Sorghum originated in Northeast Africa and spread to Asia, Europe and the Western Hemisphere. In the United States, sorghum is the second most important feed grain for biofuel production and is known for its excellent drought tolerance and superior adaptability to different environments. The first written record of sorghum in the U.S. traces to a letter that Benjamin Franklin wrote in 1757.

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United Sorghum Checkoff Program

www.SorghumCheckoff.com

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