Peanut Production Guide

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UNIVERSITY OF GEORGIA
EXTENSION

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INTRO

Chapter 1

Introduction

Scott Monfort

Peanut (*Arachis hypogaea* L.) is a four-foliate legume with a prominent taproot, yellow sessile flowers and subterranean fruit (Shokes and Melouk, 1995). It is native to South America. Its cultivation spread from South America to other areas of the New World, Europe, Africa, Asia and the Pacific islands. Peanut was probably introduced into the southern United States during the early period of exploration, although the exact time and location of the introduction has not been well documented. There are 4 distinct market type peanuts grown commercially today in the United States. They are the Runner, Spanish, Virginia, and Valencia types (Figure 1). Georgia accounts for 40 to 55 percent of the peanut production in the United States, with recent plantings averaging 500,000 to over 800,000 acres (Figure 2) of runner type peanuts. Peanut yield per acre in Georgia has consistently been among the highest in the United States. Most of the commercial peanut production in Georgia is in the southern third of the state (south of a line extending from Columbus to Augusta). Historically, the heaviest concentration of peanut production is in southwest Georgia; however, peanut acreage has increased dramatically in southeast Georgia in the last 10 years (Figure 3). The southern region of Georgia is characterized as having loose friable sandy soils which are optimum for peanut production.

Figure 1. Illustration of the market type peanut grown in the United States. Image from Texaspeanutboard.com

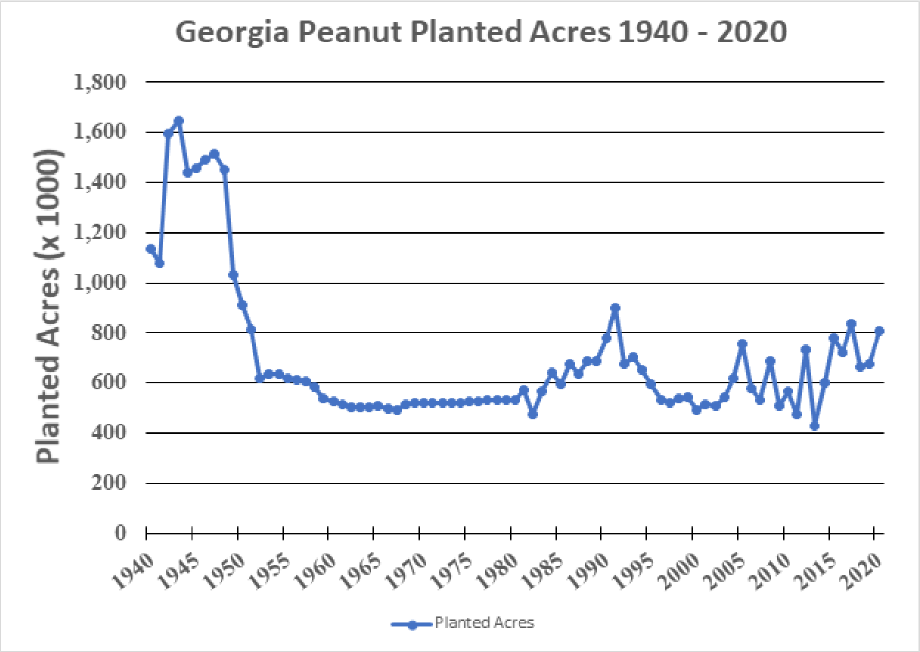


*Figure 2. Peanut Planted Acres from 1940 to 2020. *Data S ource: USDA,National Agricultural Statistical Service. http://nass.usda.gov/*

These soils allow for efficient fruit set and harvesting. Much of the successful peanut production is due to these soils, in addition to climate, technology and available irrigation. The Georgia peanut belt receives an average of 42 to 45 inches of rainfall per year. Recent surveys indicate that 45 to 55 percent of the peanut acreage is irrigated. The frost free period ranges from 230 to 260 days per year across the Georgia peanut belt. These factors have allowed Georgia peanut yields to be among the highest. In addition, they make it feasible for peanuts to be planted over an extended period of time (Mid-April through early July).

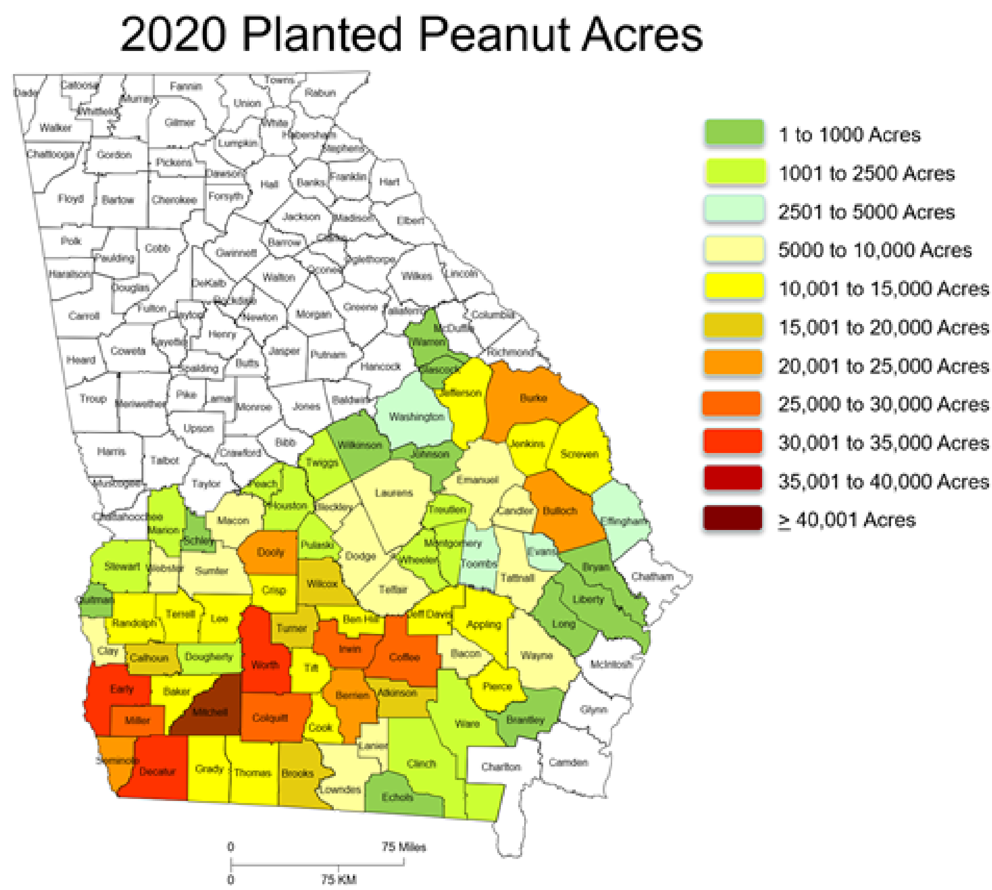


*Figure 3. Peanut Planted Acres by County. *Data source USDA, National Agricultural Statistical Service. http://nass.usda.gov*

Average peanut yields in Georgia have continued to increase over the years since 1940 (Figure 4). During the 1940's through mid- 1960s peanut yields rarely exceeded 1500 lbs/A. After the 'Florunner' (Norden et al., 1969) cultivar was released and planted by Georgia peanut farmers, peanut yields increased significantly again in the 1970s crossing the 3000 lbs per acre mark. Another important factor that led to these yield increases was due in part to the development and use of chlorothalonil fungicide in Georgia peanut production. This fungicide provided excellent control of leafspot diseases, allowing peanuts to achieve optimum maturity without excessive harvest losses. Although some growers were making record yields in the late 1970s to mid-2000s approaching the 4000 lbs per acre, the state average remained at the 2000 to 3000 lbs per acre level. This was largely due to drought conditions that plagued

Georgia growers from 1986 to 2001 causing significant yield losses. Yield was also negatively impacted by Tomato Spotted Wilt Virus (TSWV) in the 1990's. Yield began trending back in the up in the early to mid-2000s as a result of more optimum growing conditions and the introduction of Georgia Green (Branch, 1996). Georgia Green had improved levels of TSWV resistance and a higher yield potential than Florunner. This period also saw implementation of the TSWV Risk Index which provided further protection against yield losses (Culbreath et al., 1999). Beginning in 2008, growers once again observed a significant yield increase across the state as growing conditions improved and with the introduction of Georgia-06G (Branch, 2007), a high yielding, TSWV resistant cultivar was introduced.

In recent years, peanuts have become one of the few row crops that consistently offers a significant profit margin. Because of this, farmers willingly increased their inputs into peanut production in order to maximize yield and quality. However, even with the considerable profit margins there is a tendency to increase production costs beyond the point where they are economically justified. In many cases, the increased cost of production has reduced the actual profit margin (or the maximum economic yield). Attempts to reduce production costs can unintentionally reduce or eliminate many basic production practices. While production costs are reduced, however, so are yield and quality. The end result is still reduced profit margins. There is obviously a point between these two extremes where production inputs are held at conservative levels with optimum yields and quality being achieved. The end result is maximum economic yield. The only way that maximum economic yield can be achieved is to carefully evaluate every practice involved in peanut production, from crop rotation to pesticide usage to peanut drying, and all practices in between. These must be integrated into an efficient and well-coordinated peanut production strategy that reflects the uniqueness of each farm's operation.

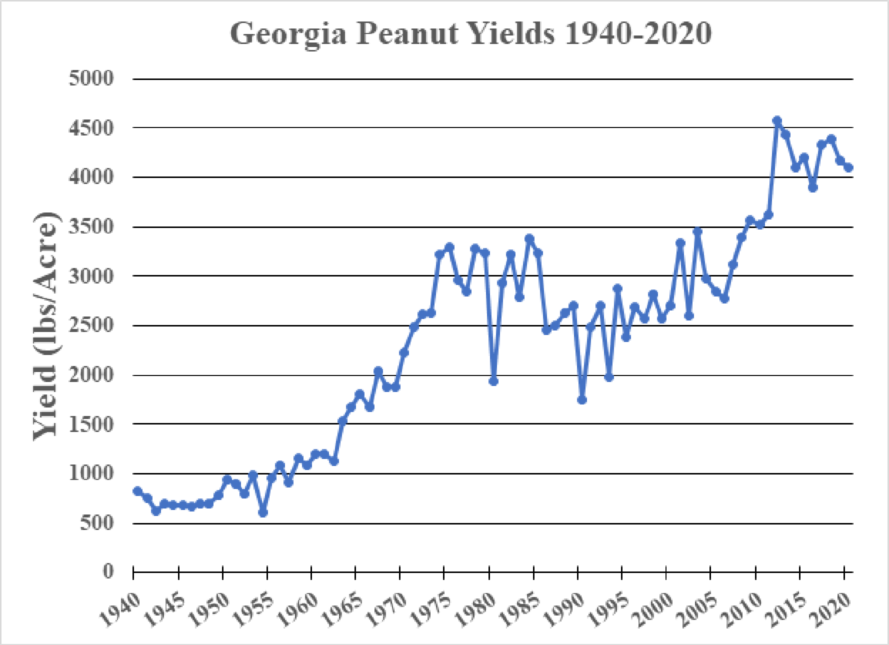


*Figure 4. Peanut Yields (lbs/acre) from 1940 to 2020. *Data Source: USDA, National Agricultural Statistical Service. http://nass.usda.gov/*

WEATHER AND CLIMATE

Chapter 2
Weather and Climate Information for Peanut Production

Pam Knox

One of the single biggest factors in the success or failure of the peanut crop is the weather that the crop experiences over its lifetime. In any given year, the weather is affected by the overall climate pattern that is occurring. This chapter will provide basic information on sources of weather tools as well as provide guidance on the major cli-mate pattern that affects the Southeast, specifically the El Niño Southern Oscillation (ENSO).

Weather Data

There are many commercial sources of weather data and forecasts available that provide useful information to peanut producers. There is also useful information at the University of Georgia's Weather Network. On this web site, peanut weather information can be accessed by going to the menu on the top right and picking out "Crop Weather" and then "Peanuts" to get either soil temperature or precipitation. This information can also be accessed for individual locations by picking out the station of interest and looking at the current conditions, which include air temperature, wind speed and di-rection, precipitation, humidity, and a variety of soil temperature and moisture measurements. The site also includes a degree day calculator which allows the user to input a base temperature and planting date to help track plant development by degree days.

Similar information is available through the National Weather Service (NWS) cooperative observer measurements. The data are available

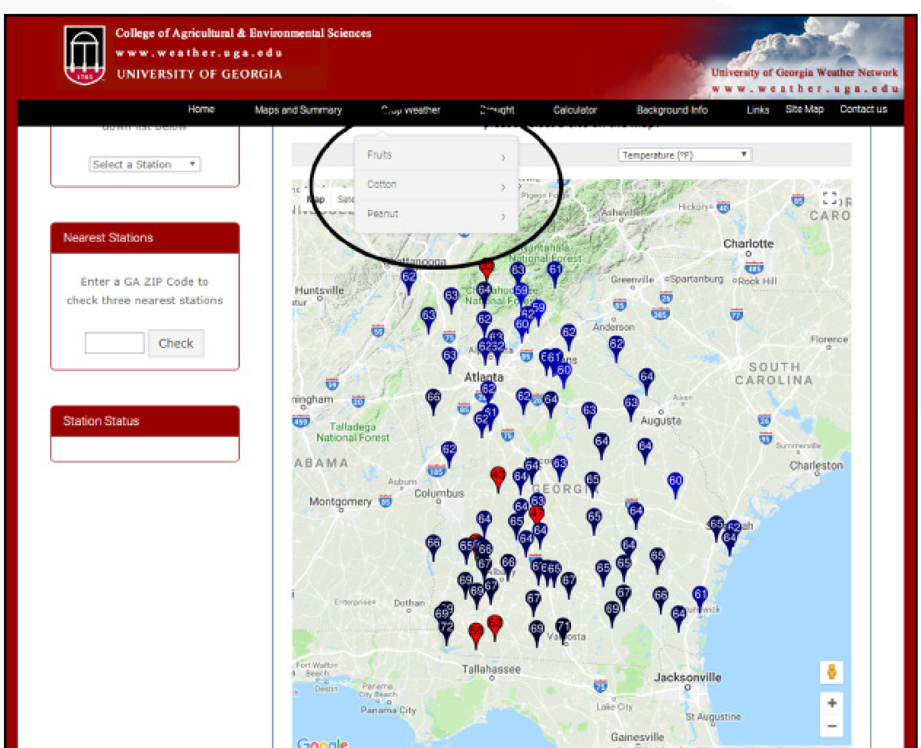


Figure 1. Georgia Weather Network website with peanut weather information indicated on top menu.

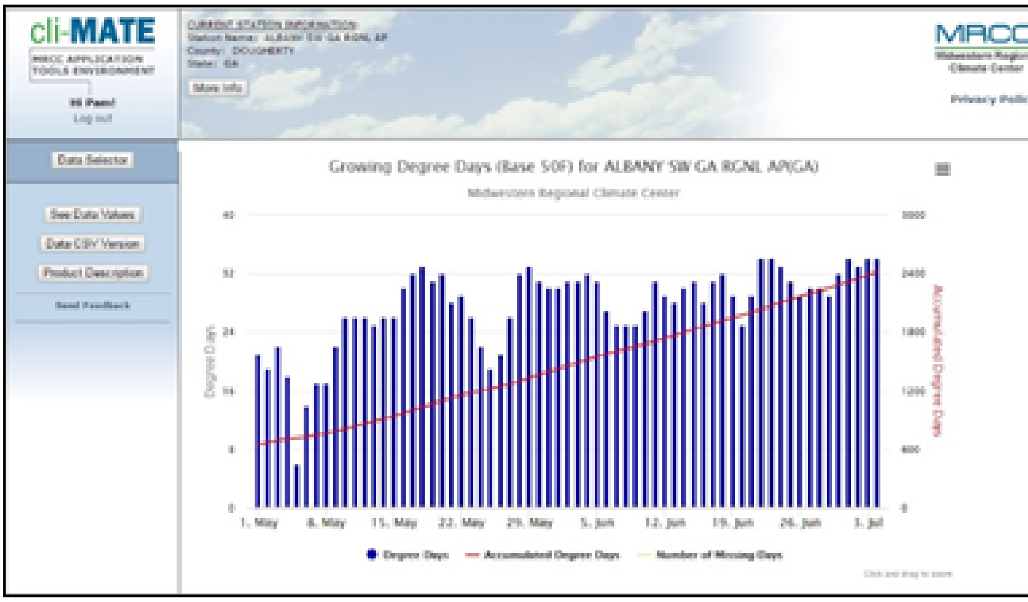


Figure 2. Growing degree day chart for Albany GA from the MRCC's cli-MATE website.

from a variety of sources: an easy one to use is the Midwestern Regional Climate Center's (MRCC's) site, which requires a free user ID. The Georgia Forestry Commission also has a few weather sites, although that site does not provide tools for calculating degree days or other quantities.

Additional rainfall information can be obtained from the National Weather Service's interactive graphical precipitation map. This web site provides radar-based precipitation estimates that may be more represen-tative of local conditions than the nearest UGA station, which might be located quite a distance away. This web site also allows you to look back in time over the last 7, 14, or 30 days or up to 180 days in time to get a sense of the rainfall deficit or surplus over the chosen time period.

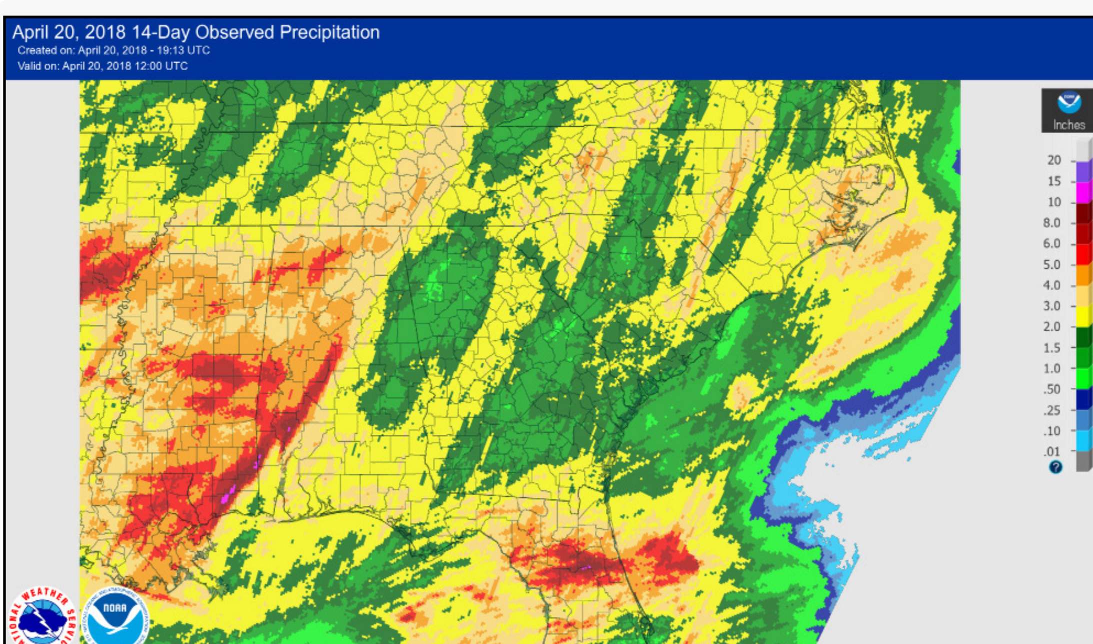


Figure 3. Radar-estimated rainfall from the National Weather Service website.

Climate Data

While weather data are useful for pinpointing current conditions and helping determine short-term management decisions such as when to spray agricultural treatments, climate information can help producers determine longer-term trends in weather patterns as well as provide an idea of expected conditions for the upcoming growing season.

Longer-term weather and climate forecasts are available from [NOAA's Climate Prediction Center] for periods ranging from 6-10 days to several months ahead. The outlooks provide information on generally expected temperature and precipitation pat-terns across the US based on long-range forecast models. One-month and 3-month outlooks are also available on the main website. Forecasts out farther into the future (as much as a year ahead) are available [here].

Predictions from the CPC are probabilistic and show the chance of above, near, or below normal conditions. If there is no statistical indication that one of these conditions is favored, the maps will show "EC" for equal chances of occurrence. This means that the period of forecast has a 33% chance of near normal along with 33% chances of both above and below normal. If the map shows a 40% chance of above normal precipitation, then there is still a 33% chance of near normal and a 27% chance of below normal conditions, since statistics can only predict in terms of which conditions are most likely, not give a definitive forecast.

While there are a number of different climate patterns that affect weather around the Southeast, by

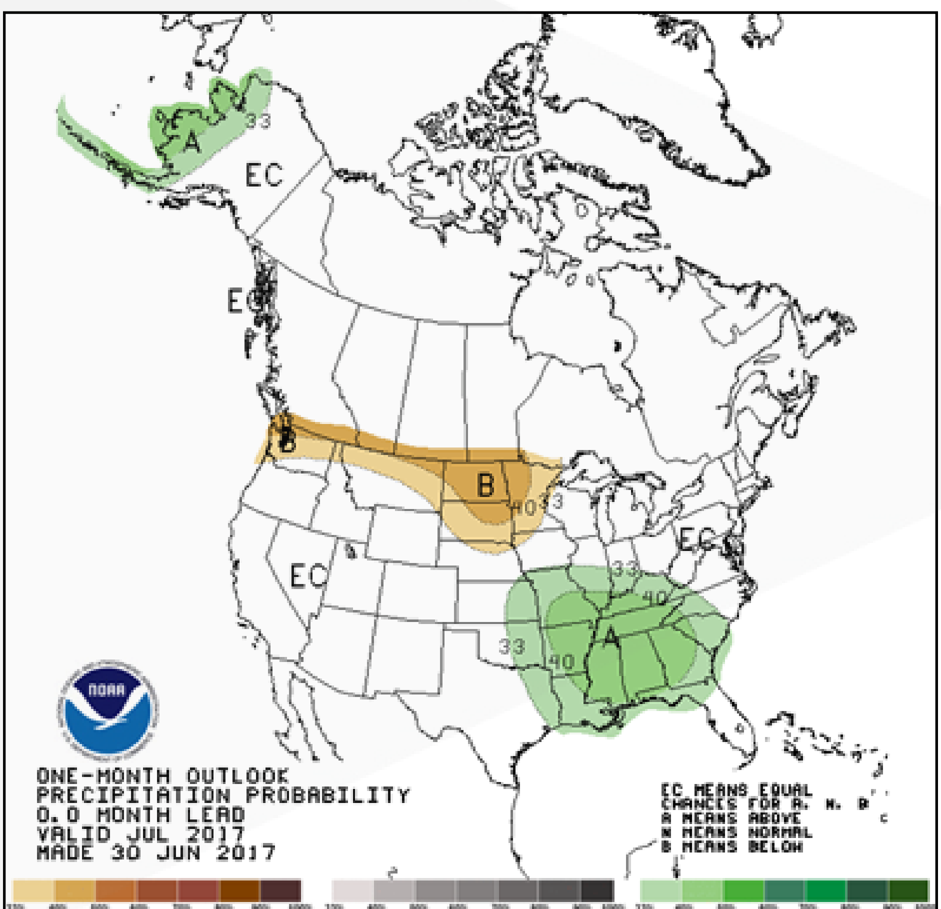


Figure 4. One-month precipitation probability from the Climate Prediction Center.

far the most useful for climate prediction in the range of months to a year is the El Niño Southern Oscillation. This oscillation is a semi-regular "see-saw" of atmospheric pressure associated with ocean temperatures in the Eastern Pacific Ocean (EPO).

When the sea surface temperatures in the EPO are warmer than normal, the pattern is called an El Niño because it is usually strongest right around Christmas and has been associated in the Spanish-speaking South American countries near the EPO with the coming of the Christ Child, or El Niño. The warm water helps produce rising air motion and thunderstorms above the warm water, which then affects the atmospheric circulation in a wide area around this region. ENSO affects the US by moving the position of the subtropical jet stream, an area of

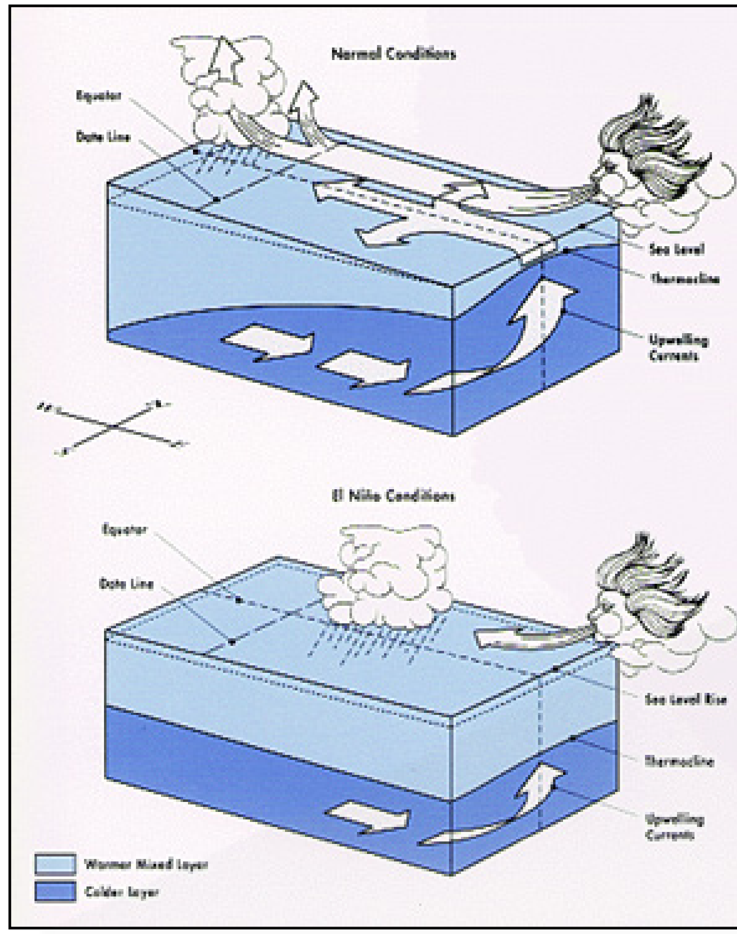


Figure 5. Atmospheric and oceanic conditions in the Eastern Pacific Ocean in normal (also called neutral) conditions and in El Niño conditions. (Source: National Climatic Data Center)

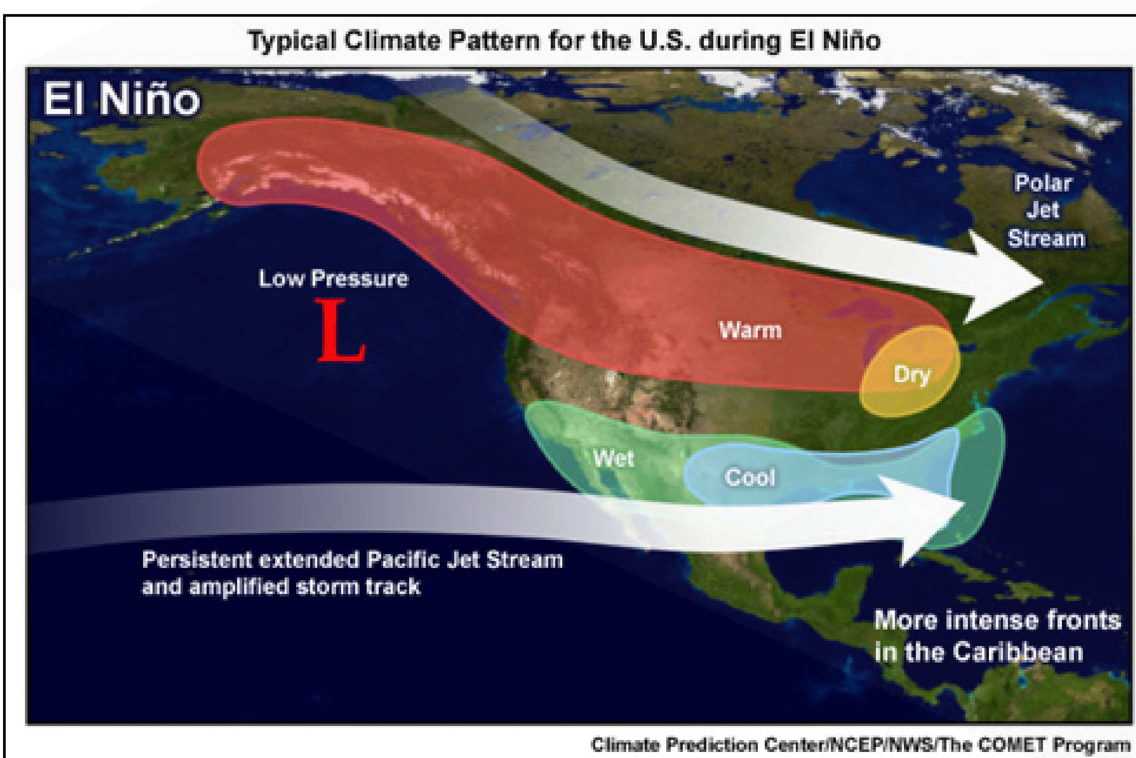


Figure 6. Typical wintertime climate patterns in an El Niño. (Source: CPC)

strong winds around the height of long-distance airplane flights. These powerful winds direct the movement of low pressure areas and associated rain systems. In El Niño winters, the Southeastern parts of the US are usually cooler and wetter than normal due to the presence of more low pressure and rain clouds in the region. In general, El Niño ef-fects are less noticeable in other seasons, although in El Niño years there are usually less hurricanes than usual because the subtropical jet makes it hard for tropical storms to develop. This can affect the amount of summertime rain as well as how dry conditions are in the fall later in the growing season and during harvest.

When the sea surface temperatures in the EPO are colder than usual, then it is called La Niña. The weather patterns in La Niña are generally just the opposite of El Niño years, and winters tend to be warmer and drier than usual because the storm systems are shifted to the north over the Ohio River valley, leaving drier and sunnier conditions in the south. In some years, neither pattern is present—those are called "neutral" years and their weather patterns are in-between what is seen in El Niño and La Niña years. It is notable that in neutral years there tends to be more wide swings in temperature from hot to cold and back again, and late spring frosts are more likely in neutral conditions than in either El Niño or La Niña years.

Because the signal of the ENSO is so strong in the Southeast, it can be used to identify some statistical trends in peanut yields. The AgroClimate website developed at the University of Florida uses differ-ences between ENSO phases to determine statisti-cal differences in yields in years with different ENSO conditions. The AgroClimate web site has a variety of tools to help determine planting dates and yield probabilities under the "Tools" portion of the top menu on that site.
More information about ENSO, including what the

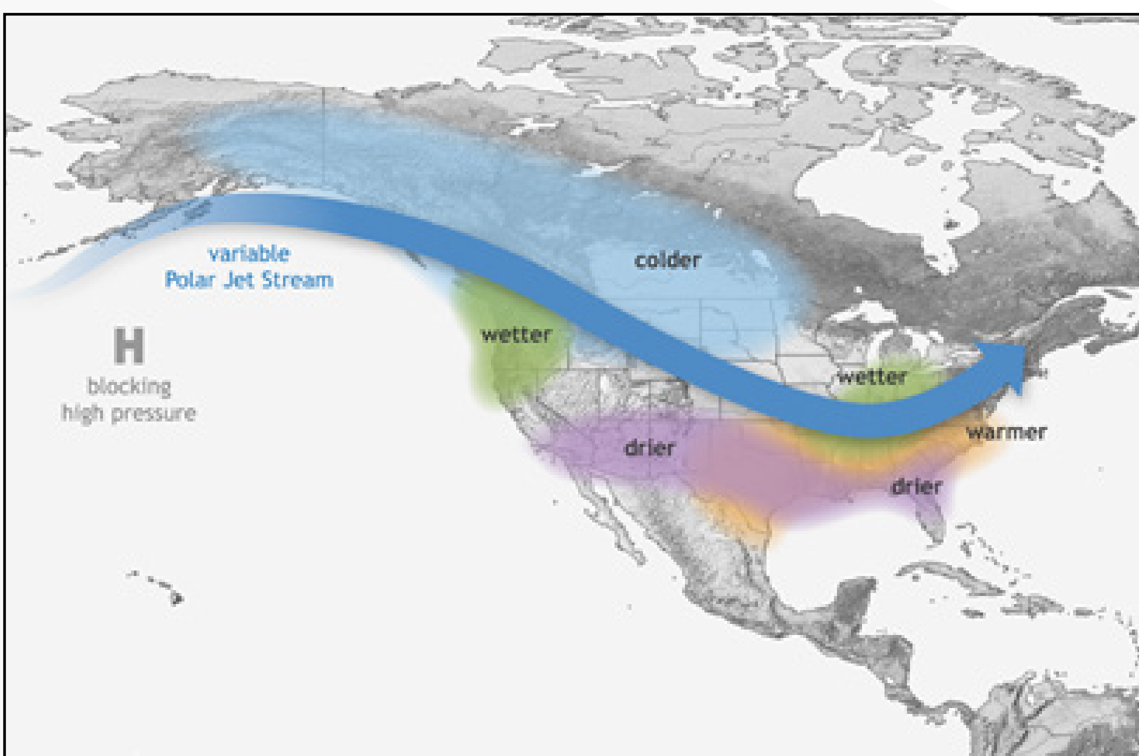


Figure 7. Typical wintertime climate conditions in a La Niña. Source: NOAA Climate.gov

current phase is, can be found at the links below:

- National Centers for Environmental Information
- NOAA's Climate Prediction Center
- International Research Institute for Climate and Society (IRI)

CROP ROTATIONS

Chapter 3

Peanut Crop Rotations

R. Scott Tubbs and W. Scott Monfort

Row crop acreage for the four primary row crops in Georgia was relatively stable until around 2005, but has been turbulent since that time, especially for cotton and peanut (Figure 1). In the last decade, peanut has recorded its largest acreage in over 25 years (835,000 in 2017) and the smallest acreage in almost a century (430,000 in 2013). The fluctuations in peanut acreage have been extreme, such as a 55% increase from 2011 to 2012, followed immediately by a 41% decrease the very next year, only to rebound by 40% in 2014, and an additional 32% increase into 2015. Acreage was more consistent from 2015-2020, but consistently greater (averaging 20% more) compared to the 20 year average (628,000 acres). This is a strain on the ability to maintain recommended crop rotations for peanut.

When evaluating effective crop rotation strategies for peanut, it is important to consider more than just peanut acreage in the calculation. Since soybean is also a legume and is host to some similar pest problems, it is not considered a good rotation crop with peanut. Therefore, when assessing land availability for peanut rotation, it is more appropriate to view acreage as combined leguminous (peanut + soybean) and non-leguminous (cotton + corn) crops. When observed in this manner, a trend is seen where the acreage of the two categories are negatively correlated with each other (Figure 2). When acreage of legumes increases, it is at the expense of non-leguminous acres, and vice-versa. Total acreage planted to the four major row crops remains relatively consistent from year to year.

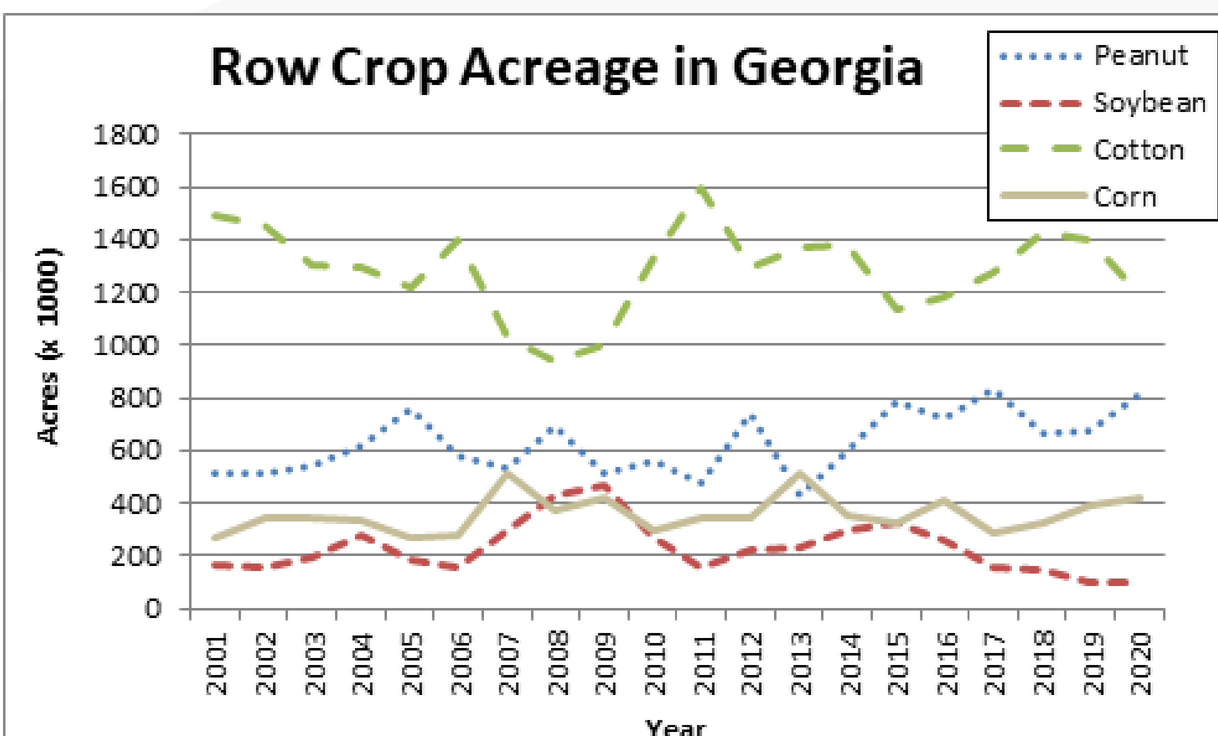


Figure 1. Planted acreage in Georgia for major row crops, 2001-2020.

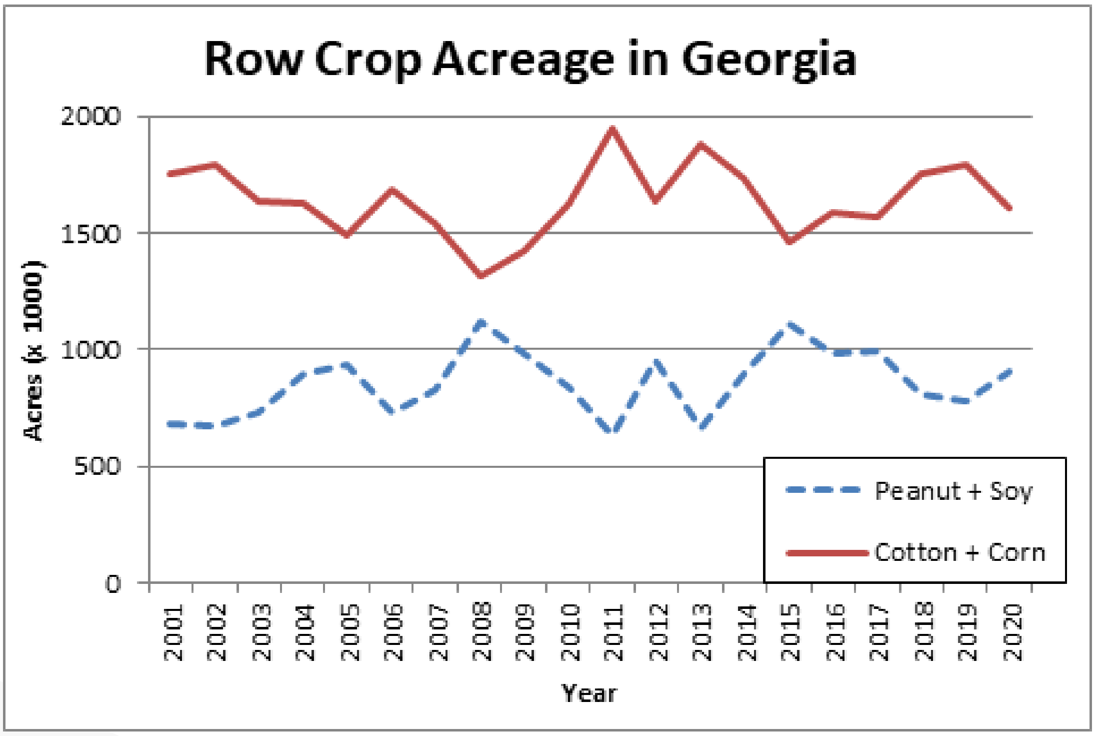


Figure 2. Planted acreage in Georgia for leguminous (peanut + soybean) and non-leguminous (cotton + corn) row crops, 2001-2020.

The ratio of non-legume row crop acreage to leguminous row crop acreage can sustain the recommended 3-year rotation between legume crops when the ratio remains above 2:1. However, when that ratio drops drastically lower, it is impossible to keep the recommended rotation length on a large proportion of the peanut crop without the introduction of new crop land. The ratio was below 2:1 for four consecutive years from 2014-2017 (Table 1), making it consistently impossible to maintain recommended rotations for leguminous crops. At that rate, barely half of the peanut acres in Georgia could continue in a 3-year rotation, while a large number of fields were forced into a 2-year rotation. In those circumstances, it is more difficult to find land suitable for good rotation practices, and pest pressure increases substantially. When peanut is planted on shorter rotations, an increase in pest incidence can threaten yield potential and increase the likelihood of pest resistance developing for the

	Cotton + Corn	**Peanut + Soybean**	**Ratio**
Year	Planted acres x 1,000		
2001	1,755	680	2.6 : 1
2002	1,790	670	2.7 : 1
2003	1,640	735	2.2 : 1
2004	1,625	900	1.8 : 1
2005	1,490	935	1.6 : 1
2006	1,680	735	2.3 : 1
2007	1,540	825	1.9 : 1
2008	1,310	1,120	1.2 : 1
2009	1,420	980	1.5 : 1
2010	1,625	835	2.0 : 1
2011	1,945	630	3.1 : 1
2012	1,635	955	1.7 : 1
2013	1,880	665	2.8 : 1
2014	1,730	900	1.9 : 1
2015	1,460	1,110	1.3 : 1
2016	1,590	980	1.6 : 1
2017	1,570	990	1.6 : 1
2018	1,755	810	2.2 : 1
2019	1,795	775	2.3 : 1
2020	1,610	910	1.8 : 1

Table 1. Combined planted acreage in Georgia for leguminous (peanut and soybean) and non-leguminous (cotton and corn) row crops, 2001-2020. Source: USDA – National Agricultural Statistics Service

most reliable methods of pest suppression currently available. This could lead to loss of genetic resistance and failures by chemical modes of action. Loss of either genetic resistance or certain classes of fungicides, herbicides, or insecticides could be devastating to the future of peanut production in Georgia and the U.S.

Elevated acres can also cause an imbalance between demand and usage of peanuts. Six of the seven largest peanut crops (in terms of total pounds of production have occurred over the last six growing seasons. This large supply is reflected in the total value of the crop, with average price per ton dropping below $400 per ton in 3 of 5 years from 2015-2019. The value had not been that low since 2006. Average price will not rebound much as long as production remains so large. Variations in price are mostly being driven by supply (and demand), as well as the price of potential alternative crops that could be planted. There has been a large increase in average peanut yield in Georgia starting around 2012 (state average yield from 2012-2020 = 4263 lb/A; state average yield from 2008-2011 = 3530 lb/A; state average yield from 2004-2007 = 2930 lb/A). When coupled with provisions in the Farm Bill that benefit peanut compared to most other row crops in Georgia, the revenue potential for peanut remains favorable compared to the other traditional row crops grown in the state. However, continued large-scale production will not only affect price, it will also put stress on yield and grade factors. This could further reduce net revenue potential in the long-run. Research from crop rotation experiments demonstrate the potential yield effect on peanut after various crop rotations (Figure 3).

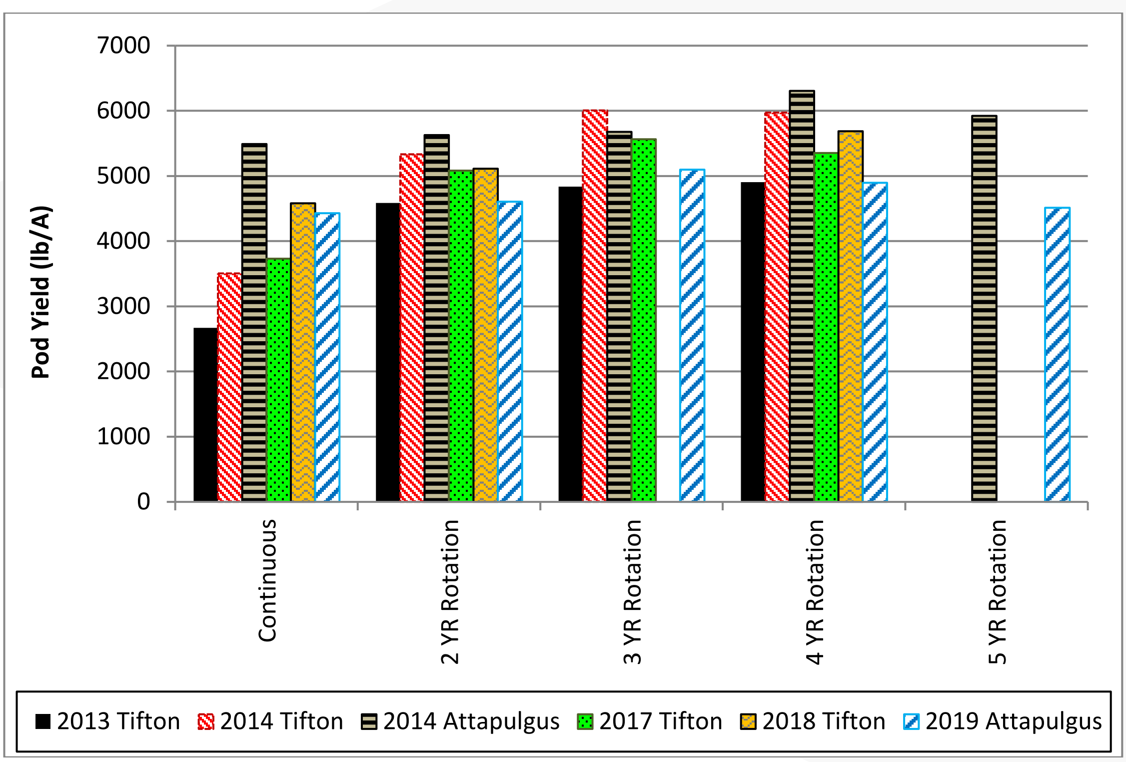


Figure 3. Pod yield of peanut as influenced by average number of years in rotation (years between peanut planting). University of Georgia Lang Farm in Tifton, GA and Attapulgus Research and Education Center in Attapulgus, GA.

In all cycles, the continuous peanut rotation resulted in the poorest yield, while the greatest yield was from a 3-year or 4-year rotation every time. The greatest incidence of leaf spot in 2013 and root-knot nematode in 2014 were likewise observed in continuous peanut plots (Figure 4). In one of the Attapulgus cycles, there was also an improvement in grade (78.5% total sound mature kernels [TSMK]) with the 4-year rotation compared to the other rotations, which were all less than 78.0% on average (data not shown).

In summary, crop rotation is still a vital component of any cropping system strategy for long-term peanut yield goals and keeping pest incidence under control. The UGA extension recommendation for a minimum of a 3-year rotation is validated with the most recent rotation data presented here. Exercise caution when planning for peanut planting and adhere to traditional row crop rotations including corn and cotton, with a minimum of two of these crops between the next planting of peanut. If you are considering planting a field to peanut that grew peanut within the last two years, it is strongly recommended that you investigate other alternatives for the sake of long-term production goals, keeping pest pressure at a minimum, and relieving stress on pesticide modes-of-action so resistance does not develop.

Figure 4. Peanut following a 3-year rotation after cotton and corn (left foreground) compared to continuous peanut (right foreground). Damage in continuous peanut rows from peanut root-knot nematode.

SOIL FERTILITY

Chapter 4
Soil Fertility

Glen Harris and R. Scott Tubbs

Peanuts have a well-defined and deep taproot system. Therefore, a peanut crop responds better to residual soil fertility than to direct applications of fertilizer. For example, if soil test levels of phosphorous (P) and potassium (K) are maintained at adequate levels for corn or cotton in rotations, then no P or K fertilizer applications should be needed on peanut. However, soil test P and K levels can drop low enough to trigger a fertilizer recommendation of these two key nutrients, but high yields may not be achieved in this situation. Also, most peanut soils in Georgia have a clayey subsoil that can trap leachable nutrients such as nitrogen (N), sulfur (S) and boron (B), which can help supply the peanut plant via the deep taproot with theses nutrients. Since peanuts can fix N and are good scavengers of P and K, the most important nutrient for peanut is calcium (Ca). The following discussion outlines the essential plant nutrients. It describes their metabolic roles in peanut physiology, fertilizer sources, and methods of application of each.

Lime

Soils of the Coastal Plain are naturally acidic. Therefore, liming is an essential production practice that neutralizes soil acidity, reduces aluminum (Al) and manganese (Mn) toxicity, and can help provide Ca and magnesium (Mg) (if dolomitic lime is used).

