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Effects of Within-Row Plant Spacings on Growth, Boll Retention, and Yield of Four Cotton Cultivars

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Abstract

Plant spacing in cotton, *Gossypium hirsutum* L., has gained importance due to the cost of seed with value-added traits. The objectives of this study were to investigate growth, boll retention and yield of four cultivars when grown in four within-row plant spacings in four-planted, two-skip row configurations. Cultivars DP555 BG/RR, SG215 BG/RR, DP444 BG/RR, and ST4892BR were grown at Mississippi State University during 2003 and 2004 in plots seeded in a plant four-row, skip two-row configuration using within-row plant spacings of 8, 15, 23, and 30 cm. The experimental design was a split plot with six replicates, with cultivars as the main factor and within-row spacing as the split factor. Data were collected from both interior (solid row) and exterior (next to skip row) rows from each plot. Plants were taller in the exterior row than the interior row, and the 8-cm spacing had fewer main stem nodes in both interior and exterior rows. The number of bolls on monopodial branches increased with increased spacing in both the interior and exterior rows. Boll retention was higher in the exterior row than the interior row. There were no differences in yield between the within-row plant spacings in the interior row in 2003, but in the exterior row, spacings greater than 8 cm showed significant reductions in yield. In 2004, yield was significantly affected by plant spacing; the 8-cm spacing tended to produce more yield in both the interior and exterior rows compared with the other plant spacings. Yield can be affected by planting pattern (solid or skip-row configuration) and plant spacing. Therefore, they should be considered at seeding date.

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INTRODUCTION

Upland cotton, *Gossypium hirsutum* L., is widely grown and provides a source of natural fibers for the textile industry. Producers are constantly searching for ways to offset increases in production cost. This concern has led to changes in seeding rates, row spacings, and row configurations such as solid-planted and skip-row patterns. Although research has been conducted for the past century in these areas there is still need for refinements.

Numerous studies have been conducted in cotton using different plant densities and measuring their effects on total yield (Albritton, 1967; Bednarz et al., 2002, 2005; Bridge et al., 1973; Douglas et al., 1964; Duncan and Pate, 1964; Hawkins and Peacock, 1970; Kerby et al., 1990; Mohamad et al., 1982; Ray et al., 1959; and Smith et al., 1979). A wide range of plant densities (35,000 to 175,000 plants per hectare) resulted in optimum total yields in these studies. Duncan and Pate (1964) reported reduced yields with a population below 32,278 plants per hectare. Today, producers in the Midsouth generally use about a 96.5- to 101.5-cm row and plant three to four seeds per 30 cm, with a final plant population of 100,000 to 120,000 plants per hectare.

Cotton yield is directly related to boll retention, which is very complex and can be affected by many interacting factors, such as genetics, physiology, nutrition, the environment, insects or any combination of these. Guinn (1985) suggested that boll retention is primarily related to nutrition. If the plant is stressed because of low levels of carbohydrates or other nutrients, it will begin to shed squares and small bolls. Boll retention can also be affected by competition for water, nutrients, and photosynthates (Boquet and Moser, 2003). Bednarz et al. (2000) showed that the fruiting habits of cotton give it the ability to compensate for reduced plant densities by producing more fruit on longer sympodial branches and producing more main stem nodes and monopodial branches. A sympodial branch will generally provide photosynthates primarily to a single fruiting site (fruiting site 1). If the fruiting structure at this site is shed, the photosynthates are provided to a second fruiting site in close proximity to the original site, fruiting site 2 (Peoples and Matthews, 1981). This process helps the plant compensate for boll loss, but Peoples and Matthews (1981) found that under field conditions, the loss of a boll was not fully compensated by the development of additional or larger bolls.

Cotton produces two to three times more fruiting sites than the number retained until harvest under commercial conditions (Constable, 1991). If fruit is lost for any number of reasons, the plant will compensate for fruit loss and result in boll production at nodes or positions where fruit would not otherwise be produced (Hearn and Room, 1979). Pettigrew (1994) reported that early-season sympodial fruit removal increased the mass of bolls at fruiting site 1 but not necessarily at fruiting site 2, but later in the season, fruit of both sites acquired similar mass. Ehlig and LeMert (1973) reported that boll load is a major factor in boll retention. Reddy et al. (1992) established that prolonged temperatures of 35–40°C may cause shedding of squares and small bolls.

From a 2-year study in 1987 and 1988, Jenkins et al. (1990a, 1990b) reported that first-position bolls accounted for 66–75% of lint yield, and second-position bolls accounted for 18–21% of lint yield on sympodial branches. Monopodial branches accounted for 3–9% of lint yield. All other positions combined produced 2–4% of lint yield.

Plant mapping has been used for many years to help researchers and producers monitor retention and fruit development. Plant mapping is a specific, prearranged method of recording, or "mapping," cotton growth that defines the location and stage of fruit by its position on the main stem node and its position on the fruiting branches. Plant-mapping techniques are often used to determine nodes above white flower (NAWF), nodes above cracked boll (NACB), and fruit retention, as well as to compare fruit retention on selected horizontal or vertical zones of the cotton plant. NAWF can be used to measure plant growth and is used quite frequently to estimate or predict physiological cutout (Oosterhuis et al., 1992, 1996). Waddle (1974) was the first to use node number of first-position white flower relative to the plant terminal as an indicator of maturity in cotton. NACB is another measure that can be useful in determining crop maturity.

The objectives of this research were to investigate the effects on plant growth, boll retention yield and yield components associated with four commercial cultivars grown in four-planted, two-skip row patterns using four within-row plant spacings.

Materials and Methods

Experimental Site, Establishment, and Design

Experiments were conducted at the Mississippi State University Plant Science Research Center in 2003 and 2004 on a Marietta clay loam (fine-loamy, siliceous, active, thermic Fluvaquentic Eutrodept) soil. Four Midsouth cultivars that varied in maturity were used in these experiments: 'DP555 BG/RR' (DP555), 'SG215 BG/RR' (SG215), 'DP444 BG/RR' (DP444), and 'ST4892BR' (ST4892). DP444 and SG125 are considered early-maturity cultivars. ST4892 is an early- to mid-maturity cultivar. DP555 is a mid- to full-season cultivar. These four cultivars were seeded on about 42% of Midsouth cotton acreage in 2003 and 49% in 2004 (NASS, 2003, 2004).

