Published March, 1990

Effectiveness of Fruiting Sites in Cotton: Yield

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ABSTRACT

The fruiting sites at which cotton, *Gossypium hirsutum* L., plants set bolls that are harvested influence how well the plants tolerate insects. The objective of this research was to determine the fruiting patterns of eight cultivars of cotton in terms of fruiting sites of harvestable bolls when planted in a conventional pattern of rows spaced 1-m apart with a plant population of approximately 95 000 plants ha^{-1} for 2 yr in Mississippi. Descriptive terms are defined as follows: (i) sympodium—a fruiting branch; (ii) monopodium—a vegetative branch; (iii) node—the place on the main stem where sympodia or monopodia arise, we numbered the nodes beginning with the cotyledeonary node as number one; (iv) position—refers to the order in which buds (potential bolls) are produced on a sympodium branch; and (v) fruiting site—any specific node-position combination. Cultivars compared and their release dates were: Stoneville 213, 1962; Stoneville 506, 1980; Stoneville 825, 1979; Tamcot CAMD-E, 1979; Deltapine 50, 1984; McNair 235, 1975; DES 119, 1986; and Deltapine 20, 1985. Bolls at position one on sympodial branches produced 66 to 75% of total yield; those at position two produced 18 to 21%; all other positions on sympodial branches produced from 2 to 4% of total yield. Monopodial branches produced from 3 to 9% of the total yield. Sympodial branches from Nodes 9 through 14 produced the bulk of the lint in all cultivars. Distribution of lint over sympodia among cultivars was significantly different for positions one and two, with the newer, early maturing cultivars producing significantly more lint from sympodial branches at Nodes 6 through 8 than the older cultivar Stoneville 213. Tamcot CAMD-E, McNair 235, and Deltapine 20 also produced less lint on monopodial branches than Stoneville 213. This research provides valuable information needed to more effectively manage the production of the newer, early maturing cultivars of cotton presently being grown in the mid-South.

THE TIME that cotton cultivars remain in commercial production is changing. In 1972 two cultivars, Stoneville 213 (ST 213) and Deltapine 16, accounted for over 50% of the US acreage; however, by 1986, it required six Stoneville cultivars and 13 Deltapine cultivars to account for 43% of the acreage (Bridge and McDonald, 1987). This indicates the newer cultivars are planted on fewer hectares and/or are planted in a more narrow geographic range than previously. Cultivars are changing in the direction of earlier, more rapid maturing types. Major shifts towards the early cultivars began in the early 1970s and was virtually complete by 1987. In the Mississippi Delta, these new cultivars coupled with improved management practices have reduced the time required to grow a crop by 2 to 3 wk, while at the same time yields have increased (Bridge and McDonald, 1987).

The newer cultivars are setting bolls in a different time frame than the older cultivars. From our research in developing strains tolerant to tobacco budworm, *Heliothis virescens* (Fab.), we observed that the rate of boll set and number of bolls on a plant influenced how well it tolerated tobacco budworm. For example, the early season, fast boll setting cultivar Tamcot-CAMD-E (CAMD-E) required higher levels of infestation with tobacco budworm than ST 213 and it had to be infested over a longer time period in order to receive the same amount of damage; i.e., it was more tolerant of tobacco budworm than ST 213 (Jenkins et al., 1986; McCarty et al., 1986).

Given these situations, we examined the fruiting patterns of eight cultivars as a guide to further research in host plant resistance. This should also provide valuable information relative to management of these cultivars to optimize production and profits. The objective of this research was to determine the fruiting patterns in terms of fruiting sites of harvestable bolls of eight cultivars of cotton when managed in a conventional pattern of rows spaced 1-m apart.

MATERIALS AND METHODS

Descriptive terms used in this manuscript are defined as follows:

1. Sympodium—a fruiting branch.
2. Monopodium—a vegetative branch.
3. Node—the place on the main stem where sympodia or monopodia arise. We numbered the nodes beginnning with the cotyledonary node as number one.
4. Position—refers to the order in which buds (potential bolls) are produced on a sympodium branch. In this manuscript we refer to bolls as being produced at positions one, two, or three. Bolls with position numbers greater than three were classified as three. Thus, the term position is not branch specific; for example, position one refers to the first potential boll on all sympodia.
5. Fruiting site—specific node-position combination.

