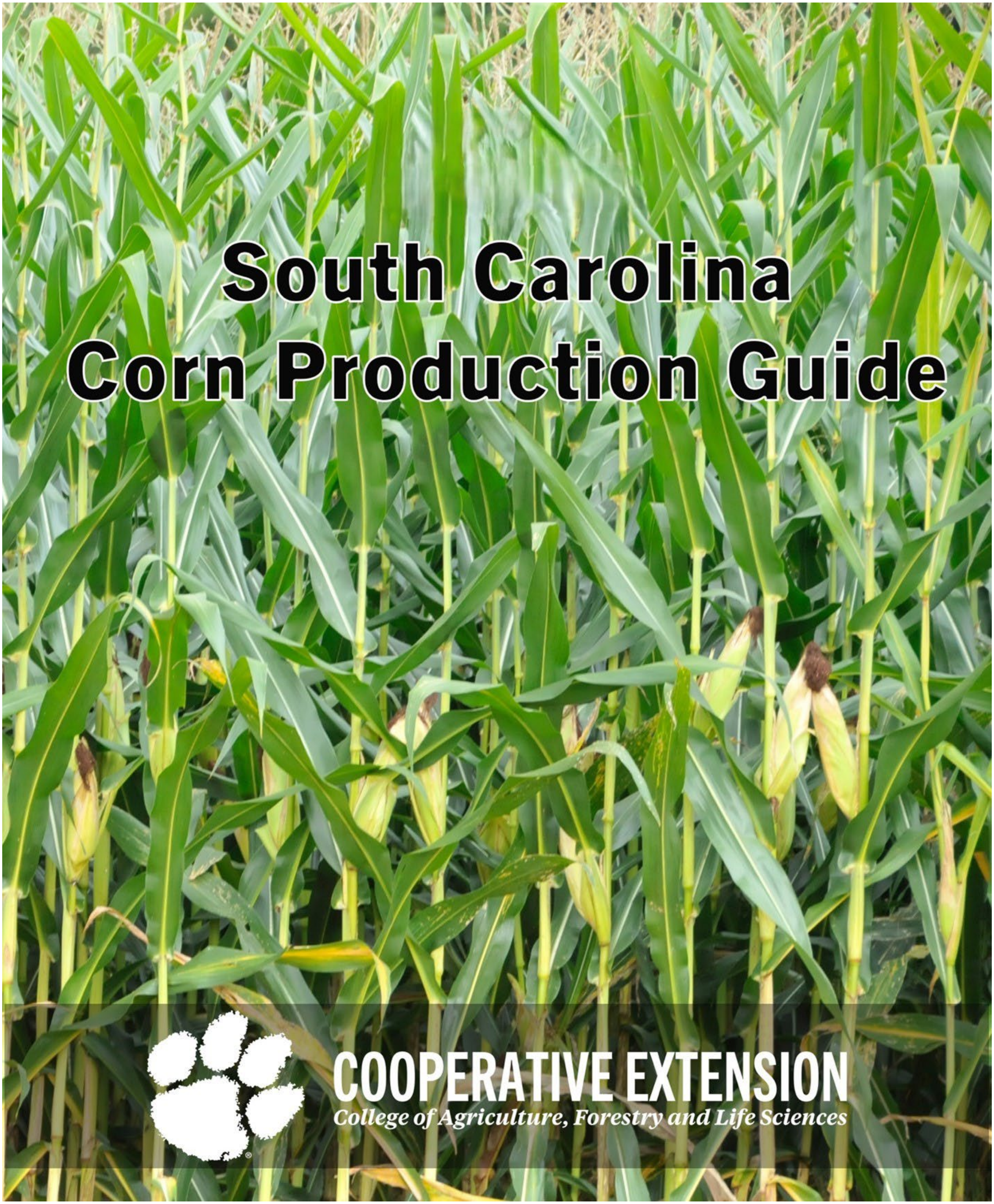
South Carolina Corn Production Guide



COOPERATIVE EXTENSION

College of Agriculture, Forestry and Life Sciences

2024 South Carolina Corn Production Guide

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Edited by:

Michael Plumblee, Ph.D., Assistant Professor - Agronomist
Department of Plant and Environmental Sciences
Clemson University
Edisto Research and Education Center
64 Research Rd., Blackville, SC 29817
E-mail: mplumbl@clemson.edu
Clemson Cooperative Extension

Agronomic Crops Program Team website: clemson.edu/extension/agronomy/index.html

The 2024 South Carolina Corn Production Guide is available as a PDF download at this link and can also be accessed from the Agronomic Crops Program website .

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Introduction

Michael Plumblee, PhD

Corn is one of the major row crops in the United States. According to the USDA National Agricultural Statistics Service, the acreage of planted corn in the United States averaged 89.4 million acres from 2004 to 2024. Corn production has also increased from 11.81 to 15.15 billion bushels from 2004 to 2024 in the United States. In South Carolina, the acreage of planted corn has been approximately 345,238 acres over the last 20 years. Table 1 shows the South Carolina corn production by county in 2023.

Table 1. 2023 county corn production in South Carolina. Bolded values represent top counties.

County	Planted (acres)	Harvested (acres)	Yield (bu/acre)	Production (bushels)
Bamberg	7,400	6,240	166.3	1,038,000
Berkeley	3,400	3,230	123.2	398,000
Calhoun	10,200	9,830	173.6	1,706,000
Chester	1200	580	87.1	50,500
Chesterfield	9,300	8,900	106.3	946,000
Clarendon	40,700	40,000	173.4	6,935,000
Darlington	20,100	19,300	147.0	2,837,000
Dillon	24,000	23,700	162.1	3,842,000
Dorchester	7,600	7,330	158.7	1,163,000
Edgefield	800	770	77.0	59,300
Florence	20,700	20,000	131.5	2,629,000
Georgetown	2,000	1,890	151.3	286,000
Greenville	800	770	103.8	79,900
Hampton	7,500	7,210	155.3	1,120,000
Horry	19,500	19,200	147.3	2,828,000
Lee	25,900	25,500	156.5	3,991,000
Marion	9,600	9,290	160.8	1,494,000
Marlboro	16,800	16,400	169.9	2,787,000
Newberry	3,400	2,700	112.2	303,000
Oconee	800	730	108.8	79,400
Orangeburg	35,400	34,700	155.0	5,378,000
Sumter	28,400	27,200	159.8	4,347,000
Williamsburg	22,400	21,600	123.5	2,668,000
All Other	44,800	40,800	130.6	5,326,900
State Total	**365,000**	**350,000**	**137.5**	**52,500,000**

Counties with the highest estimated corn acreage (>20,000 acres) in 2023 were Clarendon, Darlington, Dillon, Florence, Horry, Lee, Orangeburg, Sumter, and Williamsburg counties. These top counties accounted for about 65% of total planted corn in the State in 2023. The highest estimated corn yields in 2023 were for Bamberg, Calhoun, Clarendon, Marlboro, Dillon, and Marion Counties and ranged from 160.8 to 173.6 bushels/acre. The updated state average yield was 137.5 bushels/acre in 2023.

Marketing Corn Production

Scott Mickey

Profitable corn production is critical for the sustainability of the farm business. Profitable production requires the producer to market their products at a price that covers the cost of production as well debt repayment, family living, and income tax needs, and equity growth. Corn prices are influenced by the supply of corn in the United States and globally and the demand for corn by end-users. Successfully marketing corn requires several steps:

Step 1: Calculate price targets that cover the cost of production and provide the earnings needed for

- Family living and income taxes
- Interest expense on operating and term debt
- Equity growth

Step 2: Identify pricing opportunities

- Compare market price against the break-even price
- Evaluate fundamental supply and demand trends
- Review technical trends of the market

Step 3: Execute the sale

- Consider seasonality of corn prices
- Choose the appropriate marketing tool - cash sale, futures, or options
- Determine quantity to market

Let's see how these steps work using information available in December 2021.

Step 1: Calculate price target

This producer expects a 2022 corn yield of 125- bushels and operating costs of $635 per acre this year. This is about $100 less than the Clemson enterprise budget for non-irrigated strip-tilled corn but reflects the producer's management practices, tillage operations, labor efficiency, and soil type. Family living draws and debt service are expected to be $46 and $104 per acre, respectively. The producer also expects to receive $57 an acre for non-crop revenue such as government payments, refunds, and custom work. Their break-even corn price calculation is shown below (table 1).

Table 1. Break-even corn price calculation.

Calculation	Per Acre
Operating Cost	$635
Family Living	$ 46
Principal and Interest	$104
Total Cash Need	$785
Less: Non-Crop Revenue	-$57
Crop Revenue Required	$728
Expected Yield	125
Break-Even Price	$5.82
Less: Harvest Basis	$0.50
Break-Even Futures Price	$5.32

Remember your breakeven price will differ according to your actual cost of production, family living needs, and debt repayment terms.

Step 2: Identify pricing opportunities

On December 3, 2021, December 2022 corn futures closed at $5.52 per bushel. This producer needs a futures price of $5.32 per bushel to pay operating expenses and expected family living and debt service needs. This pricing opportunity of $5.52 would cover the producer's Family Living needs, Operating expenses, Interest expenses, and long-term Debt payments (FLOID) and leave $0.20 per bushel ($25/acre of corn) for equity Growth if the 125-bushel yield is achieved.

Table 1 below is a recap of USDA's World Agriculture Supply and Demand Estimates (WASDE), released in November 2021. The 22/23 column are estimated numbers based on analysts' expectations for the corn crop to be planted in 2022. USDA will not release their 2022-23 S&D estimates until May 2022.

Table 2. USDA World Agriculture Supply and Demand Estimates (WASDE), released in November 2021.

-	**19/20**	**20/21**	**21/22**	**22/23**	**23/24**
-	WASDE-618	WASDE-618	Estimate	Estimate	Estimate
Planted	89.7	90.7	93.3	92.0	91.7
Harvested	81.3	82.3	85.1	84.3	84.0
Yield	167.5	171.4	177.0	51.6	52.2
Beg Stocks	**2,221**	**1,919**	**120**	**137**	**185**
Production	13,620	14,111	15,062	15,075	15,189
Imports	42	24	25	25	27
Total Supply	**15,882**	**16,055**	**16,323**	**16,593**	**16,869**
Feed	5,903	5,597	5,650	5,800	6,000
Food/Seed	1,430	1,437	1,430	1,440	1,445
Ethanol	4,852	5,032	5,250	5,200	5,200
Exports	1,778	2,753	2,500	2,500	2,550
Total Demand	**13,963**	**14,819**	**14,830**	**14,940**	**15,195**
Ending Stocks (ES)	**1,919**	**1,236**	**1,493**	**1,653**	**1,674**
Percent Use	14%	8%	10%	11%	11%
USDA Price	**$3.56**	**$4.53**	**$5.45**	**-**	**-**
Futures as of 12/3/21	**-**	**-**	**-**	**$5.52**	**-**

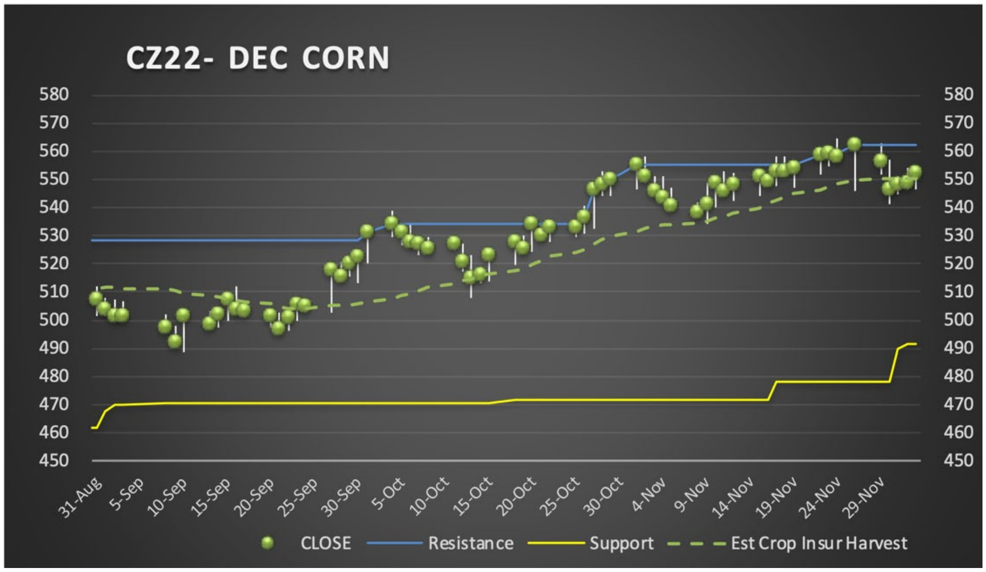


Figure 1. December corn futures price activity from August 31, 2021 through November 29, 2021.

These three factors (current price versus break-even price, projected increased ending stocks, and futures price direction) indicate that a pricing opportunity exists for this producer.

Step 3: Execute the sale

Commodity prices tend to follow a seasonal pattern of relatively higher prices around planting and lower prices at harvest. Corn's historical seasonality of prices shows that prices are highest in May and June and lowest in November. Unfortunately, this pattern is not perfect, as we found out in 2020. Nevertheless, this producer should consider pricing a portion of expected production soon while the price is profitable and because the 2022 price is expected to decline from a supply and demand perspective.

The method of pricing could be a cash forward contract which will require the producer to deliver the contracted quantity as outlined in the forward contract. Producers should use cash forward contracts when they are comfortable with the delivery requirements. Alternatively, the producer could hedge their corn using the futures market. Futures contracts do not require delivery but will require the use of a commodities broker. Producers will need to provide margin money to secure the trade and wire additional margin if prices rise. Put options allow producers to set a minimum price for corn in exchange for the option premium. The premiums are paid at the time of purchase and, like futures require the use of a commodity broker.

Determining the quantity to market is one of the last decisions a producer needs to make. When using cash forward contracts, the minimum quantity is often 1,000 bushels. Futures and options contracts are typically in 5,000-bushel increments, although mini contracts of 1,000 bushels may be available. Given a 125-bushel expected yield, a 5,000-bushel contract commits 40 acres of corn. If growing 500 acres, one contract represents 8% of expected production.

Consider pricing up to your crop insurance guarantee before harvest. For example, if the producer has a 75% Revenue Protection policy, he may choose to price up to 94 bushels per acre before harvest. For this example, the producer may consider pricing 25% of production before planting (December to April), another 25% post-planting (May to August), and another 25% as actual production becomes clearer (September to October).

Marketing is important for the profitability of corn. Spend some time each week monitoring your marketing activity. If you would like more information about commodity marketing, read the weekly Commodity Market Outlook newsletter on the Clemson Extension Agribusiness Program Team website (clemson.edu/extension/agribusiness/marketing/commoditymarketing.html).

Corn Vegetative and Reproductive Growth Stages

Michael Plumblee, PhD

Identifying the corn growth stages is essential for proper crop management of pests, irrigation, and fertility. Generally, corn growth and development can be divided into vegetative (V) and reproductive (R) growth stages. The beginning of each stage starts when at least 50% of plants in the field or area are at that stage. Vegetative growth stages start with corn emergence, and reproductive growth stages start with silking. An additional source on corn growth stages can be found at "A Visual Guide to Corn Growth Stages".

Vegetative (V) Growth Stages

The vegetative growth stages start with corn emergence (VE) and finish with tasseling (VT) (table 1). Description of corn plant during early development is shown in figure 1. During the VE stage (figure 2), the mesocotyl elongation pushes the growing coleoptile to the soil surface, and the radicle root and some lateral roots develop from the seed. This seminal root system absorbs water and nutrients until the V3 growth stage (3 leaves with collars). Following emergence, the coleoptile and mesocotyl elongation stops, and the growth continues from the growing point (stem apex), which is located just above the mesocotyl and below the soil surface until the V5–V6 growth stage (5 to 6 corn leaves with collars). The rapidly developing embryonic leaves grow through the coleoptile tip.

Table 1. Vegetative (V) corn growth stages.

Stage	Description
VE	Plant emergence (depends on temperature and moisture).
V1	First fully expanded leaf with the leaf collar (figure 3).
V2	Second fully expanded leaf with the leaf collar (figure 4).
V3	Third fully expanded leaf with the leaf collar.
Vn	(n) number of fully expanded leaf with the leaf collar.
VT	Tassel fully emerged (figure 5).

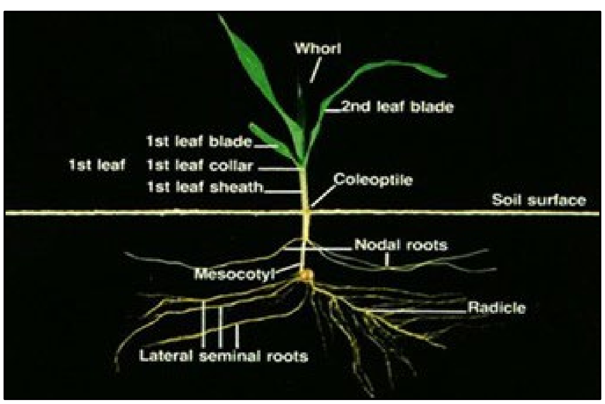


Figure 1. Description of corn plant during early development. Image credit: Michael Plumblee, Clemson University.

Figure 2. VE – Corn emergence. Image credit: Michael Plumblee, Clemson University.

Figure 3. V1 – First fully expanded leaf with the leaf collar. Image credit: Michael Plumblee, Clemson University

Figure 4. V2 – Second fully expanded leaf with the leaf collar. Image credit: Michael Plumblee, Clemson University

Stages between VE and VT are designated numerically as V1 (figure 3), V2 (figure 4), through V(n). The (n) represents stage with top leaf fully expanded before the VT stage (figure 5). A leaf is considered fully expanded if the leaf collar (discolored line between the leaf blade and leaf sheath) is visible. The eventual number of leaves to be produced by a plant is determined by V6 - V7 growth stage.

Reproductive (R) Growth Stages

The reproductive (R) stages are designated with R1 through R6 (table 2). These stages start with silking (R1) (figure 6) and finish with physiological maturity (R6). Following R1, stage R2 refers to blister, R3 - milk, R4 - dough, R5 - dent, and R6 - physiological maturity (grain black layer).

At R1 (figure 6), silks are first visible outside the husks. Pollination occurs when the falling pollen grains are caught by these silks. All silks emerge from the base to the tip in 2 to 5 days and remain receptive for up to two weeks. The silks will continue to elongate until fertilized. The ears pollinate from the base to the tip. Silks are pollinated within 2 to 3 days. For successful pollination, it is important that silks emerge and pollinate at the same time. Moisture stress at this time causes poor pollination and reduced seed set, and therefore reduced yield. More information on conditions affecting corn can be found in the chapter, "Environmental Conditions Affecting Corn Growth."

Figure 5. R1 - Silking. Image credit: Michael Plumblee, Clemson University

Figure 6. R6 – Physiological maturity. Black layer. Image credit: Michael Plumblee, Clemson University

At R2 stage, the kernels are white on the outside and have a blistered appearance. At R3, the kernel is yellow outside and filled with a milk-colored fluid which is mainly starch. Kernels at this stage have 80% moisture. During the R4 stage, starch continues to accumulate and thickens to a pasty consistency. At the R5 stage, most kernels are dented. The kernels at the R5 stage are drying down, beginning at the top, where a small hard white layer of starch is forming. The line indicating the hard starch layer will advance toward the base of the kernel.

Table 2. Reproductive (R) corn growth stages.

Stage	**Description**
R1	Silking (figure 6).
R2	Blister.
R3	Milk.
R4	Dough.
R5	Dent.
R6	Physiological maturity. Black layer. (figure 7)

The kernels reach their maximum dry matter weight at the R6 stage (figure 6) when the hard starch layer has advanced completely to the cob and formed a brown or black abscission layer (black layer) right above the kernel tip. The "black layer" is an indication of physiological maturity. Kernels at the R6 stage have about 30% to 35% moisture content.

Planting Considerations

Michael Plumblee, PhD

Field Selection

Corn can be grown on a wide range of soils. Field selection should be based on the potential to produce optimum yields. Information to assist with field selection is presented in the County Soil Survey, available from local USDA-NRCS offices. In addition to soil survey maps, Clemson scientists are utilizing geo-referenced equipment (Veris 3100) that can map the spatial variability in soil type and depth to the subsoil within fields.

Rotation

Corn rotation with other crops like soybean, peanut, tobacco, and cotton, can help with reducing the weed, insect, and disease pressure and improve yields. Additionally, rotating crops helps to remove phytotoxic substances produced by corn and improve soil physical properties.

Growing legumes prior to corn add residual nitrogen to the soil, which can be utilized by corn, and therefore the nitrogen rates can be reduced on corn by 20 to 30 lb/A.

Tillage

Most of the soils in South Carolina are sandy and have low water and nutrient holding capacity. These soils tend to form natural compacted zones or hardpans that are restrictive to corn root growth and development. Hardpans are formed either by tillage operations (6 to 8 inches deep) or naturally (8 to 15 inches deep) right above but not extending into the clay subsoil. These compacted layers or hardpans range in thickness from 2 to 12 inches. When present, they prevent or delay root development into the subsoil, resulting in lower grain yields.

Corn is sensitive to the presence of hardpans and responds well to deep tillage, which breaks the hardpan layers to allow corn roots to reach for water and nutrients at lower soil depths and, therefore, better withstand short drought periods during the growing season.

Research over the past twenty years has shown significant yield increases as a result of deep tillage when hardpans exist. Deep tillage, such as in-row subsoiling, promotes deeper root penetration into the soil, allowing roots to extract more subsoil moisture and nutrients. The advantages of subsoiling over shallow cultivation are usually more pronounced in drier years. Fields should be checked to confirm the presence of a hardpan each year. This can be done by pushing a sharpened metal rod through the topsoil when soil moisture conditions are good. A hardpan can usually be detected by an increase in resistance to rod penetration between the 4- and 14-inch soil depth. The depth of the subsoil depends on the soil type. To properly adjust the operating depth of the deep tillage equipment, it is necessary to know the depth of clay throughout the field.

Chisel plows can operate to a depth of 11 to 12 inches but have a very high draft requirement when run at these depths. In-row subsoilers perform more efficiently at these depths or deeper and offer the advantage of not inverting the topsoil or mixing the subsoil with the topsoil. For subsoiling to be economically effective, the subsoiler must reach the bottom of the hardpan layer but not into the clayey subsoil. Subsoiling deep into the clay will not increase yields but will increase the costs of operation. In deeper sandy soils where the subsoiler will not reach to the clay, subsoil to a depth of 16 to 18 inches if possible. Because of the curvature of the subsoiler shanks, the depth of penetration of the shanks is seldom equal to the length of the shank. Inadequate penetration into the soil is a common problem in South Carolina that does not increase grain yields but increases time, energy, and labor costs. In-row subsoiling must be combined with some additional method to prevent the seed from settling too deep in the loose soil slit made by the subsoiler shank. Several types of slit-closing devices are available such as spider-gangs or rolling cultivators, fluted coulters, concave disks, and press wheels. These closing devices require that their position, angle, and spring tension be adjusted based on subsoiler depth and the soil and residue conditions. The benefits of deep tillage may be reduced if subsoiling is conducted when soil conditions are too dry (creates a cloddier seed zone) or too wet (compacts soil adjacent to subsoiler slit). If needed, disking operations should be conducted before subsoiling to prevent recompaction. When in-row subsoiling is done correctly, it should substitute for deep plowing and part of the secondary tillage.

Conservation Tillage

Conservation tillage refers to soil preparation that leaves a percentage of the soil surface covered by some form of plant residue after a crop is established. The minimum portion of surface coverage to qualify as conservation tillage is 30 percent after planting. This residue coverage on the soil surface reduces the risk of erosion and protects water quality from degradation caused by runoff carrying sediment and possibly traces of fertilizer, pesticides, or both. Tillage systems affect soil properties such as temperature, moisture, bulk density, aggregation, organic matter content, and plant properties such as root density. Spring soil temperatures are usually lower in conservation tillage systems than other tillage systems. Conservation tillage systems increase the amount of water stored in the soil profile by reducing evaporation and helping the plants survive short periods of drought. Long-term conservation tillage practices also increase organic matter levels in the soil. Lower soil temperatures and increased soil moisture contribute to slower rates of organic matter oxidation. In conservation tillage systems, reduced tillage leads to nutrient distributions that differ from those in other tillage systems. Less mixing of the soil in reduced tillage systems leads to the distribution of phosphorus and potassium near the soil surface. Also, capturing more of the rainfall through good use of conservation tillage can often help to improve corn yields and profitability.