Plots were overseeded on May 28, 2003, and May 10, 2004. Plots were six rows wide (four planted/two unplanted) on 0.97-m centers. Each row was 9 m in length. Approximately 3 weeks after emergence each year, plots were hand-thinned to within-row plant spacings of 8 cm, 15 cm, 23 cm, or 30 cm. Terrachlor Super X (5-ethoxy-3-trichloromethyl-1-1,2,4-thiadiazole) at 11.2 kg per hectare and aldicarb [2-methyl-2-(methylthio) propionaldehyde O-(methylcarbamoyl) oxime] at 0.34 kg of active ingredient per hectare were applied in-furrow with seeds at planting each year. In 2003, 140 kg of N per hectare was applied to all plots in split applications with 56 kg applied preplant and 84 kg applied at prebloom. In 2004, a preplant application of 84 kg of N per hectare was applied, but the second application was prevented by excessive rainfall. Machine-harvest dates were November 7, 2003, and October 8, 2004. The experimental design was a split plot with six replications, with cultivar as the main plot and within-row plant spacing as the split plot.

End-of-Season Plant Mapping

Nondestructive end-of-season plant map data were collected the last 2 weeks of October 2003 and the last week of September 2004 on all plots after defoliation and just before machine harvest. Plant map data were collected on 10 consecutive plants beginning at a random location for an interior and exterior row (next to skip) for each plot. The cotyledon scar was recorded as node zero and served as a reference point for determining the node of the first sympodial branch. For each sympodial branch, fruiting sites were recorded using a "B" for boll present or an "X" for boll missing. Mapping data was limited to the first four fruiting sites on a sympodial branch. Total main stem nodes, plant height, node of first sympodial branch (NFSB), number of monopodial bolls, and sympodial branches with fruit or missing fruit were recorded.

Yield Data

A 25-boll sample of first-position bolls was hand-picked after the collection of end-of-season plant map data and before machine harvest from each plot near the middle nodes of the plants. Samples were ginned on a 10-saw laboratory gin and used to estimate lint percent and boll weight. Plots were machine-harvested with a research plot picker on November 7, 2003, and October 4, 2004. Machine harvest yield data were applied to plant mapping data for yield and yield component distributions. Yield data were calculated on a land-acre basis, and the exterior row (next to skip) was calculated as a 2:2 skip so that an equal comparison could be made to the interior row (solid rows).

Data Analysis

All data collected in 2003 and 2004 were subjected to analysis of variance (ANOVA) using SAS version 8.2 (SAS Institute, Cary, North Carolina). Means were separated using Fisher's protected least significant difference (LSD) at the 0.05 α level. All F-tests were performed as described by McIntosh (1983). Data for 2003 and 2004 were analyzed separately because of significant interactions of within-row plant spacing and cultivars with years.

Weather Conditions

In 2003, plots received 61 cm of rainfall from planting to harvest with a fairly uniform distribution across the growing season. In 2004, plots received 63 cm of rainfall from planting to harvest with most of it skewed toward the early season and very little late in the season. Temperatures were similar both years. The average minimum and maximum temperatures were 17.7°C and 29°C, respectively, for 2003 and 19.2°C and 29.8°C, respectively, for 2004. Accumulated degree days (DD 60's) were compared for both years, and the differences were minimal. Accumulated DD 60's from planting to harvest were 2,324 for 2003 and 2,384 for 2004.

Results and Discussion

The precipitation distribution and nitrogen levels differed significantly between the years. Grimes et al. (1969a, b) reported that cotton growth, yield, and quality characteristics are greatly enhanced by adequate soil moisture and nitrogen supply. In terms of growing conditions, the 2003 growing season exhibited greater plant growth and yield compared with 2004. In 2004, excessive early-season rain was followed by trace amounts midseason, and then a hurricane hit near the end of the season. Heavy early precipitation caused the plants to grow rank and prevented ground equipment from applying the second application of nitrogen. Wells and Meredith (1984) reported that when the initiation of reproductive growth coincides with excessive vegetative development, a negative effect on yield might result. Major weather differences between years resulted in significant interactions with years. For this reason, data for years were analyzed separately.

End-of-Season Plant Mapping

Height, main stem nodes, node of first sympodial branch and monopodial bolls — We detected no significant interaction for cultivar by spacing in either year. There was little difference among cultivars when averaged across within-row plant spacing for plant height; however, DP555 produced approximately one more main stem node than the other cultivars in both years (Table 1). Plants were taller in the exterior row compared with the interior row. The 8-cm plant spacing had fewer main stem nodes compared with the 30-cm spacing.

The node of the first sympodial branch was approximately one node lower for the early-season cultivars, SG215 and DP444, relative to the mid- to full-season cultivars, DP555 and ST4892, and was 2.5 nodes higher in 2003 than in 2004 across all plant spacings (Table 1). However, the node of the first sympodial branch was not related to the within-row plant spacing in our study, which is in agreement with Galanopoulou-Sendouka et al. (1980) and Bednarz et al. (2000). Monopodial branches produced more bolls in the exterior row than the interior row. The only difference among cultivars was in 2004 in the interior row when DP555 produced fewer bolls on monopodial branches. The number of bolls on monopodial branches significantly increased as within-row plant spacing increased from 8 cm to 30 cm in both the exterior and interior row.

Managing earliness through the use of close plant spacing was used quite often in early efforts to control boll weevils (*Anthonomous grandis* Boheman.) (Blackwell and Buie, 1924). The earliness trend for narrower within-row plant spacing was found in height and node data and also in the end-of-season plant mapping data. These findings agree with Buehring et al. (2004), who found maturity was delayed by wider spacing by as much as 6 days. This finding is similar to our result of 6–7 days in wider spacings. In both 2003 and 2004, the total nodes per plant were inversely related to within-row spacing. Differences in plant heights among plant spacings were not significant either year in the exterior row, but differences in height

Table 1. Mean number of main stem nodes, plant height, node of first sympodial branch (NFSB), and number of bolls present on monopodial (MON) branches for four cotton cultivars grown in four-planted, two-skip row patterns with four different within-row plant spacings, 2003 and 2004.[1]