The optimum pH range for peanuts is 6.0 – 6.5. At pH readings lower than 5.5, Al and Mn may cause toxicity and cations such as Ca, K, and Mg would likely be deficient. Lower pH values inhibit the symbiotic relationship between the Bradyrhizobium bacteria and the peanut plant (see "Nitrogen"). In addition, low soil pH results in increased

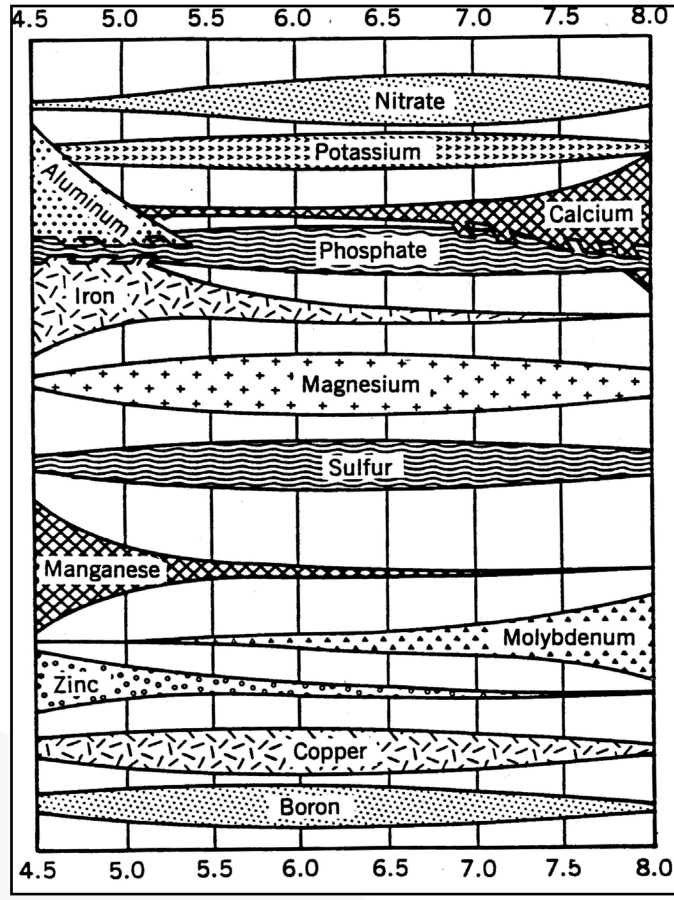


Figure 1. Relative nutrient availability for essential plant elements at various soil pH.

availability of zinc (Zn) which is a potential toxic element to peanuts (see "Zinc") Soils that are over limed can create a Mn deficiency (see "Manganese"). How the availability of soil nutrients for plant uptake is affected by pH can be seen in Figure 1.

In this graph, the wider the bar is at a given pH level, the more available the nutrient is for plant uptake. (Source = from Soil Fertility, Foth and Ellis)

The recommended liming material for peanuts in Georgia is dolomitic limestone, which contains both $MgCO3$ and $CaCO3$. Dolomotic limestone is preferred over calcitic limestone since it provides a cheap form of Mg while effectively neutralizing soil acidity.

The amount of liming materials applied will depend on many factors, including soil pH, buffer pH, and soil type. Therefore, base all limestone applications on soil test results.

Apply liming materials at least three to four months prior to planting if possible. This will allow enough time for the material to neutralize acidic soils. If delayed, lime can be applied right up to planting time. If you apply liming material close to planting, do not deep turn in order to leave the Ca in the pegging zone.

Variable rate liming based on precision agriculture grid soil sampling has proven to be a useful management practice to avoid nutritional problems related to soil pH on peanuts (too high or too low). The standard size of the grids is usually 2.5 acres and recommendations will be made accordingly. This allows lime to be applied where it is needed and not applied where it is not needed compared to a "blanket" application.

Nitrogen

Peanut is a legume that fulfills its own N requirement through symbiosis with specific Rhizobium soil bacteria (called Bradyrhizobia). These soil bacteria penetrate the root hairs, forming nodules. The bacteria allow the peanut plant to convert atmospheric N to a form utilized by the peanut. The peanut is a member of the cowpea cross-inoculation group which is fairly widespread in most soils. Other legumes that are members of the cowpea cross-inoculation group that are commonly found in Georgia include aeschynomene, alyceclover, cowpea, crotalaria, Florida beggarweed, hairy indigo, kudzu, lespedeza, and velvetbean among others. Since these bacteria and other members of the cowpea cross-inoculation group are fairly widespread, peanut often nodulates without artificial inoculation. Artificial inoculation with a commercial inoculant is recommended if peanut is planted in soils where it has not been grown within 3 to 4 years or where adverse conditions have occurred since the last time peanut was grown in the field (i.e. extreme temperatures, prolonged dry or saturated soil pore space, etc.). A different species of Rhizobium inoculates soybean. This species will not inoculate peanut (or other members of the cowpea cross-inoculation group). Therefore, do not use soybean inoculant on peanut.

Nitrogen deficiency is occasionally a problem on peanuts. This could be due to a failure to use commercial inoculate on peanuts when needed. It could also be caused by water-logged (anaerobic) soils that inhibit Bradyrhizobium activity. Nitrogen deficiency in water-logged soils will often correct itself once the soil dries out if the bacteria remain alive and N-fixation remains active. A shallow cultivation will help aerate the soil and can correct this type of N deficiency.

In extreme cases of poor nodulation, it may be necessary to apply N fertilizer. If you note N deficiency, apply 60 lb elemental N when peanut is 40 to 60 days old. A granular form of N fertilizer (such as ammonium sulfate) is recommended. To prevent foliar burn, apply granular N fertilizer as a side dressing when the foliage is dry. Based on recent UGA research results, application rates higher than 60 lb N/A or later than 60 days after planting will not produce a significant peanut yield response. Low rates of foliar applied liquid N fertilizer will not increase peanut yields, even though the foliage may be greener. Also, be cautious when choosing to apply N fertilizer to peanut however, as nodulation and N-fixation can be reduced when rates exceed 30 lb N/A. Once the supplemental N is exhausted, the diminished N being supplied by the Bradyrhizobia likely will not be enough to sustain rapid pod and kernel development at peak reproductive production time.

How does inoculation occur?

At planting, Bradyrhizobia strains of bacteria must be in the soil. These bacteria begin to infect the roots of the peanut plant within a few days after seed germination. Three to four weeks after germination, small "nodules" appear on the roots as a result of these infections. The mature nodules are round in appearance. The presence of these nodules on the roots of peanut is proof that the bacteria have successfully infected the roots. This is very important since the Bradyrhizobia living in the nodule are able to enter into a symbiotic association with the plant. The plant and the bacteria together are able to reduce or "fix" N gas (N2) from the air into ammonium (NH+ 4) in the plant root. In this form it can be readily used by both the bacteria and the plant as a nutrient for growth. The peanut is a highly efficient legume able to synthesize its N needs, beginning about 30 days after planting if the correct strains of bacteria are present in sufficient quantities.

The presence of a pink-to-red color within the nodule indicates that N is being fixed. This can be seen by slicing nodules. Very young nodules have a white-to-tan interior. Old nodules have a green-to-brown interior color. Little or no nitrogen is fixed when nodules are at this stage.

Need for inoculation

Research in Georgia has shown a tendency for yields to be slightly higher (up to 200 lb/A) when commercially prepared inoculants are used in standard rotations, and significantly larger (as much as 1,500 lb/A) yield improvements when peanut has never been grown in a field (Figure 2). Evaluate the responses to inoculation and compare the cost of the material and application with potential returns

Figure 2. Alternating sections of twin row peanuts planted without or with liquid inoculant in a field that has never grown peanut. Non-inoculated plants show severe N deficiency and stunting..

when deciding whether or not to inoculate peanut that is planted in a field that grew peanut within the last five years. Also consider weather extremes that may have influenced Bradyrhizobia survival since the last time peanut was grown.

Methods of inoculation

There are several inoculant formulations that are commercially available:

Liquid

This is the most common and most effective form currently used. These inoculants are sprayed (often with a stream nozzle) directly onto the seed in the planting furrow immediately ahead of the stream and immediately prior to row closure. This gives the most uniform and complete coverage of the seed and the surrounding soil environment where roots will grow in early developmental stages, ensuring maximized nodulation as early as nodule development is possible. This formulation typically delivers the largest quantity of viable cells to the seed.

Granular

The granular form provides the lowest quantity of viable cells at labeled application rates, although still considered abundantly adequate. Overall, the granular formulation has had less consistently as the liquid formulation in plant performance (yield, nodulation, etc.). However, in certain situations, it may provide some additional benefits such as in dry soil conditions where it will remain at the bottom of the furrow next to the seed, while a liquid may disperse away from the seed through the soil profile. A properly set granular applicator is important for appropriate delivery of this material. The hopper and tubes should be thoroughly cleaned to ensure there is no residue from a previous application since moisture from humid environments can cause clumping of previous material to occur. Also, the metering method should be tested before proceeding to the field, since a rolling wheel applicator can grind the relatively soft material and cause a clog in the neck of the tube.

Sterile Peat/Powder

This type is usually spread in dry form over peanut seed in the planter box or immediately prior to loading in the hopper. Distribution and uniform coverage are often difficult. Making a slurry can aid in adherence to the seed, however this can damage the seed coat, requires additional time for preparation and drying, and still is less effective than the other two formulations. Use of a vacuum planter also can remove some of the treatment when getting the seed to hold to the planter plate. This formulation is only recommended if liquid or granular application is not possible, but is considered a better alternative than no inoculant in situations where the potential for benefit from an inoculant is possible.

Selection and Handling of Inoculants

The Bradyrhizobia bacteria in commercial inoculants are living organisms and subject to being damaged or destroyed by many environmental and management practices. Proper storage and handling of inoculants is important. The cause or causes of poor nodulation are not always readily apparent, as there can be several reasons for the death of the bacteria. Since hot and dry weather often exists during planting time, take special care when inoculating the seed. Some precautions to follow include:

- Purchase a fresh inoculant of the proper strain from a reliable source. Store the inoculant in a cool, dry, shaded place until it is used. Do not place opened or unopened containers of inoculant in direct sunlight.
- Take to the field only the amount of inoculant

that will be used that day. Keep it in the shade and do not let the unused inoculant remain in the hoppers for extended time. If liquid inoculant sits in tank overnight, add a fresh batch before planting.

- Most peanut seed are treated with fungicides which can be detrimental to adherence of powder inoculants.
- Plant peanut at least two to three inches deep in moist soil. Shallow planting may result in the loss of bacteria due to hot, dry soils.
- Prepare well-drained fields for peanut, not only to ensure good nodulation, but also to reduce risk of water-logged soils from heavy rains.
- If using a liquid inoculant, the carrier liquid for the spray solution should be chlorine-free water to avoid killing the bacteria. Apply with at least 5 gal/Ac of water. Also, liquid fertilizers are not recommended to be used as a carrier since there is the potential for them to reduce the effectiveness of the inoculant.
- If a heavy rain occurs shortly after planting, a liquid inoculant may be diluted or carried away from the seed through the soil profile, thus reducing efficacy.
- Fertilizer applications should be broadcast. Banded applications close to the seed could possibly result in high salt levels which could damage bacteria. It is recommended to broadcast peanut fertilizers and turn them into the soil prior to planting.
- Avoid excessive N. Nodulation is delayed or reduced in the presence of high levels of soil N.
- Adequate soil levels of calcium, phosphorus, and potassium aid in Bradyrhizobia survival.
- Do not mix commercial inoculants with soil-applied pesticides, unless the manufacturer recommends it. Flow rates may be different due to variable granular sizes and more importantly, pesticides may adversely affect the bacteria. Follow all label directions when applying pesticides and inoculants.
- The product is listed on the label to be delivered at around 1.0 fl oz per 1,000 linear row feet (may differ slightly depending on which product is selected). This is developed on a per furrow basis. Therefore, a twin row planting inoculant application will double the amount of inoculant applied compared to a single row planting.

Other benefits of N-Fixation

Fertilizer savings - Due to the N-fixing ability of the peanut plant in association with soil Bradyrhizobia bacteria, production costs are saved by not needing to apply N fertilizers.

Nitrogen Credit to Crops in Rotation – Crops following peanut in rotation such as small grains, corn or cotton will benefit from N fixed by peanut and carried over and should enhance yield and reduce fertilizer costs of the following crop. Although a mature, standing peanut crop can contain upwards of 150 lb N/a the "N Credit" to the following non-leguminous crop is valued at approximately 30 lb N/a. The exact amount of N credit can vary due to the effectiveness of the fixation process, soil reactions, phosphorus and potash levels in the soil, amount of N already available in the soil, size of the crop, and the portion of the crop left on the land. However, even when peanut vines are removed from the field, the "fertilizer replacement value" for N is still 30 lb N/a due to the occurrence of "non-N rotation affects" and the fact that not all of the vines and fine leaves are removed.

Improved soil conditions - Properly inoculated peanuts are rich in N, often containing several times more N as was withdrawn from the soil. Due to the presence of certain high N chemical compounds in leguminous plants, they decompose rapidly, leaving organic matter in the soil which improves its physical, chemical, and biological condition.

Phosphorous

Phosphorous deficiencies on peanuts are rare in Georgia. Phosphorous does not readily leach from the soil and little is removed from the soil by peanut production. Since most peanut fields have been under cultivation for an extended period of time, P levels are usually adequate. In addition, the use of poultry litter as fertilizer in the peanut belt of Georgia also helps maintain good levels of soil test P. As is the case for the other macronutrients, phosphorous fertilizer is normally applied to peanuts as a maintenance treatment, not a corrective treatment. Broadcasting P fertilizer in either conventional or strip till production systems is acceptable. Deep turning P fertilizer prior to planting if soil test levels are low and P is recommended may be advantageous in order to get P placed deep where the peanut taproot can reach the fertilizer. Starter fertilizers with P should also not be needed unless soil test levels of P are very low and if used should be placed in a ‘2 x 2” (2 inches to the side and 2 inches below the seed) and not in the planting furrow.

Potassium

Under most conditions, K is rarely deficient in peanuts. Potassium is not as leachable as N and even if moved deeper in the soil profile by heavy rains on sandy soils should still be available for uptake by the deep tap root of the peanut plant. However, in recent years more K deficiencies have been reported and confirmed in Georgia peanuts. Symptoms of K deficiency are yellowing and eventual necrosis on the outer edges of the leaves, similar to as in other crops. Symptoms may show on older leaves first since K is relatively mobile in the plant. Potassium deficiency should be confirmed with a leaf tissue sample taken prior to or at early bloom. The earlier the deficiency is detected and confirmed the better chances of reducing its affects with K fertilization.

Potassium deficiency can occur for a number of reasons including 1) on deep sands where there is no subsoil clay within the top 20 inches of soil, 2) on “new ground” just brought into production, usually after pine trees, 3) after a long term grass crop (such as bahiagrass or bermudagrass) 4) when peanut follows peanut for 2 or more consecutive years (which is not recommended) and 5) when peanut hay or vines are baled and removed from the field (vines can contain nearly five times as much potassium as the nuts). For any of these cases, soil sampling and applying the recommended potassium fertilizer is even more critical in order to avoid potassium deficiency. If large amounts of potassium fertilizer are recommended, deep turning or disking the fertilizer is recommended to avoid concentrating potassium in the pegging zone of peanuts and interfering with calcium nutrition which can lead to “pops”, pod rot and reduced yields.

Calcium

Peanuts have unusually high Ca requirements and are unique in the way Ca is supplied to the developing nut. This makes Ca management one of the most critical aspects of peanut production. When Ca is deficient, the symptoms are expressed as "pops"(underdeveloped kernels in the pod), darkened plumules, poor seed germination, higher incidence of aflatoxin contamination, and pod rot (pod breakdown). In these cases, vegetative growth appears to be unaffected whereas the reproductive growth (pods, kernels) is severely affected. Unfortunately, this means Ca deficiency is usually not detected until harvest when it is too late to try to fix the deficiency.

Calcium is a cation that is passively absorbed by the peanut. The amount absorbed depends on the concentration of Ca in the soil solution and the amount of water absorbed by the plant. Most Ca is transported upward in the xylem while essentially none is translocated downward through the phloem.

Like other plants, peanut plants absorb Ca through the roots. However once the peanut begins to peg, Ca is no longer transported to the peg through the xylem. At that point, the peg and developing pod passively absorbs water and Ca directly from the soil solution. For this reason, abundant levels of Ca must be in the soil solution in the pegging zone (top 3 or 4 inches) of soil where peanut pods develop.

Calcium must be available to the developing peg and pod in a water soluble form. Therefore, any supplemental Ca must be in a water soluble form. The most commonly recommended form of supplemental Ca is $CaSO_4$ (also referred to as gypsum or landplaster). Apply gypsum as a top dressing at the early flowering stage. Runner and spanish peanuts require around 200 lb/A of elemental Ca. Large-seeded virginia type peanuts require twice the level as runners or around 400 lb/A of elemental Ca.

There are a number of different gypsum fertilizer materials available to Georgia peanut growers. Currently, the most common is flue gas desulfurized (FGD) gypsum also referred to as "smoke stack" or "synthetic" gypsum. This material is a by-product of scrubbing or removing sulfur from emission stacks of coal burning power plants. The levels of heavy metals in FGD gypsum are low enough to be considered safe and the material itself spreads relatively easily. Naturally mined products such as "USG 500" are also available and usually contain less moisture than FGD gypsums so they can be used at a slightly lower rate and may spread more easily. Recycled wallboard also contains $CaSO_4$ and can be used as a Ca source if the paper associated with this product is not an issue. Fortunately, all of these forms of gypsum contain approximately 20% Ca. Therefore, the recommended rate to supply the needed 200 lb Ca/A is 1000 lb/A of gypsum.

Lime (regular ground agricultural limestone) can also be used as a Ca source for peanuts if a soil pH adjustment is needed. In order to keep the Ca from the lime in the pegging zone and available for absorption into the pods, the lime should be applied before planting but not deep turned. Since the Ca in lime is not as soluble or available as in gypsum, lime should not be applied too late, for example at early bloom like with gypsum. Also, both dolomitic and calcitic lime can be used despite the belief that only calcitic lime works in this situation.

In a "rescue" situation where the need for Ca is discovered later in the season on peanut, 10 gal/A of $CaCl_2$ applied through a center pivot may prove beneficial. Since peak pod fill occurs around 60 to 90 days after planting, this application should be made around between 60 and 75 days after planting so the Ca is supplied when the developing nuts are absorbing Ca through the hulls. Also, since Ca is not translocated from leaves to developing fruit, typical "foliar Ca" rates of 1 qt/A are not recommended.

Since Ca is absorbed through the soil solution, Ca deficiencies have been noted when gypsum was applied under extremely dry conditions. Timely irrigation after application, if available, can minimize this problem. Because it is relatively soluble, gypsum can also leach out of the pegging zone. Calcium deficiencies have been noted where excessive rainfall (4 to 6 inches) occurred within three weeks after application. In this situation, replacing 500 lb/A gypsum or putting 10 gal/A CaCl2 liquid through a pivot should be considered.

Fortunately, the need for supplemental Ca on peanuts can be easily evaluated. To do this, collect a soil test sample from the pegging zone (“pegging zone test”) shortly after peanut emergence. The samples should be collected slightly offset from the row, approximately three inches deep. Soil test results will provide an accurate indication of Ca levels in the pegging zone. Based on extraction methods currently used by the UGA Agricultural and Environmental Services laboratory located in Athens (website = aesl.ces.uga.edu), two conditions are used in determining the need for supplemental Ca:

1. The soil test for Ca must be at least 500 lb/A.
2. The Ca:K ratio must be at least 3:1 (i.e. at least three times as much Ca as K).

Supplemental Ca is required if either or both of these criteria are not met. Also, the extraction method currently used is called “Mehlich 1”. These recommendations are not reliable when other extraction methods are used such as “Mehlich 3” or ammonium acetate. Also, this soil test is only for runner and spanish peanuts. It is not valid for virginia-type peanuts. Virginia-type peanuts have very high Ca requirements. Therefore, supplemental Ca should be applied automatically, regardless of the soil test results. Additionally, all peanuts grown for seed should automatically be treated with supplemental Ca.

Many peanut growers base their Ca needs on a winter soil sample, often collected in January or February at a 6 inch or greater depth. This is not as reliable as the pegging zone test and is not recommended to guide Ca needs for peanut if the soil is deep turned after soil sampling.

Magnesium

Peanuts have tremendous affinity for Mg uptake (similar to K) which is easily “scavenged” by the deep tap root system of a peanut plant. Dolomitic limestone, which contains $MgCO_3$ and $CaCO_3$, is the recommended liming material in Georgia. Most fields should have adequate levels of Mg if they have been properly limed.

Because it is a cation, Mg can cause nutrient imbalances that result in pod rot problems. Magnesium and K cations compete with the Ca for absorption by the peanut pod. This is normally not a factor unless soil test levels of Mg are extremely high. If a soil test indicates Mg deficiency and liming is not required, normally 25 lb/A of Mg custom blend-ed with other fertilizers is sufficient.

Sulfur

Sulfur is rarely deficient on peanuts grown in Georgia. This is because gypsum contains 20 percent S and is extensively used in Georgia. Also, S will accumulate in soils with a clay subsoil (but not deep sands). Sulfur used to be included in some fungicide sprays, but the form was elemental S instead of SO_4-S and had value as a fungicide but did not have nutritional value.

Boron

Boron affects crop quality. Boron deficiency causes "hollow heart" which is often classified as hidden damage (Figure 3). Hollow heart is caused by

Figure 3. Hollow heart caused by boron deficiency compared to normal peanuts

collapse of cells on the inner faces of the cotyledons, leaving a shallow depression. Boron deficiency caused by leaching is common on Coastal Plain soils because they are acidic and coarse in texture. Apply elemental B at a rate of 0.5 lb/A. Make this a yearly preventative treatment.

Take care to prevent B toxicity. Never apply more than 0.5 lb/A of B. Excessive B will cause marginal leaf burn on peanut leaflets.

Some formulations of B are recommended at very low rates (e.g. 6 oz/A). This rate only supplies around 0.025 lb B/A and is not considered to be an economically viable option. Even though the manufacturers of these formulations of B claim these low rates are effective since they are taken up more efficiently, this has not been the case based on rep-licated field research results.

Boron can be applied as part of bulk blended fertilizer that is deep turned prior to planting, as a tank-mixture with preplant incorporated herbicides, or as a tank-mixture with early leafspot fungicide sprays. It is important to apply the B fertilizer as accurately and uniformly as possible. Therefore, the tank-mixture options with herbicides or fungicides are the best.

Copper

On the mineral soils of the Coastal Plain (which are low in organic matter) Cu deficiency is very rare. Copper deficiency on peanuts is more likely found in organic or peat soils, primarily in underdeveloped countries. It has also been documented on calcareous soils of Texas and New Mexico. Copper is fixed and rendered unavailable to peanuts on these soils.

Manganese

Manganese is an essential plant element that is less available to plants at higher soil pH. Therefore, it is important to maintain the proper balance between soil pH and soil test Mn levels to avoid Mn deficiency. The graph below (Figure 4) was developed using information from the UGA Soil Test Handbook and originally developed for soybean. It can be used however, to predict the occurrence of Mn deficiency on peanut.

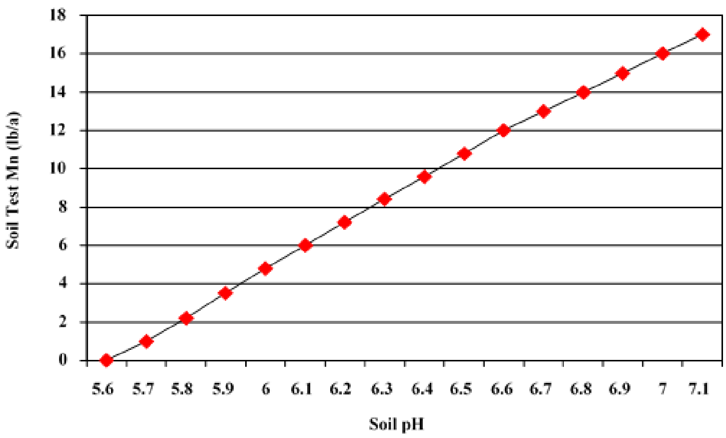


Figure 4. Relationship between pH and manganese availability. Maintain soil manganese levels above the line to avoid manganese deficiency.
Source: Soil Test handbook for Georgia

Basically, if the soil pH/soil test Mn level combination (again using Mehlich 1 extractant) is above the line, then Mn deficiency is not likely. For example, if soil pH is 6.5 and soil test Mn is 16 lb/A, then Mn deficiency is not likely to occur. However, if soil pH is 6.5 and soil test Mn is 4 lb/A, then Mn deficiency is very likely. This is not a ”hard and fast” rule, especially with combinations very close to or on the line, but should instead be used as a guide to predict if Mn deficiency is an issue and respond accordingly. Interveinal chlorosis, or “yellowing between the veins” is the main symptom of Mn deficiency (Figures 4-5). Manganese deficiencies can be addressed symptomatically or on a preventative basis. If symptoms are observed (Figures 5 and 6), it is recommended to confirm the deficiency with a leaf tissue analysis since similar symptoms can be caused by other factors such as herbicide injury or disease. If a Mn deficiency is confirmed with tissue testing, then an application of $MnSO_4$ as a foliar spray is recommended. Manganese sulfate can be tank-mixed with fungicides or herbicides. The earlier the deficiency is detected the better chance of fixing the problem with foliar applications. Also multiple applications may be required. Manganese deficiency can also suddenly appear in the new growth in the top of the plant late in the season (past peak pod fill or 90 days after planting). Late Mn deficiencies are not thought to be a problem as far as reducing yields and do not require remedial action. If a particular field has a history of Mn deficiency, custom blend Mn fertilizer with other fertilizers and apply prior to planting.

Conversely, soils with a low or acidic pH and high soil test Mn combination (upper left side of the graph) could theoretically suffer from Mn toxicity. However, research indicates that peanuts are relatively tolerant to high levels of Mn. A leaf tissue sample will also indicate if you are above the recommended range for Mn in the tissue and susceptible to Mn toxicity.

Figure 5. Close up of manganese deficiency. Note the interveinal chlorosis.

Molybdenum

Molybdenum is critical in the N-fixation process. Therefore, Mo deficiency may be masked as an apparent N deficiency. Molybdenum is more readily available as soil pH is increased. Therefore, Mo deficiency is likely only under extremely acid soil conditions. If a Mo deficiency in peanut is suspected, it needs to be confirmed through soil and tissue testing. Even if confirmed, the best remedy

Figure 6. Field showing symptoms of manganese deficiency.

may be to apply N fertilizer instead of foliar feeding Mo.

Zinc

Zinc is technically an essential element for peanut growth. However, peanuts are extremely sensitive to Zn, making Zn toxicity a major issue in Georgia peanut production. Zinc is more available as the pH decreases. When Zn toxicity occurs, it is usually the result of a combination of high levels of Zn and low soil pH. At one time, peanuts were considered to be susceptible to Zn toxicity when soil test levels of Zn exceeded 10 lb/A (using Mehlich 1 extractant). However, newer research indicated that Zn levels greater than 10 lb/A can be offset by raising soil pH above 6.0. The graph below (Figure 7) can therefore be used to predict Zn toxicity and if detected early enough, remedied with applications of lime. Soil pH/soil test Zn combination levels should be

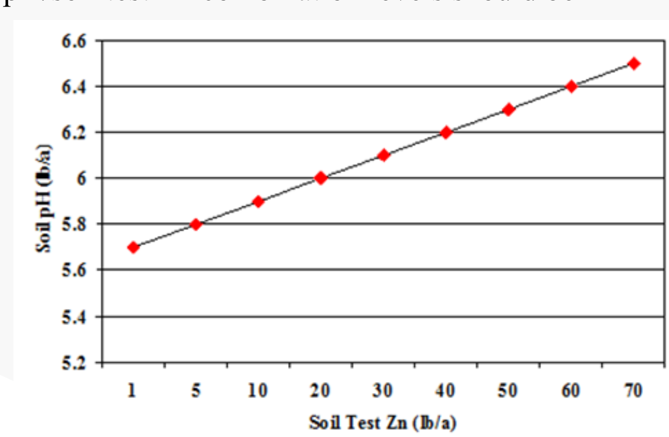


Figure 7. Relationship between pH and zinc availability. Maintain soil pH levels above the line to help reduce zinc toxicity.
Source: Davis-Carter, J. et al. 1991 Peanut Research Extension Report

maintained above the line of the graph to avoid Zn toxicity on peanut and again is not a hard and fast rule when near or on the line.

Excess Zn can accumulate in areas where peanuts are grown in rotation with irrigated field corn or in old pecan orchards which received excessive Zn fertilizer applications over an extended period of time (Figure 8). Zinc toxicity in peanuts has also been observed on house sites, hog lots, and fence rows where galvanized (Zn treated) metal was used. Zinc is an immobile element that is very resistant to leaching, so once it accumulates it is very difficult to lower the levels via crop removal. Once toxic levels of Zn accumulate, it will take several years to lower them and accurate soil sampling to monitor the soil pH /Zn level combination is recommended. Also, in particular fields with soil test levels above 70 lb/A (off the chart) are not recommended to be planted to peanut.

Symptoms of Zn toxicity are very distinct. The plants appear healthy until they are 4 to 5 weeks old. At that time their growth becomes severely stunted. The leaflets exhibit chlorosis. Stems are flattened and often have a purple tint. The distinctive characteristic is a longitudinal splitting of the stem at the soil line (Figure 9). All symptoms can develop to the point of plant death.

Soil and Tissue Testing

Most soil fertility problems seen in peanuts can be avoided with good soil sampling and management practices. Grid sampling and variable rate applications of lime and P and K can avoid most soil fertility problems with peanut. Tissue sampling is highly recommended if a nutritional problem is suspected and should be taken early in the season in order to have a better chance of fixing nutritional problems.

Poultry Litter

Poultry litter (manure mixed with bedding) is a good source of fertilizer for most crops. However, peanut is usually not the first choice of crops to receive litter applications. This is due to the fact that peanuts can fix their own N and are good scavengers of P and K. Therefore, to get the most economical benefit from using poultry litter it should be applied to crops such as corn, cotton and forages. In the less common case where soil P and K levels are very low (such as new ground) poultry litter can be used on peanut but should be limited to an application rate of 4,000 lb/A and incorporated into the soil if possible. Also, poultry litter should not be applied to conservation-till or strip-till peanuts since research has shown this can encourage disease and reduce yields.

Figure 8. Field symptoms of zinc toxicity. This field was previously a pecan orchard. Dead areas correspond to locations of pecan trees that received large quantities of zinc fertilizer.

Figure 9. Symptoms of zinc toxicity on peanut. Notice longitudinal splitting of stem. Picture courtesy of Dan Anco.

LAND PREP

Chapter 5
Land Preparation

Scott Monfort and R. Scott Tubbs

Land preparation has remained a key agronomic practice in peanut production in the state of Georgia. Land preparation is needed to provide a smooth and uniform seedbed for rapid and uniform peanut seed germination, good root development and penetration, fracture the hardpan, bury previous crop residue, and aid in effective weed control. Effective burial of crop residue and weed seed are essential for both disease and weed suppression. Historically, intensive tillage practices (harrowing, moldboard plowing, etc.) were utilized for a majority of the peanut crop. However over the last two decades, some growers have adopted a reduced tillage program for peanut due to lower commodity prices and increased input costs. Although reduced tillage programs have been proven to save growers time and input costs, only a small percentage of peanuts are now produced using this type of land preparation.

Intensive Tillage (Conventional) Land Preparation:

Managing plant residue from the previous crop is the initial step in preparing a desired seedbed. Residue containing plants with woody taproots or fibrous roots should be uprooted and shredded through mowing and harrowing in advance of deep turning. Several harrowing operations may be needed to reduce previous crop residue. Moldboard or switch plows equipped with concave disc coulters are used for deep turning. The design of these plows allowed for the inversion of the soil profile to a depth of 8 to 14 inches, burying the surface trash while breaking the hardpan and aerating the soil. Breaking the hardpan allows for a more rapid root penetration along with greater root water storage in the lower root zone increasing the plants ability to grow and develop. In some cases, the root-bed may still contain a mild hardpan immediately below plow layer. If this the case a ripper shank may be used in the furrow immediately behind the moldboard to break this hardpan.

It is best to establish smooth, uniform seed beds in freshly prepared soils immediately after breaking. Form beds by driving a tractor over the field, leaving wheel track depressions. A "table-top" profile about five inches high can achieved by using a power tiller or a rigid horizontal blade attachment (bed shaper) behind the tractor. For accuracy, these implements should have their weight supported by gauge wheels. Bed establishment can improve crop management from planting to harvest.

Soil incorporated preplant herbicides can be applied as "beds" are established. Early cool season weeds may germinate prior to planting and are easily controlled by flat sweeps (set to run shallow) shearing roots and leaving the soil level. Growers need to plant in weed-free seedbeds. Disc harrows are not preferred since they cause soil compaction and loss of moisture. Disc harrows are also costly to operate and disrupt the beds.

Conventional tillage systems have also been noted for warming the soil quicker than reduced tillage systems, allowing for quicker and uniform correction of soil pH and fertility issues, and allowing for bed formation that also aids in warming of the soil and in the digging process.

Reduced Tillage Land Preparation:

Strip or reduced tillage has been adopted by some peanut producers in Georgia in an effort to reduce time, inputs, and labor used to produce peanuts. However, wide-spread adoption of reduced tillage in peanut has been slow due to reduced yields and problems with weed management. Reduced tillage peanuts may require changes in field preparation and planting equipment. The premise for reduced tillage is to minimally disturb the soil and plant residue on the soil surface allowing for a reduction in wind and water erosion of the soil. To eliminate or reduce hard pan issues, the field needs to be subsoiled with a ripper shank set to a depth of 8 to 12 inches. In a reduced tillage system, only an 8 to 12 inch wide strip of soil is tilled. The soil and plant residue between the rows remains intact.

Some growers have elected to enhance the effects of reduced tillage by planting a cover crop (e.g., cereal rye or wheat) during the fall of the previous growing season. The addition of the cover crop increases the water holding capacity of the soil along with suppressing weed germination. Cover crop residue has been shown to reduce the onset of some diseases in peanut. The soil in reduced tillage systems also tend to be cooler and wetter than in conventional tillage systems. With this in mind growers will need to track soil temperatures more closely to make sure not to plant too early. Planting in unfavorable conditions will slow growth and development of the peanut plant potentially increasing the risk for seedling disease issues.
As with conventional tillage, growers need to make sure to plant into a weed-free field. To achieve this in reduced tillage an application of burndown herbicides is needed. Please refer to the weed management chapter for further information (Chapter 12).

Intensive Tillage

Examples of intensive tillage practices. Top left and right: field cultivation with a disc harrow. Bottom left: switch plow for deep turning soil, as illustrated in bottom right. Images courtesy of Kris Balkcom, Auburn University

Reduced Tillage

Examples of reduced tillage practices. Top:rolling of cover crop before tillage operation (left) and ripping into covercrop residue before planting (right). Bottom: two pictures of a 1 trip rip and plant combination used in reduced tillage. Images courtesy of Kris Balkcom, Auburn University

VARIETIES

Chapter 6 Peanut Varieties

Scott Monfort and Bill Branch

Peanuts are divided into two subspecies and six botanical cultivars, three of which are grown as market types in the USA: the Virginia and runner market types belong to var. *hypogaea* in subspecies *hypogaea,* the spanish market type to var. *vulgaris* in subs. *fastigiata*, and the valencia market type to var. *fastigiata* in subs. *fastigiata*. Virginia and runner peanuts do not flower on the main stem and in general terms are late maturing, have a higher water requirement and are large seeded. Spanish and valencia peanut types flower on the main stems as well as on the branches, and relative to Virginia types are early maturing, have a low water requirement, and are small seeded.

There are four main peanut production areas in the United States: Virginia-Carolinas (Virginia, North Carolina, and South Carolina), Southeast U.S. (Georgia, Florida, and Alabama), Mississippi Delta (Arkansas, Mississippi, and Missouri), and the Southwest (Oklahoma, Texas, and New Mexico). Virginia market types are grown primarily in the Virginia-Carolinas area and Texas. Runners are mostly in the Southeast but are grown in all growing regions in the US. Spanish and valencia types are mainly grown in the Southwest.

Georgia is unique because all four market types have been grown here (Table 1). However, the runner type is primarily grown in Georgia. Diversity in cultivars is good because genetic diversity reduces the vulnerability of the peanut crop to attack by some unforeseen disease or insect problem. It also spreads out harvest when cultivars with different maturity are grown. This gives a better chance for avoiding unfavorable weather during harvest and prevents congestion at the buying points.

Table 1. Peanut Market Types Planted in Georgia

	Harvested Acres[1]					
	2015	**2016**	**2017**	**2018**	**2019**	**2020**
Runner	777,000	720,000	827,265	655,939	666,365	803,568
Virginia	60	NA	625	216	755	848
Spanish	45	NA	NA	NA	71	NA
Valencia	TR[2]	NA	150	NA	3.5	11
Total Acres	777,105	720,000	828,040	656,155	667,195	804,427
Yield[3] (lbs/A)	4330	3940	4330	4390	4170	4100

[1]*Based on Final Estimated Acreage and Yield Reported by GA FSA, NASS* [2]*TR=Trace=less than 5 acres*
[3]*Yield = Average for Runner Peanuts Only*

Below is a list and brief description of cultivars by type that have been successfully grown in Georgia (order of listing does not imply order of preference). Yet, not all cultivars are recommended in Georgia due to lower yield potential and risk of pest incidence, such as the lack of disease resistance compared to other cultivar options. If a disease is not listed in the cultivar description, it can be assumed to be susceptible.

Runner Type (Tables 2 and 3)

- **AUNPL-17** is a new high-yielding, high-oleic, TSWV-resistant, runner-type peanut cultivar that was released in 2017 by Auburn university and The USDA Peanut Lab in Dawson, GA. AUNPL-17 is a medium maturing (140 to 145 days), medium sized seed, runner-type cultivar.
- **Georgia Greener** is a medium maturing (130 to 145 days), medium sized seed, runner-type cultivar. This cultivar was developed by the University of Georgia-Tifton Campus and was released in 2006. It has a high level of resistance to Tomato Spotted Wilt Virus (TSWV) and some resistance to Cylindrocladium Black Rot (*Cylindrocladium parasiticum*, CBR).
- **Georgia-06G** is a high yielding, runner-type cultivar. Georgia-06G has a large sized seed and displays a medium maturity pattern. This cultivar was developed by the University of Georgia-Tifton Campus and was released in 2006. Georgia-06G has a high level of TSWV resistance and good yield potential in a wide range of conditions.
- **Georgia-07W** is a large seeded, medium maturing, runner-type peanut. This cultivar was developed by the University of Georgia-Tifton Campus in Tifton, GA and was released in 2007. Georgia-07W is TSWV resistant and Southern Stem Rot (*Sclerotium rolfsii,* white mold) resistant.
- **Georgia-09B** is a high-oleic, medium maturing, medium seed size, runner-type cultivar. This cultivar was developed by the University of Georgia-Tifton Campus and was released in 2009. Georgia-09B has an intermediate runner growth habit with a high resistance to TSWV.
- **Georgia-12Y** is a high yielding, medium-late maturing, runner-type cultivar with a medium sized seed. This cultivar was developed by the University of Georgia-Tifton Campus and was released in 2012. It is also TSWV resistant and white mold resistant. Due to later maturity, Georgia-12Y is less suitable for later planting dates (after May 15).
- **Georgia-13M** is a high-oleic, runner-type cultivar with a medium-late maturity and a small sized seed. This cultivar was developed by the University of Georgia-Tifton Campus and was released in 2013. Georgia-13M is resistant to TSWV. Due to later maturity, Georgia-13M is considered to be highly susceptible to leaf spot.
- **Georgia-14N** is a high-yielding, high-oleic, runner-type cultivar. Georgia-14N is a medium-late maturing cultivar with a small sized seed. This cultivar was developed by the University of Georgia-Tifton Campus and was released in 2014. Georgia-14N is TSWV resistant and also a high level of resistant to the peanut root-Knot (*Meloidogyne arenaria*) nematode. Due to later maturity, Georgia-14N is less suitable for later planting dates.
- **GEORGIA 16HO** is a new high-yielding, high-oleic, TSWV-resistant, large-seeded, runner-type peanut cultivar released by the Georgia Agricultural Experiment Station in 2016. Georgia 16HO also has a large runner seed size similar to two other large-seeded, high-oleic, runner-type varieties, Florida-07 and TUFRunner ‘727’.
- **GEORGIA 18RU** is a new high-yielding,

normal-oleic, TSWV-resistant and leaf scorch-resistant, medium-large seeded, runner-type peanut cultivar released by the Georgia Agricultural Experiment Station in 2018. Georgia-18RU combines high yield, high grade, high dollar value, TSWV resistance, and leaf scorch resistance with the desirable normal-oleic trait for peanut butter manufacturers.

- **GEORGIA 20VHO** is a new high-yielding, high-TSMK grading, very high-O/L ratio, TSWV-resistant, runner-type peanut cultivar released in 2020 by the Georgia Agricultural Experiment Stations. Georgia-20VHO has higher percentage of total sound mature kernel (TSMK) grade compared to several other high-oleic runner varieties in Georgia. Georgia-20VHO combines high-yield, grade, and dollar values with TSWV-resistance and very high-O/L ratio for longer shelf-life of peanut and peanut products.
- **Florida-07** is a medium maturity, medium seeded, high-oleic peanut developed by the University of Florida, North Florida Research and Education Center in Marianna, Florida. The cultivar was released in 2006 because of its high-yield potential, competitive grades, and resistance to TSWV.
- **FloRun™ 107** is a medium maturity, medium seed sized, high-oleic peanut. It has moderate to excellent TSWV resistance and moderate white mold resistance. This cultivar was developed by the University of Florida, North Florida Research and Education Center in Marianna, Florida, and was released in 2010.
- **FloRun™ 157** is a medium maturity, high oleic runner-type cultivar with medium to small seed. It was developed by the University of Florida, North Florida Research and Education Center in Marianna, Florida and released in 2015. It has moderate resistance to TSWV.
- **Tifguard** has a high level of resistance to peanut root-knot nematode. Tifguard has good yield and grade potential, especially in fields where root-knot nematode is at damaging levels. It offers good resistance to TSWV and is medium maturity. Tifguard was developed by USDA's Agricultural Research Service in Tifton, Georgia.

Table 2. Seed Size and Maturity Range of Runner Peanut Varieties

Cultivar	Seed Per Pound[1]	Maturity Range[2]
AUNPL-17	701	140-145
Georgia Greener	720	130-145 DAP
Georgia-06G	660	140-145
Georgia-07W	697	140-145
Georgia-09B	725	135-140
Georgia-12Y	749	150+
Georgia-13M	796	145-150
Georgia-14N	786	150+
Georgia-16HO	690	140-145
Georgia-18RU	702	140-145
Georgia-20VHO	708	140-145
Florida-07	628	145-150
FloRun™ 107	710	145-150
FloRun™ 157	768	145-150
Tifguard	672	140-145
TUFRunner™ 727	651	145-150
TUFRunner™ 511	611	145-150
TUFRunner™ 297	625	145-150

[1]Seed per pound the average seed size in the OVT trials in Tifton, Georgia across irrigated and Non-Irrigated from 2018 to 2012, http://www.swvt.uga.edu/pct-tests.html
[2]Maturity data from Bill Branch, UGA Peanut Breeder

- **TifNV-High O/L** is a high-yielding, high-oleic, cultivar with a high level of peanut root-knot nematode resistance. It is a large seeded, medium maturing, runner-type cultivar with excellent resistance to TSWV. TifNV-High O/L was jointly developed by the USDA-ARS and the University of Georgia-Tifton Campus and was released in 2014.
- **TUFRunnerTM 727** is a medium to late maturing, high-oleic, large seeded, runner-type cultivar. This cultivar was developed by the University of Florida, North Florida Research and Education Center in Marianna, Florida, and was released in 2012. TUFRunner '727' has very good resistance to white mold, resistance to TSWV and some resistance to late leaf spot (*Cercosporidium personatum*).
- **TUFRunnerTM 511** is a medium maturing, high-oleic, large seeded, runner-type cultivar. This cultivar was developed by the University of Florida, North Florida Research and Education Center in Marianna, Florida, and was released in 2013. TUFRunner '511' has good resistance to white mold and moderate resistance to TSWV.
- **TUFRunnerTM 297** is a medium maturing, high-oleic, extra-large seeded, runner-type cultivar. This cultivar was developed by the University of Florida, North Florida Research and Education Center in Marianna, Florida, and was released in 2014. TUFRunner '297' has very good resistance to white mold, good resistance to TSWV but is susceptible to leaf spot (*Cercosporidium personatum* and *Cercospora arachidicola*).

Table 3. Three-year (24 tests) Average Disease Incidence, Pod Yield, TSMK Grade, Seed Count, and Dollar Values of Fourteen Runner-type Peanut Varieties at Multilocations in Georgia, 2018-2020.

Runner Variety	TSWV[1] (%)	TD[2] (%)	Yield (lb/a)	TSMK[3] (%)	Seed (no./lb)	Value ($/a)
Georgia-18RU	5	16	5057	78	702	951
***Georgia-16HO**	6	16	5098	75	690	931
Georgia-06G	4	13	5042	75	660	920
***Georgia-20VHO**	5	15	4873	77	708	916
***TUFRunner™ '297'**	6	19	4986	75	625	909
Georgia-12Y	4	9	5090	73	749	903
***FloRun™ '331'**	9	21	5009	74	735	902
Georgia Greener	6	14	4784	76	720	879
***Georgia-09B**	6	18	4684	76	725	861
Georgia-07W	5	15	4756	75	697	861
***TifNV-High O/L**	7	15	4568	74	662	816
***AU-NPL 17**	7	14	4624	73	701	814
***Georgia-14N**	6	16	4377	76	786	811
Tifguard	6	16	4406	74	672	796

**Represents high-oleic cultivars, 1TSWV = % Tomato Spotted Wilt Virus, 2TD = Total Disease, 3TSMK = Total Sound Mature Kernels, 4Value ($/A) is based on $355 contract price + market grade improvements. Data from Bill Branch, UGA Peanut Breeder*

Virginia Type (Tables 4 and 5)

- **Bailey** is a large seeded, medium maturing, Virginia cultivar. This cultivar was developed by the NC State University and was released in 2008. Bailey has tolerance to CBR, Sclerotinia blight (Sclerotinia minor), TSWV and white mold.
- **CHAMPS** is a large seeded, early maturing, Virginia cultivar. This cultivar was developed by the NC State University and was released in 2004. CHAMPS has moderate tolerance to TSWV but is susceptible to white mold and CBR.
- **Florida Fancy** is a large seeded, high oleic Virginia-type cultivar released by the University of Florida, North Florida Research and Education Center in Marianna, Florida. It is medium maturity with moderate resistance to TSWV.
- **Georgia-11J** is a high-yielding, high-oleic, Virginia-type cultivar. Georgia-11J is medium-late maturing with large seeds and pods. This cultivar was developed by the University of Georgia-Tifton Campus and was released in 2011. Georgia-11J is resistant to TSWV.
- **GEORGIA-19HP** is a new high-yielding, high-protein, high-oleic, TSWV and RKN-resistant, leaf spot-resistant, virginia-type peanut variety that was released in 2019 by the Georgia Agricultural Experiment Stations. It was developed at the University of Georgia, Coastal Plain Experiment Station in Tifton, GA. Georgia-19HP is similar to another high-oleic, virginia-type variety '**GEORGIA-11J**' in having the high-oleic fatty acid profile. However, during three-years averaged over multiple location tests in Georgia, Georgia-19HP had the highest pod yield, TSMK grade, dollar value, and number of seed per pound compared to the virginia-type varieties, Georgia-11J and Bailey. Georgia 19HP was likewise found to have a lower percent TSWV and total disease incidence than Georgia-11J and Bailey. Georgia-19HP combines TSWV-resistance, RKN-resistance, leaf spot-resistance, and high yield, grade, and dollar value with high-protein and high-oleic trait.
- **Sugg** is a large seeded, medium maturing, Virginia-type variety. This variety was developed by the NC State University and was released in 2009. Sugg has resistance to TSWV, CBR,

Table 4. 2019 Average Field Performance of Georgia-19HP and Georgia-11J vs. Several Other Virginia-type Peanut Varieties over Multilocations in Georgia.

Virginia Variety	TD[1] (%)	Yield (lb/A)	TSMK[2] (%)	Seed (no./lb)	Value[3] ($/A)
Georgia-19HP*	15	4761	73	581	916
Georgia-11J*	23	4921	70	478	900
Bailey II*	20	4277	68	528	762
Bailey	19	4237	69	540	754
Sullivan*	21	3850	67	556	681
Wynne*	27	3881	64	500	657

**Represents high-oleic varieties, [1]TD = Total Disease, [2]TSMK = Total Sound Mature Kernels, [3]Value ($/A) is based on $355 contract price + market grade improvements. Data from Bill Branch, UGA Peanut Breeder.*

Sclerotinia Blight and early leaf spot.

- **Sullivan** is a high-oleic, large seeded, medium maturing, Virginia-type cultivar. This cultivar was developed by the NC State University and was released in 2013. Sullivan has good tolerance to TSWV, CBR, Sclerotinia Blight, white mold and early leaf spot.
- **Titan** is an extra-large seeded, early maturing, Virginia-type cultivar. This cultivar was developed by the Virginia Cooperative Extension's Tidewater Agricultural Research and Extension Center and was released in 2010. Titan is moderately susceptible to TSWV, CBR and Sclerotinia Blight.
- **Wynne** is a high-oleic, extra- large seeded, medium maturing, Virginia-type cultivar. This cultivar was developed by the North Carolina State University and was released in 2013. Wynne has tolerance to CBR, TSWV and early leaf spot.

