REVISITING THE MATURITY PARADIGM IN COTTON

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Abstract

Quantifying maturity in cotton cultivars can be vital in cotton production for a variety of reasons. Planting date, variety, and irrigation techniques for a specific location or environment can be better selected when maturity of common cultivars has been accurately assessed. One of the challenges in choosing cotton cultivars for maturity characteristics is that there is not a single, consistent method for determining cotton crop maturity. Maturity has historically been evaluated by using height, total nodes, and nodes above white flower (NAWF). This method of determining maturity may however not be consistent over multiple cultivars. Other approaches, such as mapping the boll distribution, may be more dependable in determining crop maturity. Differences in boll distribution can affect crop maturity characteristics, response to stress, and environmental suitability. This study was initiated to compare the maturity characteristics of seven cotton cultivars in multiple locations of the cotton belt. A method of determining maturity based on box plots of boll distribution was tested and compared with in-season measurements of nodes above white flower and nodes above cracked boll in Texas, Tennessee, and Georgia.

Introduction

Unlike corn and soybean (Voldeng *et al.*, 1997), cotton maturity has historically been described using several different working definitions. This is due largely to cotton's indeterminate growth habit, which is affected by both growing environment and management, as well as past production practices. Historical agronomic earliness was often defined as the proportion of the total crop produced by the first picking (Leffler, 1979; Ray and Richmond, 1966; Richmond and Radwan., 1962). Evaluating the proportion of cotton harvested during the first two harvests was an established way of determining cotton maturity when a single cotton crop was harvested by hand multiple times. However, the advent of mechanical harvesting has modified this definition (Bourland *et al.*, 2001).

Flowering intervals, boll filling periods, and whole plant yield distributions have all been used to assess the maturity of cotton cultivars, demonstrating the complexities of the many different facets necessary to define cotton maturity (Bednarz and Nichols, 2005). The need for an efficient, definite, and standard way of establishing the maturity of a cotton cultivar was evident.

One method of measuring end-of-season yield and quality by fruiting site is box picking. Box picking consists of removing a pre-determined area of plants from a plot, then hand harvesting the bolls and grouping them by fruiting site. Typical measure parameters include number of plants, number of bolls by fruiting site, number of bolls from vegetative branches, and the mass of bolls from each fruiting site. Because bolls are hand harvested and separated based on fruiting site and developmental date, it is possible to measure fiber quality by fruiting site throughout the sample. This method of plant mapping has recently become more widespread and is a popular way to map the fruiting distribution of cotton.

All of the above mentioned methods rely on a node by node comparison of boll retention or weight. However, maturity is really an overall vertical distribution of bolls on the plant. Representing boll accumulation fraction by node with a box and whisker plot was a way to estimate maturity and yield a more visibly clear idea of how a cultivar accumulates yield. Some researchers have suggested (Bednarz and Nichols, 2005; Ritchie *et al.*, 2009; Whitaker *et al.*, 2008) using the accumulated fraction of total bolls by mainstem node to estimate yield accumulation over time. Our research objective was to extend this concept by quantifying cotton maturity and vertical boll distribution by the nodes where a plant has accumulated specific proportions of its total yield using box and whiskers plots, as shown in Figure 1.