	2003				2004			
	Nodes	**Height**	**NFSB**	**MON**	**Nodes**	**Height**	**NFSB**	**MON**
	no.	*cm*	*no.*	*no.*	*no.*	*cm*	*no.*	*no.*
Exterior row next to skip								
Cultivar								
DP555	21.6	112.8	8.1	8.1	15.7	94.4	5.5	1.7
DP444	19.0	102.8	7.3	8.3	13.7	89.4	5.0	2.6
SG215	18.6	113.8	7.3	8.3	13.9	92.3	5.0	1.9
ST4892	19.8	113.3	8.2	9.0	14.9	99.7	5.2	2.2
F	**	**	**	NS	**	**	**	NS
LSD(0.05)	0.6	3.6	0.3		0.4	4.3	0.3	
Spacing								
8 cm	19.0	110.5	7.8	3.5	13.5	95.2	5.3	0.2
15 cm	19.4	109.4	7.9	6.5	14.4	94.8	5.2	1.3
23 cm	20.1	112.4	7.5	9.8	15.1	94.6	5.2	2.5
30 cm	20.5	110.4	7.7	13.9	15.3	91.1	5.0	4.3
F	**		NS	**	**	NS	NS	**
LSD(0.05)	0.6	NS		1.9	0.4			0.7
Interior row (solid)								
Cultivar								
DP555	19.8	100.0	8.2	3.6	14.3	87.6	5.5	0.6
DP444	17.0	92.2	7.3	3.8	12.7	82.3	4.9	1.1
SG215	16.9	101.8	7.3	3.9	13.0	85.8	5.0	0.9
ST4892	18.2	100.9	8.3	4.5	13.4	91.0	5.2	0.7
F	**	*	**	NS	**	*	**	**
LSD(0.05)	0.5	2.9	0.3		0.5	4.0	0.2	0.3
Spacing								
8 cm	16.5	94.8	7.6	1.4	12.4	88.5	5.0	0.1
15 cm	17.8	97.9	7.9	2.9	13.2	88.0	5.1	0.5
23 cm	18.5	100.5	7.8	4.5	13.6	86.3	5.2	0.9
30 cm	19.1	101.6	7.8	7.0	14.2	84.0	5.3	1.8
F	**	**	NS	**	**	NS	NS	**
LSD(0.05)	0.5	2.9		0.7	0.5			0.3

[1]Data were collected from an interior row and exterior row next to skip. *, ** = significant at the 0.05 and 0.01 levels of probability, respectively. NS = nonsignificant.

were absent in the interior row in 2003, which followed the same trend as the nodes. Both years, DP555 had the most total nodes and was one of the tallest cultivars, and DP444 had the fewest total nodes and was one of the shortest cultivars.

Boll Retention

Exterior row (next to skip) and interior row (solid) cultivar means in 2003 — We observed few significant interactions among cultivars or plant spacings across nodes and by fruiting position. Cultivar means for the exterior row are presented by nodes (as percentages) in Tables 2–4 for positions 1–3. For position 1, in the exterior row, the cultivars showed the majority of differences in the lower nodes (≤ 10) and the upper nodes (≥ 17). Differences were mostly due to the different maturities exhibited by the cultivars. For position 2, the patterns were similar to position 1 in that most of the differences were observed in the lower nodes (≤ 9) and the upper nodes (≥ 12). For position 3, the differences were sporadic but mainly below node 15. For position 4, which made a small contribution to yield, there were no differences except for a small difference noticed at node 9 (data not shown).

Maturities among the cultivars accounted for most of the differences in boll retention among nodes. DP555 reached peak boll retention later and retained more bolls on the middle and the upper fruiting branches than the other cultivars. SG215 and DP444, the two early cultivars, performed almost identically with very few differences between them. ST4892, which is considered early- to mid-maturity, showed more of a mid-maturity pattern, but it was not different from the two early-maturing cultivars in the later nodes. Jenkins et al. (1990a, b) reported that early-maturing cultivars mature the majority of their bolls on the middle to lower nodes of the plant, and the later-maturing cultivars mature the majority of their bolls on the middle to upper nodes of the plant.

For position 1, in the interior row, the cultivars showed more differences in boll retention than were observed in the exterior row (Table 2, 3, and 4). All of the cultivars exhibited a slightly lower retention at all positions in the interior row compared with the exterior row next to the skip.

Exterior row (next to skip) and interior row (solid) spacing means in 2003 — Over all the positions, plants at all within-row spacings in the exterior row had higher retention than in the interior row (Tables 2–4). For position 1, in the exterior row next to the skip, most of the differences in retention occurred between node 12 and 20. On position 2, there were differences at almost every node; plants in the 8-cm spacing set the fewest bolls, followed by the 15-cm, 23-cm, and 30-cm within-row spacing. Plants in the wider spacing retained more bolls than plants in the narrow spacing. On positions 3 and 4, we noticed a few differences in retention in the lower nodes, but retention was fairly similar in the higher nodes.

On position 1 in the solid-row pattern, most boll retention differences were found at node 12 and above (Table 2). Most of these differences in retention reflect differences in cultivar maturity caused by the different plant spacing; these differences were greater than those observed in the exterior row for position 1. Fruiting position 2 had boll retention differences at almost every node; the wider the spacing, the higher the retention throughout the growing season (Table 3). At position 3, there were some differences in boll retention; however, retention was very low at all nodes (Table 4). At position 4, boll retention was typically less than 1% (data not shown).

Exterior row (next to skip) and interior row (solid) cultivar means in 2004 — In 2004, fruit retention and number of nodes produced were dramatically lower than 2003, due primarily to an extended drought

Table 2. Mean percent of first-position bolls for cotton cultivar and spacing on interior and exterior rows in 2003.[1]

