# COTTON PHYSIOLOGY TODAY

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## EARLY SEASON GROWTH

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*A casual observer of an early season cotton field might not imagine that the field could survive much less flourish in a few months. Day after day goes by with barely perceptible growth. Sometimes the plants appear to be shrinking back into the earth. In contrast, growers recognize this as a hesitation stage which the crop must pass through before it gets down to business. This newsletter will consider the causes of this lag phase, what impact it has on later growth and development and review some management options that can benefit the early season crop.*

The period from planting to early square can be frustrating to cotton farmers. The cotton appears unresponsive to our best management efforts at this time. Even applying the full complement of recommended practices including seed bed preparation and crop protection materials may achieve only mediocre success. Stand establishment, the time of greatest uncertainty, was covered in the last newsletter (Cotton Stand Establishment, Vol. 6, No. 2, February-March 1995). Unfortunately, once established, the crop may display only marginal improvements for several more weeks to come. Meanwhile — while cotton flounders — a whole host of pests thrives.

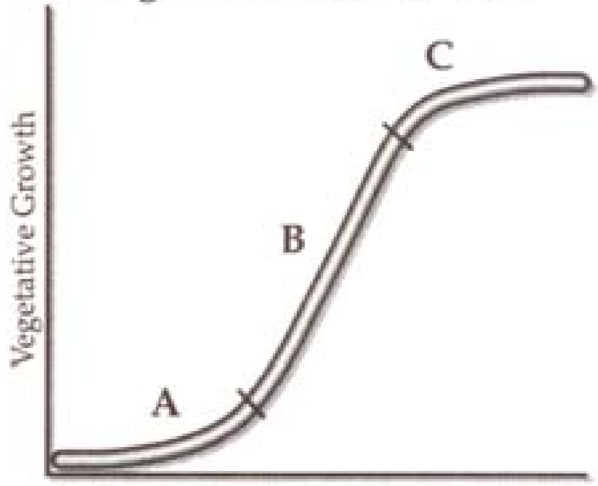
Until cotton outgrows this stage, all manner of preventative and remedial actions are considered. Producers may resort to applying materials that have not been adequately evaluated. If the application coincides with the arrival of favorable environmental conditions, the crop responds. Squares become visible, the growth rate accelerates and the past fades — at least until next year. Did the treatment make the difference or was it the weather or a combination of the two? In order to effectively manage cotton prior to squaring, it is important to understand the cause of the growth delay and what, if any, long term affects may linger to hobble future prospects.

### Early Season Developmental Priorities

The time from emergence to pinhead square is the least complicated growth stage in cotton's development. Squares that have initiated in the plant's terminal are minute, with minimal demands for nutrients or water. In time, they become dominant sinks for carbohydrates, mineral nutrients and water. But for now, their influence on vegetative growth and development is minor.

Cotton vegetative growth follows what is described as an S-shaped curve. (Figure 1). The recently emerged seedlings begin to grow quite slowly as illustrated by the initial lag phase (A). In time a perceptible acceleration in growth recognized by cotton growers at about match-head square is evident (B). Once boll loading begins and the plant's carbohydrate production and nutrient supplies are increasingly diverted to the bolls, the vegetative growth flattens as illustrated (C). Prior to reaching this plateau, the plant's resources can be devoted almost exclusively to developing leaf area and root mass. Later these vegetative structures will supply the plant with resources to mature seed and develop secondary (woody) growth capable of surviving into a new growth cycle.

**Vegetative Growth Curve**




### Causes of the Lag Phase — Limited Leaf Area

The focus of this newsletter is on the initial lag phase (A). One fundamental cause of the early season lag phase can be traced back to the young plant's limited leaf area. Solar radiation is the ultimate energy source that drives cotton growth and development. Sunlight that reaches the ground is photosynthetically lost to the plant. Additionally, only a narrow band of this radiation — referred to as photosynthetically active radiation — is harvested by the plant to produce sugars. Leaf area index (LAI) is one convenient measure used by researchers to describe the ability of a plant to intercept radiant energy. The LAI is defined as the total area of leaves in a crop divided by the land area. For example, a LAI = 2 means that one acre of land (43,560 $ft^2$) is covered by 43,560 X 2 = 87,120 square feet of leaves.

A cotton crop is able to intercept all incident solar radiation when the LAI reaches

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about 3. At peak bloom the LAI may exceed 5. In contrast, young cotton LAI ranges from less than 0.01 at emergence to perhaps as much as 1 at pinhead square. This means that a very small proportion of the total available radiation is used by the plant to make the raw materials needed for leaf initiation and expansion. Before canopy closure, the ability of the canopy to intercept light is of the utmost importance in determining photosynthesis and hence crop growth. Greater early LAI attainment translates into greater early growth. Once canopy closure is reached, light interception is maximal. With each additional healthy leaf, LAI and the rate of growth increases. It is a question of time and numbers.