The release dates for the eight cultivars used in this study were as follows: ST 213, 1962; Stoneville 506 (ST 506), 1980; Stoneville 825 (ST 825), 1979; CAMD-E, 1979; Deltapine 50 (DPL 50), 1984; NcNair 235 (MC 235), 1975; DES 119, 1986; and Deltapine 20 (DPL 20), 1985. The line ST 213 is representative of the types grown in the 1970s. The Line CAMD-E is an early season cultivar developed for and adapted to the Coastal Bend area of Texas. The others are current early season cultivars adapted to the mid-South and the Mississippi Delta growing area.

The cultivars were planted inn plots with two rows, 14-m long spaced 1-m apart. We thinned plots to approximately 95 000 plants ha^{-1}. Cultivars were planted on a Leeper silty clay loam (fine, montmorillonitic, nonacid, thermic Vertic Haplaquept) soil in 1987 and on a Marietta sandy clay loam (fine-loamy, siliceous, thermic Fluvaquentic Eutrochrept) soil in 1988. Planting dates were on 4 May 1987 and 28 Apr. 1988 with emergence being 11 May 1987 and 5 May 1988. Plots were fertilized with 140 kg N ha^{-1} each year. In both years Terrachlor super-x[1] (5-Ethoxy-3-trichloromethyl-1,2,4-thiadiazole) at the rate of 11.2 kg ha^{-1} and aldicarb [2-methyl-2-(methylthio) propionaldehyde *O*-(methylcarbamoyl) oxime] at 0.34 kg a.i. ha^{-1} were applied in furrow at planting. In 1987, the N was applied as 56 kg preplant and 73 kg sidedress at first bloom. In addition, two applications of 5.45 kg each from urea were applied as a foliar spray on

USDA-ARS, Crop Science Res. Lab., P.O. Box 5367, Mississippi State, MS 39762. Contribution of the USDA-ARS in cooperation with Mississippi Agric. and Forestry Exp. Stn. Received 24 Mar. 1989. *Corresponding author.

Published in Crop Sci. 30:365–369 (1990).

[1] Names of products are included for the benefit of the reader and do not imply endorsement or preferential treatment by USDA.

14 and 21 July. In 1988, N was applied 56 kg preplant and 84 kg sidedress at first bloom. A full season insecticide program was used to control all insects and mite pests. Preplant levels of N were measured in the soil before planting. In 1987, the residual levels of N at 15-cm intervals of depth were 13, 8, 8, 11, 12, and 11 kg ha^{-1}. In 1988, these levels were 16, 18, 12, 12, 0, and 0. In 1987, we applied two irrigations, flooding the soil to field capacity each time. These were applied on 15 and 31 July. In 1988, we applied 10 cm of irrigation by drip in a 48-h period beginning 30 June. Rainfall was 112 and 7 mm in June 1987 and 1988, and 34 and 166 mm for July 1987 and 1988, respectively.

At first bloom we marked a 3.07-m section in one row of each two-row plot to be used for mapping in the fall. When all bolls were open, we removed each plant in the marked section and harvested the bolls by hand, keeping each fruiting site separate for the 3.07-m section. The number of bolls harvested at each fruiting site was recorded with the cotyledonary node counted as Node 1. The number of bolls and the weight and cotton produced at each fruiting site in the marked section was determined. A few plants in each section had aborted terminals, and thus could not be mapped accurately. We harvested all the bolls on these and recorded the number and weighed the cotton. Yield and boll numbers from aborted plants were then distributed across fruiting sites based upon the percentage of yield or of bolls at each fruiting site from mapped plants in the plot. Thus, data from aborted plants did not influence yield distribution across fruiting sites. All cotton on the monopodial branches was harvested as one position; however, the number of bolls was recorded. This gave an accurate accounting of all cotton in terms of number of bolls and weight of cotton produced in each plot. We harvested 50-boll samples from the nonmarked row of each pair for lint fraction.