Table 5. Three-Year (30 Tests) Average Disease Incidence, Pod Yield, TSMK and ELK Grade, Seed Weight, and Dollar Values of Georgia-19HP vs. Georgia-11J and Bailey at Multilocations in Georgia, 2016-18.

Virginia Variety	TSWV[1] (%)	TD[2] (%)	Yield (lb/A)	TSMK[3] (%)	ELK[4] (%)	Seed (no./lb)	Value[5] ($/A)
***Georgia-19HP**	4	13	4869	75	53	554	933
***Georgia-11J**	8	19	4762	72	57	435	884
Bailey	7	19	3945	69	36	526	699

**Represents high-oleic varieties, [1]TSWV = % Tomato Spotted Wilt Virus, [2]TD = Total Disease, [3]TSMK = Total Sound Mature Kernels, [4]ELK - % Extra Large Kernels, [5]Value ($/A) is based on $355 contract price + market grade improvements. Data from Bill Branch, UGA Peanut Breeder*

Spanish and Valencia Type

There are very few valencia and spanish type peanut cultivars planted in Georgia. Most valencia and spanish cultivars are grown for green, immature peanuts to be used in boiling for roadside markets and other specialty markets.

Spanish Type (Tables 6 and 7)

- **AT 9899-14** is a high-oleic cultivar with a spreading growth habit (runner) and is late maturity. It is not resistant to TSWV. Trial yields are significantly lower than common spanish peanut cultivars. The cultivar can produce a prolific number of pods, but peg attachment is weak.
- **Georgia-04S** is a medium maturing, high-oleic, small seeded, spanish-type cultivar. This cultivar was developed by the University of Georgia-Tifton Campus and was released in 2004. Georgia–04S is highly resistant to TSWV.
- **GEORGIA-17SP** is a new high-oleic, large-seeded, spanish-type peanut variety that was released in 2017 by the Georgia Agricultural Experiment Station.
- **Olé** is a high-oleic spanish-type cultivar released by USDA-ARS, Stillwater, Oklahoma. Olé has resistance to Sclerotinia blight.
- **OLin** is a high-oleic, medium maturing, spanish-type cultivar. This cultivar was developed by Texas A&M University and was released in 2002.
- **Pronto** is a relatively large seeded spanish type jointly released by the Oklahoma and Georgia Agricultural Experiment Stations. It has a maturity of 120-130 days and has yields and grades similar to Tamnut 74. Pronto's greatest advantage over other spanish cultivars is its ability to yield relatively well and grade high under short seasons and limited soil moisture.
- **Schubert** is a high-yielding cultivar released by Texas A&M AgriLife in 2012.
- **Spanco** is a high-yielding, spanish-type cultivar released from Oklahoma State University, Spanco is early maturing (similar to Pronto), and has good yield potential.
- **Tamnut OL06** is a Texas A&M University spanish line that has a large-pod and large seed, is a high-oleic cultivar with potential use in the runner market. Maturity and yield potential are similar to Tamspan 90.
- **Tamspan 90** was released from Texas A&M University in 1990, this cultivar exhibits typical spanish growth habit. Tamspan 90 has a maturity of 140 to 145 days. It has good yield potential.

Table 6. Seed Size and Maturity Range of Spanish Peanut Cultivars

Cultivar	Seed Per Pound	Maturity Range
Tamnut 90	1021	140-145**
AT 9899-14	NA	10-14 days later
Georgia-04S*	1023	10-14 days earlier
Olin*	1009	5 days later
Pronto	1020	10-14 days earlier
Spanco	1051	10-14 days earlier
Tamnut OL06*	906	Same

**High Oleic , **Maturity in West Texas. Data from Bill Branch, UGA Peanut Breeder.*

Table 7. Ten-Year (20-Tests) Average TSWV and TD Incidence, Pod Yield, TSMK Grade, Seed Size, and Dollar Value of Six Spanish-Type Peanut Varieties in Georgia, 2010-2019.						
Spanish Variety	**TSMV[1] (%)**	**TD[2] %**	**Yield (lb/A)**	**TSMK[3] (%)**	**Seed (no./lb)**	**Value[4] ($/A)**
***Georgia-17SP**	4	11	4711	75	886	855
Georgia Browne	5	18	4278	72	1093	756
***Georgia-04S**	5	17	4164	71	1116	731
Tamspan 90	10	30	3136	65	1117	512
***Tamnut-OL06**	11	34	3138	63	994	492
***OLin**	9	33	2573	64	1182	415

** High-oleic. [1]Percentage of tomato spotted wilt virus (TSWV) incidence, [2]Percentage of total disease (TD) incidence, [3]Percentage of total sound mature kernel (TSMK), and [4]Value ($/A) is based on $355 contract price + market grade improvements.*

Valencia Type (Tables 8 and 9)

The latest valencia varieties released by the University of Georgia are Georgia Valencia and Georgia Red. Like with other market types, some valencia varieties may not be suited for our growing area in Georgia due to their lack of disease resistance and yield potential.

- **GenTex 101** has a high percentage of three- and four-kernel pods. It is similar in maturity to New Mexico Valencia C, but generally yields slightly less than New Mexico Valencia C or GenTex 102.
- **GenTex 102** is similar to GenTex 101 in terms of maturity, but yields higher by several hundred pounds. Maturity and yields are comparable to New Mexico Valencia C.
- **GenTex 136** is a large-seeded, large pod cultivar. Yields are comparable to other top-yielding valencias, but may grade lower because of the thick hull. Maturity is similar to New Mexico Valencia C. Caution should be taken at harvest to minimize digging and combine losses.
- **Georgia Red** is Georgia Red is a high-yielding valencia-type cultivar that is an excellent choice for the fresh market boiling trade in the Southeast. Georgia Red is similar to Georgia Valencia in Maturity and growth habit.
- **Georgia Valencia** is a high-yielding valencia-type cultivar that is an excellent choice for the fresh market boiling trade in the Southeast. This cultivar offers high-yield performance, large pods and seed size and compact bunch growth habit. Georgia Valencia offers better disease tolerance with similar maturity as other valencia cultivars.
- **NuMex-01** is a high oleic valencia cultivar, developed by the New Mexico Agricultural State University Experiment Station located at Clovis, NM released in 2013. NuMex-01 has a higher yield potential than NM Valencia A. NuMex-01 has a similar maturity to that of NM Valencia A.
- **New Mexico Valencia A** has a high percentage of three- and four-kernel pods. The cultivar has the potential to emerge more quickly than New Mexico Valencia C, but takes a few days longer to reach maturity, approximately 130 to 135 days.

- **New Mexico Valencia C** has an excellent percentage of three- and four-kernel pods. New Mexico Valencia C emerges one to three days later than the New Mexico Valencia A, but relative maturity may be sooner. It normally yields as well as or slightly higher than most other valencia cultivars.

Table 8. Seed Size and Maturity Range of Valencia Peanut Cultivars		
Cultivar	**Seed Per Pound**	**Maturity Range**
Georgia Red	955	130-135
Georgia Valencia	879	Same
New Mexico Valencia A	1081	Same
New Mexico Valencia C	1063	5 days Earlier
GenTex 101	940	5 days Earlier
GenTex 102	1250	5 days Earlier
GenTex 136	890	5 days Earlier

Data from Bill Branch, UGA.

CULTIVAR SELECTION

Before a grower selects a cultivar(s) to grow, he or she should consider several factors including soil type, environmental conditions, pest pressure, maturity, yield and grade potential, and market availability. Growers should also visit with their local county extension agent to review the University research and recommendations to ensure they make the most informed decision regarding peanut cultivars and production practices best suited for each cultivar (i.e. cultivar selection with respect to leaf spot susceptibility in high pressure situations such as short rotation or reduced fungicide programs, as seen in Figure 1 below).

Table 9. Seventeen-Year Average Field Performance of Five Valencia-Type Peanut Cultivars in Georgia, 2001-2017.

Valencia Variety	Yield (lb/A)	TSMK[1] (%)	Seed (no./lb)	Value[2] ($/A)
Georgia Valencia	2571	58	803	407
Georgia Red	2040	63	981	356
N.M. Val. C.	1612	57	1204	254
Val. McRan	1629	55	1195	252
N.M. Val. A.	1537	55	1245	235

[1]TSMK = Total Sound Mature Kernels and [2]Value ($/A) is based on $355 contract price + market grade improvements. Data from Bill Branch, UGA Peanut Breeder

Table 10. Disease Risk Index

**** The higher the points, the higher the risk for disease development.**

Cultivar[1]	Spotted Wilt Points	Leaf Spot Points	Soilborne Disease Points
			White mold
AUNPL-17	10	15	15
Bailey[3]	10	15	10
Florida-07[2]	10	20	15
Florida Fancy[2]	25	20	20
FloRun™331[2]	15	20	15
Georgia-06G	10	20	20
Georgia-07W	10	20	15
Georgia-09B[2]	20	25	25
Georgia-12Y[5]	5	15	10
Georgia-13M[1,2]	10	30	25
Georgia-14N[1,2,4]	10	15	15
Georgia-16HO[2]	10	25	20
Georgia-18RU[1]	10	25	20
Georgia Green	30	20	25
Georgia Greener[3]	10	20	20
Sullivan	10	25	15
Tifguard[4]	10	15	15
TifNV-HiOL[2,4]	5	15	15
TUFRunner™ '297'[1,2]	15	25	20
TUFRunner™ '511'[2]	20	30	15

[1]Adequate research data is not available for all cultivars with regards to all diseases. Additional cultivars will be included as data to support the assignment of an index value are available.
[2]High oleic cultivar.
[3]Cultivars Georgia Greener, and Bailey have increased resistance to Cylindrocladium black rot (CBR) than do other cultivars commonly planted in Georgia.
[4]Tifguard has excellent resistance to the peanut root-knot nematode.
[5]Georgia-12Y appears to have increased risk to Rhizoctonia limb rot and precautions should be taken to protect against this disease.

Figure 1. On-farm cultivar trial, Effingham County, GA --- Cultivar reaction to leaf spot diseases

PHYSIOLOGY

Chapter 7
Peanut Physiology

C.K. Kvien, C.C. Holbrook, P. Ozias-Akins, C. Pilon, A.K. Culbreath, and T.B. Brenneman

Peanut is an impressive plant that adapts to many stresses both abiotic (temperature and moisture) and biotic (diseases, nematodes, and insects). Although grown as an annual, the peanut - botanically - is a perennial, herbaceous, nitrogen-fixing legume, giving it important advantages. Perhaps the greatest advantage is indeterminate flowering and fruiting, enabling the plant to recover from a stress and produce a reasonable yield, as long as the temperature stays above freezing. From planting through post-harvest, knowing more about the physiology of the plant will improve management decisions.

Seed

Mature, fully-developed seed have more developed embryos, energy, and a greater ability to quickly develop large root and shoot systems. Seedlings, from mature seed, are better able to compete with weeds and tolerate stress. Past research has shown field emergence of immature seed is 65% compared to 75% for mature seed even within the same seed size. Total plant biomass 30 days after planting will be greater (up to 30% more) with mature seed than immature seed of the same seed weight. Generally, the larger seed sizes have a greater percentage of mature seed (see % maturity vs seed size graph). High-count seed may produce more plants per pound, yet field emergence will be lower, seedlings weaker, and at harvest, yield and grade will be lower than fields planted with larger, mature seed.

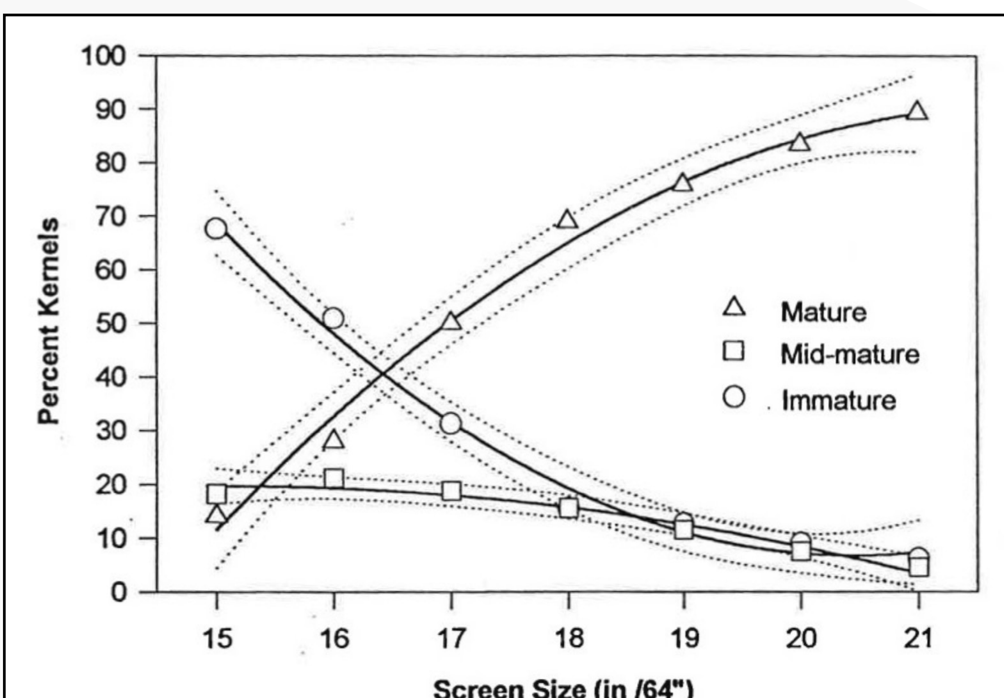


Figure 1. Maturity distribution of Florunner peanut by seed size.

There is an easy way to determine seed maturity. Count out a hundred seed and sort them into 3 piles according to their appearance. An immature seed (left seed in Figure 2) is more elongated than mature seeds, and has a light pink seed coat with longitudinal wrinkles, a bit like a raisin. This is because a seed first grows to its full size, yet is mostly water. As the seed matures, the water is replaced by carbohy-drates, proteins, and oils. Thus, when immature seed is dried, the seed will shrink much more than the seed coat (testa) - similar to how a grape turns into a raisin. A seed that is more mature, yet not fully mature, will have a darker pink testa with a smooth surface and a more rounded shape (middle seed in Figure 2), and a fully mature seed will be dark pink to brown and take on a waffle like pattern with brown splotches, result-ing from the seed pressing hard into the hull and taking on the pattern of the inside of the hull, where veins cross each other (right seed in Figure 2).

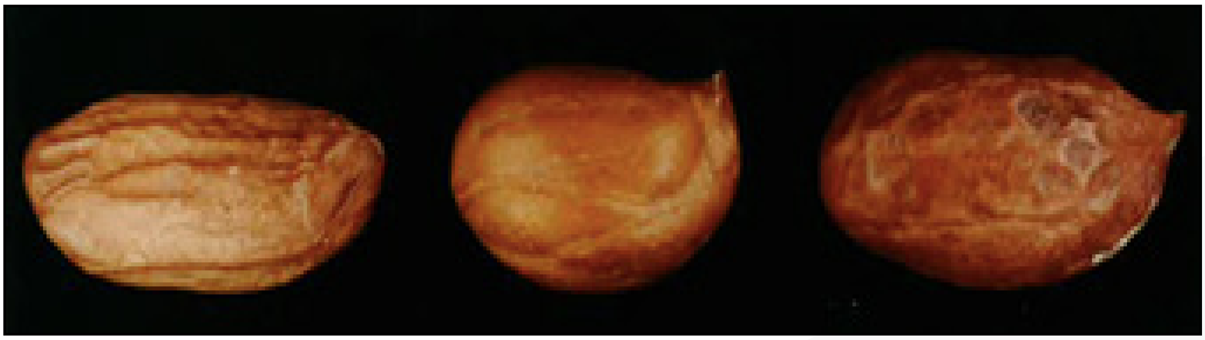


Figure 2. Surface characteristics of peanut seed as they mature – immature have longitudinal wrinkles, similar to a raison, mid mature seed have a smooth seed coat and mature seed have taken on a waffle like texture and brown splotching resulting from being pressed tightly against the pod shell interior.

Figure 3. Peanut seed split in half, showing the cotyledons, first true leaves, and embryonic root.

Figure 4. Peanut seedling with first leaves and develop-ing root.

The peanut seed (Figure 3) is made up of two cotyledons (which contain storage proteins, carbo-hydrates, and oils) and the embryo. The embryo's parts include the plumule (which will become the first true leaves), the hypocotyl, and the embryonic root (which protrudes slightly from the seed). Seed should be handled with care as mechanical dam-age to the seed coat or to the embryonic root will affect germination and plant growth. Exposing the seed to high temperatures, as would happen inside a seed bag left in the sun, will also reduce seed viability.

Germination

Seeds need moisture to germinate, so planting into a moist seedbed is preferred over planting into a dry one and hoping for rain. There are slight differences between cultivars in optimum germination temperature. In general, a sustained (over 3 days)

4-inch soil temperature between 68 ºF and 90 ºF is best for germination. Below 65 ºF, seeds produce a higher percentage of plants with short, stubby curled roots and thick hypocotyls. A sharp decline in germination, seedlings with black root tips and necrotic areas on roots and hypocotyl occur when soil temperatures exceed 95 ºF.

Root Development

Peanut establishes a deep and widespread root system early in the growth season and will continue to develop roots throughout the growing season (Figure 5). Like many plants, peanuts use their stored seed energy to first establish a root system. For the first month, over half of the weight of the peanut is in the root system. Roots will continue to grow throughout the season, yet a higher proportion of the plant's weight will be in the leaves and then the pods.

Figure 5. 30 days after planting, foliage may be 10" tall, yet the root system may be 36" deep.

Figure 6 shows development of the root system, and its ability to extract water at different

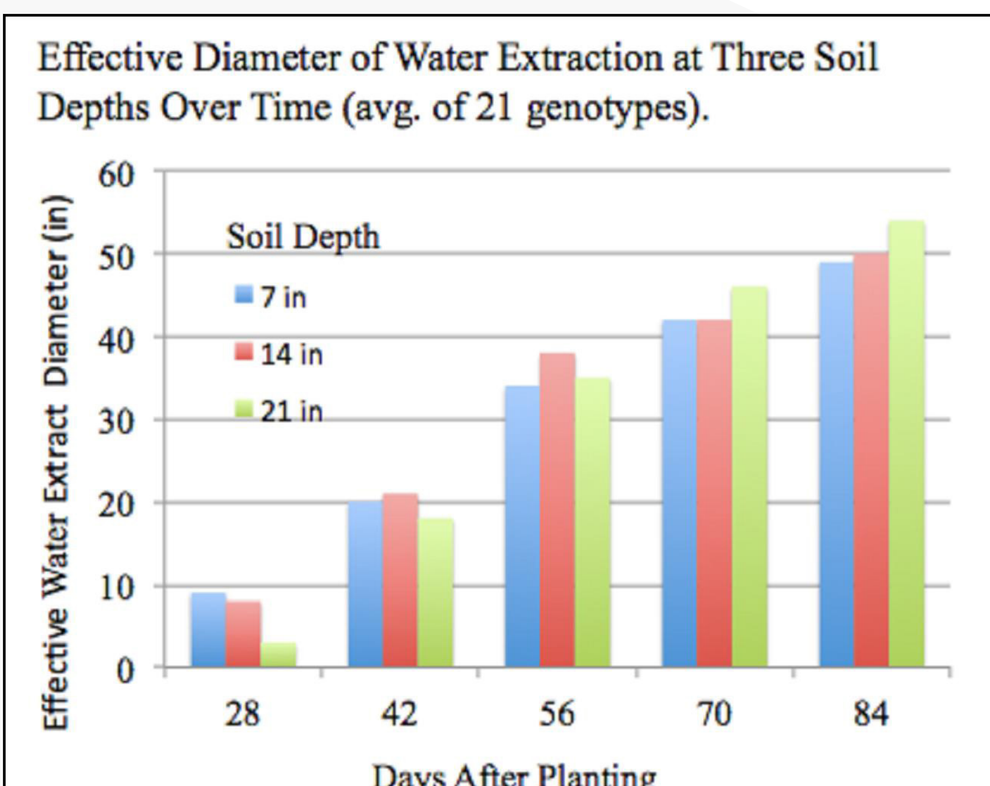


Figure 6. Effective diameter of water extraction at three soil depths over time (avg. of 21 genotypes).

depths over time (from 28 to 84 days after planting) at three soil depths (7 in., 14 in., and 21 in.). This research showed continued root growth over the growing season, which is what you would expect to see with a perennial plant. The effective diameter of water extraction continued to expand throughout the test period, yet the rate of expansion began to slow about 56 days after planting, which would be expected as the plant begins to divert energy towards pod production.

The plant will continue root growth in areas of moist soil, yet as the season progresses, a greater proportion of carbohydrates produced in the leaves will go to developing pods. At 16 days after planting, about 50% of the plant's weight will be in the roots; at 30 days, about 40% will be in the roots, and by 40 days after planting, roots will be about 33% of the total plant weight.

In addition to seed size, seed maturity plays a large role in early root and shoot development. A mature seed has a better developed embryo than an immature seed, and the types and percentages of carbohydrates, proteins, oils, and other nutrients in mature seeds are better matched for early season root and shoot development. If you dig a peanut up several days after planting you will see rapid root growth. After the second week, the nutrients stored in the seed are almost used up and the plant is relying on the energy now being produced in the young leaves to keep both root and shoot developing. Like plant growth in general, many factors influence continued root growth and water/nutrient uptake by roots. Soil moisture, pH, and nutrients, genetics, past crops, pests (weeds, diseases, nematodes, insects) canopy growth and fruiting patterns, air/soil temperatures, field traffic, and soil conditions in general are important.

The highest density of peanut roots will be in the upper soil profile, yet roots can be found over six feet deep if conditions are right. Peanut roots do not "look" for water, they grow in areas with water, needing moist soil to develop in. An early season (20 to 50 days after planting) drought will reduce root growth in the upper soil layer unless irrigation water is added. Irrigating to keep the soil profile moist throughout the season is a good idea, as the demand for water increases as the season progresses. A favorable pH (6.0-6.5) and available calcium helps root growth. Root development is also aided by root channels made by previous crops, which is another reason, along with decreased disease potential, that following a grass crop with a dense fibrous root system, helps.

Peanut genotypes that have abundant roots deep in the soil often have enhanced drought tolerance. Genotypes with large, deep root systems are of-ten classified as drought responsive as the root mass increases in deeper soil layers in response to drought. Yet, root growth in the deeper soil layers would be expected, as roots need moisture to grow, and the deeper layers will be where that moisture is as drought develops. In research studies involving mid-season droughts, a strong, positive relationship was found between percent root mass in the deepest soil layers and yield.

Canopy Development

Variety, planting date, seeding rate, row spacing, twin or single rows, soil moisture, and many other factors determine how fast a peanut canopy develops. As shown in the image (opposite page), some varieties develop much larger canopies than others. Twin rows generally cover the bed 1-2 weeks quicker than single rows, even at the same number of seed per acre.

Figure 7. Canopy development of five peanut lines.

In general, because of cooler soil and air temperatures, canopy growth, flowering and seed growth is slightly slower for peanuts planted in late April than in May. Early crop growth rate (3 to 5 weeks after planting) can be 50% slower in April than May for cultivars such as Georgia-06G, Georgia-14N, and TifNV. At harvest, it is likely that the April plantings will be ready to harvest only one week earlier than those planted 2 to 3 weeks later. The peanut's tetra-foliate, pinnately compound leaves are the main source of photosynthesis and energy production. The best temperature for photosynthesis and dry matter production is 86 ºF. Higher plant populations will change canopy architecture, as the main stem will be taller, with slightly more dry weight than stem tissue in less dense plantings. Densely planted peanuts have greater competition for sunlight.

Many biotic and abiotic stresses affect canopy growth. Nematodes reduce a plant's capacity to gather water and nutrients, reducing canopy growth. Pod growth and development reduces canopy growth, as nutrients flow in greater proportion to the developing pods. Likewise, reduced pod set, due to unfavorable temperatures, soil moisture, or pod feeding insects will result in greater canopy growth.

The partitioning of photosynthates to root, shoot, and pods over time varies by variety, pod load and environmental factors. Plants with a heavy pod load send most of the newly formed photosynthates to the pods. The two drawings in Figure 8 provide data using radio-labeled carbon dioxide to show where newly formed photosynthates are translocated.

Two hours after the leaves on the main stem (N) were exposed to carbon-14-labeled CO_2, 85% of the newly formed photosynthates remained in the main stem. After 2 days, only 28% remained in the main

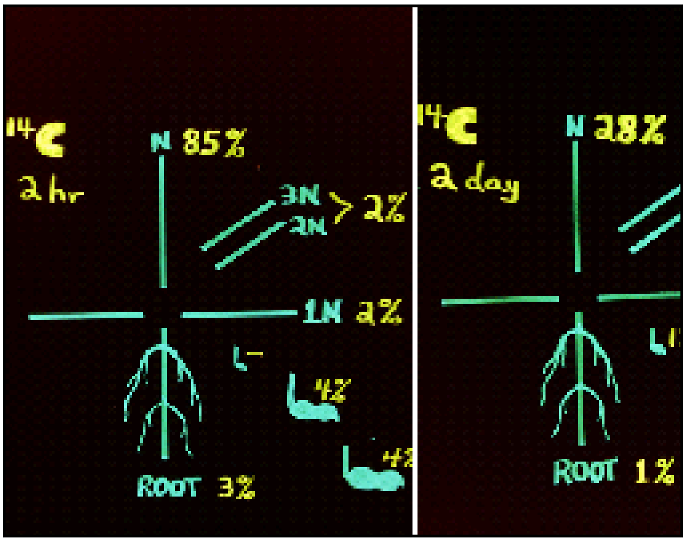


Figure 8. Photosynthate partitioning over time from a pulse of $14CO_2$ to the main stem (N).

stem, and 68% was in the pods.

Peanut scientists often debate the pros and cons of indeterminacy in peanut. Would yield and grade be higher if the plant diverted all of its energy to pod development at a certain point in the season, as do plants such as corn and soybean? If growers were able to control all potential biotic and abiotic stresses, higher yields might result. Yet new leaves rapidly generate more photosynthates than they cost the plant to make. The value of the peanut's indeterminate nature is that it can live through a stress and rapidly develop pods once the stress is relieved - so long as soil moisture remains favorable and temperature stays above freezing. A determinate plant does not have that capability.

Other often debated questions are what is the optimum leaf area index (LAI)?, and what value are new leaves late in the season? Would that energy be better placed in pods? Some varieties generate six inches of leaf for every inch of soil below them (LAI of 6), while other varieties may have an LAI of 4. Often, yet not always, varieties with higher LAIs are later maturing. Peanut leaves rapidly increase their photosynthetic capacity from the time they unfold as new leaves until they reach peak capacity, about 20 days later. By the time leaves reach 50 days old, they are only about 20% as efficient as they were at their peak. Thus, late season leaf growth likely adds more photosynthates for pod development than it uses to develop the new leaves.

Flower and Pod Development

Boote developed a system for identifying peanut stages of growth (see image below). Most peanut varieties begin flowering (R1 stage) around 30 days after planting seed. Number of flowers produced on

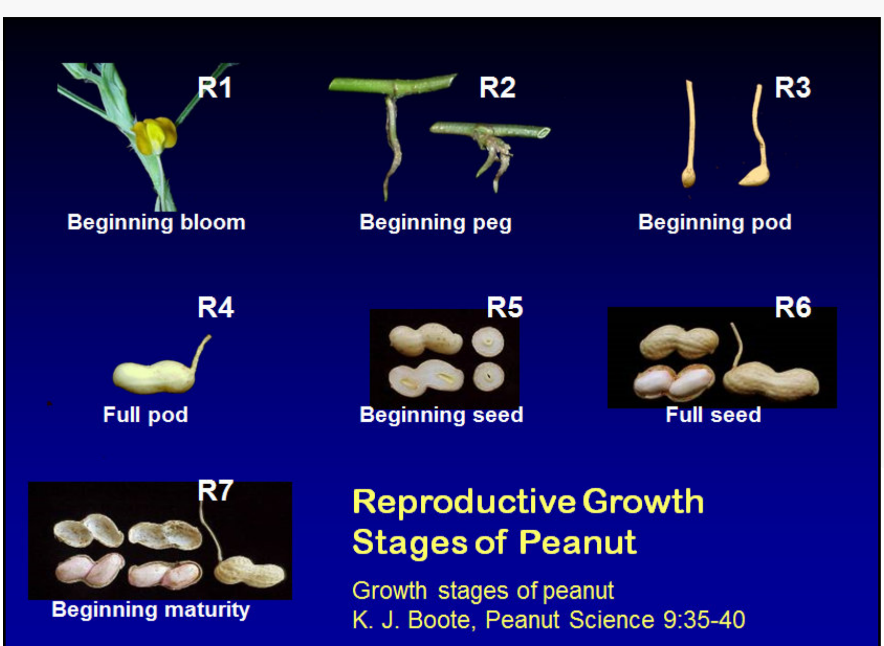


Figure 9. Reproductive Growth Stages of Peanut – K. J. Boote (Peanut Science 9 35-40).

a daily-basis will increase up to 60 days after planting, then decrease to just a few flowers per day during pod filling.

Flowers usually last one day – opening in the morning already fertilized, and wilt in the evening. Ten days after flowering begins, pegs will be visible from the nodes that flowered (R2 stage) growing downward into the soil (due to positive geotropism) until reaching a depth of about 1 1/2 inches. The depth at which the peg stops is dependent on soil type (light penetration). Pegs will go deeper in sandy soils than in heavy clays (mainly due to greater light penetration in sand).

Figure 10. Plant and pods near harvest (about 135 days after planting). Note the plant continues to flower (although at a very low rate).

Flowers located at an above ground height of 6 inches or lower will produce most of the pegs that develop into pods.

The number of days it takes for a pod to mature is dependent on the variety and the environment. Pods from early maturing varieties may require 60 days or less to mature. Late maturing varieties may need 80 days or more to mature. After pods reach maturity, nutrient flow to the pod stops and the pod stem weakens over the next few weeks until becoming too weak to mechanically harvest.

Figure 11. The color change in the mesocarp used in hull-scrape profiling generally begins where the basal seed is attached to the pod. This is the area where color is determined to place the pod on the profile board.

From 30 days after planting until harvest, the plant will continue to grow leaves and roots, and produce flowers and pods. The amount of energy the plant puts to each is dependent on the variety, pod set, and the environment.

The Hull-Scrape Technique, developed in the early 1980's for the Florunner variety, is still helpful in assessing the reproductive status of the crop. This technique focuses on the changing color of the mesocarp as the pod matures. Immature pods have a white mesocarp, which, as the pod matures, goes through a light and dark yellow, to an orange, brown and ultimately black at full maturity.

The images of sectioned pods (Figures 12-14) show three of the stages of pod development. The top section shows a very young pod, just 7 days after the peg entered the ground. The pod is largely water filled parenchyma cells with the testa of two seeds beginning to form. This pod will have a white mesocarp and be classified in column 3 of the hull scrape. The middle pod is 20 days old and has a yellow mesocarp - hull scrape column 8. The bottom section shows a nearly mature pod, about 65 days after the peg entered the soil. This pod would be classified in column 19 or 20 and have a dark brown to early black mesocarp in the pod's "saddle" area.

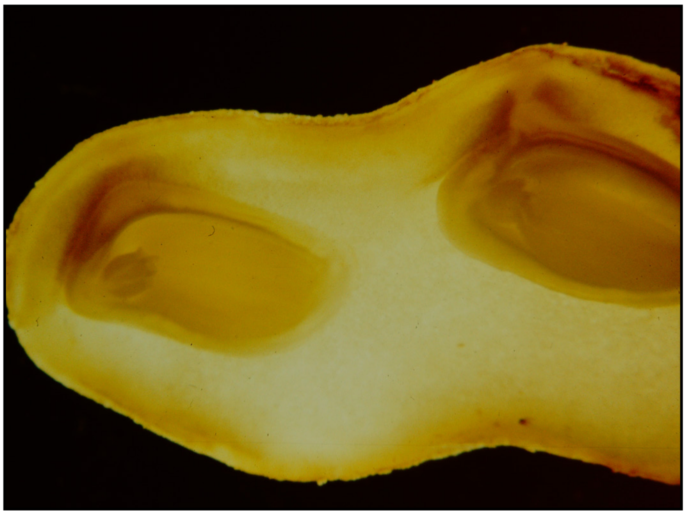


Figure 12. Developing peanut pod, showing the seed just beginning to form.

Generally, peanuts set a crop in a bell shaped curve, as shown on the lower hull scrape board example in Figure 15. Once this initial group of pods is set and maturing, the plant will continue to flower and set fruit, yet at a reduced rate throughout the season. The plant will produce a reserve group of very immature peanut that is held primarily in the white mesocarp class (hull scrape columns 1-4). A portion of the pods in this reserve group will continue to mature, the number depends on plant resources available and environmental conditions. Yet, if a stress, like a mid-season drought period, interrupts pod set and fill a split-crop will result reducing yield and grade as shown in the top profile board in Figure 15.

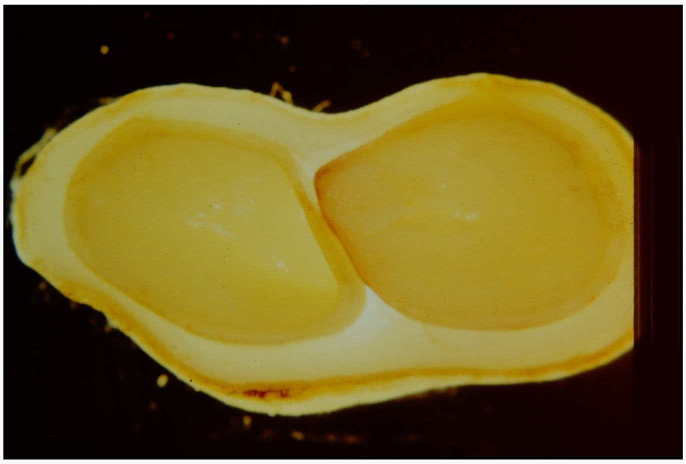


Figure 13. Peanut pod, just after reaching full size, note seed cotyledons are beginning to fill.

Thus, along with a harvest date prediction, the Hull-Scrape profile board also provides growers with a season long analysis of pod set and development. The impact of stresses, such as drought or temperature will be seen in the profile board as interruptions in pod development - fewer pods will be in the columns corresponding to the dates of the stress.

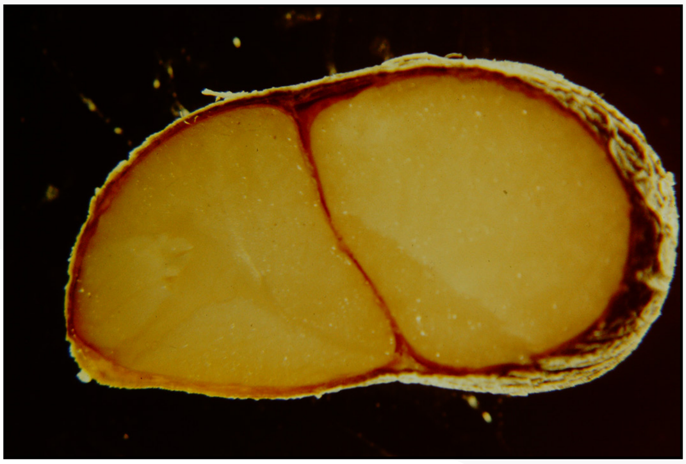


Figure 14. Mature seed.

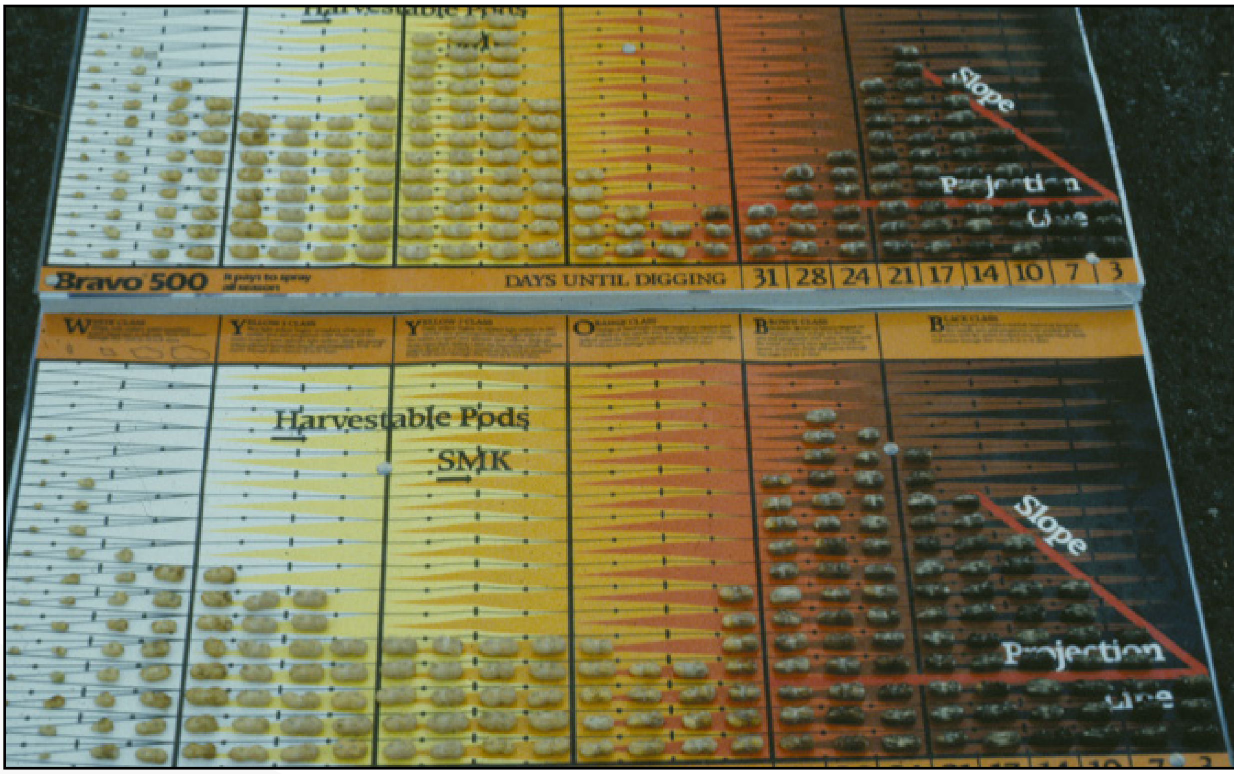


Figure 15. Profile board showing normal crop development (below) and a split crop, due to a mid-season water stress (top).

The math imbedded in the hull-scrape chart is cultivar dependent. Yet the method can relatively easily be adapted to most varieties. For example, the current chart has 25 columns – each column representing 3 1/2 days of development time after the peg enters the soil. Full seed weight occurs when the pod first enters the black category (the 20th column – which epresents 70 days of seed growth).

When the method was first developed, the number of columns in the black category were determined from multiple digging date experiments, and found that Florunner pod stem was likely to be too weak to harvest the pod, 21 days after the seed reaches maturity – thus 6 columns in black – representing 21 days. Yet, the strength of the pods stem will vary, as leaf and limb diseases will decrease pod stem strength, harvest soil moisture conditions and pod size will also impact pod stem strength.

The chart uses the first column on the right with 3 pods in it to predict best harvest date. This column represents the break-even point - when pod weight loss equals the weight gained by the rest of the pods. The reason for 3 pods is that the chart is based on the use of approximately 200 pods. Three pods (each with 70 days of growth) represent the same amount of weight gained by the rest of the pods on the chart gain each day. While the weight gain in each class is not perfectly linear, it is close, and the basic idea of calculating the weight gains and weigh losses as the field matures is sound. The best harvest date will balance weight gains and losses, the state of leaf and limb diseases, past and expected weather, labor and equipment availability, soil conditions, and many other issues.

The maturity distribution of seed and pod weight over time, as averaged over 7 varieties, is presented in the graphs. As the season progresses, the percent of weight in mature pods and seed (brown and black) increases until about 149 days after planting,

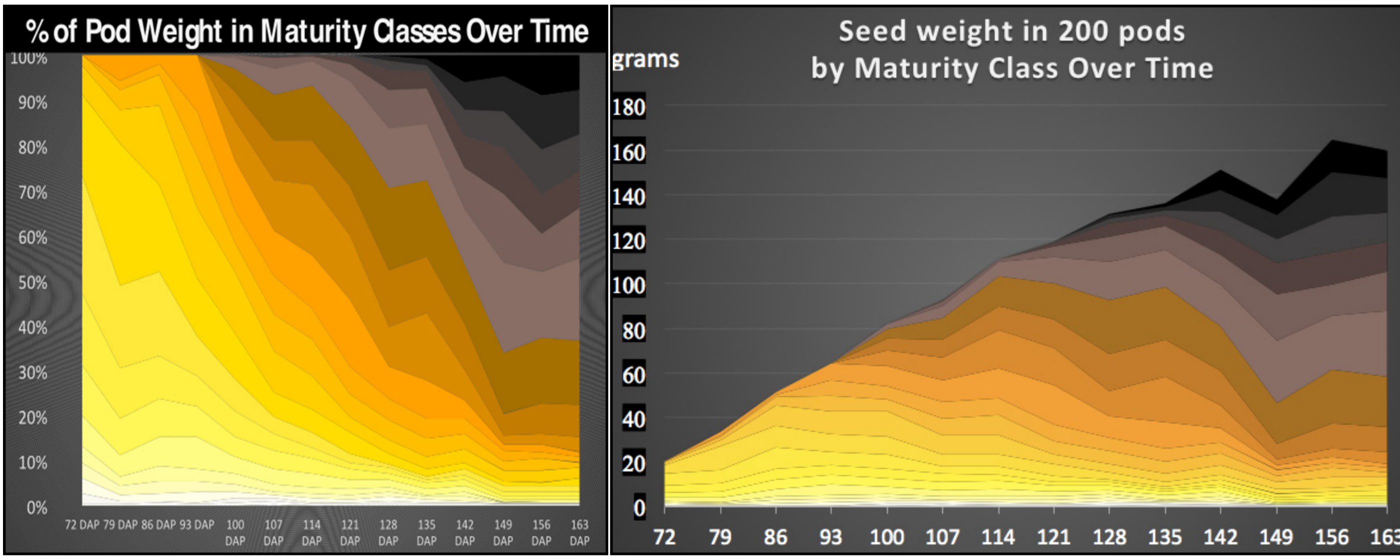


Figure 16. The graph on the left shows the % of pod weight in the different maturity classes over time (avg. of 7 cultivars). The graph on the right shows seed weight in 200 pods by maturity over time (avg of 7 cultivars).

which was the average optimum digging date for the 7 varieties tested.

In general, the improved disease resistance in many current varieties along with improved fungicides have enabled growers to push the digging date a little further out, resulting in more fully mature seeds, higher yields and grades. Yet if disease pressure becomes heavy, as in many fields in 2017, growers may need to harvest their crop earlier, as less photosynthate will be available to fill pods and pod stems will weaken resulting in more pods left in the field.

Usually, digging early will result in lower yields and grades, and more immature peanut seeds – with a higher risk of *Aspergillus flavus* contamination, and off-flavors. Digging late may also result in lower yields, grade, and increased immature peanuts. Figure 17 shows the average (of 7 varieties) reduction in yield resulting from missing the best harvest date by one or two weeks (early and late).

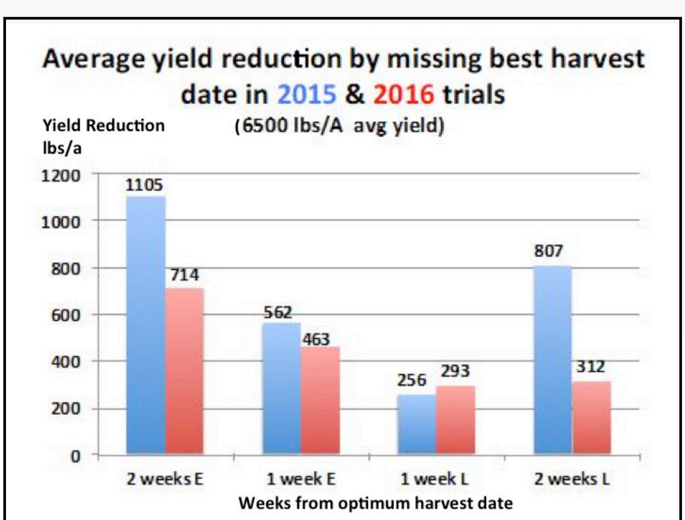


Figure 17. Average yield reduction by missing harvest date by one or two weeks early and late (avg of 7 cultivars).

Adaption of the Hull-Scrape chart for aiding harvest date scheduling of current varieties is relatively straightforward. Combining varieties with improved disease resistance with a good rotation, irrigation, fertility program, and the use of a good disease control program will result in the plants being able to hold their most mature pods longer.

The results using the current Hull-Scrape board to predict best harvest date for 5 of current varieties is presented below:

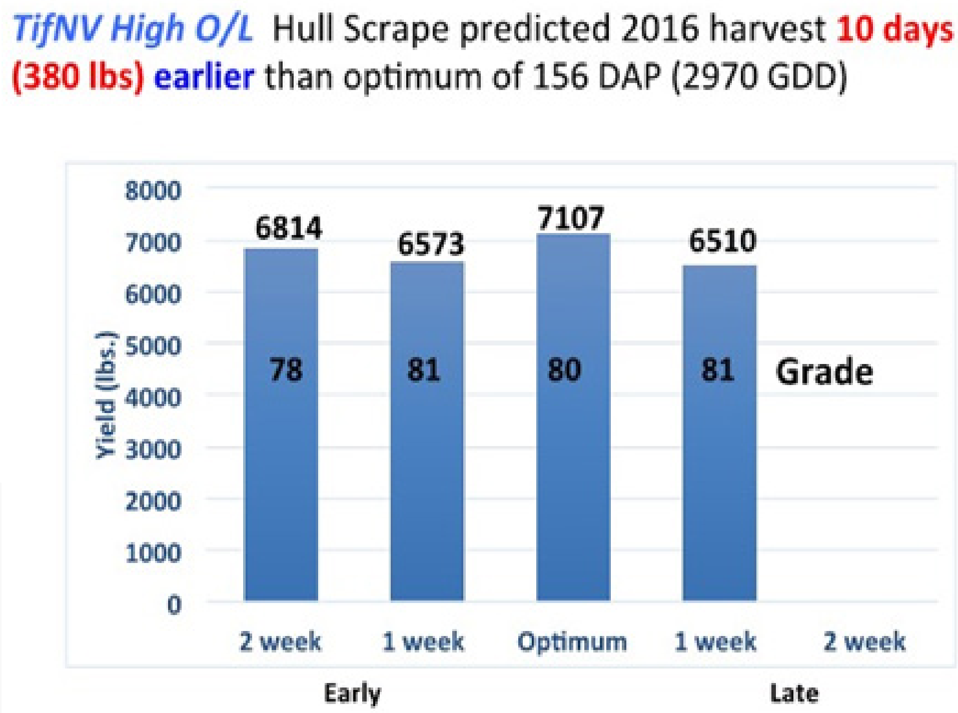


Figure 18.

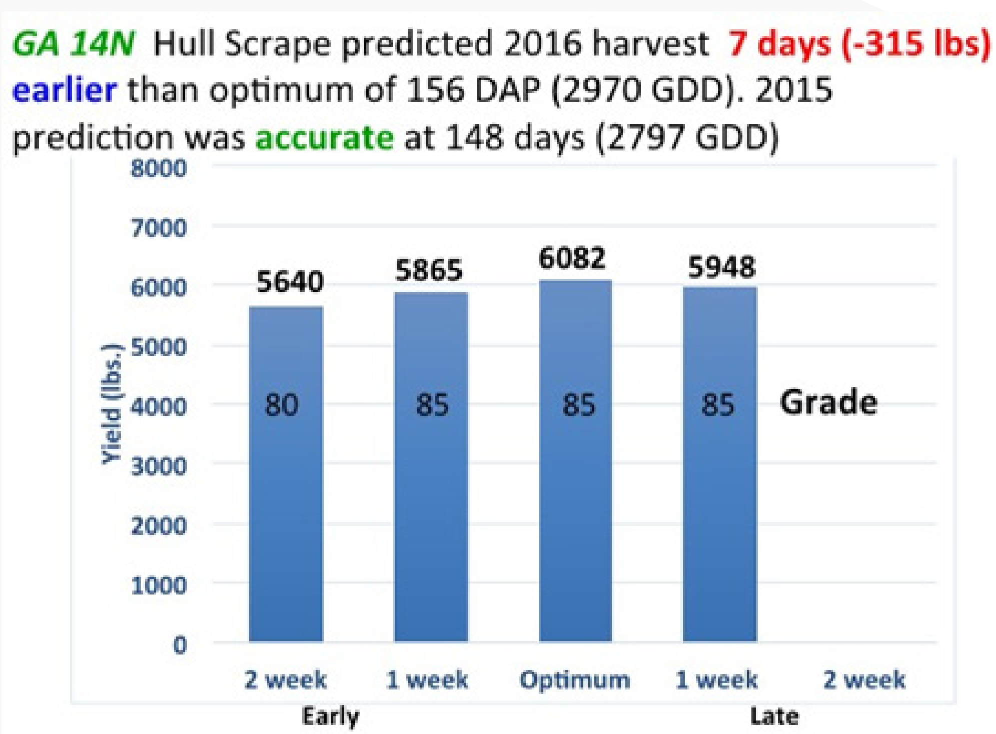


Figure 19.

