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Balancing Plant and Crop Performance

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Cotton is capable of producing acceptable yields in a wide range of plant populations. This is fortunate from a historical perspective as cotton stand establishment is never guaranteed at planting. However, with the availability of current technology seedling rate can more closely approximate final stand. With our enhanced capabilities and knowledge base, it is worth questioning whether our accepted plant population guidelines enable us to achieve peak field performance and profitability. This newsletter updates the physiology and management of plant population discussed in an earlier newsletter (see Physiology Today, February 1991).

How Density Affects a Cotton Plant

A cotton plant will sense the proximity of its neighbors and respond by modifying its growth habit. From the plant's perspective, maximum growth and productivity is achieved if competition is kept to a minimum. As a woody perennial, cotton can take advantage of wide plant spacing if given sufficient time. The same process is at work in trees growing in mature forests or open woodlands. A tree growing in the open can develop multiple trunks and many large limbs. That same species in a mature forest will have one leading trunk and a much reduced branching system.

As stand density increases, the total communal demand for sunlight, water and nutrients increases. The relative availability of each of these inputs will help shape the individual response of plants growing in competition with each other. In most cotton-growing regions, competition for available sunlight will drive the initial growth modifications in response to increasing population density. During the vegetative growth phase, a plant growing in a dense stand (>60,000 plants/acre) will tend to grow taller to capture more sunlight. Internodes are elongated to position leaves in regions of higher sunlight intensity.

As plant-to-plant competition increases with continued development, the availability of water to individual plants decreases. At this stage, the soil texture and structure will begin to shape plant response. Medium textured, deeper soils can supply more water per unit volume of soil than clayey or sandy soils. Plants growing in soils with less available water quickly will become drought stressed as plant population increases.

With the arrival of bloom and boll loading, the plant demand for nutrients, water and light increases rapidly. A new dimension of competition is introduced as different portions of a single plant compete for the available inputs. Vegetative terminals must compete with the developing boll load. When this intra-plant competition is compounded by higher plant densities (>60,000 plants/acre), drastic growth modifications result.

These modifications to cotton growth can be monitored in several ways. Three commonly used methods include measurements of plant height, number of nodes and growth rate. Growth rate, a sensitive measure of the plant's recent growth history, can be calculated by comparing the increase in height with the increase in nodes during a given time frame. If growth is rapid, the growth rate might exceed 3 inches per new node. If, on the other hand, growth was slowed by some environmental or biological stress (e.g. high plant population or rapid boll loading), the growth rate might dwindle to 1 inch per new node. This growth measurement is particularly valuable during early and midbloom prior to the cessation of node development.

The growth response of individual plants to increasing density has been followed in several studies. Figure 1 compares the growth of plants growing in high populations (>60,000/acre) with that of plants in lower densities (<40,000/acre). Measurements taken at first square, first bloom and cutout indicate that at first bloom plants in dense stands are slightly taller than those in thinner stands. By cutout, the added plant-to-plant competition in higher density fields reduces height by about 10%. It is interesting that, in higher populations, the development of nodes is depressed throughout the season, suggesting that terminal growth is very sensitive to plant population.

This interaction of terminal growth and internode elongation magnifies variation in the growth rate. At first square, node development has slowed resulting in a marginal increase in growth rate. By first bloom a taller plant has fewer nodes and a corresponding dramatic increase in the growth rate. However,

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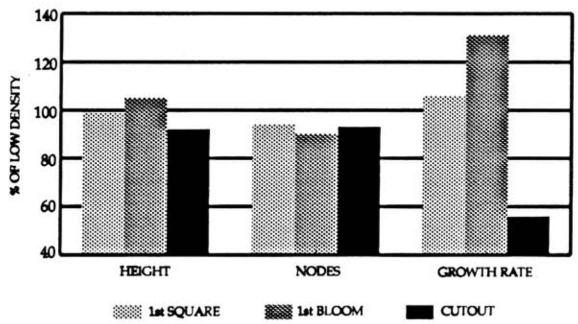
with progressive boll loading, the inability of plants in dense populations to sustain vegetative growth is demonstrated by the severely reduced growth rate.

Figure 1
GROWTH RESPONSE TO DENSITY
HIGH (>60000/A) vs LOW (<40000/A)



BELTWIDE MONITORING PROJECT,1992

The presentation of average trends suggests that the impact of density on growth and development is straightforward. This is an oversimplification. The interplay between the availability of moisture, nutrients, light and temperature create an array of possible responses. Soils with high fertility and moisture availability will tend to produce abundant vegetation. Leaves deep in the canopy may not be sufficiently illuminated to support the development of the earliest bolls. The resulting boll shed stimulates the growth rate, promoting rankness. Boll loading may be delayed until the blooms progress up the stalk into areas with more available sunlight.