The lint percentages from these 50-boll samples were used to convert seed cotton yields into lint yields for each cultivar. Lint percentage varies by fruiting site on the plant; however, due to the small amount of seed cotton produced at some fruiting sites it was not possible to obtain an accurate lint percentage for every positon. Rather than introduce this variability into the data, we chose to use the lint percentage for each cultivar based upon the 50-boll sample data. This allows the cultivar specific lint percentages to enter into the lint yield data, yet produces only a small bias across positions within a cultivar. This bias is less, however, than it would be if we had used lint percentages from every position since many of these would not have been accurately measured due to the small amount of seed cotton produced at these positions. The net result is to slightly overestimate the lint yield from positions two and three and from nodes above 15. We believe this is an acceptable manner in which to handle these data.

The plots were grown in a randomized complete-block experiment with six replications. We analyzed the data over years with a mixed model (random years, fixed cultivars and positions), as described by McIntosh (1983). The data are presented as 2-yr means by fruiting site and cultivar.

RESULTS AND DISCUSSION

It was apparent from our mapping and data collection that all fruiting sites on the plant did not make equal contributions to yield in any of the cultivars. Differences were apparent in yield, boll size, and percent of plants with a boll and fiber properties. This manuscript will discuss only lint yield. The general fruiting pattern for Delta type cotton is to have about 3- and 6-d vertical and horizontal fruiting intervals, respectively. Under good growing conditions plants usually have 20 to 24 vertical nodes produced during a growing season. The first sympodial (fruiting) branch usually occurs at Node 5 to 7 and sympodia continue to arise at each vertical node for the remainder of the growing season. Thus, a plant will produce about 16 to 18 symbodial branches with 2 to 5 fruiting positions each. From approximately 48 fruiting sites on the sympodial branches, only a few will produce a harvestable boll on any given plant. The plant also produces 1 or 2 monopodial (vegetative) branches at a plant density of 95 000 ha^{-1} that may bear fruit near mid-season.

An analysis of variance of the 2-yr total lint yield of cotton indicated no significant difference between cultivars or years nor was the year × cultivar interaction significant. Lint yields ranged from 962 to 1198 kg ha^{-1} based on 2-yr means with CAMD-E being the lowest yielding cultivar and DES 119 being the highest.

When yield was considered by fruiting sites within each cultivar the analysis of variance indicated a significant fruiting site effect, and year × fruiting site interaction.

There was a significant interaction for year × fruiting site within each cultivar except DPL 20. The general nature of the fruiting site × year interaction was such that the cultivars in 1988 produced less yield on monopodial branches and in the important Nodes 9 through 14 and more at the higher nodes than in 1987. When cumulative yield data curves for each cultivar and for years were constructed, it was apparent that most of the cultivars in 1988 began to fall behind the respective cultivar in 1987 at about Node 10, although after Node 14 the plants in 1988 matured more bolls than in 1987. We attributed this to weather related factors that differed between the two years (Jenkins et al., 1989, unpublished data). When plants mature less fruit at lower nodes, they are fruiting later in the season at a time which is less desirable from a climatic standpoint.

Based upon 2-yr means the percentage of total lint produced from all first position bolls ranged from 66 to 75% across cultivars. The percentage of the total lint produced on monopodial branches ranged from 3 to 9%. Bolls on monopodial branches are usually at the first position. Lint produced from all second position bolls produced from 18 to 21% of the total yield. Bolls at all other positions on the plants produced from 2 to 4% of the total yield.

Analysis of variance of yield for positions one, two, and three (yield × positions summed across nodes) revealed no significant differences between cultivars or years, nor was the cultivar × years interaction significant; however, there were significant differences between positions. Averaged over years and cultivars, the yields from positions one, two, three, and monopodial were 774, 220, 34, and 69 kg ha^{-1}, respectively.

When the data were summarized for total yield by nodes there were significant differences among nodes as expected (Table 1). LSDs at the 0.05 level were computed by nodes so that cultivars could be compared for yield by nodes. For each cultivar, Nodes 9 through 14 were the largest contributor to yield. Nodes 6 through 8 were more important on some cultivars than others. The new cultivars that fruit earlier tended to have more yield on Nodes 6 through 14, than ST 213, the oldest cultivar in this study. The Lines DPL 50, MC 235, DES 119, and DPL 20 produced signif-

Table 1. Lint yields by node for eight cultivars of cotton averaged over 2 yr.