	Main stem nodes (%)																			
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Exterior row																				
Cultivar																				
DP555	0.8	5.4	21.3	49.6	64.6	73.3	76.7	77.9	79.6	81.3	75.8	65.0	58.3	59.6	41.3	37.1	26.3	16.3	7.9	4.2
DP444	8.3	20.4	50.8	66.7	74.2	72.9	75.8	70.4	75.4	70.4	62.1	53.8	46.7	35.0	24.6	10.4	3.8	2.1	0.4	0.4
SG215	4.6	16.7	48.8	72.9	78.3	79.2	78.3	82.1	80.4	75.0	64.6	60.0	43.8	27.9	20.4	8.8	2.5	~	~	~
ST4892	2.1	3.3	17.9	45.4	70.0	80.8	77.9	72.1	73.8	70.0	60.8	62.1	53.8	34.2	24.6	15.0	5.8	2.1	0.8	~
F	**	**	**	**	*	NS	NS	**	NS	NS	NS	NS	NS	**	**	**	**	**	*	**
LSD(0.05)	4.0	6.6	10.0	11.3	8.8			7.1						10.1	10.0	9.0	7.1	3.9	2.3	2.5
Spacing																				
8 cm	2.9	9.6	26.7	57.1	70.0	76.3	75.0	71.3	72.1	65.0	58.8	52.1	40.4	27.5	15.4	12.1	6.3	5.0	2.1	0.4
15 cm	3.3	8.8	32.9	54.6	72.9	75.0	77.9	76.7	77.9	75.0	62.9	59.2	50.8	38.3	27.5	15.0	7.9	2.9	1.7	1.3
23 cm	5.8	15.8	41.3	62.1	72.5	78.8	78.8	73.3	75.4	80.4	68.3	62.1	58.8	48.8	37.5	20.0	11.7	5.8	1.7	0.8
30 cm	3.8	11.7	37.9	60.8	71.7	76.3	77.1	81.3	83.8	76.3	73.3	67.5	52.5	42.1	30.4	24.2	12.5	6.7	3.8	2.1
F	NS	NS	*	NS	NS	NS	NS	*	**	*	*	*	*	**	**	*	NS	NS	NS	NS
LSD(0.05)			10.0					7.1	6.8	9.6	9.2	10.4	11.0	10.1	10.0	9.0				
Interior row																				
Cultivar																				
DP555	0.8	9.2	22.1	41.3	62.5	67.5	66.3	73.3	68.8	67.1	57.9	43.8	39.6	32.9	27.1	13.3	10.8	8.8	0.8	~
DP444	4.6	17.9	47.5	62.1	76.3	77.5	67.9	65.0	53.3	44.2	36.3	21.7	15.0	10.0	5.4	1.3	0.4	0.4	~	~
SG215	2.9	12.9	47.5	70.8	76.3	76.3	70.0	70.0	59.2	45.8	37.9	33.3	17.9	6.7	2.9	2.1	0.8	0.4	0.4	~
ST4892	0.4	2.9	13.3	43.3	72.1	66.7	64.6	61.7	50.0	53.3	39.6	31.7	25.0	19.2	10.0	4.2	2.1	0.4	~	0.4
F	NS	**	**	**	NS	*	NS	NS	**	**	**	*	**	**	**	**	**	**	NS	NS
LSD(0.05)		6.4	9.9	10.6		8.6			8.9	10.0	9.8	9.2	8.0	7.5	5.7	4.7	4.9	2.7		
Spacing																				
8 cm	2.9	10.4	38.3	58.3	70.8	69.2	60.4	59.6	43.3	37.9	27.5	15.8	12.5	7.9	5.0	1.3	0.4	0.4	~	~
15 cm	1.7	10.8	27.9	51.7	70.0	68.8	69.2	68.8	56.7	50.8	39.2	28.3	23.3	14.2	8.3	4.2	5.0	2.1	0.8	~
23 cm	2.5	12.1	30.8	52.9	73.3	73.3	69.6	70.0	62.9	60.8	52.1	45.8	31.7	20.4	12.9	4.2	1.3	3.3	~	~
30 cm	1.7	9.6	33.3	54.6	72.9	76.7	69.6	71.7	68.3	60.8	52.9	40.4	30.0	26.3	19.2	11.3	7.5	4.2	0.4	0.4
F	NS	NS	NS	NS	NS	NS	NS	*	**	**	**	**	**	**	**	**	*	*	NS	NS
LSD(0.05)								8.3	8.9	10.0	9.8	9.2	8.0	7.5	5.7	4.7	4.9	2.7		

[1] *, ** = significant at the 0.05 and 0.01 levels of probability, respectively. NS = nonsignificant.

during the growing season. Fruit retention across all plant spacings and cultivars was higher in 2004, but there were fewer nodes and lower retention on the upper nodes of the plants (Tables 5–7). For position 1 in the exterior row, cultivars showed retention differences at some nodes but not at the high retention nodes of 8, 9, and 10 (Table 5). On position 2, there were fewer differences in retention, and they occurred in the middle nodes (8–12), mainly due to the later-maturity characteristics of DP555 and ST4892. Retention was higher but extended over fewer nodes than in 2003. On position 3, we noticed the same trend as in position 2, except for lower retention. On position 4, retention was down to about 7% (data not shown).

In the interior row (solid pattern), cultivar means are presented in Tables 5–7. For position 1, we noticed the same basic trend as in the exterior row; there were many fruit retention differences in the early and later nodes but not in peak retention nodes of 7, 8, and 9. Position 2 was also similar to the exterior row but with much lower retention. Again, most of the retention differences were recorded in the late-maturity cultivar DP555. On position 3, the peak retention was down to about 10%, with only one retention difference noticed at node 5, in SG215. On position 4, retention was less than 2% (data not shown).

Exterior row (next to skip) and interior row (solid) plant spacing means in 2004 — Over all the positions, plants at various spacings in the exterior row had higher boll retention than those in the interior row (Tables 5–7). For position 1, in the exterior row next to the skip, we noted higher boll retention at the wider plant spacings. On position 2, there were cultivar differences in retention at almost every node; the few exceptions in the late nodes were due to the higher retention of the wider spacings. On position 3, we noticed the same trend as on position 2 but with lower retentions. We also noticed this trend on position 4 (data not shown) but with even lower retentions.

