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Fruiting Efficiency in Cotton: Boll Size and Boll Set Percentage

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ABSTRACT

Cotton plants, *Gossypium hirsutum* L., initiate more fruiting buds than are matured. This research quantified the boll set percentage and boll size by fruiting site in a population of cotton plants. The fruiting sites of harvestable bolls were recorded for 2 yr in eight cultivars: Stoneville 213 (ST 213), Stoneville 506 (ST 506), Stoneville 825 (ST 825), Tamcot CAMD-E (CAMD-E), Deltapine 50 (DPL 50), McNair 235 (MC 235), DES 119, and Deltapine 20 (DPL 20). Plants were thinned to ~95 000 plants ha^{-1} in rows spaced 1 m apart. All cultivars behaved similarly; however, in the newer, early-season cultivars (DPL 50, DPL 20, and DES 119), more plants retained a boll at Nodes 6 through 8 than in the older cultivar ST 213. Percentage of plants with a harvestable boll at Position 1 on a sympodial branch increased from 9.6% at Node 6 to 48.7% at Node 12, declining thereafter, and varied from 0.2 to 21.2% at Position 2. Fewer than 5% of the plants matured a boll at Position 3. Percentage of plants with a harvestable boll peaked at Nodes 11, 9, and 8 for Positions 1, 2, and 3, respectively. Assuming a 3-d vertical flowering interval, boll size and boll set percentage began decreasing 15 to 18 d after first bloom. In 1988, fewer plants matured a harvestable boll at Nodes 9 through 12 than in 1987. This was attributed to reduced solar radiation, lower temperatures, and more daytime rainfall events during July. Bolls at Position 1 were 14 and 21% larger than those at Positions 2 and 3, respectively. Boll size followed a pattern similar to percent of plants with a harvestable boll. Partitioning of photosynthate to older bolls resulted in fewer mature bolls at Positions 2 and 3 for all nodes. Smaller bolls had fewer and smaller seed. This information on plant fruiting by positions and nodes can guide breeders in selection for earlier- and higher-yielding cultivars.

CHOOSING A CULTIVAR of upland cotton for commercial production is more complex today than a few years ago. The correct cultivar choice is critical to maximizing profits. Breeders have developed cultivars that produce high yields in a shorter time than the standard cultivars of the 1970s (Bridge and McDonald, 1987). Jenkins et al. (1990) compared eight cultivars for effectiveness of lint production by fruiting sites. Bolls at Position 1 on sympodial branches produced from 66 to 75% and bolls at Position 2 produced 8 to 21% of the total yield. Sympodial branches arising from mainstem Nodes 6 through 8 were more important to yield on the newer, early-maturing cultivars (Jenkins et al., 1990). Research was needed to quantify the relationships between boll size and boll set percentage with fruiting sites in the newer cultivars compared with ST 213.

The cotton plant initiates many more fruiting buds than it matures as harvestable bolls. Our objective was to quantify boll set percentage and boll size at various fruiting sites for cotton grown in Mississippi in a conventional planting pattern.

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MATERIALS AND METHODS

The eight cultivars used in this research and the production practices and data collection procedures were the same as those used by Jenkins et al. (1990). The cultivar ST 213, released in 1962, was compared with the newer cultivars ST 506, ST 825, CAMD-E, DPL 50, MC 235, DES 119, and DPL 20. Plants were thinned to approximately 95 000 ha^{-1} in rows spaced 1 m apart. Seed were planted 4 May 1987 and 28 April 1988. Plants were grown in a randomized complete-block experiment with six replicates.

Descriptive terms are defined as follows.

1. Sympodium—a fruiting branch.
2. Monopodium—a vegetative branch.
3. Node—the place on the mainstem where sympodia or monopodia arise, numbered beginning with the cotyledonary node as Number 1.
4. Position—the order in which buds (potential bolls) are produced on a sympodium. In this study, we considered bolls as being produced at Positions 1, 2, or 3 only. Bolls with position numbers greater than three were classified as Position 3. Thus, the term position is not branch specific; for example, Position 1 refers to the first potential boll on any or all sympodia.
5. Fruiting site—specific node–position combination.

We recorded the number of plants and harvested all bolls in a 3.07-m section on one of each pair of rows, keeping the number of bolls and the weight of cotton separate by fruiting site as described by Jenkins et al. (1990). These data were converted into percentage of plants with a boll at each fruiting site. Boll size was calculated from the weight of seed cotton and number of bolls at each fruiting site. Analyses of variance were conducted with years random and cultivars fixed, as per McIntosh (1983). Arcsine transformations of the percentage data did not improve the analysis; thus, we used the actual data in each analysis of variance. Boll set percentage and boll size were computed with standard errors for each node–fruiting position combination over all cultivars. Regression equations were developed for boll set percentage and boll size with node and position.