On the other hand, plants growing on soils with low fertility and available moisture will have responded to this stress by reducing leaf size, terminal growth and internode elongation. Light can penetrate into the smaller canopy. Initially, boll loading on a small crowded plant will exceed boll loading on a large crowded plant. Instead, the reduced leaf area and fruiting branches of a crowded plant will predispose it to a lower carrying capacity, premature cutout and reduced yield.

Plant density also plays a role in intra- or within-plant competition. In dense stands, the position closest to the main stem (position 1) may account for more than 90% of harvestable bolls. In thinner stands (<40,000/acre), position 1 may contribute less than 60% of the harvestable bolls. This has implications on the overall productivity of fruiting branches. As density increases, positions 2 and beyond are less able to support bolls due to lack of nutrients and sunlight. Their reduced productivity contributes to an overall decrease in the productivity of a given branch.

The ability of individual plants to resume growth and boll loading following drought is reduced in dense stands. Plants growing in dense populations will have a reduced root volume to replenish water lost to evaporation and transpiration. They become more prone to drought stress. Once drought occurs, the progression of flowering up the stalk does not stop, although boll retention decreases. With a reduced number of fruiting branches, the likelihood of a stress-induced cutout is increased.

In summary, dense stands increase between-plant and within-plant competition. The end result of this competition is a plant more susceptible to additional stress and less able to resume growth when the stress is alleviated.

Plant Density Effects on Crop

The preceding discussion has centered on the response of a cotton plant to density. It can be summed up by saying that a single plant has greater opportunities to achieve maximum productivity when given ample room to grow. However, cotton farmers are more concerned with the community of plants in fields and the combined productivity and profitability of the entire farm enterprise. Attempts to maximize the productivity of individual plants must be tempered by these larger considerations.

Harvestable yield is partially determined by the total number of flowers produced during the effective bloom period. Fields with very low densities (below 10,000/acre) may take 7-14 days longer to reach peak bloom than fields with moderate densities (25-40,000/acre). Earliness in low density fields is compromised by the lack of flowers early in the bloom period. These fields will require a longer season of favorable environmental conditions to achieve full yield potential.

Increasing flowering rates can enhance earliness and yield, but only to a point. Fruit production is relatively inexpensive to a cotton plant up to flowering. The real cost occurs once seed and fiber development begins. Therefore, increasing flowering will not be beneficial if it is not coupled with comparable boll loading.

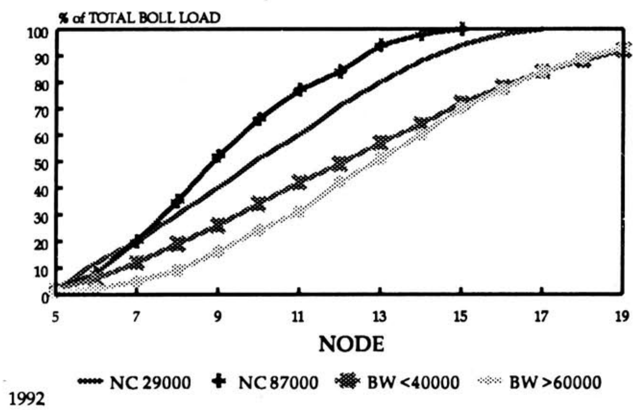
Boll retention has rightfully gained the attention of cotton researchers and producers alike. It is regarded as desirable to increase boll retention. What is not clear is how plant population fits into this equation. Should boll retention at position 2 be considered when establishing desirable retention levels? How does plant density affect the importance of these flowering positions? While these questions are still being actively investigated, it is clear that there is no one boll retention profile that will guide producers in all regions in all situations. Desirable retention benchmarks must be developed for different plant densities. Fruiting branch productivity guidelines also would be useful, particularly in low density population systems.

Boll Loading

Increasing plant density can speed boll loading under certain circumstances. This is illustrated in Figure 2. This graph details the progress of boll loading in two different situations. The North Carolina (NC) data records boll loading in DP50 at two plant densities — 29,000 and 87,000 plants per acre. The higher density set a larger proportion of its fruit at lower nodes that developed earlier. The concentrated boll set enabled the dense population to achieve 95% of the total boll load about 2 nodes or six days earlier than the less dense population.