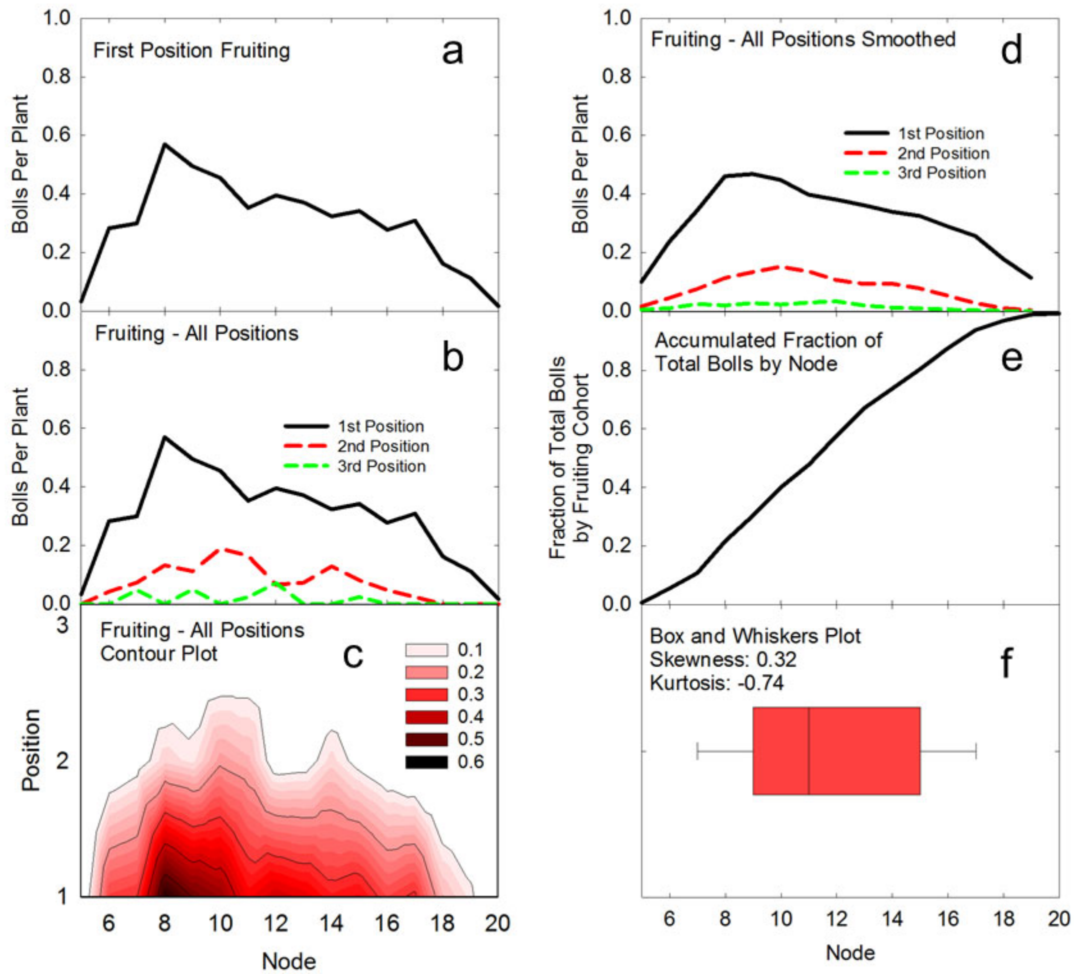

Figure 1. Examples of methods used to determine fruiting patterns in cotton. These include (a) first position fruit distribution by node; (b) distribution of 1st, 2nd, and 3rd position fruit by node; (c) contour plots to show the overall distribution; (d) smoothing to decrease node-to-node variability; (e) calculation of boll or mass accumulation at all nodes up the plant based on fruiting cohort; and (f) measures of vertical boll distribution shape using box and whiskers plots or skewness and kurtosis measurements.

Materials and Methods

Research was conducted over the course of two years and five locations in Georgia, Tennessee, and West Texas. Studies were conducted at two locations in Georgia, one location in Tennessee, and two locations in the Texas High Plains. The soil in Midville, GA is a Norfolk sandy loam (Typic Paleudult), while the soil in Tifton, GA was a Tifton loamy sand (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults). The soil classification at the research site in Jackson, TN is a Loring silt loam (thermic Oxyaquic Fragiudalf). In Texas, the studies were conducted at the Texas Tech University research farm in New Deal, TX and the Texas Tech University Quaker research farm in Lubbock, TX. The soil at the New Deal location is a Pullman clay loam (fine, mixed, superactive, thermic Torrertic

Paleustoll), while the soil classification at the Lubbock location is an Acuff sandy clay loam (Fine-loamy, mixed, superactive, thermic Aridic Paleustoll).

All of the locations received adequate irrigation and fertility based on local extension guidelines. The Georgia and Tennessee locations were irrigated using overhead low pressure sprinklers, while the Texas locations were irrigated using a sub-surface drip irrigation system (SDI), with the SDI tape placed .20 m below each row. The irrigation systems are described, because irrigation type has been shown to affect cotton growth and boll distribution (Whitaker et al., 2008; Ritchie et al., 2009).

The cultivars were planted in a randomized complete block (RCB) design with four replicates at both the New Deal and Quaker locations. Plot size consisted of two 12-m rows in 2011 and in 2012. Total plant density ranged from ten to fourteen plants per meter square, with most plots ranging from twelve and a half to fourteen plants per meter square. Row spacing was 0.91 m in Georgia and Tennessee and 1.0 m in Texas. As shown in Table 1, all of the studies were planted in May, with harvesting conducted at crop maturity, which ranged from late September to early November.

In both 2011 and 2012, the study included four Delta&Pineland (DP) cultivars, two Phytogen (PHY) cultivars and one FiberMax (FM) cultivar. The trademarked technology represented by the cultivars included Bollgard II® Roundup Ready® Flex (B2RF) and WideStrike Roundup Ready Flex® (WRF). The following cultivars were used in this study: DP0912B2RF, DP0949B2RF, DP1050B2RF, DP104B2RF, PHY755WRF, PHY375WRF, and FM1740B2RF.

Maturity

After flowering began, main-stem NAWF were measured on seven random plants in each plot weekly during the 2011 season. Main-stem nodes above the uppermost 1st position cracked boll were also measured from first open boll until defoliation. In addition, plant height, total number of main-stem nodes, white flower and cracked boll node by position were recorded weekly in 2012.

Yield and Yield Distribution

Prior to harvest, 1 m row from one of the middle harvest rows was destructively harvested and plant mapped. The plants were cut at soil level and removed from the field. For each plant within the 1 m sample, bolls were removed and grouped by individual fruiting site (node and fruiting position). The number of bolls by fruiting site was counted for all plants in each plot sample, and boll mass was measured using a laboratory balance. The plants from each plot sample were counted so that boll numbers could be compared between cultivars on either a per-plant basis or on per-unit area. Plant mapping data were smoothed using the method described by Ritchie et al. (2011): boll fractions at individual nodes for each position were subjected to a weighted smoothing factor between adjacent nodes to reduce within-node variability.