RESULTS AND DISCUSSION

No significant differences in yield were found among cultivars averaged across 2 yr; however, there were differences in earliness (Jenkins et al., 1990). In an examination of the data across cultivars by mainstem nodes and sympodia positions, we found only the following major differences among cultivars for percentage of plants with a harvestable boll: for Position 1, Nodes 6 through 8, 15, and 17; for Position 2, Nodes 6, 9, and 16. No significant differences were found for Position 3. At Node 6, Position 1, a significantly lower percentage of ST 213 plants produced a mature harvestable boll than plants of CAMD-E, DPL 50, DES 119, and DPL 20. At Node 7, Position 1, a significantly lower percentage of plants of ST 213 had a boll than plants of CAMD-E, DPL 50, MC 235, DES 119, and DPL 20. At Node 15, Position 1, a significantly greater percentage of plants of ST 213 had a boll than the newer cultivars. Thus, the early-season cultivars had a greater percentage of plants that matured a harvestable boll at early nodes than ST 213.

The data averaged across cultivars and years with SE bars at 0.05% are shown in Fig. 1. The percentage of plants with a harvestable boll at Position 1 was as much as 35% greater than at Position 2 or 3 for every node. This agrees with Kerby and Buxton (1981), who found 76% of the bolls at Position 1. Nodes 9 through 14 had the highest boll set and would account for the majority of the yield. If we assume a 3-d vertical flowering interval and a 6-d horizontal interval, the peak boll set occurred 15 to 18 d after first bloom. Peak boll set was at Node 11 for Position 1, Node 9 for Position 2, and Node 8 for Position 3. Considering Position 1, there was an increase in percentage of plants with a boll from Nodes 6 through 12 and a decrease at each node after 12. Guinn (1985) reported that active boll load influenced boll retention, and that boll retention started to decrease almost as soon as the first bolls were set.

Regression equations (plotted in Fig. 1) for percentage of plants with a boll were calculated with the data averaged across all cultivars and for both years. The equations are $Y = -177.4 + 47.4\,X - 3.1\,X^2 + 0.058\,X^3$ for Position 1, $Y = -98.6 + 28.0\,X - 2.1\,X^2 + 0.046\,X^3$ for Position 2, and $Y = -36.4 + 10.6\,X - 0.087\,X^2 + 0.022\,X^3$; for Position 3, where Y = percentage of plants with a boll and X = mainstem node. The R^2 = 0.99, 0.96, and 0.96 for Positions 1, 2, and 3, respectively. Kerby et al. (1987), in their research in California, found the peak boll set on 'Acala SJ-2' cotton was Nodes 9 to 10 for Position 1 and 8 to 9 for Position 2. We counted the cotyledonary node as Node 1, whereas Kerby et al. (1987) counted it as zero. When corrected for cotyledonary node count differences, these two data sets are remarkably close.

The year × node interaction was significant (Fig. 2). The 1988 crop had a lower percentage of plants with a harvestable boll than the 1987 crop at Nodes 9 through 12 at Position 1 and Nodes 8 through 10 at Position 2. The percentage of plants with a boll at Position 1 peaked at Node 11 in 1987, but at Node 15 in 1988. The reduced boll load at Nodes 9 through 12 in 1988 resulted in a later crop than in 1987. This supports the hypothesis that, when plants reach a predetermined fruit load, a reduced capacity exists to set and mature bolls, due to a carbohydrate shortage (Guinn, 1985).

Assimilates and plant hormones interact. Certain hormones such as indole acetic acid (IAA), cytokinins, and gibberellins are involved in assimilate mobilization and their movement; assimilates are required for the continued production of these hormones. The production of ethylene and abscisic acid (ABA) hormones, which promote abscission, is increased by a deficiency of assimilates (Guinn, 1982). Levels of IAA in bolls decrease dramatically at anthesis and remain low for about 4 d, which may promote abscission of small bolls (Guinn and Brummett, 1988).