Figure 2

CUMULATIVE BOLL LOADING



Data compiled from the Beltwide (BW) monitoring project during 1992 does not follow this trend. Unlike the NC location, the higher density BW fields (>60,000/acre) were located on loam and clay loam soils that supported additional vegetative growth. Boll retention on the lowest fruiting branches was reduced to less than 20%. This low productivity at these nodes prevented the plants from capitalizing on a potentially higher early population of flowers and bolls. The earliness factor was lost as productivity trailed that of the lower population until quite late in the bloom period (node 17). The reason for the low productivity may have stemmed from excessive shading, heightened attractiveness to insects or both. The end result was unthrifty plants that matured late.

Early maturity at the cost of yield must be similarly avoided. Premature cutout, particularly on sandy soils, can be another downside risk from high population. If the soil and plant carrying capacity is exceeded by the developing boll load, shed will occur. Once boll loading has begun, additional fruiting branch development is curtailed severely. Dense stands are less able to rebound following environmental stress because the plant's carrying capacity is smaller and node development is retarded. Once the bloom has progressed to within 3 or 4 nodes of the terminal, cutout has arrived.

Balance

Plant density decisions should not be regarded as fixed and unchanging. As planting situations change, these decisions require modification to maximize field and farm productivity. Factors deserving consideration include soil type and fertility, water availability, season length, planting date, row spacing, plant type and management philosophy.

Soil Type and Fertility

Earlier discussion surrounded the issue of a soil's carrying capacity. Soils with high water availability and fertility can support greater mass of vegetation, particularly bolls. As a soil's carrying capacity increases, plant population can rise in an effort to enhance earliness and possibly yield. Sandy soils with lower fertility should have reduced plant density to avoid risk of premature cutout.

Water Availability

Soils with low water availability can still support higher populations if they are irrigated frequently enough to sustain vegetative growth and boll loading. Without reliable water supplies, intermittent drought can induce premature cutout, particularly in dense populations.

Season Length and Planting Date

The interaction between density and boll loading can be complex. However, as a general rule, plant population should increase as season length decreases. With a shorter season, the time available to develop a complete boll load is shorter. Additional plants can help overcome this handicap if the risks associated with high density populations can be managed.

Row Spacing

Prevailing thinking suggests that per acre plant population will remain the same irrespective of row spacing. This translates into a 33% increase in in-row spacing when moving from 40" to 30" spacing. Adjusting the in-row spacing is one crucial modification to achieve the benefits of narrow row production. Without this adjustment, rank growth on strong soils and premature cutout on sandy soils may limit yield.

Plant Type

In theory, the growth habit of different varieties will impact on selecting appropriate plant density guidelines. Columnar or stovepipe cottons with genetically reduced numbers of 2nd or 3rd positions can positively respond to higher densities. A similar argument can also be made for short-statured varieties that are less prone to rank growth. If premature cutout can be avoided by increasing a field's carrying capacity, short varieties can positively respond to increasing plant densities.

Management Philosophy

It is undeniable that selection of a target plant density involves uncertainty. A manager's approach to uncertainty must be considered when determining guidelines. Ideally, the season progresses as if conceived on paper. In reality, it twists and turns, with a full complement of downs and, hopefully, ups. When the progression follows the script with ample sunshine, heat, water and nutrients, high and low density populations perform well. However, some years are more troublesome than others.

Late planting, delayed development and early frost sometimes occur in the same year — 1992 for instance. Under this scenario, should plant density guidelines be modified? It depends on all of the factors considered earlier, but also on a producer's management philosophy. Responsible risk management dictates caution. It is arguable that plant density should not be modified in this situation because it will introduce another variable that must be factored into the management equation. However, it also can be argued that if time is extremely critical, a moderate increase in stand density may be justified if growth is tightly managed, water availability can be insured and insect management is heightened. Without that commitment backed by performance, a willful increase in plant density can be counterproductive in late- planted cotton where earliness is crucial to profitability.

This article began with an acknowledgement of the uncertainty that accompanies planting cotton. The selection of a plant density does not guarantee delivery or performance. The stand may not remotely resemble selected density. Stand performance also may be modified by a full host of environmental stresses, including disease, cold, insects and weed pressure. Once the stand has been established, ongoing management can help the sparse or dense plant community to achieve maximum productivity.

Regular monitoring of the plant's growth and development and nutritional status can provide the framework around which management decisions are modified in response to the changing landscape. The inherent resiliency of cotton equips the plant to adjust to its surroundings. The grower's challenge is to recognize that adjustment and manage it to his benefit.

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