Planting Depth

Good soil preparation is important for uniform placement of seeds in the soil to achieve high corn yields and quality. It should protect the soil from water and wind erosion, provide a good seedbed for planting, break the hardpans or compacted layers, and allow an increase of organic matter. Cultivate the soil so that the soil is just fine enough to give good contact between the seed and soil. Good seed to soil contact is necessary so the seed can absorb moisture from the soil particles. Overworking the soil does not help the corn seed to germinate or emerge, but it will increase production costs, the risk of soil crusting, and soil erosion during periods of heavy precipitation.

The seeding depth should be adjusted according to soil conditions. Avoid planting corn into cold (soil temperature below 50°F at the top two inches) and wet soils if at all possible. Corn should be generally planted between 1½ to 2 inches deep. If planted early, the seed can be planted at 1½ inches deep due to generally higher soil moisture and less evaporation. Later planting in warm soils requires deeper seed placement of up to 2 inches. It is important to establish a good seed-soil contact while planting by using seed-press wheels.

The risk associated with more shallow than 1½ inch depth is the possibility of poor development of the secondary (permanent) root system. Check the seeding depth periodically to ensure proper depth across the field. Irregular depth of planting may result in uneven plant emergence and reduced yields. Germination time will depend on moisture and temperature. The temperature in the top 2 inches is influenced by the air temperature. Cooler soil temperatures will extend the time from corn planting to emergence. Below 50°F, little, if any, germination can be expected. With deeper planting, seeds are placed in cooler soil, which leads to slower emergence. Planting depths greater than 2 inches result in seedlings with less vigor, slower growth and development, and less yield. Planting corn seeds too deep may result in the coleoptile growth terminating below the soil surface. As the shoot grows through the coleoptile tip, it will continue to grow unprotected towards the surface. In heavy soils, crusted or compacted soils, an unprotected shoot will be torn apart before it can emerge.

Regarding the organic soils where drainage is a problem, the recommended planting depth should be 1 inch during the early part of the planting season. Deeper planting on organic soils often results in poor germination and emergence.

Environmental Conditions Affecting Corn Growth

Michael Plumblee, PhD

Besides management practices, corn production depends on environmental conditions. The main environmental factors influencing corn growth are temperature, moisture, and solar radiation. Especially important are temperature and moisture.

Temperature

The optimal average temperatures for corn growth range between 68°F and 73°F. However, the optimum temperature varies over the corn growing season and between daytime and nighttime. Corn can survive short exposure to low and high temperatures of 32°F and 112°F, respectively.

Cooler temperatures slow down the growth of plants. Growth decreases once the temperature drops to about 41°F. Temperatures between 32°F and 28°F have very little effect on corn. Extremely low temperatures cause freeze damage, the severity of which will depend on the temperature, duration, and corn growth stage. Extended low temperatures at the seedling stage that reduce the soil temperatures to below freezing two inches below the surface may kill corn. Later in the season, a long exposure of corn to temperatures below 28°F can damage corn by damaging the "growing point." The growing point for corn is located in the center of the stem and below the soil surface until the V5 - V6 growth stage (5 to 6 corn leaves with collars). At the V6 growth stage, corn would be approximately 12 inches tall. It is important to remember that although corn can germinate and grow slowly at about 50°F, the planting should start when the average soil temperature reaches 55°F at the top two inches. Poor germination and stand usually are the result of low soil temperatures.

Corn yield may also be reduced due to high air temperatures (95°F and higher) during pollination. High temperatures during this time can cause damage to pollination if plants are under drought stress. During moisture stress, especially at low relative humidity, high temperatures can desiccate silks and damage or kill pollen. Pollination will not be affected by high temperatures if there is adequate moisture in the soil because pollen shed usually occurs during morning hours.

Growing Degree Days (GDD)

Corn productivity is also correlated with the length of the growing season, which is characterized by the Growing Degree Day (GDD) accumulations (referred to as "heat units"). The GDD is accumulated from the day after planting until physiological maturity. The GDD calculation method most commonly used for corn in the United States is the 86/50 method. Growing degree days are calculated as the average daily temperature minus 50 using the following formula:

$$GDD = ((T_{max} + T_{min}) / 2) - 50$$

where Tmax is the maximum temperature, and Tmin is the minimum temperature. If the maximum temperature is above 86°F, 86 is used, and if the minimum temperature is lower than 50°F, 50 is used in the calculations of the average temperature. Corn hybrids require a certain number of accumulated GDDs to reach maturity. Long-season hybrids require more GDDs to reach physiological maturity than short-season hybrids. This GDD method is more accurate in corn production than the traditional method of days from planting to maturity.

Moisture

The highest corn yields can only be obtained under optimum moisture conditions during the growing season. Moisture stress at any of the growth stages will result in potential yield reduction. Corn generally has high water requirements and can use about 0.25 inch of water per day during rapid growth. However, water usage may increase up to 0.35 inch per day during pollination. Corn yields are reduced when evapotranspiration exceeds water supply from the soil at any time during corn growth. Evapotranspiration is the sum of the water loss from the soil through evaporation and water used by the plant during transpiration. Major water loss in early corn growth is from evaporation. During moisture stress, the availability and uptake of nutrients are also reduced, and therefore stress weakened plants are also more susceptible to disease and insect damage. The yield loss due to water stress will depend on the growth stage of corn during the drought stress as well as the length and severity of the drought. Corn is most sensitive (highest potential yield loss) to water stress during pollination, followed by grain-filling and vegetative growth stages.

Water stress during vegetative growth stages will reduce stem and leaf cell expansion as well as dry matter accumulation due to lower water and CO_2 intake. This results in reduced plant height and leaf area and lower yield potential. Severe moisture stress is indicated by leaf wilting. Corn plants in the initial phases of drought wilt in the afternoon. During longer periods of drought, wilting occurs earlier in the day. Eventually, leaves remain wilted all day. A 10% to 20% yield reduction may occur if drought stress occurs during vegetative stages of corn.

Moisture stress during pollination is the most critical for reducing yield potential of corn. Severe moisture stress will result in delayed silking and reduced pollination due to lack of viable pollen and reduced synchronization between silking and pollination. Under severe stress, some plants will not form any silks, or silks will emerge after pollen production has ended; therefore, resulting in poorly developed ears. The moisture stress during this stage may cause up to 50% yield reduction. Kernels, especially near the tip of the ear, are most susceptible to abortion during the first two weeks following pollination. Tip kernels are generally fertilized last and are less vigorous. During the kernel dough stage, yield losses are mainly due to reductions in kernel dry weight accumulation. Stress during dough and dent stages will decrease kernel weights and often causes premature black layer formation. Once grain has reached physiological maturity, moisture stress will have no further physiological effect on final yield. High plant populations in moisture-limiting environments increase moisture stress and silking problems, which lead to reduced kernel number.

Soil Sampling and Fertility Management

Bhupinder Farmaha, PhD

The information provided in this chapter will help producers to make decisions related to lime and fertilizer to help with maintaining high corn yields. For complete detail, readers are referred to Clemson University Cooperative Extension Circular EC 476, Nutrient Management for South Carolina (bit.ly/3pH4HSb).

Soil Testing

The first step in soil testing is to obtain a representative soil sample from the field. Here are the steps for obtaining a representative soil sample:

- Divide field into 2.5-acre areas (also used in the precision ag sampling) based on similar management history and soil characteristics - sample should not represent a field over 10 acres. Consider using precision agriculture techniques such as grid sampling or zone sampling for more detailed information about soil variability.
- Take into consideration difference in surface color is the most evident feature separating soil types, indicating possible variability in texture, organic matter content, and drainage.
- Nutrient removal rates by crops are important in determining residual soil fertility levels. Therefore, cropping history is another important factor to consider when defining a sample area.
- Construct an accurate map of the field to take samples from the same areas each year, preferably in the fall after harvest, to enhance the relevance of annual comparisons. Consistent timing of sampling from year to year is crucial for meaningful comparisons.

Taking soil samples:

- Obtain 10 to 20 soil cores (brush away surface plant residue material) from a 6 to 8 inches depth for tilled areas. For no-till areas, consider stratified sampling: 0-2 inches and 2-8 inches to account for nutrient stratification.
- Place soil cores in a clean plastic bucket and mix thoroughly.
- Fill a one-pint sample box with the soil subsample.

Detailed information to develop management zones and prescription maps is available in the Land-Grant Press publication, Precision Agriculture-Based Soil Sampling Strategies (bit.ly/3vJQAz2).

In most sandy Coastal Plain soils where deep tillage is practiced to break root restrictive hardpans, a sample of the top four inches of subsoil can be used to determine the availability of potassium, sulfur, and magnesium. These nutrients readily leach through the sandy surface layer but are retained in the upper part of the subsoil. The results of subsoil samples can be used to adjust fertilizer recommendations made from the analysis of the A horizon sample.

Soil samples can be sent to Clemson University's Agricultural Services Lab for analyses (visit the Lab website, bit.ly/3vJQAz2), or to a private lab. Your Cooperative Extension county office can help provide soil sample boxes, submission forms, and advice on taking soil samples. The county office will also mail your samples to the Clemson University's Agricultural Services Lab on a fee basis.

Soil samples are analyzed for soil pH and the plant-available contents of potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg), zinc (Zn), copper (Cu), boron (B), and manganese (Mn). Based on these soil test results, recommendations are made regarding the correction of soil pH and fertilization requirements to achieve top yields. These recommendations are based on several years of soil test calibration research conducted in South Carolina and neighboring states. Soil analysis procedures determine the amount of each nutrient available for crop uptake.

Soil pH and Liming

A soil pH too low or too high can adversely affect nutrient availability and hence, corn growth and yield. The best pH for corn grown in most South Carolina soils is between 5.8 and 6.5. Low soil pH is one of the most frequent problems encountered in cornfields across South Carolina. If soil tests show a low soil pH, lime can be applied to enhance yield by

- Reducing toxicity of soil aluminum and/or manganese
- Improving uptake of phosphorus, potassium, and molybdenum
- Increasing availability of calcium and magnesium (with dolomitic lime)

Lime Application

Soil pH decreases over time due to use of application of nitrogen fertilizer, crop nutrient removal, and leaching of basic cations (like calcium). Symptoms of low pH include stunted plant development, uneven crop growth across the field, premature senescence of lower leaves, and interveinal chlorosis (yellowing between veins) on upper leaves. Low soil pH can limit plant growth through aluminum and acid effects on plant roots, manganese toxicity, calcium, magnesium, or molybdenum deficiency, and reduced phosphorus availability. Additionally, under low pH conditions, bacterial activity is reduced, slowing the breakdown of soil organic matter, crop residues, and organic fertilizer sources (such as animal manures). Thus nutrient release from these sources is lessened.

The best time to apply the recommended rate of lime is following the harvest of the previous crop to allow lime for neutralizing soil acidity prior to planting corn. Lime application will be slower in dry soil because water is required for lime to react with the soil. Usually, liming materials with a high calcium carbonate equivalent (CCE) tend to neutralize soil acidity faster than those with a low CCE. Faster activity of lime will be from finer material due to greater surface area. Use dolomitic lime when magnesium levels are low or anticipated to be low prior to the next time lime is needed. Dolomitic lime will supply 80 to 240 pounds of magnesium and 400 to 600 pounds of calcium per ton. Calcitic lime will supply 8 to 12 pounds of magnesium (usually not enough) and 700 to 800 pounds of calcium per ton. The Land-Grant Press publication, Basis of Selecting a Lime Material (bit.ly/3pHx7eS), provides additional information about how to evaluate liming materials and choose the most effective and economical lime source and appropriate rate for the crop production system.

When selecting a liming material, consider both the CCE and the fineness of the material. Finer materials react more quickly with the soil. For no-till systems or when a quicker pH change is needed, consider using finely ground lime.

Variable rate lime application based on precision soil sampling results can improve the efficiency of liming practices and ensure more uniform soil pH across the field.

A soil with a low cation exchange capacity (CEC) has a low buffer capacity and will not require a lot of lime to correct soil pH but may need lime applied frequently. A soil with a high CEC may require a large amount of lime to initially correct pH but may not need another application for a few years due to a high buffering capacity.

Starter Fertilizers

Research in several states in the Southeast has shown that the placement of some fertilizers near the seed at planting may increase grain yields in years of good rainfall or when corn is grown with irrigation. Usually, this fertilizer is placed 2 inches to the side and 2 inches below the seed. Higher yields will usually be achieved on sandy soils if the starter fertilizer is applied. Applying phosphorus as a starter may be beneficial if the soil test shows phosphorus to be very low or if corn is planted in cold soil. Starter fertilizer may help to increase early plant growth but doesn’t always translate to higher grain yield.

Nutrient Deficiencies

Even when soil fertility levels are optimum, nutrient deficiencies may occur if root growth and function are restricted by soil compaction and hardpans, nematodes, diseases, low soil temperatures, or excess rain over a prolonged period of time. If nutrient deficiencies are suspected, take leaf samples from both healthy and deficient plants for tissue test analyses. Soil samples should also be collected from the same areas and sent to the lab for nutrient analysis.

Nitrogen (N)

Optimum levels of nitrogen are required to sustain high corn growth and yield. Nitrogen is critical in many plant processes, such as a key component of chlorophyll and the leaf enzymes associated with sugar production. It is also a major component of amino acids to build proteins, energy-transfer compounds, such as ATP (adenosine triphosphate), which allow cells to use energy during metabolism, and nucleic acids such as DNA - genetic material that allows plant cells to grow and reproduce. Nitrogen is also vital in maintaining green leaf area and proper ear development.

Soil nitrogen exists in organic and inorganic (mainly as ammonium (NH_4^+) and nitrate (NO_3^-) ions) forms. Most of the potentially available nitrogen in the soil is in organic forms, which are not directly available to plants until converted to NH_4^+ by soil microorganisms. Ammonium ions bind to the soil's negatively-charged cation exchange complex while nitrate ions exist dissolved in the soil water.

Nitrogen-deficient corn plants are pale green and have small, spindly stalks. Additional symptoms include a V-shaped yellowing beginning at the leaf tip and proceeding to the base of the leaf on lower leaves. Corn plants generally accumulate up to two-thirds of their total nitrogen two weeks before and two weeks after tasseling (figure 1). Recent research has shown, however, that many stay-green hybrids accumulate even a greater proportion of their total nitrogen during the grain-filling period. Therefore, nitrogen applications must be properly managed to ensure that adequate nitrogen is available to the plants during this period of development. The most profitable rate of nitrogen fertilizer depends on many factors such as soil type, amount of rainfall during the growing season, plant population, cultural practices, residual nitrogen from the previous year (especially following a year with low rainfall), and decomposition of organic matter under warm soil conditions.

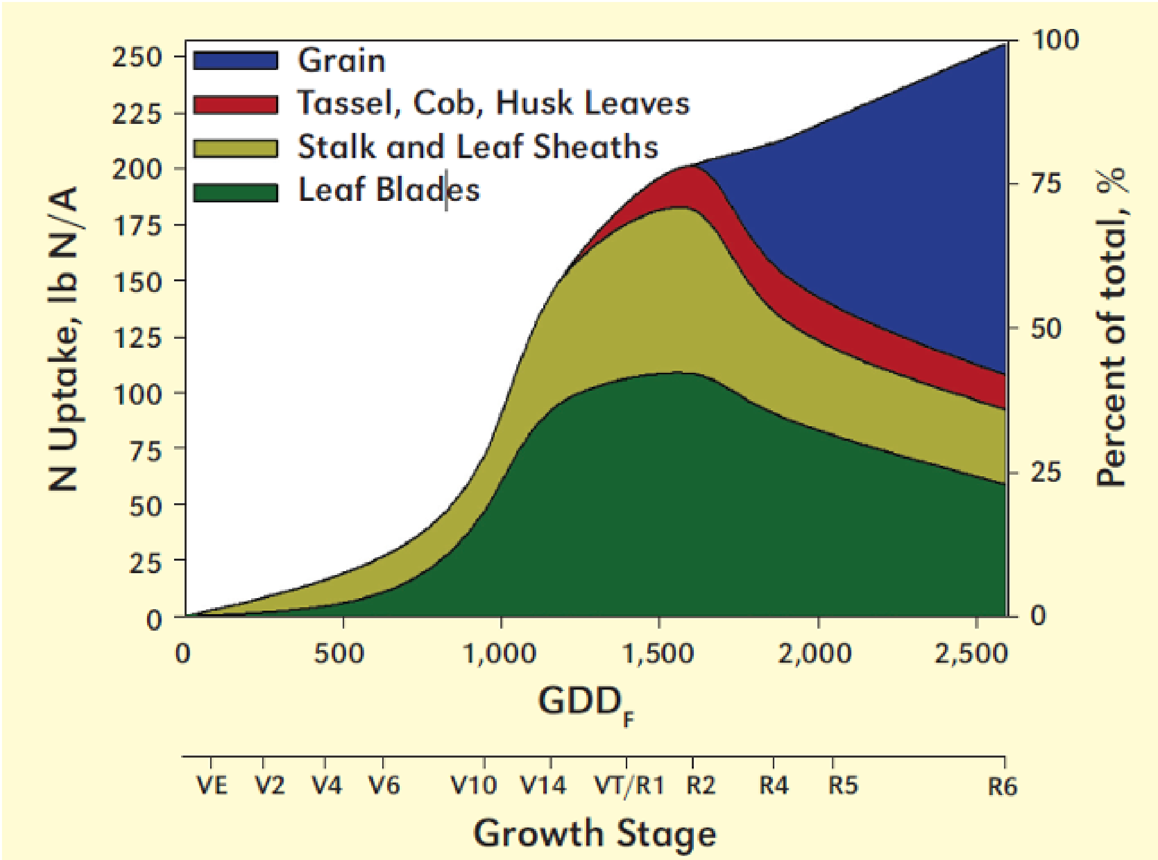


Figure 1. Seasonal N accumulation and partitioning averaged over six hybrids evaluated at Urbana, IL and DeKalb, IL in 2010. The average grain yield of the six hybrids was approximately 191 bu ac−1. GGDF = growing degree days (Fahrenheit). (Source: Bender, R.R., Haegele, J.W., Ruffo, M.L., and Below F.E. 2013. Modern corn hybrids' nutrient uptake patterns. Better Crops Plant Food 97: 7–10.).

The suggested rates of nitrogen need to be adjusted based on the grower's experience. For most corn, under dryland conditions, a rate from 120 to 150 pounds per acre should be sufficient. For very sandy soils with yield potentials of 80 bushels per acre or less, 100 pounds of nitrogen per acre is adequate. Use from 150 to 180 pounds of nitrogen per acre on river bottoms or on soils with high water and nutrient holding capacities which produce yields of 130 bushels per acre or more.

When corn is irrigated, apply 180 to 225 pounds of nitrogen per acre. Reduce the rate by 20 to 30 pounds per acre when corn follows soybean in a rotation. When a legume cover crop is grown and turned under before planting corn, reduce the rate of nitrogen applied by 50 to 80 pounds per acre.

When animal manure is applied to the field, adjust inorganic fertilizer nitrogen rates for the nitrogen supplied by the manure. Since animal waste is highly variable in nutrient content (nitrogen, phosphorus, and potassium), laboratory analyses are needed to determine its nutritive value. Animal waste analyses for cropland application can be obtained from the Agricultural Service Laboratory of Clemson University. See your county Extension agent for submission forms and sampling instructions.

A broadcast application of nitrogen immediately before or after planting may be the most convenient method to apply nitrogen to the soil, but it is the least effective. Nitrate, the most prevalent form of nitrogen in the soil, is a very mobile compound in sandy soils and is subject to leaching during periods of heavy precipitation. Consequently, nitrogen fertilizer should be applied in a split application to increase the efficiency of nitrogen application. Apply 30 to 40 pounds of nitrogen at planting. The start-up nitrogen application may be combined with a small amount of phosphorus. The early phosphorus application may help to improve its uptake under cool soil temperatures, which generally reduce phosphorus uptake under these conditions. The best method to apply this nitrogen is to band it 2 inches to the side and 2 inches below the seed or on the soil surface, 2 to 4 inches to the side of the row. Application too close to the germinating seed or emerging plant may cause severe salt injury. Also, the fertilizer salts may cause plants to wilt in low moisture soils by pulling water away from corn roots. Another method is to apply the nitrogen in a band over the row. If banded over the row, use the lower rate of nitrogen and have the band at least 8 inches wide to avoid injury to the seed or seedlings. The remainder of the nitrogen rate for corn should be applied when the plants are 15 to 30 inches high (between six and eight fully expanded leaves on the plants), just before corn begins rapid growth and development.

Corn will obtain this height usually 21 to 30 days after plant emergence. Moisture and nutrient deficiencies after this stage of growth will affect ear development. The nitrogen use efficiency can be improved by splitting the sidedress nitrogen portion (balance) into two sidedress applications for dryland corn and three applications for irrigated corn. For example, apply the first half of the sidedress balance when corn plants are 12 inches tall and the second half of the balance when corn plants are 24 to 30 inches tall for dryland corn. For irrigated corn, the timing of the first two applications would be similar to the dryland corn, and a third portion would be applied two weeks later through the irrigation system. All sources of nitrogen are equally effective for corn production when applied correctly. To increase the period of availability, growers may consider using slow-release forms of nitrogen or add a nitrification or urease inhibitor to the fertilizer. When nitrogen is applied with irrigation water (fertigation), the additional nitrogen may be applied over two or three applications. A 100 bushel per acre corn yield will remove 65 pounds of nitrogen in the grain. If harvested for silage, the grain and stover will remove 130 pounds of nitrogen per acre from the soil. Nutrient levels on the soil test report are indexed into the following categories (table 1).

Table 1. Soil test report nutrient levels.

Level	Category
Low	Soil is deficient, and applied nutrient will significantly increase yields.
Medium	There will be a response to nutrient application approximately 50 percent of the time.
Sufficient	Soil plant nutrient element level is in that range adequate to meet the crop requirement as well as that needed for consistent high crop yield production. A maintenance application rate is recommended to compensate for expected crop removal.
High or Excessive	Nutrient supply in the soil is sufficient for top yield performance, and nutrient addition is not likely to increase yields.

To improve N use efficiency, consider the following strategies:

1. Use of enhanced efficiency fertilizers, such as slow-release N forms or fertilizers with nitrification or urease inhibitors.
2. Split applications of N, with multiple applications throughout the growing season.
3. Use of in-season diagnostic tools, such as chlorophyll meters or aerial imagery, to guide N applications.

When applying nitrogen through irrigation systems (fertigation), consider multiple small applications throughout the season to match crop demand and reduce the risk of leaching losses.

Phosphorus (P)

Phosphorus is an essential component in the structure of many plant compounds and plays an important role in energy storage and transfer within the plant. It is relatively immobile and moves very little in the soil profile under most conditions. Most phosphorus is tightly bound to soil particles and unavailable to plants. Over-fertilization of soils with poultry litter, dairy wastes, and other animal manure contributes to the buildup of very high levels of phosphorus and may result in leaching in sandy soils.

A fibrous and extensive corn root system is essential for optimal phosphorus uptake. Early in the growing season, deficiency symptoms (purple leaves) may appear during periods of cold weather even when soil phosphorus is adequate because root growth is slowed to a relatively greater extent than vegetative growth. Sugars accumulated in the leaves and stem of the plant are not moved fast enough to slowly growing roots and therefore trigger anthocyanin production resulting in purple plants.

Small ears, undeveloped kernels at the ear tips, and twisted or bowed ears indicate that phosphorus deficiency occurred during reproductive development. The rate of phosphorus fertilizer to apply can only be determined by soil testing. A broadcast application is usually satisfactory, provided the fertilizer is incorporated into the soil. When the soil test for phosphorus is low, or corn is planted in cold soil, initial growth may be improved if part of the phosphorus is banded 2 inches below and 2 inches to the side of the seed. However, this practice may not always result in higher grain yields. A 100 bushel per acre corn yield will remove 34 pounds of P205 per acre in the grain. If harvested as silage, the grain and stover will remove 45 pounds of P205 per acre from the soil. The recommended rates of phosphorus for corn are shown in tables 2 through 6.

In no-till systems, P tends to accumulate near the soil surface. This stratification may affect P availability, especially during dry periods when the surface soil dries out. Deep banding of P fertilizer may be beneficial in these situations.