## Sub-Optimal Temperatures

The lag phase resulting from limited LAI can be shortened or extended by weather encountered during the early season. Most production regions within the U.S. must resort to planting cotton in sub-optimal temperatures in an effort to capture additional yield by extending the growing season or to mature the crop in advance of heavy insect pressure and/or unfavorable weather. Cotton, a tropical and subtropical native, grows most rapidly at around 90°F. The growth rate is proportionately less at lower temperatures. Heat unit accumulations are a convenient way of expressing this temperature dependence. DD60 heat units are defined as:

$$\frac{\text{Daytime High°F} + \text{Nighttime Low°F}}{2} - 60 = \text{DD60s}$$

You can approximate the rate of node or leaf formation if you track the daily highs and lows. Up to bloom under non-stressed conditions, a new node is produced with each 50 DD60 accumulation. Over 20 DD60s accumulate per day when the highs and lows reach 90°/70°, temperatures routinely met and surpassed in many production areas from June through August. In contrast, fewer DD60s (5-10/day) accumulate when temperatures are cooler. Prolonged cold weather following a cold front may slow node development to a node every 10-14 days.

The first 2 months of the season can have a dramatic impact on crop maturity and final yield. This influence is most apparent along the northern tier of the Belt where low temperature limits on yield are most pronounced. This is illustrated in the following example. If 200 DD60s (~7/day) are normally accumulated in May, and you planted on May 1, then at the end of the month you estimate the plants would have about 3 true leaves (or 50 DD60s until emergence plus 3 X 50 = 200 DD60s). If instead 300 accumulates (~10/day), the plant has an additional 2 true leaves and can be expected to reach early bloom about 5-7 days earlier. However, if May was cooler than normal, the resulting delay could have a catastrophic impact on yield.

## Early Season Root Growth

Initially, root growth is more rapid than top growth. The young tap root (radical) may extend 6" or more into the soil by the time the first true leaf is visible. Soon thereafter, the roots begin developing an extensive system of lateral branches. The early predominance of root growth could certainly have some adaptive value by allowing the young root system to explore a large soil volume for water and nutrients.

This adaptation may be an outgrowth of cotton's genetic heritage. Upland cotton and most of its relatives are native to arid regions or areas that have pronounced wet and dry cycles. This places a high biological priority on securing an adequate water supply before the onset of drought. Research data supports this view. Although root and shoot elongation is greatest at about 90°F, when soil moisture was reduced, top growth declined by 90% while root growth was reduced by less than 30%.

## Temperature and Oxygen Effects on Roots

Early season cotton root growth is equally important in commercial production. Once boll loading begins, the root systems' exploration of new soil has dropped dramatically. Additionally, older roots die and are not replaced as rapidly which serves to decrease the total root absorption potential. In other words, the best opportunity to develop a large and healthy root system is limited to the early season.

There are several environmental factors that can hinder root growth. Reduced soil moisture was already mentioned. Low temperatures, whose impact on top growth was previously mentioned, also can hamper root growth. As temperatures decline, root growth is reduced and fewer lateral roots are formed. As a consequence of this reduced growth, water and nutrient uptake also declines. As mentioned in the last newsletter, adequate oxygen levels are crucial to root growth. If soil oxygen is limited, the root tips cannot produce the cellular products required to support the root expansion.

The atmosphere contains about 20% oxygen and less than 0.1% carbon dioxide. The relative proportions differ in the soil air where the oxygen levels decline and carbon dioxide may increase to 5%. Cotton roots can absorb oxygen directly from the soil air. When the soil moisture is at or below field capacity, oxygen can occupy soil pore spaces. But if the soil is waterlogged, soil pores are filled with water which prevents the diffusion of atmosphere oxygen and limits the concentration available to the root. To illustrate the importance of oxygen to the roots, consider this, **waterlogged soils may contain less than 2% oxygen and the tap root may die after a short exposure to zero oxygen levels.**

## Pests and Environmental Stress

Damage due to pests and other stresses is magnified by environmental stress. One example is observed when thrips feed on cotton during cool weather. The primary feeding site is the young terminal, which during warm (80°/60°) temperatures produces a new node in about 5 days. If DD60s decline to ≤ 5/day, the same leaf primordia is subject to thrips injury for at least twice the length of time. Weed pressure may also be greater during a cool spring. Weeds adapted to more temperate climatic zones are less impacted by the cooler temperatures and therefore more competitive. Cotton damage from diseases is also more prevalent following any stresses that delay growth such as low temperatures and saturated soils. As a final example, plant protection products normally considered benign can cause phytotoxicity if root growth into unaffected areas is delayed. This damage may become pronounced if cool, wet conditions are replaced by hot, sunny weather. The stunted root system may absorb abnormal amounts of the applied materials which then concentrate in the reduced leaf area. A field can be lost when a combination of these individually sub-lethal stresses overwhelm the young, compromised plants.

## Long Term Affects of Lag

The last section detailed some of the dominant factors that are responsible for the lag phase in growth and help determine its duration. Before discussing some management strategies that might be employed to shorten the duration or severity of the lag phase, it is worth considering what are some recorded long-term consequences of stress encountered during the early season lag phase.