NODE	ST 506	ST 213	ST 825	CAMD-E	DPL 50	MC 235	DES 119	DPL 20	LSD 0.05	F
	kg ha^{-1}									
21	0.6	2.9	0.6	5.7	1.5	1.1	0.8	1.6	4.0	NS
20	5.0	11.2	3.0	7.5	2.4	3.7	2.9	6.1	10.4	NS
19	12.9	21.7	11.6	15.6	9.7	6.3	9.0	9.4	20.2	NS
18	19.8	35.4	29.7	23.2	19.5	14.8	16.4	29.3	22.0	NS
17	35.6	45.3	43.2	34.7	32.5	29.8	26.6	43.0	26.7	NS
16	59.1	61.1	72.9	49.5	50.8	52.0	45.0	61.2	20.7	NS
15	79.4	79.2	93.6	64.0	69.1	73.5	77.6	100.7	22.5	*
14	99.2	90.7	112.3	70.2	84.0	85.5	98.7	105.7	25.6	*
13	108.2	89.2	111.3	88.7	96.0	92.5	114.6	121.5	29.9	NS
12	117.6	96.1	109.7	83.3	96.4	102.1	134.8	127.5	27.7	*
11	114.3	105.5	124.2	103.8	106.6	108.4	129.6	127.2	32.5	NS
10	109.9	109.4	128.9	98.9	102.3	120.0	125.9	105.7	46.4	NS
9	97.0	102.6	107.4	99.7	120.9	119.3	118.2	105.9	29.4	NS
8	77.0	61.0	76.9	79.5	120.0	134.0	106.6	96.6	29.8	*
7	46.6	25.6	38.7	58.9	76.8	69.9	69.5	68.1	24.6	*
6	9.6	3.7	5.9	37.3	25.1	19.9	23.2	43.0	17.5	*
Mono†	83.7	88.1	80.4	41.5	79.3	41.6	99.0	37.6	38.0	*
Total	1075.5	1028.7	1150.3	962.0	1092.9	1074.4	1198.4	1190.1	191.0	NS
LSD (0.05)	47.7	80.6	55.8	40.7	50.1	44.9	70.5	25.1		
F	*	NS	*	*	*	*	*	*		

* Significant at the 0.05 level. NS = not significant.
† Monopodial branch.

icantly more yield from Nodes 6 through 8 than ST 213. The Line CAMD-E produced significantly more yield from Nodes 6 and 7 than ST 213. At Node 12, DES 119 and DPL 20 produced significantly more lint than ST 213. At Nodes 9, 10, 11, 13, and above Node 15 no significant differences were detected among cultivars (Table 1).

Considering all cultivars, the newer short season cultivars matured more fruit early, regardless of the year, when compared to ST 213, the older cultivar. Researchers have shown that modern cultivars make an earlier transition from vegetative to reproductive growth and may have a better coordination of assimilatory capacity with reproductive sink activity as well as making more reproductive development during the time when maximal leaf mass and area are present (Wells and Meredith, 1984a,b). What these researchers called modern cultivars only included two released as late as those in our study (ST 213 and ST 825). Our study indicates that breeders have again made major shifts in earliness and yield. This has many implications for crop management. These data should be useful for managment decisions by growers who are now growing the new cultivars.

Data are presented as 2-yr means in Tables 2 through 4, which show lint yields for each cultivar. The LSDs at $P = 0.05$ were calculated for each fruiting site across cultivars and by positions within cultivars. The data should be useful for providing cultivar specific calibration factors and fruiting site specific data for the GOSSYM-COMAX system now being used in cotton production. At position one where most of the lint is produced, cultivars were significantly different at Nodes 6 through 8, and Node 12 and 15 (Table 2). There were also significant differences between cultivars in lint produced on monopodial branches. At position two all cultivars fruited similarily and produced 202 to 249 kg ha^{-1} of lint (Table 3). Very little lint was produced from position three in any cultivar (Table 4).

Kerby et. al. (1987) presented mapping data for the

Table 2. Lint yields by node for position one for eight cultivars of cotton averaged over 2 yr.