Potassium (K)

Potassium is important to maintain the plant's salt balance and regulate water and sugar movement within the plant. Because of its positive charge, potassium is involved in charge balance within the plant cells as well as making enzymes functional. Deficiency symptoms are usually first detected on older leaves and include the yellowing and dying of plant leaf margins beginning at the tips of lower leaves. The ears will not be filled at the tip, and the stalks will be weak and may lodge. Potassium movement depends on soil cation exchange capacity and will leach into the subsoil eventually in most sandy soils. A single application of potassium is sufficient on most soils, but split applications are recommended on very sandy soils. The rate of potassium fertilizer to apply must be determined by soil testing. The plant will take up more potassium than needed (luxury consumption) if excess potassium is added to the soil. Also, a high rate of potassium application may induce magnesium deficiency on soils with low magnesium levels. A 100 bushel per acre corn yield will remove 24 pounds of K2O in the grain. If harvested for silage, the grain and stover will remove 100 pounds of K2O per acre from the soil. The recommended rates of potassium for corn are shown in tables 2 through 6 (Source: General Comments for Agronomic Crops guide, (bit.ly/3pEhIeX).

Like P, K can also become stratified in no-till systems. Soil testing of separate depth increments (e.g., 0-2 inches and 2-8 inches) can help identify stratification issues. If stratification is severe, deep banding of K fertilizer may be beneficial.

Table 2. Fertilizer recommendations for corn grain yield goal of 100 bu/acre based on soil test results in South Carolina.

Phosphorus	**Potassium**				
	Low	Medium	Sufficient	High	Excessive
		pounds of N-P_2O_5-K_2O per acre			
Low	120-80-110	120-80-80	120-80-40	120-80-0	120-80-0
Medium	120-55-110	120-55-80	120-55-40	120-55-0	120-55-0
Sufficient	120-30-110	120-30-80	120-30-40	120-30-0	120-30-0
High	120-00-110	120-00-80	120-00-40	120-00-0	120-00-0
Excessive	120-00-110	120-00-80	120-00-40	120-00-0	120-00-0

Table 3. Fertilizer recommendations for corn grain yield goal of 150 bu/acre based on soil test results in South Carolina.

Phosphorus	Potassium				
	Low	Medium	Sufficient	High	Excessive
	pounds of N-P_2O_5-K_2O per acre				
Low	170-105-135	170-105-95	170-105-60	170-105-30	170-105-0
Medium	170-80-135	170-80-95	170-80-60	170-80-30	170-80-0
Sufficient	170-55-135	170-55-95	170-55-60	170-55-30	170-55-0
High	170-00-135	170-00-95	170-00-60	170-00-30	170-00-0
Excessive	170-00-135	170-00-95	170-00-60	170-00-30	170-00-0

Table 4. Fertilizer recommendations for corn grain yield goal of 200 Bu/acre based on soil test results in South Carolina.

Phosphorus	Potassium				
	Low	Medium	Sufficient	High	Excessive
	pounds of N-P_2O_5-K_2O per acre				
Low	220-130-170	220-130-120	220-130-75	220-130-40	220-130-0
Medium	220-105-170	220-105-120	220-105-75	220-105-40	220-105-0
Sufficient	220-80-170	220-80-120	220-80-75	220-80-40	220-80-0
High	220-00-170	220-00-120	220-00-75	220-00-40	220-00-0
Excessive	220-00-170	220-00-120	220-00-75	220-00-40	220-00-0

Table 5. Fertilizer recommendations for corn grain yield goal of 250 Bu/acre based on soil test results in South Carolina.

Phosphorus	Potassium				
	Low	Medium	Sufficient	High	Excessive
	pounds of N-P_2O_5-K_2O per acre				
Low	270-155-220	270-155-145	270-155-85	270-155-50	270-155-0
Medium	270-130-220	270-130-145	270-130-85	270-130-50	270-130-0
Sufficient	270-105-220	270-105-145	270-105-85	270-105-50	270-105-0
High	270-00-220	270-00-145	270-00-85	270-00-50	270-00-0
Excessive	270-00-220	270-00-145	270-00-85	270-00-50	270-00-0

Table 6. Fertilizer recommendations for corn silage based on soil test results in South Carolina.

Phosphorus	Potassium				
	Low	Medium	Sufficient	High	Excessive
	pounds of N-P_2O_5-K_2O per acre				
Low	180-100-100	180-100-60	180-100-50	180-100-0	180-100-0
Medium	180-50-100	180-50-60	180-50-50	180-50-0	180-50-0
Sufficient	180-40-100	180-40-60	180-40-50	180-40-0	180-40-0
High	180-00-100	180-00-60	180-00-50	180-00-0	180-00-0
Excessive	180-00-100	180-00-60	180-00-50	180-00-0	180-00-0

Calcium (Ca)

Calcium is involved in the construction of plant cell walls. Consequently, when a young plant is deficient in calcium, the tips of new leaves will not unroll properly and will stick together. Other symptoms include dark green stems, weakened stems, and poor ear formation. Applying lime will supply enough calcium for optimum corn growth, and deficiencies will not occur if a favorable soil pH is maintained. A soil test level of 300 pounds per acre or greater will supply adequate calcium for corn production. Apply sulfate forms (gypsum is calcium sulfate) if calcium deficiencies occur at optimum soil pH.

Magnesium (Mg)

Magnesium is an important component of chlorophyll molecules. Deficiency symptoms include chlorosis (yellowing) between the leaf veins of upper leaves and often a reddish tint on the stem and underside of lower leaves. Magnesium may become limiting at low pH on sandy soils.

Compact layers or hardpans and a high rate of potassium or calcium may also cause magnesium deficiencies in corn. Also, magnesium deficiency may be induced by high crop nitrogen uptake but usually disappears after about two weeks. If the soil test level for magnesium is 32 pounds per acre or greater, the corn plant will have adequate magnesium. Magnesium saturation of the cation exchange capacity should be greater than 10% to ensure adequate magnesium availability. Magnesium is seldom a limiting nutrient if dolomitic limestone is applied as the lime source several months prior to planting corn. The use of calcitic lime sources (including some types of poultry manures) are often the cause of magnesium deficiency. If magnesium needs to be added to the soil without adding lime, apply 10 to 15 pounds per acre of magnesium as magnesium sulfate, sulfate of potash-magnesia, or magnesium oxide. Dolomitic lime is always the least expensive source of magnesium.

Sulfur (S)

Sulfur is a key component of many compounds in the plant, such as the energy-producing chloroplast and several amino acids. Sulfur deficient plants are small and spindly and have slower growth and delayed maturation. Sulfur deficiency is expressed as an overall yellowing of the plant or yellowing of the new leaves. This response is in contrast to nitrogen deficiencies which are more apparent on old lower leaves. During periods of low temperature and/or with excessive rainfall in the spring, sulfur deficiencies on corn can occur shortly after seedling emergence, especially on sandy soils. The plants often recover when roots reach the subsoil zone where sulfur has accumulated. Side-dressing with a nitrogen-sulfur solution or a sulfate-sulfur source will help the plants to recover. Elemental sulfur is not a good choice for alleviating sulfur deficiency because it is only slowly available and can decrease soil pH drastically. Sulfur, like nitrate, is relatively mobile in the soil and may be leached to the clay layer with rainfall.

However, sulfur will accumulate in the subsoil, unlike nitrate. Soils with the clay layer within the root zone will generally have adequate sulfur for corn production. Apply 10 pounds of sulfur per acre when the depth to clay is greater than 15 inches. Apply sulfur with phosphorus and potassium fertilizers at planting or with the nitrogen side-dress—split applications for deep sandy soils. Corn requires a relatively large amount of sulfur, generally 20 to 30 pounds per acre.

The importance of S fertilization has increased in recent years due to reduced atmospheric deposition of S. Consider including S in your fertilizer program, especially on sandy soils or those low in organic matter. Tissue testing during the growing season can help identify S deficiencies.

Zinc (Zn)

Because of its involvement in chlorophyll formation, zinc deficiencies will often appear as a bleached-colored chlorosis on the lower portion of new leaves. Also, deficiencies include decreased stem length (rosetting) and interveinal chlorosis. Deficiencies have been observed on young corn plants in cold soil during cool weather, but the plants usually grow out of the deficiency with warmer temperatures. Severe zinc deficiencies may occur when deep sandy soils are limed to a soil pH of 6.5 or higher, which results in the reduction of zinc available to plants.

Soils having the suggested soil pH (5.8 to 6.5) will have adequate zinc for corn production if the soil test shows 1.8 pounds of zinc per acre or higher. To prevent zinc deficiency, apply 3 pounds per acre of actual zinc preplant or at planting, but only when soil tests are low.

Boron (B)

Boron deficiency may appear on new plant growth, especially on sandy soils low in organic matter. Symptoms of boron deficiency include shortened internodes, necrotic speckling on leaves, and poor tassel and ear formation. Boron occurs in the soil in both organic and inorganic forms, but only a small amount is available to plants. The best method for determining when boron is needed is plant analysis, not soil testing. High levels of calcium, potassium, or nitrogen levels can interfere with boron uptake. Soils high in calcium will require more boron. Generally, apply 1 - 2 pounds of boron per acre in split applications (with the nitrogen). Soils in the pH range of 5.8 to 6.5 will have adequate boron for corn production.

Boron is particularly important for pollination and kernel set in corn. Foliar application of B during the reproductive stages may be beneficial, especially if soil tests or tissue analyses indicate low B levels.

Manganese (Mn)

Manganese deficiencies may appear on new corn growth, especially on over-limed soils or with lime-amended biosolids. Manganese-deficient upper leaves become pale and chlorotic and are much narrower than normal leaves. Avoid stockpiling lime in the field and apply lime based on soil test recommendations. Soils in the suggested soil pH range of 5.8 to 6.5 will have adequate manganese for corn. If needed, manganese can be applied as manganese sulfate, manganese oxide, and manganese chelates or organic complexes. Manganese oxide must be finely ground to be effective. Manganese sulfate can be effectively applied either to the soil or to the crop foliage. In some soils, the chelates may be better than Mn sulfate but not for foliar application.

Copper (Cu)

Common Cu deficiency symptoms include stunting, leaf tip/shoot dieback, and poor upper leaf pigmentation. Copper deficiency is most likely on organic soils. Copper is commonly applied as copper sulfate, although copper oxides, copper chelates or organic complexes, and copper ammonium phosphates are also applied either to the soil or as foliar sprays or dusts. Copper chelates and organic complexes should be applied as a foliar application at much lower rates than soil applications. However, soil-applied copper will have much longer residual effects.

Selecting the Right Hybrid

Michael Plumblee, PhD

Corn hybrid selection depends on the farming operation. Plant corn early and use early-season hybrids if you plan to harvest early. Choose full-season hybrids if you plan to harvest late in the season. Planting different maturities at different times helps to spread the planting and harvest operations. Choose hybrids that produce consistently high yields across multiple locations and years. However, the selection should not only be based on the yields but also lodging, which may severely decrease yields under certain situations. Consider varieties with good tolerance to insects and diseases and good grain quality. If the feeding or other values are important, check the protein and oil composition of corn grain. Select hybrids with high grain protein for feeding and high oil content for processing. Typical relative maturity in hybrids grown in South Carolina range from 111 days. to 120 days. Earlier RM hybrids have been evaluated but are not always suited for our climate and diseases.

Hybrid selection should be based on

- Maturity: appropriate for location and farming operations. Selecting two to three different maturity groups can help to minimize the adverse effect of weather conditions and spread planting and harvesting operations
- Yield: high yielding hybrids using local data over multiple locations and years should be used
- Stalk strength: good stalk strength helps to minimize grain yield losses due to lodging
- Disease and insect tolerance: select varieties with good disease and insect resistance
- Grain quality: choose hybrids with good grain quality
- Select hybrids with high digestibility if used for silage

Corn producers should plant different maturity corn to minimize the adverse effect of weather conditions and reduce risk. Corn maturity is described as Relative Maturity (RM). However, the actual days to maturity will depend on the time of planting and seasonal weather changes. More accurate determination of days to maturity can be calculated based on the GDD. Due to changes in temperature, the actual number of GDDs experienced for any given period will vary from year to year. The kernel moisture content at physiological maturity generally averages about 30% to 35%.

At physiological maturity, a "black layer" will form under the outer layer of the kernel tip. When this forms, it signals that kernel dry matter accumulation has reached the maximum level.

Planting Dates

Michael Plumblee, PhD

Spreading the planting dates and maturity groups can help with planting and harvesting operations. If conditions allow, corn needs to be planted at the optimum time. The most active planting for South Carolina is between March 20 and April 20. Planting usually begins in early March. If many acres of corn need to be planted, start planting when the conditions allow it, so the planting can finish within the optimum planting time. Calendar date and soil temperature are reliable indicators for making the decision on when to begin planting corn. Some other advantages of early planted corn include higher soil moisture at planting, lower temperatures during pollination, earlier maturity and harvest in the fall, and higher yield and test weight potential. Early planting dates also result in faster canopy closure in the growing season, better stalk quality, and may help reduce late insect and disease pressure.

When planting, start with full-season hybrids first, and then plant early-season and mid-season hybrids. The full-maturity hybrids would have the benefit of maximum heat-unit accumulation. Delaying planting of full-season hybrids would reduce yields more than other short- and mid-season hybrids. Therefore, use short- or medium-season hybrids instead of full-season hybrids when planting late. However, planting corn late in the growing season increases the insect and disease pressure and the risk of low corn yields due to pollination occurring during a period of high temperature and moisture stress.

Higher grain yields are usually obtained when corn is planted as early as weather conditions permit. Higher yields of early planted corn are mainly due to reduced pest pressure late in the season, better rainfall patterns, and cooler air temperatures during corn silking. Start planting corn when the soil temperature reaches about 55°F at 2-inch depth in the morning, and the weather forecast indicates a good chance of warm temperatures over the next few days. Soil temperature will depend on soil type and moisture content. Light sandy soils will warm up faster than heavy and wet soils. Also, planting should be delayed by three to five if planting in the no-till system due to plant residue and higher moisture. Corn should be planted during optimum moisture to support traffic without causing soil compaction and mudding the seeds. Frost may still occur following planting, but corn normally withstands frost damage to above-ground tissue since the growing point is still below the soil surface until corn reaches V5–V6 stage (about 12 inches).

Plant Populations

Michael Plumblee, PhD

Plant population is correlated with corn yields and should be based on soil type. Heavier soils have higher water and nutrient holding capacity than sandy soils and have higher yield potential. Recommended populations range from 19,000 to 24,000 for sandy soils with low rainfall, 24,000 to 28,000 for heavier soils, and 28,000 to 32,000 for irrigated corn. The seeding rate should be about 10% to 15% higher than desired harvest population (table 1). Seeding rates will also depend on the tillage, hybrid tolerance, and standability.

It is important to remember that extremely high plant populations will lead to increased lodging, smaller ears, a lower number of kernels per ear, and lower yields. Usually, high-yielding grain corn hybrids produce high biomass yields. Also, there are corn hybrids developed specifically for silage. The plant population for growing corn for silage should be 2,000 to 3,000 plants higher compared to planting a hybrid for grain. The elevated plant population increases the biomass yields and total digestible nutrient production without the risk of lodging due to the earlier harvest of corn for silage. Table 2 can assist with calculating the plant stand per acre after counting the number of plants within a specific row width and length and multiplying this number by 1,000.

Table 1. Kernel spacing within the row for different seeding rates and row spacings.

Seeding rate/acre	Stand/acre (10% loss)	Row spacing (inches)							
		15	20	22	28	30	36	38	40
		Space between kernels (inches)							
19,000	17,100	22.0	16.5	15.0	11.8	11.0	9.2	8.7	8.3
20,000	18,000	20.9	15.7	14.3	11.2	10.5	8.7	8.3	7.8
21,000	18,900	19.9	14.9	13.6	10.7	10.0	8.3	7.9	7.5
22,000	19,800	19.0	14.3	13.0	10.2	9.5	7.9	7.5	7.1
23,000	20,700	18.2	13.6	12.4	9.7	9.1	7.6	7.2	6.8
24,000	21,600	17.4	13.1	11.9	9.3	8.7	7.3	6.9	6.5
25,000	22,500	16.7	12.5	11.4	9.0	8.4	7.0	6.6	6.3
26,000	23,400	16.1	12.1	11.0	8.6	8.0	6.7	6.3	6.0
27,000	24,300	15.5	11.6	10.6	8.3	7.7	6.5	6.1	5.8
28,000	25,200	14.9	11.2	10.2	8.0	7.5	6.2	5.9	5.6
29,000	26,100	14.4	10.8	9.8	7.7	7.2	6.0	5.7	5.4
30,000	27,000	13.9	10.5	9.5	7.5	7.0	5.8	5.5	5.2
31,000	27,900	13.5	10.1	9.2	7.2	6.7	5.6	5.3	5.1
32,000	28,800	13.1	9.8	8.9	7.0	6.5	5.4	5.2	4.9
33,000	29,700	12.7	9.5	8.6	6.8	6.3	5.3	5.0	4.8
34,000	30,600	12.3	9.2	8.4	6.6	6.1	5.1	4.9	4.6
35,000	31,500	11.9	9.0	8.1	6.4	6.0	5.0	4.7	4.5
36,000	32,400	11.6	8.7	7.9	6.2	5.8	4.8	4.6	4.4

Table 2. Row spacing and row length for 1/1,000 acre method.

Row spacing (inches)	Row length (1/1,000 acre)
15	34 ft 10 in
20	26 ft 2 in
22	23 ft 9 in
28	18 ft 8 in
30	17 ft 5 in
36	14 ft 6 in
38	13 ft 9 in
40	13 ft 1 in

Corn Irrigation

Michael Plumblee, PhD

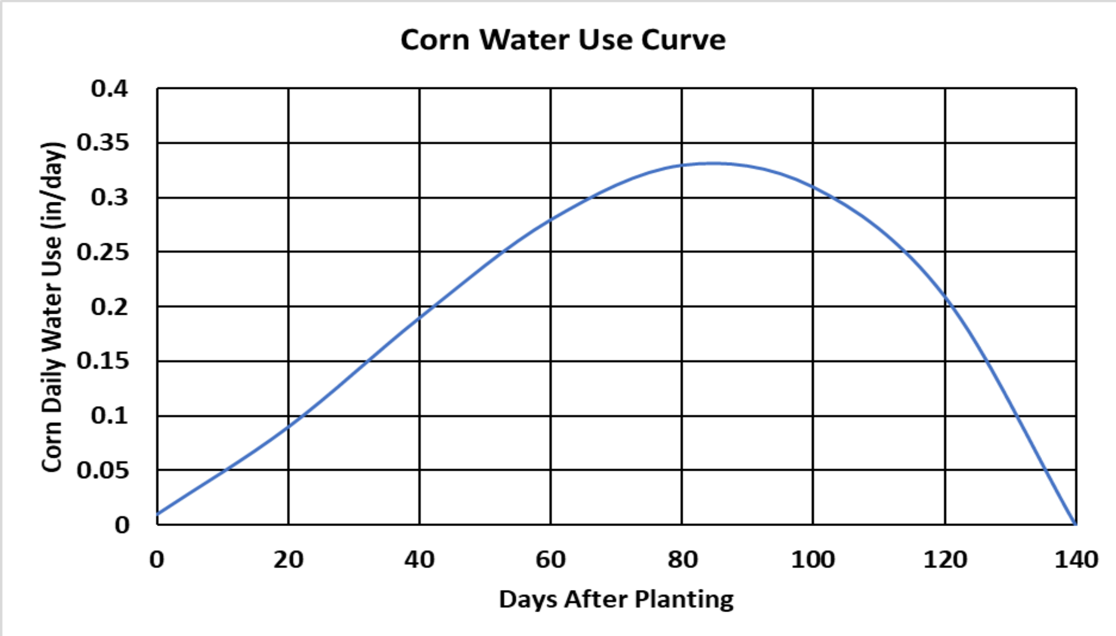
Irrigated corn acres are typically our highest irrigated row crop acres in South Carolina compared to other commodities such as soybean and cotton. Irrigating corn has the potential to maintain or improve yield if crop water use is met at the right time and with the right amount of water. The goal of supplemental irrigation is to make up for rainfall deficits to meet crop water use demand. Understanding how much water a corn crop uses at each crop growth stage is imperative in accurately and effectively scheduling irrigation (table 1).

Table 1. The corn seasonal crop water use and irrigation schedule.

Days after Planting	Weeks After Planting	Inches per Week	Inches per Day
1 to 7	1	0.21	0.03
8 to 14	2	0.35	0.05
15 to 21	3	0.63	0.09
22 to 28	4	0.84	0.12
29 to 35	5	0.98	0.14
36 to 42	6	1.33	0.19
43 to 49	7	1.47 – 1.61	0.21 - 0.23
50 to 56	8	1.75	0.25
57 to 63	9	1.96	0.28
64 to 70	10	2.17	0.31
71 to 77	11	2.31	0.33
78 to 84	12	2.31	0.33
85 to 91	13	2.38	0.34
92 to 98	14	2.31	0.33
99 to 105	15	2.17	0.31
106 to 112	16	1.89 – 1.68	0.27 – 0.24
113 to 119	17	1.47	0.21

Corn water use curve by growth stage*

Irrigation in corn can have several other secondary advantages, such as improving the effectiveness of soil-applied herbicides, stand establishment, fertigation, and chemigation.



*This water use curve is to be used as a guide for scheduling irrigation, and water use values may not directly correlate with calendar dates or growth stages.

Several better alternatives than the above rule-of-thumb method are available. The Irrigator Pro model from the USDA Agricultural Research Service website (bit.ly/35VwdUF) bases irrigation decisions on soil moisture sensors. The UGA EASY (Evaporation-based Accumulator for Sprinkler-enhanced Yield) Pan Irrigation Scheduler allows crop water needs to be monitored in the field using a low-cost system that can be built on farm after a trip to the hardware store. Review the bulletin on the UGA website for more information (bit.ly/3HLn0M3).

Soil moisture sensors are another alternative to the checkbook-type scheduling methods listed above. Some of the benefits from using an irrigation schedule to know when to irrigate are to meet the crop water demand with supplemental irrigation at appropriate timings throughout the growing season; Reduce the likelihood of plant stress, often yield has been lost by the time visual stress symptoms are observed; Reduce over-watering crops; Maximize pod yield, quality, and profits. Benefits of scheduling irrigation with soil moisture sensors relative to other methods are that they allow real-time site-specific monitoring of soil moisture, they can assist with determining water-sensitive periods throughout the growing season by accurately depicting crop water use, and sensors help quantify the actual amount of rainfall that enters the soil and into the rooting zone.

Soil moisture sensors are separated into main categories based on how they read soil moisture. The first category, volumetric sensors (Volumetric water content and Capacitance sensors), measure the amount of water in a given volume of soil providing a soil water content percentage. The second category, soil water tension (Gypsum blocks and Watermark sensors), measures the force the plant roots must overcome to extract water from the surrounding soil particles. These sensors provide readings in units of kilopascals (kPa) or centibars (cbar). Several differences exist between the two categories of sensors, including price, accuracy, recurring subscription costs, and telemetry or how data is accessed; however, both categories are suitable for irrigation scheduling in row crops.

The following are recommendations on commonly asked questions concerning soil moisture sensors.

How many sensors do I need? At least one sensor or set of sensors (if multiple sensors are needed for multiple depths) per irrigation management zone (i.e., under each center pivot) will aid in irrigation decision-making. Other scenarios where more than one sensor per irrigation management zone may be warranted include changes in soil texture across the field in areas that can be managed separately or with the use of a variable rate irrigation system. Furthermore, if a particular system takes several days to make one revolution, consider placing sensors at the start and stop of the irrigation cycle to determine if the system needs to continue to another irrigation cycle after the prior cycle.

Where do I put my sensors within the field? Several factors should be considered when placing sensors in the field to ensure a representative reading will be obtained. Consider soil texture differences; try to manage irrigation based on the soil texture representing the majority of the field. Avoid putting sensors in areas that are very droughty or hold water during the growing season. If yield data is available, yield maps can be used as another tool to evaluate areas of the field to avoid or try to stay in with placement. Try to place sensors in the field after planting and in areas where a representative stand exists. Avoid traffic rows and minimize damage to plants when installing sensors. Due to the limitations on irrigation sprinkler packages on center pivot systems, avoid placing sensors near the center point of the system. It is recommended to install sensors a tower or two from the end of the system to ensure irrigation uniformity.

Do I install sensors in the row or row middle? Install soil moisture sensors within the planted row of plants. By installing sensors within the row, accurate soil moisture measurements within the crops rooting zone can be achieved. With all soil moisture sensors, sensor to soil contact is essential to read soil moisture accurately. Therefore, the correct installation of soil moisture sensors is critical to the sensors working correctly.

How do I know when to irrigate based on the soil moisture sensor? Most sensor manufacturers have generic threshold values associated with the crop and soil texture that the sensor is placed into. Typically, these threshold values reflect allowing the plant available water of a specific soil texture to deplete 25% to 50% before irrigation is applied to recharge. On-going research at Clemson University is evaluating sensor thresholds in multiple crops to develop sensor threshold recommendations based on South Carolina soil textures and crop.