Table 3. Mean percent of second-position bolls for cotton cultivar and spacing on interior and exterior rows in 2003.[1]

	Main stem nodes (%)																			
	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Exterior row																				
Cultivar																				
DP555	0.4	5.0	17.9	34.6	54.2	57.9	59.6	55.8	52.1	40.0	36.7	37.1	26.3	20.4	20.4	9.2	3.8	1.3	~	~
DP444	7.9	12.5	35.0	44.6	47.1	50.0	46.3	46.7	37.9	31.7	23.8	20.0	15.0	7.1	1.7	0.8	0.8	0.4	~	~
SG215	2.5	10.4	38.3	53.8	49.6	54.2	47.5	47.1	32.9	30.4	23.8	17.5	10.4	4.6	0.8	~	~	~	~	~
ST4892	2.1	2.1	13.3	32.9	51.7	51.3	45.8	47.9	38.3	33.3	30.0	20.0	16.7	7.1	3.3	1.7	0.4	0.4	~	~
F	**	**	**	**	NS	NS	NS	NS	**	NS	*	**	*	*	**	**	NS	NS		
LSD(0.05)	3.4	5.1	7.8	9.3					9.8		10.1	9.2	9.0	5.8	5.2	3.3				
Spacing																				
8 cm	2.1	5.8	17.1	29.6	36.3	40.8	34.6	40.8	30.4	28.8	21.3	13.3	6.7	5.8	3.8	1.3	1.7	0.4	~	~
15 cm	2.1	5.4	22.9	38.3	46.7	50.8	47.9	46.3	33.8	26.7	27.1	21.7	13.3	7.5	5.8	1.7	0.4	~	~	~
23 cm	5.4	10.0	32.1	47.5	57.1	57.9	57.1	54.6	48.3	38.3	36.3	30.8	25.8	15.8	7.9	4.6	0.4	1.3	~	~
30 cm	3.3	8.8	32.5	50.4	62.5	63.8	59.6	55.8	48.8	41.7	29.6	28.8	22.5	10.0	8.8	4.2	2.5	0.4	~	~
F	NS	NS	**	**	**	**	**	**	**	**	*	**	**	**	NS	NS	NS	NS		
LSD(0.05)			7.8	9.3	9.8	8.8	8.4	9.4	9.8	9.7	10.1	9.2	9.0	5.8						
Interior row																				
Cultivar																				
DP555	0.4	3.8	10.4	22.1	34.2	41.7	37.1	34.6	26.7	17.9	16.7	12.1	8.8	9.6	3.3	3.3	1.3	~	~	~
DP444	2.5	9.6	26.7	36.7	41.7	29.6	20.4	15.8	11.3	9.6	6.3	5.4	2.1	1.3	~	0.4	~	~	~	~
SG215	1.7	5.8	28.3	35.0	38.3	28.3	24.2	15.0	12.1	12.5	6.3	2.1	2.1	1.3	0.4	~	~	~	~	~
ST4892	~	0.4	8.3	27.9	35.4	35.4	25.0	22.5	16.7	14.2	11.7	6.3	5.0	2.5	0.4	0.8	~	~	~	~
F	NS	**	**	**	NS	*	*	**	**	*	**	**	**	**	NS	*	*			
LSD(0.05)		4.6	7.5	9.4		8.4	7.8	7.9	6.6	6.9	6.0	4.9	3.9	4.1		2.1	0.8			
Spacing																				
8 cm	0.4	3.3	12.1	19.2	21.7	17.1	15.0	9.6	5.8	3.8	5.0	0.4	0.8	0.8	0.4	~	~	~	~	~
15 cm	0.8	5.8	17.5	25.0	30.0	32.9	19.6	20.8	13.8	10.0	9.2	7.1	4.6	2.5	1.3	0.8	~	~	~	~
23 cm	0.8	5.4	20.8	41.3	46.7	37.9	31.7	26.7	22.1	17.9	13.8	7.9	4.6	2.9	0.4	1.3	~	~	~	~
30 cm	2.5	5.0	23.3	36.3	51.3	47.1	40.4	30.8	25.0	22.5	12.9	10.4	7.9	8.3	2.1	2.5	1.3	~	~	~
F	NS	NS	*	**	**	**	**	**	**	**	*	**	**	**	NS	NS	**			
LSD(0.05)			7.5	9.4	10.0	8.4	7.8	7.9	6.6	6.9	6.0	4.9	3.9	4.1			0.8			

[1] *, ** = significant at the 0.05 and 0.01 levels of probability, respectively. NS = nonsignificant.

On position 1 in the interior row, the peak retentions were higher than in 2003, except for the 8-cm spacing, which was lower. Most of the differences found in retention were in the 8-cm spacing. However, retention generally extended over fewer nodes than in 2003. On position 2, there were differences in retention at every node except nodes 12 and 13. The wider spacing had the highest retention. On position 3, the trend was the same as position 2, except with lower retentions, and for position 4 (data not shown) the boll retentions were less than 1%.

Yield and Yield Components

Lint percent — The means for lint percent for 2003 and 2004 are presented in Table 8. Within each year, there was no significant interaction between cultivar and spacing. In 2003, the cultivars differed dramatically for lint percent and ranked similar in the interior and exterior rows. In the exterior row, DP555 had the highest lint percent (45%), followed by ST4892 (42%), DP444 (41%), and SG215 (41%). In the interior row, DP555 was the highest (46%), followed by ST4892 (43%), DP444 (42%), and SG215 (42%).

Plant spacing in 2003 had little effect on lint percent. In the exterior row, plants in the 30-cm spacing had higher lint percent than plants in other spacings. In the interior row, no significant differences were detected for lint percent in 2003.

In 2004, the cultivars were significantly different for lint percent in both the exterior and interior rows. In the exterior row, DP555 was the highest (47%), followed by ST4892 (44%). DP444 and SG215 were lower but not different from one another with 43% and 42%, respectively. In the interior row, DP555 was still significantly higher than the other cultivars. In 2004, plant spacing did not affect lint percent in either row.

Boll Weight — In 2003, boll weight was significant for cultivar and plant spacing in each row (Table 8). In the exterior row, SG215 and ST4892 produced

Table 4. Mean percent of third-position bolls for cotton cultivar and spacing on interior and exterior rows in 2003.[1]