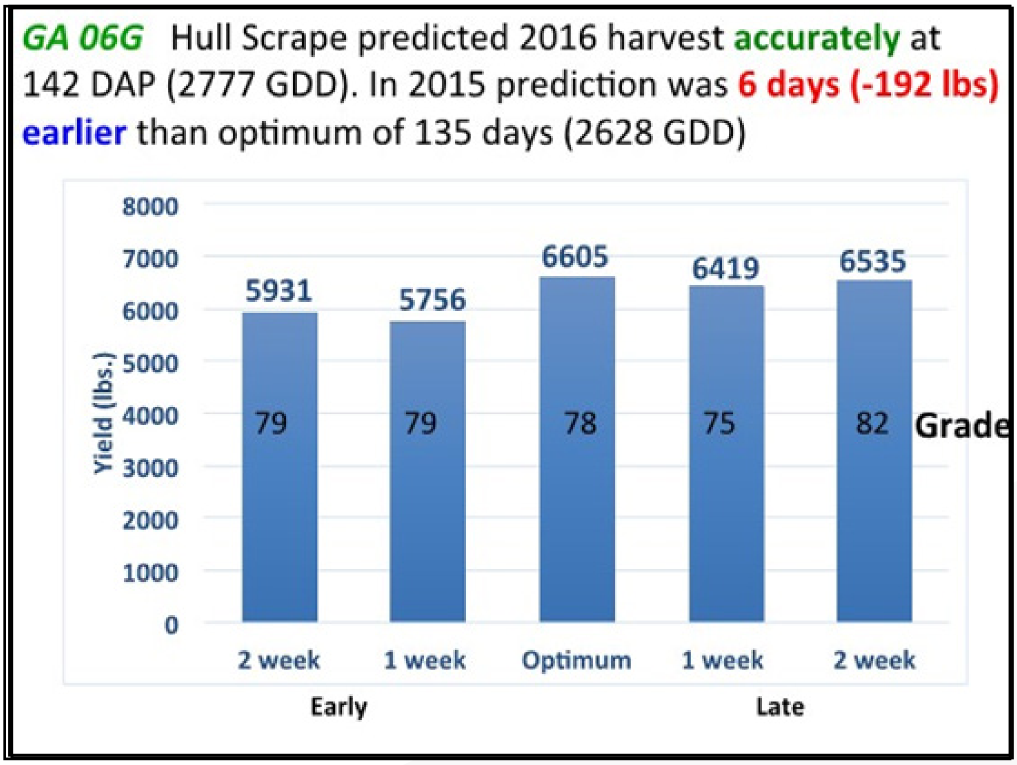


Figure 20.

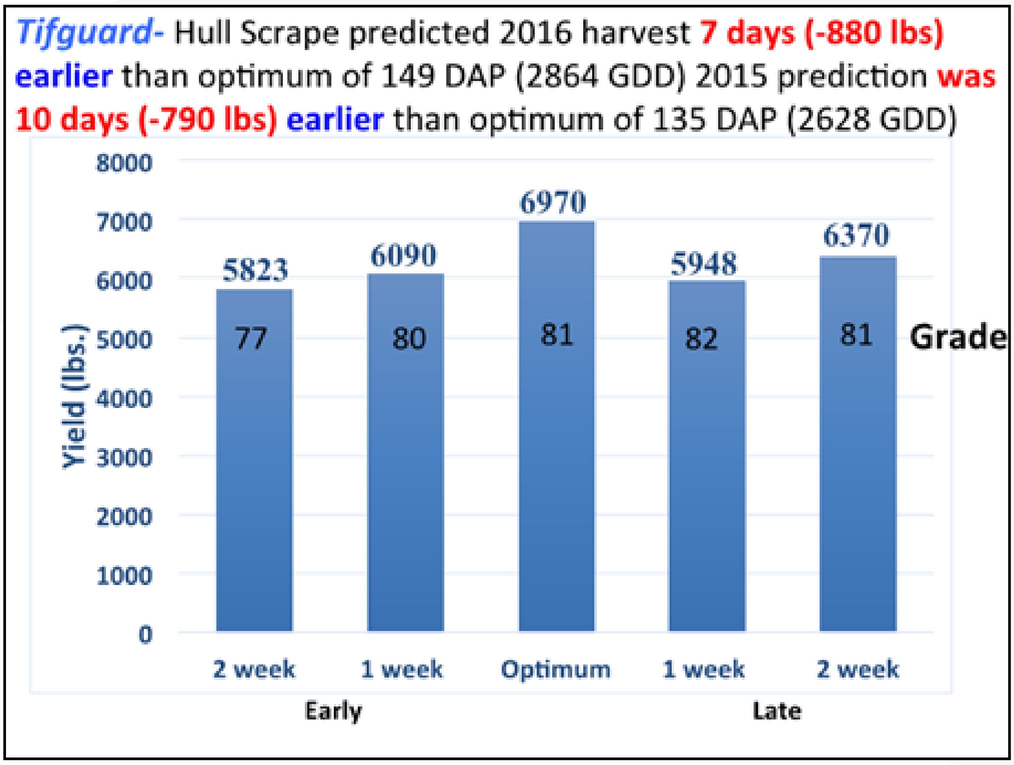


Figure 21.

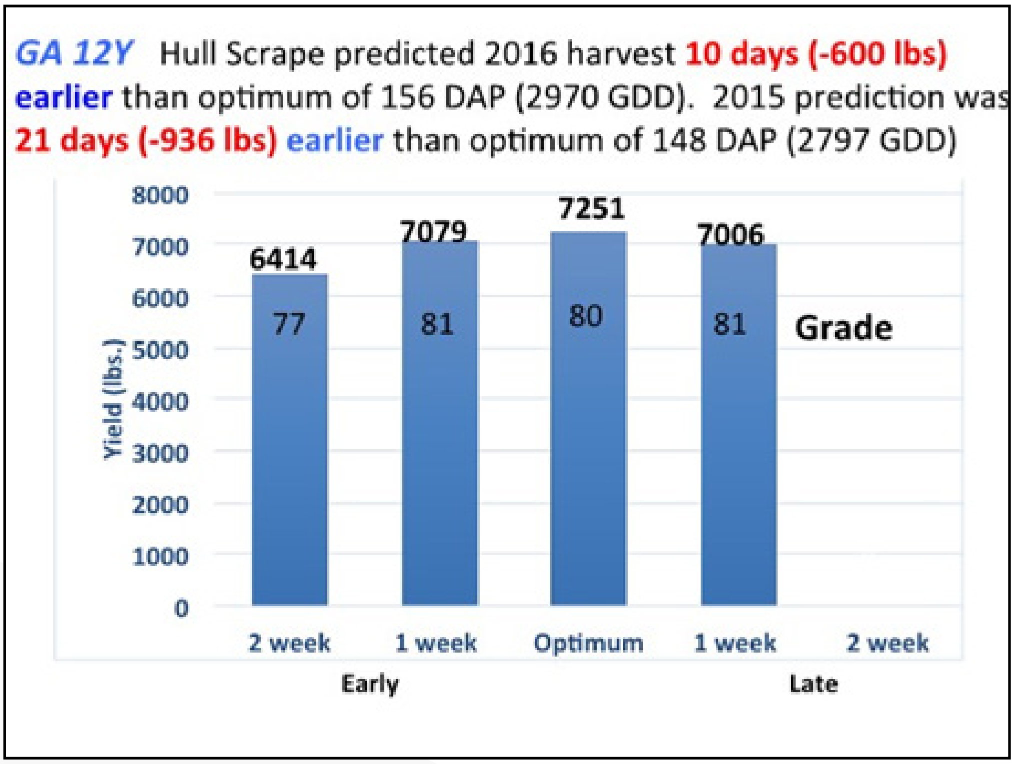


Figure 22.

In general, when foliar and soil borne diseases are under control, digging a week earlier than optimum was more detrimental than digging a week late. Yet, in fields with significant soil borne disease pressures, digging earlier than what the Hull Scrape procedure predicts may minimize pod shed and result in higher yields. Heavy leafspot pressure will also result in earlier harvests to prevent excessive pod shed.

As noted in the graphs, when diseases are under control, the current hull-scrape chart is fairly accurate for the varieties GA-06G, GA-14N, and TUFRunner 297. Yet the chart is predicting an earlier harvest, by 7-14 days, than is optimum for optimum yield for TifGuard, GA-12Y, and TifNV. When disease is under control, the penalty for being one week early or late was less than 5% for GA-12Y, GA-14N, and TUFRunner 297. Yet missing the optimum date by one week resulted in 15% loss for TifGuard and some other cultivars. Growing degree days for each of these harvests was calculated, but did not accurately predict the best harvest date in these cases.

Stress Response

The peanut is exceptional at managing / recovering from stress. For example, the plant responds to drought in several ways. Roots continue to develop in the lower moist soil depths, while flowering, peg and pod development will slow or stop - with the emphasis of those pods closest to maturity receiving priority for continued development. Stomates in the leaves will close and the leaves will wilt, folding so the silvery, more reflective, under side of the leaves are exposed, yet angled nearly parallel to the sun's rays - thus minimizing exposure. The plant canopy structure helps funnel moisture from dew or rainfall down the plant stem to the pod stem and around the pod.

The timing of a drought determines its impact on yield and quality. Early season droughts will cause harvest delays, yet do not split the crop as a mid-season drought will. The primary concern of a late season drought is the increased risk of aflatoxin. Drought's impact on yield and grade is below. In this study, the soil profile was full entering the drought period and recharged completely once the drought period was over - which is generally not the case. In most circumstances, the drought effect would be greater than these yields indicate.

The mid-season drought caused the largest reduction in yield and grade. At 65 days after planting, the peanut plant is in the early stages of pod development. The most mature pods will be in column 9 of the hull scrape chart (dark yellow). During this drought period, the plant will move the oldest pods towards maturity, and delay flowering and fruit development of the most immature pods. Once the drought is relieved, the plant will resume flowering and fruit development, yet there will be a large gap in the pod maturity profile between the early formed pods and those forming after the drought ended. Thus, the grower will have to choose to take the early crop, or to let the early crop go and hope the later crop will be more substantial (as the pod stems in early crop will likely be too weak to harvest and those pods will be lost to the soil).

Dryland fields are often the most challenging to predict best harvest date. The advantage of the hull scrape method for these situations is that growers are able to see where the most mature crop is in development, what is coming behind that crop, and how long it will take for the "second" crop to mature. Proper harvest scheduling can result in yield increases of 20% when compared to digging dates only 14 days before or after optimum.

During peanut harvest, a few of the very first set, most mature pods, are often lost in the soil as a result of a weak pod stem. These pods are sacrificed because the weight gain from the developing pods exceeds the weight lost from letting those few most mature pods go. These mature pods are lost due to weak pod stems resulting from the lack of nutrient flow to them over a number of weeks. Some peanut varieties are significantly better at retaining pods over extended harvest dates, Georgia-12Y is one example. Weakened pod stems may also result from diseases, such as white mold. In addition, pods may be lost simply from the actions of the digger such as when the blades are set too shallow, too deep, or not running straight with the row.

Table 2 gives the yield results over time when fungicide and varieties are compared. This data was generated in a Tifton, GA field with a one-year rotation in 2017 under very heavy disease pressures. Improved disease control and resistant varieties resulted in higher yields to be maintained over a longer harvest window period.

Drought Period	Yield (lb/A)	%SMK
35 - 65 days after planting	3830	75
65 - 100 days after planting	3000	71
100 - 135 days after planting	4010	76
Well-watered control	4470	75

Table 1.

Treatment*	2	4	2	4	2	4	2	4	2	4	2	4
Big DAP**	**130**	**130**	**144**	**144**	**151**	**151**	**158**	**158**	**165**	**165**	**172**	**172**
Variety	**Yield**											
AU-NPL 17	-	-	5266	5634	-	-	4564	4121	-	-	3431	1547
GA-06G	4604	5055	4656	5189	5494	4476	4491	3486	3002	2077	2305	1548
GA-14N	4218	3052	4157	4521	4581	4593	3313	3926	3239	2185	2588	1601
GA-16HO	5506	5269	5300	5093	5561	4904	5452	3631	3855	1382	1911	1448
TifNV-Hi O/L	5070	4952	5542	5548	5132	4773	5328	4427	4036	2601	2123	1452
TUFRun 297	5052	5627	5949	4570	4962	3473	3647	2184	2482	1066	1444	396
TUFRun 511	5225	5204	-	-	4376	3271	-	-	1888	1117	-	-

Table 2.

**Treatment 2 = Bravo on a 2 week schedule from 30 days after planting until harvest. Treatment 4 = Bravo on a 4 week schedule from 30 days after planting until harvest. The entire test received Convoy (32 oz) at 60 and 90 DAP.*

***Dig DAP = Days After Planting when plots were dug.*

Harvesting at the optimum time for maximum yield, quality and return is a challenge, as farms often have multiple fields near harvest maturity at the same time, and soil and weather conditions often force digging earlier or later than optimum. When maturity losses are combined with less than optimum digger and combine settings, 5% or more of the total mature pods may be left unharvested.

Post-Harvest Maturity Sorting

The physiological and compositional characteristics of mature seeds make them the best choice for seed, and for food products. Mature seed are better tasting, have a lower aflatoxin risk, and germinate better than immature seed.

As indicated on the first page of this chapter, seed size is related to seed maturity - particularly in the 16/64" and larger screen sizes. Sorting in-shell peanuts into pod density classes is another way to improve the percentage of mature seed in a lot, particularly in the #1's and medium classifications. Pod density is correlated to seed maturity because of the way the peanut seed grows in the pod.

During development, peanut pod size is rapidly established. Young pods consist mostly of watery parenchymous tissue. Shortly after pod size is established, the hull forms a layer of hard schlerenchymous tissue approximately six cells thick.

This layer gives the peanut hull its rigid structure. Shortly after the layer is established, kernels begin to enlarge and develop. Like the pod, the immature seed rapidly enlarges and is composed mainly of water. As seed development continues, solids begin accumulating in the seed, replacing water. By the time the seed reaches full maturity, kernel moisture has decreased significantly.

Immediately after digging, mature kernels are approximately 28% water, compared to immature kernels that are 47% water. Mature kernels have fully expanded to completely fill the pod cavity and, after curing, will have a significantly greater density than immature kernels. The exact differences in density will vary between varieties, yet past studies have shown density differences of 28% (0.54 g cm-3 for immature kernels and 0.69 g cm-3 for mature kernels).

Putting this in practice, an unsorted lot of farmer-stock peanut having an initial maturity distribution in No. 1 kernels of 66% immature, 23% mid-mature, and 11% mature was taken and this lot was sorted using a gravity table into four pod-density fractions, ranging from 98% immature and 2% mid-mature to 8% immature, 43% mid-mature and 49% mature in the most dense fraction. Along with improvements in maturity distributions, higher density fraction was found to have less aflatoxin. Knowing the

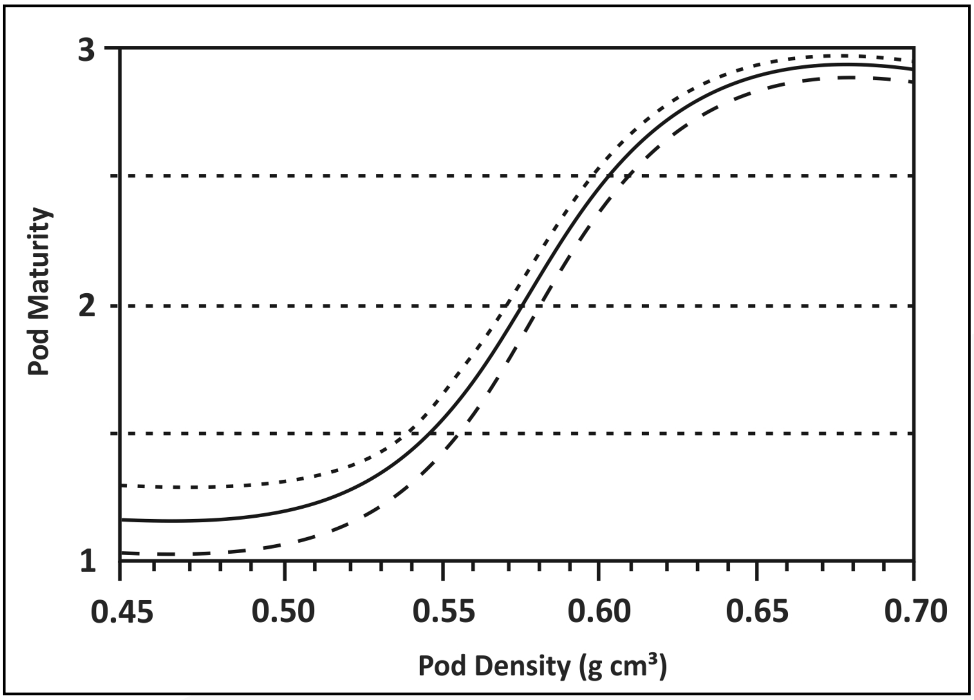


Figure 23. The effect of pod maturity on pod density.

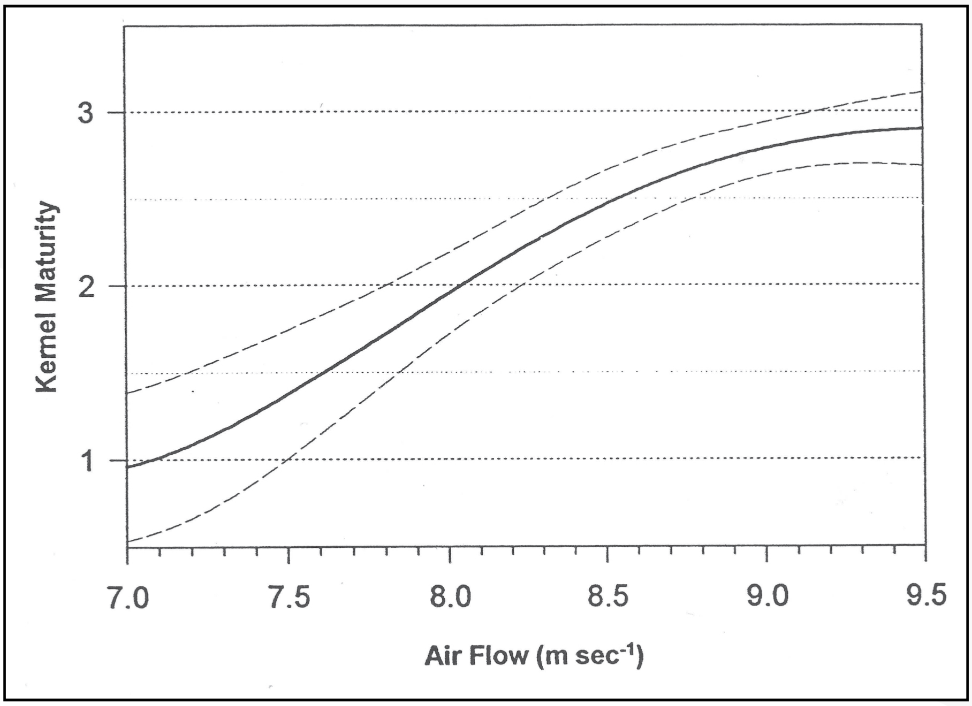


Figure 24. Seed maturity and gravity table airflow rate.

physiology of the plant improves decisions before, during, and after harvest. While peanut is grown as an annual, remembering that the plant is a perennial herb, that is very susceptible to frost, will improve decisions.

ROW PATTERNS

Chapter 8

Row Patterns

R. Scott Tubbs and W. Scott Monfort

Peanut row patterns are determined by spacing of planters. The beds (in conventional tillage) or sub-soiler shank spacing (in strip-tillage) allow for varying row spacing, drill spacing, and plant population. Row and cover crop drill spacing may vary considerably, with each greatly influencing production and harvest efficiency. Peanut have been grown on 30, 36, or 38 inch row spacing in both single and twin row patterns with success; however, the 36-inch single and twin row patterns (Figure 1) are the standards for the majority of Georgia's peanut production. The row pattern decision is often based on personal preference and planting equipment already available on the farm.

Twin rows (or four rows per bed, with an inset row approximately 7 to 9 inches to the interior of the bed from the outer row, and outer rows still spaced 36 inches apart throughout the field) have provided numerous agronomic and sometimes economic benefits over the years, but production performance depends on a multitude of factors. This row pattern requires precision and care in planting and is best suited to the sandy or loamy soils relatively free of vegetative residue interference, whether above or below ground. Twin rows in strip-tillage can be difficult depending on the width of the tilled area for seed placement. When a narrow sub-soiler is used, twin rows may end up spaced far enough apart that

Figure 1. Single row peanut with 36 inch row spacing (foreground) and twin row peanut with 36 inch outer-row spacing and 7 inch twin furrow to the interior of the bed (background).

they are planted outside of the prepared strip. This can lead to residue interference and an inconsistent depth of furrow, creating reduced plant stands or non-uniform emergence. Twin rows must also have planting and harvesting equipment adjusted to handle this type of row pattern. Improper inversion of twin rows can lead to bunching or rolling of vegetation causing delays or irregularities with field curing of the vines. Vegetation that rolls allowing the pods to remain in contact with the soil after digging may result in pod rot, sprouting, or other issues that can reduce yield and grade. Some benefits attributed to twin row pattern include early canopy closure (approximately two weeks quicker than single row) which will improve shading to aid in weed suppression and a cooler soil surface to reduce the chances of flower sterility and peg scorch and slower/less evaporation of soil moisture. In addition, tomato spotted wilt virus and the spread of southern stem rot (white mold) are reduced with twin row pattern, which have led to yield improvement depending on severity. Although, yield comparisons between single and twin row patterns are not always consistent (Table 1) and depend on many factors.

Seeding rate will also be determined by the row pattern used. Since there are twice as many furrows in twin row pattern, the seeding rate for a twin row is the sum of both twin furrows (at a 36-inch standard row spacing, 3 seed/ft of row for each twin furrow = 87,120 seed/ac) in comparison to a single row pattern equivalent (6 seed/ft of row = 87,120 seed/ac), While 6.0 seed per ft of row is considered the average, twin rows may sometimes benefit from an increase in plant population, achieved by planting up to 7.0 seed per ft of row (3.5 seed/ft for each twin furrow = 101,640 seed/ac). Research has consistently shown that seeding rates above 7.0 seed per ft of row do not provide any substantial benefit when planting high quality seed in suitable planting conditions. Twin rows can support a greater plant population since each individual plant is provided a larger surface area in which to grow with less intra-row competition for neighboring peanut plants for space, light, water, nutrients, and other resources needed to maximize production. Once the optimum plant population is reached, an increase in seeding rate will only result in lost revenue by either paying for additional seed that was unnecessary, or in the case of saved seed, not being able to sell those extra seed as part of the previous crop's yield.

Plants near compacted wheel tracks produce less than those grown further away (near the center of beds). Modified row spacing (32 inches between rows on the bed, and 40 inches to the nearest row on the adjacent bed) to allow more shoulder distance from outside rows to wheel tracks (and less distance between rows where soil has not been packed) is sometimes used because it allows more efficient use of ground equipment without crushing vines until later in the growing season. This method is more beneficial where smaller equipment is used, but has become less popular in recent years as larger planting and spraying equipment have become more common.

Narrower row spacing has gained popularity in recent years to match up equipment settings with other crops used in rotation that benefit from narrower rows, such as field corn or soybean. A uniform spacing of 30-inch single rows is used by some growers and can produce similar yield and grade as wider row spacing and row patterns. A key consideration with this spacing is seeding rate (since there are additional seed furrows added to a given unit area of land, see Ch. 9 – Planting for more details), and also equipment modifications for digging and proper inversion. A vine-cutter is strongly recommended when using narrow row spacing to assist with proper inversion.

Table 1. Pod Yield of Peanut in Single vs Twin Row Pattern from Multiple Experiments, Locations, and Years		
Trial/Year	**Single**	**Twin**
Tillage x Cover Crop	**lb/ac**	**lb/ac**
2012 (Tifton)	3775	5317*
2013 (Tifton)	5058	5607*
2014 (Tifton)	5615	6368*
Cultivar x Seed Rate	**lb/ac**	**lb/ac**
2014 (Tifton)	6819	7022
2015 (Tifton)	6450*	6278
2016 (Tifton)	5723	5859
2017 (Plains)	4609*	4089
2018 (Tifton)	4484	4536
2019 (Tifton)	5837	5967
2019 (Plains)	6191	6102
Row Pattern Large-Scale	**lb/ac**	**lb/ac**
2016 (Plains)	4246	3977
2018 (Plains)	4854	6788*
Combined Cultivar	**lb/ac**	**lb/ac**
2018 (Attapulgus)	4980	5191
2019 (Attapulgus)	5531	5710
2019 (Tifton)	5579*	5360
2020 (Tifton)	3590	3796
**Yield is statistically greater for this row pattern compared to the other in given year of the trial at P = 0.10.*		

PLANTING

Chapter 9
Planting

R. Scott Tubbs and W. Scott Monfort

Planting Timeframe

The recommended planting timeframe for peanuts in Georgia is the last week of April (if soil temperature is adequate – daily average above 68 F at the 4-inch depth for 3 consecutive days) through the third week of May. During this time period, you can obtain optimum yields in either irrigated or non-irrigated conditions. However, the average yield of early June plantings are usually lower than yields of peanuts planted during the recommended period.

Under irrigation, you can plant peanuts in late May or early June with success. However, there is a greater threat of reduced yield and grade. These later planting dates normally provide adequate heat during late September and early October for maturity. However, day length gets shorter with cooler nighttime temperatures and October historically (30 year averages) has the least rainfall of any month which can slow pod fill of the limb crop. An early cold front can shut down maturation and prevent peanuts from advancing to maximum yield and grade potential. This rain distribution may be less favorable for production but more favorable for harvesting peanuts.

The last week of April through the third week of May gives roughly a four week period to plant peanuts. This should be ample for most average sized growers, but can become problematic for large growers with many acres to plant, especially when rainfall is too abundant (keeping equipment out of the field) or too infrequent (where there is inadequate soil moisture for peanuts to germinate without supplemental irrigation). Planting too early may subject peanuts to cool, wet soils and increased chance of seedling diseases and tomato spotted wilt virus. Planting too late may result in loss of yield and quality, and could be jeopardized by frost damage. Planting late also pushes the time period when peanuts need the most water (during pegging and pod fill, or about 50 to 100 days after planting) into late August and September which is normally a drier period than late July and early August which is more typical for this stage of growth. This can also lead to a greater threat of peanuts being graded as Segregation 2 (i.e. freeze damage) or Segregation 3 (aflatoxin).

Seeds

To assure a good stand, plant well-matured, disease free seed of known origin, performance, purity, and quality. If possible, plant seed that has been grown in the absence of stress. Do not plant immature seed. Using certified seed will minimize risk of poor quality and purity. Peanut seeds contain a very thin skin that offers little or no protection against mechanical injury. Therefore, germination and seed vigor are severely affected by impact, abrasion, or crushing. Adjust and operate planting units for mild handling.

Seed Placement

Most planters today are vacuum/air pressure planters that hold seed to a plate with suction. These planters are relatively precise with seed placement when operated at proper speed and with adequate suction on the vacuum. Excessive speed (generally above 3.5 miles/hr) can greatly diminish the efficiency of operation preventing seed from settling onto the seed plate and making seeding rate and eventual plant population highly unpredictable. Proper soil moisture is also needed for effective operation. When conditions are too dry it is difficult to open a furrow without either 1) soil refilling the furrow before the seed can be placed (usually in lighter/sandier soil conditions) or 2) inability for the disc openers to penetrate the surface at the appropriate depth (in heavier/loamy soil conditions). In either situation, seed placement at the proper depth is difficult and seed often are planted too shallow and unable to reach adequate moisture for emergence without supplemental irrigation or a rainfall within a few days after planting. After placement in the furrow, seed should be covered and gently enclosed in the soil with a press wheel or dual disc closers that provide good seed to soil contact around the entire surface area of the seed. Row areas should remain almost level with the bed. If using a residue cleaner ahead of the double-disc opener, be sure it is placed at a depth that merely moves residue away from the row, not where the cleaners are brushing soil out of the way and creating a depressed furrow that is lower than the height of the rest of the bed.

Peanuts should emerge from a flat surface mildly compacted from the sides to increase moisture retention. A depression in the line of the row can cause extra water to sit on the germinating seedling causing soil crusting and compaction or the inability to move soil out of the way for seedlings to emerge. Also, seed which emerge from a depression are subject to having soil shifted on to the plant parts. Avoid this practice, as any plant part covered is lost to production. When covered, growing points fail to develop further, suffocate in the soil and become food for disease organisms.
Where you can insure emergence by irrigating, place seed 1.5 to 2.0 inches deep. Otherwise, place 2.5 inches deep in light-textured soils and approximately 2.0 inches deep in heavier soils. When there is less soil moisture and increased soil temperature, plant seed slightly deeper. Planting too deep can cause erratic emergence and greater opportunity for seedling disease such as *Aspergillus niger* to damage or kill an emerging seedling.

Seeding Rate

Drill spacings depend on seed quality, row pattern, and percent germination. The ultimate goal is obtaining an adequate final plant population. Maximizing peanut yield and grade and minimized impact of most pest risks occur when single row peanut have a final plant population of 3.0 to 4.0 plants/ft of row (approximately 44,000 to 58,000 plants/ac). A seeding rate of 5.0 to 6.0 seed/ft of row (73,000 to 87,000 seed/ac) is typically adequate when planting quality seed in good conditions and maintaining equipment with recommended operation settings (i.e. tractor speed and vacuum pressure). Twin row production can support a higher plant population with less plant to plant competition for resources (space, water, light, etc.). Plant populations of 4.0 to 5.0 plants/ft of row (total of both twins combined, or 2.0 to 2.5 plants per twin furrow; approximately 58,000 to 73,000 plants/ac) will usually maximize yield and grade of peanut in twin row management. Seeding rates of 6.0 to 7.0 seed/ft of row (total of both twins combined, or 3.0 to 3.5 seed/ft in each twin furrow; approximately 87,000 to 102,000 seed/ac) are often adequate to achieve these desired plant populations. If seed of lower quality or reduced germination percentage are used, then seeding rate should be adjusted accordingly to reach the targeted final plant population. It is recommended to test each seed bag for germination percentage just prior to planting to ensure expected germination.

Using average seed size of common varieties, most peanut varieties will be planted at anywhere from 105 to 145 lb/ac on a weight basis. A chart is shown below with average seed size and estimated planted weight using the UGA recommended seeding rate of 6.0 seed/ft of row (Tables 1 and 2). Planting more seed usually does not result in increased yield as the number of pods per individual plant are reduced due to competition, despite having more plants in the field. Seeding rates above the UGA recommendations are typically added expense for no extra benefit and remove more kernels that could be sold to the edible market.

Table 1. Seeding rates for common varieties of peanuts.

Variety	Seed weight in g/seed	Seed count in No./lb	lb/acre when planted at 6 seed/ft
Large Seed Size*			
+TUFRunnerTM '297'	0.763	595	146.4
+TUFRunnerTM '511'	0.745	609	143.0
+TifNV-High O/L π	0.737	616	141.4
Georgia-06G	0.733	619	140.7
Tifguard π	0.733	619	140.7
+TUFRunnerTM '727'	0.716	634	137.5
Georgia-07W	0.710	639	136.3
+Florida-07	0.706	643	135.5
+Georgia-16HO†	0.695	654	133.3
Medium Seed Size*			
Georgia Greener	0.679	668	130.4
+Georgia-09B	0.665	682	127.7
Georgia-12Y	0.660	688	126.7
+FloRunTM '107'	0.648	700	124.4
Small Seed Size*			
Georgia Green‡	0.587	773	112.7
+Georgia-13M	0.586	775	112.4
+FloRunTM '157'†	0.582	780	111.6
+Georgia-14N π	0.555	818	106.5

Note. This table shows average seed weight, number of seed per pound, and pounds needed to plant 1 acre at 6 seed per foot of row for common peanut varieties. Based on University of Georgia Statewide Variety Testing irrigated trials over 3 years (2014–2016) at three locations each year (Tifton, Plains, and Midville, GA).

* There is no official standard definition of large, medium, or small for runner peanuts. Category limits were assigned arbitrarily.

+ Indicates a high-oleic variety.

π Denotes resistance to the peanut root-knot nematode (*Meloidogyne arenaria*).

† Data only available for 2015–2016.

‡ Data from 2011–2013.

Table 2. Pounds of seed per acre based on plant and row spacing.

	36 in. row			38 in. row		
Seed per lb	5 seed/ft	6 seed/ft	7 seed/ft	5 seed/ft	6 seed/ft	7 seed/ft
500	145	174	203	137	165	192
525	138	166	193	131	157	183
550	132	158	184	125	150	175
575	126	151	176	119	143	167
600	121	145	170	115	137	160
625	116	140	163	110	132	154
650	112	134	156	106	127	148
675	108	129	151	102	122	143
700	104	124	145	98	118	137
725	100	120	140	95	114	133
750	97	116	136	92	110	128
775	94	112	131	89	106	124
800	91	109	127	86	103	120
825	88	106	123	83	100	117
850	85	102	120	81	97	113

Note. This table provides the total pounds of peanut seed needed to plant 5, 6, and 7 seed per foot on row spacing of 36 in. and 38 in

WATER USE AND RELATIONSHIPS

Chapter 10
Water Use and Relationships in Peanut Production

Wesley M. Porter

Georgia peanut producers have planted over 600,000 acres of peanuts annually since 1984. Many production and management factors contribute toward final yields. However, water amount and distribution during the growing season continues to be foremost in influencing the final yield of peanuts.

Years in which drought is predominant have taken their toll on Georgia's $500 million peanut industry. Georgia produces over 40 percent of the peanuts in the United States annually. Because of successive years of drought, over 50 percent of Georgia's peanut producers provide supplemental irrigation to their crop. However, irrigation alone is seldom enough to maximize yields or reduce losses, and must be used along with all other production practices.

Supplemental irrigation contributes to stable crop production and generally increases crop quality. Yield increases due to irrigation are most often seen on sandy and loamy sand soils that normally lose water rapidly. Years when substantial water stress has occurred during the pod filling period show the most benefit from irrigation.

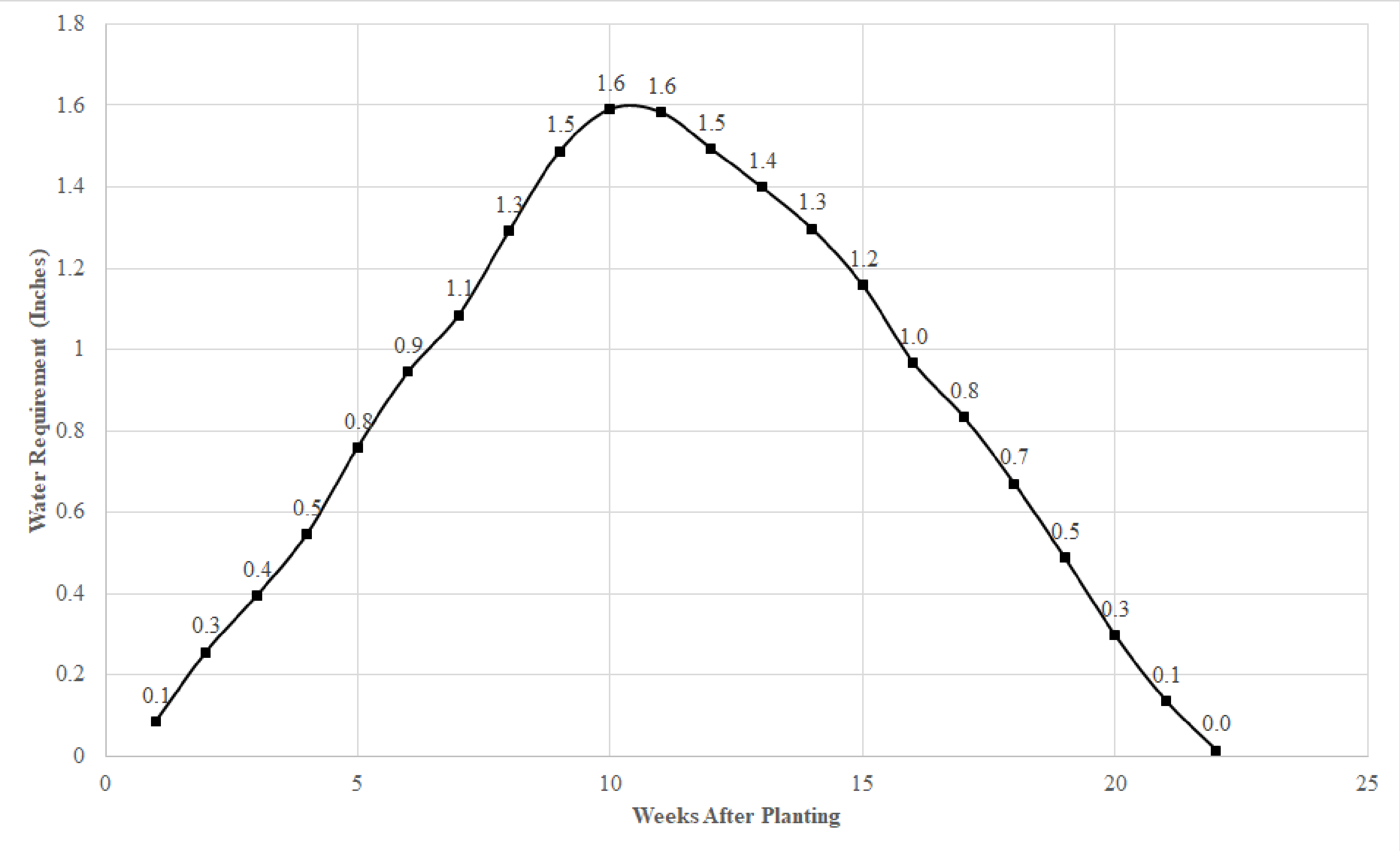
Peanut response to irrigation varies widely from year to year and depends on soil type, environmental conditions, and other factors. Response to water by the peanut crop is most effective when diseases, nematodes or other pests are controlled through proper rotation, chemical and other cultural management methods. In addition to water stress over-irrigating peanut during the season has been shown to reduce both yield and profitability. This publication addresses water use by the peanut and water relationships as it affects peanut growth and development. Also, discussed will be the basic needs of the peanut plant for water, critical stages for maximum water use, and the most efficient and effective means for scheduling supplemental irrigation currently available.

WATER USE BY PEANUTS

Water use by the peanut crop depends on the growth stage of the plant and environmental conditions such as temperature, relative humidity and wind speed. Experiments in the southeastern United States have shown that a peanut crop generally requires 18 inches of water (irrigation + rainfall) for achieving acceptable yield levels. Even though the crop only requires 18 inches of water, total water input may need to be greater since water applied or rainfall received is not 100 percent efficient or can be lost to runoff and deep percolation.

Rainfall distribution and irrigation scheduling are very important factors in crop response to water. Daily rates of water use for peanuts are low during early vegetative growth, but increase to a maximum of 0.20 to 0.25 inches per day as the canopy approaches full development.

With leaf area sufficient to shade the entire soil surface, plant water use will nearly equal pan evaporation (Weeks 5-8). Most local television, radio, or weather stations report daily pan evaporation. After full canopy development, this information can be quite helpful in estimating water use by the peanut crop. The following curve (Figure 1) illustrates the weekly water requirement of the



peanut plant. This curve was developed based on a historical 15-year average, thus, some variation in actual use may occur.

After the crop develops maximum leaf area, water use rates decline slowly (after Week 12) until maturity (Figure 1). However, as long as green leaf area completely shades the soil surface, rates of water loss will be near maximum. After complete canopy development, water use is more dependent on environmental factors than crop factors, assuming the crop is in good condition and not water-stressed. High air temperatures, sunlight, low relative humidity, and high wind speeds cause higher rates of crop water use. Cloudy and cool days and overcast days with high relative humidity may significantly reduce crop water use. Thus, peanut crop water use rates may vary from day to day depending on environmental conditions. A knowledge of factors affecting water use along with estimates of average daily and seasonal water use rates can be helpful in developing irrigation schedules. In addition, if the "Checkbook" method below is going to be implemented, a thorough record of rainfall and daily water requirements is

Table 1. Critical Periods for Crop Water Use by Peanuts

Plant Growth Stage	Plant Indicators Susceptibility	Relative Drought
Germination	Planting to Emergence	High
Early Vegetative	Emergence to Flowering/Pegging	Low
Nut Development and Fruiting	Flowering/Pegging to Pod Addition	High
Maturation	Pod Formation to Harvest	Moderate

recommended to ensure accuracy of irrigation timing and amounts.

CRITICAL GROWTH STAGES

Experience and research have shown three time periods during a crop year when water availability to the crop is critical in determining final yields (Table 1). The first occurs with planting and germination. Place the seeds in a moist bed to insure rapid germination. Producers can wait to plant until the soil moisture is adequate for germination, or they can irrigate before planting with 0.25 to 0.5 inches of water. A second critical water requirement occurs during the pegging and pod setting period which is usually from 40 to 110 days after planting. The third critical period is from 110 days until harvest as pods mature.

CROP RESPONSE TO WATER

Considerable research has been conducted in Georgia and throughout the southeast on the effects of water stress on peanut growth and yield.

Water deficits affect primarily vegetative growth the first seven weeks after germination. The major effect is decreased crop growth rate. Dry matter production, leaf expansion and stem elongation, and the mainstem length are all affected by water deficit at this time. Slight water deficits during this stage will not affect yield and may reduce vine growth enough to minimize disease problems later.

Too much water during early vegetative growth, on the other hand, may result in excessive vegetative growth and shallower root depth. Results of several studies show increased rooting depth with mild water deficits during early vegetative growth. Early season droughts have been shown to delay pegging and pod formation, although pod formation may resume normally when water is received.

During the flowering period, water stress can delay formation of flowers or depending on the stress severity, completely inhibit flowering. After flowering, peg penetration into the soil requires adequate moisture. Once active pegging and pod formation have begun, (About 50 days after planting) it is recommended that the pegging zone (top 3 to 4 inches of soil) be kept moist, even though adequate soil moisture may be available deep in the profile. A moist pegging zone facilitates the uptake of calcium by pods which is essential for proper pod development. Failure of pegs to penetrate and develop pods can result from low relative humidity, high soil temperatures, greater compaction and soil strength, low turgor pressure if roots are also in dry soil, and reduced calcium uptake by the developing pods.

A lack of water in the pegging zone during pod addition and development can result in more pops, more one-seeded pods, and lower calcium content in the seed. A lack of water later (after 100 days after planting) mainly reduces yield by causing smaller and younger fruits to abort and reduces growth rate of older pods.

Excessive water in wet years or frequently irrigated fields will promote excessive vine growth, greater disease pressure, peg deterioration and non-uniform maturity late in the season. One or more of these factors combined typically add to a yield reduction at the end of the season. There is a fine line of under- and over- irrigating peanuts to maximize yield potential. One reason for maintaining adequate moisture the last 40 to 60 days of the season is that the potential for *Aspergillus flavus* mold is reduced in well-irrigated cool soils.

The response of the peanut crop to water is often altered by other factors which limit crop yields, such as insects, diseases, nematodes, weeds, soil fertility, crop rotation, and environmental factors. Closer water management is required when other factors are affecting growth. As can be seen in the example soil water tension graph below, when peanut is not irrigated properly stress is induced once the average soil water tension data reaches above 45 kilopascals (kPa). Rainfall was received on July 10, 25, 30, August 6, 14, and 30. These were the only events that relieved drought stress during this season. The crop was in stress during the periods from July 8-10, 24-30, August 3-6, 12-14, and 24-30. Each time the soil water tension was allowed to go above 45 kPa the crop stress caused reductions in yield potential, in an irrigated scenario irrigation should have been triggered prior to the crop reaching drought stress.

IRRIGATION SCHEDULING METHODS

To schedule irrigation for highest water use efficiency (WUE) and maximum production, it is essential to frequently determine the soil water conditions throughout the root zone of the crop being grown. Several methods for doing this have been developed and used with varying degrees of success, these methods include a water balance or checkbook method (Figure 1 below), weather or evaporation tools, computer models, and soil moisture sensors. The two methods which have proven to achieve highest profitability, yields, and WUE are soil moisture sensors and computer models. Most of the computer models are free and the soil moisture sensors are relatively inexpensive compared to the investment in irrigation equipment. The irrigation scheduling method utilized is up to the individual producer based on their current irrigation scheduling strategy. It is strongly encouraged that some sort of irrigation scheduling strategy be utilized. It cannot be stated enough, that data have shown that both over- and under- watering peanuts will reduce yields.

WATER BALANCE METHODS

The most commonly used method that does not require frequent field activity is the water balance method or more commonly known as the UGA Checkbook method (Figure 1). The principle of the water balance method is to obtain a balance of in-coming and outgoing soil water so that adequate soil water is maintained for the plant.

Inputs include incoming water in any form whether rainfall or irrigation. Outputs include evapotranspiration, runoff, and deep percolation.

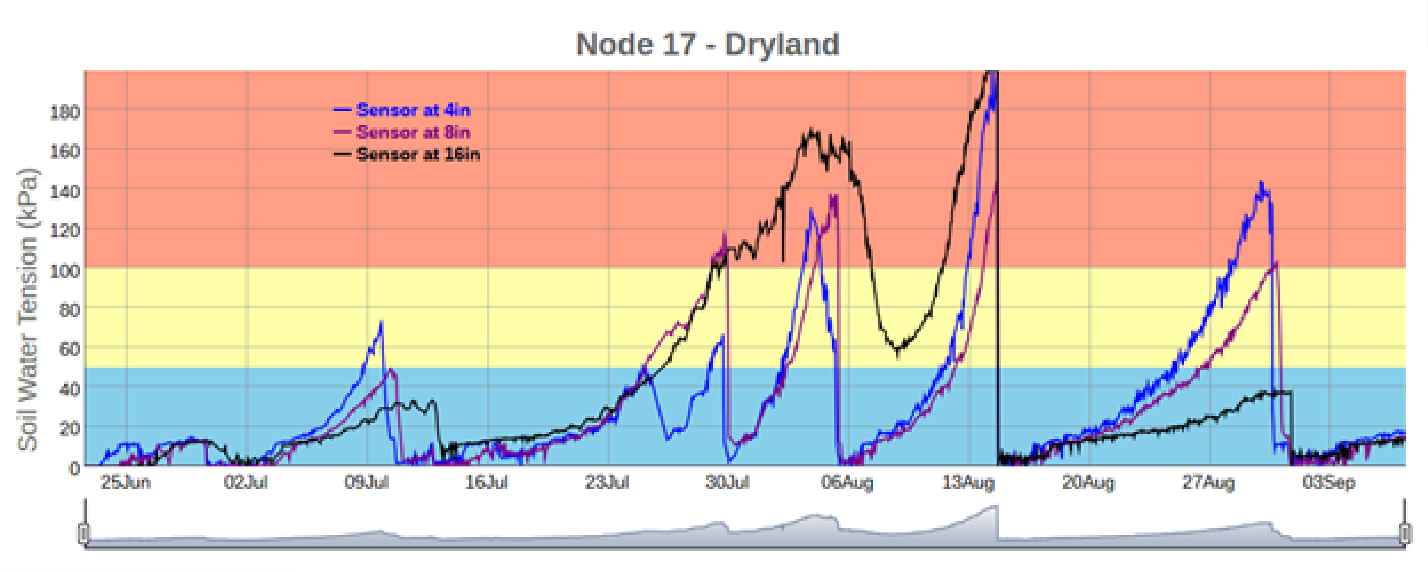


Figure 2. An example dryland soil water tension graph representing a typical growing season, and crop stress.

Water removal is more commonly referred to as evapotranspiration (ET). Evapotranspiration is usually expressed in inches per day. It consists of water removal and transpiration by the plant and water loss directly by evaporation from the soil. Two variations of the water balance method are used. One uses crop water use curves, the other uses pan evaporation data. The UGA ET Checkbook method utilizes a combination of these two methods by combining crop water use curves with historical ET data to estimate how much water the crop requires per week of the growing season.

To use either variation you must know your soil type and the available water holding capacity of the soil. You can get this information from your local Soil Conservation Service or the NRCS Web Soil Survey. Next, determine the zone you are trying to manage. This zone will vary per the effective rooting depth of the peanuts. Usually less than 24 inches (2 feet) is the most that can be managed with irrigation. Determine the total water you have available to manage in this zone. It is desirable to try to maintain water content above 50% of the available water holding capacity, as plants cannot extract more than 50% of the soil water. As water is removed daily (by ET) these amounts are subtracted from the water available. When the moisture available approaches a zero balance it is time to irrigate. The amount to add depends on the soil type, but will usually be the same as the 50 percent value calculated earlier plus an additional amount to account for application efficiencies less than 100 percent. (Typical application efficiencies for sprinkler irrigation equipment vary from 75 percent to 90 percent).