If soil water tension sensors, such as WATERMARK, are being utilized to schedule irrigation, Clemson University has put together a simple web-based application that can be accessed via smartphone or computer to take actual sensor readings and assist with making irrigation decisions based on predefined or manually entered thresholds. Visit the Clemson Precision Agriculture Watermark Calculator website (bit.ly/3Cjtf8F) for more information.

References

Bryant et al. 2021. Corn Production in Georgia. The University of Georgia Extension. Accessed at: https://grains.caes.uga.edu/content/dam/caes-subsite/grains/docs/corn/2021-Corn-Production-Guide.pdf.

Weed Management in Corn

Michael W. Marshall, PhD

Weeds can be a significant determinant of efficient and profitable corn production. Early to mid-season weeds can compete with the crop for light, nutrients, and water, reducing its yield potential. Therefore, it is critical to manage weed populations during early vegetative growth. Palmer amaranth is the most common and troublesome weed in corn. If Palmer amaranth emerges at the same time as the crop, yield reductions up to 91% have been reported. Late emerging weedy grasses, such as Texas panicum, can also impact corn yield. The weeds listed in table 1 are the most troublesome in South Carolina corn production.

Table 1. Troublesome weeds in South Carolina corn production.

Weed	Lifecycle
Palmer amaranth	Annual
Texas panicum	Annual
Annual morningglory	Annual
Sicklepod	Annual

Weed Biology and Lifecycles

Weeds are classified into three different plant lifecycles: annuals, biennials, and perennials. Annuals complete their lifecycle from within one season (either summer or winter). For example, Palmer amaranth and Texas panicum are summer annuals, and cutleaf eveningprimrose and wild radish are winter annuals. Annuals are propagated by seed. Therefore, reducing or eliminating seed production is a highly effective management strategy in reducing these populations over time. Annuals have a significant variation in seed production capability. Palmer amaranth can produce up to 500,000 seeds per plant in a single growing season. However, large-seeded annual weeds (e.g., common cocklebur) produce fewer seeds per plant.

Weeds that complete their lifecycle over a two-year period are biennials. Bull thistle is an example of a biennial weed. During the first season, the seed germinates and forms a whorl of leaves at the soil surface known as a rosette that overwinters, and the following spring/early summer, bolts (forms a stalk) on which flowers, fruits, and seed are borne. Similar to annual weeds, eliminating seed production is a highly effective management strategy for biennials over the long term. Herbicide treatment of biennial weeds is recommended during the rosette or vegetative growth stage.

Perennials reproduce by seed and vegetative structures. Spreading perennials use stem or root structures to propagate. These weeds often form colonies using aboveground stems (e.g., stolons), underground stems (e.g., rhizomes), and creeping roots, which produce new daughter plants from the source plant. Johnsongrass is an example of a perennial weed that reproduces by seed and underground stems (i.e., rhizomes). In contrast, simple perennials produce new shoots from a taproot. Common pokeweed is an example of a simple perennial. Other perennial reproductive structures include tubers (e.g., yellow nutsedge) and bulbs (e.g., wild garlic). Perennials are typically the most difficult to manage. A combination of several different management practices is needed.

Weed Scouting

Weed populations respond over time to the predominant management practice(s) imposed on a production field. For example, using one herbicide over and over can select weed populations resistant to that herbicide. Visually inspecting and recording changes in weed populations each year can detect shifts in weed populations and document weed escapes (possible herbicide-resistant biotypes) before they become a significant problem in your fields. In summary, documenting weed population changes over time is a critical component in your weed management decisions.

Herbicide Tolerance Traits Available in Corn

Several herbicide tolerance traits are available in corn hybrids. They are typically printed on the seed tag as RR2 (Roundup Ready or glyphosate tolerance) and LL (Liberty-Link or Liberty tolerance) (table 2). These traits are usually packaged with insect protection traits. Examples include Herculex HX1, Optimum Intrasect YHR, and YieldGard VT3 or Genuity VT double PRO and SmartStax SSX. Enlist corn hybrids were recently introduced with enhanced tolerance for the postemergence applications of 2,4-D choline. Select the herbicide based on your weed spectrum and use a soil residual herbicide at each application.

Table 2. Herbicide-tolerant traits available in corn.

Platform	Herbicide Tolerance
Roundup Ready 2	Glyphosate
Liberty Link	Liberty
Enlist	Glyphosate + 2,4-D

Precautions for Using Herbicides with other Pesticides in Corn

The use of ALS-inhibitors (Group 2 herbicides) or HPPD-inhibitors (Group 27 herbicides) after the application of a soil-applied insecticide/nematicide and/or tank mix with a foliar organophosphate/carbamate insecticide can result in severe corn injury depending on the combination and timing of application. This injury can also be exacerbated by poor environmental conditions at or following application, including cold temperature and waterlogging. See table 3 for information on using these herbicides with the insecticides/nematicides.

Table 3. Herbicide use precautions with insecticides and nematicides in corn.

Herbicide[1]	APSIN[2]	FOPCI[3]
Accent	Do not apply (in-furrow)	Do not tank mix
Beacon	Do not apply (in-furrow)	Do not tank mix
Capreno	Do not apply (all use patterns)	Do not tank mix, wait 7 days
Corvus	Do not apply (all use patterns)	Do not tank mix, wait 7 days[4]
Hornet	Do not apply (all use patterns)	Do not tank mix, wait 10 days
Instigate	Do not apply (all use patterns)	-----------------------------
Option	Do not apply (all use patterns)	Do not tank mix, wait 7 days
Python	T-band or band only (no in-furrow)[5]	-----------------------------
Realm Q	Do not apply within 45 days of Counter	Do not tank mix, wait 7 d before or 3 d after
Resicore	Do not apply after an at-plant application of Phorate or Terbufos	Do not tank mix, wait 7 days before or after
Resolve Q/DF	Do not apply within 45 days after an at-plant application of Terbufos	Do not tank mix
Revulin Q	Do not apply within 45 days of Counter	Do not tank mix, wait 7 d before or 3 d after
Steadfast/Q/ATZ	Do not apply (in-furrow)	Do not tank mix
SureStart II	T-band or band only (no in-furrow)[5]	-----------------------------

[1]The following herbicide products have an ALS-inhibitor (MOA=Group 2) active ingredient that can interact with the insecticides/nematicides and cause substantial corn injury.

[2]APSAIN, At-Plant Soil Applied Insecticide/Nematicide (i.e., Counter 15G, Counter 20G, Lorsban 15G, Thimet, Dyfonat). Soil use patterns include T-band, band, or in-furrow.

[3]FOPCI, Foliar Organophosphate/Carbamate Insecticide application (i.e., corn herbicide tank mixture with the insecticides Lorsban, Malathion, and/or Parathion).

[4]Do not tank mix Corvus with organophosphate or carbamate insecticides and apply to emerged corn.

[5]Do not use Terbufos (Counter) or Phorate (Thimet) insecticide/nematicides.

Corn Hybrid Sensitivity to Herbicides

Variation in environmental conditions following herbicide application can result in crop response of any crop variety. Certain corn hybrids have warning or caution statements about using ALS-inhibitors (Group 2), Growth Regulators (Group 4), HPPD-inhibitors (Group 27), and Amides (Group 15). These injury response values were provided by the seed company. Corn hybrids change yearly, so this is not meant to be an exhaustive list of all corn hybrids grown in South Carolina (table 4). Check with your seed dealer for up-to-date information on herbicide precautions for your corn hybrid selection(s).

Table 4. Sensitivity of selected corn hybrids to herbicides.

Hybrid	Amide[1]	Benzoic/Phenoxy[2]	HPPD[3]	ALS/SU[4]
Dekalb	-	-	-	-
DKC 63-57	-	A	A	A
DKC 65-20	-	A	A	C
DKC 67-44	-	A	A	A
Pioneer	-	-	-	-
P1506YHR	A	A	C	A
32B16	A	A	C	A
P1870YHR	A	A	A	A

Abbreviations: ---=no information available; A=Acceptable, herbicide injury unlikely to occur; C=Caution, injury usually does not occur under normal herbicide use rates or timings; however, injury may occur in adverse environmental conditions, high product use rates, or abnormal soil conditions, use drop nozzles for postemergence applications to avoid potential interactions; W=Warning, do not use, injury has occurred using this herbicide.

[1]Amide product examples include s-metolachlor (Dual Magnum), acetochlor (Warrant), dimethanemid-p (Outlook).

[2]Benzoic product examples include dicamba (Xtendimax); Phenoxy product examples include 2,4-D (Enlist One).

[3]HPPD product examples include tompramezone (Impact), isoxaflutole (Balance), mesotrione (Callisto).

[4]ALS/SU product examples include nicosulfuron (Accent), primisulfuron (Beacon), rimsulfuron (Resolve)

Guidelines for Using Triazine Herbicides in Corn

Atrazine and simazine users are strongly encouraged to follow label guidelines discussed below to share in the responsibility of preserving the future use of atrazine and simazine. These restrictions apply to all formulations of atrazine and simazine and all pre-mix package products that contain atrazine and simazine (table 4).

Application Rate Restrictions

For soils that are not defined as highly erodible, the maximum use rate for atrazine is 2.0 lb ai (active ingredient) per acre and for simazine is 2.0 lb ai per acre per season. For soils classified as highly erodible (as defined by NRCS), If conservation tillage is practiced with at least 30 percent crop residue coverage at planting, the maximum use rate is 2.0 lb ai per acre for atrazine and simazine. If crop residue coverage is less than 30 percent, then the maximum rate for atrazine and simazine is 1.6 lb ai per acre. If atrazine **was not** applied prior to corn emergence, then the total amount applied should not exceed 2.0 lb ai per acre. If atrazine was applied to a field preemergence, then the total amount of atrazine **should not** exceed 2.5 lb ai per acre per calendar year. The total amount of simazine **should not** exceed 2.0 lb ai per acre per calendar year.

Setbacks

Operations that involve mixing, loading, rinsing, or washing atrazine or simazine within 50 feet of wells (including abandoned wells, drainage wells, or sinkholes), rivers, intermittent streams, lakes, or reservoirs is prohibited. This restriction does not apply to operations within a properly designed impervious pad and diked mixing/loading areas. Atrazine or simazine must not be applied aerially or by ground equipment within 66 feet of points where field surface water enters perennial or intermittent streams and rivers or within 200 feet around natural or impounded lakes and reservoirs. If atrazine or simazine is applied to highly erodible land, the 66-foot buffer or setback from runoff entry points must be planted to crop, seeded with grass, or other suitable crop.

If atrazine or simazine is applied to tile-terraced fields containing standpipes, then users are advised to follow one of the following restrictions: 1) do not apply atrazine or simazine within 66 feet of standpipes; 2) After applying atrazine or simazine to the entire field, immediately incorporate it to a depth of 2-3 inches; or 3) Apply atrazine or simazine to the entire field under conservation tillage practices where high crop residue levels are present.

Table 5. Examples of herbicide products containing the active ingredient Atrazine or Simazine.

Product Name	Active Ingredient(s)	Product Name	Active Ingredient(s)
Aatrex	*atrazine*	Keystone NXT	*acetochlor + atrazine*
Bicep II Magnum	*atrazine + s-metolachlor*	Lexar	*s-metolachlor + mesotrione + atrazine*
Cinch ATZ	*s-metolachlor + atrazine*	Lumax	*s-metolachlor + atrazine + mestrione*
Degree Xtra	*acetochlor + atrazine*	Marksman	*dicamba + atrazine*
Expert	*glyphosate + s-metolachlor + atrazine*	Princep	*simazine*
Fultime NXT	*acetochlor + atrazine*	Steadfast ATZ	*nicosulfuron + rimsulfuron + atrazine*

Mixing and Loading Guidelines for Use of Acetochlor Containing Herbicides in Corn

Do not mix or load acetochlor (i.e., Warrant, Harness) products within 50 feet of any wells (including abandoned wells and drainage wells), sinkholes, perennial or intermittent streams and rivers, and natural or impounded lakes and reservoirs. This setback does not apply to properly capped or plugged abandoned wells and does not apply to impervious pad or properly diked mixing/loading areas. Operations that involve mixing, loading, rinsing, or washing of this product into or from pesticide handling or application equipment or containers within 50 feet of any well are prohibited unless conducted on an impervious pad constructed to withstand the weight of the heaviest load that may be positioned on or moved across the pad. Such a pad shall be designed and maintained to contain any product spills or equipment leaks, product container or application equipment rinsate, and rainwater that may fall on the pad. Surface water shall not be allowed to either flow over or from the pad, which means the pad must be self-contained. The pad shall be sloped to facilitate material removal. An unroofed pad shall be of sufficient capacity to contain a minimum of 110% of the capacity of the largest pesticide container or application equipment on the pad. A pad that is covered by a roof of sufficient size to completely exclude precipitation from contact with the pad shall have a minimum containment capacity of 100 percent of the capacity of the largest pesticide container or application equipment on the pad. Containment capacities as described above shall always be maintained. The above specified minimum containment capacities do not apply to vehicles when delivering pesticide shipments to the mixing/loading site. States may have additional requirements regarding wellhead setbacks and operational containment.

Herbicides for Weed Management in Corn

Herbicides are a key component of a successful weed management program in corn. They provide a cost-effective and efficient option for weed control. Always follow the label and use the guidelines discussed on the product label. Although they are several broad-spectrum herbicides available in corn (i.e., atrazine, glyphosate, glufosinate), scouting and monitoring the weed populations present at the time of application (or will be present after the crop emerges) is critical for long-term success. Changes in these weed populations over time can indicate the development of herbicide resistance in weed populations in corn. It is important to remember to rotate your herbicide mode-of-action and not rely on a single herbicide for all your weed control.

Preplant Burndown

Corn is planted early (i.e., February–March) in South Carolina. A clean, weed-free field is important to ensure a competition-free environment during and after crop emergence. Preplant burndown is an application that occurs 7 to 14 days before planting and controls the existing weeds. In corn, most waiting intervals between application and planting are 7 days or less. However, some herbicides like glyphosate and 2,4-D need 10 to 14 days after application before planting for maximum activity on weeds (especially large ones). Paraquat (i.e., Gramoxone) is another broad-spectrum burndown herbicide option for corn. Paraquat is effective on small weeds but limited activity on large, flowering weeds or perennials. Consult the product label for specific details on recommended waiting periods before planting.

Preemergence

A herbicide product that is applied shortly after the crop is planted is a preemergence or soil active residual. These herbicides are designed to be applied to the soil surface and are activated by rainfall or irrigation. Preemergence herbicides control or prevent weed seed germination in the upper soil profile (usually less than 1 inch). These reduce the overall germination cohort of the weed populations before the postemergence herbicides are used. Small-seeded weed seeds (e.g., Palmer amaranth, crabgrass) are generally more affected by these herbicides (e.g., s-metolachlor, Dual Magnum) than large-seed ones (e.g., cocklebur).

Postemergence

Herbicides that are applied after the weeds have emerged are called postemergence. They are used to control weeds and minimize early season competition with the crop. Typically, postemergence herbicides can vary in weed selectivity. For example, nicosulfuron (Accent) will only control grass weeds in corn. There are corn hybrids with genetic tolerance to several broad-spectrum postemergence herbicides, including glyphosate (e.g., Roundup) and glufosinate (Liberty). There are several HPPD herbicides available for use in corn. This mode-of-action is not available in our other crops (i.e., soybean or cotton); therefore, it can serve as an effective rotation for other herbicides used in those crops. Some herbicides in corn are limited to certain growth stages. For example, atrazine can only be applied up to the 6-leaf growth stage. The key to remember for successful herbicide performance is to apply these herbicides when weeds are small and actively growing as compared to large and/or drought-stressed weeds, which often need retreatment for satisfactory control. Consult the product label for information on recommended spray additives and adjuvants, effective weed spectrum, and other application parameters.

Preharvest/Harvest Aids

The growing season in South Carolina is relatively long, and most of our herbicide products are applied in the first 6 weeks of corn growth. Some weed species have an extended germination period throughout the summer. For example, annual morningglory can germinate after the corn starts to mature and rapidly climb the stalk (several inches per day). Weeds like morningglory with their vining growth habit and succulent tissue can cause harvest issues with combines and other field equipment. A preharvest herbicide (i.e., paraquat, carfentrazone (Aim), or glyphosate) is often advised to kill and dry down weeds that may impede harvest operations.

Postharvest

After corn harvest, there are several months of favorable growing conditions before the first frost for the weeds in the field. For weeds like Palmer amaranth, annual morningglory, and Texas panicum, preventing seed production is critical because of resistance issues in other crops. Several options are available for control of these weeds, including tillage, mowing, and herbicides (i.e., paraquat).

Corn Nematode Control

John D. Mueller, PhD
Saleh Ahmed

Nematodes are relatively unique pathogens that feed on the roots of many row crops. This feeding can cause extensive damage to the root systems resulting in significant aboveground stunting and eventually yield losses (figures 1 and 2). The nematode species that feed on corn tend to have wide host ranges, including most of the row crops grown in South Carolina. This minimizes the opportunity to use crop rotation as a management tool. Although some nematicides are available, the application rates that growers feel they can afford often do not provide adequate control of the nematodes. To successfully manage nematodes on corn, a management scheme must be developed for each individual field based on the density of each species present in the field and possible crop rotation options. To determine the nematode species and densities, each field will need to be sampled and the samples sent to the Clemson University Nematode Assay Laboratory.

Figure 1. Severely stunted, nontreated corn (left).Image credit: John Mueller, Clemson University.

Figure 2. Healthy corn (left) compared to corn severely stunted by Columbia lance and sting nematodes (right). Image credit: John Mueller, Clemson University.

More than a dozen species of plant-parasitic nematodes can feed on corn, potentially causing significant yield losses. Nematodes are vermiform (i.e., wormlike) and must move through the soil in a serpentine motion. Most nematodes are 0.5 to 2.0 mm long and 15 *u* to 20 *u* in diameter. This makes them almost, but not quite microscopic in size. If nematodes are placed in a droplet of water, they are visible using most handheld magnifying glasses. Nematodes feed through a stylet, which is a hollow tube that they insert into a plant cell and ingest the contents through a tube. The greatest damage nematodes cause to corn roots and the roots of other crops is by feeding on the growing tips of young roots, destroying their integrity, and causing them to be swollen and dysfunctional. The damaged roots are unable to produce normal secondary roots, and the result is often a bottle brush appearance (figure 3). These “stubby roots” are unable to absorb the levels of water and nutrients needed by the plant for normal growth. Multiple nematode species may occur in the same field resulting in severe damage, including galling and “stubby roots.” Nematode infected roots are often discolored due to infections by soilborne fungi such as *Rhizoctonia* spp. and *Fusarium* spp. (figure 4).

Yield losses due to nematodes are common in many South Carolina cornfields. Several plant-parasitic nematode species occur commonly in the coarse-textured sands of the Coastal plain. The species causing the most damage to corn in South Carolina are stubby root nematode, Columbia lance nematode, lesion nematode, sting nematode, and several species of root-knot nematodes (table 1). Other species such as ring nematode and spiral nematode are often recovered from cornfields but normally cause very little yield loss.

Figure 3. Close up of stunted and swollen root tips commonly referred to as the "bottle brush" or "stubby root." Image credit: John Mueller, Clemson University.

Figure 4. Discolored, galled, and swollen roots caused by a combination of damage from root-knot, stubby root, Columbia lance, and sting nematodes. Image credit: John Mueller, Clemson University.

Field Distribution

Except for sting nematode, most of the nematode species listed in table 1 can be found throughout the Coastal plains of South Carolina and in some areas of the Piedmont where sandy soils are present. Within a field, nematodes are often associated with areas of the field that exceed 80% sand content. However, some species such as lesion nematode can be found even in soil textures with less than 70% sand. Some species, such as sting nematode, are restricted to soils with more than 90% very coarse-textured sands. Columbia lance is generally restricted to soils with more than 80% coarse-textured sand. These two species are relatively large nematodes that need the space in the soil pores to move. In these areas, stunting can be severe and result in greater than 25% yield losses.

Symptoms

The most common symptom of nematode damage on corn is "stubby root" (figure 2). The stubby root symptom is the result of nematodes feeding on the growing points of young roots. These roots have very small side roots, often clustered at the end of a secondary root. These roots are often swollen and produce a "bottle brush" effect. This "stubby root" symptom is commonly caused by stubby root nematode but can also be caused by Columbia lance, lesion, and sting nematode.

Aboveground symptoms resulting from nematode feeding are normally rather nondescript. Stunting can be severe, especially where nematodes occur in very sandy areas of the field. Chlorosis is not as distinct as seen from nematode feeding on soybean.

Management

Currently, there are no commercially available hybrids known to be resistant or tolerant to any of the common nematodes occurring on corn. There are some inbred lines that have been shown to be resistant to Southern root-knot nematodes, but it is difficult to predict or test for this trait in the hybrids resulting from crosses with these inbred lines.

The nematodes which feed on corn have a very wide host range. Most include cotton and soybean in their host ranges (table 1). The only viable rotations to reduce damage on corn from nematodes utilize peanuts. Peanuts will reduce levels of Columbia lance and Southern root-knot nematodes as well as some populations of sting nematode. However, stubby root nematode, lesion nematode, ring nematode, and peanut root-knot nematode all reproduce on peanut. Soybean is very ineffective as a rotation crop to control nematodes on corn since all the nematode species which infect and reproduce on corn also reproduce on soybean.

Table 1. Host status of nematode species commonly recovered from row crop fields in South Carolina.

Common name ***Scientific name***	**Corn**	**Cotton**	**Peanut**	**Soybean**	**Grain Sorghum**
Columbia lance *Hoplolaimus columbus*	Host	Host	Nonhost	Host	Host
Sting *Belonolaimus longicaudatus*	Host	Host	Nonhost	Host	Host
Stubby root *Paratrichodorus minor*	Host	Host	Host	Host	Host
Lesion *Pratylenchus* species	Host	Host	Host	Host	Host
Southern root-knot *Meloidogyne incognita*	Host	Host	Nonhost	Host	Host
Peanut root-knot Race 1 *Meloidogyne arenaria*	Host	Nonhost	Host	Host	Poor host
Peanut root-knot Race 2 *Meloidogyne arenaria*	Host	Nonhost	Nonhost	Host	Poor host
Ring *Criconemella* species	Host	Host	Host	Host	Host
Reniform *Rotylenchulus reniformis*	Nonhost	Host	Nonhost	Host	Nonhost
Soybean cyst *Heterodera glycines*	Nonhost	Nonhost	Nonhost	Host	Nonhost

Race 1 of Peanut root-knot nematode goes to both peanut and soybean; Race 2 of Peanut root-knot nematode does not go to peanut.

Sampling for Nematodes

Fields with histories of 3+ years of continuous corn have a high probability of having a nematode problem. Fields rotated with soybean or cotton also have a high probability of containing high nematode populations. Fields with lower-than-expected yields or yields that decline over time should be tested for nematodes.

Nematode damage thresholds vary greatly between nematode species and between soil types within a species. To predict whether a specific field will be subject to nematode-induced yield losses in the following year, it is recommended that you take a soil sample after the previous crop has been harvested. These samples should be taken as soon after harvest as is possible. The core sampler should be inserted into the soil approximately 8- to 10-inches deep, approximately 2- to 4-inches from stems of the previous crop. You should feel roots snap as you push the soil sampler into the ground. Either a cone sampler or a tube sampler can be used (figure 5). Your county agent can provide nematode sample bags for your use. They can also help you fill out the form that needs to be included with your samples. In addition to your name and contact information, the form should include the

Figure 5. Two types of soil samplers Image credit: Jonathan Croft, Clemson University.

previous crop grown and crops you are interested in growing in the next growing season. The agent will send your sample to the Clemson University Nematode Assay Laboratory for analysis. There is a charge, currently $20 per sample, for this analysis. You should receive an answer in 2 to 3 weeks. Nematode species present in the sample will be identified, and their densities reported as "nematodes per 100 cm^3 soil". Nematodes vary widely in the densities it takes to cause yield losses (table 2). Just 1 or 2 sting nematodes per 100 cm^3 soil can cause extensive damage. For most of the species, such as root-knot or Columbia lance nematodes, the damage thresholds are between 100 and 300 nematodes per 100 cm^3 soil. One of the reasons that stubby root nematode is recognized as perhaps the most common problem nematode species on corn is that the damage threshold is just 40 nematodes per 100 cm^3 soil.