	Main stem nodes (%)																			
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Exterior row																				
Cultivar																				
DP555	0.4	1.7	8.3	19.6	17.9	18.3	23.3	18.8	20.8	15.8	8.3	10.4	9.2	5.8	2.1	0.8	0.8	~	~	~
DP444	3.3	6.7	10.8	19.2	15.4	12.1	10.8	10.4	10.0	7.1	7.5	5.0	1.3	0.8	0.4	~	~	~	~	~
SG215	1.3	3.8	10.4	13.3	12.9	12.5	15.8	13.8	12.5	11.3	6.3	3.8	0.4	0.4	~	~	~	~	~	~
ST4892	0.4	1.3	4.2	7.5	14.6	11.7	12.1	10.4	13.3	14.6	9.6	6.3	2.9	0.8	~	~	~	~	~	~
F	NS	**	NS	**	NS	NS	**	NS	*	*	NS	NS	NS	NS	NS	NS	NS			
LSD(0.05)		3.4		6.7			8.5		7.5	6.9										
Spacing																				
8 cm	0.4	1.7	3.8	5.0	8.3	8.8	9.2	10.4	11.7	10.4	5.0	3.8	2.9	1.3	0.4	~	0.4	~	~	~
15 cm	~	1.3	4.2	11.7	10.0	12.1	15.0	13.8	14.2	12.5	7.5	3.8	2.1	0.8	~	~	~	~	~	~
23 cm	2.9	5.0	10.4	21.7	17.5	13.8	17.9	12.5	14.6	11.3	8.8	7.9	3.3	2.5	0.4	~	~	~	~	~
30 cm	2.1	5.4	15.4	21.2	25.0	20.0	20.0	16.7	16.3	14.6	10.4	10.0	5.4	3.3	1.7	0.8	0.4	~	~	~
F	NS	*	**	**	**	**	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS			
LSD(0.05)		3.4	4.9	6.7	7.2	6.6						4.9								
Interior row																				
Cultivar																				
DP555	~	0.8	5.0	7.5	7.5	9.2	9.2	5.4	2.5	2.1	2.5	3.3	0.4	0.8	0.4	~	~	~	~	~
DP444	~	2.9	6.7	10.0	2.5	2.1	2.5	2.1	1.3	~	0.4	0.4	~	~	~	~	~	~	~	~
SG215	0.8	0.8	5.4	5.4	3.3	2.5	3.8	2.9	3.3	0.8	0.8	~	0.4	~	~	~	~	~	~	~
ST4892	~	~	0.4	2.5	2.5	2.9	4.6	5.8	2.9	3.3	1.3	0.4	~	~	~	~	~	~	~	~
F	NS	NS	*	NS	*	**	NS	NS	NS	NS	**	NS	NS	NS	NS					
LSD(0.05)			3.8		3.8	4.3					2.1									
Spacing																				
8 cm	~	1.3	0.8	3.3	0.4	0.8	1.7	~	0.8	~	~	0.4	~	~	~	~	~	~	~	~
15 cm	~	1.3	2.9	2.9	2.1	3.8	3.8	3.3	2.1	0.8	0.8	0.4	0.4	0.4	~	~	~	~	~	~
23 cm	0.4	1.7	5.8	7.5	3.8	5.4	5.8	5.4	3.3	1.7	1.3	1.3	0.4	~	~	~	~	~	~	~
30 cm	0.4	0.4	7.9	11.7	9.6	6.7	8.8	7.5	3.8	3.8	2.9	2.1	~	0.4	0.4	~	~	~	~	~
F	NS	NS	**	**	*	NS	*	*	NS	**	*	NS	NS	NS	NS					
LSD(0.05)			3.8	5.0	3.8		5.0	4.5		2.1	2.1									

[1] *, ** = significant at the 0.05 and 0.01 levels of probability, respectively. NS = nonsignificant.

the heaviest bolls at 5.78 g and 5.65 g, respectively, while DP444 and DP555 produced the lightest bolls at 5.14 g and 5.08 g, respectively. In the interior row, the same ranks were observed — SG215 and ST4892 were heaviest, and DP555 and DP444 were lighter. Boll weight in the exterior row was significant among spacings. The 8-cm spacing had the lightest boll. The 15-cm and 23-cm spacings had the next lightest bolls but were not different from one another. The 30-cm spacing produced the heaviest bolls. In the interior row, boll weights for the 15-, 23-, and 30-cm spacings were not different from one another, but they were different from the 8-cm spacing.

In 2004, boll weight was not significant among cultivars in the exterior row but was significant in the interior row for both cultivar and spacing. In the interior row, ST4892 and SG215 produced significantly heavier bolls than DP444 and DP555.

In the exterior row for 2004, bolls were significantly heavier in the 30-cm spacing. In the interior row, boll weights were similar for the 15-cm and 23-cm spacing, significantly lighter for the 8-cm spacing, and significantly larger for the 30-cm bolls.

Constable (1991) reported that the size of bolls and particularly the location of bolls affect yield and earliness. We found that the wider the spacing, the heavier the boll. Longenecker et al. (1970) reported smaller bolls in their narrow-row plant spacings than in their wider plant spacings.

Lint yield — Lint yields for the exterior and interior rows were calculated on a land-acre basis. The exterior row (next to unplanted row) was calculated as a plant-two, skip-two row pattern for comparisons of the interior (solid) and exterior (skip) rows. There was a significant interaction between years for lint yield; however, no significant interaction between cultivar by plant spacing was detected either year.

In 2003, there were no significant differences among cultivar in the exterior or interior rows, and no differences among the spacings for the interior row

Table 5. Mean percent of first-position bolls for cotton cultivar and spacing on interior and exterior rows in 2004.[1]