KEEPING A CHART

One can get the full benefit of using manually read soil moisture sensors by recording readings and plotting them on a chart. The chart lines show what has happened in the past. By following trends and projecting them, you can have an advance indication of what you can expect in a few days. This helps in scheduling the next irrigation and in measuring the effectiveness of an irrigation (what depth of penetration was achieved and how soon the soil dried out). When a type of telemetry is included with these systems the online data portal will typically plot the readings and display this chart for the user. Utilizing a soil moisture sensor chart provides the user with insight as to what their irrigation strategy is doing from the perspective of soil moisture.

TENSIOMETERS

A tensiometer is a sealed, water-filled tube with a porous ceramic tip on the lower end and a vacuum gauge on the upper end. The tube is installed in the soil with the ceramic tip placed at the desired root zone depth and with the gauge above-ground. Even though reliable, these sensors typically require high maintenance levels and manual reading, thus may not be the best option for irrigation scheduling.

Figure 3. WaterMark soil water tension sensor.

A better option is a gypsum block or tensiometric sensor, an example of one of these sensors is Irrometer's© WaterMark® solid state electrical resistance sensor which still measures soil water tension. These sensors can be integrated with a telemetry system so that data can be remotely acquired and utilized.

Figure 4. WaterMark soil water tension sensors installed in a probe

Figure 5 represents a recommended soil water tension curve when following a recommended weighted sensor threshold of 40 to 45 kPa. Each time the weighted sensor average reaches the threshold irrigation should be applied to ensure that the weighted average stays below the recommended threshold as shown below. When compared to figure 2, it can be seen that stress was not induced to the peanuts when they were irrigated properly.

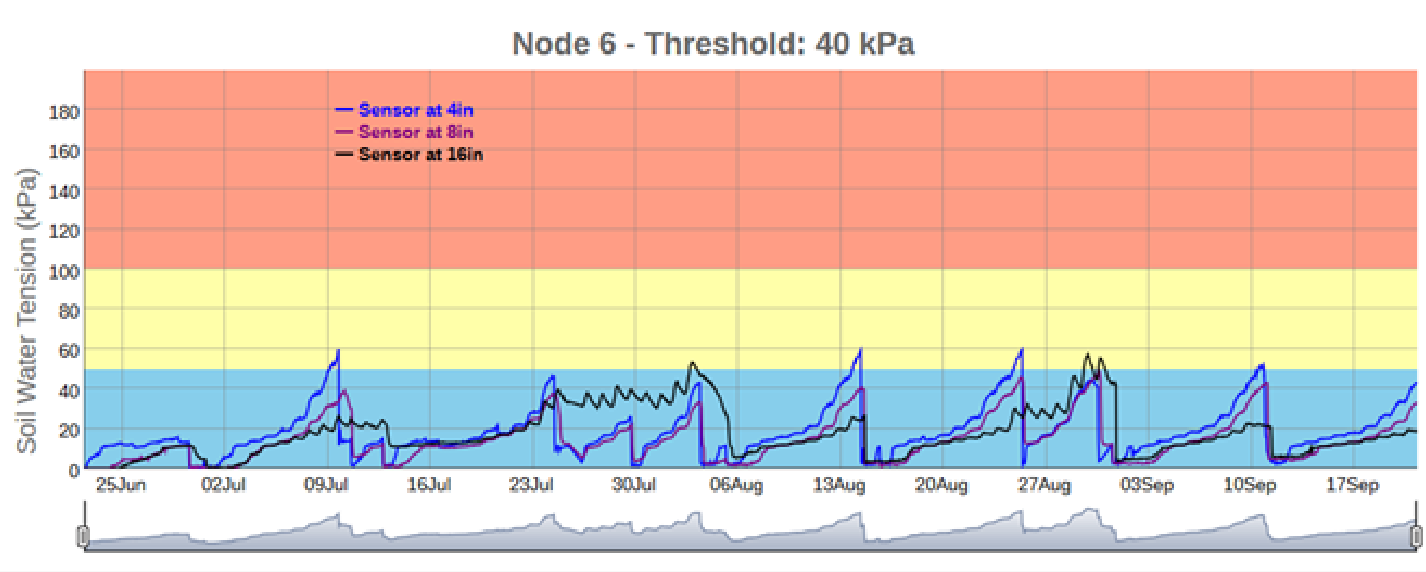


Figure 5. An example recommended 40 kPa soil water tension graph representing a typical growing season, rainfall, and irrigation events

CAPACITANCE SOIL MOISTURE SENSORS

A different type of soil moisture sensor is a capacitance soil moisture sensor. This sensor measures the volumetric soil moisture usually as a percentage. Soil moisture typically ranges from 30% (wet) to less than 10% (dry). Capacitance soil moisture sensors are typically more responsive than resistive types of sensors, but are usually more costly. An example of a capacitance type sensor is Meter's© EC-5®. Just like the WaterMark sensors, the sensors can be read either manually or remotely

Figure 6. Meter© EC-5® Capacitance Sensor.

once a type of telemetry is added. There are many types of capacitance soil moisture sensors available commercially, it is up to the user to determine which sensor is the best fit for their individual operation.

IRRIGATION SCHEDULING COMPUTER MODELS

Computer models have been developed which utilize the water balance method in combination with current crop and environmental conditions. Two such models available to Georgia growers are the USDA's IrrigatorPro (http://irrigatorpro.org/) and PeanutFARM (http://peanutfarm.org/). Both irrigation scheduling tools require local input (i.e. field location, local weather station selection, soil temperature, and on the advanced side radio link identification numbers from select soil moisture sensor systems(Trellis Dashboard (mytrellis.com)) and utilize this input to aid in determining irrigation trigger points. These models typically track the estimated soil moisture and crop maturity to determine how often and how much irrigation is required. These tools are free and work very well. It is suggested that a producer who is currently not scheduling irrigation using any method should consider employing some sort of computer model such as Irrigator Pro or PeanutFARM since they provide an opportunity for tracking irrigation and estimating when an irrigation event is required.

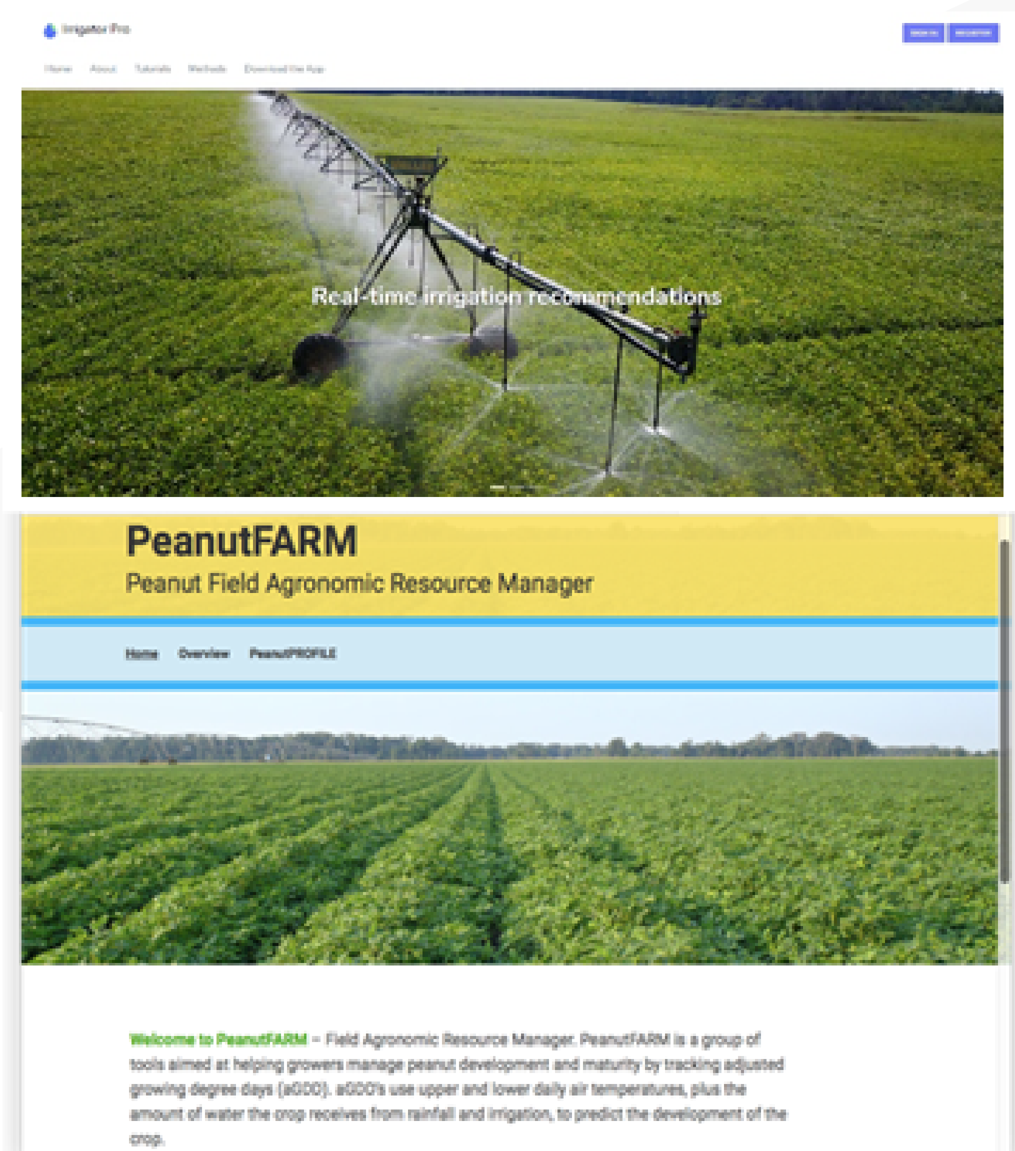


Figure 7. Web interface for USDA's IrrigatorPro and PeanutFARM.

CROP RESPONSE TO IRRIGATION SCHEDULING

Irrigation Scheduling Results 2014-2018

Just as a quick refresher irrigation scheduling results from 2014 through 2018 are presented below. Of all five years 2014 was a relatively dry production year and Table 2 contains the mean yields listed by irrigation scheduling treatment for the 2014 and 2015 production seasons. There were slight variations in variety based on each of the treatments tested, but the more definitive differences were between the scheduling treatments and amounts of irrigation applied, thus those are what are shown.

As shown in Table 2, during 2014 when about half the total amount of required water was received via rainfall, even a very conservative method such as the UGA Checkbook did not seem to perform as well as more advanced methods, even with the addition of 75% more irrigation applied. 2014 was a very good year to encourage the utilization of irrigation, especially since the dryland yield was basically equivalent to 0 due to the weight being comprised mainly of immatures. During 2015 22.65 inches of rainfall was received, the trial was planted on May 18, dug on October 5 and harvested on October 12. As can be seen from Table 3, there were no major differences between yields from irrigation scheduling treatments for the 2015 season what we could call a wet year. Irrigator Pro was the highest yielding treatment with the 45 kPa treatment a close second. It should be noted that the version of Irrigator Pro used for this trial incorporated Watermark soil moisture sensors thus was operated very similar to the 45 kPa treatment. It should also be noted that even though the UGA Checkbook method yielded very well during 2015, it also applied three to four times more irrigation than did the most of the other irrigation scheduling treatments which used a sensor, drastically decreasing water use efficiency.

Table 3 represents the mean irrigation scheduling treatments for 2016 and 2017. Both years had

Table 2. Mean Results from all varieties tested in 2014 and 2015.
Irrigation Scheduling Treatment Differences

2014 Rainfall: 12.33 inches			
Irrigation Treatment	**Irrigation Amount (in.)**	**Total Water (in.)**	**Yield (lbs/ac)**
Dryland	0.40	12.73	465
WaterMark (45 kPa)	9.40	21.73	6052
UGA EASYPan	11.65	23.98	5725
UGA ET Checkbook	15.02	27.35	5025
UF Peanut Farm	7.90	20.23	4802
2015 Rainfall: 22.65 inches			
Dryland	0.50	23.30	5193
WaterMark (45 kPa)	4.45	27.25	5478
UGA ET Checkbook	12.50	35.30	5313
UGA EASYPan	5.20	28.00	5404
UF PeanutFarm	5.20	28.00	5327
Irrigator Pro	2.80	25.60	5542
50% Checkbook	6.76	29.56	5176

excessive rainfall and can be considered wet. There were not significant differences between any of the treatments for 2016, even the dryland treatment had a respectable yield. This year instead of using the full Checkbook due to its excessive irrigation a decision was made to only implement it at a 50% rate. All of the sensor-based methods and even the 50% Checkbook had yields above the three ton level. Irrigator Pro had the highest yields. Similar to 2016 there were not significant differences in yields for 2017, but there were significant differences for the total amount of water applied. Similar to the past years both the 45 kPa treatment and Irrigator Pro had the highest yield levels with the lower amount of irrigation applied. As can be seen the Checkbook had more irrigation applied but had the lowest overall yield. Similar to previous years 2018 did not have a large spread in data, but did have some significant differences between irrigation applied.

Table 3. Mean Irrigation Scheduling Results for 2016, 2017, and 2018. Irrigation Scheduling Treatment Differences			
2016 Rainfall: 25.80 inches			
Irrigation Treatment	**Irrigation Amount (in.)**	**Total Water (in.)**	**Yield (lbs/ac)**
Dryland	1.00	26.80	5249
WaterMark (45 kPa)	9.25	35.05	6292
PeanutFARM	7.75	33.55	6371
Irrigator Pro	10.00	35.80	6540
50% Checkbook	8.43	34.23	6367
2017 Rainfall: 24.30 inches			
Dryland	1.00	25.30	5875
WaterMark (45 kPa)	2.85	27.15	6396
PeanutFARM	5.50	29.80	5936
Irrigator Pro	4.00	28.30	6260
50% Checkbook	6.75	31.05	6262
Checkbook	10.50	34.80	5749
EASYPan	4.75	29.05	5979
2018 Rainfall: 32.43 inches			
Dryland	2.50	34.93	5591
WaterMark (45 kPa)	2.50	34.93	5849
Old Checkbook	7.80	40.18	6204
New Checkbook	6.70	39.13	6147
50% New Checkbook	4.00	36.45	6231
Irrigator Pro (Soil Temp)	6.30	38.68	5996
Irrigator Pro (Sensor)	3.30	35.68	6433
PeanutFARM	4.80	37.18	5984

Table 4 represents a two-year (2018 and 2019) study that focused on determining the effects of early (too wet) and delayed (too dry) irrigation trigger levels. Independent of the rainfall received during both years, as they are dynamically different, a trend can be observed of increasing yield as the soil water tension was allowed to dry to the 50 kPa level and then a reduction in yield if the soil was allowed to dry too much, or up to the 60 kPa level. These minor differences in soil water tension had significant impacts on final crop yield. Thus, it is critical that when an irrigation scheduling strategy is selected, that it is followed as recommended. As can be seen in all of the data presented in this chapter, irrigation scheduling is a critical component of successful yield production and making the wrong decision or not following a scientific method can lead to lost yield and/or lost profitability. Thus, in conclusion, irrigation management is a critical component of successful yield, and it is up to the producer to select a sound irrigation scheduling method that fits into their production operation and can be followed as directed. More information on irrigation management on peanuts can be found by reaching out to your local county Extension Agent.

Table 4. Mean Irrigation Scheduling Trigger Level Results for 2018 and 2019. Irrigation Scheduling Treatment Differences

2018 Rainfall: 32.43 inches			
Irrigation Treatment	**Irrigation Amount (in.)**	**Total Water (in.)**	**Yield (lbs/ac)**
Dryland	2.50	35.16	5591
WaterMark (20 kPa)	6.25	38.91	5847
WaterMark (30 kPa)	5.50	38.16	5729
WaterMark (40 kPa)	4.00	36.66	5900
WaterMark (50 kPa)	4.75	37.41	6047
WaterMark (60 kPa)	4.75	37.41	5862
2019 Rainfall: 19.74 inches			
Dryland	2.50	22.17	5874
WaterMark (20 kPa)	15.18	34.92	6572
WaterMark (30 kPa)	11.41	31.15	6779
WaterMark (40 kPa)	6.93	26.67	6834
WaterMark (50 kPa)	9.18	28.92	7076
WaterMark (60 kPa)	5.41	25.15	6798

PLANT GROWTH REGULATORS

Chapter 11
Plant Growth Regulators

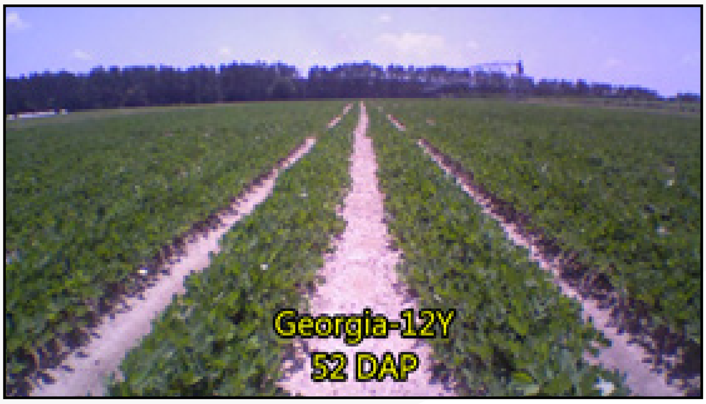
W. Scott Monfort

Plant Growth Regulators (PGR's)

Prohexadione calcium is the only plant growth regulator currently registered for use on peanuts. It is sold as Apogee® or Kudos®, and is formulated as a 27.5% WDG. When used properly, PC treated peanut vines are shorter and more erect allowing for increased efficiency in the digging and inversion process. Unfortunately, yield increases have been erratic and often insignificant on runner type peanut due to slower growth habit compared to virginia type peanut. Research in North Carolina on virginia type Peanut suggests that in addition to increased row visibility, Prohexadione calcium minimizes pod shed and pod loss during digging and harvesting operations. Based on research conducted at the University of Georgia, two applications of Prohexadione calcium increased yields an average of 96 pounds per acre higher than yield from non-treated peanut. The greatest beneficial effect has been reduced vine growth of newer more vigorous growing varieties on irrigated peanut fields with high levels of residual soil fertility. However, even under these conditions, use of Prohexadione calcium was not always economically justified. Make any decision to use Prohexadione calcium applications on a field by field basis.

Based on recent UGA research trials on new vigorously growing runner cultivars, the use of Prohexadione calcium can help managing vine growth. Reduction in vine growth could help in reducing digging losses along with increasing drying and harvest time in the field. The big concern is the effects of Prohexadione calcium on yield and grade. Unlike results on virginia type peanuts, the labeled rate of 7.25 oz per acre (two application) has shown some negative impacts on yield and grade. However, reduced rates (½ and ¾ rates applied twice) has shown positive yield increases while continuing to manage vine growth similarly to the 7.25 oz/per acre rate (See Table 1).

Images 1 and 2. Timing of initial application of Prohexadione calcium on peanuts where 50% of lateral vines are touching in row middles.



****** 50 % LAP --- Do Not Apply ******

50 % Lateral Vines Touching ---Apply

There are a few concerns regarding the use of Prohexadione calcium that need to be considered.

- The use of Prohexadione calcium is only recommended on irrigated acres where vines growth is excessive
- Use of Prohexadione calcium in non-irrigated or in irrigated fields where vine growth is not an issue will lead to stunted growth and potential yield loss.
- Include COC (1 quart/acre) and UAN (1 pint/ acre) or AMS with PC to help with plant uptake and consistency of performance.
- Prohexadione calcium requires eight hours for absorption by the peanut foliage to be effective.
- Prohexadione calcium is not recommended on plants that are under stress due to lack of moisture, disease pressure, or other stress conditions.

- Prohexadione calcium is not recommended on plants that are under stress due to lack of moisture, disease pressure, or other stress conditions.

Tank-Mix Considerations

Based on communication with BASF and others, PC has been shown to be compatible with many of the fungicides and insecticides growers utilize in peanut. The only problem is there are thousands of chemical combinations used in peanut each year. The only true way to determine if a select mixture is compatible is to do a compatibility test. Growers need to remember to include COC and UAN or AMS with PC to help with plant uptake and consistency of performance. This could affect compatibility with other products or cause increased burn on peanut.

Table 1. Recommendations for use of Prohexadione calcium (PC)

Peanut Type	Rate	Application Timing is Critical
Virginia Type Peanut	7.25 oz/A (twice)	1st App when 50% of Lateral vines are touching (see images 1&2) from adjacent rows, 2nd App - in 14 to 21 Days
Runner Type Peanut	3.63 to 5.44 oz (twice)	1st App when 50% of Lateral vines (see images 1&2) are touching from adjacent rows, 2nd App - in 14 to 21 Days

Images 3. Visual growth differences in peanut treated with Prohexadione calcium (PC) compared to untreated plots

WEED MANAGEMENT

Chapter 12
Weed Management in Peanut

Eric P. Prostko, Timothy L. Grey, W. Carroll Johnson III

One of the most important aspects of peanut production is weed management. Uncontrolled weeds not only reduce peanut yields through their competition for light, nutrients and moisture, but they can also severely reduce fungicide effectiveness and digging/harvest efficiency. Additionally, certain weed species, such as burgherkin, nutsedge, groundcherry, or horsenettle can produce tubers or fruits which can contaminate harvested pods resulting in lower quality and economic returns.

Troublesome Weeds in Georgia

Table 1 lists the top 10 most troublesome weeds in Georgia peanut. With proper identification and implementation of the appropriate management strategies, most of these weed species can be adequately controlled. Color photographs of these troublesome peanut weeds can be found at the end of this chapter.

Table 1. Top 10 Most Troublesome Weeds of Georgia Peanut.[a]

Rank	Weed
1	Palmer amaranth
2	Florida pusley
3	tropical spiderwort/Benghal dayflower
4	Florida beggarweed
5	sicklepod
6	tropic croton
7	nutsedge spp. (yellow and purple)
8	Texas panicum/millet
9	morningglory spp.
10	common bermudagrass

[a]*Webster, T.M. 2013. Weed Survey - Southern States. Proceedings of the Southern Weed Science Society 66:280.*

Weed Competition

A general understanding of weed competition can be helpful in making economical weed management decisions. It is not absolutely necessary to maintain 100% weed control to produce high peanut yields. Generally, peanuts must be kept weed-free from 4 to 6 weeks after emergence in order to obtain optimum yields although some weeds have longer weed-free requirements (Table 2). Weed emergence after this time period will not reduce peanut pod yields but could influence harvest efficiency, fungicide spray deposition, and add seed to the soil/weed-seed bank which will contribute to future weed problems in subsequent crops. In recent years, the threat of herbicide-resistant weeds has made soil/weed-seed bank management even more critical.

It is also important to note that all weeds are not created equal in regards to their potential effects on peanut yield (Table 3). Thus, some weeds may require extra management while others may not.

Table 2. Critical Periods of Growth of Various Weeds in Peanut.

Weed	Year	Location	Minimum weed-free period (weeks)a	Maximum interference period (weeks)b
bristly starbur	1989	AL	6	2
broadleaf signalgrass	1982	NC	6	6
common cocklebur	1997	FL	12	2
fall panicum	1977	NC	8	2
Florida beggarweed	1975	AL/GA	4	10
horsenettle	1987	OK	2	6
sicklepod	1975	AL/GA	4	10
silverleaf nightshade	1987	OK	4-12	4
tropical spiderwort	2007	GA	3-6	4
wild poinsettia	1992	GA/FL	10	2

[a]*Minimum amount of time after emergence that peanuts must be maintained weed-free in order to prevent yield losses. Generally, weeds emerging after this time period do not reduce yield but may influence harvest efficiency.*

[b]*Maximum amount of time after emergence that peanuts can tolerate interference without influencing yields. Weeds allowed to grow past this time period will cause significant yield losses.*

Cultural Practices

The use of UGA recommended cultural practices (planting date, seeding rate, row spacing, fertility management, and irrigation scheduling) that promote the development of uniform, rapidly emerging, vigorous peanut plants will be beneficial in terms of weed management. The effects of row spacing on weed control in peanut are presented in Table 4. Non-uniform peanut plant stands and/or diseased/weaker peanut plants help create an environment where weeds can flourish, dominant, and greatly complicate future weed management efforts.

Mechanical Cultivation

Increases in strip-tillage, narrow row patterns, and diesel fuel prices, coupled with the concern for potential increases in disease pressure from white mold, have all contributed to the recent decline in traditional mechanical cultivation for weed control in peanut. If cultivation is used as a weed management strategy in peanut, plow sweeps should be operated flat and shallow to remove weeds without ”dirting” the peanut plants or pruning lateral roots. The germination of certain weed species, particularly Florida beggarweed, can be stimulated by excessive cultivation, especially when the cultivation is followed by a significant rainfall event.

Herbicides

Peanut growers are fortunate in that there are 22 active ingredients registered for use as herbicides in Georgia peanut. The use of a particular herbicide should be based upon several factors including weed species, crop rotations, and cost/A. A brief description of the herbicides labeled for peanut are in Table 5 (page 95).

For weed efficacy ratings and current recommendations regarding the use of these herbicides in peanut, please refer to the latest edition of the Georgia Pest Control Handbook - Special Bulletin 28. Although a single herbicide program for all fields may be preferred, the most cost-effective herbicide programs are based upon individual field histories.

Crop Rotation Concerns and Herbicide Selection

As indicated previously, one of the main factors to consider when selecting an herbicide is its rotational crop restrictions. In Georgia, many specialty crops such as tobacco, onions, watermelons, carrots, etc., are grown which can be very sensitive to low soil residual levels of certain herbicides. Consequently, some herbicides should not be used for weed management in peanut if a future rotational crop could be at risk. Generally, herbicides with low rotational crop risks include 2,4-DB, Arrow, Basagran, Cobra, Dual Magnum, Gramoxone, Outlook, Poast, Prowl/Pendimax, Sonalan, Select, Storm, Ultra Blazer, Valor, and Warrant. Herbicides with a higher risk to rotational crops include Cadre, Classic, Pursuit, Spartan, and Strongarm. Refer to the most recent herbicide label for specific information about the various rotational restrictions for other crops before using them in a peanut field.

Weed Control in Strip-Tillage Peanut Production

The key to weed management in strip-tillage peanut production systems is to have a seed-bed where the cover crop is totally killed and weed-free at planting. This provides peanut plants with a competitive advantage over the development of later emerging weeds. Generally, the herbicides available for use in strip-tillage systems are the same as those for conventional systems. However, tillage is replaced by the use of non-selective, burndown chemicals and herbicides cannot be mechanically incorporated before planting.

Table 3. Peanut Yield Loss Caused by 1 Plant/Meter of Crop Row[a].	
Weed	**Peanut Yield Loss - %**
common cocklebur	70
common ragweed	40
Palmer amaranth	28
wild poinse	17
tropic croton	17
horsene	14
bristly starbur	13

[a]Burke, I.C., M. Schroeder, W.E. Thomas, and J.W. Wilcut. 2007. Palmer amaranth interference and seed production in peanut. Weed Technology 21:367-371.

Table 4. Weed Control as Influenced by Peanut Row Spacing		
Weed	**Control (%)a**	
	single row	**twin row**
common cocklebur	93	95
Florida beggarweed	87	93
ivyleaf morningglory	93	93
sicklepod	76	82

[a]Averaged over 12 herbicide treatments and 2 tillage systems (conventional and strip). bStephenson IV, D.O. and B.J. Brecke. 2006. Weed management in single vs. twin-row peanut (Arachis hypogaea). Weed Technology 20:368-376.

Table 5. Herbicides Labeled for Use in Peanut.				
Common Name	**Trade Name(s)**	**Application Method(s)a**	**Mechanism of Action (WSSA)**	**Important Weeds Controlled**
acetochlor	Warrant	PRE AC POST	15 VLCFA inhibitor	Pigweed, tropical spiderwort, annual grasses
acifluorfen	Ultra Blazer Avalanche Ultra	POST	14 PPO inhibitor	annual morningglories, pigweed, tropic croton, hemp sesbania, common ragweed, hophornbeam copperleaf
acifluorfen + bentazon	Storm	POST	14 + 6 PPO + photosynthesis inhibitor (site B)	annual morningglories, pigweeds, tropic croton, common cocklebur, hemp sesbania, hophornbeam copperleaf
bentazon	Basagran Broadloom	POST	6 photosynthesis inhibitor (site B)	cocklebur, coffee senna, eclipta, smallflower morningglory, yellow nutsedge
carfentrazone	Aim	Harvest-aid	14 PPO inhibitor	annual morningglory (except smallflower, pigweed, tropical spiderwort
carfentrazone + pyroxasulfone	Anthem Flex	AC POST	14 + 15 PPO inhibitor + VLCFA inhibitor	annual grasses, Florida beggarweed, pigweed, tropical spiderwort
chlorimuron	Classic	POST	2 ALS inhibitor	Florida beggarweed - 60 days after peanut emergence
clethodim	Arrow Select	POST	1 ACCase Inhibitor	annual and perennial grasses
diclosulam	Strongarm	PPI PRE AC POST	2 ALS inhibitor	bristly starbur, Florida beggar-weed, Florida pusley, common cocklebur, common ragweed, eclipta, hophornbeam copper-leaf, tropical spiderwort
dimethenamid-p	Outlook	PPI PRE AC POST	15 VLCFA inhibitor	annual grasses (except Texas panicum), Florida pusley, yellow nutsedge, tropical spiderwort, pigweeds

(table continued on next page)

Table 5. Herbicides Labeled for Use in Peanut.				
Common Name	**Trade Name(s)**	**Application Method(s)a**	**Mechanism of Action (WSSA)**	**Important Weeds Controlled**
ethalfluralin	Sonalan	PPI PRE	3 microtubule inhibitor	annual grasses, Florida pusley, pigweeds
flumioxazin	Valor SX/ Valor EZ Panther RedEagle Flumioxazin Rowel	PRE	14 PPO inhibitor	Florida beggarweed, tropic croton. eclipta, hophornbeam copperleaf, Florida pusley, pigweeds
fluazifop	Fusilade	POST	1 ACCase inhibitor	Annual and perennial grasses
lactofen	Cobra	POST	14 PPO inhibitor	morningglories, tropic croton, eclipta, pigweed, wild poinsettia, copperleaf
imazapic	Cadre Impose	POST	2 ALS inhibitor	yellow and purple nutsedge, sicklepod, annual morningglories, pigweeds, wild poinsettia, Florida beggarweed (< 2”)
imazethapyr	Pursuit	PPI PRE POST	2 ALS inhibitor	yellow and purple nutsedge, wild poinsettia, annual morningglories, pigweeds, tropical spiderwort
paraquat	Gramoxone SL Firestorm Parazone Helmquat	AC Harvest-aid	22 PSI electron diverter	Florida beggarweed, sicklepod, annual grasses, tropical spiderwort, burndown for strip-tillage
pendimethalin	Prowl Pendimax Prowl H_20 Satellite Satellite HydroCap	PPI PRE	3 Microtubule inhibitor	Annual grasses and small seeded broadleaf weeds (pigweed, Florida pusley)
pyraflufen	ET	Harvest-aid	14 PPO Inhibitor	Annual morningglory and small pigweed
pyroxasulfone	Zidua	POST	15 VLCFA inhibitor	Residual control of annual grasses and pigweed

(table continued on next page)

Table 5. Herbicides Labeled for Use in Peanut.				
Common Name	**Trade Name(s)**	**Application Method(s)a**	**Mechanism of Action (WSSA)**	**Important Weeds Controlled**
sethoxydim	Poast Poast Plus	POST	1 ACCase inhibitor	annual and perennial grasses
s-metolachlor	Dual Magnum	PPI PRE AC POST	15 VLCFA inhibitor	annual grasses (except Texas panicum), Florida pusley, yellow nutsedge, tropical spiderwort, pigweeds
metolachlor	Stalwart Me-Too-Lachlor Parallel PCS			
sulfentrazone	Spartan	PPI PRE	14 PPO inhibitor	annual broadleaf weeds including pigweed and morningglory
2,4-DB	Butyrac Butoxone	AC POST	4 Synthetic auxin	annual morningglories, common cocklebur, sicklepod, citronmelon

[a]*PPI = preplant incorporated; PRE = preemergence; AC = at-cracking or early postemergence; POST = postemergence*

Cover crops and most winter weeds should be controlled 3 to 4 weeks ahead of planting with either Roundup (glyphosate) or Gramoxone (paraquat). In fields where cutleaf eveningprimrose is a problem, 2,4-D should be applied in February or March before the general burndown. Valor can be tank-mixed with either glyphosate or paraquat to increase their activity on broadleaf weeds and provide residual control, especially when there will be a delay between the burndown application and planting.

The foundation of weed control systems in conventional peanuts has been the use of preplant incorporated applications of Prowl EC/Prowl H2O/PendiMax or Sonalan. Consequently, their use in strip-tillage systems has been questioned because they cannot be mechanically **incorporated.** Research and experience over the past several years has shown that season-long control of Texas panicum and Florida pusley with these herbicides applied preemergence can be difficult, even when properly activated. However, this does not mean that they should not be excluded in strip-tillage peanuts. The “yellow” herbicides are still some of the most economical and cost-effective products used in peanuts. Prowl EC/Prowl H_2O/PendiMax are pref-erable to Sonalan in strip-tillage systems because they are less subject to volatility losses.

Recent strip-tillage research has shown that the most important factors that influence the perfor-mance of Prowl EC/Prowl H_2O/PendiMax in strip-tillage systems are time of application and herbicide rate. In non-irrigated fields, timing Prowl applications just prior to a rainfall will greatly improve the overall weed control, especially in the row middles. In irrigated, strip-tillage production systems, Prowl should be applied immediately after planting and activated within 48 hours with a minimum of 0.75" of overhead irrigation.

Other preemergence herbicides such as Strongarm, Valor, Dual Magnum, and Warrant can be used in strip-tillage peanut production systems. Regardless of tillage method, the use of these herbicides should be based upon the weed species present, rotational crop restrictions, and cost/A. In order for these preemergence herbicides to be effective, they also must be applied and activated before the weeds have germinated or emerged. Activation can be achieved by either rainfall or irrigation as discussed above. Valor should not be applied prior to operating the strip-tillage implement because mechanical incorporation may reduce its activity. All of these preemergence herbicides can be tank-mixed with glyphosate or paraquat if a new flush of weeds has occurred since the burndown application was made.

In strip-tillage systems with heavy residues that may protect emerged weed seedlings from a burndown treatment or prevent soil-applied herbicides from reaching their target, a greater reliance on postemergence herbicides should be expected. Greater reliance on postemergence herbicides for weed control in strip-tillage peanut production may increase herbicide costs and force peanut growers to make timelier weed control decisions compared to weed control in conventional tillage systems.

Lastly, long-term reduced tillage practices could cause shifts in weed populations from common annual species to unusual annual or perennial species such as bermudagrass, horsenettle, nutsedge, and/or others. This will add to the overall cost of production, lead to a greater dependence on herbicides, and require an extra effort to manage these perennial weeds during the off-season.

Tank-Mixtures

In an effort to reduce trips across a field, it is common for growers to tank-mix herbicides, fungicides, insecticides and fertilizers. There are over 90,000+ potential tank-mixtures that can be used in peanut. It would be almost impossible for UGA to adequately test all of these tank-mixes. Reduced performance, increased peanut injury, and chemical incompatibility are major issues with tank-mixtures. Generally, it is not recommended to have more than 2 chemicals in a tank-mix at one time unless UGA data/experience would suggest otherwise. Contact your local County Extension Agent for any known tank-mix issues.

Perennial Weeds

Perennial broadleaf weeds such as dogfennel, horsenettle, maypop passionflower, and trumpet creeper, can be very difficult to control in peanut. There are no herbicides labeled in peanut for their selective control. The best approach for perennial weed control in peanut would be to avoid planting in suspect fields and/or to apply maximum labeled rates of glyphosate in the fall sometime after peanut harvest and weed regrowth but at least 2 weeks before a hard frost. It will take several years of these fall glyphosate treatments to get perennial weed populations under control.

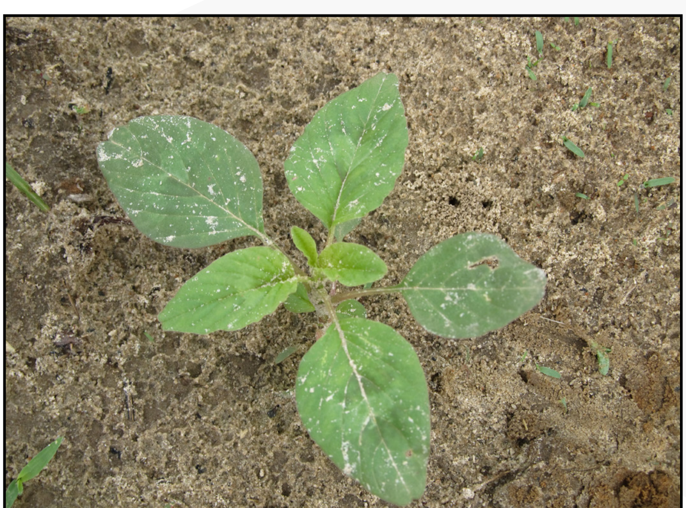
Herbicide-Resistant Weeds

Herbicide resistance is a process of selection that occurs from the overuse of herbicides and/or the over-dependence on a single herbicide or herbicides with the same mode of action. Over the past several years, reduced pigweed control has been a major issue for many peanut growers. Consequently, concerns have been raised about the increased incidence of herbicide resistant weeds, particularly to ALS-inhibiting herbicides (Cadre, Strongarm, Pursuit, and Classic). Populations of ALS-resistant pigweed have been identified in numerous counties in Georgia.

It is important to note that there are many factors that influence herbicide performance including rate, weed size, environmental conditions, nozzle type, spray volume, tractor speed, boom height, and many others. When weed control in unacceptable, herbicide resistance should only be considered when these other factors have been ruled out as the cause of the problem.

Herbicide-resistant weeds should be managed using an integrated approach that combines cultural (cover crops, crop rotations, narrow/twin row spacing), mechanical (tillage, cultivation), chemical (herbicide), and hand-weeding practices. For additional information about herbicide-resistant weeds, refer to the UGA Weed Science Website.

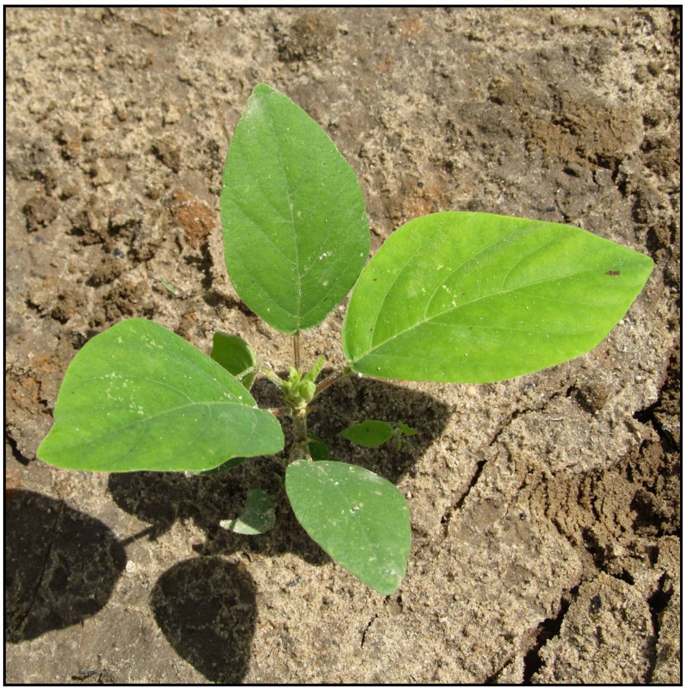
Weed Identification



Palmer Ameranth

Florida pusley

Benghal dayflower/tropical spiderwort



Florida beggarweed

Sicklepod

Tropic croton

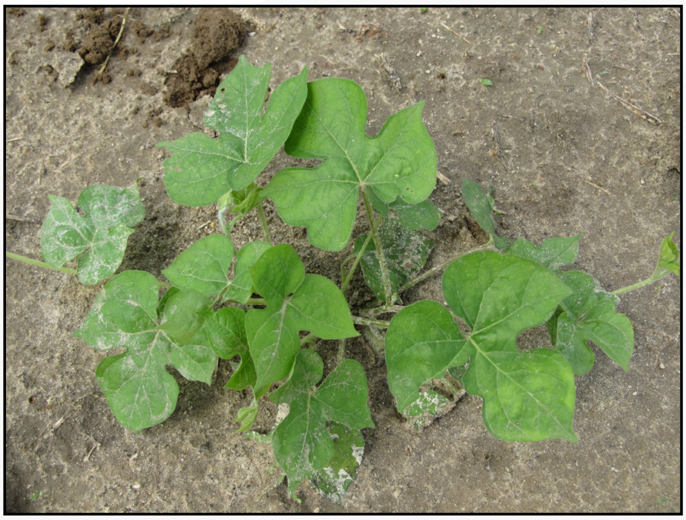
Purple nutsedge

Texas millet/panicum

Smallflower morningglory

Red morningglory

Cypress vine morningglory



Ivy leaf morningglory

Pitted morningglory

Yellow nutsedge

Bermudagrass

DISEASE AND NEMATODE MANAGEMENT

Chapter 13
Disease and Nematode Management in Peanut

Bob Kemerait, Tim Brenneman, and Albert Culbreath

The importance of disease and nematode management:

Losses to and protection from diseases and nematodes cost peanut growers in Georgia millions of dollars every year. Management of diseases and nematodes is one of the most important, and also one of the most expensive, aspects of peanut production in the southeastern United States.

In this section, information will be provided on the diseases and nematodes likely to be found in the peanut fields of Georgia, as well as on several "disease-like" symptoms. For each disease, practical information will be presented on identification, factors that increase risk to damage and yield loss, and management.

Factors that increase the risk to disease outbreaks.

The "disease triangle" is a model often used to describe the development of plant diseases. The disease triangle is made up of three parts. These include disease-causing pathogens (fungi, bacteria, and viruses), a susceptible host, and a favorable environment. Disease develops when each factor is present; diseases are managed by disrupting or minimizing one or more "legs" of the triangle.

For peanuts , the "pathogens" are those organisms, typically fungi, which cause the disease. The "host" is the peanut plant and a "favorable environment" is one that is conducive for the development and spread of disease. For many diseases affecting peanuts, warm and wet weather is most conducive to the spread of disease. For a few diseases, "hotter and drier" conditions favor disease outbreaks. Based upon environmental conditions during the season, growers can anticipate diseases that are likely to be of increased concern.

1. Cooler and wetter conditions at planting and early in the season increase the risk for seedling diseases, as caused by Rhizoctonia solani, and may also increase Cylindrocladium black rot (CBR). Early-season infection for CBR is favored by cool, wet conditions; symptoms of the disease typically occur later in the season.

2. Hotter conditions and warmer soils early in the season can increase the risk for southern stem rot (Sclerotium rolfsii), also known as white mold. Hotter and drier conditions also favor outbreaks of Aspergillus crown rot. Hot soils, especially without rainfall or irrigation, can scald the young taproot and predispose the injured plant to the crown rot disease.

3. Abundant moisture during the growing season predisposes the crop to fungal diseases, especially leaf spot diseases. Abundant rainfall not only provides the moisture needed for infection, growth and spread of disease, but it also may delay the timeliness of fungicide applications which adds to the difficulty in managing disease.

4. Hot and dry conditions during a growing season typically reduce the threat to leaf spot diseases, but increase risk to white mold, especially in non-irrigated fields. During warm conditions, white mold may be more problematic because the fungus often thrives in the hottest part of the

summer. Under dry conditions, the disease is likely to be occur just below the soil surface where moisture allows the fungus to attack the pods and pegs. Not only is this "underground" white mold difficult to detect, but it is also more difficult for the fungicide to reach the target area. Rainfall and irrigation are important for movement of the fungicide from the foliage to the crown and limbs of the plants. During dry weather, the fungicides are less likely to be moved to the areas where soilborne diseases occur.

5. Hot and dry conditions late in the season and harvest greatly increase the risk of aflatoxin in the peanuts. It becomes even more critical that peanuts are segregated based upon whether or not they received adequate rainfall during the season. This includes separating peanuts harvested from "dry corners" from well-irrigated parts of the same field.

6. The type of soil in a field can have a major impact on the risk to the peanut root-knot nematodes. Peanut root-knot nematodes are most commonly found in fields where the soil has a higher sand content and in the sandier areas of fields.

Strategies for management of the diseases:
"AVOIDANCE" includes decisions in peanut production that allow growers to reduce exposure of the crop to disease causing organisms and the environmental conditions that favor development and spread of diseases. Factors that help growers to "avoid" diseases include:

1. Planting dates: As per Peanut Rx, earlier planting dates reduce risk to leaf spot diseases; planting dates in early May reduce risk to tomato spotted wilt.

2. Conditions at planting: Planting seed into warm soils with adequate moisture often result in rapid germination, uniform emergence and vigorous growth. Such reduces risk to Rhizoctonia seedling disease and also to tomato spotted wilt.

However, planting into very hot and dry soils increases risk to Aspergillus crown rot and perhaps white mold (southern stem rot). Planting into cool and wet soils increases risk to Rhizoctonia seedling disease and to Cylindrocladium black rot (CBR).

"To REDUCE populations of pathogens" is an effective strategy to reduce the lower the risk of disease in a field. Fungal pathogens often survive in the soil or in the peanut debris (stems, leaves, pods, roots, etc.) remaining in the field after harvest. Tactics to reduce the amount of survival over time include:

1. Rotation with a non-host crop. By increasing the interval between peanut crops in a field (and crops that are susceptible to the same diseases, such as soybeans) growers can reduce the impact of diseases and nematodes and also reduce the reliance on chemical control methods. Note: Winter cover crops do not count as "rotation" crops for reducing nematode populations, though they have other benefits in crop production.

We recommend that peanuts are planted not more than once in field over a three-year period; increasing rotation to where peanuts are planted in a field on even longer intervals further helps to protect the crop from diseases and nematodes. Planting peanuts in the same field more than once in three years is not recommended. Growers should have a minimum of two years between each peanut crop. Short rotations lead to increase damage from disease and nematodes and increased yield losses.

Rotation crops:

A. Bahiagrass is an excellent rotation partner with peanut as the crops do not share pathogens or the peanut root-knot nematode (*Meloidogyne arenaria*). Bahiagrass is one of the very best crops to rotate with peanut. Note: Bahiagrass and peanut are both hosts to the lesion nematode (*Pratelynchus* spp.). Though this nematode has not been considered an important problem for peanut growers, it has been recently associated with losses in some fields.

B. Field corn is also an excellent crop for rotation with peanut and does not share any of the same diseases, though it is a host for the peanut root-knot nematode. Nonetheless, it is a very good crop to rotate with peanut.

C. Cotton is a good host to rotate with cotton. Both crops are affected by seedling diseases caused by the fungus *Rhizoctonia solani*, but that is typically the only disease they share in common. Cotton and peanut are generally not susceptible to the same nematodes, though there is concern that the sting nematode (*Belonolaimus* sp.) which is an important concern for the cotton crop could, in some situations, affect the peanut crop.

D. Soybean is not a good rotation crop with peanut. Though soybean is not a host for peanut leaf spot diseases, it is susceptible to CBR (known as red crown rot in soybeans), peanut root-knot nematodes (unless a resistant variety is planted) and to some extent, Rhizoctonia disease and southern stem rot (white mold). Note: Legumes (bean crops) are not recommended for rotation because they are likely to share similar diseases with peanut, also a legume crop.)

E. For questions regarding rotation with other crops, please contact your local UGA Extension agent.

2. Tillage and residue management are practices that can be helpful in reducing pre-season levels of some pathogens.

A. Many fungal pathogens can survive in crop debris, for example *Rhizoctonia solani* and fungi causing early and late leaf spot. Burying residue hastens the decomposition of the debris and hence deprives the pathogens of a source of nutrition between crops.

B. Conservation/reduced tillage reduces risk to tomato spotted wilt and also to leaf spot diseases, assuming a winter cover-crop is planted. For leaf spot, this is most effective when peanuts are not planted in consecutive seasons. Conventional tillage is likely more beneficial in the management of soilborne diseases and plant-parasitic nematodes, but small benefits for disease management may be offset by other production benefits from conservation tillage practices.

RESISTANCE and RESISTANT VARIETIES can be very effective ways to minimize both the impact of disease and the use of chemical control measures. Both of these factors can make the crop more profitable by a) increasing yields and b) lowering the cost of production. Also, resistant varieties can be especially important when chemical control and other production tactics are limited or are not available. Such is the case for tomato spotted wilt and for organic peanut production. In some instances, as in the case of root-knot nematodes, use of resistant varieties will not only protect the crop for this season, but will also reduce nematode populations for future crops.

"Partial resistance", "tolerance" and "immunity" are all terms that may be used when describing varieties that are used in the management of diseases and nematodes. "Immunity" indicates that the variety will not be affected by the disease or nematode at all; immunity is not common. However, our current root-knot nematode varieties are "nearly immune". "Partially resistant" varieties are not immune to a disease; however they are less affected by disease than are other "susceptible" varieties. Disease development on partially resistant varieties is likely to be delayed from that on susceptible varieties and is typically not as severe. In terms of fungal diseases, such as leaf spots, white mold, and Rhizoctonia limb rot, "partially resistant" varieties may require less fungicide usage to maintain disease control and protect yield. Highly root-knot-nematode-resistant varieties also have the advantage over susceptible varieties in that they inhibit nematode reproduction and reduce nematode populations in the soil.