The weather during 1988 is related, we believe, to the unusual decrease in boll set percentage for Nodes 9 through 12. The weather was cooler in 1988, with

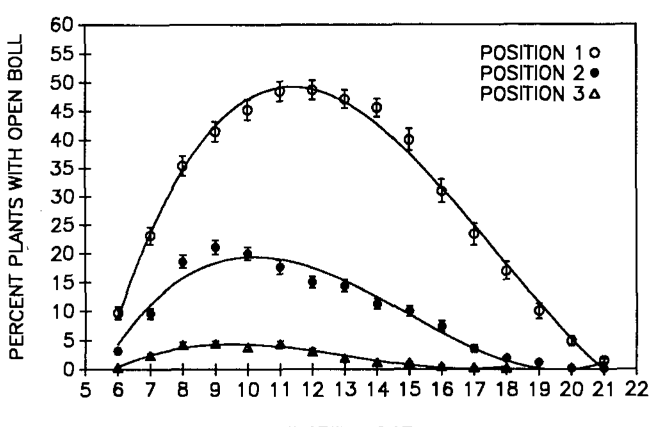

Fig. 1. Percentage of cotton plants with a harvestable boll (±SE) and regression lines by mainstem node averaged across eight cultivars and 2 yr.

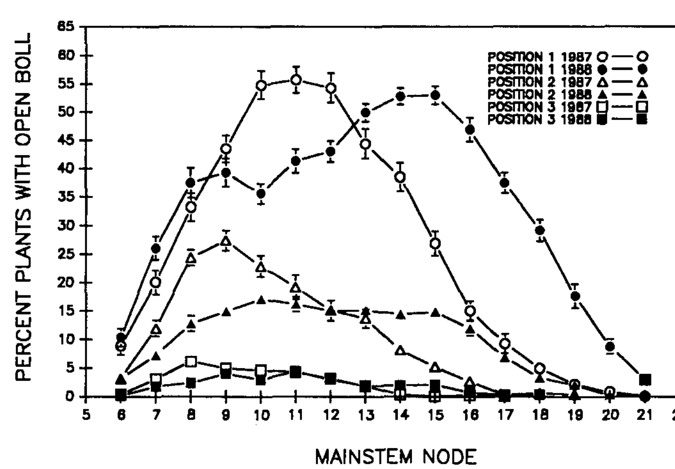

Fig. 2. Percentage of cotton plants with harvestable bolls (±SE) by mainstem node averaged across eight cultivars by years.

night-time temperatures in May below 17.5 °C every night but two. The flowers that produce harvestable bolls bloom during July. Less solar radiation occurred nearly every day in July 1988 compared with 1987, the temperature was cooler, and 11 rainfall events occurred in 1988 compared with three minor rainfall events in 1987. The rainfall events occurred mostly during daylight hours and probably affected pollination.

Effects of weather and other environmental factors on square and boll set are discussed by Guinn (1982). Guinn reported that cloudy weather, accompanied by rain that falls on open flowers, results in poor pollination and reduces the number of fertilized ovules in small bolls; these ovules probably produce the hormones that mobilize assimilates necessary for continued growth. In this way, cloudy and rainy weather contributes to boll abscission. Cloudy weather also reduces photosynthesis. Thus, the 1988 weather patterns in July should have set up conditions for lower boll retention than usual. This agrees with our 1988 results of lower boll retention at Nodes 9 through 12 than in 1987. A reduction in boll load at Nodes 9 to 12 should in turn prepare the plants to set more bolls above Node 12, and this is in fact what we observed.

Guinn (1982) presented data consistent with the hypothesis that growth, flowering, and boll retention decrease when the demand for photosynthates exceeds the supply. Our data for boll retention to maturity support Guinn's hypothesis.

Boll size in most cultivars behaved the same, except for Nodes 6 through 10 for Position 1 and Nodes 7 and 8 for Position 2. At Position 3, no significant differences were detected between cultivars. Bolls of ST 506, CAMD-E, DPL 50, MC 235, and DES 119 generally were larger than in the other cultivars.

Boll size varied across nodes in each cultivar, much like the variation based on the mean of all cultivars (Fig. 3). At Position 1, boll size tended to increase from Node 6 up through Node 12, decreasing after Node 12. Bolls from Position 1 were 14% larger than bolls from Position 2 and 21% larger than those from Position 3 at every node. Meredith and Bridge (1973) reported that boll size in four cultivars decreased as the season progressed. Bolls above Node 15 in CAMD-E were not reduced in size as much as were bolls in the other cultivars. Regression of boll size on boll set percentage gave r^2 values of 0.76, 0.66, and 0.44 for Positions 1, 2, and 3. This indicated that reduced boll set and smaller bolls occur at about the same time. This would be expected if both were related to partitioning of available photosynthate.