	Main stem nodes (%)																
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
								Exterior row									
Cultivar																	
DP555	10.0	35.0	60.8	75.4	88.3	87.1	84.6	81.3	75.8	67.1	50.4	31.7	16.7	4.2	0.4	0.0	~
DP444	17.5	62.5	83.8	85.4	88.8	85.8	78.3	71.7	54.2	30.8	15.8	3.8	1.3	0.0	0.0	0.0	~
SG215	17.1	65.4	81.3	85.0	87.9	80.8	76.7	67.9	57.1	33.8	16.3	5.8	3.3	0.8	0.4	0.0	~
ST4892	15.0	54.6	77.1	84.6	88.8	88.8	85.8	79.2	61.7	45.8	25.4	14.2	7.1	1.3	0.0	0.4	~
F	NS	**	**	*	NS	NS	NS	*	**	**	**	**	**	**	NS	NS	
LSD(0.05)		10.3	8.3	7.0				10.4	10.6	8.9	8.0	6.9	5.6	2.3			
Spacing																	
8 cm	12.5	43.8	71.3	77.9	80.4	73.8	70.8	58.8	43.8	28.3	15.8	8.3	5.8	1.3	0.0	0.0	~
15 cm	10.0	54.6	77.9	85.0	92.1	90.0	78.3	75.0	60.0	42.5	25.4	7.5	4.2	1.3	0.0	0.0	~
23 cm	13.3	56.3	75.8	82.9	90.0	87.5	86.7	79.6	69.6	50.0	32.5	20.4	10.4	2.5	0.4	0.0	~
30 cm	23.8	62.9	77.9	84.6	91.2	91.3	89.6	86.7	75.4	56.7	34.2	19.2	7.9	1.3	0.4	0.4	~
F	NS	**	NS	NS	**	**	**	**	**	**	**	**	NS	NS	NS	NS	
LSD(0.05)		10.3			6.5	7.4	9.1	10.4	10.6	8.9	8.0	6.9					
								Interior row									
Cultivar																	
DP555	8.3	36.3	61.7	82.1	86.3	81.3	80.4	65.4	54.2	36.3	20.8	6.7	1.7	0.8	~	~	~
DP444	22.5	66.7	80.0	84.2	80.0	73.3	58.3	36.3	20.0	10.0	2.1	0.0	0.0	0.0	~	~	~
SG215	19.2	69.6	81.7	78.3	84.6	74.6	65.4	47.5	27.5	12.9	4.2	0.8	0.8	0.0	~	~	~
ST4892	11.7	53.8	75.0	75.4	77.9	76.3	70.4	52.9	27.9	13.8	3.8	1.3	0.0	0.0	~	~	~
F	**	**	**	NS	NS	NS	*	**	**	**	**	*	NS	NS			
LSD(0.05)	11.0	11.2	9.1				9.6	11.6	11.8	9.0	6.0	2.9					
Spacing																	
8 cm	9.2	43.3	65.4	65.4	68.8	63.8	50.0	30.0	18.8	8.8	3.3	0.4	0.4	0.4	~	~	~
15 cm	16.3	55.0	77.1	83.3	84.2	75.8	67.5	47.1	29.2	20.0	7.5	1.3	0.4	0.0	~	~	~
23 cm	14.6	61.3	77.1	86.3	87.1	77.1	77.1	55.4	34.2	20.8	10.0	3.3	0.8	0.0	~	~	~
30 cm	21.7	66.7	78.8	85.0	88.8	88.8	80.0	69.6	47.5	23.3	10.0	3.8	0.8	0.4	~	~	~
F	NS	**	*	**	**	**	**	**	**	**	NS	NS	NS	NS			
LSD(0.05)		11.2	9.1	8.2	8.0	9.0	9.6	11.6	11.8	9.0							

[1] *, ** = significant at the 0.05 and 0.01 levels of probability, respectively. NS = nonsignificant.

pattern for lint yield (Table 8). The 8-cm spacing produced significantly higher lint yields (1,448 kg per hectare) than the other within-row spacings. Yields in the 15-cm and 23-cm spacings were not different from each other, but they produced significantly more lint than the 30-cm spacing. A recent study in upland Mississippi with DP555 found no differences in lint yield for seeding rates planted from 2.5 to 6 seeds per 30 cm of row (Johnson et al., 2003).

In 2004, there was a significant difference between the exterior and interior rows for cultivars and spacings for lint yield. In the exterior row, DP555 and ST4892 yielded significantly more than DP444 and SG215. Interior row DP555 continued to be the highest yielder, producing significantly higher yields than the other cultivars. DP444 produced the lowest yield in both the exterior and interior rows.

In 2004, plant spacing significantly affected yield in both the exterior and interior rows. In the exterior row, the 8-, 15-, and 23-cm spacings yielded significantly more than the 30-cm spacing. In the interior row, the 8-cm spacing produced significantly higher yields. Lint yields were not different in the 15-cm and 23-cm spacings, but the 30-cm spacing produced yields significantly lower than the other spacings.

Yield and yield components are often affected by several interacting environmental components. Since many environmental components are not controllable, breeders must strive for plant populations that offer buffers to variable growing conditions.

Table 6. Mean percent of second-position bolls for cotton cultivar and spacing on interior and exterior rows in 2004.

	Main stem nodes (%)																
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Exterior row																	
Cultivar																	
DP555	7.5	30.0	45.4	56.7	59.6	51.7	48.3	34.6	21.3	7.5	5.0	0.8	1.3	0.4	~	~	~
DP444	11.7	44.6	56.7	55.4	48.8	37.1	21.3	7.5	2.5	0.8	0.0	0.0	0.0	0.0	~	~	~
SG215	12.5	43.8	53.3	51.7	44.2	35.0	22.1	10.4	4.6	2.5	1.3	0.4	0.0	0.0	~	~	~
ST4892	8.7	40.0	53.3	62.1	54.2	40.0	27.5	15.4	10.0	5.0	0.4	0.4	0.4	0.0	~	~	~
F	NS	NS	NS	NS	**	*	**	**	**	NS	NS	NS	NS	NS			
LSD(0.05)					10.9	9.7	7.2	6.2	5.7								
Spacing																	
8 cm	5.4	15.0	23.3	25.4	22.9	15.4	14.2	7.5	5.4	2.1	1.3	0.8	0.0	0.0	~	~	~
15 cm	6.7	35.8	50.8	54.2	49.2	37.5	24.2	12.1	5.4	2.1	0.8	0.0	0.0	0.4	~	~	~
23 cm	8.3	49.6	60.8	67.9	61.7	48.3	34.6	20.8	12.1	6.7	1.7	0.0	1.3	0.0	~	~	~
30 cm	20.0	57.9	73.7	78.3	72.9	62.5	46.3	27.5	15.4	5.0	2.9	0.8	0.4	0.0	~	~	~
F	**	**	**	**	**	**	**	**	**	*	NS	NS	NS	NS			
LSD(0.05)	8.4	9.5	9.4	8.9	10.9	9.7	7.2	6.2	5.7	3.3							
Interior row																	
Cultivar																	
DP555	4.2	22.5	34.6	41.3	36.3	23.8	18.8	10.0	2.5	0.8	~	~	~	~	~	~	~
DP444	8.3	31.7	38.3	32.9	20.8	10.4	4.6	0.4	0.0	0.0	~	~	~	~	~	~	~
SG215	8.3	36.3	40.4	35.0	25.8	10.8	6.7	1.7	0.8	0.0	~	~	~	~	~	~	~
ST4892	4.6	27.5	36.7	33.8	25.8	11.3	6.7	1.7	0.0	0.4	~	~	~	~	~	~	~
F	NS	*	NS	NS	*	**	**	**	NS	NS							
LSD(0.05)		8.8			8.4	7.4	5.9	3.1									
Spacing																	
8 cm	0.4	6.7	7.9	12.1	5.4	2.1	2.9	0.4	0.0	0.0	~	~	~	~	~	~	~
15 cm	2.9	23.8	29.6	28.3	22.1	9.2	6.7	1.7	0.8	0.0	~	~	~	~	~	~	~
23 cm	5.4	37.1	45.8	42.9	33.3	18.8	10.8	3.8	0.8	0.4	~	~	~	~	~	~	~
30 cm	16.7	50.4	66.7	59.6	47.9	26.3	16.3	7.9	1.7	0.8	~	~	~	~	~	~	~
F	**	**	**	**	**	**	**	**	NS	NS							
LSD(0.05)	6.1	8.8	8.7	9.2	8.4	7.4	5.9	3.1									