1. Plant breeders have been able to develop varieties with improved resistance to leaf spot diseases and white mold. The specific (and practical) benefits of this resistance can be found in the latest version of Peanut Rx. Growers who plant these more-resistant varieties will have less threat from disease and may have the opportunity to reduce the use of fungicides or adopt less costly programs.

2. When planted in fields where diseases or nematodes are not a problem (often because of excellent crop rotation), resistant varieties may not yield as well as our best, susceptible varieties. However, the true value of our resistant varieties is observed when they are planted in fields with increased nematode populations or with higher risk to disease.

Protecting the peanut crop from diseases with fungicides is a critical component of production for the majority of peanut growers in Georgia. Deploying a fungicide program can be quite frustrating for at least four different reasons. First, an effective fungicide program must control a number of different diseases, most notably late leaf spot, early leaf spot and white mold (stem rot). Second, fungicides are applied throughout the entire season and timing of multiple applications can be confusing. Third, peanut growers have an ever expanding arsenal of fungicides from which to choose. Growers must make decisions based on efficacy and cost. Lastly, fungicide resistance management is important for the long-term efficacy of the different classes of chemistries.

Common questions associated with fungicide programs include:

What are the components of a fungicide/ nematicide program? Growers need to consider protecting their crop with fungicides during three different phases of the growing season.

1. **At-plant options**: Planting high quality seed is an important consideration for achieving a good stand and for protecting the seed and young plants for disease. A fungicide seed-treatment is essential to getting a good stand of peanuts and to protect the seed and seedlings from diseases like Aspergillus crown rot and others caused by *Rhizoctonia solani* and other fungal pathogens. Commercial seed will come pre-treated; growers who are using farmer-saved seed should insure that their seed is treated with an effective fungicide package by a reputable seed treater. Poor stands due to seedling diseases also impact the risk for tomato spotted wilt disease.

Growers can use in-furrow-applied fungicides to compliment fungicide seed treatments for control of seedling diseases. Complimenting a seed-treatment with an in-furrow fungicide application is generally not needed where quality seeds are planted. However, where the quality of the seed is questionable, or where farmer-saved-seed is planted, use of the seed treatment and the in-furrow fungicide may beneficial. Further information to help decide on the most appropriate in-furrow fungicide will be outlined later in this chapter.

In-furrow fungicides may also be used to protect the peanut crop against Cylindrocladium black rot (CBR) and early-season outbreaks of white mold (southern stem rot). In-furrow fungicide applications of some materials may also provide early benefits for leaf spot control as well.

Peanuts grown in Georgia are affected by the peanut root-knot nematode (*Meloidogyne arenaria*), the lesion nematode (*Pratelynchus* sp.) and the sting nematode (*Belonolaimus* sp.). By far, the peanut root-knot nematode causes the greatest damage to the peanut crop, as compared to the lesion and sting nematodes. To manage the root-knot nematodes, growers can plant resistant varieties, or they can use chemical control. Chemical control measures include pre-plant fumigation with 1,3-dichloropropene (Telone II) or at-plant applications of liquid products such as Velum (fluopyram) or granular products such as AgLogic (aldicarb). Growers must remember that once the furrow is closed, they have very few management options left with which to reduce damage to nematodes.

2. **Leaf spot control during the season**. To maximize yield potential, all peanut growers must protect their crop from leaf spot diseases and, occasionally, peanut rust. Fungicide programs for leaf spot diseases typically begin approximately 30 days after planting; however with improved fungicides and the development of Peanut Rx, fungicide programs for management of leaf spot can be initiated as late as 45 days after planting. The peanut crop should be protected against leaf spot diseases throughout the growing season. Fungicides are typically applied on a 14-day interval. Where risk to leaf spot is high, for example in fields with short rotations, where a susceptible variety is planted, where extended periods of rain are in the forecast, or where peanut rust is found, growers may tighten this interval to 10-12 days between applications. Where growers follow Peanut Rx and assess their field to be "low" or "moderate" risk, or during lengthy periods of dry weather, grower can extend the application interval beyond 14 days, sometimes to as much as 21 to 28 days.

To protect against leaf spot diseases, growers have a number of fungicides from which to choose. The most commonly used fungicide for the peanut farmer is chlorothalonil, which is sold under a number of brands, most notably "Bravo". Clorothalonil is a protectant fungicide that needs to be applied before leaf spot diseases occur in a field. Once leaf spot diseases occur in a field, or in anticipation of disease, grower may choose to use "systemic" fungicides which have limited "curative" activity. "Systemic" fungicides have the ability to move to some degree within the leaf and to help "cure" very recent infections. However, systemic fungicides cannot eliminate older, well-established infections, such as when spots are clearly evident on the leaf.

Full-season fungicide programs include a number of applications for management of soilborne diseases like white mold (southern stem rot) and Rhizoctonia limb rot. Growers often focus on the "white mold" control from these fungicides; however they should also insure that leaf spot management is considered in every application.

3. **Soilborne disease and nematode control during the season.** Growers must protect their crop from soilborne diseases, to include white mold (southern stem rot) and Rhizoctonia limb rot. Typically white mold and Rhizoctonia limb rot become problematic when the canopy of leaves becomes dense and traps moisture and humidity, thus creating near-perfect conditions for infection and development of disease. While the peanuts are still small, white mold and Rhizoctonia limb rot are less problematic because without the canopy of foliage and the peanut limbs resting along the moist soil, the fungal pathogens are less able to affect the crop.

Historically, fungicide programs for management of white mold and Rhizoctonia limb rot in Georgia have been initiated approximately 60 days after planting and continued over the next six to possibly eight weeks. Today, growers may take steps to protect their crop from white mold with in-furrow fungicide application and banded fungicide applications within the first five weeks of the season. As harvest of our current peanut varieties may occur 150 days after planting, timing of fungicide applications for control of white mold may extend longer now than in the past.

Where nematodes are a problem, growers may choose to make an application of an appropriate nematicide (e.g. Velum or Vydate-CLV) somewhere between 45 and 70 days after planting to further protect the developing pods and pegs. Depending on the timing of the application, growers should consider not only nematode control, but also control of leaf spot and soilborne diseases at the same time.

How late should fungicide applications continue?

Growers often request advice on adjusting digging dates based upon disease in the field. Generally, it is best to wait until appropriate pod maturity is reached in order to assure maximum grade, rather than digging the peanuts early. For example, though tomato spotted wilt may be severe in a field, it is usually recommended to wait for maturity to dig the peanuts. However, where defoliation from leaf spot is severe, it is worth considering digging earlier. Where white mold is severe, for example greater than 50% incidence, the grower should consider if digging early is appropriate. Significant defoliation from leaf spot diseases and severe outbreaks of white mold can increase digging losses by weakening peg-strength and pod loss when the peanuts are dug. Severe infestation with the lesion nematode can also necessitate early digging of peanuts.

NOTE: A critical consideration late in the season is that pre-harvest intervals (PHI) vary among fungicides. For example, Alto has a 30-day PHI, and Convoy, Umbra, and EXCALIA have a 40-day PHI, compared to 14-day PHI for other fungicides. Growers must always check the label for the appropriate PHI.

Below are some typical situations that peanut growers in which growers may find themselves and suggestions for control:

Grower is 4 or more weeks away from harvest and currently has excellent disease control.

Suggestion – Recommend the grower apply a minimum of one more fungicide, at least for leaf spot control and perhaps for white mold control.

Suggestion – Given the low cost of tebuconazole, the grower may consider applying a tank-mix of tebuconazole + chlorothalonil for added insurance of white mold and leaf spot.

NOTE 1: If white mold is not an issue, then the grower may use a leaf spot spray only.

NOTE 2: If grower has planted Georgia-06G or a disease-resistant variety like Georgia-12Y and the plants are leaf spot-free at 4 weeks prior to the anticipated digging date, an additional fungicide application for leaf spot may not be needed assuming the grower is willing to watch/scout the field for other diseases such as peanut rust.

Grower is 4 or more weeks away from harvest and has disease problems in the field.
If the problem is with leaf spot – grower should insure that any fungicide applied has systemic/ curative activity. If a grower wants to use chlorothalonil, then they should mix a product like thiophanate methyl (Topsin M), tetraconazole (Domark) or cyproconazole (Alto), with the chlorothalonil. Others may consider applying fluxapyroxad + pyraclostrobin (Priaxor), if they have not already applied Priaxor twice earlier in the season.

If white mold is the problem, then growers should continue with fungicide applications for management of white mold. If they have completed their regular white mold program, then they should extend the program, perhaps with a tebuconazole/ chlorothalonil mix, or other products, such as Provost Silver or Fontelis, with 14-day pre-harvest intervals. If the grower is unhappy with the level of control from their fungicide program, then UGA Extension can offer alternative fungicides to apply.

If the problem is underground white mold – Underground white mold is difficult to control. Applying a white mold fungicide ahead of irrigation or rain, or applying at night, can help to increase management of this disease.

Grower is 3 weeks or less away from projected harvest and does not currently have a disease issue. Good news! This grower should be good-to-go for the remainder of the season and no more fungicides are required. **SEE NOTE BELOW ABOUT HURRICANES**

Grower is 3 weeks of less away from harvest and has a problem with disease.

If leaf spot is a problem and 2-3 weeks away from harvest, a last leaf spot fungicide application may be beneficial. Tank-mixing chlorothalonil with a systemic fungicide, like thiophanate methyl or other appropriate systemic fungicide, could be beneficial. However, if leaf spot is too severe and significant defoliation has occurred, then a last application will not help.

If white mold is a problem and harvest is 3 weeks away, then it is likely beneficial to apply a final fungicide for management of this disease. If harvest is 2 weeks or less away, then it is unlikely that a last fungicide application will have time to be of any benefit.

NOTE: If harvest is likely to be delayed by threat from a hurricane or tropical storm, then the grower should reassess recommendations for end-of-season fungicide applications.

How often should fungicides be applied?
Historically, fungicide programs were initiated approximately 30 days after planting and continued on a 14-day interval, typically concluding after a total of seven applications. However, with the development of Peanut Rx and prescription fungicide programs, the recommended interval between fungicide intervals can vary between 14 days, for higher risk, and 21-to 28 days for lower-

risk fields. Additionally, where conditions are favorable for disease, or where disease is present in the field, growers may be encouraged to shorten the interval between applications to 10-to 12 days.
If fungicides of the same chemical class or mode of action (FRAC Groups) are applied too frequently to a peanut crop, then fungicide resistance can develop. Resistance to a fungicide occurs when fungal pathogens are repeatedly exposed to a single class of chemistry with the same mode of action (that is, the specific way in which the fungicide attacks the fungus). Over time, the population of pathogens in the field shifts from "more sensitive" to "more resistant" and is less affected by the fungicide to the point that it is much less effective. This situation is to be avoided as long as possible.

Resistance management includes efforts made in developing fungicide programs to protect the longevity of a fungicide or a class of fungicides in order to prolong their efficacy and usefulness over time. Resistance management programs require that growers NOT USE fungicides within a class of chemistry more often than noted according to the pesticide label, or at lower-than-recommended rates, no matter how inexpensive or effective they are.

Fungicides are an important tool for the management of many diseases affecting the peanut crop. To obtain the greatest benefits from a fungicide, growers must decide which is the best fungicide to use and also the most appropriate and effective application strategy. Use of the "wrong" fungicide impacts disease control. Improper applications will also reduce efficacy of the product no matter which is selected.

Classes of fungicides: Fungicides are grouped together into "classes" based upon the way in which they affect fungal pathogens, also known as "mode of action". All fungicides within the same class affect the pathogen in the same way. Growers can find the "FRAC Code" on the front page of the pesticide label. ("FRAC" stand for "Fungicide Resistance Action Committee".) All fungicides with the same "FRAC Code" belong to the same family and have the same mode of action.

Understanding the "FRAC Code" and classes of fungicides are important to peanut farmers for two reasons. First, in selecting a fungicide, growers are able to determine if two products are closely related, or not. This is important when deciding on the best fungicide to use, especially if a grower is trying to find a "better" product. Second, in order to minimize the risk of fungicide resistance and to extend the useful life of a fungicide, it is important to avoid over-use of any single class of chemistries.

In addition to the fungicides groups mentioned above, research efforts continue to determine how best inorganic products, e.g. sulfur, can be used to improved leaf spot control in peanuts.

Protectants versus systemic fungicides: Growers should recognize that fungicides are broadly divided into two groups, the protectant fungicides and the systemic fungicides. Protectant fungicides, most notably chlorothalonil, must be applied BEFORE infection has occurred, as they do not enter the plant. Systemic and locally-systemic fungicides, such as triazoles, strobilurins and SDHIs, are able to enter the plant tissue and move within the leaf to some degree, therefore providing some limited "curative" activity.

Strategies for Application: In addition to selecting the "best" fungicide, peanut growers must also apply the fungicides correctly in order to achieve maximum control of disease. Two of the most important considerations for growers are to protect the plants before disease is established in the field and to ensure the fungicide reaches the intended target. Getting good coverage of the leaves is fairly easy; however reaching the crown and limbs of the plants and even the pegs and pods is much more difficult. The dense canopy of foliage makes it more difficult to get adequate coverage of these parts.

Below are some of the factors that affect the performance of a fungicide program.

Pressure: Increasing spray pressure at time of application is one tactic deployed to try and get better penetration of the leaf canopy and coverage of the crown and limbs of the plants, thus protecting them from soilborne diseases.

Nozzles: There are a number of different spray tips that are used by farmers when protecting their peanut crop from diseases, insects and weeds. While there may be some small differences in control of diseases based upon choice of spray tips, these differences are likely dwarfed by other factors to include timing of application, time to an irrigation or rainfall event, and spray volume.

Volume: It is generally agreed that an increased spray volume improves the coverage of the fungicide on the peanut plant. A larger spray volume may also increase the amount of fungicide that penetrates the canopy, thus better protecting crown and limbs against soilborne diseases.

However, increasing spray volume will   increase the amount of time and the amount of water needed to treat a field. In general, fungicide applications by ground-driven equipment should not be applied in less than 10-12 gal/A and are rarely applied at greater than 20 gal/A Further research is needed to better understand how much efficacy of a fungicide is improved with increased spray volumes. Aerial applications should be at the highest volume that can be negotiated with the pilot.

Speed: Growers are pressed to cover ground as quickly as possible when spraying a field. However, it is likely that in travelling to fast across a field, effective coverage with a fungicide is significantly reduced as the spray booms bounce and sway. Growers are likely to improve coverage and disease control if they can reduce their speed as they travel through the field.

Aerial vs ground application: Many growers ask for a comparison of disease control when a peanut field is sprayed using ground-driven equipment versus an airplane. Though data is lacking, it is generally believed that spraying a field with ground-driven equipment is advantageous because of a) increased pressure, b) increased spray volume and c) potential for reduced drift. Aerial applications have three advantages over ground equipment. First, fields can be sprayed using an airplane at times when it would be impossible to get a tractor in the field. Second, a plane may be able to spray a field more quickly than would be possible with a tractor, should the need arise. Third, applying a fungicide by air eliminates the need to damage vines as a tractor moves through the field; damaged vines increase risk to diseases like white mold.

Timing: In addition to selection of a fungicide, the timing of an application is critical for the success of a disease-management program. Application of a fungicide too early is likely to add to production costs while resulting in little, if any, yield increases. Applying a fungicide too late, for example once disease is established in a field, may result in lost ability to control the disease and also lower yields.

Growers get best results if fungicides are applied ahead of disease. Once disease is established, control becomes much more difficult, if not impossible. Timing of applications should be based upon "time since last fungicide application", scouting observations, and weather conditions that are more favorable or less favorable to disease development and spread.

Irrigation and rainfall events: Water in the form of irrigation or rainfall can play a significant role in the efficacy of a fungicide program in several different ways. For example, during periods of abundant rainfall, diseases tend to be more severe while during period of drought, fungal disease tend be to be less severe. However, white mold, in particular "underground white mold", can actually be more severe in non-irrigated fields during periods of extended dry weather.

Fungicides are typically applied to the upper canopy of the plant; however redistribution to the crown of the plant is important for the management of soilborne diseases such as white mold and Rhizoctonia limb rot. An effective way to move a fungicide from the leaves of the plant to the crown of the plant is through rainfall or irrigation. Optimal timing of irrigation or rainfall is somewhere between 8 and 24 hours after the fungicide is applied. Applying the irrigation too early will still be beneficial for control of soilborne diseases but may reduce efficacy of control of leaf spot diseases. Irrigation or rainfall beyond 24 hours will likely result in reduced benefit for redistribution of fungicides and compromise disease management. Note: Irrigation of 0.10-0.25 in/A should be enough to assure sufficient redistribution of the fungicide.

Night-time versus day-time applications: As mentioned above, one of the difficulties in managing soilborne diseases is to redistribute the fungicide from the leaves to the crown and limbs of the plants. When fungicide applications are made during the day, the leaves of the peanut plant are fully expanded and intercept much of the spray. However the leaves of the peanut plant fold up at night, thus exposing the crown and limbs to more direct fungicide deposition. Fungicides sprayed at night typically provide better control of white mold than do the same fungicides sprayed during the day.

Growers often ask, "When at night is the best time to apply the fungicide?" In truth, the most important consideration is that it is dark enough that the leaves are folded. However, there may be a slight benefit to spraying in the early morning when the leaves are folded and dew has fallen, thus wetting the leaves and further assisting in redistribution of the fungicide. Growers are rightfully concerned about the impact of spraying fungicides at night on control of leaf spot diseases as only the underside of the leaf is exposed. Leaf spot control is not a problem so long as the fungicide has some systemic activity and is able to enter the leaf tissue. If a protectant fungicide like chlorothalonil is applied, then it advisable to tank-mix an additional systemic fungicide for enhanced leaf spot control.

In-furrow fungicide treatments and seed treatments: Seed-treatment fungicides are most commonly used to protect the seeds and young seedlings from seed rot and seedling diseases. Vigorous germination and growth is important not only to achieve a good stand but also to reduce risk to tomato spotted wilt disease. Generally, the seed treatments are highly effective to control seedling diseases like Aspergillus crown rot and Rhizoctonia seedling blight. However, there are times, for example when environmental conditions are favorable for seeding disease or the quality of the seed is in question, that growers may choose to enhance seedling disease control by applying an in-furrow fungicide. In rare instances where seed it to be planted without a fungicide seed treatment, use of an in-furrow fungicide is essential to protect young plants and maintain stand.

Azoxystrobin (sold as “Abound” and other trade names) has been the fungicide most commonly used in-furrow in peanut production. While azoxystrobin remains effective in protection of seedlings from *Rhizoctonia solani*, it is now less effective against *Aspergillus niger* (Aspergillus crown rot) and *Aseprgillus flavus* (yellow mold). Fluopyram (sold as “Velum”), prothioconazole (sold as “Proline”), and fluopyram + prothioconazole (sold as “Propulse) can all be applied in-furrow for additional protection from seedling diseases, especially where diseases caused by *Aspergillus niger* or *A. flavus* are expected to be a threat.

Historically, in-furrow fungicides have been used to improve stand and to protect seed and young plants from diseases. Recently, however, in-furrow fungicides are now used to assist in the management of Cylindrocladium black rot (CBR) and white mold. In-furrow applications of Proline (prothioconazole) fungicide is a standard treatment for management of CBR. In-furrow applications of some fungicides, to include Proline, are now used to provide early-season control of white mold. The “critical” timing for protecting the peanut crop from white mold with foliar-applied fungicides begins approximately 60 says after planting. However, during unusually warm planting seasons white mold may become active in the field very early in the season. In-furrow applications of the appropriate fungicides can reduce impact of early-season white mold.

Banded applications: As mentioned above, when weather conditions are unusually warm during planting and the early part of the season, beginning a white mold/soilborne program within the first five weeks after planting can be beneficial. Though some fungicides may be “broadcast” applied, the most effective applications are made (when specifically allowed on the label) by applying the full broadcast rate in a narrow band over the small plants. To date, the greatest amount of data has been collected for Proline (prothioconazole). A single banded application is recommended sometime between the second and fifth week after planting when conditions are favorable for development of white mold. This application is also effective for initiating a leaf spot program as well.

Resistance management: Many of the most important and effective fungicides used today in peanut production are at significant risk for resistance. When resistance develops, fungicides that were once effective in disease management become less effective and, perhaps, ineffective. Steps that growers can take to reduce the risk of fungicide resistance include applying the fungicides in a timely manner to slow the development of disease and to use fungicides at labeled, rather than reduced rates. As mentioned earlier, the “FRAC Code” found on the front page of each fungicide label identifies the chemical class of the fungicide. Growers should insure that they do not overuse fungicides from a given class. Overuse increases the risk for development of resistance.

PEANUT RX: Risk in a field to tomato spotted wilt, leaf spot and white mold can be estimated based upon a number of factors to include the variety planted, planting date, crop rotation, tillage, plant population, use of in-furrow insecticides, and field history. When using Peanut Rx, growers can modify their production practices to reduce risk in the field. For fungal diseases, growers have the opportunity to use "prescription" fungicide programs appropriate for a given risk level. Fields found to be "low risk" can be effectively treated with a reduced fungicide program as compared to a "moderate risk" or "high risk" fields without compromising yield. The risk points in Peanut Rx are updated yearly.

Diseases and Specific Recommendations

Tomato Spotted Wilt
Symptoms: Plants affected by tomato spotted wilt are often stunted and leaves show characteristic rings and mottled patterns. Plants that develop symptoms later in the season may have less-dramatic leaf symptoms and the plants often have a yellowed and wilted appearance. The taproot of these affected plants is often rotted and necrotic.

Causal Organism: *Tomato spotted wilt virus* (TSWV) which is spread (vectored) by infected thrips, typically the tobacco thrips and the western flower thrips.

Factors influencing increased risk: See Peanut Rx for a complete list of risk factors.

Management tactics: Follow management tactics outlined in Peanut Rx. Specifically, growers can reduce their risk to losses from tomato spotted wilt by planting resistant varieties. Growers can further reduce their risk to spotted wilt by considering the impact of planting date, seeding rate, tillage, single-rows versus double-rows, choice of at-plant insecticide and use of Classic herbicide.

Figure 1. Typical symptoms of tomato spotted wilt early in the season, plants may be stunted and leaves with ring-spots and mottled appearance. Later in the season, plants affected by tomato spotted wilt often show yellowing, wilt, and a necrotic taproot.

Diseases Caused by Fungi:

Early leaf spot
Diagnostic Symptoms: Tan-to-dark brown spots developing first in the interior of the canopy. Spores, sometimes difficult to see with the naked eye, are found on the top of the leaf.

Causal Organism: *Passalora arachidicola* (*Cercospora arachidicola*)

Effect on yield: If not controlled, early leaf spot can cause significant yield loss. Premature defoliation because of early leaf spot can affect not only yield potential but also the strength of the pegs, increasing risk to digging losses.

Factors influencing increased risk: Peanut planted too often in the same field, frequent rain events and high humidity. The fungus survives in the crop residue and debris that remains in the field after harvest. Crop rotation and also burying the crop debris can help to reduce the potential for disease. See Peanut Rx for specific information practices that affect risk to leaf spot diseases.

Management tactics: Early leaf spot can be managed with crop rotation, planting resistant varieties, judicious use of fungicides. Additional factors found in Peanut Rx can be used to control early leaf spot.

Figure 2. Early leaf spot, note sporulation on top of leaf. The yellow halos encircling the spots are commonly observed; however they are not always present.

Figure 3. Early leaf spot, note sporulation on top of leaf.

Late leaf spot

Diagnostic Symptoms: Dark-brown-to-black spots developing first in the interior of the canopy. Many dark spores are typically visible on the underside of the leaf. The spores often profusely cover the underside of the spots. Premature defoliation can reduce the strength of the pegs and increase losses at harvest.

Causal Organism: *Nothopassalora personata* (*Cercospordium personatum*)

Factors influencing increased risk: Peanut planted too often in the same field, frequent rain events and high humidity all increase risk to late leaf spot. As with the pathogen that causes early leaf spot, the fungus causing late leaf spot survives in the crop residue and debris left in the field. See Peanut Rx for further management options.

Management tactics: As for early leaf spot, crop rotation, use of resistant varieties, judicious use of fungicides, and other factors can be integrated to manage late leaf spot and to protect yield. See Peanut Rx.

Figure 4. Late leaf spot, note dark sporulation on the underside of the leaflets.

Figure 5. Late leaf spot, note the yellow halos around the dark spots. Though yellow halos are more commonly observed on spots caused by early leaf spot, they can also occur with late lead spot.

Characteristics important for identification of early and late leaf spot diseases. Both of these diseases form spots that are initially found on the leaves in the interior of the canopy. While symptoms can be variable, spots resulting from "early leaf spot" tend to be dark brown and often, but not always, encircled by a yellow "halo". The most critical symptom is the presence of small, fine spores on the UPPER side of the leaf. These spores can be very difficult to see without magnification and are not always present, especially during periods of dry weather.

Spots associated with "late leaf spot" are typically a darker, chocolate brown and are only rarely encircled by a halo. A thick carpet of spores is typically found on the UNDERSIDE of the leaf.

Note: Symptoms that may be confused with early and late leaf spot diseases: Phytotoxicity from use of Thimet/Phorate: Numerous spots are frequently observed near the leaf tips/margins after Thimet and other products containing the active ingredient phorate are used in-furrow at planting. Leaves may also yellow and drop; plants typically outgrow this damage quickly. No control measures are needed in response to these symptoms.

Peanut rust

Diagnostic Symptoms: Small brown and orange pustules are observed on the underside of the leaf. Leaves severely affected by rust turn brown and die, but do not fall from the plant as they would with leaf spot diseases.

Causal Organism: *Puccinia arachidis*

Factors influencing increased risk: Peanut rust typically appears late in the season, often after tropical storms and hurricanes which transport spores from more southerly locations. Unlike the fungal pathogens that cause early leaf spot and late leaf spot diseases, the rust pathogen does not survive without a living host and the spores will not successfully overwinter between peanut seasons.

Management tactics: A good fungicide program is essential to protect a peanut crop from peanut rust. Once rust is established in a field, growers are encouraged to shorten the interval between fungicide applications to 10-12 days.

Figure 6. Peanut rust pustules (orange) and late leaf spot on the underside of a peanut leaf.

Aspergillus Crown Rot and Yellow Mold

Diagnostic Symptoms of Aspergillus crown rot: Typically affects seedlings and young plants this diseased is characterized by rapid wilt and death. Lesions on the crown and the upper taproot are usually visible, often in association with a mass of black, powdery spores that have a sooty appearance. Aspergillus crown rot is generally considered a "post-emergent" disease.

Causal Organism: *Aspergillus niger*

Diagnostic Symptoms of Yellow Mold: Unlike Aspergillus crown rot which is a post-emergent seedling disease, yellow mold affects the seed itself and typically causes plant death and stand loss before the seedling emerges from the soil. Yellow mold is characterized by green-to-yellow sporulation over the infected seed and, occasionally, lesions on the pre-emergent young stem.

Factors influencing increased risk: Aspergillus crown rot is most severe when conditions are very hot and dry at planting and early in the season. The hot soil can damage the young, succulent taproot which is then easily colonized by the fungal pathogen. Aspergillus crown rot is commonly associated with damage from lesser cornstalk borers. Aspergillus crown rot tends to be more problematic on low quality seed and on farmer-saved seed.

Yellow mold is most severe where seeds have been damaged by insects, or when conditions later in the growing season and during harvest are very hot and dry. Yellow mold may also be more severe when environmental conditions during seed storage prior to shelling are warmer and wetter than normal.

Note: Stand loss associated with Aspergillus crown rot and yellow mold will result in greater risk to tomato spotted wilt. *Aspergillus niger* is commonly found in the soil; rotation away from peanuts is not as effective at reducing this disease as rotation is in minimizing other diseases.

Management tactics: Yellow mold and Aspergillus crown rot are managed in several ways. Growers should plant high quality seed and ensure that the seed is well-treated with an appropriate fungicide seed treatment. Because fungicide resistance has developed in both *Aspergillus niger* and *Aspergillus flavus,* it has been increasingly important that peanut seed treatments include fungicides other than, or in addition to, azoxystrobin to manage these harmful pathogens. Use of in-furrow fungicides can offer further protection beyond that which is provided by seed treatments. While azoxystrobin (Abound) remains a popular fungicide for use in-furrow at planting, the potential remains for problems where Aspergillus crown rot is a threat. Products that include fluopyram (Velum) or fluopyram + prothioconazole (Propulse) can be very effective alternatives to azoxystrobin. Growers should manage lesser cornstalk borers if necessary. Irrigation can be used to cool the soil and reduce risk to the disease.

Figure 7. Aspergillus flavus/yellow mold on rotted peanut seed. (Photo T.B. Brenneman)

Figure 8. Aspergillus niger on cotlyedons of young peanut plant. (Photo T.B. Brenneman)

Figure 9. Aspergillus crown rot. Note damage to the upper taproot of the young plant. Hot soil can damage the young, succulent taproot and leads to increased losses to this disease.

Figure 10. Aspergillus crown rot. Note the diagnostic dark and sooty sporulation at the site of the disease lesion.

Figure 11. Aspergillus crown rot. Note severely wilted seedling at right and healthy seedling at left.

Southern Stem Rot (White Mold)

Diagnostic Symptoms: There are several symptoms commonly associated with white mold. Among these are wilt of plants and, often, the presence of white fungal growth that causes significant lesions on the crown, limbs and pegs of the plants. Also, small BB-sized “sclerotia” are often present as well. Sclerotia are like fungal “seeds” that survive in the soil after the peanut crop is harvested.

“Underground” white mold is caused by the same disease but is not observed until the peanut plants are inverted at harvest. When underground white mold occurs, there not be any above-ground symptoms. However, significant damage may occur to the pegs and to the pods and they may be covered with white fungal growth.

Note: The fungus *Phanerochaete* spp. can also be associated with the peanut crop, especially when the crop is planted to conservation tillage. Early in its development, the Phaneorchaete fungus can be nearly indistinguishable from the true white mold pathogen. However, it will not cause damage to the peanut plant and will not cause lesions. The benign fungus is found on the crop debris as well, which does not happen for the true white mold pathogen.

Causal Organism: *Sclerotium rolfsii*

Factors influencing increased risk: White mold is most often problematic in fields where peanut is planted in short rotation, that is, where peanuts are planted more often than once every three years in the same field. White mold, especially underground white mold, can be especially severe when the growing season is warmer than normal. White mold is favored by the high humidity within the canopy of the peanut plants. Early outbreaks of white mold occur when warmer-than-normal temperatures occur early in the season.

White mold is less of a problem in well-rotated fields and when cooler temperatures prevail either later in the season or during periods of prolonged cloudy weather and rainfall.

Management tactics: White mold is best managed with crop rotation (plant peanuts in a field no more than once out of three years), judicious use of fungicides and use of resistant varieties. For more detailed information, growers should consult Peanut Rx.

Figure 12. Damage from southern stem rot or “white mold”. Note the complete loss of pods where the disease is severe.

Figure 13. Southern stem rot or white mold Note the white fungal growth and stem lesions associated with this disease.

Leaf Scorch and Pepper Spot

Diagnostic Symptoms: Leaf scorch is readily identifiable a "V-shaped" lesions on the leaves. Pepper spot is less commonly observed, but is identified by small, black "pepper-grain-like" spots on the leaves.

Leaf scorch can be confused with leaf-hopper burn and, at times, injury to the leaves from use of Thimet applied in-furrow at planting.

Causal Organism: *Leptosphaerulina crassiassca*

Factors influencing increased risk: Leaf scorch typically affects younger plants, but can occur anytime in the season. Leaf scorch is does not typically cause yield losses.

Management tactics: Leaf scorch is almost never associated with any significant injury to the peanut crop. Standard fungicide programs for control of leaf spot is enough to manage leaf scorch.

Figure 14. Leaf scorch. Note V-shaped lesions on the leaves.

Figure 15. Leaf scorch.

Cylindrocladium Black Rot (CBR)

Diagnostic Symptoms: Yellowing of leaves, wilt and plant death occurs later in the season. Affected plants are typically clustered in specific areas of a field. The taproots of the affected plants are often dark and necrotic; the pods are typically dark as well. Small, brick-red fruiting structures (perithecia) are often found on the affected plants at the crown of the plant, the pegs and the pods. Seeds in symptomatic pods are frequently covered with small, red "specks". These are micorsclerotia that survive in the soil between peanut crops.

Later in the season, plants affected by CBR and tomato spotted wilt can look similar and it can be difficult to tell the two apart. Plants affected by CBR and tomato spotted wilt later in the season may both be yellowed, wilted and with a necrotic taproot. The roots of plants affected by tomato spotted wilt may also be infected by the fungus *Neocosmospora vasinfectum* which produces fruiting structures similar to the CBR pathogen. The most obvious difference between late-season tomato spotted wilt and CBR is the distribution in the field. Plants affected by CBR tend to be clustered in specific areas of the field. Those affected by tomato spotted wilt are likely more scattered across the field.

Causal Organism: *Cylindrocladium parasiticum*

Factors influencing increased risk: Cylindrocladium black rot tends to be most severe when cooler and wetter conditions occur at planting as this facilitates infection by the fungus. Cylindrocladium black rot tends to be more severe in fields where the peanut root-knot nematode is also a problem. Because soybeans are also a host for the CBR fungus, soybeans are not a good rotation crop for peanut. The fungus that causes CBR can be seed-borne; therefore it is important that seed should not be saved from fields infested with CBR.

Management tactics: Management of CBR requires rotation away from peanut and soybean crops. If available, growers can plant resistant varieties. Chemical management of CBR begins with fumigation of the soil with metam sodium or in-furrow applications of a product like Proline (prothioconazole). Though of limited benefit, some fungicides applied for management of white mold also have efficacy against CBR.

Figure 16. , Pods and seeds affected by Cylindrocladium black rot. Note diagnostic brick-red fruiting structures on the pods and small, red micorsclerotia "speckles" on the seeds.

Figure 17. Cylindrocladium black rot late in the season. Note that the distribution of the disease is "clustered in the field" and appears to occur along the row. This may indicate that the disease is being moved with soil during field preparation.

Rhizoctonia Limb Rot

Diagnostic Symptoms: This disease is most often observed in fields with vigorous growth and dense foliage. Limbs lying along the ground are most vulnerable to infection, though the disease can affect the pegs and pods as well. The lesions on the limbs often take on a characteristic "target shaped" lesions of expanding rings within the lesion.

Causal Organism: *Rhizoctonia solani*

Note: *Rhizoctonia solani* can also cause a seeding disease in peanut which is especially problematic when peanuts are planted in cool and wet conditions.

Factors influencing increased risk: Limb rot is most severe in well-irrigated, fields with good fertility and strong growth. Rhizoctonia limb rot is most problematic where the limbs of the peanut plant are continuously exposed to high humidity. Rotation can also affect limb rot, but because Rhizoctonia solani infects many different crops, it is difficult to find a good rotation crop. Two of the best crops for rotation with peanuts are field corn and bahiagrass as neither is affected by *Rhizoctonia solani*.

Management tactics: Fungicides are most often used to manage Rhizoctonia limb rot. Fungicides used to control white mold are also effective for management of limb rot. However, some fungicides are more effective than others for control of limb rot. Where Rhizoctonia limb rot is a major concern, growers should seek guidance on the best fungicide to use.

Diplodia Collar Rot

Diagnostic Symptoms: Diplodia collar rot is typically observed late in the season and most often in association with plants affected by tomato spotted wilt. Plants (the whole plant or limbs on the plant) affected by Diplodia collar rot often die quickly and become a distinctive dark gray in color. The dead limbs are covered with many small, black fruiting structures that give the dead limb a rough feel to the touch. Pods can be affected and when opened often contain a dark, greenish-black fungal growth.

Diplodia collar rot occasionally affects seedlings and young peanut plants as well, leading to dead plants with a distinctive shredded tissue.

Causal Organism: *Lasiodiplodia theobromae*

Factors influencing increased risk: Plants infected with the Tomato spotted wilt virus seem to be more susceptible to Diplodia collar rot.

Occasionally, a variety is highly susceptible to Diplodia collar rot; however this is extremely rare.

Management tactics: Any efforts to manage tomato spotted wilt should also help to reduce Diplodia collar rot. It is not known at this time how fungicide programs may help to reduce Diplodia collar rot; however a fungicide program deployed to manage white mold could have some benefit.

Figure 18. Diplodia collar rot. Note dead plant with dark, gray limbs.

Plant-Parasitic Nematodes

There are three plant-parasitic nematodes that could affect the peanut crop in Georgia. The most widespread of these, and the one that is the greatest cause for concern, is the peanut root-knot nematode (*Meloidogyne arenaria*). Growers in southwestern Georgia report the highest incidence of the peanut root-knot nematode in their fields. The lesion nematode (*Pratylenchus sp.*) appears to be widely distributed in Georgia, however this needs to be confirmed with further surveys. The lesion nematode is generally believed to cause only superficial and minor damage; however when present in large numbers, there is concern that damage from lesion nematodes could lead to some yield loss. The sting nematode (*Belonolaimus* sp.) has not been thought to cause significant damage to Georgia's peanut crop in the past, though it has caused noticeable damage to cotton and corn in some parts of the state. Recently, a few peanut fields have been identified where sting nematodes have been associated with severe stunting and yield loss.

Both the peanut root-knot nematodes and the sting nematodes are found in soils with greater sand content. They are generally not observed in soils which have a larger percentage of clay and silt. This is likely why the root-knot nematodes are of greater importance in southwestern Georgia.

To date, consideration for recommendations for crop rotation have largely been focused on ways to reduce populations of the peanut root-knot nematodes and little attention has been given to the lesion and sting nematodes. Bahiagrass is not a host for the peanut root-knot nematode. Cotton is not a host for the peanut root-knot nematode, and is therefore and excellent rotation crop to reduce peanut root-knot nematodes in a field. Corn is a host for the peanut root-knot nematode, but still is a fair-to-good host to rotate with peanut especially because it is not a host for many of the same pathogens that cause diseases in peanut. Soybean is a host for the peanut root-knot nematode, unless a resistant variety can be planted.

Bahiagrass and corn are hosts for the lesion nematode and cotton is a host for the sting nematode. Further research is needed to determine what, if any, importance this has on increased losses to lesion and sting nematodes in peanut fields in the state.

Management of Plant Parasitic Nematodes

To date, significant effort has been made for management of peanut root-knot nematodes and much less attention has been given to the sting and lesion nematodes. Because of this, chemical control recommendations have been developed based upon management of the root knot nematodes.

To reduce populations of plant-parasitic nematodes in a field, growers should practice good crop rotation.

To manage the peanut root-knot nematode, growers can plant resistant varieties, such as TifGuard , Georgia-14N and TifNV-HiOL.

Growers can manage root-knot nematodes in a field by fumigating the soil prior to planting with 1,3-dichloropropene (Telone II). This can be an extremely effective treatment and is the best treatment when nematode populations are very high.

Growers can manage root-knot nematodes with fluopyram (Velum) or aldicarb (AgLogic) applied in-furrow at planting.

Growers can apply Propulse (prothioconazole + tebuconazole) or products containining oxamyl (Vydate-CLV and Return XL) when the peanut plants are pegging to further reduce damage to the pegs and to the pods.

Peanut Root-knot Nematode

Figure 19. Note stunted plants. Movement of soil in field preparation may explain row-pattern affect.

Figure 20. Galling from root-knot nematodes to peanut root system. The similarity to the beneficial Rhizobium nodules can be confusing. Galls from the root-knot nematodes are actually swellings within the root itself and cannot be removed without destroying the root in the process. Rhizobium nodules can be removed intact from the roots by rubbing gently.

Figure 21. The peanut root-knot nematode affects not only the root-system of the plant, but also the pegs and the pods.

Figure 22. Damage to the pods and pegs from the lesion nematode. In severe cases, damage from the lesion nematodes can weaken pegs to the point that they break when the plants are inverted, leaving mature pods behind in the soil.

INSECT MANAGEMENT

Chapter 14
Insect Management in Peanut

Mark Abney

Recognition or identification of different insects and their damage in a peanut field is necessary for insect management. Some insects are harmful and can reduce yield and quality of peanuts by feeding on the roots, stems, foliage or fruit of the peanut plant. The life cycles of different insects vary. It is important to realize this in order to effectively plan control measures. Climatic conditions influence the life cycle of insects and may also alter their feeding habits. Crop rotation may also influence the species of insects in a peanut field.

Not all insects are harmful to the peanut plant. Some insects and spiders feed on harmful insects. These beneficial insects often keep harmful insects at low levels and treatment is not necessary. However, once an insecticide is applied to peanut fields these beneficial insects can be killed and further treatment may be needed to keep damaging insects under control.

HARMFUL INSECTS

Soil Dwelling/Pod Feeding Pests

<u>Lesser Cornstalk Borer</u>

The lesser cornstalk borer, *Elasmopalpus lignosellus*, is an important economic insect pest in the southeastern and southwestern peanut growing areas of the United States. It is a much more serious problem during hot, dry weather and is more often a problem on coarse sandy soils than on heavier soils. These borers (under favorable conditions), can cause extensive damage on any soils where peanuts are produced in the southeastern United States.

The lesser cornstalk borer is a dark, blue-green larva, ranging from ½ to ¾ inch long. It has brown or purple bands around its body (Figure 1). When disturbed, it flips about rapidly. It lives in tube shaped webs attached to the plant where it is feeding (Figure 2). Soil particles adhere to the webs making them appear much larger than they really are.

Figure 1. Late instar lesser cornstalk borer larva

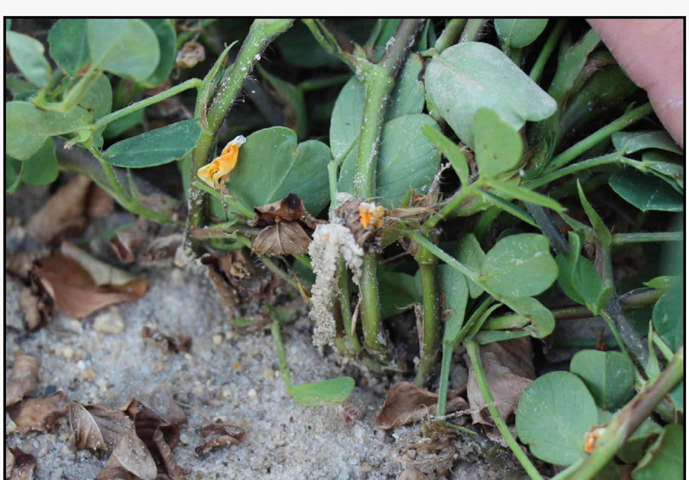


Figure 2. Tube-shaped lesser cornstalk borer webbing covered with soil

Figure 3. Male lesser cornstalk borer moth

Figure 4. Lesser cornstalk borer feeding injury on mature pods

The adult female (moth) is usually charcoal gray with brown markings toward the head. The male is a light buff color with a dark charcoal gray line down the middle of the back and along the rear border of the wings (Figure 3). Both male and female are about one-half inch long.

Under favorable conditions (such as hot, dry weather) this insect completes its life cycle in 30 days or less. When conditions are less favorable, the life cycle may require more than 40 days. This is probably one of the primary reasons that most heavy losses to this pest occur during extended periods of hot, dry weather. This shortening of the life cycle contributes to population explosions.

The lesser cornstalk borer damages peanuts in all stages of growth and will feed on any part of the plant that is in contact with the surface of the soil. It also tunnels into the soil to feed on pegs and pods (Figure 4). During the early stages of plant development it will tunnel into the hypocotyl, sometimes killing plants and often stunting them. Its habit of moving along the surface of the soil, and at times tunneling into the soil to feed, is the reason this insect is characterized as a semisubterranean pest. The most important damage by the lesser cornstalk borer is its peg and pod feeding.

To check a field for lesser cornstalk borers and their damage, carefully examine the plants on a three-foot section of row, at 10 locations scattered across the field. At each of the locations, lift the limbs of plants gently, and examine them for soil covered webs. If webs are found, break them up and look for borers and determine whether damage is fresh. Split plant branches and other damaged parts to look for borers.

It may be necessary to remove some plants from the soil to examine them thoroughly. If fresh damage and/or borers are found at three of the ten locations, apply a recommended insecticide for control. When checking a peanut field, be alert for lesser cornstalk borer moths and wilted plants or plant parts. These are signs that should alert you to the possibility of a problem. However, only use an insecticide if you actually find borers and fresh damage.

<u>Bahiagrass Borer</u>

The Bahiagrass borer, *Derobrachus brevicollis*, has been recognized as an occasional pest of peanuts since about 1965. The adult is a large, long-horned beetle. This insect has only caused problems when peanuts were planted following bahiagrass that was heavily infested with the soil tunneling larvae.

This large larva does not feed to any extent on the peanut plant. It simply cuts the tap root, causing the plant to die. Stands have been reduced by as much as 50 percent in a few fields due to this damage.

Thorough, deep soil preparation seems to minimize damage. This is especially true if a power driven tiller is used. Heavy rates of a soil insecticide (turned deep) have apparently helped to reduce damage. Probably the best approach to handling this problem is to delay the planting of peanuts for at least one year after bahiagrass (if borers are present).

Peanut Burrower Bug

The peanut burrower bug, *Pangaeus bilineatus*, is a sporadic but potentially severe pest of peanut (Figure 5). The insect inserts its mouthparts through the pod wall and feeds by sucking juices from the peanut kernel. A discolored and/or slightly sunken area on the mature seed is characteristic of burrower bug feeding damage (Figure 6). Studies have shown that dry soil conditions and the use of conservation tillage practices increase the risk of burrower bug damage. Nevertheless, burrower bug infestations and reduced peanut grades from burrower bug feeding damage have been reported in conventionally tilled, irrigated fields. Control of this pest with insecticides has been inconsistent; to date, only granular chlorpyrifos applied during the growing season has provided any significant reduction in burrower bug populations or damage in replicated university trials. Peanut burrower bug is native to the southeastern US, and the reason(s) for its relatively recent rise in pest status is unknown. Current research is focused on understanding the population dynamics of the insect, identifying additional risk factors associated with infestations, and evaluating novel management tactics.

Figure 5. Adult and immature peanut burrower bugs

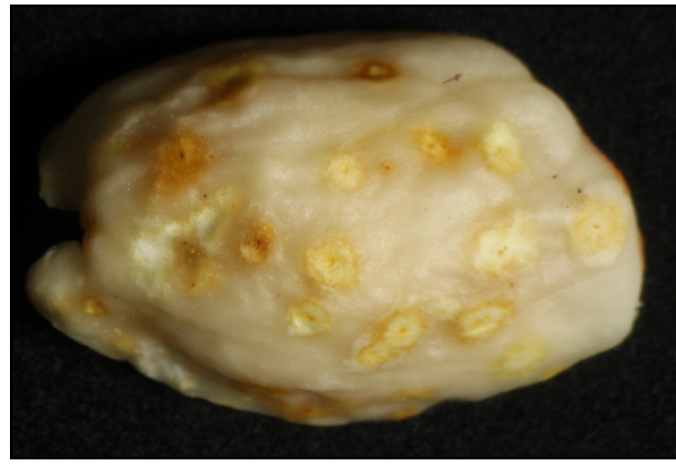


Figure 6. Burrower bug feeding injury to a peanut kernel

Southern Corn Rootworm

The southern corn rootworm, *Diabrotica undecimpunctata*, has become a major pest of peanuts in the southeastern United States. It is the larva of the spotted cucumber beetle (Figure 7). The banded cucumber beetle, *Diabrotica balteata*, a related species with similar biology, can also damage peanut and has been observed in fields with southern corn rootworm. In the early 1960s, southern corn rootworm was first found damaging peanuts in a few fields in extreme Southwest Georgia. This insect is more often a problem on heavy soils that are poorly drained. However, during extremely wet weather, it damages peanuts on sandy soils. Damage may vary from a slight decrease in yield and grade to complete destruction of the crop.

Figure 7. Southern corn rootworm adult

The southern corn rootworm is a slender, white to cream colored larva that reaches a length of ½ to ¾ inch when mature (Figure 8). It has a very fragile, wrinkled body with three pairs of inconspicuous legs. The head and the last segment of the body are dark brown to black. At first glance it may appear to have a head at both ends due to the dark-colored disc on the last segment. However, the head is actually narrower. The adult is a greenish-yellow beetle, approximately one fourth inch long, with 12 irregular black spots on its back.

The entire life cycle is usually completed in 30 to 40 days but is probably closer to 30 days during the hot humid weather that typically occurs when it infests peanuts in Georgia.

This pest is strictly a subterranean feeder. It may feed on the roots of peanut plants to some extent, but the most important damage occurs when it feeds on pegs and pods (Figure 9). Many of the holes cut into pegs and pods will be almost cylindrical, as if they were made by a tiny drill. In contrast to lesser cornstalk borer feeding, there is no webbing associated with the southern corn rootworm. To check for this pest, remove pegs and pods from the soil (it is actually helpful to remove entire plants). As with the lesser cornstalk borer, check plants on three feet of row at 10 locations scattered across the field. Completely remove one bunch of plants from the soil. Carefully sift the loose soil that remains for rootworms. Carefully examine all pegs and pods for feeding damage. If fresh damage or rootworms are found at three or more of the ten locations, apply a recommended insecticide.

Preventive applications of insecticide are more effective against the southern corn rootworm than corrective treatments. However, because the problem only occurs sporadically it is not practical to recommend a preventive control program in Georgia.