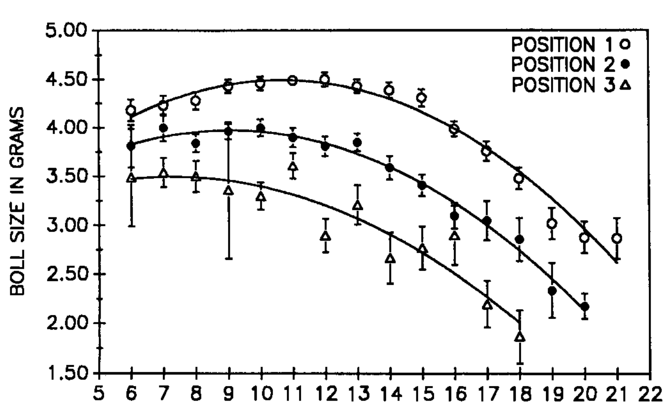

Fig. 3. Boll size (g ± SE) by position and nodes, with regression lines, averaged across eight cultivars and 2 yr.

Regression equations (plotted in Fig. 3) for boll size by position averaged across all cultivars are $Y = 2.51 + 0.373\ X - 0.017\ X^2$ for Position 1, $Y = 2.72 + 0.277\ X - 0.015\ X^2$ for Position 2, and $Y = 2.82 + 0.186\ X + 0.013\ X^2$ for Position 3, where Y = boll sizing and X = node. The R^2 values are 0.96, 0.98, and 0.86 for Positions 1, 2, and 3, respectively. Although third-order polynomial regressions were the best fit for boll retention, second-order regressions fit the boll-size data as well as third order.

Many plants within a population, regardless of the cultivars, did not have a boll to mature at a given fruiting site. Even at Position 1, >44% of the plants did not produce a harvestable boll at any given fruiting site in each cultivar. This was not caused by insect damage, but was due to a combination of genetic and environmental effects. At some fruiting sites, ≥90% of the plants did not mature a boll at Position 1 in any cultivar. More plants have a harvestable boll at Nodes 6 through 8 in the newer cultivars exemplified by DPL 50, DPL 20, and DES 119 than the older cultivar ST 213. This seems to be how the increased earliness and yield has been obtained in these cultivars. Compared with ST 213, fewer plants of these newer cultivars tended to produce a mature boll at higher nodes at Position 1.

As a minimum, researchers need to understand why so many plants do not mature a boll at these fruiting sites. It may be related to light interception, shading, or leaf area index as related to photosynthesis. At Nodes 6 through 9, boll rot reduces the percentage of plants with a harvestable boll; however, other factors also are involved, such as shading of lower sympodia leaves. Perhaps a smaller leaf area index is needed during the midseason growth cycle of the plants. Data from a plant type with a smaller leaf (sub-okra) indicates that yields can be increased significantly with this leaf type (Meredith, 1984, 1988). It is not known where the bolls are produced to give the increased yields in sub-okra leaf types. Using the model GOSSYM, Landivar et al. (1983) predicted that a leaf shape smaller than normal leaf should be a better yielding type.

Kerby et al. (1990a,b) reported that spacing and plant genotype were both important in boll set and size. They suggested that strongly determinate genotypes should be evaluated under modified cultural practices to maximize their potential usefulness. Research with an experimental genotype, 2086 (Kerby et al., 1990b), showed that it was adapted to high-density planting patterns, because of lower node number of first fruiting branch, faster production of mainstem nodes early in the season, and increased retention of early squares. In our study, a greater percentage of plants produced a boll at about Node 12 for Position 1. This is about 18 d after the first flower appears. The marked difference between number of bolls matured at Positions 1 and 2 and the smaller boll size at Position 2 probably reflects greater partitioning of photosynthate to older bolls. Smaller bolls had fewer and smaller seed in our study. The general reduction in percentage of plants with a mature boll after Node 14 and the smaller boll size at the higher nodes is surely a reflection of the boll load and photosynthetic demand on the plant.

These data provide information that is not available from total yield data as presented by Jenkins et al. (1990). With over 44% of the plants in the best cultivars not having a mature boll at the important Nodes 9 through 14, improvement in boll retention until harvest is a desirable breeding objective. Perhaps breeders could select for plants that retain a boll at Position 1 at Nodes 9 through 14, and thereby increase yields, or select for plants with a harvestable boll at Nodes 6 through 8 and increase both yield and earliness.

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