Science Societies

Optimizing cotton stand establishment

Seed size, temperature stress, and the role of leaf area

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Tractor planting cotton seeds (left) and resulting cotton rows in the field (right), showing some gaps with poor stand establishment. Photos by C.O. Adegbenro.

Getting cotton off to a strong start is critical, yet early-season temperature swings and seedling stress often threaten stand establishment. This article explores how seed size, temperature extremes, and leaf area development interact to shape early vigor—and ultimately influence yield potential. Learn how smarter cultivar selection and planting decisions can help improve stand uniformity and reduce risk in challenging conditions. Earn 0.5 CEUs in Crop Management by reading the article and taking the quiz.

Establishing a strong, uniform cotton stand is the very foundation of this crop's productivity. Cotton is known to have poor stand establishment and less vigorous seedling growth compared with other cultivated row crops (Pilon et al., 2016; Snider et al., 2016). Hence, having vigorous seedlings in the early weeks after planting is important as it sets the tone for the season, influencing how well plants compete with weeds, withstand pest and pathogen pressure, and capture sunlight during peak radiation periods (Cook et al., 2011; Virk et al., 2019).

However, cotton producers across the U.S. Cotton Belt face a common challenge: unpredictable swings in early-season temperatures. For instance, early cotton planting potentially offers the promise of higher yields (Pettigrew, 2002) and greater flexibility in crop management. However, this period increases the exposure of cotton plants to cold spells, resulting in low-temperature stress (Singh et al., 2018). Heat waves can also pose a significant threat to cotton seedlings in some regions (Virk et al., 2021). As a result, temperatures below or above the optimum mean (Bradow & Bauer, 2010) may cause a loss of stands, uneven growth, and seedlings with poor vigor (Virk et al., 2021), which can lead to reduced yield potential.

Helping farmers navigate these conditions involves understanding how planting decisions, such as cultivar selection, and environmental factors interact during early-season growth. Recent research has shed new light on how seed size and temperature extremes interact to influence cotton seedling vigor (Adegbenro et al., 2025). These insights help explain why some cultivars may have better stand establishment and why timing and planting conditions are so critical. Armed with this knowledge, advisers can make more targeted recommendations, thereby improving stand uniformity and yield potential in cotton production.

This article highlights three core points: how seed size affects seedling performance across a range of temperatures, how temperature extremes (heat and cold stress) influence early growth, and how leaf area development is a critical driver of seedling vigor.

Seed size and early seedling growth

Seed size may not be the first trait cotton growers consider when selecting a cultivar, but its influence on early growth, emergence, and vigor is both measurable and consistent (Kaydan & Yagmur, 2008; Snider et al., 2020). Cotton seeds with similar yield potential (Hand et al., 2023) vary considerably in mass depending on cultivar, with a range from approximately 70 to 140 milligrams per seed recently reported (Table 1). This difference translates into real variation in the reserves of oil and protein available to fuel early growth before photosynthesis takes over. Larger seeds often carry greater energy reserves, which support seedling emergence and initial development before the plant becomes fully photosynthetically independent (Snider et al., 2020).

This advantage is most visible in the first few weeks after planting, when seedlings face the dual challenge of establishing roots and expanding their first leaves. Additionally, larger seeds not only contain more oil and protein, but also produce cotyledons with greater surface area, enabling higher rates of photosynthesis per seedling.

Table 1. Mean seed mass and composition for cotton cultivars (Source: Adegbenro et al., 2025).

Cultivar	Seed weight (mg/seed)	Protein (%)	Oil (%)	Protein (mg/seed)	Oil (mg/seed)	Oil + protein (kcal/seed)
DP 2038	70	19.99	17.05	14.00	11.93	0.19
DG 3799	137	24.65	23.17	33.77	31.74	0.49

Adegbenro et al. (2025) showed that seedlings with larger seeds consistently produced taller seedlings and had greater seedling dry weight and leaf area than those with smaller seeds. On average, large-seeded cultivars accumulated nearly 20% more biomass and developed roughly 8% more leaf area under a wide range of growth temperatures than small-seeded cultivars (Adegbenro et al., 2025). These findings, which are supported by another similar study (Raphael et al., 2017), suggest that large-seeded cultivars have an early-season growth advantage, providing support for seedlings to withstand stresses from fluctuating growth temperatures.

From a management perspective, seed size is an often-overlooked, yet important, trait in variety selection. While yield potential and fiber quality often dominate decision-making, considering seed size may help improve stand establishment and seedling vigor during early-season growth, thereby reducing or eliminating the costs associated with replanting.

Temperature effects on seedling growth

While larger seed size may provide seedlings with a vigorous head start, temperature is the dominant factor that ultimately determines early growth.

Although the base temperature for cotton is 60°F, a day/night temperature of around 68/59°F was shown to impose substantial limitations on vegetative growth in cotton (Figure 1) (Adegbenro et al., 2025) Under these conditions, seedling biomass and leaf area declined by more than 90% compared to plants grown under optimal (86/68°F) regimes (Adegbenro et al., 2025). The physiological explanation for growth reductions lies in the slowing of metabolic processes (Bange and Milroy, 2004; Reddy et al., 2017).