Figure 8. Southern corn rootworm larva and injured pod

Figure 9. Peanut pods injured by southern corn rootworm

Granular chlorpyrifos is currently the only insecticide recommended for the control of this pest. Apply the granules when the foliage is dry so it will filter through to the soil surface. Wetting the granules following application is even more important with this pest than it is with the lesser cornstalk borer. The insecticide need to be leached into the soil as much as possible since this pest remains beneath the soil surface at all times.

White Grubs

White grubs are the larvae of May or June beetles. There are more than 100 species of these brown or black beetles that fall into this group. There are some other closely related species of beetles that have grub stages that are found in the soil, and some of these cause the same type of damage as the larvae of May and June beetles.

Mature white grubs vary from one-half to one inch in length. When uncovered in the soil they typically curl into a “C” shape (Figure 10). Their bodies are white, and heads are brown. There are three pairs of prominent legs attached to the underside of the body just behind the head. The rear portion of the body is smooth, shiny and usually dark brown or black.

The life cycle of white grubs ranges from one to four years in length, with three years being the most common. These insects overwinter as grubs or adult beetles that have not left the soil. Problems with white grubs in peanut production are rare. Grub infestations sufficient to cause problems may occur where peanuts follow sod crops that have been established for several years. When preparing such land for planting peanuts, closely check for the presence of grubs. There are no data to indicate how many white grubs are required to cause economic loss. However, if an average of one or more larvae per square foot is present, control is probably justified.

To control white grubs in soil that will be planted to peanuts, make a broadcast application of a recommended insecticide at least 10 to 14 days prior to planting. Thoroughly mix the insecticide into the top four to six inches of soil.

Wireworms

Wireworms are the immature stages of “click beetles” (Figure 11). There are many species that damage plants by feeding on the underground parts.

Figure 10. White grub larva. Photo credit: Alton N. Sparks, Jr., University of Georgia, Bugwood.org

Figure 11. Adult wireworm (also known as click beetles). Photo credit: Natasha Wright, Cook's Pest Control, Bugwood.org

The immature stage is always found in the soil. Wireworms are slender-bodied larvae that vary from yellowish to brown in color. Their bodies are distinctly segmented, hard and shiny. They have three pairs of legs attached to the underside of the body just behind the head (Figure 12).

Figure 12. Wireworm larva and injured peanut pod

These pests have life cycles ranging from one to six years in length. Most of the economically important species in the south complete their development within two years. They overwinter in the soil as larvae or as adults.

Wireworms can be a major problem in peanut production. They are more difficult to find in the soil than white grubs. It may be necessary to screen some soil at several locations during field preparation to determine if wireworms are present. Soil baits can be used to assess wireworm presence in a field prior to planting, but baiting is time consuming and expensive. As with white grubs, no data are available to show what level of infestation may cause an economic problem. However, use control measures if an average of one or more larvae are found per square foot.

To control wireworms in peanut production make a broadcast application of a recommended insecticide, at least 10 to 14 days prior to planting and thoroughly mix it into the top four to six inches of soil. This insecticide may be applied with the pre-plant incorporated herbicide. Insecticide efficacy can vary by wireworm species, and pre-plant insecticides will not control all species season long.

Whitefringed Beetle

Whitefringed beetle larvae cause sporadic serious problems in peanut production in the southeastern United States. There are three species of this pest, all belonging to the genus *Graphognathus*. Since all are biologically and ecologically similar, and all cause the same type of crop damage, there is no practical reason to differentiate between the species. There are only female whitefringed beetles. Reproduction is by parthenogenisis (development of eggs without fertilization).

The larvae are white or cream colored, legless grubs that are up to one-half inch long (Figure 13). The head of the larva is not conspicuous and only the dark colored mandibles (jaws) are apparent at the front. It is somewhat shorter and fatter than other grubs. The adult beetle is up to one-half inch long. Its color varies from light to dark gray and there are

Figure 13. Whitefringed beetle larva. Photo credit: Edward L. Barnard, Florida Department of Agriculture and Consumer Services, Bugwood.org

Figure 14. Whitefringed beetle adult. Photo credit: Gerald J. Lenhard, Louisiana State University, Bugwood.org

faint white stripes on each side (Figure 14).

Whitefringed beetles overwinter as eggs or larvae in the soil. Larvae mature, pupate in the soil, and emerge as adults from May through September. Adults feed on foliage of many plants but seem to prefer certain broadleaf plants, especially legumes such as peanuts and soybeans. They return to the soil to lay eggs. The life cycle usually lasts one year but sometimes requires two. The adults do not fly, and populations can remain in the same field for many years if a suitable host is present.

The most important damage caused by these pests is the larvae feeding on underground parts of young plants. They often cut the taproot, causing the plant to die. Other plants may be damaged and stunted for the remainder of the growing season. Severe damage may be present in spots within a field. These spots are often near a road. Occasionally entire fields are infested to the point that a crop cannot be profitably grown. If there are large num-bers of adults in a field during a growing season, check closely for larvae during soil preparation the following season.

Above Ground/Piercing Sucking Pests

Aphids

Aphids (plant lice) are small, soft bodied, sucking insects (about 1/15 inch in length) that secrete a sticky substance called "honeydew" while feeding. Coloration of aphids may vary from pale yellowish green to dark green or almost black. Both winged and wingless forms may occur.

Aphids feed by inserting their mouthparts into the tender portions of plants and sucking juices from them. This feeding usually produces distorted leaves in the infested area. Aphid feeding interferes with leaf functions and heavy infestations can se-verely reduce plant vigor. However, aphids seldom build up to high enough levels over widespread areas of peanut fields to require treatment.

Aphids overwinter either as adults on wild host plants or as eggs. In the spring, infestations may build rapidly on these host plants and then spread to peanuts. Aphids may begin reproducing at ap-proximately 12 days of age which (under favorable conditions) allows rapid buildup of infestations. Aphids are readily controlled with systemic insecti-cides applied at planting.

Leafhoppers

Leafhoppers (several species) feed on peanut wher-ever it is grown and also feed on a wide variety of other plants. Leafhoppers are small wedge shaped green insects about 1/8 to 1/4 inch long. Both adult and immature stages are similar in shape, but the immature stage does not have wings (Figures 15 and 16). Leafhoppers have a habit of hopping or flying ahead of persons moving through peanut fields. They feed on the undersides of peanut leaflets by inserting their mouthparts into the midrib and suck-ing the juices. This feeding causes the leaflet to turn yellow from the point where the feeding occurred to the tip. This yellowing and resulting leaf deterio-ration is often referred to as "hopperburn" (Figure 17). Validated economic thresholds for leafhoopers in peanut do not exist, though severe injury can

Figure 15. Leafhopper adult and hopperburn on peanut

Figure 16. Immature leafhopper on peanut leaflet. Photo credit: Steve L. Brown, University of Georgia, Bugwood.org

result in defoliation of peanut plants. Hopperburn remains noticeable in the field for some time after leafhopper infestations have declined, and it is important to ensure the pest is still present before applying an insecticide.

The time required to develop from egg to adult is 18 to 24 days during warm weather. As the weather becomes cool, this period may increase to 60 days. During the adult stage (which may last 30 days) the females lay an average of three or more eggs per day. Applying an appropriate foliar insecticide when infestations occur will control these insects.

Garden Fleahopper

Garden fleahopper, *Microtechnites bractatus*, population densities occasionally reach very high levels in peanut. Adult and nymph stages feed primarily on the underside of peanut leaves creating a stippling on the upper leaf surface similar to the injury caused by the two spotted spider mite (Figure 18). The underside of infested leaves will typically have black tar-like fecal spots (Figure 19). The economic impact of garden fleahopper feeding is unknown, and there are no published action thresholds. Adults occur in three forms: brachypterous (short-winged) females, macropterous (long-winged) females, and macropterous males (Figure 20).

Figure 17. Hopper burn on peanut foliage associated with feeding by potato leaf hopper

Figure 18. Speckling injury on peanut leaf associated with garden fleahopper feeding

Figure 19. Black "fecal spots" created by garden fleahopper on the underside of a peanut leaflet

Figure 20. Long and short winged forms of garden fleahopper

Figure 21. Threecornered alfalfa hopper adult

<u>Threecornered Alfalfa Hopper</u>

Threecornered alfalfa hoppers, *Spissistilus festinus*, feed on peanuts as well as many other plants, especially legumes. Adult threecornered alfalfa hoppers are light green in color, wedge shaped and about one fourth inch long (Figure 21). The immature or nymphal stage is similar in shape and color to the adult but does not have wings. Additionally, the abdomen of the nymph is covered with many spines (Figure 22). Both adults and nymphs have piercing mouthparts and feed by inserting their mouthparts into stems and sucking the plant juices. As they move around the stem feeding, the stem is girdled and weakened. The damaged area usually galls over, leaving a swollen area (Figure 23). The damaged area remains weak, and the movement of plant nutrients can be restricted for some time. The threecornered alfalfa

Figure 22. Threecornered alfalfa hopper nymph

Figure 23. Stem girdle on peanut caused by threecornered alfalfa hopper feeding

hopper usually feeds on the main stems, but feeding has also been noted on leaf petioles and pegs.

Feeding by threecornered alfalfa hopper adults and nymphs usually goes unnoticed until the galls form around the damaged area. It is important to look closely for the insect and damage when scouting peanut fields. Adults may be seen flying about ahead of a person as he or she moves through the field. Closer examination is necessary to see the immature stage. They can be found by parting the foliage and closely checking the stems within the canopy. Adults can be sampled in sweep nets, but beat sheets or close examination of plant stems are required to sample nymphs. It is believed that nymphs cause the majority of the stem galling observed in peanut.

Nymphs will move to the opposite side of the stem or hop away when disturbed, but they cannot fly. Threecornered alfalfa hoppers overwinter as eggs in plant tissue in protected areas. Adults may be active throughout the year in areas where winters are mild, but hibernate in plant residue in colder areas. Each female usually produces about 40 offspring, and up to four generations may occur annually. Economic thresholds have not been established for this insect in peanut. Insecticides are often applied when adults and nymphs are abundant to prevent potential yield loss. Broad spectrum insecticides like pyrethroids are most commonly used for three cornered alfalfa hopper management, but these products will kill beneficial insects and may lead to secondary pest infestation.

Thrips

The most common species of thrips found on seedling peanut is tobacco thrips, *Frankliniella fusca*. These are tiny, slender insects about 1/16 inch in length that jump or fly when disturbed. The immature or nymphal stage is similar to the adult in shape but does not have fully developed wings. Thrips vary in color from yellow to black in the adult and immature stages.

Thrips damage small peanut plants more severely than larger plants. The insects pierce the upper surface of the developing leaflets, and as the leaf-lets unfold they have a scarred, deformed appear-ance (Figures 24 and 25). Damaged leaves are often referred to as “possum-eared”. When infestations are severe, stunting occurs, and the damaged plants recover slowly and perhaps incompletely. Thrips

Figure 24. Adult tobacco thrips and thrips feeding injury on peanut leaflet

Figure 25. Tobacco thrips feeding injury on seedling peanut

damage usually disappears or becomes less noticeable as the plants develop. After peanuts begin blooming, most thrips will be found in the blooms.

The eggs of thrips are deposited in tissues of the foliage and usually hatch in about seven days. The immature stage is completed in five to six days, and during this time feeding is almost constant. After an inactive stage of three-four days the adult emerges and immediately begins feeding. The time for development from egg to adult is approximately 16 days, the period being shorter in warm weather and longer when the temperatures are relatively low. Reproduction is continuous throughout the warm months with five or more generations occurring each year. The female lives for an average of 30 days and deposits 50 to 60 eggs.

Thrips presumably hibernate under grass or in other protected places. Intermittent breeding possibly takes place on wild and cultivated host plants during warm periods of the winter in the southern range. Rapid build-up on wild host plants occurs in the spring, and the thrips move to peanuts as soon as plants emerge. Tobacco thrips are vectors of Tomato Spotted Wilt Virus, and an integrated pro-gram of cultural and chemical control tactics should be used to reduce thrips populations and disease incidence. Systemic insecticides provide the most consistent chemical control of these insects.

Foliage Feeding Caterpillars

Several species of foliage feeding caterpillars regularly infest peanut fields, and a caterpillar population in an individual field is often comprised of a complex of two or more species. The most common method for monitoring caterpillar density in peanut is to dislodge the insects from three linear feet of row onto the soil surface or beat cloth. All cater-pillars are counted and identified to species at ten, three foot sample locations per field. Caterpillar density is reported as number per row foot, and the economic threshold is 4 to 8 caterpillars per foot. The lower threshold should be used when plants are small or growing slowly; the higher threshold is used when vines are rank and/or plants are vigorously growing.

Correct caterpillar identification is critically important for choosing the most economical and effective insecticide active ingredient when thresholds are reached.

Figure 26. Corn earworm moth. Photo credit: Steve L. Brown, University of Georgia, Bug-wood.org

<u>Corn Earworm and Tobacco budworm</u>

Corn earworm, *Helicoverpa zea*, and Tobacco budworm, *Heliothis virescens*, can be serious pests of peanuts as well as many other plants in peanut producing areas. Corn earworm moths may vary in color; however, they are generally light grayish brown or buff in color with dark, irregular lines and a dark area or spot near the tip of the wing (Figure 26). The wings of tobacco budworm moths are generally olive in color with three dark bands (Figure 27). The moths are most active at dusk and may fly for long distances.

Figure 27. Tobacco budworm moth

The biology and behavior of the two species is similar. Female moths lay their eggs singly, as many as 3,000, on or near the growing tip of the pea-nut plant. These eggs hatch in 2 to 3 days, and the young larvae begin feeding in the bud of the plant. This early feeding (while the leaflets are folded) re-sults in “mirror images” or identical damage to each side of the leaflet when it opens.

Later feeding by the larvae causes ragging at edges of the leaves and may cause complete defoliation of the peanut plant. These larvae may feed for two to three weeks. The color of larvae varies from light green or pink to brownish or near black on the back; larvae are generally lighter in color on the underside. They are marked by alternating light and dark stripes running the length of the body. The skin is somewhat coarse and (when magnified) shows many spiny projections (Figures 28 and 29). Corn earworm and tobacco budworm larvae are nearly impossible to distinguish from one another with the naked eye, but can be positively identified

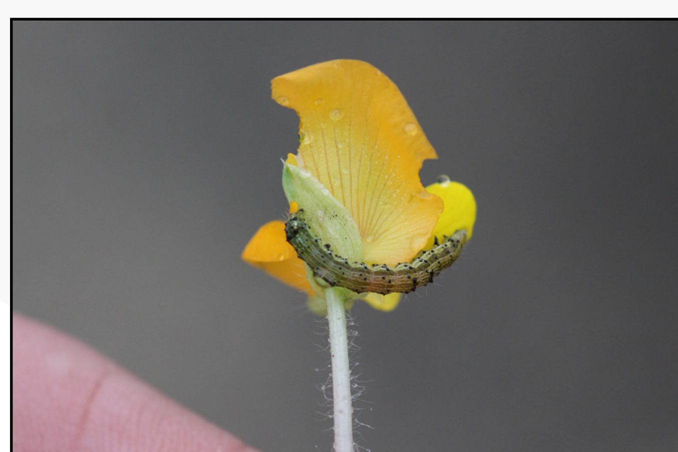


Figure 28. Tobacco budworm larva on a peanut bloom

Figure 29. Tobacco budworm larva on peanut

Figure 30. Fall armyworm moth. Photo credit: Lyle Buss, University of Florida, Bugwood.org

Figure 31. Fall armyworm caterpillar

with a hand lens or microscope. Identification of the pest is important because of pyrethroid insecticide resistance in tobacco budworm populations. After feeding for 15 to 18 days, the larvae burrow into the soil and pupate. They remain in the soil for approximately seven days after which they may emerge as an adult. A complete generation requires approximately 30 days and usually three generations per year occur in the southern United States.

Fall Armyworm

The fall armyworm, *Spodoptera frugiperda*, is a periodic pest across the peanut belt. Some damage occurs each season, and occasionally this insect occurs in sufficient numbers to cause complete defoliation of peanuts. The moths are dark gray, mottled with lighter and darker splotches with a noticeable whitish spot near the extreme tip of the wings (Figure 30). They are active mainly at night and not usually seen during daylight hours. Female moths may lay as many as 1,000 eggs. These eggs are laid in masses averaging 150 eggs per mass.

After hatching, the young larvae feed out from the mass and cover the entire plant and adjacent plants. They feed during both daylight and night hours. Fall armyworm larvae vary in color from dark tan to green to nearly black. They have three yellowish-white hair lines down the back from head to tail. In comparison to the corn earworm they are smoother and slicker in appearance (Figure 31). Fall armyworm can be distinguished from the true armyworm by the more prominent whiter inverted Y on the front of the head. A complete life cycle from egg to adult requires approximately 30 days.

When abundant, fall armyworm caterpillars crawl in "armies" from one field to another after all the food in the first field has been consumed.

Beet Armyworm

Beet armyworm, *Spodoptera exigua*, is common in peanut fields, but damaging populations are relatively rare. The larvae are usually green but may have dark stripes running lengthwise on each side of the body (Figure 32). Larvae have a small black spot located on each side of the body directly above the second set of true legs. The forewings of moths are brown and gray with irregular light colored patterns (Figure 33).

Granulate Cutworm

Granulate cutworms, *Feltia subterranean*, are smooth, cylindrical stout worms, grey to brown in color. The underside of the worm is lighter in color than the back. Cutworms curl into a ball when disturbed. Full grown cutworms may be up to 1 ½ inches in length (Figures 34, 35, 36).

The granulate cutworm is the most abundant and damaging of the cutworms found in the south-

Figure 34. Granulate cutworm caterpillar on peanut foliage

Figure 35. Granulate cutworm caterpillars in characteristic "C" shape

Figure 32. Beet armyworm caterpillar

Figure 33. ***Beet armyworm moth***

Figure 36. Granulate cutworm moth. Photo credit: Mark Dreiling, Bugwood.org

eastern United States. The female moth lays eggs exclusively on the plant foliage. Eggs are generally laid singly on the upper leaf surface. A female may produce over 1500 eggs which hatch in four to five days. The larval or immature stage is completed in about 20 to 30 days. Five generations occur each year from March through September. Peak populations usually occur on peanuts in late June, late July and again in late August.

Cutworm larvae may cause serious damage by cutting off or feeding on the young plant stems near the soil surface. They also have the ability to subsist on dry organic matter for long periods of time. The larvae may also climb up on peanut plants where they feed on the foliage. Cutworms are voracious feeders and can consume foliage at a rate that exceeds the velvetbean caterpillar, loopers and the armyworms. A single cutworm larva can consume from 20 to over 35 square inches of leaf surface during its three week life. The cutworms often go unnoticed because they usually feed exclusively at night. In the daylight hours they may be found on or beneath the soil surface or hiding under trash.

It is not unusual to find two to 15 cutworms per linear foot of peanut row. Occasionally lesser numbers of worms cause more damage than higher numbers. Just what "triggers" them to feed on foliage is not understood. Often large populations are found, but there is little foliage feeding. The reverse can be true of smaller populations. Parasitic wasps commonly attack cutworms in peanut fields, and the tiny wasps' cocoons are often seen on foliage (Figures 37 and 38). Foliar insecticide sprays can be used to control this insect.

Figure 37. Parasitic wasp larvae emerging from granulate cutworm caterpillar

Figure 38. Mass of parasitic wasp cocoons on a peanut leaflet

<u>Green Cloverworm</u>

The green cloverworm, *Hypena scabra*, is an occasional pest of peanuts that may occur from mid to late season. Green cloverworms overwinter in the pupal or adult stage. The moths lay their eggs singly on the undersides of leaves, and complete development from egg to adult usually requires about four weeks. The larvae are green in color with two narrow stripes running down each side of the body (Figure 39). Though similar in appearance to the vel-vetbean caterpillar and loopers, green cloverworm can be distinguished from other foliage feeders by its three pairs of abdominal prolegs.

<u>Loopers</u>

Loopers, *Trichoplusia ni* and *Chrysodeixis includens*

Figure 39. Green cloverworm caterpillar showing three pair of abdominal prolegs. Photo credit: Adam Sisson, Iowa State University, Bugwood.

Figure 40. Soybean looper moth. Photo credit: Russ Ottens, University of Georgia, Bugwood.

(Figure 40), may feed on peanut foliage. However, they are seldom a serious defoliator of peanuts. Looper moths lay their eggs singly on the peanut foliage, and the young larvae first feed by skeletonizing the leaves and later eating entire leaves. Loopers have only two pairs of abdominal prolegs (figure 41). They move across the plant with a looping motion. Soybean and cabbage loopers are usually green in color with white stripes running the length of the body. Soybean looper is typically more abun-dant in peanut and more difficult to control than cabbage looper. Full-grown larvae reach a length of 1 ½ inches.

Rednecked Peanutworm

The rednecked peanutworm, *Stegasta bosquella*, has caused occasional minor damage to peanuts.

Figure 41. Small soybean looper caterpillar showing two pair of abdominal prolegs.

Figure 42. Rednecked peanutworm moth. Photo credit: Natasha Wright, Cook's Pest Control, Bugwood.org

Figure 43. Rednecked peanutworm caterpillar

Figure 44. Injury to terminal growing point of a peanut plant caused by rednecked peanutworm feeding

Figure 45. Typical pattern of injury associated with rednecked peanutworm feeding on peanut

Figure 46. Velvetbean caterpillar moth on peanut

Rednecked peanutworm moths lay their eggs singly on or near the growing tip or bud of the plant. The larvae feed in the bud, and if infestations occur early in the season the feeding may stunt the plants.

Adults are small gray/black and cream colored moths (Figure 42). The larvae are cream to green in color with a brown head and a narrow red band or plate just behind the head (Figure 43). Full grown larvae are three-eighths to one-half inch in length. Larvae feed within young, unfurled leaflets in terminal buds (Figures 44 and 45). There is no published economic threshold for this insect.

Velvetbean Caterpillar

The velvetbean caterpillar, *Anticarsia gemmatalis*, is an occasional pest of peanuts. This insect may also damage other crops, especially legumes, by completely defoliating them. Heavy populations usually occur only in the latter part of the growing season. Velvetbean caterpillars are tropical or subtropical and do not overwinter in the peanut producing areas of the United States. The moths (Figure 46) fly north each summer and lay their eggs singly on the underside of the leaves of peanuts and other host plants. Eggs hatch in three to four days, and the young larvae "loop" when they move across the plant foliage. As the caterpillar grows larger, it loses its looping action. The caterpillars feed for 16 to 26 days. Most of the damage occurs during the last 4 to 5 days of feeding.

The velvetbean caterpillar has a yellow head capsule with a body color varying from light green to

Figure 47. Velvetbean caterpillar larva showing four pair of abdominal prolegs

black. There are yellowish-white stripes running the length of the body (Figure 47). Caterpillars have four pair of abdominal prolegs. The last pair of (anal) prolegs project backward and are very noticeable when the larvae are resting on the plants. Velvetbean caterpillars will thrash violently when handled. While relatively easy to manage with insecticides, failure to discover velvetbean caterpillar infestations when larvae are small can result in rapid, severe defoliation.

Figure 48. Yellowstriped armyworm caterpillar. Photo credit: Russ Ottens, University of Georgia, Bugwood.

Yellowstriped Armyworm

The yellowstriped armyworm, *Spodoptera ornithogalli*, occurs sporadically and in low populations on peanut. The larvae of this species are readily recognized by a pair of dorsal, triangular, black spots on most of the segments (Figure 48). Often a bright orange or yellow stripe occurs just outside these spots on each side. Moths are brown to gray with irregular light colored patterns on the forewings (Figure 49).

Figure 49. Yellowstriped armyworm moth. Photo credit: John Capinera, University of Florida, Bugwood.

NOTE: Foliage feeders such as the corn earworm, granulate cutworm and fall armyworm will move at harvest or inversion time from drying foliage to the exposed pods. They will eat part of the tender pod and devour the kernels. They prefer "pops" or under developed pods which take longer to dry. However, if populations are heavy and weather occurs that delays harvest, economic damage can occur. Determine caterpillar population density shortly before harvest, so control measures can be applied if necessary to prevent loss.

Foliage feeders seldom occur on peanuts in populations of only one species. Control measures are often needed for a complex of several foliage-feeding species rather than for a single species. Knowing the identity and abundance of each species present in the field is the first step to choosing an appropriate insecticide active ingredient. Insecticides targeting caterpillars and other foliage feeding insects are often tank mixed with fungicides; it is important to read all pesticide labels carefully to determine the proper methods for combining products in tank mixtures.

Mites

Spider Mites

Two spotted spider mite, *Tetranchyus urticae,* is a tiny insectrelated pest that feeds on peanuts by sucking plant juices from the undersides of the leaves. This feeding (which usually begins near the mid-ribs of the leaves) results in a speckling of the upper surfaces of the leaves. As the infestations become more severe the leaves may turn yellow and die (Figures 50 and 51).

Figure 50. Yellowing associated with two spotted spider mite feeding on peanut

Although spider mites are small, they can be seen with the naked eye, especially if they are moving (Figure 52). Immature spider mites have three pairs of legs, and the mature or adult mites have four pairs of legs. This clearly separates them from the insects. Spider mites multiply rapidly (as many as 17 generations per year), which accounts for population explosions when dry, hot conditions exist for extended periods. Spider mite infestations often begin near field margins especially those adjacent to dirt roads and field paths. Care should be taken to check field edges for signs of infestation during regular insect scouting. The use of broad spectrum insecticides such as pyrethroids and organophosphates can flare spider mite populations when environmental conditions are favorable for infestations to develop.

Figure 51. Injury resulting from severe two spotted spider mite infestation near a field margin in peanut

Foliar miticide sprays can control this pest, but complete control can be difficult to obtain. Because mites feed on the lower surface of the leaves, coverage of this part of the plant is necessary for control.

Insect Scouting Procedures

To carry out an effective peanut pest management program each grower must know the number and species of insects present before any control decision can be made. Inspect each field closely for soil insects when preparing soil before planting. If white grubs, wireworms, whitefringed beetle larvae and/or bahiagrass borers are present, apply insecticides and incorporate them into the soil before the crop is planted.

Figure 52. Two spotted spider mites congregating on the tip of a peanut leaflet

All fields should be checked at least once each week from the time the peanut plants emerge until harvest in order to make treatment decisions. Thorough coverage of each field is necessary to make an accurate assessment of the insect population. Ten randomly selected locations should be sampled in each field.

To check for foliage feeding caterpillars (such as corn earworms, loopers, armyworms, and velvetbean caterpillars) briskly shake the plants to dislodge these insects. Afterwards count them on the soil. Check three row feet at each location. This can be best accomplished by shaking one-half of three foot sections of two adjacent rows into the middle between the rows then parting the plants and counting the insects on the soil surface. To check for cutworms examine the soil surface around the base of the plant and the top inch of the soil where cutworms may be hiding.

Foliage feeding caterpillar thresholds vary with plant size and condition. Thresholds on seedling peanut have not been established, but plants at this stage cannot tolerate severe defoliation. Control foliage feeding caterpillars when an average of four or more per foot of row are present in a field that is passed the seedling stage if plants are stressed. In fields with healthy vigorous plants, foliage feeding caterpillars do not require treatments until populations approach an average of eight per row foot. Insecticides applied in early or mid-season can destroy beneficial insects which could otherwise prevent the foliage feeding caterpillars from increasing to damaging levels.

To check for lesser cornstalk borers and their damage look for damage or entry holes into the stems of all plant parts that are in contact with the soil. Examine pegs and pods for damage. Examine the soil for larvae that may be outside the stems. For southern corn rootworms, remove a few plants from the soil and examine the pegs and pods for damage. Also check the soil three or four inches deep where these plants were removed for rootworms.

If larvae or fresh damage of either the lesser cornstalk borer or southern corn rootworm is found in three or more of the 10 locations checked, apply a recommended insecticide. Infestations of leafhoppers, threecornered alfalfa hoppers or spider mites are recorded as none, light, medium or heavy. Light damage means only occasional pests or damage are seen, medium means that the pest or damage is readily seen, and heavy means that the pest and/or damage is generally seen throughout the field. With spider mites it may be advisable to treat small areas of a field to prevent the infestation from spreading. Treat leafhopper infestations when adults and immature stages are present and they appear to be spreading across the field from the initial infested area. Treatment of threecornered alfalfa hoppers usually occurs when large numbers of adults are seen in the field. Research is continuing on treatment thresholds, and these thresholds may be revised as more is learned about each peanut pest.

NOZZLE SELECTION AND CALIBRATION GUIDE

Chapter 15
Nozzle Selection and Calibration Guide

Glen C. Rains

Nozzle Type Selection

Nozzle type selection is one of the most important decisions related to pesticide applications. The type of nozzle affects not only the amount of spray applied to a particular area, but also the uniformity of the applied spray, the coverage obtained on the sprayed surfaces and the amount of drift that can occur. Each nozzle type has specific characteristics and capabilities and is designed for use under certain application conditions. The types which are commonly used for ground application of agricultural chemicals are flat fan, even flat-fan and cone nozzle. Air induction nozzles are also available that have added drift reduction characteristics. Always check the chemical label for additional instructions. There may be restrictions or guidelines that affect the nozzle chosen.

Nozzles perform three tasks, they regulate flow, form droplets and disperse a specific pattern. Depending on the application, nozzles are selected that have the best combination of these three functions.

Nozzle selection starts by looking at what you are spraying. Herbicide, fungicide or insecticide, and whether it is contact, systemic, pre-emergence or post-emergence. The best way to select a nozzle based on these attributes is to refer to manufacturers charts that give nozzle recommendations. These are easily assessable on the manufacturer's website or in hardcopy. They will break down the applications and the type nozzles that perform best. For peanut production, most nozzles are some type of flat fan and/or air induction flat fan nozzle. Air induction nozzles add entrained air into the liquid stream that help create larger droplets that are less susceptible to drift. Here are some of the most popular manufacturer websites that indicate nozzle types and applications:

1. http://www.teejet.com/english/home/selection-guides/spray-nozzles.aspx - interactive nozzle tip selection guide
2. http://www.greenleaftech.com/dynamic. php?pg=Choosing_the_Right_Nozzle/Nozzle_Calculator - Nozzle calculator shows nozzle selections for specific GPA, speed and nozzle spacing
3. http://www.delavanagspray.com/Products-a.htm - basically a catalog on the website.

Some other things to consider are:

1. Do you need to get under the leaf?
2. Does the end of the boom need extra protection from drift to sensitive areas?

Application Droplet Size

Once a nozzle type is determined, there are still some choices within the nozzle type. Specifically, spray angle and volume flow rates at specific pressure. Most nozzles are named by their nozzle type, spray angle, and spray volume at a nominal pressure (usually 40 psi).

So, an AIXR110025 (TeeJet), is an Air induction, XR nozzle with a 110 degree spray angle and a 0.25 GPM flow rate at 40 psi.

Requirements, or recommendations, are specified on most pesticide labels, such as the application rate, droplet size and drift risk under weather conditions such as inversions. Nozzle manufacturers will

Spray Quality*	Size of Droplets	VMD Range (Microns**)	Color Code	Retention on Difficult to Wet Leaves	Used for	Drift Potential
Extremely Fine	Small	<60	Purple	Excellent	Exceptions	High
Very Fine		61-105	Red	Excellent	Exceptions	
Fine		106-235	Orange	Very Good	Good Cover	
Medium		236-340	Yellow	Good	Most Products	
Coarse		341-403	Blue	Moderate	Systemic Herbicides	
Very Coarse		404-502	Green	Poor	Soil Herbicides	
Extremely Coarse		503-665	White	Very Poor	Liquid Fertilizer	
Ultra Coarse	Large	>665	Black	Very Poor	Liquid Fertilizer	Low

*Always read the pesticide label to determine which spray quality is required.
**Estimated from sample reference graph in ASABE/ANSI/ASAE Standard S572.1

ASABE S572.1 standard uses eight droplet classification categories, six of which are common for agriculture and horticulture:

Very Fine | Fine | Medium | Coarse | Very Coarse | Extremely Coarse

Table 1. Standard droplet size chart and color codes.

specify droplet sizes for nozzles and pressure settings. These are normally color coded by the ASABE standard for droplet size as shown in Table 1

Different applications will recommend different droplet sizes and nozzles that provide adequate COVERAGE, PENETRATION and DRIFT CONTROL.

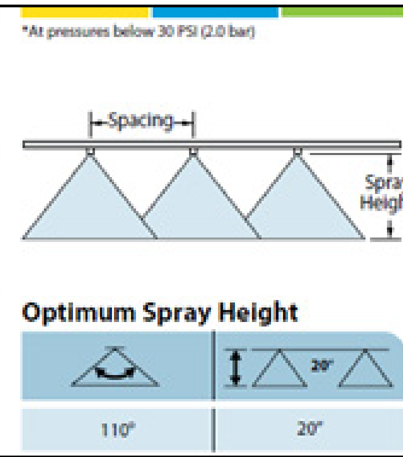
ASABE also has a standardized recommendation for droplet size and application shown in Table 2. Approximate VMD (volumetric median diameter) ranges are shown. VMD is the droplet diameter where 50% of the sprayed droplet volume is below and 50% of the sprayed droplet volume is above this size.

Application	Droplet Category[2]	Approximate VMD Range[3] (in microns)
Fungicide		
foliar protective or curative	Medium (M)	226-325
Insecticide		
foliar contact or stomach poison	Medium (M)	226-325
foliar systemic	Coarse (C)	326-400
soil-applied systemic	Coarse (C) Very Coarse (VC) Extremely Coarse (XC)	326-400 401-500 > 500
Herbicide		
foliar/postemergent contact	Medium (M)	226-325
foliar/postemergent systemic	Coarse (C)	326-400
soil-applied/preemergent systemic	Coarse (C) Very Coarse (VC) Extremely Coarse (XC)	326-400 401-500 > 500

[1] Always read the label. Pesticide product labels may specify what droplet size to use, which will direct nozzle selection and, in turn, affect spraying equipment configuration and calibration.
[2] ASABE (American Society of Agricultural & Biological Engineers) Standard 572.
[3] Reported VMD ranges vary widely, based upon the type of laser analyzer used. VMD = Volume Median Diameter: a value where 50% of the total VOLUME or mass of liquid sprayed is made up of droplets LARGER than and 50% SMALLER than this value.

Table 2. Recommended droplet size categoiry by application type.

TT11003 (50)	15	VC	0.18	23	13.4	10.7	8.9	6.7	5.3	4.5	3.6	2.7	0.61	0.41	0.31	0.24
	20	VC	0.21	27	15.6	12.5	10.4	7.8	6.2	5.2	4.2	3.1	0.71	0.48	0.36	0.29
	30	C	0.26	33	19.3	15.4	12.9	9.7	7.7	6.4	5.1	3.9	0.88	0.59	0.44	0.35
	40	C	0.30	38	22	17.8	14.9	11.1	8.9	7.4	5.9	4.5	1.0	0.68	0.51	0.41
	50	M	0.34	44	25	20	16.8	12.6	10.1	8.4	6.7	5.0	1.2	0.77	0.58	0.46
	60	M	0.37	47	27	22	18.3	13.7	11.0	9.2	7.3	5.5	1.3	0.84	0.63	0.50
	75	M	0.41	52	30	24	20	15.2	12.2	10.1	8.1	6.1	1.4	0.93	0.70	0.56
	90	M	0.45	58	33	27	22	16.7	13.4	11.1	8.9	6.7	1.5	1.0	0.77	0.61
TT11004 (50)	15	XC	0.24	31	17.8	14.3	11.9	8.9	7.1	5.9	4.8	3.6	0.82	0.54	0.41	0.33
	20	VC	0.28	36	21	16.6	13.9	10.4	8.3	6.9	5.5	4.2	0.95	0.63	0.48	0.38
	30	C	0.35	45	26	21	17.3	13.0	10.4	8.7	6.9	5.2	1.2	0.79	0.60	0.48
	40	C	0.40	51	30	24	19.8	14.9	11.9	9.9	7.9	5.9	1.4	0.91	0.68	0.54
	50	C	0.45	58	33	27	22	16.7	13.4	11.1	8.9	6.7	1.5	1.0	0.77	0.61
	60	C	0.49	63	36	29	24	18.2	14.6	12.1	9.7	7.3	1.7	1.1	0.83	0.67
	75	M	0.55	70	41	33	27	20	16.3	13.6	10.9	8.2	1.9	1.2	0.94	0.75
	90	M	0.60	77	45	36	30	22	17.8	14.9	11.9	8.9	2.0	1.4	1.0	0.82
TT11005 (50)	15	XC	0.31	40	23	18.4	15.3	11.5	9.2	7.7	6.1	4.6	1.1	0.70	0.53	0.42
	20	VC	0.35	45	26	21	17.3	13.0	10.4	8.7	6.9	5.2	1.2	0.79	0.60	0.48
	30	VC	0.43	55	32	26	21	16.0	12.8	10.6	8.5	6.4	1.5	0.97	0.73	0.58
	40	C	0.50	64	37	30	25	18.6	14.9	12.4	9.9	7.4	1.7	1.1	0.85	0.68
	50	C	0.56	72	42	33	28	21	16.6	13.9	11.1	8.3	1.9	1.3	0.95	0.76
	60	C	0.61	78	45	36	30	23	18.1	15.1	12.1	9.1	2.1	1.4	1.0	0.83
	75	C	0.68	87	50	40	34	25	20	16.8	13.5	10.1	2.3	1.5	1.2	0.92
	90	M	0.75	96	56	45	37	28	22	18.6	14.9	11.1	2.6	1.7	1.3	1.0
	15	XC	0.37	47	27	22	18.3	13.7	11.0	9.2	7.3	5.5	1.3	0.84	0.63	0.50
	20	XC	0.42	54	31	25	21	15.6	12.5	10.4	8.3	6.2	1.4	0.95	0.71	0.57



These are guidelines. Always check the label for specific recommendations and specifications on nozzle selection and droplet sizes. An example of nozzles and the droplet size categories are shown in the image above from the Teejet catalog.

Selecting the Nozzle Tip

Once nozzle selection has been made and droplet size is considered, the correct nozzle tip for that nozzle type can be selected. The correct nozzle tip size depends on an application rate in gallons per acre (GPA), ground speed (MPH), and effective spray width of each nozzle (W). The best method for choosing the correct nozzle tip size is to determine the gallons per minute (GPM) of nozzle output required and then select a nozzle tip size that, when operated within the recommended pressure range, will provide this flow rate. Avoid relying on the "gallons per acre (GPA)" rating which some manufacturers give their nozzles as means of selecting nozzle tip size. This rating is correct only for standard conditions (usually 40 psi, 4 MPH, and 20- inch nozzle spacing). The gallon per acre rating is useless if any variance from the standard occurs.

By following the steps described below, the proper nozzle tip size can be selected.

1. Determine "GPA" - First select the application rate in gallons per acre (GPA) used. The application rate consists of the gallons of carrier (water, fertilizer, etc.) plus chemical applied per treated acre. The best guides for this decision are the recommended ranges listed on the label, the recommendation of a chemical dealer or county agricultural agent, and experience with that particular chemical.
2. Determine "MPH" - Select an appropriate ground speed in miles per hour (MPH) for the field to be sprayed. Experience is the best guide here. Generally, speeds between 3 and 7 MPH are considered appropriate for ground sprayers. Do not rely solely on speedometers as an accurate measure of ground speed, especially on older tractors. Slippage and variation in tire sizes can result in speedometer errors of 30 percent or more. Ground speed can be determined by the following equation: MPH=[Distance (ft)*60]/([Time (seconds)*88])
3. Determine "W" – Determine the effective sprayed width per nozzle (W) in inches. For broadcast spraying W = nozzle spacing. For band spraying, W = band width. For directed spraying, such as 3 nozzles per row, W = row spacing.
4. Determine Tip Size - Once the application rate, ground speed, and spray width per nozzle have been determined, the flow rate required for each nozzle in gallons per minute (GPM) can be determined by using a nozzle catalog, tables or the following equation:

$$GPM = GPA * MPH * W/5,940$$

Example 1: A herbicide is to be broadcast at 20 GPA at a speed of 5 MPH, using flat fan nozzles spaced 20 inches apart on the boom. What size nozzle tip should be selected?

The required flow rate for each nozzle is as follows:

$$20 * 5 * 20/5,940 = 2,000/5,940 = 0.34 \text{ GPM}$$

The nozzle selected must have a flow rate of 0.34 GPM when operated within the recommended pressure range of a flat-fan nozzle (20 to 30 psi). By checking nozzle catalogs, you will find a number of different brands of flat-fan nozzles which will provide this flow rate. For example, the Spraying Systems XR8004 and Delavan LFR80-4R nozzles have a rated output of 0.35 GPM at 30 psi. Either of these nozzles will be sufficient for this application.

Example 2: A foliar fungicide is to be applied at 15 GPA at a speed of 7 MPH, using hollow cone nozzles. The row spacing is 36 inches with three nozzles directed toward each row. What size tip should be selected?

The required flow rate for each row is as follows:

$$GPM_{row} = GPA*MPH*W_{row} /5,940$$

$$GPM_{row} = 15*7*36/5,940 = 3,780/5,940 = 0.64 \text{ GPM}_{row}$$

The flow rate for each nozzle is the row GPM divided by the number of tips per row.

$$GPM_{nozzle} = 3 \text{ nozzles/row} = 0.64/3 = 0.21 \text{ GPM}_{nozzle}$$

The nozzle selected must have a flow rate of 0.21 GPM operating between 40 to 80 psi. Checking the nozzle manufacturer's website or catalog, the Spray Systems TX-4 and Delavan HC-4 cone spray nozzles have a rated output of 0.20 GPM at 60 psi. Or the Spray System D4-23 and Delavan DC4-23 disc-core nozzles have a rated output of 0.21 GPM at 80 psi. Either one of the nozzles chosen would deliver the proper amount per acre.

Nozzle Tip Material

Another factor to consider when choosing a tip is the material. Various types of nozzle bodies and caps, including color-coded versions, and multiple nozzle bodies are available with threads as well as quick-attaching adapters. Nozzle tips are interchangeable in the cap and are available in a wide variety of materials, including hardened stainless steel, stainless steel, brass, ceramic and various types of plastic. Hardened stainless steel and ceramic are wear-resistant materials but are also the most expensive. Stainless steel tips have excellent wear resistance with corrosive or abrasive materials. Plastic tips (polymer) are resistant to corrosion and abrasion and are proving to be very economical for applying pesticides. Brass tips have been common but wear rapidly when used to apply abrasive materials such as wettable powders and are corroded by some liquid fertilizers. Brass tips are economical for limited use, but other types should be considered for more extensive use. Figure 1 shows the increase in flowrate of spraying an abrasive material for 40 hours.

Type of Diluent

The diluent (diluting agent) for most spray applications is water. However, situations may require the use of another diluent. The pesticide labeling usually recommends the diluent to be used with that product. You must know what diluent you will use before you can select the appropriate nozzles for the job.

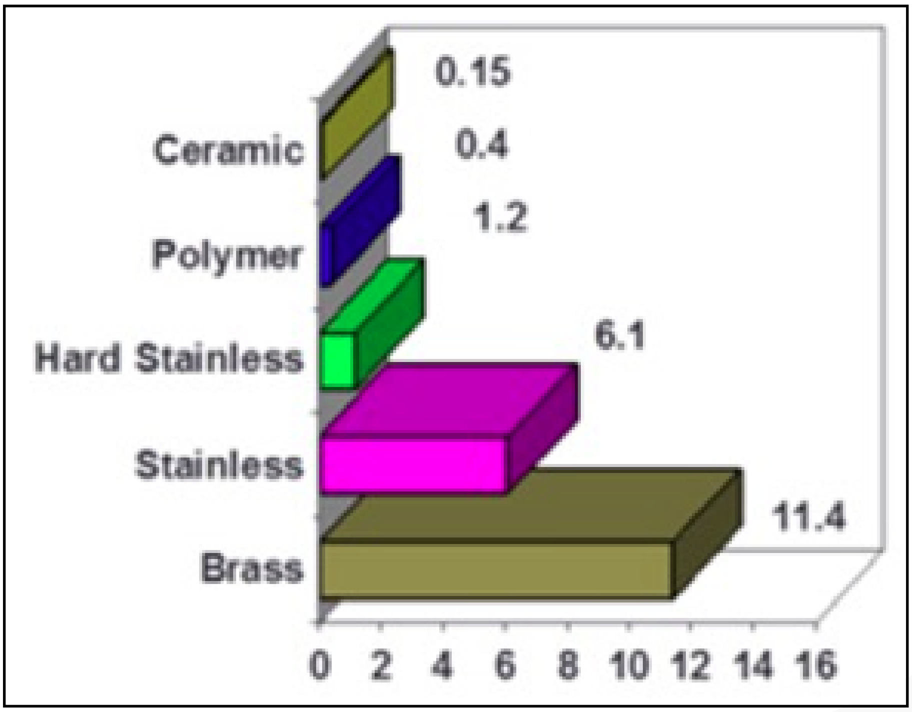


Figure 1 Percent increase in flow rate after 40 hours of operation for various nozzle tip materials.

Table 3. Diluent Conversion Factors.		
Weight of Solution (lbs/gal.)	**Specific Gravity**	**Conversion Factor**
6.6 (kerosene)	0.79	0.89
7.0	0.84	0.92
8.0	0.96	0.98
8.34 (water)	1.00	1.00
9.0	1.08	1.04
10.0	1.20	1.10
10.65 (28% N)	1.28	1.13
11.0	1.32	1.15
12.0	1.44	1.20
14.0	1.68	1.30
16.0	1.92	1.39

Because most selection charts provided by nozzle manufacturers are based on spraying with water, the figures will not be correct if you are using another diluent. A table such as Table 3 is often provided to help you adjust the figures to fit your situation. Multiply the values on the nozzle charts by the conversion factor from the table to determine the correct GPM for the solution being sprayed.
Example 3: You have determined that you would be applying 15 gallons per acre of a 28% nitrogen solution with a flat fan nozzle at a speed of 5 MPH. The nozzle spacing is 20 inches. The nozzle to select from the catalogs (based on water) would be calculated as follows:

15 GPA (28% N)x1.13 (conversion factor from Table 3) = 16.95 GPA (water)

GPM = GPA * MPH * W/5,940
GPM = 16.95 * 5 * 20 = 0.285 GPM/5,940

The nozzle selected must have a flow rate of 0.285 GPM when operated within the recommended pressure range. Checking the website, Spraying Systems XR8004 nozzles have a rated output of 0.28 GPM at 20 psi.

There are different diluents used for spray application. A conversion factor for a weight of solution not shown in Table 3 can be determined by the following procedure:

1. Determine the weight of solution (pounds per gallon). Measure out a gallon of diluent in a container. Weigh the container plus diluent in pounds. Subtract the weight of the container. Your supply dealer can also provide this information.
2. Determine the specific gravity (SG) of the solution. Divide the weight of solution/gallon by the weight of water/gallon.

   SG = Weight of solution/8.34
3. Calculate the conversion factor by taking the square root of the specific gravity.

   Conversion Factor = √SG

This conversion factor can then be used to determine the corrected GPM.

Calibration

Calibration is a method of determining the amount of spray volume applied per acre. Sprayers should be calibrated to determine the amount of mixture that is actually being applied per acre. It allows the producer to determine the correct operating speed, spray pressure, and nozzle size for a specific application. The initial calibration will indicate how close a sprayer is to the target application rate. Adjustments to operating speed, spray pressure, or nozzle size can be made to correct the volume being applied. Recalibrate sprayers after 15 - 20 hours of operation. The following is a procedure for calibrating a sprayer. It is based on the 1/128th acre coverage method:

1. From Table 4, determine the distance to drive in the field (two or more runs suggested). For broadcast spraying nozzle spacing is the distance between nozzles. For band spraying, use the band width for nozzle spacing and for over-the-row spraying, use the crops row spacing for nozzle spacing.
2. Measure the time (seconds) to drive the required distance from Table 4; with all equipment attached and operating. Maintain this throttle setting!
3. To measure GPA, collect the spray from appropriate nozzles for the measured time:
   - For broadcast: Ounces collected (for the time determined) per nozzle = GPA
   - For a band: Ounces collected per band (all

Table 4. Distance to Drive to Spray 1/128th Acre. One Ounce Discharged Equals One Gallon Per Acre (GPA).			
Nozzle Spacing (inches)	**Distance (feet)**	**Nozzle Spacing (inches)**	**Distance (feet)**
6	681	20	204
8	510	22	186
I O	408	24	170
12	340	30	136
14	292	36	113
16	255	38	107
18	227	40	102

nozzles directed to the band) = GPA

- For row: Ounces collected per row (all nozzles directed at a row) = GPA

To determine a calibration distance for an unlisted spacing, take 4096 and divide by the desired nozzle spacing in inches. For example: Calibration distance for a 13” band = 4096/13 = 315 feet.

Things to Consider

1. For any particular nozzle tip, droplet sizes will decrease and spray angle will increase as you increase pressure (see Figure 3), so do not get locked onto a specific tip selection without taking into account what the pressure may do to your droplets. Change tips to match GPM AND droplet sizes.
2. Air induction nozzles are excellent at reducing drift. If using a herbicide application, it is prudent to consider these types of nozzles. However, as just stated, increasing pressure will still reduce droplet size.
3. The slower the better when it comes to coverage.
4. Check the chapters on weed, disease and insect control. There are recommended nozzle and application practices based on research specific to peanut production.
5. Weather is an important factor when spraying. Pesticide labels may indicate when you can or cannot spray due to wind. In general, do not spray if wind speeds exceed 10 mph. Also do not spray if there is an air inversion (air gets warmer as you go up)This can create a layer of air and chemical that can rise with the heating air as the day progresses and then disperse chemical over a wide area. Inversions are worst in early morning and late afternoons with little wind. If there is sufficient moisture in the air, you will see fog as a consequence of an inversion. Figure 4 shows the intensity of a typical air inversion over a 24 hour period.
6. Consider buying a handheld weather station. They can be used to measure temperature, dewpoint, humidity and wind speed. Amazon.com has several that are available.