NODE	ST 506	ST 213	ST 825	CAMD-E	DPL 50	MC 235	DES 119	DPL 20	LSD (0.05)	F
	kg ha^{-1}									
21	0.6	2.9	0.6	5.4	0.6	1.1	0.8	1.6	3.3	NS
20	4.8	10.8	3.0	7.2	2.4	3.8	2.9	6.0	9.8	NS
19	12.2	20.5	10.6	13.3	8.9	5.5	7.7	9.1	19.2	NS
18	17.6	32.0	27.4	19.7	18.7	14.2	14.2	27.4	18.0	NS
17	33.1	36.0	39.3	27.7	29.7	27.0	24.5	40.5	13.5	NS
16	51.7	51.7	56.3	42.9	42.0	45.6	38.9	53.2	16.1	NS
15	66.8	66.6	75.2	49.7	57.6	64.5	64.5	83.3	18.7	*
14	81.1	75.1	87.7	60.5	69.8	72.4	82.3	86.6	20.1	NS
13	77.9	71.8	87.4	67.3	78.9	76.1	82.1	97.0	21.2	NS
12	88.8	76.9	86.7	67.2	75.2	76.0	102.6	95.2	20.5	*
11	82.0	79.3	89.2	81.4	77.7	87.4	90.5	85.9	23.2	NS
10	73.6	77.6	79.9	73.6	72.5	89.3	82.8	70.4	37.9	NS
9	62.4	72.8	65.1	67.7	87.3	81.1	68.5	66.2	45.7	NS
8	47.9	36.7	49.4	41.2	83.5	96.6	63.2	62.6	22.5	*
7	31.0	17.3	26.6	36.1	53.8	53.5	51.4	46.5	19.7	*
6	7.6	2.3	5.2	25.1	18.2	14.9	17.7	33.7	13.4	*
Mono†	83.7	88.1	80.4	41.5	79.3	41.6	99.0	37.6	37.6	*
Total	822.8	818.4	870.0	727.5	856.1	850.6	893.6	902.8		
LSD (0.05)	41.5	62.5	50.2	36.5	36.8	41.4	62.4	21.8		
F	*	NS	*	*	*	*	*	*		

* Significant at the 0.05 level. NS = not significant.
† Monopodial branch.

Acala SJ-2 cultivar. There are striking similarities and also differences between their data set and ours. Their study was conducted in the irrigated San Joaquin Valley of California, which contrasted with our location in Mississippi. Both studies found most of the yield came from nodes in the middle of the plant (generally 9–14). In the California study, lint was distributed across fruiting positions as 58.1, 21.4, 5.6, and 14.7% for fruiting positions one, two, three, and monopodial branches. In our study, lint was distributed 71, 20, 3, and 6%, respectively, across fruiting positions one, two, three, and monopodial branches. We thus found a greater amount of the lint at position one, and less on position three and the monopodial branches than in the California study; however, Kerby et al. (1987) had a plant population of 82 000 plants ha^{-1} where we had a plant population of 95 000 plants ha^{-1}. Mauney (1986) reported that about 80% of the total yield was produced at fruiting positions one and two on the sympodial branches. We obtained about 90% in our Mississippi study (Tables 1–4). Plotting our data showed that from Nodes 6 through 11 we had increasing amounts of lint produced on each sympodial branch and after Node 11 we had decreasing amounts of lint produced on each sympodial branch. These peak values for position one were Node 11 and for position two Node 9. Similarily, the California study showed that Node 9 to 10 was the peak for position one and Nodes 8 to 10 for position two. In the California study the cotyledon node was counted as zero, whereas we counted it as one. Thus, the two dissimilar types of cotton are fruiting similarly in this respect.

Bridge and McDonald (1987) indicated that with today's cultivars and improved management practices the time required to produce a crop of cotton had been shortened considerably. Their estimates varied from 20 to 45 d at various locations. They attributed the earlier harvests to improved management practices and to the development of earlier maturing cultivars. Our data support part of this as being due to earlier maturing cultivars. At Nodes 6, 7, and 8 (flowering at position one about July 1, 3, and 6), DPL 20 had twice as much lint mature on the plant as ST 213. At any given node during weeks two and three of flowering DPL 20 and 100 to 200 kg more lint ha^{-1} maturing on the plant than ST 213. Thus, 6 to 10 d of the earlier

Table 3. Lint yields by node for position two for eight cultivars of cotton averaged over 2 yr.