It should be mentioned at the outset that measuring the effect of short-term stress on season long performance is difficult. There are so many intervening events that can mask, modify or magnify the earlier stresses. For example if an early season stress delays development until a period that inadvertently coincides more closely with favorable growing conditions, one might erroneously conclude that the delay was beneficial. It is dangerous to draw conclusions regarding cause and effect.

However, there are several studies that have attempted to assess recoverability of cotton following simulated stress. Research conducted in several regions across the Belt have evaluated the effect of early season leaf injury on subsequent crop performance and yield. The data indicates that the primary impact of this injury is on crop earliness. Yield is unaffected if adequate season remains to fill bolls after the LAI is re-established. But delayed maturity may translate into lost yield if planting along the northern tier of the Cotton Belt or in a late replant situation. Additionally, delayed maturity often increases insecticide and harvest aid costs and decreases cotton quality.

## Early Season Management Options

**Aerate the Soil:** The central management theme for the early season should be to create a favorable environment for crop growth. The potential damage that can arise from low soil oxygen levels was outlined earlier. In conventional (clean tillage) systems, producers confronted with saturated soil conditions can enhance soil aeration with a shallow cultivation that breaks any soil crust and speeds surface drying. The observed spurt in growth following an early season cultivation that breaks the crust can be attributed partially to improved soil oxygen levels. This may not be an available option in conservation tillage systems. Fortunately, plant residue on the soil surface helps prevent crusting. Root channels and higher organic matter from prior crops also can improve soil oxygen levels.

**Soil Temperature Modification:** Soil temperatures can be raised by conducting some practices and avoiding others. A dry soil warms faster than a wet soil. Shallow cultivators also help to warm the soil by speeding the drying process. Conversely, early season irrigation that could significantly lower soil temperatures below optimal levels should be approached with caution.

**Seedling Protection:** Sand blasting damage to young seedlings occurs across the Cotton Belt each year, especially in large open fields without wind breaks. Early season cultivation can be used to roughen the soil to reduce sand blowing and provide some protection of young seedlings.

**Maintain Effective Leaf Area**: Timely crop development is dependent on maintaining an effective leaf area. Pests such as thrips that can severely reduce leaf area must be controlled to avoid developmental delays. Many producers apply in-furrow systemic insecticide at planting to control early season thrips. However, poor soil moisture or a damaged cotton root system can limit uptake. Producers should be monitoring the crop closely at this point, before damage is noticed from the seat of the pickup. Crop protection chemicals should be chosen and applied according to the pest detected. Crop protection chemicals should be chosen and applied carefully to avoid phototoxicity. If salvage over-the-top herbicide treatments are required, crop damage can be minimized if environmental conditions are otherwise favorable for cotton growth. Try to time potentially damaging treatments to coincide with warm periods when soil moisture is adequate and roots are actively growing.

**Control Competitors:** Pest damage during this period can have season-long consequences. Thrips damage already has been outlined. Cutworms can take out a stand of cotton quickly. Weeds can outpace the crop, robbing the young plants of needed sunlight, moisture and possibly nutrients. Without rapid intervention, salvage remedies may be required that have undesirable crop effects such as leaf or root damage. The near-term availability of new herbicide chemistry and herbicide resistant varieties promises to widen producers' options. Disease pressure can be avoided or minimized with preventative in-furrow, hopper-box or seed treatments. Once disease symptoms are observed, producers must rely on cultural practices that enhance growth such as shallow tillage and avoid additional stress from other pests.

**Foliar Fertilization:** Producers with damaged stands may be persuaded to apply foliar fertilizers to augment inadequate root uptake. Similarly, it is argued that even healthy plants can be stimulated by foliar treatments. It is reasonable to conclude that injured roots are less capable of supporting top growth. However, attempts to verify this speculation have not proved successful. In fact, several published field studies do not support the practice of early-season foliar fertilization to injured or healthy young cotton plants. While it has been noted that some foliar treatments can produce a deeper green color, this benefit does not translate into recorded yield or maturity enhancements. Cotton's lack of response to these applications most likely can be traced back to cotton's low need for nutrients at this growth stage. As mentioned earlier, there are more dominant factors that limit early season growth. Fertilizer can not substitute for needed heat units, oxygen or moisture.

**Plant Growth Stimulants:** Several plant growth regulators have been promoted as early season stimulants of top or root growth. More research must be conducted to validate the publicized benefits of these treatments. The experimental results to date are mixed. Producers who choose to employ these materials are strongly encouraged to conduct a controlled trial on a limited basis. In other words, in a few select fields treat half the field with the product, leave the other half untreated.

## Wrap Up

Patience and a sound nuts-and-bolts management approach are required during the early weeks following emergence. Temperatures may be sub-optimal while moisture is excessive. Meaningful management approaches that can benefit the crop are limited. After these recognized practices are applied diligently, it's time to wait for the arrival of environmental conditions that the crop is adapted to. Heroic efforts using unproven technology can be costly, particularly if it keeps you away from the proven basics.

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