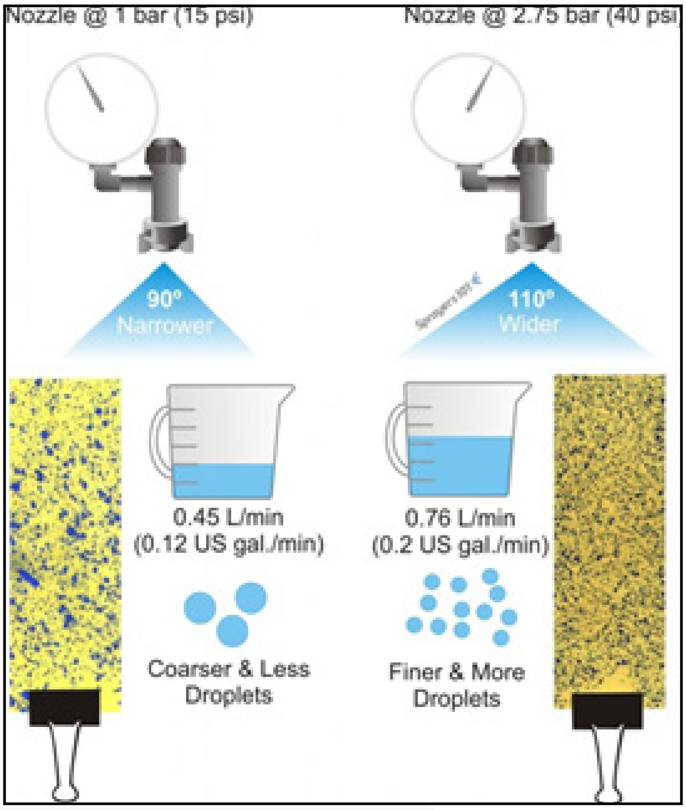


Figure 2. Effect on droplet size and spray angle with increasing pressure.

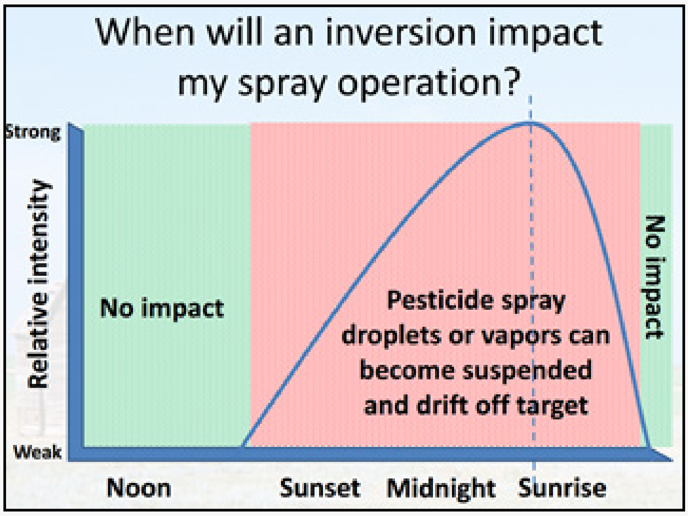


Figure 3. Potential air inversion intensity throughout a day.

RTK-BASED GPS GUIDANCE FOR PLANTING & INVERTING

Chapter 16
Using RTK-Based GPS Guidance for Planting and Inverting Peanuts

George Vellidis

The peanut is a low growing crop which produces its fruit underground. As the peanut plant matures, it produces nuts (fruit) on the crown of the plant (taproot crop) as well as on vines that extend outwards from the main stem (limb crop). Peanut harvesting is a two-step process. First an inverter passes through the field. The inverter undercuts the tap root and inverts the plant so that it is laying on the soil with the leaves down and the nuts lying upwards. This process is commonly referred to as "digging" the peanuts. After a few days of drying in the field, the plants are harvested mechanically.

It is very important that the inverter pass as close as possible over the centerline on which the peanuts were planted otherwise the inverter will cut off sections of the vines and those peanuts will remain in the soil. With most modern "runner" type cultivars, when the peanut plants are mature, their canopy completely covers the soil and it is visually very difficult to identify the centerline on which peanuts were planted. Consequently farmers regularly incur "digging losses" – peanuts lost during inverting. Digging losses are also affected by the tillage system used (conventional versus conservation tillage), soil texture, soil moisture conditions at the time of inversion, digger speed, and peanut maturity. Digging losses may range from 15 to 30% of the peanut crop's potential yield. Global Positioning System (GPS) –based guidance offers peanut farmers the potential of being able to follow the planting centerline with both accuracy and precision when inverting their peanuts.

RTK-Based Automated Steering (Auto-Steer)

GPS guidance of farm machinery has been adopted by increasingly larger segments of the farming community over the past decade because of the inherent gains in efficiency that it provides. Several researchers have attributed increased crop yields to the use of GPS guidance for strip-tillage and planting. Others have reported significant reductions in user fatigue and fuel consumption. As a result, it is now common to find farmers who own tractors, sprayers, and harvesters equipped with GPS guidance.

The most accurate form of GPS guidance is Real Time Kinematic (RTK)-based automated steering or auto-steer. An on-board computer known as the navigation controller uses GPS to accurately locate the position of the vehicle and automatically steer the vehicle along the desired path. Auto-steer has the ability to guide a vehicle over the desired path with one inch accuracy and one inch year-to-year repeatability.
To achieve this level of performance, the auto-steer system must use RTK differential correction for the GPS system. RTK differential correction uses GPS base stations that are within a few miles of the user to calculate errors in the GPS signal and transmit a differential correction to the navigation controller in the vehicle. The correction can be transmitted to the user by radio from towers, over the internet, or by cell phone modems. Users can subscribe to a RTK differential correction service or purchase and establish their own base station.

Studies to Measure the Yield Benefits for Peanuts

The University of Georgia (UGA) Precision Agriculture Team conducted studies to qualify the

Figure 1. Planting peanuts using and RTK-based auto-steer system (left) and inverting peanuts using and RTK-based auto-steer system (right).

yield benefits of using auto-steer to plant and invert peanuts. Studies were conducted for two consecutive years (2010 and 2011) on two different fields on a working farm in southern Georgia. During each year a field with sloped land and field rows with varying degrees of curvature ranging from extreme to mild was selected for the study. Both fields contained steep earthen terraces installed decades ago to reduce erosion. These terraces were not parallel to each other nor were they parallel to the row pattern currently used by the farmer. As a result, the tractor and implement was required to cross these terraces at various angles during all field operations. The fields were divided into alternating strips representing treatments.

During each year, there were two treatments – manual and auto-steer. Each strip consisted of three passes of four row equipment (12 rows, 4 rows per pass). The same farm equipment (tractor equipped with RTK-based auto-steer, planter, and inverter) was used for all treatments – the auto-steer was either engaged or not engaged depending on the treatment. Manual treatments were planted and inverted conventionally (without auto-steer). Auto-steer treatments were planted and inverted using the RTK-based auto-steer system (Figure 1).

Peanuts were planted using strip-tillage. Tillage and planting was done as a single operation. The Georgia-06G peanut cultivar was used during both years. Peanuts were inverted and allowed to dry for three days before harvest. The peanuts harvested from each strip were emptied by the harvester into a peanut wagon mounted on four load scales and the yield of peanuts recorded.

The measured yield of peanuts was corrected for foreign material content and moisture content using information provided by the United States Department of Agriculture grading office at the buying point to which the cooperating farmer sold his peanuts. Data were analyzed two different ways: 1) they were grouped together by treatment and compared, and 2) they were grouped by curvature of the rows harvested (low, medium or high curvature) and treatment (conventional or auto-steer) and compared.

Measured Yield Benefits for Peanuts

When all data were grouped together, auto-steer outperformed conventional by 516 lb/A in 2010 and 402 lb/A in 2011 (Table 1). In 2010, auto-steer outperformed conventional by 301 and 663 lb/A in high curvature and medium curvature rows, respectively (there were no low curvature rows in the 2010 field). In 2011, auto-steer outperformed conventional by 156, 447, and 572 lb/A in high curvature, medium curvature, and low curvature rows, respectively. Table 1 summarizes the comparison between conventional and auto-steer.

Auto-steer outperformed conventional much more under medium and low curvature conditions than under high curvature conditions. This observation was somewhat surprising because it was originally assumed that under low curvature conditions, a human operator would be able to follow the centerline well. In fact, the solid green peanut canopy encountered when inverting peanuts makes it difficult for the human operator to align the tractor with the planting centerline whereas the auto-steer system can place the tractor within one inch of the centerline. When coupled with better performance of the auto-steer system itself under low curvature conditions than under high curvature conditions, this results in much higher yields for planting and inverting with auto-steer under low to medium curvature conditions.

Effect of auto-steer on digging losses

As mentioned earlier, digging losses in peanuts may range from 15 to 30% of the crop's potential yield. When peanuts are grown with strip-tillage on finer-textured, less friable soils as was done in this study, digging losses may approach the upper end of this range. A recent study measured digging losses of 26% in strip-tillage peanuts planted and inverted without auto-steer at a location in south-ern Georgia with similar soils. By using auto-steer, digging losses were reduced by 516 lb/A (32%) in 2010 and 402 lb/A (23%) in 2011. In other words, estimated digging losses were reduced to 18% in 2010 and 20% in 2011. Digging losses were further reduced in the medium and low curvatures.

Economic returns from using auto-steer

Table 1 also includes the economic benefit resulting from applying the measured yield gains to the average area planted to peanuts each year by the cooperating farmer (200 ac). Using the yield gain resulting from auto-steer under all curvature conditions (516 lb/ac in 2010 and 402 lb/ac in 2011), the farmer would have realized an economic gain of $30,960 in 2010 and $38,166 in 2011. The large difference in economic return between 2010 and 2011 is caused by the large difference in peanut prices between the two years. In 2010, the farmer sold his peanuts for $600/ton while in 2011 he sold his crop for $950/ton. Considering that installation of an RTK-based auto-steer system on a tractor costs between $22,000 and $25,000 (depending on the manufacturer) and requires an annual RTK correction subscription of between $800 to $1200, investing in an auto-steer system is a good economic decision as the system can easily pay for itself in short order.

Conclusions

The experiment reported here conclusively shows that using RTK-based auto-steer to plant and invert peanuts results in substantial yield gains and associated economic returns. When added to the other efficiency gains resulting from consistently using auto-steer for farm operations such as spraying, tillage, etc., investing in auto-steer appears to be a sound investment for many farmers.

Table 1. Comparison between the effect of conventional and auto-steer on peanut yield during the 2010 and 2011 studies.							
Curvature	Treatment	2010			2011		
		Avg. Yield (lb/A)	Diff.[1] (lb/A)	Econ. Gain[2] ($)	Avg. Yield (lb/A)	Diff.[1] (lb/A)	Econ. Gain[2] ($)
All	Auto-Steer	5120	516*	30,960	5473	402*	38,166
	Conventional	4604			5072		
High	Auto-Steer	5170	301	18,060	5509	156	14,804
	Conventional	4869			5354		
Medium	Auto-Steer	4915	663*	39,780	5594	447*	42,465
	Conventional	4251			5147		
Low	Auto-Steer	N/A			5356	572*	54,321
	Conventional	N/A			4784		

[1]*Difference = Auto-steer – Conventional.*

[2]*Economic Gain was calculated using peanut prices of $600/ton in 2010 and $950/ton in 2011 and extrapolated to 200 acres.*

**Indicates that difference between Auto-Steer and Conventional was statistically significant.*

MATURITY ASSESSMENT

Chapter 17
Maturity Assessment

W. Scott Monfort and Scott Tubbs

Time of harvest is one of the most important decisions growers make each year. Peanuts may lose 300 to 500 pounds/A and 2 to 3% in grade during the week and a half before optimum harvest. Even greater losses may occur if harvest is delayed past optimum maturity. Table 1 illustrates the average loss over several years from digging too early or too late. Dollars lost represent losses in clear profit, as no additional input is required other than digging at the optimum time. See Chapter 7 for more information on optimum maturity by varieties.

Gross returns on peanuts depend on yield and quality. In current grading standards, the dollar value received per ton is based partially on the percent of total sound mature kernels (TSMK). Basically, this is a measurement of how completely the kernel fills the pod.

Fully mature peanuts are essential to the industry for providing consumers with the most flavorful, nutritious products possible. Immature peanuts have poor flavor, often deteriorate quickly in storage and can have significant problems with aflatoxin.

Botanically, peanuts are indeterminate plants. They continuously flower and form pods until the plant dies. Because peanuts are indeterminate, peanuts should be harvested when the greatest amount of the most profitable peanuts (highest yield and grade) can be collected. Therefore, timing of harvest is based on a risk-benefit analysis. That is, growers need to decide if losing a few older pods is worth the benefit of gaining a substantial number of younger pods or if they should harvest earlier to save a large crop of older pods when there are only a few younger pods maturing.

Hull-Scrape Method

The hull-scrape method is the most accurate means of assessing the maturity of runner peanuts. This procedure has been utilized for more than 20 years in Georgia and it is universally accepted as being simple and accurate for determining maturity. The

Table 1. Harvesting at Optimum Maturity

	Pounds lost/acre*	$ lost/acre (0.25 / lb)
Dug 2 weeks early	744	$179
Dug 1 week early	208	$50
Dug at optimum	0	0
Dug 1 week late	601	$144
Dug 2 weeks late	1746	$419

**Data compiled from Williams, E.J. USDA/ARS Tifton and Monfort et al., Tifton, GA, UGA.*

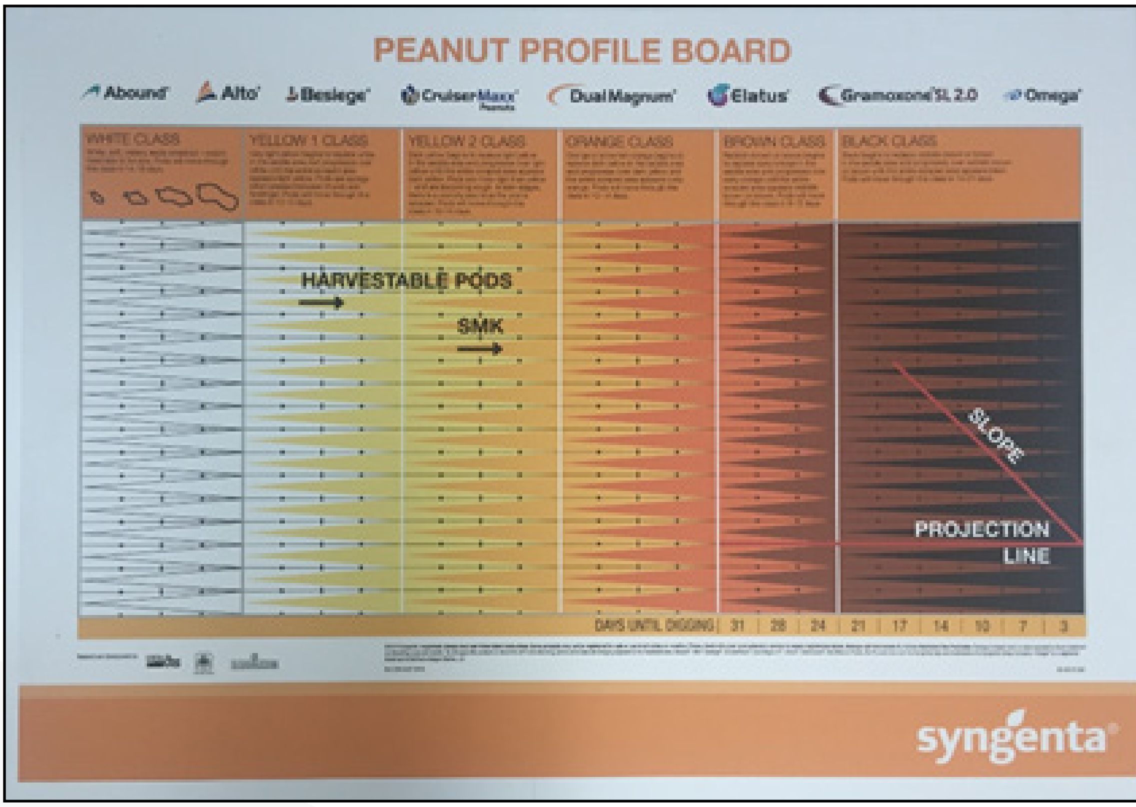


Figure 1. Peanut profile board (color coded chart) used to determine peanut maturity.

hull-scrape method requires a color coded chart (Figure 1) and a pocket knife. The knife is used to scrape away the outer hull covering (exocarp). A pressure washer system with an oscillating nozzle is now the preferred system to quickly remove the exocarp.

The scraped hull exposes the mesocarp, which darkens as the peanut matures. The color gradually changes from white to yellow to dark yellow to orange to brown and to black as the peanut matures. By matching the scraped peanuts with the colors on the chart, maturity can be determined.

The success of the hull-scrape method depends on accurate samples. The color coded peanut profile chart is calibrated on the basis of an approximate 200 pod sample. This sample must include peanuts of all sizes, from match head size to mature peanuts. Normally, four mature peanut plants will provide enough pods. Randomly collect the plants so the sample represents the entire field. Poor sampling techniques will distort the peanut profile, making the results useless.

Each field should be sampled approximately 110-120 days after planting to predict the digging date. Then sample a second time approximately 10 days before the predicted digging date to confirm that maturation is proceeding normally. If there is a significant difference between the two predicted digging dates, then take a third sample test immediately. If an accurate sample was taken, the pods were accurately separated into maturity groups, the crop is developing normally, and drought, disease, or insect pressure is not heavy enough to force early harvest, the profile board will predict the best harvest date.

Step 1: How to Sample. Carefully lift at least five adjacent plants from at least three representative field areas which can be dug in one day. The samples must accurately represent the field or the results will be meaningless. Keep samples from each area of the field separate from each other. When sampling an area consider differences in soil type, drainage, planting dates, variety, and various other factors. Note the overall condition of the plants and refer to an accurate field history. Give special attention to the presence of leafspot, rust, white mold and Rhizoctonia limb rot. In addition look for severe infestations of nematodes, southern corn rootworms, and wireworms (which are most effectively managed by preventive treatment). These factors (diseases, insects, pests, etc.) can potentially affect the timing of peanut harvest and may cause rapid vine decay and severe harvest losses.

Be sure to note peg condition and strength when collecting the sample. Under normal conditions, most recommended peanut varieties have adequate peg strength. However, pegs can be weakened by severe disease pressure and wet soils. The larger Virginia market type varieties are very susceptible to losses due to weakened pegs and large pods. Early peanut harvest may be necessary to prevent excessive losses.

Step 2: Determine the color of the inner hull tissues. Remove the outer hull tissue (exocarp) to expose the color of the inner hull tissue (mesocarp) with a sharp pocket knife To properly scrape the peanut, hold the pod with the beaked (apical) end of the pod away and the beak hook pointed downward. Scrape the peanut starting in the saddle area along the line where the hull splits when shelled and extend back towards the pod stem. This is the area where the pod color change is initiated (see Figure 2). The color change progresses from this point down the sides of the pod towards the beaked end. Scraping down one side of the pod indicates the degree of color change.

Another method, the wet blasting system (Figure 3) completely removes the exocarp from all peanuts in the sample simultaneously. Concentrate on the same area of color change as previously described. Once the mesocarp is exposed by either method, the tissues dry quickly. Scraped tissues should be kept wet before and after they are placed on the color profile board for accurate reading of the color.

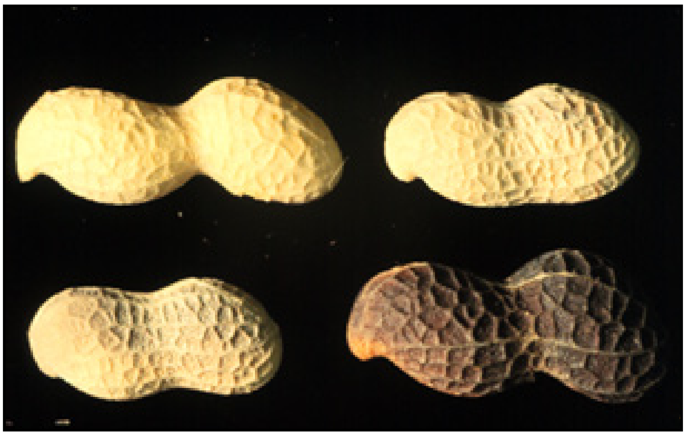


Figure 2. Mesocarp color change as peanut pod matures.

Step 3: Place the peanuts on the color chart (Williams and Drexler 1981). There are six major color categories on the profile chart; white, yellow, dark yellow, orange, brown and black. The color of the exposed mesocarp, in the saddle area, indicates the major color category in which the peanuts should be placed. Once the major color category is determined, note the color change on the sides of the hull. If the color in the saddle area extends half way around the hull (indicated that the tissue color is in transition), place the peanut on the color profile chart where the column is half the major color and half the previous lighter color. Place all the peanuts in the sample on the maturity profile chart using this procedure (see Figure 3). This arrangement, referred to as the peanut maturity profile, indicates how the pods set throughout the season and the overall maturity of the crop.

Step 4: Predict a harvest date. Along with the guide for color placement, the profile board has a slope

Figure 3. Pressure washer with orbital nozzle to blast on outer layer (exocarp) of hull. Source: CAES. Miscellaneous Publication No. ENG 03-004.

line and a harvest projection line. The leading edge of the sample profile should be approximately the same angle as the slope line on the profile board. The slope line represents the typical rate that pods are set. The rate of pod set for a given field, however, may be slightly greater or less than shown by the slope line.

The projection line is set at a height of three pods. This represents the balance point for maturity risk management. Most normally developing crops can make up a loss of up to three mature pods (in a 200 pod sample) per half week by gain in the weight of immature pods. Scan the profile board from right to left. Find where the leading edge (slope) of the sample profile crosses the projection line. Read the days until digging directly below. (See Figure 4).

This estimate is the middle of a three to four day range of possible harvest dates. Repeat this procedure with samples from other areas in that field. Representative samples will generally project within a week of each other. The average of the three areas should provide an accurate digging date for that field. Using the hull scrape method, it is even possible to estimate harvest for peanuts whose pod set has been interrupted by environmental stresses. For example, since few peanuts are set during an extreme mid- season drought, a "gap" occurs in the peanut profile. This "gap" will be clearly depicted on the profile chart. Due to the circumstances, it might be difficult to determine harvest since two crops exist as a result of the "gap." A properly constructed profile will indicate the relative size and age of the two crops. Using this information, it is much easier to determine the optimum harvest time. Remember

Figure 4. Peanut maturity profile board. The peanut maturity profile board is used to estimate maturity based on mesocarp.

that the hull scrape method is not an absolute indicator of when to harvest peanuts. Since other factors such as weather, acreage, equipment limitations and vine health influence harvest, it is impossible to predict peanut harvest to the day based strictly on peanut maturity. However, all factors considered, the most accurate prediction of harvest will likely fall within a three-to four-day range. However, final harvest decisions should not be made more than 10 to 14 days prior to harvest because other factors can take precedent over maturity.

New Maturity Tools

The adjusted Growing Degree Day (aGDD) model on the PeanutFARM website was developed as a tool to aid in determining optimum maturity. This heat unit model, developed just for peanut, automatically accesses the nearest weather station data (specified by the grower) and uses temperature plus rainfall and irrigation totals entered for individual fields to calculate a daily aGDD value. Research in Georgia, Alabama, and Florida over the last 5 years has indicated that 2500 accumulated aGDDs is the estimated optimal harvest for most current peanut cultivars. Please remember the optimum 2500 accumulated aGDDs may not correspond directly to age of the crop (days after planting). Planting date and weather conditions can alter how quick heat units are accumulated, and thus how the crop develops. The web program automatically provides two messages to a grower: one at 2300 aGDDs indicating that a maturity check (maturity provide board or the Digital Image Model through the PeanutPROFILE page of PeanutFARM) would be beneficial, and another once the optimum 2500 accumulated aGDDs level has been reached.

For the optimal maturity prediction plan:

1. growers would begin monitoring their aGDDs from the start of the season,
2. utilize the warning flag that the program provides at 2300 aGDDs,
3. at that point, collect a maturity prediction sample in the field, and
4. utilize the traditional board method or upload a scanned image of the pods to PeanutPROFILE for maturity confirmation. Using this plan would ensure a grower was harvesting at the right time, optimizing yield, grade, and quality and benefitting from all the hard work and efforts at managing the crop through the season.

Important Things to Consider When Predicting Maturity

Drought, cool temperature stress, soil-borne diseases and foliar diseases may cause abnormal maturation. The shape of the pod maturity profile can sometimes provide a clue to what has gone wrong. For example, if the height of the brown or black columns exceed the spaces provided on the profile board, or the slope of the profile leading edge is much greater than the profile board slope line, then move a few of these pods forward to obtain this slope before reading the days until digging. Under conditions of plant stress or where pods were classified incorrectly, this procedure provides a more accurate estimate of the pod age. Normal maturation is slowed when temperatures dip below 65°F. Sequential sampling may show little or no movement of the profile leading edge. The optimum maturity profile may be greatly delayed or never realized. Check the stems of the oldest pods for disease and possible breakdown. Do not schedule digging if frost is likely within the next two days.

Severe infections of leafspot or other foliar diseases may require digging earlier than the profile board indicates. Sample and profile the field again in half the normal follow-up interval and check peg strength carefully. Do not base digging on the profile board projection, but use the profile to indicate whether to immediately dig or not dig.

A projection is no more than just that - a projection. Many things can happen to the peanuts between the time of sampling and the projected harvest. Follow-up checks are imperative. However, having an earlier projection is advantageous. For example, a severe late season drought can stop maturation in orange, brown or black group. Shell out some of the pods. Kernels with bronze-colored seed coats have separated from the pod and will no longer gain weight or size and are susceptible to be lost in the digging process about three weeks after they stop being fed by the plant. Projecting a harvest from that sample would not be valid because excessive losses may occur before achieving optimum maturity. Determining when to dig is a complex decision with many factors, yet most of the quality and profits depend on that decision being made accurately. Optimize maturity and use your county Cooperative Extension Agent when you need help in this important decision.

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DIGGER AND COMBINE EFFICIENCY

Chapter 18
Peanut Digger and Combine Efficiency

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Harvest Management

When to dig peanuts is one of the most important decisions growers make each year. The hull-scrape method of determining peanut maturity is an accurate way of judging when to harvest For more information on the hull-scrape method, check with your county Extension agent.

An effective weed control program makes harvesting easier, reduces weed pressure and lessens soil compaction. Use periodic harrowings or herbicide treatments to suppress grass and other weeds along field borders and at the ends of peanut rows. When vegetation is present where the digger blades engage the soil, it has a tendency to wrap around the blades, covering the cutting edge. The presence of tough, dead plants at harvest time hampers digging even more than the presence of live plants.

Digging: The First Step for Harvesting Peanuts

The modern peanut digger-inverter (Figure 1) cuts the tap root just below the pods, lifts peanuts from the soil, elevates and shakes the soil from the vine mass, then inverts and windrows the vines, exposing pods to the air for curing.

Peanut inverters can be classified into two types. One type uses a conventional rattler bar system for moving the peanuts upward from the digger blades until the vines are inverted. The second type uses a tangent chain or chain rod combination to move the peanuts up to the inverter attachment. The first type of machine is the most common and will be discussed in detail.

With a conventional rattler bar system, the peanut plant passes through three stages: digging, shaking or dirt removal, and inversion. Digging is accomplished by cutting the peanut taproot with a horizontal blade just below the pods. This blade has a slight forward pitch to lift the plant onto a shaking conveyer just after the taproot is severed. The shaking conveyer is made up of horizontal bars that

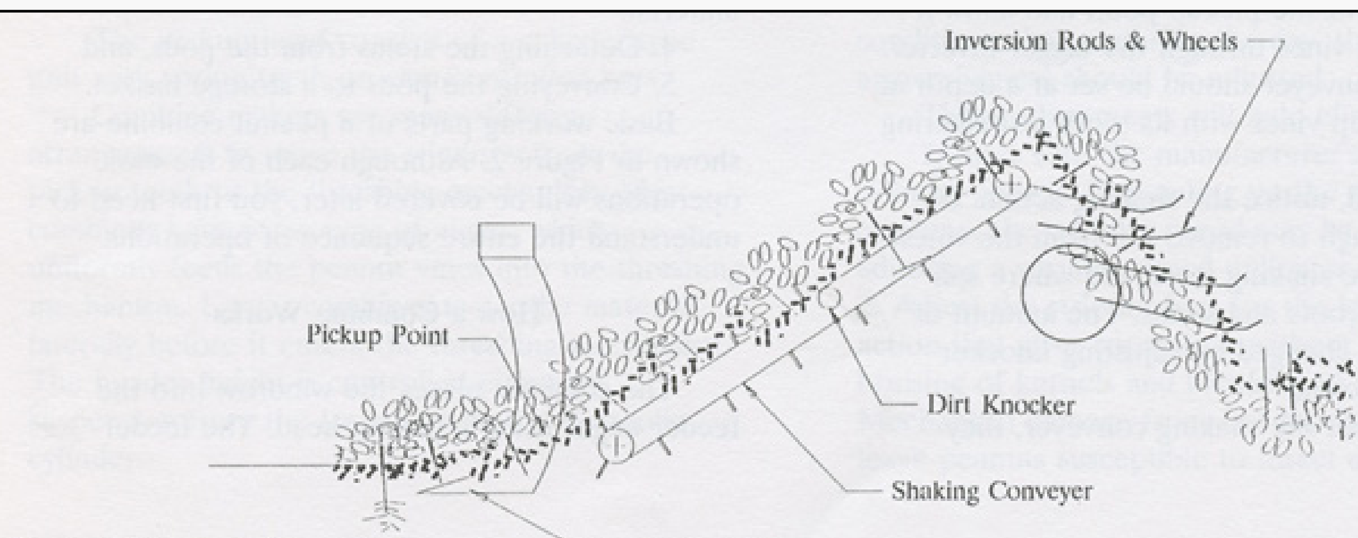

Figure 1. Peanut Digger Schematic

ride over small rubber wheels that cause the bars to vibrate, which helps remove soil from the plants and pods. As vines exit the shaking conveyer, they engage the inversion wheels and rods that flip and combine two adjacent rows into a single windrow.

Digger Operation and Adjustments (Adapted from Research conducted at Clemson University)

Digger setup and operation, along with proper timing often has a greater impact on yield recovery than any other aspect of peanut production; put simply, more revenue can be made or lost during digging than during any other field operation from seedbed preparation to combining. Even with the greatest care in proper setup and maintenance, digging losses in 2013 through 2016 Clemson studies on virginia type peanuts were demonstrated to range from 52-700 lb/ac (average 275 lb/ac) under good soil moisture conditions (3-7% volumetric moisture content) and 140-600 lb/ac (average 344 lb/ac) under dry soil moisture conditions (1.6-2.4% volumetric moisture content). In all of these studies, the numbers reported were as dry weight and only those losses considered to be mechanically induced; over-mature and diseased pod losses were not included in the numbers reported.

Row Center Deviation

Substantial losses will be incurred if the digger's path is not maintained precisely over the row center. One study indicated 105 lb/ac yield loss for every 0.5 in. deviation from row center (Ortiz et al., 2013). Studies conducted by N.C. State and University of Georgia independently demonstrated approximately 10% boost in yield recovery from the implementation of RTK auto-steering to maintain the peanut digging path directly over the planting path (Gary Roberson and George Vellidis, See Chapter 16). While capital costs of such guidance systems are high, the payoff period can be short due to the large gains. Assuming 2 ton/ac peanuts at $400/ton, a 10% increase in yield recovery would amount to an additional 0.2 tons/ac, or $80/ac.

Digging Angle (digging depth)

Digging angle is controlled by top link extension length. Retracting the top link results in a more aggressive angle, causing the blades to run deeper; extending the top link results in a less aggressive angle, causing the blades to run shallower. To complicate this, soil friability will also have an effect on blade depth. Soil friability defines the ease in which digger blades and pods can be moved through the soil; generally heavier soils or less sandy textures have lower friability and lighter soils or more sandy textures have higher friability. Soil moisture and organic matter content can also impact friability. Generally, friability increases with increasing soil moisture and/or organic matter content. While increasing soil moisture content generally results in improved friability and therefore reduced digging losses, in soils with sufficient clay content there is a point where further increasing moisture content can make the soil sticky, which will cause it to adhere to the digger blades and to the pods, increasing digging losses.

If the digging angle is set properly for the least friable soil in a field, then it will likely be too aggressive and therefore too deep in the most friable soil. The effect of soil texture on blade depth as a function of digging angle is most pronounced in dry soil conditions, where the soil is less friable. Proper depth adjustment results in blades cutting the taproot about an inch below the pods. The digger blade experiences less resistance in more friable soils, allowing it to move to a greater depth at a given top link adjustment than the depth to which it would travel in a less friable soil. Conversely, less friable soils provide greater resistance to blade travel than more friable soils, which causes the blade to travel to a shallower depth for a given top link position.

If the top link is too short, the peanuts will be dug too deep and excessive soil builds up on blades causing losses by pushing the plants forward before the taproot is severed. In extremely too deep cases, the taproot is not sheared and plants are ripped from the ground. Further losses occur as pods ride over soil mounded on the blades. If the top link is too long, the peanuts will be dug too shallow, shearing some pods and leaving others in the soil. So, if the top link is properly set up for a medium texture soil, relative to the range present in a given field, movement into a lighter or more friable soil will result in excessive blade depth and movement into a heavier or less friable soil will result in inadequate depth, both of which conditions will contribute to greater harvest losses.

Conveyor Speed

Amadas and KMC operator's manuals suggest that the conveyor speed should be matched to your forward travel speed. It is generally assumed that conveyors traveling too fast tend to prematurely rip the vines from the soil, which increases pod losses. It is also assumed that conveyors traveling too slowly tend to cause the vines to bunch up at the bottom of the conveyor, causing excessive agitation of the vines and therefore increased pod losses. A 2016 Clemson study demonstrated similar results for Amadas and KMC diggers, suggesting that digging losses for 80-110% conveyor speed (as percent of travel speed) were similar, whereas digging losses increased by 100-200 lb/ac when conveyor speed was equal to 120% of travel speed. The results support the manufacturers' recommendations of matching conveyor speed to ground speed, although more testing across a range of soil textures, soil moistures, and peanut varieties must be conducted for confidence.

A simple way to set the conveyor speed is to adjust it until the inverted windrow falls slightly (about 2 ft) down-field from where the plants were growing. This can be assessed by placing a flag outside of the digger path at the beginning of a row and observing the location of the end of the windrow relative to the flag. This only works well if the digger is engaged at full operating speed prior to entering into the peanuts. If the end of the windrow is several feet farther into the field than the flag, then the conveyor speed is too slow. If the end of the windrow is equal in position to or behind the flag, then the conveyor is too fast. Many current models of Amadas diggers provide an interface with a digital readout of the conveyor speed in mph, so that hydraulic flow rate can be easily adjusted to match conveyor speed to travel speed.

A more accurate method of matching conveyor speed to ground speed can be conducted through simple calculation and setup:

- First, the total length of the conveyor must be determined, which is simply equal to the rod spacing on the conveyor multiplied by the total number of rods. After determining conveyor length, convert it to units of feet.
- Next, the operating ground speed should be converted to units of ft/min, which can be done by multiplying ground speed in mph by 88 (a factor that is derived from 5280 [ft/mi] divided by 60 [min/hr]).
- The conveyor speed required (total conveyor revolutions per minute, or rpm), to match ground speed, is equal to the ground speed [ft/min] divided by the conveyor length [ft].
- From the conveyor speed [rpm], the conveyor cycle time can be calculated as 60 [sec/min]

divided by the conveyor speed [rpm]. This value represents the number of seconds required for one full revolution of the conveyor. For accuracy, it may be convenient to multiply this value by 10, to determine the number of seconds required for 10 full revolutions of the conveyor.

- Once required conveyor cycle time is determined, setting the conveyor speed is simple. Place a flag of masking tape or other convenient marker on one of the conveyor rods. With the tractor rpm set for normal operating speed, the tractor in park, the digger lifted, and all personnel clear of moving parts, engage the conveyor and use a stopwatch to observe the time to make 10 full revolutions. If this time is less than what was calculated in the previous step, then the conveyor is too fast; if this time is greater than what was calculated in the previous step, then the conveyor is too slow. Adjustment on a pto conveyor drive requires reduction or increase in pto speed. Adjustment on a hydraulic conveyor drive requires adjustment of hydraulic flow rate to the appropriate circuit.

Ground Speed

Amadas literature suggest "starting speeds" of 2.5 to 3 mph and KMC literature suggests ground speeds of 3 to 3.5 mph. KMC further suggests that digging too fast causes bunching and that digging too slowly pulls vines apart, pulling off pods. The larger pod runner varieties and Virginia type peanuts have more surface area per pod and therefore higher drag forces, so they are more likely to be ripped from the peg resulting in losses. Because of this, it is reasonable to assume that lower speeds should be used for these large pod peanuts, as compared to those used for small to medium size runner, spanish, and valencia types. A study conducted at the Edisto Research and Education Center in Blackville, SC tested ground speeds of 2, 3, 4, and 5 mph on Amadas and KMC 2-row diggers. Conveyor speed for these tests was set to match ground speed. The results showed that 2-3 mph is the statistically the best speed range to reducing yield losses. Speeds above 3 mph showed statistically higher yield losses for both the KMC and Amadas diggers tested. In both test with the diggers showed an average ~250 lbs/ac higher yield loss when increasing speeds from 3 to 4 mph. At today's prices of about $400/ton that would equal almost $50/ac saving for slowing down.

In ideal situations, digging ground speeds should be economically optimized. Further testing is required to substantiate, but it is expected that optimum digging speeds will vary as a function of conditions. Theoretically, economically optimum digging speed should: decrease with increasing pod size, increase with increasing sand content, increase with increasing organic matter, and decrease with decreasing soil moisture content. However, weather conditions at harvest and required timeliness of digging with respect to other farming operations must also be considered, which make generalizations about economically optimum digging speeds challenging to make.

Inspect the digger-inverter for broken, bent or missing parts before making adjustments. Many adjustments can be performed before actual field work starts. First, make sure the front tool bar is level with the tractor by standing at the rear of the machine with the implement raised and sight the top of the tool bar with the top of the rear axle (For accuracy, first be sure the rear tractor tires are inflated to the same pressure.) If the tool bar is not parallel to the tractor axle, level the digger by adjusting the lift arms.

Next, **inspect the blades**. A well-adjusted digger will have sharp, flat-running blades set to clip taproots just below the pod zone where the taproot starts branching. Blades should run level, with a slight forward pitch to lift plants into the shaker. This adjustment can be accomplished best on a flat surface. Excessive pitch of the digger blades may result in soil and pods being carried forward by the blade before being freed by the cutting edge. Such pods are usually lost. Dull blades cause most digging losses because they fail to cleanly cut the taproot and may drag roots or pods, dislodging the pods from the plant.

After plants pass over the digger blades, they are transferred onto the shaking conveyer. **Check the conveyer chain speed and depth**. The chain speed should be slightly faster than the forward speed of the digger-inverter to avoid pod loss as the plant moves from the digger blade to the shaking mechanism. This speed will avoid a pileup of vines ahead of the pickup point and allow a smooth flow of vines through the digger-inverter. The shaking conveyer should be set at a depth at which it picks up vines with its teeth just clearing the soil.

In the field, **notice the shaking action**. It should be enough to remove soil from the vines. More aggressive shaking is needed where soil clings to pods, roots and stems. The amount of shaking can be changed by adjusting knocker wheels up or down.

As vines exit the shaking conveyer, they engage the inversion wheels and rods. These rods are factory set; however, they will change position with use. **Adjust the inversion rods before going to the field** by placing the digger on a level surface and setting them according to the operator's manual. Properly inverted peanut plants will form a uniform, fluffy, well-aerated windrow with very few peanut pods touching the soil.

How to Estimate Digging Losses

If you suspect problems with your digger setup or if you want to compare one mode of operation to another, you may want to take the time to estimate your digging losses. Digging losses are challenging to quantify because they must be distinguished from combining losses and because some of the lost pods are located below-ground. The best way to effectively measure pod losses is to count or weigh pod losses within a particular sample area. Sampling should be conducted after digging but prior to combining. A standard sample grid should be constructed, such as a small PVC pipe frame. A manageable frame size would be one or two rows wide by one foot long. Multiple samples should be collected from different areas to build confidence in the estimate, as digging losses can be highly variable. Sampling requires carefully moving a section of windrow to the side, placing the frame on the ground, and collecting all above- and below-ground losses found within the frame area. Digging losses will generally be greatest in the least sandy (heaviest) soils and lowest in the sandiest (lightest) soils, so it may be desirable to take samples from different areas of the field, although the most economically important areas to assess are generally the heavier soils.

NOTE: Digging losses reported in all of the above tests reflect what we refer to as mechanical digging losses; over-mature and diseased pods are not included in the counts. If you are comparing modes of operation of the digger, over-mature and diseased pods should be ignored, as they are generally not attributable to digger setup and operation.

A general estimate of losses is provided in the Clemson University Peanut Money-Maker Production Guide, stating that each pod lost per row foot is equivalent to 40 lb/ac in runner type and 60 lb/ac in virginia type peanuts. A more accurate estimate of dry weight collected from the sampling area can be calculated by multiplying the dry weight per pod by the number of pods for that area collected.

Combining or Threshing Peanuts

All peanuts produced commercially in Georgia are harvested directly from the windrow with a combine. The peanut combine removes peanut pods from the vines, separates pods from vines and other material, and delivers pods to an overhead basket. When the windrowed peanuts have reached a moisture content of 16 to 20 percent, which usually occurs two or three days after digging, they can be combined with minimum mechanical damage. There is less mechanical damage and header losses when the plant has partially dried than when it is very green or very dry. Most peanut growers prefer this time for combining when all quality and cost factors are considered.

An improperly set combine can result in reduced peanut yield and a product with excessive pod damage, loose-shelled kernels (LSK) and foreign material (FM).

Combine Functions

Basic combine operations include:
Picking up vines from the windrow by a header and conveying them to the threshing mechanism,
Threshing (removing peanut pods from the vines),
Separating pods from vines and other material,
Detaching the stems from the pods, and Conveying the pods to a storage basket.

There are two types of peanut combines: a conventional and an axial flow or rotary combine that differ primarily in the threshing mechanism used to separate the peanut pod from the vines. Basic working parts of a conventional peanut combine are shown in Figure 2. Although each of the basic operations will be covered in detail later, you first need to understand the entire sequence of operations.

How a Combine Works

The combine places the windrow into the feeder auger using a pickup head. The feeder auger delivers the material into the threshing mechanism. In a conventional combine, the threshing mechanism consists of picking cylinders that operate over concaves. Stripper bars slow the movement of vines. In a rotary combine, the threshing mechanism consists of an auger that transports through an expanded metal housing. The peanut pods extend through the openings in the expanded metal and are pulled off as the auger transport the vine material toward the rear of the machine.

Most of the peanut pods and small vine material fall onto the shaker pan. The material that doesn't fall through is transferred rearward, either by straw walkers or some type of agitation device, where further separation takes place. The material that has fallen on the shaker pan is conveyed rearward onto an oscillating chaffer and sieve or other type of separation device. Openings in the chaffer or other mechanism allow the peanuts to fall through but retain the trash. As the material moves rearward, an air blast directed upward through the sieves helps separate pods from small vine material and other foreign material.

The peanut pods fall onto stemmer saws that remove the stems. Finally, the air delivery system conveys the pods to a storage basket. In the rotary combine, bucket elevators transport the peanut pods into the storage basket.

Windrow Pickup, Conveying and Feeding Checkpoints

The pickup head consists of a cylinder-type unit with spring teeth on cam-controlled bars. Combine manufacturers use many different arrangements to move the windrow from the pickup teeth to the threshing mechanism. Most combines have some type of auger, which uniformly feeds the peanut vines into the threshing mechanism. Larger combines move the material laterally before it enters the threshing mechanism. The header height is controlled either by suspension from the tractor or with a hydraulic cylinder.

Check these points in the operation:

1. The pickup head should run from 1 to 3 inches above the ground to avoid excessive wear on the springs and help minimize the amount of dirt entering the combine.
2. The pickup head speed should match the forward speed. This allows the windrow to be lifted into the combine without separating or overrunning the vines, which pulls pods from plants before they enter the combine.

Threshing: How it Works, Adjustments to Make

Threshing is done by moving the peanut vines through a cylinder or a series of cylinders operated over concaves. Stripper bars can be engaged to different degrees to slow the movement of the vines through the combine. Once the vines and pods are inside the combine, they should be separated using the slowest possible threshing cylinder speed and stripper bar engagement. The idea is to have the least aggressive threshing that gives good separation of the peanut pods and vines. This will help prevent LSKs and pod damage. As windrow conditions change during the day, the threshing aggressiveness should be adjusted.

These adjustments will help eliminate LSKs:

1. Start with the manufacturer's recommended cylinder speeds. Depending on the make of the combine, the cylinder speed may be changed by adjusting a variable speed pulley or changing the cylinder drive sprocket.
2. Adjust the stripper bars for the least aggressive action that gives separation without excessive kernel bruising and hull breaking. Mechanical damage from fast-moving parts may leave peanuts susceptible to insect damage and undesirable molds.
3. Always use the lowest combine cylinder speed that gives good separation of pods from vines. This will keep mechanical damage to the lowest possible level (Table 1).

Separation: Keeping the Peanuts, Discarding the Trash

Most of the peanut pods and some small vine material fall through the concaves onto an oscillating shaker pan. The pan conveys the pods and other material to the rear of the machine for further cleaning. The remaining pods are transferred rear- ward, either by straw walkers or by

Table 1. Effect of combine cylinder speed on hull damage, LSKs and germination.

Cylinder Speed	% Hull Damage	% LSK	% Germination
Slow	17.1	2.6	80
Medium	24.6	3.3	70
Fast	33.4	5.4	68

Table 2. Recommended chaffer and sieve openings for initial combine start-up.			
	Spanish	**Runner**	**Virginia**
Chaffer	5/8”	3/4 - 7/8”	1 - 1 1/8”
Sieve	1/2”	5/8 - 3/4”	3/4 - 7/8”

some type of agitation device, where further separation takes place. The heavier peanuts fall through grates onto the shaker pan.
The material on the shaker pan is conveyed onto an oscillating chaffer and sieve or some other type of separation device (for example, a group of revolving disks). Air is blown upward through the separation device, which causes fine foreign material to be airborne until it is discharged from the rear of the combine.

The amount of cleaning air is adjustable, which allows for good separation as the moisture content of pods and other materials varies. Too much air will cause good peanuts to be discharged. Too little air will result in excess foreign material deposited in the bin. Slippage of the fan drive belt also influences the volume of air. This occurs when belts are loose or in poor condition.

Chaffer and sieve openings also influence the amount of separation, and should be adjusted according to the size and variety of peanuts. Although vine and field conditions influence final settings, Table 2 provides recommendations for initial start-up.

Conveying: The Final Step
After the peanuts are separated from vines and other materials, they fall onto a set of stemmer saws. The saws remove the stems from the pods and dispose of vine fragments. The pods are conveyed to one side of the combine and enter an air stream that moves them into the overhead storage basket.

The amount of air required to carry the pods upward varies with peanut yields. Adjust the amount to get the smallest airflow possible without the airlift duct clogging. Too much air damages the pods, which may crack and result in LSKs.

When the basket is filled, the peanuts must be emptied into a cart or directly into a conveyance for transport to the buying point or on farm drying facility. Some combines use on-the-go offloading by conveyor. Make sure the conveyor is in good working order including hydraulic cylinders to extend the belt, roller bearings, and belting.

Make sure the both the dump cart and drying wagon/trailer are clean before offloading peanuts from the combine. Dirt and other crop residues in wagons are one source of foreign material that can be eliminated easily before harvest.

The dump carts and combines have mechanisms to divert the dirt that has sifted through peanuts from going into the trailer when dumping. When loading, the trailer, make sure that the operator is the proper distance from the side of the trailer so that the dirt is emptied beside the trailer and not into the trailer. Operators should load the trailers evenly from back to front to facilitate load stability during transport and uniform drying.

Do not overload trailers. Maximum allowable GROSS Vehicle Weight (GVW) on semi –trailers is 80,000 lb. Semi-drying trailers are designed to hold 2200 cu. ft. either by utilizing a maximum fill line or by limiting sidewall height. A properly filled semi-drying trailer will hold about 40,000 lbs of clean peanuts at 7% moisture content. A semi-drying trailer loaded to capacity with clean peanuts at 20% moisture content will hold approximately 51,000 lbs with a GVW of approximately 91,000 lbs. An accident involving and overloaded trailer increases the liability risk to the grower, truck driver, and the peanut buying point. Be aware that semi-drying trailers tend to be top heavy compared to similarly filled conventional over-the-road vans. The weight capacity of 14, 21, and 28 foot dryings trailers are 4, 7, and 10 tons, respectively.

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