This reinforces the importance of the time of planting. Waiting until soil temperature is consistently above 65°F, and ensuring a forecast of at least 50-80 degree-days (base temperature of 60°F) over the five days following planting (Bayer-CropScience, 2019), greatly improves the chances of rapid and uniform emergence. Cold stress not only reduces stand counts but can also delay canopy closure in the long run, leaving fields more vulnerable to weeds and pests.

Low Temperature **Optimum Temperature**

Figure 1. *Cotton seedlings grown under low (68/59°F) and optimum (86/68°F) day/night temperature conditions. Seedlings under low temperature show slower growth and smaller leaf area compared with those grown under optimum temperature. Photos by C.O. Adegbenro*

On the opposite extreme, heat stress also constrains seedling growth (Figure 2). When day/night temperatures reached 104/86°F, seedlings exhibited reductions in biomass and leaf area of up to ~50%. Observable increases in the number of nodes, indicating accelerated development, were offset by smaller individual leaves and less biomass at higher temperatures, compared with optimal temperature regime (Adegbenro et al., 2025).

High Temperature **Optimum Temperature**

Figure 2. *Cotton seedlings grown under high (104/86 °F) and optimum (86/68 °F) temperature conditions. High-temperature seedlings show reduced leaf expansion compared to those at the optimum temperature. Photos by C.O. Adegbenro.*

Nevertheless, the overall trend was clear: While cotton tolerates warmth better than many crops, there is a threshold beyond which higher temperatures reduce growth rather than stimulate it. Ultimately, larger-seeded cultivars maintained higher growth than small-seeded cultivars, irrespective of the temperature regime; hence, they may be more suitable for planting scenarios where soil temperatures are higher than ideal or where temperature fluctuations are common.

Leaf area development: The critical driver

While both seed size and temperature clearly shape seedling performance, a key result revealed that among all the traits measured, leaf area development is the most important driver of early vigor under a wide range of temperatures (Adegbenro et al., 2025). This follows logically as larger leaves may capture more sunlight, drive higher rates of photosynthesis, and support faster accumulation of biomass (Liu et al., 2015; Virk et al., 2019). Early in the season, rapid leaf development enables seedlings to intercept light efficiently and transition more quickly from reliance on seed reserves and the cotyledons to independence through photosynthesis by true leaves. This demonstrates the mechanism behind the effects of early-season stresses on cotton seedlings, where any factor that limits leaf expansion, whether it is cold stress or excessive heat, could directly translate into reduced growth.

Furthermore, smaller-seeded cultivars have the tendency to delay leaf area development (Adegbenro et al., 2025; Liu et al., 2015). In each case, restricted leaf area translates into reduced vigor and slower canopy formation. In cotton, where early competition with weeds and pests can significantly impact success, slower leaf area development may have ripple effects throughout the season. This suggests that the long-term implications of leaf area development are significant. Faster canopy closure suppresses weeds and improves light interception during the critical fruiting period. In this way, the early advantage of greater leaf area persists throughout the season, potentially influencing the final yield (Wanjura et al., 1969).

Consequently, leaf area growth may also serve as a useful visual indicator of early-season seedling vigor. Shortly after emergence, the extent of leaf expansion could help growers have a quick gauge of seedling vigor and good stand establishment by observing the uniformity and size of leaves. Furthermore, modern technology, such as UAV-based remote sensing, could be more efficient for quantifying leaf expansion rates across large land areas during the early stage of growth (Feng et al., 2020). It should be noted, however, that although limited leaf area growth may indicate suboptimal planting conditions, poor variety selection, or other underlying stressors, this does not always translate to yield loss or dictate final productivity. The cotton plant can overcome early-season growth setbacks without compromising yield if the growing season is sufficiently long to ensure maximum light capture (Lee et al., 2026).

Management considerations

Several interacting factors influence how growers manage early-season stand establishment in cotton. There is no "one-size-fits-all" strategy that guarantees success under all environments as soil temperature, weather conditions, and seedling growth dynamics vary from field to field and season to season. Management decisions should, therefore, be guided by local conditions, cultivar characteristics, and current weather patterns. While environmental stress cannot always be controlled, informed choices regarding variety selection, such as seed size, planting timing, and field monitoring, can significantly reduce the risks of poor stand establishment.

Dig deeper

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1. **Larger seeds often ________, which supports seedling emergence and initial development before the plant becomes fully photosynthetically independent.**

   a. germinate faster due to smaller seed coats

   b. carry greater energy reserves

   c. absorb less water during germination

   d. have lower respiration rates

2. **According to Adegbenro et al. (2025), on average, large-seeded cultivars accumulated nearly ________ more biomass than small-seeded cultivars under a wide range of temperatures.**

   a. 5%

   b. 10%

   c. 20%

   d. 40%

3. **Although the base temperature for cotton is 60°F, a mean daily temperature of 68°F (68/59°F day/night) may impose substantial limitations on vegetative growth in cotton.**

   a. True

   b. False

4. **According to Adegbenro et al. (2025), when day/night temperatures reached ________, seedlings exhibited reductions in biomass and leaf area of up to ~50% when compared with an optimal temperature regime.**

   a. 104/55°F

   b. 95/86°F

   c. 95/55°F

   d. 104/86°F

5. **_________ development is the most important driver of early vigor, under a wide range of temperatures, as identified by Adegbenro et al. (2025).**

a. Root length

b. Leaf area

c. Plant height

d. Cotyledon thickness

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