Table 2. Fall threshold values for nematode species that cause damage to corn. All nematode densities are reported as nematodes per 100 cm3 soil. "High" designates the level at which severe damage (>15% yield loss) may occur and treatment with a nem

Common Name	Damage Level	Sandy to Sandy Loam	Clay Loam to Clay
Columbia lance	High Low	100+ 6-99	200+ 150-199
Sting	High Low	4+ 4+	N.A.
Stubby root	High Low	40+ 10-39	80+ 0-79
Root-knot species	High Low	300+ 150-299	400+ 200-399
Lesion	High Low	500+ 200-499	500+ 200-499
Ring nematode	High Low	200+	600+

N.A. (not available) for sting nematode since sting nematodes do not occur in clay or clay loam soils.
Source: Nematode Guidelines for South Carolina, EC703 from the Clemson Extension Service by O. J. Dickerson, J. H. Blake, and S. A. Lewis (clemson.edu/public/regulatory/plant-problem/pdfs/nematode-guidelines-for-south-carolina.pdf).

Each nematode species is somewhat unique in its combination of physical characteristics, damage thresholds, preferred soil textures, and optimal soil temperature ranges. The major species are described below.

Stubby Root Nematode

Image credit: Saleh Ahmed, Clemson University.

Stubby root nematode is perhaps the species most strongly identified with damage to corn in the southeastern United States. The incidence of stubby root nematode appears to be increasing substantially in the last few years. Stubby root nematode is a migratory parasite feeding on the terminal ends of young roots. This feeding causes the typical "stubby root" symptom" (figure 2). Stubby root nematode becomes active at lower soil temperatures than other nematodes; therefore, it has no competition for feeding sites on roots. Stubby root nematode occurs across a wide range of soil textures and has a wide host range. There are no commercially available corn hybrids or varieties of cotton or soybean known to be resistant to stubby root nematode. This makes management of this nematode difficult, depending mostly upon the use of nematicides.

Columbia Lance Nematode

Image credit: Saleh Ahmed, Clemson University.

Columbia lance nematode occurs across the Coastal plain soils of South Carolina. It is especially common in the region between the Santee Cooper lakes and the Savannah River. It is not found as commonly in the heavier soils of the Piedmont region. Columbia lance nematode can feed either on the surface of corn roots or inside the root, migrating through the root as it feeds. Like many other nematodes, its preferred feeding sites are the growing points of young roots. There are no commercially available corn hybrids known to be resistant to Columbia lance nematode. There are no varieties of cotton or soybean known to be resistant to Columbia lance nematode. Columbia lance nematode has a wide host range. The only common row crop that is not a host is peanut. Peanut is very effective at reducing Columbia lance nematode population densities for the following crop. Nematicides are the only other effective control measure for Columbia lance nematode.

A second species of lance nematodes, *Hoplolaimus galeatus*, is common in the Piedmont area of South Carolina and throughout the Midwest. It is not found in the coarse-textured sandy soils that favor Columbia lance nematodes. Like *H. columbus,* it has a wide host range, and no resistant corn hybrids or cotton or soybean varieties are known. Management relies on the use of nematicides applied preplant or at planting.

Sting Nematode

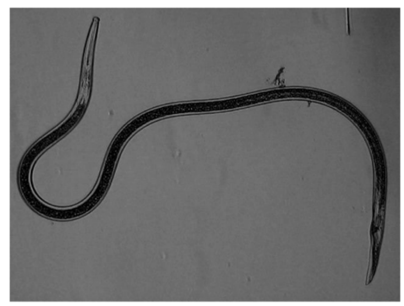


Image credit: Saleh Ahmed, Clemson University.

Sting nematode (*Belonolaimus longicaudatus*) is a very large nematode that requires a soil texture with greater than 90% coarse-textured sand. Therefore, it is not common in South Carolina row crop fields and is not found in the Piedmont area of South Carolina. However, where it does occur, it causes severe stunting both above ground and on roots. Typically, it is in small pockets in a field. However, yield losses in those pockets can be severe since the coarse-textured sands predispose the plant to moisture stress, which is made worse by nematode-induced root stunting. The threshold for sting nematode damage on corn is very low, normally 1 to 5 per 100 cm^3 soil. Management is difficult since its host range includes cotton, soybean, and grain sorghum. Peanut is not a host for some sting nematode populations and will reduce population levels where those populations are present. No corn hybrids are known to be resistant to sting nematode. Most soil-applied nematicides are effective in controlling sting nematode.

Southern Root-Knot Nematode

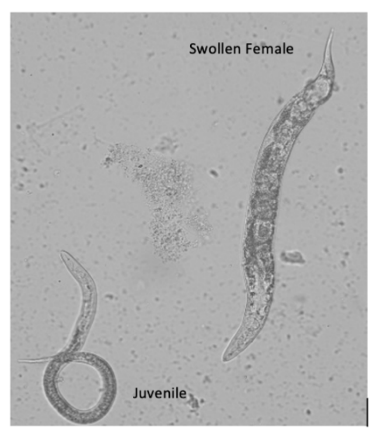


Image credit: Saleh Ahmed, Clemson University.

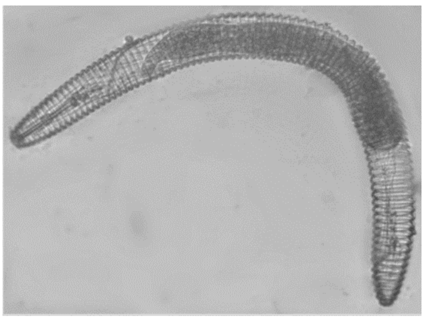
Southern root-knot nematode is perhaps the most common “problem” nematode in the Southeastern United States. It can cause significant damage to corn. However, in South Carolina, stubby root and Columbia lance nematodes probably occur more commonly on corn than root-knot nematodes. Unlike the other pathogenic nematodes on corn, root-knot nematode establishes a feeding site inside the root and remains sedentary for the remainder of its life cycle. The female root-knot nematode swells inside the root as it produces eggs, creating galls on the root. The galls produced by root-knot nematodes on corn are normally smaller than those observed on soybean or cotton. However, they are visible, especially on young roots (figure 6).

In addition to Southern root-knot nematode, Peanut root-knot nematode (*Meloidogyne javanica*) can infect and cause yield losses on corn. Like Southern root-knot nematode, Peanut root-knot nematode has a wide host range making management via crop rotation difficult.

There are no commercial hybrids resistant to either root-knot nematode species. Control of root-knot nematodes on corn relies on the use of nematicides applied preplant or at-planting. There are commercially available cotton and soybean varieties with resistance to Southern root-knot nematode.

Figure 6. Close up of small galls on very young plant roots caused by root-knot nematode. Image credit: John Mueller, Clemson University.

Ring Nematode



Ring nematode is one of the more unique nematodes found in the southeastern United States. It feeds on the exterior of small corn roots. It is mostly sedentary, but its relatively long stylet allows it to feed extensively into a corn root. It has a very thick cuticle with annulations (rings) that allow it to have limited movement in the soil. The damage threshold for ring nematodes is relatively high, and yield losses in corn due to ring nematodes are not common. Ring nematode has a very wide host range, and no commercial corn hybrids are known to be resistant to ring nematode. No cotton or soybean varieties are known to be resistant to ring nematodes. Control of ring nematode is primarily by the use of nematicides.

Other Nematode Species

Other species of nematodes, including dagger nematode (*Xiphinema americanum*) and stunt nematode (*Tylenchorhynchus species*), can occur in row crop fields in South Carolina and are capable of causing yield losses on corn. However, their damage thresholds are relatively high. Spiral nematodes are very common in the Coastal plain soils of South Carolina. However, their damage threshold (500+/100 cm^3 soil) is so high they rarely cause significant yield losses.

Using Nematicides

The wide host range of most of the nematode species that affect corn, and the absence of any resistant commercial corn hybrids, means that most nematode management plans rely heavily on the use of nematicides. Several nematicides are currently available for use on corn (Table 3).

Telone II is probably the most reliable nematicide for use on corn. It will provide consistent control of all nematode species, but it has several drawbacks. It is a Restricted Use Pesticide and requires specialized application equipment. It is relatively expensive. The recommended application rate of 3.0 gallons per acre of Telone II currently costs approximately $50 per acre. It must be applied 10 to 14 days prior to planting. It is effective against all of the nematodes that affect corn.

Counter 20G has been used for nematode control in corn for many years. It is a granular material applied over the open furrow as seed is planted. It is not as efficacious as Telone II, but the price is considerably lower. According to the Counter® 20G Lock'n Load® label, "ALS inhibitor (HRAC group 2),* mesotrione (postemergence applied) and saflufenacil containing herbicides MUST NOT be used if Counter® 20G has been applied to corn at the time of planting unless specified otherwise by the herbicide label."

Propulse and Velum are liquid materials that are applied over the open seed furrow. The levels of control provided are not as consistent as with Telone II, but the price is considerably lower. Check with the 2EE label before applying tank mixing Propulse any fertilizers or micronutrients. A 2EE label also exists for the use of Velum for suppression of nematodes at a reduced application rate on corn in South Carolina

Some seed treatments are available, including both chemical nematicides such as abamectin (available in Avicta Complete Corn) and biocontrol agents such as *Bacillus firmus* I-1582 (available in Poncho Votivo 5.01 FS) or *Burkholderia* spp. A396 (available in BioST Nematicide 100).

In general, results from nematicide use on corn have not been as consistent as results from nematicide usage on soybean or cotton.

Table 3. Nematicides labeled for nematode management in corn in South Carolina. Species included are Columbia lance, lesion, root-knot, and stubby root nematodes.

Nematicide	Active Ingredient(s)	Rate per acre for 30-inch rows	Comments
Avicta Complete Corn 500/1250 with Vibrance	abamectin + thiamethoxam + azoxystrobin + mefenoxam + fludioxonil + sedaxane	Seed treatment	Available through commercial seed companies and dealer distributors.
BioST Nematicide 100	*Burkholderia* spp. A396	Seed treatment 7 fl oz/cwt	Use only where nematode pressure is low to moderate
Counter 20G lock 'n Load	terbufos	6.5 lbs	Apply over seed furrow at planting according to the label. Do not exceed 6.5 lbs/acre total
Poncho/Votivo 5.01 FS	Clothianidin + *Bacillus firmus* I-1582	Seed Treatment	Available through commercial seed companies and dealer distributors.
Propulse	fluopyram + prothioconazole	8 fl oz In-furrow spray during planting directed on or below seed	See 2ee label Tank mixes with some fertilizers and micronutrients have been problematic.
Telone II	1,3-dichloropropene	3 to 6 gal per acre	Restricted use pesticide Can be used where nematode pressure is severe. Inject 12 inches below planting depth and seal immediately with bedding equipment. Wait 7 to 14 days before planting
Velum	fluopyram	3 fl oz	In-furrow spray during planting directed on or below seed

Cultural Practices for Nematode Management in Corn

Using deep tillage to break hardpans can be helpful in minimizing damage from nematodes in corn. In most fields, significant levels of volunteer corn sprout after harvest (figure 7). These volunteer plants have large root systems which serve as a second crop to allow higher levels of survival and reproduction by nematodes in the field (figure 8). Discing or chemical termination of these plants before they are 20-days-old will help minimize the carryover nematode population that will serve as primary inoculum in the next crop.

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Wise, K., Mueller, D., Sisson, A., Smith, D., Bradley, and Robertson, A. 2016. A Farmer's Guide to Corn Diseases. APS Press.

Figure 7. Volunteer corn. Image credit: Jonathan Croft, Clemson University.

Figure 8. Volunteer corn large root systems. Image credit: Jonathan Croft, Clemson University

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Disease Management

John D. Mueller, PhD

Corn is subject to many seedling diseases, foliar diseases, stalk rots, and ear rots. Fortunately, a wide array of tools is available to combat these problems, including tillage practices, crop rotations, resistant hybrids, and fungicides. The challenge is to identify the disease(s) you need to control and choose the combination of control measures that provides the most economical level of control.

Seedling Diseases and Seed Rots

Seedling diseases and seed rots are common in most corn-growing regions of the United States. In South Carolina, they are most severe in soils with lower sand and higher clay content, typically the Piedmont soils, compared to the sandy soils of the Coastal Plain. Early planting dates with cooler soil temperatures are more conducive to seedling diseases than later planting dates. Heavy rains coupled with early planting dates and accompanying lower soil temperatures are the worst-case scenario for seedling diseases in South Carolina. Two types of fungi are involved with seedling diseases. *Pythium* spp. and *Phytophthora* spp. are water molds that have mobile spores. They are the predominant pathogen in cold, wet soils. *Rhizoctonia* spp. and *Fusarium* spp. are more common in drier, slightly warmer soils. In general, the two types of fungi are controlled by two different groups of fungicides. To control *Pythium* and *Phytophthora* requires a fungicide containing a metalaxyl type fungicide. Most other fungicides have activity against *Rhizoctonia* spp. and *Fusarium* spp.

Excellent control of most seed rots and seedling diseases is provided by the fungicide seed treatments provided by most seed companies. Delaying planting until soil temperatures are consistently above 55ºF will improve germination and emergence.

Foliar Diseases

Physoderma Brown Spot

Physoderma brown spot (PBS) is caused by the fungus *Physoderma maydis*. Physoderma brown spot has become more common in South Carolina and the United States in recent years. This fungus has one of the more unique life cycles among fungi causing corn diseases. Most fungi produce spores that have no active means of movement. They must be spread by wind or water. *Physoderma maydis* produces zoospores, which are mobile in water. Like many diseases, it overwinters in debris from previous corn crops in the field. It infects the corn plant while leaves are in whorls, so fungicide treatments must be applied at planting or just after planting. Fungicides applied at tasseling will be too late to control damage to the lower stalks and leaves that are the damaging part of this disease.

No resistance to PBS is available. Rotations with any crop other than corn will help reduce levels of the fungus overwintering in debris. Fungicides must be applied at planting or just after planting. XYWAY™ 3D fungicide (flutriafol) is the only fungicide labeled for use at planting on corn. Early applications of XYWAY™ will not control other later season foliar diseases or stalk rots.

Northern Corn Leaf Blight

Northern corn leaf blight (NCLB) is caused by the fungus *Cochliobolus carbonum*. In some years, NCLB can be quite common in South Carolina. It normally appears at or after pollination. This fungus overwinters on corn residue from previous crops as a saprophyte. Leaf symptoms include large cigar-shaped lesions 1 to 6 inches long that are gray-green in color (figure1). Mature lesions appear tan with dark zones of fungal spores. There are many resistant hybrids available, and along with rotation to crops other than corn to reduce overwintering on crop debris, they are the primary control method. Most fungicides are effective in limiting yield losses due to NCLB. However, there are at least five races of NCLB that vary in pathogenicity. Most races are considered to be mild pathogens. One complicating factor with NCLB is that some populations of *C. carbonum* are resistant to some fungicides. NCLB lesions can produce spores within one week of initial infection. These spores are distributed by wind currents.

Figure 1. Northern corn leaf blight. Image credit: Jonathan Croft, Clemson University

Common Rust

Common rust is caused by the fungus *Puccinia sorghi*. In South Carolina, "common rust" is actually seen less frequently than Southern Rust which is caused by a different fungus. Symptoms of common rust include pustules predominately on the upper leaf surface, but pustules can also occur on the lower leaf surface. Initially, pustules produce cinnamon-brown urediniospores, but later they produce golden brown to black teliospores, which give the pustules a brownish-black appearance (figure 2).

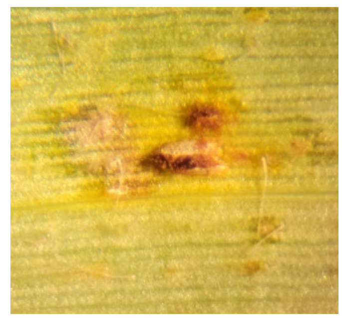

Figure 2. Common rust. Image credit: Jonathan Croft, Clemson University

Typically, common rust has very little effect on yield. Unlike most of the foliar diseases of corn which overwinter on crop debris, common rust overwinters in tropical Mexico on *Oxalis* spp. (a genus in the wood-sorrel family). Spores are windborne and are progressively blown northward into the southern United States. Spores require six hours of free moisture and have a 7-day latent period for disease to develop. During disease development, conditions that favor infection include 95% humidity and temperatures between 61° and 77° F. These conditions often do not occur in the southern United States, so disease development is often minimal. Resistant varieties are available, and fungicides provide effective control. Normal levels of common rust do not justify fungicide sprays.

Southern Rust

Southern rust is caused by the fungus *Puccinia polysora*. Normally it is not a problem in South Carolina, but in years where conditions are right, it can be serious on late-planted corn. It is often a bigger problem in the Midwest. Symptoms of Southern rust include small circular to oval pustules that are light cinnamon to orange in color. Normally they are on the upper leaf surface and only rarely occur on the bottom leaf surface. They can occur on leaves, stalks, sheaths, and husks.

Southern rust inoculum blows in from states south and southwest of South Carolina. Normally symptoms are not present on leaves in South Carolina until mid-summer. Southern rust often is first observed on the edges of fields at low levels. It is first seen at mid-canopy level 4 to 5 feet up the stalk. Conditions that favor the disease include temperatures of 80° to 90° F and high humidity, heavy dew, or rainfall. Disease development can be rapid in those conditions.

Management of Southern rust begins with choosing a variety that is less susceptible to rust and being prepared to spray a fungicide if needed. Normally these fungicides should be applied at VT/R1 to act as a preventive spray.

Gray Leaf Spot

Gray leaf spot (GLS) is caused by the fungus *Cercospora zea-maydis*. Like NCLB and SCLB, it overwinters in crop debris. Spores produced on debris on the soil surface are spread by wind and splashing rain. Early season symptoms include small necrotic spots with a yellow halo. Mature lesions are tan to gray and expand linearly between the leaf veins creating a rectangular-shaped lesion. If moist warm (72° to 86° F) conditions persist, GLS can spread rapidly through the upper foliage and at times may kill full-size plants.

Management starts with avoiding monocropping corn. In fields where minimum tillage is employed, resistant varieties should be grown. Foliar fungicides may be required, especially if a susceptible variety is monocropped in a field with minimum tillage.

Southern Corn Leaf Blight

Southern corn leaf blight (SCLB) is caused by the fungus *Bipolaris maydis* (formally *Helminthosporium maydis*) and is still considered by growers to be one of the most important foliar diseases of corn in South Carolina. However, much of this reputation is a result of the 1970 SCLB epidemic, which occurred across the United States. This epidemic was due to the extensive use of an SCLB susceptible parent inbred line in the crosses used to create the majority of corn hybrids grown in the United States. It was estimated that 15% of the nation's corn crop, valued at $1 billion dollars, was lost to SCLB in 1971. Resistant inbred lines were rapidly identified, and now at least in the southern United States, yield losses are usually minimal.

Symptoms of SCLB include leaf lesions that vary in shape, color, and size according to the hybrid grown. In general, they are oval to elongated tan-colored lesions with yellow-green borders. SCLB lesions may occur on the foliage, sheaths, stalks, and husks. The SCLB fungus infects many wild grasses.

Management is primarily by selecting resistant hybrids. Tillage and rotation to a non-host crop will reduce overwinter survival of the fungus on crop debris. Fungicides can be effective but are rarely needed specifically for SCLB in South Carolina.

Stalk Rots

Stalk rots are very common in most areas where corn is grown. However, in most cases, the yield losses they cause are relatively low. The causal agent is usually a fungus. Anthracnose stalk rot, Charcoal rot, Diplodia stalk rot, Fusarium stalk rot, and Gibberella crown rot and stalk rot can all occur in South Carolina.

Like many of the foliar fungal diseases, the primary inoculum for stalk rots is present on crop debris from the previous year. Monocropping corn in a minimum tillage scenario can result in higher levels of stalk rots than in a field that has been rotated to a crop other than corn. Any problem that stresses the corn plant during the growing season can increase the severity of stalk rots. Foliar diseases reduce the photosynthetic area of a leaf, and this means fewer photosynthates to fill ears and support stalks and roots.

To evaluate the levels of stalk rot in a field, you should scout between R-5 and R-6. Stalk rot is severe if you can crush the 1^{st} to 3^{rd} internode while pinching with just your fingers. Splitting the stalks in half will also reveal any fungal growth or hollowing of the stem.

If stalk rots are present, they cannot be eliminated by applications of a fungicide. The primary method of minimizing yield losses due to stalk rots is to prioritize harvesting those fields as early as possible. This early harvest may even lead to higher grain moisture at harvest and subsequent greater grain drying costs.

Keys to Better Fungicide Applications

Deciding when to apply a fungicide to control foliar diseases of corn in South Carolina is difficult. First, you need to utilize the other control measures available. Crop rotation, especially avoiding monocropping of corn, is critical to minimizing the fungal inoculum present on crop debris for many foliar diseases such as Northern Corn Leaf Blight. The use of minimum tillage in fields that will be monocropped or that have had high levels of disease in the previous crop(s) should be avoided. Crop debris should be destroyed or buried. For most foliar diseases, resistant hybrids are available and should be used.

Figure 3. Appropriate growth stage to spray fungicides on corn. Image credit: John Mueller, Clemson University.

When is it appropriate to spray? In terms of crop growth stages, the most opportune time to spray appears to be at or near the VT/R1 growth stage (figure 3). Except in very wet years, most foliar diseases develop after VT/R1. Spraying just before diseases occur allows the fungicides to function in a preventative rather than a curative mode. Most fungicides are more effective in preventing than eliminating diseases. However, spraying before disease symptoms are visible can be a gamble. Fungicides should not be applied prior to 100% tassel or later than fourteen days after brown silk.

The following three tables list the fungicides labeled for use on corn in South Carolina. They are divided by the number of active ingredients in each product. In general, more active ingredients provide better and longer control. However, that is a “general rule” and does not always hold true.

The Corn Disease Working Group has constructed a table giving relative efficacy ratings for many fungicides for control of each of the major foliar diseases of corn. This table is constructed with input from specialists in many states and is updated every year. It is available on the Crop Protection Network website (crop-protection-network.s3.amazonaws.com/publications/fungicide-efficacy-for-control-of-corn-diseases-filename-2020-03-18-150007.pdf).

Table 1. Fungicides with one active ingredient available for application to control foliar.

Fungicide	Active Ingredient	Rate/acre	FRAC Code	Days to Harvest (PHI)
Aftershock 480 SC	fluoxastrobin	2 – 5.7 fl oz	11	30
Andiamo 230 ME	tetraconazole	4 - 6 fl oz	3	R3
Aproach 2.08 SC	picoxystrobin	3 – 12 fl oz	11	7
Domark 230 ME	tetraconazole	4 – 6 fl oz	3	R3
Evito 480 SC	fluoxastrobin	2 – 5.7 fl. oz	11	30
Multiple generic tebuconazoles (3.6 F)	tebuconazole	4 - 6 fl oz	3	36
Headline 2.09 SC	pyraclostrobin	6 – 12 fl oz	11	7
Proline 480 SC	prothioconazole	5.7 fl oz	3	14
Propimax 3.6 EC	propiconazole	4 fl oz	3	30
Quadris 2.08 SC Multiple generics	azoxystrobin	6 - 15.5 fl oz	11	7
Tilt	propiconazole	4 fl oz	3	30
Topguard 1.04 SC	flutriafol	7 - 14 fl oz	3	7

Table 2. Fungicides with two active ingredients available for the control of fungal diseases of corn.

Fungicide	Active Ingredients	Rate	FRAC Code	Days to Harvest
Affiance 1.5 SC	Azoxystrobin + Tetraconazole	10 - 17	11 + 3	7
Aproach Prima 2.34 SC	Picoxystrobin + cyproconazole	3.4 - 6.8	11 + 3	21
Brixen 1.85 SC	Azoxystrobin + Tetraconazole	13 - 19 fl oz	11 + 3	R3
Cover XL 2.2 SE	Azoxystrobin + Propiconazole	10.5 - 14	11+ 3	30
Dexter Max 0.75 DC	Mancozeb + Azoxystrobin	1.6 lbs	11 + 3	40
Fortix 3.22 SC	Fluoxastrobin + Flutriafol	4 - 6 fl oz	1 + 3	30
Headline AMP 1.68 SC	Pyraclostrobin + Metconazole	10 - 14.4 fl oz	11 + 3	20
Helmstar Plus	Azoxystrobin + Tebuconazole	7.2 - 10.8	11+ 3	36
Lucento 4.17 SC	Flutriafol + bixafen	3 - 5.5 fl oz	3 + 7	30
Preemptor 3.22 SC	Fluoxastrobin + Flutriafol	4 - 6 fl oz	11 + 3	30
Priaxor 4.17 SC	Pyraclostrobin + Fluxapyroxad	4 - 8 fl oz	11 + 7	21
Prosaro 421 SC	Prothioconazole + Tebuconazole	6.5 fl oz	3 + 3	36
Quilt Xcel 2.2 SE	Azoxystrobin + Propiconazole	10.5 - 14 fl oz	11 + 3	30
Stratego 2.08 SC	Trifloxystrobin + Propiconazole	12 fl oz	11 + 3	30
Stratego YLD 4.18 SC	Trifloxystrobin + Prothioconazole	4 - 5 fl oz	11 + 3	14
Zolera FX 3.34 SC	Fluoxastrobin + tetraconazole	4.4 - 6.8	11 + 3	30
Topguard EQ 4.29 SC	Azoxystrobin + Flutriafol	5 - 7 fl oz	11 + 3	7
Veltyma 3.34 SC	Pyraclostrobin + Mefentrifluconazole	7 - 10 fl oz	11 + 3	21

Table 3. Fungicides with three active ingredients available for control of fungal diseases of corn.