Accumulated boll fraction was calculated by node from the lowest fruiting node to the highest fruiting node for each cultivar. For each node, the first position boll was grouped with second- and third-position bolls from the same flowering dates for the purpose of boll accumulation estimates. Second position flowers were observed an average of two nodes below first position flowers on the same dates, so second position bolls were grouped with first position bolls that occurred two nodes higher on the plant. Likewise, there was a four node difference in first and third position flowers on the same flowering date, so third position bolls were grouped with first position bolls that occurred four nodes higher on the plant.

Bolls at each first, second, and third position by node were summed to obtain accumulated fraction of bolls. Boll fraction values for each fruiting position were calculated as the ratio of boll number at each node to the total boll number.

Two rows were harvested using a cotton stripper and weighed. Grab samples were collected during harvest. The grab samples were ginned on a table top gin and weighed for lint yield and lint percentage. Ginned samples were analyzed at the Texas Tech University Fiber Biopolymer Research Institution.

Results and Discussion

The sites chosen for the maturity research represented very distinct growing environments, both in terms of temperature and rainfall. The Georgia locations consistently had the highest heat unit accumulation, suggesting a long growing season with high daily mean temperatures. In 2011, an unusually hot year on the Texas High Plains, accumulated heat units at the Texas locations were still lower than those accumulated at Tifton. In 2012, accumulated heat units in Texas were substantially less than those at the Georgia locations and closer to those in Tennessee. The Tennessee location consistently had low accumulations of heat units.

Rainfall was also distinct among the locations. The Georgia and Tennessee locations consistently had hundreds of mm more rainfall than the Texas sites. The growing conditions, therefore, can be generally summarized as long-season environments with substantial rainfall (Georgia), mid-season environments with scant rainfall (Texas), and short season environments with substantial rainfall (Tennessee). The combination of increased rainfall and overhead irrigation that were observed in Georgia and Tennessee favors additional vegetative growth, while the lack of rainfall combined with drip irrigation in Texas favors a more compact growth habit.

In-season measurements of maturity were tested against final boll distribution within each environment to determine whether the in-season measurements (NAWF) might provide an adequate estimate of crop boll distribution. Within each environment, NAWF values declined over the growing season until physiological cutout (NAWF = 5), with substantial variations in timing of the decline over most of the environments. If the rate of NAWF decline correlated closely with boll distribution, assigning relative maturity would be a simple task that could be accomplished by in-season measurements. However, NAWF and NACB were not strong determinants of boll distribution, a pattern that was observed in all years and locations.

Some cultivars consistently produced NAWF values that would suggest that they were substantially earlier or later maturing than they were. From our observations, the relationship between NAWF and boll distribution appears to be cultivar-specific. Several factors may cause this, including the potential that there was a difference in the rate at which white flowers and fruit developed among cultivars. However, no consistent trends in the rate at which white flowers formed were observed in any of the locations. On a day to day basis, the node at which first square, white flower, and cracked boll occurred were quite consistent among cultivars. This pattern was observed for all locations. The evidence suggests that variations between NAWF and boll distribution were not due to differences in flowering interval.

Boll accumulation characteristics between the lower percentiles and the higher percentiles showed some differences; the 10th and 25th percentile nodes varied somewhat from the 75th and 90th percentiles. However, the variation was not so great that early accumulation could not be used to estimate later accumulation. The 50th percentile node correlated well with both the lower percentile nodes and the higher percentile nodes, with r^2 values ranging from 0.83 to 0.93 when measured over all locations. Therefore, we suggest that a measure of the node at which 50% of the yield has been accumulated would provide an accurate estimate within an environment of the relative maturity of the plant.

Conclusions

Most methods of ascertaining cotton crop maturity depend on a node by node comparison of boll retention or weight. Nonetheless, maturity is more of an overall vertical distribution of bolls on the plant as cotton plants accumulate yield over time as we extend up the plant. This study looked at alternative ways to analyze crop maturity as a function of boll distribution. The results of this study suggest that boll distribution measurements are able to provide a consistent method for determining crop maturity, which may not be achieved with other various methods such as in-season NAWF.

We determined boll accumulation by taking the average number of bolls at a certain node cohort for a specific cultivar and dividing it by the total number of bolls produced by that same cultivar. This allowed us to break up boll accumulation into percentiles and then graph the cumulative boll fraction by node into box and whisker plots. Box and whisker plots were found to be an easy and comprehensive method of estimating maturity based on how rapidly cotton produces fruit, the total fruiting period of cotton, and how high or late cotton produces fruit on the plant. They also help to show how maturity, which has many facets, can be summarized in to a single metric.

Box and whisker plots allow for easy visual identification of fruiting characteristics and boll distribution of cultivars at different locations. These plots can be used to compare many cultivars at once based on how early or late in the season they produced fruit or cultivars can be ranked based on where they accumulated fruit over time. This would then allow maturity classifications to not only be categorized by total yield, but also by where the cotton plant produces fruit, or how fast it does so.

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