[1] *, ** = significant at the 0.05 and 0.01 levels of probability, respectively. NS = nonsignificant.

Table 7. Mean percent of third-position bolls for cotton cultivar and spacing on interior and exterior rows in 2004.[1]

	Main stem nodes (%)																
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
								Exterior row									
Cultivar																	
DP555	4.6	13.8	25.0	28.3	22.9	12.5	8.3	3.3	1.3	0.4	0.0	0.4	~	~	~	~	~
DP444	5.4	20.0	20.4	23.3	12.9	4.6	0.8	0.0	0.4	0.0	0.0	0.0	~	~	~	~	~
SG215	5.8	19.2	28.3	19.6	12.9	6.3	2.9	1.3	1.3	0.4	0.0	0.0	~	~	~	~	~
ST4892	2.9	18.3	25.0	27.5	18.8	7.1	6.7	3.3	0.8	0.4	0.0	0.0	~	~	~	~	~
F	NS	*	NS	NS	*	**	**	*	NS	NS	NS	NS					
LSD(0.05)		7.3			8.0	5.0	4.3	2.3									
Spacing																	
8 cm	0.8	1.7	5.8	5.4	4.2	2.5	0.8	0.8	0.4	0.0	0.0	0.0	~	~	~	~	~
15 cm	2.9	7.9	17.1	15.8	12.5	2.5	2.9	0.8	0.4	0.0	0.0	0.4	~	~	~	~	~
23 cm	3.8	24.2	29.2	34.2	17.9	8.8	7.5	2.9	0.8	0.4	0.0	0.0	~	~	~	~	~
30 cm	11.3	37.5	46.7	43.3	32.9	16.7	7.5	3.3	2.1	0.8	0.0	0.0	~	~	~	~	~
F	**	**	**	**	**	**	**	NS	NS	NS	NS	NS					
LSD(0.05)	5.5	7.3	7.9	8.2	8.0	5.0	4.3										
								Interior row									
Cultivar																	
DP555	2.5	7.9	7.5	8.3	3.8	0.8	0.8	~	~	~	~	~	~	~	~	~	~
DP444	2.1	6.3	7.9	4.6	2.1	0.4	0.0	~	~	~	~	~	~	~	~	~	~
SG215	3.8	12.1	12.1	7.5	2.1	0.8	0.4	~	~	~	~	~	~	~	~	~	~
ST4892	0.8	6.7	7.1	2.1	2.5	0.8	0.0	~	~	~	~	~	~	~	~	~	~
F	NS	**	NS	NS	NS	NS	NS										
LSD(0.05)		4.9															
Spacing																	
8 cm	0.0	0.4	0.4	0.8	1.7	0.0	0.0	~	~	~	~	~	~	~	~	~	~
15 cm	0.8	2.9	5.4	1.7	1.7	0.4	0.4	~	~	~	~	~	~	~	~	~	~
23 cm	2.9	10.8	10.0	5.8	2.9	0.0	0.8	~	~	~	~	~	~	~	~	~	~
30 cm	5.4	18.8	18.8	14.2	4.2	2.5	0.0	~	~	~	~	~	~	~	~	~	~
F	*	**	**	**	NS	*	NS										
LSD(0.05)	3.5	4.9	4.8	4.6		1.7											

[1] *, ** = significant at the 0.05 and 0.01 levels of probability, respectively. NS = nonsignificant.

Table 8. Mean lint percentage, boll weight, and lint yield for four cotton cultivars grown in four-planted, two-skip row patterns with four different within-row plant spacings in 2003 and 2004.[1]

	2003			2004		
	Lint percentage	Boll weight	Lint yield	Lint percentage	Boll weight	Lint yield
	%	g	kg/ha	%	g	kg/ha
			Exterior row next to skip			
Cultivar						
DP555	44.91	5.08	1458	47.36	4.50	894
DP444	41.34	5.14	1211	42.91	4.28	662
SG215	40.82	5.78	1344	42.50	4.80	755
ST4892	42.23	5.65	1374	44.34	4.68	822
F	**	**	NS	**	NS	**
LSD(0.05)	0.58	0.12		0.42		90
Spacing						
8 cm	42.09	5.19	1448	44.39	4.46	801
15 cm	42.26	5.41	1334	44.48	4.52	764
23 cm	42.06	5.49	1363	44.20	4.54	849
30 cm	42.88	5.56	1241	44.06	4.73	720
F	*	**	**	NS	*	*
LSD(0.05)	0.58	0.12	70		0.17	90
			Interior row (solid)			
Cultivar						
DP555	45.86	4.89	1647	48.61	4.19	1218
DP444	41.83	4.86	1422	43.52	4.08	859
SG215	41.55	5.44	1509	42.85	4.66	1032
ST4892	42.85	5.37	1531	44.65	4.43	1009
F	**	**	NS	**	**	**
LSD(0.05)	0.44	0.15		0.38	0.12	52
Spacing						
8 cm	43.07	4.89	1526	45.22	4.17	1110
15 cm	42.92	5.13	1534	44.84	4.31	1027
23 cm	43.04	5.25	1568	44.79	4.37	1045
30 cm	43.05	5.28	1482	44.78	4.50	937
F	NS	**	NS	NS	**	**
LSD(0.05)		0.15			0.12	52

[1]Data were collected from an interior row and exterior row next to skip. *, ** = significant at the 0.05 and 0.01 levels of probability, respectively. NS = nonsignificant.

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