Fungicide	Active Ingredients	Rate	FRAC Code	Days to Harvest
Revytek 3.33 SC	Fluxapyroxad + Pyraclostrobin + Mefentrifluconazole	8 - 15 fl oz	7 + 11 + 3	21
Trivapro 2.21 SE	Benzovindiflupyr + Azoxystrobin + Propiconazole	13.7 fl oz	7 + 11 + 3	30

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Management of Insects in Corn

Francis Reay-Jones, PhD

Grain yield reductions and losses in grain quality can occur in corn in South Carolina as a result of feeding by a number of insect pests. Control options include cultural practices to prevent or avoid injury, transgenic Bt corn, at-planting insecticides (including seed treatments), and foliar insecticides. Decisions concerning pest management options should be made in careful consideration of the history of insect problems in each field where corn is to be planted. Fields should be scouted regularly for insect pests and associated crop damage.

Most Common Insect Pests of Corn

Stink Bugs

Stink bugs are the most important economic pests of corn in South Carolina. Several species can feed on corn, though the brown stink bug (*Euschistus servus*) is the most common. From emergence to V6, feeding on the growing point can lead to stunting, tillering, and plant death. When the ear is elongating prior to tasselling, feeding by stink bugs through the stalk can lead to deformed ears and reduced kernel weight. During R1-R2, feeding will result in the loss of individual kernels. Economic thresholds for insecticide use are one bug per ten plants from V1-V6, one bug per 8 plants from V14 to VT, and one bug per 4 plants from R1-R2. Early season migration of stink bugs from wheat fields can sometimes lead to significant numbers of stink bugs in nearby cornfields. Higher rates of pyrethroid insecticides are needed when the brown stink bug is the dominant species, as other common stink bug pest species are more susceptible to these insecticides.

Corn Earworm

Corn earworm is the most common ear-feeding pest of corn in South Carolina. Feeding can sometimes occur on foliage throughout the season, though this is generally rare. After the moth lays eggs on the corn silks, young larvae feed on silk as they move down towards the ear. Feeding is often limited to the tip of the ear, where kernels do not fully develop. Kernal feeding can occur, though feeding is generally not sufficient to reduce yields. Corn earworm is not considered an economic pest of corn, especially when planting during the recommended planting window. Because of increased corn earworm pressure later in the season, planting late can sometimes lead to heavier corn earworm pressure and kernel injury. Ear injury caused by earworms can sometimes create entry points for fungal pathogens that may lead to increased levels of aflatoxins and fumonisins. Insecticides are not recommended for corn earworm control in field corn, as insects are quickly concealed within ears where contact with insecticide is reduced. Bt corn hybrids can provide varying levels of control or suppression.

Fall Armyworm

Fall armyworm can injure corn plants by feeding on leaves, stalks, ears, though leaf damage is the most common type of injury. While corn plants are fairly tolerant of leaf-feeding due to compensation, feeding on the apical meristem can sometimes lead to stunted plants and even plant death. Yield loss is often greater when feeding occurs at earlier vegetative stages. Decisions for insecticides for whorl infestations can be made using a threshold of 25% of plants infested with live larvae. Fall armyworm does not overwinter in South Carolina and needs to migrate every year from southern regions. Timing and location of infestations can vary greatly across the state and from year to year. However, planting corn within our recommended window will often avoid higher fall armyworm populations that typically occur later in the season. Planting date can therefore be used as a cultural practice by avoiding later planting with higher risks of significant fall armyworm pressure. While resistance to the Bt protein Cry1F has been reported in some populations, Bt products will help to suppress or control fall armyworm (see table below) and are generally more effective than using foliar applications of insecticide.

Sugarcane Beetles

The sugarcane beetle is a sporadic pest of corn in South Carolina. With a single generation per year, adult beetles emerge in the late summer and early fall, spending most of the time in the soil and emerging on warm days to feed on grasses. As temperatures drop in the winter, the insect can burrow deeper into the soil before remerging in March or early April. In addition to egg-laying, adults then burrow into the soil and feed on roots and crown of corn seedling plants. It is the adult, and not the larval stage (grub), that is responsible for economic damage to corn. Injury can occur from emergence to V10, though V3 to V5 is more typical. Management decisions need to be made prior to planting, as foliar applications of insecticides are ineffective once damage is present. Insecticide seed treatments or in-furrow applications of insecticide can help to reduce damage. Fields with established grasses, including pastures, should be avoided when selecting a field to plant corn, as such environments can harbor sugarcane populations. Among other cultural practices, peak sugarcane beetle emergence can be avoided by planting early, and deep tillage can be used in fields with frequent sugarcane beetle problems.

Billbugs

Billbugs are small weevils that feed on the base of a corn stem right below the soil surface. The insect can chew holes in the stem, leading to stunted or even dead plants when feeding occurs at the seedling stage. Plants can often have traverse row holes caused by feeding. The larval stage of billbugs (grubs) can also feed on corn plants. In-furrow applications of insecticide and higher rates of seed treatments can be used for control, in addition to foliar applications of insecticide.

Transgenic Bt Corn

Several types of transgenic corn that express Bt toxins are available, each characterized by an 'event' (i.e., successful insertion of the genetic package into a plant) and Bt proteins. In a nutshell, there are Bt traits for above-ground pests and Bt traits for rootworms. Please refer to the table below for the efficacy of available products.

Bt traits for above-ground pests:

- Herculex I (event TC1507; protein Cry1F).
- Optimum Intrasect (events TC1507 and MON810; proteins Cry1F and Cry1Ab).
- Optimum Leptra (events TC1507, MON810, and MIR162; proteins Cry1F, Cry1Ab and Vip3Aa20).
- YieldGard CB (event MON810; protein Cry1Ab).
- Genuity VT Double Pro (event MON89034; proteins Cry1A.105 and Cry2Ab2).
- Agrisure Artesian 3010A (event Bt11; protein Cry1Ab).
- Agrisure GT/CB/LL (event Bt11; protein Cry1Ab).
- Agrisure Viptera 3110 (events MIR162 and Bt11; proteins Vip3Aa20 and Cry1Ab).
- Agrisure Viptera 3220 (events MIR162 and TC1507; proteins Vip3Aa20, Cry1Ab, and Cry1F)
- PowerCore (events MON89034 and TC1507; proteins Cry1A.105, Cry2Ab2, and Cry1F)
- Trecepta (events MON89034 and MIR162; proteins Cry1A.105, Cry2Ab2, and Vip3Aa20)

All products provide excellent control of stalk borers (European corn borer, southern cornstalk borer). The activity in seedling and whorl stage is greater in Herculex I, which provides good early season control of cutworms, lesser cornstalk borer, and fall armyworm. YieldGard CB and Agrisure CB/LL have fair activity for corn earworm infestations in corn ears, whereas control with Herculex I is poor. The more recent Genuity VT Double Pro was the first Bt corn trait to express two Bt toxins to control above-ground Lepidopteran pests. Genuity VT Double Pro provides very good control of fall armyworm, while control of corn earworm is inconsistent, though it can be better than single toxin Bt products. The Vip3Aa20 toxin that is included in Agrisure Viptera, Optimum Leptra, and in Trecepta hybrids is the only toxin that provides excellent control of corn earworm. These hybrids may be particularly useful in late-planted corn.

Bt traits for rootworms:

- Herculex RW (event DAS59122-7, protein Cry34/35Ab1).
- YieldGard Rootworm (event MON863, protein Cry3Bb).
- YieldGard VT Rootworm/RR2 (event MON88017, protein Cry3Bb).
- Agrisure RW (event MIR604, protein mCry3A).

All products provide control of western corn rootworms (but no control of grubs and wireworms). Western corn rootworms are not currently widespread pests in South Carolina, and these products should generally not be needed.

Stacked Bt traits for above-ground pests and rootworms:

- Optimum Intrasect XTRA (events TC1507, MON810, and DAS59122-7, cry proteins Cry1F, Cry1Ab, and Cry34/35Ab1).
- YieldGard VT Triple (events MON810 and MON88017, cry proteins Cry1Ab and Cry3Bb1).
- Agrisure CB/LL/RW (events Bt11 and MIR604, cry proteins Cry1Ab and mCry3A).
- Agrisure 3000 GT, Agrisure Artesian 3011A (events Bt11, and MIR604, cry proteins Cry1Ab and mCry3A).
- Agrisure Viptera 3111 (events MIR162, Bt11 and MIR604, vip protein Vip3A, and cry proteins Cry1Ab and mCry3A).
- Genuity VT Triple Pro (events MON89034 and MON88017, cry proteins Cry1A.105, Cry2Ab2, and Cry3Bb1).
- Powercore (events MON89034 and TC1507, cry proteins Cry1A.105, Cry2Ab2, and Cry1F).
- SmartStax or Genuity SmartStax (events MON89034, MON88017, TC1507 and DAS59122, cry proteins Cry1A.105, Cry2Ab2, Cry3Bb, Cry1F, and Cry34/35Ab1).

These products combine the cry proteins (and efficacy) of the above-ground pest and rootworm Bt corn traits.

Refuge requirements for Bt corn for above-ground pests in Cotton Belt (see dealers for complete refuge requirements):

- For YieldGard Corn Borer, Agrisure GT/CB/LL, Agrisure Artesian 3010A, Herculex I: 50% of corn on a farm can be planted as Bt corn.
- Genuity VT Double Pro, Agrisure Viptera 3110, Agrisure Viptera 3220, Optimum Intrasect, Optimum Leptra, PowerCore: 20% of corn on a farm can be planted as Bt corn.
- Blocks can be internal (within Bt field) or external (in a separate field within ½ mile of Bt field to maximize random mating; ¼ mile is, however, preferred.
- Infield strips: at least four rows wide to reduce the effect of larval movement (6 rows preferred)
- Refuge can be sprayed with any insecticide except Bt products

Refuge requirements for Bt corn for rootworms in Cotton Belt (see dealers for complete refuge requirements):

Bt corn for rootworm has specific regulations that differ from stalk borer Bt corn. The major difference for rootworm Bt corn is that refuges must be either adjacent to or within the Bt field, rather than within ¼ mile of the Bt field for stalk borer Bt corn. This is due to the poor flight ability of corn rootworm adults.

Refuge requirements for stacked Bt corn for above-ground pests and rootworms in Cotton Belt (see dealers for complete refuge requirements):

- For YieldGard VT Triple, Agrisure CB/LL/RW, Agrisure GT 3000, Agrisure Artesian® 3011A: 50% of corn on a farm can be planted as Bt corn.

- Genuity VT Triple PRO, SmartStax, Genuity SmartStax, Agrisure Viptera 3111, Optimum Intrasect XTRA: 20% of corn on a farm can be planted as Bt corn.

There are two options for the refuge for these stacked products: (1) common rootworm/corn borer refuge and (2) discrete rootworm and corn borer refuges.

- For common refuge and discrete rootworm refuge: use adjacent field, block perimeter, or in-field strip.
- For discrete corn borer refuge: separate fields can be used in addition to other refuge options.
- For shared refuge and discrete rootworm refuge: refuges must be adjacent to or within the field.
- For discrete corn borer refuge: separate refuges must be within 1/2 mile (but 1/4 mile preferred).
- At least four rows (for discrete corn borer refuges, at least six rows are recommended).
- Refuge can be sprayed with any insecticide except Bt products.

At-Planting Use of Insecticides

The majority of corn seed comes with at least a base rate (250 or 0.25 mg AI/seed) of either Cruiser (thiamethoxam) or Poncho (imidacloprid), in addition to fungicides. The optional higher rates provide batter protection from several insect pests (see table below). In-furrow applications of insecticide can also be made for soil pests and early season pests.

Table 1. Relative efficacy[1] of seed treatments and soil insecticides for at-planting use in corn (reprinted with permission from Dr. G. David Buntin, University of Georgia; 2021 Corn Production Guide).

Product[2,3]	Seed-corn maggot	Sou. corn rootworm	Wire-worm	White grubs	Lesser corn-stalk borer	Cut-worm	Chinch bug	Corn bill-bug	Sugarcane beetle
Counter 20G	E	E	E	E	P,nl	P,nl	F	F	P,nl
Force 3G	E	E	E	F-G	F	G	P	P	P,nl
Capture 1.15G	E	E	E	G	F,nl	G	P	P,nl	P,nl
Capture 2EC LQ	E	E	E	G	F,nl	G	P	P,nl	G,nl
Poncho 250 ST	G	E	G	F	G,nl	P-F	F-G	P,nl	F
Poncho 500 ST	E	E	G	E	G,nl	P-F	G	F	G
Poncho 1250 ST	E	E	E	E	E,nl	F-G	E	G	G
Cruiser 250 ST, PPST	G	G,nl	G	F	G,nl	P	F	P,nl	P
PPST 250 + Lumivia ST	E	G-E, nl	G	G	G,nl	E	F	F-G, nl	P
Cruiser Maxx Corn 500 or Avicta Complete corn ST	E	E	G	G	G,nl	P	F	P,nl	P-F
Cruiser Maxx Corn 500 or Avicta Complete corn ST	E	E	E	E	E,nl	F	G	G	F
Imidacloprid[4] ST 0.60 mg rate	E	G,nl	F-G	F-G	P,nl	P,nl	F	P,nl	P,nl

[1]Rating: P indicates poor or no activity; F indicates fair activity; G indicates good activity; E indicates excellent activity.

[2]G = granule insecticide; LQ = Products require specialized equipment for liquid injection in-furrow; ST = seed treatments, applied by seed dealers.

[3] nl = indicates the insect pest is not listed on the product label. Ratings in boxes with nl are listed if data from trials is available.

[4]Numerous brands.

Chemical and Rate Selection

The following section provides an overview of insecticide recommendations. A range of rates is typically given for each pest. Factors that affect the recommended rate are pest size, pest density, plant size, temperature, and application method. The higher rates generally are needed for combinations of heavy populations, larger insects, dense plant canopy, extreme temperatures (95 degrees F), and aerial application.

Insecticides at Planting

INSECT	PESTICIDE AND FORMULATION	RATE	REI	PHI	PGI	COMMENTS
Armyworm (fall armyworm) 	Transgenic Bt corn (see table above for details)	Insecticide in plant	-	-	-	See dealers for refuge requirements for Bt corn.
Billbugs (seed treatment)	Clothianidin PONCHO 1250 or ACCELERON	1.25 mg (ai)/seed	-	-	-	Seed treatment
	Thiamethoxam CRUISER 5FS 1250	1.25 mg (ai)/seed	12	-	-	Seed treatment
Billbugs (at planting insecticide)	Terbufos COUNTER 15G R	6 to 8 oz/ 1000 ft of row	48	60	30	Apply either in 7-inch band or in-furrow
	Telfluthrin FORCE 3G R	4 to 5 oz/ 1000 ft of row	0	-	-	Apply as band or T-band.
Chinch bug (seed treatment)  William & Robert Chambers *Encyclopaedia - A Dictionary of Universal Knowledge for the People* (Philadelphia, PA: J. B. Lippincott & Co., 1881)	Clothianidin PONCHO 250 or ACCELERON PONCHO 1250 or ACCELERON	0.25 mg (ai)/seed 1.25 mg (ai)/seed	- -	- -	- -	Seed treatment
	Thiamethoxam CRUISER 5FS 250 CRUISER 5FS 1250	0.25 mg (ai)/seed 1.25 mg (ai)/seed	12 12	- -	- -	Seed treatment
Chinch bug (at planting insecticide)	Terbufos COUNTER 15G R	6 to 8 oz/ 1000 ft of row	48	60	30	Apply either in 7-inch band or in-furrow
	Telfluthrin FORCE 3G R	4 to 5 oz/ 1000 ft of row	0	-	-	Apply as band or T-band.
Corn earworm  William Dwight Whitney The Century Dictionary and Cyclopedia: An encyclopedic Lexicon of the English Language (New York, NY: The Century Co., 1889)	Transgenic Bt corn (see table above for details)	Insecticide in plant	-	-	-	See dealers for refuge requirements for Bt corn.

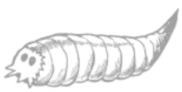
R = Restricted use pesticide; REI = re-entry interval; PHI = pre-harvest interval; PGI = pre-grazing interval

INSECT	PESTICIDE AND FORMULATION	RATE	REI	PHI	PGI	COMMENTS
Cutworm (at planting insecticide)	Bifenthrin CAPTURE 2EC R CAPTURE 1.15G R	0.15-0.30 oz/ 1000 ft of row 6.4-8 oz/ 1000 ft	12 12	30 30	30 30	
	Esfenvalerate ASANA XL R	0.45 oz/ 1000 ft of row	12	21	-	Apply in band, T-band, or in-furrow.
	Gamma-cyhalothrin PROAXIS R	0.66 oz/ 1000 ft of row	24	21	1 (green) 21 (fodder)	Apply in band, T-band, or in-furrow.
	Lambda-cyhalothrin WARRIOR R	0.66 oz/ 1000 ft of row	24	21	1 (green) 21 (fodder)	Apply in band, T-band, or in-furrow
	Permethrin PERMETHRIN 3.2EC R POUNCE 25 WP R	4-8 oz/ac *or* 0.3-0.6 oz/ 1000 ft of row. 6.4-9.6 oz/ac *or* 0.5-0.75 oz/1000 ft of row	12 12	30 30	0 (green) 30 (fodder) 0 (green) 30 (fodder)	Apply in band, T-band, or in-furrow
	Permethrin POUNCE 1.5G R	8 oz/1000 ft of row	12	30	0 (green) 30 (fodder)	Apply in band, T-band, or in-furrow
	Terbufos COUNTER 15G R	6 to 8 oz/ 1000 ft of row	48	60	30	Apply either in 7-inch band or in-furrow. *Suppression only.*
	Zeta-cypermethrin MUSTANG MAX R	0.16 oz /1000 ft of row	12	30	60	
European corn borer 	Transgenic Bt corn (see table above for details)	Insecticide in plant	-	-	-	See dealers for refuge requirements for Bt corn.
Lesser cornstalk borer 	Transgenic Bt corn (see table above for details)	Insecticide in plant	-	-	-	See dealers for refuge requirements for Bt corn. Herculex I, Herculex Xtra, and Genuity Smartstax provide good-excellent control; other Bt products will provide poor-good control.

R = Restricted use pesticide; REI = re-entry interval; PHI = pre-harvest interval; PGI = pre-grazing interval

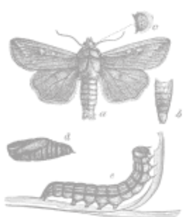
INSECT	PESTICIDE AND FORMULATION	RATE	REI	PHI	PGI	COMMENTS
Lesser cornstalk borer (at planting insecticide)	Gamma-cyhalothrin PROAXIS R	0.66 oz/ 1000 ft of row	24	21	1 (green) 21 (fodder)	Apply in 5- to 7-inch T-band or in-furrow. Use a minimum of 3 gal/ac.
	Lambda-cyhalothrin WARRIOR R	0.66 oz/ 1000 ft of row	24	21	1 (green) 21 (fodder)	Apply in 5- to 7-inch T-band or in-furrow. Use a minimum of 3 gal/ac.
	Terbufos COUNTER 15G R	6 to 8 oz/ 1000 ft of row	48	60	30	Apply either in 7-inch band or in-furrow. *Suppression only.*
	Telfluthrin FORCE 3G R	4 to 5 oz/ 1000 ft of row	0	-	-	Apply as band or T-band.
Wireworm (seed treatment)	Clothianidin PONCHO 250 or ACCELERON PONCHO 1250 or ACCELERON	0.25 mg (ai)/seed 1.25 mg (ai)/seed	- -	- -	- -	Seed treatment
	Thiamethoxam CRUISER 5FS 250 CRUISER 5FS 1250	0.25 mg (ai)/seed 1.25 mg (ai)/seed	12 12	- -	- -	Seed treatment.
Wireworm (at planting insecticide)	Bifenthrin CAPTURE 2EC R	0.15-0.30 oz/ 1000 ft of row	12	30	30	Apply in 5- to 7-inch T-band. Or in-furrow.
	Bifenthrin CAPTURE 1.15G R CAPTURE 1.15G R	6.4-8 oz/ 1000 ft of row 3.2-8 oz/ 1000 ft of row	12	30	30	Apply in 5- to 7-inch T-band. Apply in-furrow.
	Gamma-cyhalothrin PROAXIS R	0.66 oz/ 1000 ft of row	24	21	1 (green) 21 (fodder)	Apply in 5- to 7-inch T-band or in-furrow. Use a minimum of 3 gal/ac. *Suppression only*.
	Lambda-cyhalothrin WARRIOR R	0.66 oz/ 1000 ft of row	24	21	1 (green) 21 (fodder)	Apply in 5- to 7-inch T-band or in-furrow. Use a minimum of 3 gal/ac.
	Permethrin PERMETHRIN 3.2EC R	0.3 oz/ 1000 ft of row	12	30	0 (green) 30 (fodder)	Apply in-furrow, band, or T-band using at least a 4-inch band.
	Permethrin POUNCE 1.5G R	8 oz/ 1000 ft of row	12	30	0 (green) 30 (fodder)	

R = Restricted use pesticide; REI = re-entry interval; PHI = pre-harvest interval; PGI = pre-grazing interval

INSECT	PESTICIDE AND FORMULATION	RATE	REI	PHI	PGI	COMMENTS
Wireworm (at planting insecticide) (*cont.*)	Phorate THIMET 20G	4.5-6 oz/ 1000 ft of row	48	30	30	Apply either in 7-inch band.
	Terbufos COUNTER 15G R	6 to 8 oz/1000 ft of row	48	60	30	Apply either in 7-inch band or in-furrow
	Telfluthrin FORCE 3G R	4 to 5 oz/ 1000 ft of row	0	-	-	Apply as band or T-band.
Seedcorn maggot (seed treatment) 	Clothianidin PONCHO 250 or ACCELERON PONCHO 1250 or ACCELERON	0.25 mg (ai)/seed 1.25 mg (ai)/seed	- -	- -	- -	Seed treatment
	Thiamethoxam CRUISER 5FS 250 CRUISER 5FS 1250	0.25 mg (ai)/seed 1.25 mg (ai)/seed	12 12	- -	- -	Seed treatment.
Seedcorn maggot (at planting insecticide)	Bifenthrin CAPTURE 2EC R CAPTURE 1.15G R	0.15-0.30 oz/ 1000 ft of row 6.4-8 oz/ 1000 ft of row 3.2-8 oz/ 1000 ft of row	12 12	30 30	30 30	Apply in 5- to 7-inch T-band. Or in-furrow. Apply in 5- to 7-inch T-band. Apply in-furrow.
	Gamma-cyhalothrin PROAXIS R	0.66 oz/ 1000 ft of row	24	21	1 (green) 21 (fodder)	Apply in 5- to 7-inch T-band or in-furrow. Use a minimum of 3 gal/ac.
	Lambda-cyhalothrin WARRIOR R	0.66 oz/ 1000 ft of row	24	21	1 (green) 21 (fodder)	Apply in 5- to 7-inch T-band or in-furrow. Use a minimum of 3 gal/ac.
	Permethrin PERMETHRIN 3.2EC R POUNCE 3.2EC R	0.3 oz/ 1000 ft of row 0.3 oz/ 1000 ft of row	12 12	30 30	0 (green) 30 (fodder) 0 (green) 30 (fodder)	Apply in-furrow, band or T-band using at least a 4-inch band.

R = Restricted use pesticide; REI = re-entry interval; PHI = pre-harvest interval; PGI = pre-grazing interval

Post-Emergence Insecticides

INSECT	PESTICIDE AND FORMULATION	RATE	REI	PHI	PGI	COMMENTS
Armyworms 	Beta-cyfluthrin BAYTHROID XL R	1.6-2.8 oz /ac	12	21	0 (green) 21 (fodder)	
	Bifenthrin CAPTURE 2EC R	2.1-6.4 oz /ac	12	30	30	Apply broadcast in at least 10 gal/ac of water by ground.
	CAPTURE 1.15G R	3.5-8.7 oz /ac	12	30	30	Apply broadcast when insects first appear.
	Carbaryl SEVIN 80S, 80WSP	1.25-2.5 lb/ ac	12	14 (silage) 48 (ears)	14 (green) 48 (fodder)	
	4F, XLR Plus	1-2 qts/ac	12	14 (silage) 48 (ears)	14 (green) 48 (fodder)	
	Chlorantraniliprole PREVATHON	14-20 oz /ac	4	14	-	
	Deltamethrin DELTA GOLD 1.5EC R	1.5-1.9 oz /ac	12	21	12 (green) 21 (fodder)	For ground application, use at least 5 gal/ac of water.
	Esfenvalerate ASANA XL R	5.8-9.6 oz/ ac	12	21	-	
	Gamma-cyhalothrin PROAXIS R	2.56-3.84 oz /ac	24	21	1 (green) 21 (fodder)	For control of 1st and 2nd instars only.
	Lambda-cyhalothrin WARRIOR R	2.56-3.84 oz /ac	24	21	1 (green) 21 (fodder)	Use higher rates for large larvae.
	Methomyl LANNATE LV R	0.75-1.5 pts/ac	48	21 (ears)	3 (green) 21 (fodder)	
	LANNATE SP R	0.25-0.5 lbs/ac	48	21 (ears)	3 (green) 21 (fodder)	
	Methomyl LANNATE LV R	0.75-1.5 pts/ac	48	21 (ears)	3 (green) 21 (fodder)	
	LANNATE SP R	0.25-0.5 lbs/ac	48	21 (ears)	3 (green) 21 (fodder)	

R = Restricted use pesticide; REI = re-entry interval; PHI = pre-harvest interval; PGI = pre-grazing interval

INSECT	PESTICIDE AND FORMULATION	RATE	REI	PHI	PGI	COMMENTS
Armyworms (*cont.*)	Methoxyfenozide INTREPID 2F	4-16 oz/ac	4	21	21	Use only for true armyworm. Apply at first sign of egg hatch.
	Permethrin PERMETHRIN 3.2EC R POUNCE 25 WG R	4-6 oz/ac 6.4-9.6 oz/ac	12 12	30 30	0 (green) 30 (fodder) 0 (green) 30 (fodder)	Apply at first sign of egg hatch.
	Permethrin POUNCE 1.5G R	6.7-13.3 oz /ac	12	30	0 (green) 30 (fodder)	Apply at first sign of egg hatch.
	Spinosad BLACKHAWK	1.1-3.3	4	28	1 (grain) 3 (fodder)	Apply at peak egg hatch of each generation.
	Zeta-cypermethrin MUSTANG MAX R	3.2-4.0 oz /ac	12	30	60	
Chinch bug 	Bifenthrin CAPTURE 2EC R	2.1-6.4 oz /ac	12	30	30	Apply broadcast in at least 10 gal/ac of water by ground.
	Carbaryl SEVIN 80S, 80WSP 4F, XLR Plus	1.25-2.5 lb /ac 1-2 qts/ac	12 12	14 (silage) 48 (ears) 14 (silage) 48 (ears)	14 (green) 48 (fodder) 14 (green) 48 (fodder)	Use ground equipment to apply at least 20 gal/ac of water and direct spray towards stalk.
	Beta-cyfluthrin BAYTHROID XL R	1.6-2.8 oz /ac	12	21	0 (green) 21 (fodder)	
	Deltamethrin DELTA GOLD 1.5EC R	1.5-1.9 oz /ac	12	21	0 (green) 12 (fodder)	For ground application, use at least 5 gal/ac of water.
	Esfenvalerate ASANA XL R	5.8-9.6 oz /ac	12	21	-	Spray needs to be directed towards base of plant.
	Gamma-cyhalothrin PROAXIS R	3.84 oz/ac	24	21	1 (green) 21 (fodder)	
	Lambda-cyhalothrin WARRIOR R	3.84 oz/ac	24	21	1 (green) 21 (fodder)	
	Zeta-cypermethrin MUSTANG MAX R	3.2-4.0 oz /ac	12	30	60	

R = Restricted use pesticide; REI = re-entry interval; PHI = pre-harvest interval; PGI = pre-grazing interval

INSECT	PESTICIDE AND FORMULATION	RATE	REI	PHI	PGI	COMMENTS
Cutworm	Beta-cyfluthrin BAYTHROID XL R	0.8-1.6 oz /ac	12	21	0 (green) 21 (fodder)	
	Bifenthrin CAPTURE 2EC R	2.1-6.4 oz /ac	12	30	30	Apply broadcast in at least 10 gal/ac of water by ground.
	Carbaryl SEVIN 80S, 80WSP 4F, XLR Plus	2.5 lb/ac 2 qts/ac	12 12	14 (silage) 48 (ears) 14 (silage) 48 (ears)	14 (green) 48 (fodder) 14 (green) 48 (fodder)	Apply in 12-inch band over the row using sufficient volume of water to obtain thorough coverage. For broadcast, use at least 20 gal/ac of water by ground
	Deltamethrin DELTA GOLD 1.5EC R	1-1.5 oz/ac	12	21	12 (green) 21 (fodder)	For ground application, use at least 5 gal/ac of water.
	Esfenvalerate ASANA XL R	5.8-9.6 oz /ac	12	21	-	
	Gamma-cyhalothrin PROAXIS R	1.92-3.20 oz/ac	24	21	1 (green) 21 (fodder)	
	Lambda-cyhalothrin WARRIOR R	1.92-3.20 oz/ac	24	21	1 (green) 21 (fodder)	
	Methomyl LANNATE LV R LANNATE SP R	1.5 pts/ac 0.5 lbs/ac	48 48	21 (ears) 21 (ears)	3 (green) 21 (fodder) 3 (green) 21 (fodder)	
	Permethrin PERMETHRIN 3.2EC R POUNCE 25 WG R	4-6 oz/ac 6.4-9.6 oz/ac	12 12	30 30	0 (green) 30 (fodder) 0 (green) 30 (fodder)	
	Permethrin POUNCE 1.5G R	6.7-13.3 oz/ac	12	30	0 (green) 30 (fodder)	
	Zeta-cypermethrin MUSTANG MAX R	1.28-2.8 oz /ac	12	30	60	

R = Restricted use pesticide; REI = re-entry interval; PHI = pre-harvest interval; PGI = pre-grazing interval

INSECT	PESTICIDE AND FORMULATION	RATE	REI	PHI	PGI	COMMENTS
European corn borer	Bifenthrin CAPTURE 2EC R CAPTURE 1.15G R	2.1-6.4 oz /ac 3.5-8.7 oz /ac	12 12	30 30	30 30	Apply broadcast in at least 10 gal/ac of water by ground. Apply broadcast at or just before egg hatch.
	Carbaryl SEVIN 80S, 80WSP 4F, XLR Plus	1.875-2.5 lb/ac 1.5-2 qts /ac	12 12	14 (silage) 48 (ears) 14 (silage) 48 (ears)	14 (green) 48 (fodder) 14 (green) 48 (fodder)	Use ground equipment to apply at least 15 gal/acre of water and direct spray towards stalk.
	Chlorantraniliprole PREVATHON	14-20 oz /ac	4	14		
	Beta-cyfluthrin BAYTHROID XL R	1.6-2.8 oz /ac	12	21	0 (green) 21 (fodder)	Application must be made before larvae enter plant.
	Deltamethrin DELTA GOLD 1.5EC R	1.5-1.9 oz /ac	12	21	12 (green) 21 (fodder)	For ground application, use at least 5 gal/ac of water.
	Esfenvalerate ASANA XL R	7.8-9.6 oz /ac	12	21	-	Spray when eggs are in blackhead stage or before larvae enter whorl.
	Gamma-cyhalothrin PROAXIS R	2.56-3.84 oz /ac	24	21	1 (green) 21 (fodder)	Use before larvae enter stalk or ear.
	Lambda-cyhalothrin WARRIOR R	2.56-3.84 oz /ac	24	21	1 (green) 21 (fodder)	Use before larvae enter stalk or ear.
	Methomyl LANNATE LV R LANNATE SP R	0.75-1.5 pts/ac 0.25-0.5 lbs/ac	48 48	21 (ears) 21 (ears)	3 (green) 21 (fodder) 3 (green) 21 (fodder)	
	Methoxyfenozide INTREPID 2F	4-16 oz/ac	4	21	21	Apply at first sign of egg hatch. Direct application at whorl for early season (1st generation). Apply as broadcast over row mid and late season.

R = Restricted use pesticide; REI = re-entry interval; PHI = pre-harvest interval; PGI = pre-grazing interval

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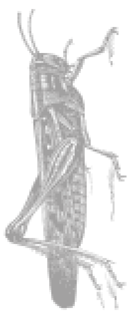
INSECT	PESTICIDE AND FORMULATION	RATE	REI	PHI	PGI	COMMENTS
European corn borer (*cont.*)	Permethrin PERMETHRIN 3.2EC R POUNCE 25 WG R	4-6 oz/ac 6.4-9.6 oz/ac	12 12	30 30	0 (green) 30 (fodder) 0 (green) 30 (fodder)	
	Permethrin POUNCE 1.5G R	6.7-13.3 oz /ac	12	30	0 (green) 30 (fodder)	
	Spinosad BLACKHAWK	1.1-3.3	4	28	7	Apply at peak egg hatch of each generation.
	Zeta-cypermethrin MUSTANG MAX R	2.72-4.0 oz /ac	12	30	60	
Flea beetle 	Bifenthrin CAPTURE 2EC R	2.1-6.4 oz /ac	12	30	30	Apply broadcast in at least 10 gal/ac of water by ground
	Carbaryl SEVIN 80S, 80WSP 4F, XLR Plus	1.25-2.5 lb /ac 1-2 qts/ac	12 12	14 (silage) 48 (ears) 14 (silage) 48 (ears)	14 (green) 48 (fodder) 14 (green) 48 (fodder)	
	Beta-cyfluthrin BAYTHROID XL R	0.8-1.6 oz /ac	12	21	0 (green) 21 (fodder)	
	Deltamethrin DELTA GOLD 1.5EC R	1.0-1.5 oz/ac	12	21	12 (green) 21 (fodder)	For ground application, use at least 5 gal/ac of water.
	Esfenvalerate ASANA XL R	5.8-9.6 oz /ac	12	21	-	
	Gamma-cyhalothrin PROAXIS R	2.56-3.84 oz/ac	24	21	1 (green) 21 (fodder)	
	Lambda-cyhalothrin WARRIOR R	2.56-3.84 oz/ac	24	21	1 (green) 21 (fodder)	

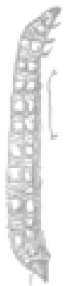
R = Restricted use pesticide; REI = re-entry interval; PHI = pre-harvest interval; PGI = pre-grazing interval

INSECT	PESTICIDE AND FORMULATION	RATE	REI	PHI	PGI	COMMENTS
Flea beetle (*cont.*)	Permethrin PERMETHRIN 3.2EC R	4-6 oz/ac	12	30	0 (green) 30 (fodder)	
	POUNCE 25 WG R	6.4-9.6 oz/ac	12	30	0 (green) 30 (fodder)	
	Zeta-cypermethrin MUSTANG MAX R	2.72-4.0 oz /ac	12	30	60	
Grasshoppers	Bifenthrin CAPTURE 2EC R	2.1-6.4 oz /ac	12	30	30	Apply broadcast in at least 10 gal/ac of water by ground.
	Beta-cyfluthrin BAYTHROID XL R	2.1-2.8 oz /ac	12	21	0 (green) 21 (fodder)	
	Deltamethrin DELTA GOLD 1.5EC R	1.0-1.5 oz /ac	12	21	12 (green) 21 (fodder)	For ground application, use at least 5 gal/ac of water.
	Esfenvalerate ASANA XL R	5.8-9.6 oz /ac	12	21	-	For 1st and 2nd instar nymph, use 3.9-5.8 oz/ac. Timing and good coverage are critical. Beyond 2nd instar, use 5.8-9.6 oz/ac
	Gamma-cyhalothrin PROAXIS R	2.56-3.84 oz/ac	24	21	1 (green) 21 (fodder)	
	Lambda-cyhalothrin WARRIOR R	2.56-3.84 oz/ac	24	21	1 (green) 21 (fodder)	
	Zeta-cypermethrin MUSTANG MAX R	2.72-4.0 oz /ac	12	30	60	

R = Restricted use pesticide; REI = re-entry interval; PHI = pre-harvest interval; PGI = pre-grazing interval

INSECT	PESTICIDE AND FORMULATION	RATE	REI	PHI	PGI	COMMENTS
Lesser cornstalk borer 	Lambda-cyhalothrin WARRIOR R	2.56-3.84 oz/ac	24	21	1 (green) 21 (fodder)	
Southern corn rootworm beetles	Beta-cyfluthrin BAYTHROID XL R	1.6-2.8 oz /ac	12	21	0 (green) 21 (fodder)	
	Bifenthrin CAPTURE 2EC R	2.1-6.4 oz /ac	12	30	30	Apply broadcast.
	Carbaryl SEVIN 80S, 80WSP 4F, XLR Plus	1.25-2.5 lb /ac 1-2 qts/ac	12 12	14 (silage) 48 (ears) 14 (silage) 48 (ears)	14 (green) 48 (fodder) 14 (green) 48 (fodder)	
	Deltamethrin DELTA GOLD 1.5EC R	1.5-1.9 oz /ac	12	21	12 (green) 21 (fodder)	Use at least 5 gal/ac for ground application.
	Esfenvalerate ASANA XL R	5.8-9.6 oz /ac	12	21	-	Apply at first sign of silk feeding.
	Gamma-cyhalothrin PROAXIS R	2.56-3.84 oz/ac	24	21	1 (green) 21 (fodder)	
	Lambda-cyhalothrin WARRIOR R	2.56-3.84 oz/ac	24	21	1 (green) 21 (fodder)	
	Methomyl LANNATE LV R LANNATE SP R	0.75-1.5 pts/ac 0.25-0.5 lbs/ac	48 48	21 (ears) 21 (ears)	3 (green) 21 (fodder) 3 (green) 21 (fodder)	
	Permethrin PERMETHRIN 3.2EC R POUNCE 25 WG R	4-6 oz/ac 6.4-9.6 oz/ac	12 12	30 30	0 (green) 30 (fodder) 0 (green) 30 (fodder)	
	Zeta-cypermethrin MUSTANG MAX R	3.2-4.0 oz /ac	12	30	60	Use at least 10 gal/ac for ground application.

R = Restricted use pesticide; REI = re-entry interval; PHI = pre-harvest interval; PGI = pre-grazing interval

INSECT	PESTICIDE AND FORMULATION	RATE	REI	PHI	PGI	COMMENTS
Southern corn rootworm beetles (*cont.*) 	Carbaryl SEVIN 80S, 80WSP 4F, XLR Plus	1.25-2.5 lb /ac 1-2 qts/ac	12 12	14 (silage) 48 (ears) 14 (silage) 48 (ears)	14 (green) 48 (fodder) 14 (green) 48 (fodder)	
	Deltamethrin DELTA GOLD 1.5EC R	1.5-1.9 oz /ac	12	21	12 (green) 21 (fodder)	Use at least 5 gal/ac for ground application.
	Esfenvalerate ASANA XL R	5.8-9.6 oz /ac	12	21	-	Apply at first sign of silk feeding.
	Gamma-cyhalothrin PROAXIS R	2.56-3.84 oz/ac	24	21	1 (green) 21 (fodder)	
	Lambda-cyhalothrin WARRIOR R	2.56-3.84 oz/ac	24	21	1 (green) 21 (fodder)	
	Methomyl LANNATE LV R LANNATE SP R	0.75-1.5 pts/ac 0.25-0.5 lbs/ac	48 48	21 (ears) 21 (ears)	3 (green) 21 (fodder) 3 (green) 21 (fodder)	
	Permethrin PERMETHRIN 3.2EC R POUNCE 25 WG R	4-6 oz/ac 6.4-9.6 oz/ac	12 12	30 30	0 (green) 30 (fodder) 0 (green) 30 (fodder)	
	Zeta-cypermethrin MUSTANG MAX R	3.2-4.0 oz /ac	12	30	60	Use at least 10 gal/ac for ground application.

R = Restricted use pesticide; REI = re-entry interval; PHI = pre-harvest interval; PGI = pre-grazing interval

INSECT	PESTICIDE AND FORMULATION	RATE	REI	PHI	PGI	COMMENTS
Stink bugs 	Beta-cyfluthrin BAYTHROID XL R	1.6-2.8 oz /ac	12	21	0 (green) 21 (fodder)	
	Bifenthrin CAPTURE 2EC R	2.1-6.4 oz /ac	12	30	30	Apply broadcast.
	Deltamethrin DELTA GOLD 1.5EC R	1.5-1.9 oz /ac	12	21	12 (green) 21 (fodder)	Use at least 5 gal/ac for ground application.
	Gamma-cyhalothrin PROAXIS R	2.56-3.84 oz/ac	24	21	1 (green) 21 (fodder)	
	Lambda-cyhalothrin WARRIOR R	2.56-3.84 oz/ac	24	21	1 (green) 21 (fodder)	
	Zeta-cypermethrin MUSTANG MAX R	2.72-4.0 oz /ac	12	30	60	Use at least 10 gal/ac for ground application.

PRE-MIXED or CO-PACKAGED INSECTICIDES

BRAND NAME	RATE	REI	PHI	PGI	COMMENTS
COBALT (chlorpyrifos, gamma-cyhalothrin)	7-42 oz/ac	24	32	1 (green) 21 (fodder)	
HERO (Bifenthrin, zeta-cypermethrin)	2.6-10.3 oz/ac	12	30	30 (green) 60 (forage)	
BESIEGE (lambda-cyhalothrin, chlorantraniliprole)	5-10 oz/ac	24	21	1 (green) 21 (fodder)	

R = Restricted use pesticide; REI = re-entry interval; PHI = pre-harvest interval; PGI = pre-grazing interval

Corn Drying and Storage

Aaron P. Turner, PhD

Drying and storage are essential components of maintaining corn quality and understanding these factors is instrumental in reducing post-harvest losses. Figure 1 shows the five-year average corn harvest progress from USDA-NASS (2021). Based on this, the first corn gets cut at the beginning of August, and the harvest runs until mid-October. For a large operation with a high-temperature grain dryer, harvest can typically begin once the grain moisture reaches around 25%. Harvest above that level is impractical because dryer capacity is greatly reduced, and there is increased mechanical damage. Smaller operations rely on some combination of field drying and low temperature/natural air bin dryers, so they start later once the moisture reaches relatively low levels. Early in the season, corn can field dry 0.5 to 1.0 pts per day, and the drying rate decreases as the grain approaches equilibrium with ambient conditions. Figure 2 shows an example of what this looks like using data from a field drying test conducted at the Piedmont REC.

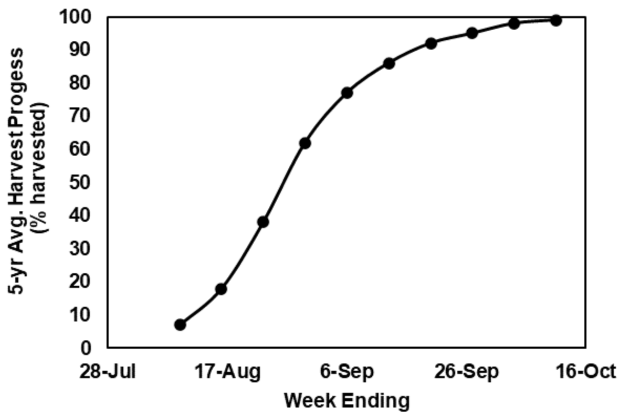


Figure 1. Five-year average corn harvest progress in South Carolina (USDA-NASS, 2021).

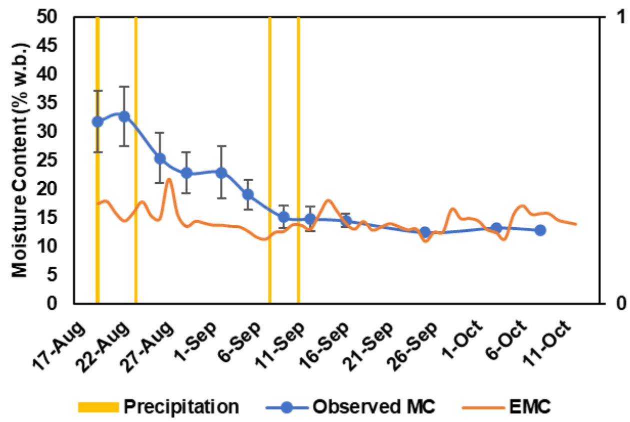


Figure 2. Results from a field drying study at Piedmont REC. Observed MC is the actual grain moisture and EMC moisture the grain would reach if in equilibrium with the ambient conditions.

Moisture Shrink

Market moisture for corn is typically 15.0%. While moisture is not a grade factor, it influences many qualities that are, and when corn above this level is sold, a shrink factor is used to adjust the weight of the grain to the equivalent weight at 15%. However, there is no "expansion factor" to adjust the weight upward if sold below 15%. Because of this, grain sold below 15% is inherently less profitable. When producers evaluate marketing locations, they should not only evaluate price per bushel but also drying and shrink charges. In addition to moisture shrink, buyers often include a drying charge and potentially a handling loss. Equation 1 and equation 2 can be used to calculate shrink and find the equivalent number of 15% bushels. Assuming no handling loss, the number of adjusted bushels shrinks by roughly 1.176% per point of moisture removed.

$$Shrink = \frac{MC\ Initial - MC\ Final}{100 - MC\ Final} + handling\ loss \quad (1)$$

$$Adjusted\ bushels = Wet\ bushels * (1 - shirnk) \quad (2)$$

Example: 1,000 wet bushels are harvested at a moisture content of 18%. To adjust to bushels at 15%, assuming no handling loss, moisture shrink is calculated as:

$$Shrink = \frac{18 - 15}{100 - 15} + 0 = 0.0353\ or\ 3.53\%$$

To adjust the number of bushels you have:

$$Adjusted\ bushels = 1000 * (1 - .0353) = 965\ bu$$

Drying System Considerations

The choice in drying method is usually dictated by system costs, harvest capacity, number of bushels to be dried, required moisture removal, and available handling/storage capacity. Allowing grain to dry in the field reduces energy costs associated with post-harvest drying, but there is an increased risk of reduced yield and/or quality with delayed harvest. In general, natural air/low temperature bin drying systems have lower equipment and operating costs but have limited capacity (both in grain volume and moisture range). High temperature tower and column grain dryers have higher throughput and can handle higher incoming moisture contents; however, these systems also have higher equipment and operating costs. There are also several configurations of high-temperature bin dryers that are not discussed in detail in this guide. For a more detailed discussion of the economics of grain drying, see the Post Harvest Management: The Economics of Grain Drying guide from Butler et al. (2018) (agecon.ca.uky.edu/files/extgraindry43.pdf), and to compare costs for different drying systems, see the Comparison of Drying Systems Calculator tool from Edwards (2014) (extension.iastate.edu/agdm/crops/html/a2-31.html).

High Temperature Self Contained Dryers

These drying systems have the highest capacity and are classified as cross-flow, counter-flow, or mixed-flow, depending on the direction of airflow relative to the grain. Cross-flow dryers are the most common and can be configured as automatic-batch or continuous flow. They can be operated to heat (dry) and cool the grain in the dryer, or they can be modified to eliminate the cooling section (typically referred to as full-heat mode). When operating in full heat mode, hot grain (120°F to 140°F) is discharged to a cooling bin at 1.0 to 1.5 pts above the desired final moisture. In the cooling bin, fans are run continuously to remove the remaining moisture by evaporative cooling. Full-heat operation can reduce drying energy use by 10% and increase capacity by 30% (MWPS-13, 2017). Allowing the hot grain to temper for several hours before cooling can help relieve stress in the kernels and allow the moisture to equalize.

Example energy costs to dry corn to 15% using a cross-flow dryer are shown in figure 3. The per bushel drying cost increases with the amount of moisture that needs to be removed. For example, it costs 16 ¢/bu more to dry grain from 25% to 15% than it does to dry grain from 20% to 15%. This represents only fuel and electric energy costs and does not include equipment or labor. To evaluate drying costs for a specific situation, see the Grain and Energy Calculator tool (uky.edu/bae/grain-and-energy-calculators)or the tools linked above. Several options are available to save energy and reduce drying costs. When operating the dryer in heat/cool mode, recovering cooling air and air from the lower portion of the heating section is a practical way to reduce drying costs by 20% to 30% (MWPS-13,2017). When operating in full-heat mode, additional energy can be saved by recovering exhaust air from the lower portion of a full-heat dryer.

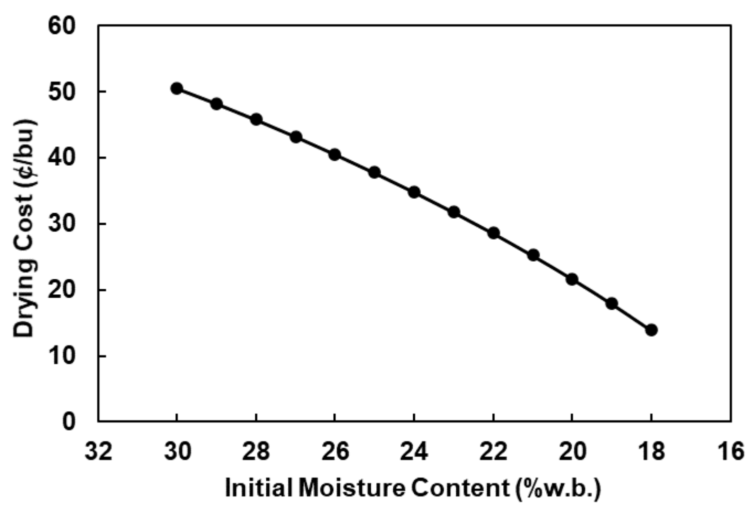


Figure 3. Drying energy costs for a high temperature cross flow dryer. Adapted from McNeill & Halich, 2019). Assumes: $2.00 gal/LP, electric energy is 5% of LP @0.12$/kWh, and drying efficiency at 10 pts removal is 2000 BTU/lb H2O.

Cross-flow dryers can operate at temperatures from 200°F to 220°F. Drying capacity increases with temperature, but so does the number of stress cracks and the amount of breakage. Kernel temperature is ultimately what leads to stress cracks/breakage and should be kept below 140°F for yellow corn and 110°F for food grade or white corn (Montross & Maier, 2000). Also, note the moisture out of the dryer should be monitored frequently to prevent over-drying.

Wet Holding

High temperature on-farm drying systems require temporary wet-holding storage bins prior to the dryer. These bins serve as a buffer between processes and allow harvest and grain delivery to progress faster than the grain can be dried. Wet holding capacity of at least 25%-50% of the peak daily intake is suggested by Maier and Bakker-Arkema (2002)

Bin Drying

Equilibrium Moisture Content

Given enough time, grain moisture will come to equilibrium with ambient conditions (temperature and relative humidity). This is referred to as equilibrium moisture content (EMC), and it can be used as an indicator of how grain moisture will fluctuate in the field during late-season harvest or when drying in a bin using natural air. If EMC, based on ambient conditions, is lower than the grain moisture, drying will occur. If EMC is higher than the current moisture, rewetting occurs (although much slower than drying). For more information on EMC, access Clemson University's Equilibrium Moisture Content (EMC) Calculator (precisionag.sites.clemson.edu/Calculators/Grain_Storage/EMC_Calc/).

Natural Air and Low Temperature Bin Drying

Drying and cooling the corn allows them to reach the safe storage conditions listed above. When drying in a bin, ambient (or slightly heated) air is blown through the grain mass. As the air moves through the grain, moisture is transferred from the grain to the air. The added moisture reduces the air's drying potential and results in a drying front several feet wide moving through the bin in the airflow direction. Generally, this results in the driest (and potentially overdried) grain near the bottom of the bin.

Drying times are dependent on airflow rate, initial moisture content, target moisture content, and EMC. Drying corn using natural air can typically occur once the grain reaches around 18%, depending on airflow (Butler et al., 2018). However, when humidity increases above 80%, a small amount of heat may need to be added (5 to 10 degrees) to reduce the EMC of the drying air below the grain's EMC. Typical airflow volumes needed for drying are between 1 to 3 cfm per bushel but will vary along with fan power requirements based on bin diameter and grain depth. Your supplier should be able to assist with recommending fans, but for more information, see this Fan Selection for Grain Bins tool (bbefans.cfans.umn.edu/) from the University of Minnesota.

When using natural air or low temperature drying, several options for fan control can be utilized. These include continuous operation, automatic control using sensors in the grain, and manual scheduling. The theme behind alternate operation strategies is to run the fans only when productive air is available, reducing electric costs. Consideration should be given to if the corn can be dried, cooled, or, if over dry, rewetted. For more reference information relating to natural air and low-temperature drying, visit these publications: The University of Arkansas' Overview of On-Farm Natural Air-Drying of Grain (uaex.uada.edu/publications/pdf/FSA-1060.pdf) and North Dakota State University's Natural Air / Low Temperature Crop Drying bulletin (ag.ndsu.edu/graindrying/documents/eb35.pdf).

Additional Tips

- Core/level the bin before drying to improve drying uniformity. Uneven surfaces and fines that accumulate in the center of the bin increase static pressure in those areas, resulting in uneven drying.
- Depth of fill impacts airflow and how fast the grain will dry. Use the fan calculator above to see how airflow changes with depth.

Storage and Quality

Storage Conditions

To reduce quality degradation and provide safe long-term storage, it is important to cool and dry the grain quickly after harvest. The desired final moisture content depends on the application. Market moisture for corn is 15.0% (or sometimes 15.5%), so if the corn is sold directly or stored for a short period (<6 mo), the moisture content should be as close to this value as possible to maximize the weight of grain sold while avoiding drying charges (see the discussion of moisture shrink). However, storage times are greatly increased at lower moisture contents, so for storage times greater than one year, a maximum moisture of 13% is recommended (MWPS-13, 2017).

At temperatures below 40°F, insect activity is greatly reduced, and when the relative humidity (RH) in the air space between kernels is below 65%, mold growth is significantly reduced. (MWPS-13, 2017) shows the relationship between corn moisture content, temperature, and relative humidity. Conditions that fall below the 65% RH line shown would generally have reduced mold growth. An estimate of the allowable storage time at various temperature and moisture combinations is shown in table 1.

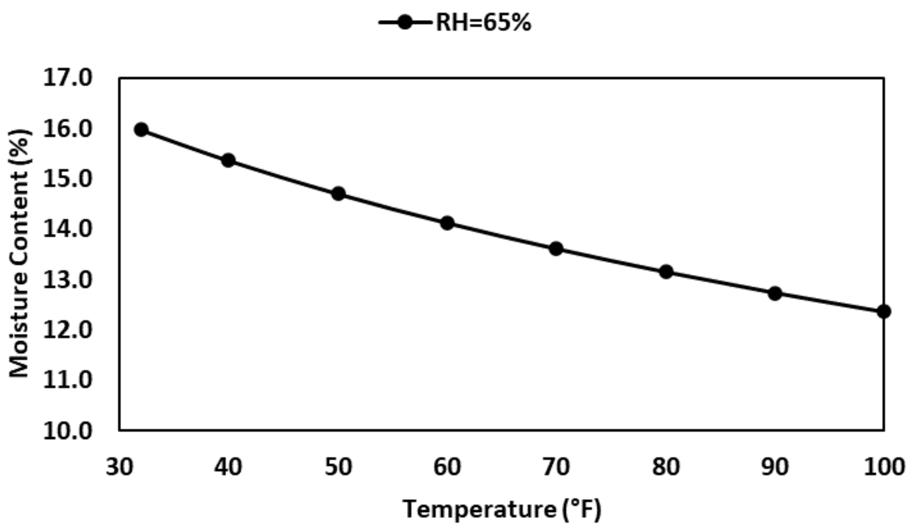


Figure 4. Equilibrium moisture content for yellow corn as a function of temperature. Based on data from ASAE Data D245.6 using the average of two models.

Table 1. Allowable Storage Time (days).*

Temperature	**Moisture Content**							
°F	**16%**	**18%**	**20%**	**22%**	**24%**	**26%**	**28%**	**30%**
35	1144	437	216	128	86	63	50	30
40	763	291	144	85	57	42	33	21
50	339	130	64	38	26	19	15	9
60	151	58	29	17	11	8	7	4
70	85	32	16	10	7	5	4	3
80	47	18	9	6	4	3	3	2

Source: *From ASABE D535 (2005). Based on 0.5% dry matter loss, which corresponds approximately one grade number loss. These effects are cumulative, four days at 26%, and 60°F would use one-half of the allowable storage time.

Aeration

Aeration is a key factor to storing grain, and it is important to remove the field heat quickly after harvest. Generally, keeping grain within 10° to 15° of ambient conditions and running air frequently throughout the storage period will help counteract moisture migration.

Monitoring

Monitoring grain condition can simply be smelling grain when first activating fans and watching for crusting or as complex as using sensors to monitor grain and automatically control fans. One of the cheapest ways to monitor grain condition is with temperature cables, which allow for the detection of temperature increases indicating insect, mold, or spoilage problems. These can be combined with RH sensors to estimate moisture content.

Safety:

In 2019 grain entrapment led to 23 fatalities (Cheng et al., 2020). Know the dangers associated with entering bins, grain handling equipment, and dust exposure. For more information on safety around grain facilities, see Clemson University's Grain Facility Safety Fact Sheet (blogs.clemson.edu/agsafety/2021/09/23/grain-bin-safety-fact-sheet/).

Corn Grading

Corn grades are determined based on test weight, the percentage of damaged kernels (heat damage and total), and broken corn and foreign material (BCFM). The grade requirements from the Federal Grain Inspection service are given in table 2 below.

Table 2. Corn grade requirements (USDA, 2013).

Grade	Minimum Limits of	Maximum Limits of		
	Test Weight per bushel (lbs)	**Heat damaged kernels (%)**	**Damaged kernels (%)**	**Broken corn and foreign material (%)**
U.S. No. 1	56	0.1	3.0	2.0
U.S. No. 2	54	0.2	5.0	3.0
U.S. No. 3	52	0.5	7.0	4.0
U.S. No. 4	49	1.0	10.0	5.0
U.S. No. 5	46	3.0	15.0	7.0

U.S. Sample Grade is corn that

1. does not meet the requirements for grades U.S. No. 1, 2, 3, 4, or 5; or
2. contains stones that have an aggregate weight in excess of 0.1 percent of the sample weight, 2 or more pieces of glass, 3 or more crotalaria seeds (Crotalaria spp.), 2 or more castor beans (Ricinus communis L.), 4 or more particles of an unknown foreign substance(s) or a commonly recognized harmful or toxic substance(s), 8 or more cockleburs (Xanthium spp.) or similar seeds singly or in combination, or animal filth in excess of 0.20 percent in 1,000 grams; or Contain 11 or more animal filth, castor beans, crotalaria seeds, glass, stones, or unknown foreign substance(s) in any combination; or
3. has a musty, sour, or commercially objectionable foreign odor; or
4. is heating or otherwise of distinctly low quality.

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Corn Harvest

Michael Plumblee, PhD

Corn harvest date should be determined by crop maturity. Most kernels accumulate dry matter until moisture decreases to about 30-35% percent. Ideally, corn should be harvestedbetween 15 and 18% moisture do reduce drying costs. However, in order to reduce mechanical damage during harvest, it is recommended to harvest corn at about 22% (for large corn acreage, corn harvest should begin at 25%). Higher kernel damage usually occurs below and above this moisture content. High moisture of 30% and above would also result in poor kernel separation from the cob. Harvesting at 15% and lower results in high levels of cracked and broken kernels. Preharvest losses at low moisture content will depend on insect damage, lodging, ear drop, and reductions to kernel weight. It is recommended to start harvesting fields with potential losses.

If corn has been grown under stress conditions (moisture, insect stress, etc.) it may be contaminated by aflatoxins. Aflatoxin may also increase due to delayed harvest. Therefore, harvest and drying of aflatoxin contaminated corn is recommended as early as possible to reduce aflatoxin increases. Generally, corn should be dried to 13% moisture or less if it is to be stored for several months.

During harvest, combine cylinder speed and cylinder-concave clearance should be properly adjusted to minimize kernel damage and loss. Damage increases with increasing cylinder speed. The adjustments should be made after harvesting the small area. Also, count the kernels left on the ground. The loss of two kernels per square foot equals approximately the loss of one bushel of corn per acre, and therefore a loss in profit. High combine speeds can result in significant yield losses. When the ideal moisture is obtained, harvest should begin as soon as possible to avoid lodging problems. Small increases in lodging will result in substantial decreases in grain yield. Losses due to lodging can be minimized by slowing down the speed of combine and harvesting as soon as the grain moisture is optimum for harvest.

In some situations (insurance purposes, calculate storage needs or loss due to lodging, etc.) there is a need to estimate the grain yield of corn prior to harvest. The most widely method to estimate corn yield is called the Yield Component Method which was developed at the University of Illinois.

Count the number of harvestable ears in a row length equivalent of 1/1000 acre (see table 2 in chapter on Plant Populations).

-Count the number of kernel rows per ear on every fifth ear. Calculate the average.

-Count the number of kernels per row on each of the same ears, but do not count kernels on either the butt or tip that are less than half-size. Calculate the average.

Yield (Bu/acre) = [(number of ears) x (average number of rows) x (average number of kernels/row)] / 90.

Farm-Stored Corn Insect Management

Michael Plumblee, PhD

Farm-stored grain quality is at its peak when it is loaded into the bin for storage. After loading the best you can do is to try to maintain this level of quality. Therefore, it is important to maximize the quality of your corn prior to storage. At harvest make sure that your corn is dry enough for storage. The longer it will be stored the drier it will need to be. Adjust your harvesting equipment to minimize breaking kernels.

Only load corn into a thoroughly cleaned, empty bin. Don't load grains on top of older grains! When loading corn into the storage bin make sure your loading auger and mechanical spreaders in the bin are in good condition and will not damage the corn when loading. Run the auger at full capacity (run at a slow speed) to minimize breaking the kernels. The cleaner and drier the corn going into the bin, the better.

Do not overfill the bin. Level the corn in the bin as soon as it is filled and immediately begin aeration to cool the corn. Poorly controlled temperatures are the most important cause of stored all stored grains, including corn, going out of condition. Get the corn cooled down to the outside air temperature as soon as possible. Keep the bin temperature no more than 10°F to 15°F of the outside temperature during storage. Ideally the temperature should be maintained at 35°F to 40°F.

Proper harvest, loading and storage of corn is critical for managing potential insect infestations. Proper storage management provides the best control for the cost. It is important in any insect management system to not rely solely on insecticides. This is particularly true for stored grains; there are few insecticides registered in this use area, and fewer still for the individual stored commodities. Also, insecticide resistance has already made at least malathion essentially useless in many stored grains environments. Malathion is not recommended on stored corn (see notes below.)

Insects will stop feeding and reproduction at temperatures below about 50°F. Because corn is harvested when temperatures can still be fairly warm, immediate aeration to get harvested corn to ambient temperature is critical to help prevent insect infestations. Even corn held at the moisture levels that will not allow mold growth, properly cooled and dried corn can still be infested by at least Indian meal moth. This moth infests the grain from the top of the bin. The adult moth can be controlled using DDVP (dicholorvos) resin strips in the headspace of the bin, using 1 strip per 1,000 cubic feet (controls adults only). Change strips at least monthly in warm weather. You may alternatively, or also, use a Bacillus thuringiensis (Bt) product (for example, Dipel) as a top dressing (grain surface treatment) applied immediately after bin loading to control larvae. Diatomaceous earth products may also be used here but monthly treatments will be needed.

Properly loaded corn should be stored in thoroughly cleaned and surface-treated bins (bin surface treatment). A grain protectant (Atellic only) can also be used when loading the corn. However, even if both of these procedures are followed, you must still regularly check the corn: check storage temperature and moisture levels and for flying moths, and surface crusting.

These recommendations are based on active ingredients. These recommendations are not a substitute for carefully reading the pesticide label. Other registered products not mentioned here may be as effective.

Pest or Application Type	Active Ingredient(s) (Products)	Rates *Read and follow the label instructions.*	Site(s)	Re-entry Interval (REI)	Comment (*and see Notes after this table*)
Bin Repair and Sanitation			Interior *and* exterior of grain storage bins prior to loading.		*Sanitation is critical.* Repair (fix and fill holes, cracks) and *thoroughly* clean bins before loading with grain. Most pesticide product labels note sanitation as a pre-treatment procedure!
Empty Bin Residual Sprays (Bin interior surface treatment)	beta- Cyfluthrin (Tempo 20WP, Tempo 2.0, Tempo SC Ultra) Chlorpyrifos-methyl + deltamethrin (Storcide II) Diatomaceous earth (DE) (Insecto)	Spray empty, cleaned bin to run-off with low pressure sprayer ("garden sprayer") (less than 50 psi) with flat fan nozzle tip. One gal. of spray covers 750–1,000 sq. ft.	Empty bin only		Do not treat any grain with Tempo. Do not store soybeans in bins treated with Tempo.
	Chlorpyrifos-methyl + deltamethrin (Storcide II) Diatomaceous earth (DE) (Insecto)	Bin surfaces: 1.8 fl. ozs. for 1.0 gal. of spray solution applied 1 lb./1,000 sq.ft. of surface	Empty bins	When sprays have dried	Must be applied from the outside only with downward spray with automated equipment. Applied through aeration fan. May meet organic requirements.
Empty Bin Fumigation	Aluminum phosphide - phostoxin gas (Phostoxin; Phosfume; Weevil-cide; pellets/tablets)	Follow label, applicator manual instructions exactly	Insects which infest stored crops	Follow label, applicator manual procedure exactly	Fumigate empty bin after thorough bin clean-out and interior residual treatment if necessary. Extremely toxic RUP with strict application procedures. No residual control.

Pest or Application Type	Active Ingredient(s) (Products)	Rates ***Read and follow the label instructions.***	Site(s)	Re-entry Interval (REI)	Comments (***and see Notes after this table***)
Grain Protectants (Direct grain / Admixture treatment)	Pirimiphos- methyl (Actellic 5E) s-methoprene (Diacon II) Diatomaceous earth (DE) (e.g. Insecto)	9.2 – 12.3 fl.ozs. (6 – 8 ppm) in 5 gal. water for 1,071 bu. (30 tons) 8 to 14 fl. ozs. / 5 gal. water/1,000 bu. grain – rate varies with kind of grain. 1- 2 lbs./ton of grain to top 2-3 ft. of grain.	Corn, grain sorghum only Wheat, corn, sorghum, (milo), oats, barley, peanuts	When sprays have dried	One (1) treatment per load of grain only. Use calibrated applicator Controls larvae only May meet organic requirements. Treatment varies with time of harvest, anticipated storage time.
Grain Top-Dressing (Stored grain surface treatment, especially for Indian-meal moth larvae-Applications are to leveled grain)	Pirimiphos- methyl (Actellic 5E) (s)-methoprene (Diacon II) Bacillus thuringiensis (Bt) (Biobit HP, Dipel DF, Javelin WG) Diatomaceous earth (DE) (Insecto)	3 fl. ozs./2 gal. water/1,000 sq.ft. (3.0 ppm) 0.2 teaspoons or 0.1ml./1,000 sq.ft. 1 lb./10-20 gal. water/1,000 sq.ft.; see label 4 lbs./1,000 sq.ft.	Corn, grain sorghum only	When sprays have dried	Clear webbing, break-up crusting. Apply 1 gal. and rake into top 4 inches of grain; apply second gal. to raked surface. Use only enough water to give coverage – Do not flood grain surface. Controls only larvae. Apply to surface and rake into top 4 inches of grain; see label instructions. Controls only larvae. May meet organic requirements. Especially for Indian-meal moth. Apply at monthly intervals. May meet organic requirements.
Empty Bin Fumigation	Aluminum phosphide - phostoxin gas (Phostoxin; Phosfume; Weevil-cide; pellets/tablets) Sulfuryl fluoride gas (Profume)	Follow label, applicator manual instructions exactly 	Insects which infest stored crops Insects which infest stored crops	Fumigant detection, post-treat ventilation. Follow label, product applicator manual procedures for all products.	Extremely toxic RUP. Strict application procedures including placarding, fumigant detection, other required measures. Extremely toxic RUP. Strict application procedures fumigant detection, other measures.

Product use sites - Read the label carefully! Use sites vary widely from product to product. Some products may only be used to treat grain storage bin surfaces and not grain; few products may be used for both applications. Grains that may be treated vary with product.

Product rates - Read product labels carefully! Rates vary with formulation of product used, use site/crop being stored, anticipated storage time, and pest species, and pest development stage. Some products may only have one (1) application made to a load. Period of control can vary with pest insect species and is shortest at the lowest rates.

Pests controlled - Read the label. Not all products control all pests, especially at the lowest rates. Bacillus thuringiensis (Bt) products control only caterpillars (moth larvae) and not beetle grubs. Control will be slow.

Insecto (a diatomaceous earth product) - "Insecto Control Plan" calls for dusting the empty bin, treating the bottom 2 feet of grain, treating the top 2 feet of grain, top-dressing leveled grain with this product at labeled rates. Inspect grain bi-weekly. Organic Materials Review Institute (OMRI) Listed.

Actellic 5E - only 1 application method is allowed per load.

Diacon II (s-methoprene) - Insect growth regulator controlling larvae only. Lowest rates give control for less than 6 months. May be applied with water or food-grade oil or soybean oil, except for peanuts. Product may be applied with an insecticide controlling adults. Read the label(s).

Fumigants are the most effective way of controlling insect infestations in stored grain; however, fumigants provide no residual control. Fumigants are Restricted Use Pesticides (RUPs) and may be purchased and used only by licensed applicators. These pesticides are Danger, Danger/Poison labeled because of acute toxicity. Fumigants have strict application requirements via the label and applicator manual. Product-specific training and/or product company supervision may be required, especially for liquid and gas formulations.

Malathion is not recommended because of pest resistance and tolerance issues in international markets.

Grain bin surface areas and capacities.

Bin Diameter (Feet)	Grain Surface Area or Bin Floor Area (Square Feet)	Approximate Surface Area of Empty Bin (Square Feet)	Bushels per Foot of Bin Height	Approximate Bin Headspace (Volume of a cone - Cubic Feet)
15	177	(Bin Height x 47) + 354	141	59 x cone height
18	254	(Height x 57) + 508	204	85 x cone height
21	346	(Height x 66) + 692	277	115 x cone height
24	452	(Height x 75) + 900	362	151 x cone height
27	573	(Height x 85) + 1146	458	191 x cone height
30	707	(Height x 92) + 1400	566	236 x cone height
33	855	(Height x 104) + 1710	685	285 x cone height
36	1,018	(Height x 113) + 2000	815	339 x cone height
42	1,385	(Height x 132) + 2770	1109	462 x cone height
48	1,810	(Height x 151) + 3,620	1448	603 x cone height
54	2,290	(Height x 170) + 4580	1833	763 x cone height
60	2,827	(Height x 188) + 5654	2263	942 x cone height

Contributing Authors

Bhupinder S. Farmaha, Assistant Professor, Extension Soil Fertility Specialist
Department of Plant and Environmental Sciences
Clemson University
Edisto Research and Education Center
64 Research Rd, Blackville, SC 29817
E-mail: bfarmah@clemson.edu

Francis Reay-Jones, Professor, Corn Entomologist
Department of Plant and Environmental Sciences
Clemson University
Pee Dee Research and Education Center
2200 Pocket Road, Florence, SC 29506
E-mail: freayjo@clemson.edu

Michael W. Marshall, Assistant Professor, Extension Weed Scientist
Department of Plant and Environmental Sciences
Clemson University
Edisto Research and Education Center
64 Research Road, Blackville, SC 29817
E-mail: marsha3@clemson.edu

Scott Mickey, Farm Business Consultant, Agribusiness Program Team
Clemson University
Sandhill Research and Education Center
900 Clemson Rd, Columbia, SC 29229
E-mail: smickey@clemson.edu

John D. Mueller, Professor, Extension Row Crop Nematologist/Pathologist
Department of Plant and Environmental Sciences
Clemson University
Edisto Research and Education Center
64 Research Rd., Blackville, SC 29817
E-mail: jmllr@clemson.edu

Michael T. Plumblee, Assistant Professor, Extension Corn and Soybean Specialist
Department of Plant and Environmental Sciences
Clemson University
Edisto Research and Education Center
64 Research Rd, Blackville, SC 29817
E-mail: mplumbl@clemson.edu

Nathan B. Smith, Professor, Extension Agribusiness, Department of Agricultural Sciences
Clemson University
Sandhill Research and Education Center
900 Clemson Rd, Columbia, SC 29229
E-mail: nathan5@clemson.edu

Aaron P. Turner, Assistant Professor, Grain Handling and Storage, Department of Agricultural Sciences
Clemson University
250 McAdams Hall, Clemson, SC 29634
E-mail: apturne@clemson.edu

Contents of this production guide are derived from these other contributing authors: Robert Bellinger, PhD; James Camberato, PhD; Hamid Farahani, PhD; Bruce Fortnum, PhD; James Frederick, PhD; and Pawel Wiatrak, PhD.