NODE	ST 506	ST 213	ST 825	CAMD-E	DPL 50	MC 235	DES 119	DPL 20	LSD 0.05	*F*
	kg ha^{-1}									
21	0.0	0.0	0.0	0.4	1.0	0.0	0.0	0.0	1.0	NS
20	0.3	0.5	0.0	0.3	0.0	0.0	0.0	0.0	0.5	NS
19	0.7	1.1	1.0	2.3	0.9	0.8	1.2	0.2	1.9	NS
18	2.1	3.2	2.0	3.5	0.8	0.5	1.5	1.7	5.6	NS
17	2.5	8.4	3.9	6.4	2.9	2.9	1.8	2.5	9.5	NS
16	7.4	9.4	15.7	5.8	7.8	5.7	6.1	6.7	6.5	NS
15	11.7	11.6	15.7	12.1	10.9	9.0	11.5	17.0	15.3	NS
14	16.0	15.3	22.8	9.1	13.3	12.7	13.6	18.6	15.4	NS
13	28.0	15.8	19.4	18.0	15.7	14.9	29.9	23.0	10.1	*
12	24.9	17.3	20.1	14.5	17.9	24.2	25.6	27.2	11.2	NS
11	28.1	21.3	27.1	17.3	24.1	16.5	32.2	33.4	12.9	NS
10	31.7	26.7	40.3	21.8	26.4	27.7	38.1	30.2	12.2	NS
9	29.7	25.3	33.7	28.5	29.9	34.3	40.9	34.8	14.4	NS
8	24.0	20.3	22.1	31.8	31.4	32.6	34.2	27.9	13.0	NS
7	11.4	7.4	8.4	19.1	21.3	15.4	14.1	16.3	8.7	*
6	1.2	6.4	0.7	11.7	6.2	5.0	4.2	9.3	6.7	*
Total	219.7	190.0	232.9	202.6	210.5	202.2	254.9	248.8		
LSD (0.05)	14.7	20.7	8.4	14.9	17.4	8.7	17.1	8.5		
F	*	NS	*	*	*	*	*	*		

* Significant at the 0.05 level. NS = not significant.

Table 4. Lint yields by node for position three for eight cultivars of cotton averaged over 2 yr.

NODE	ST 506	ST 213	ST 825	CAMD-E	DPL 50	MC 235	DES 119	DPL 20	LSD 0.05	*F*
	kg ha^{-1}									
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
19	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.1	NS
18	0.0	0.2	0.3	0.0	0.0	0.0	0.7	0.2	0.8	NS
17	0.0	1.0	0.0	0.6	0.0	0.0	0.3	0.0	1.4	NS
16	0.0	0.0	1.0	0.9	0.6	0.7	0.0	1.3	1.4	NS
15	1.0	1.0	2.7	2.2	0.6	0.0	1.5	0.3	3.3	*
14	2.1	0.3	1.8	0.6	0.8	0.5	2.9	0.6	2.2	NS
13	2.3	1.6	4.5	3.4	1.3	1.5	2.6	1.6	3.6	NS
12	4.0	1.9	2.9	1.7	3.3	1.9	6.7	5.1	4.9	NS
11	4.3	4.8	7.9	5.1	4.9	4.5	6.9	7.9	5.4	NS
10	4.6	5.1	8.6	3.5	3.5	3.0	5.0	5.1	4.7	NS
9	5.0	4.4	8.6	3.6	3.7	4.0	8.7	5.0	5.1	NS
8	5.1	4.0	5.4	6.5	5.1	4.7	9.2	6.1	4.8	NS
7	4.2	1.0	3.7	3.8	1.7	1.0	4.0	5.3	3.9	NS
6	0.8	0.0	0.0	0.5	0.7	0.0	1.2	0.0	1.2	NS
Total	33.4	25.3	47.4	32.4	26.2	21.8	49.9	38.5		
LSD (0.05)	3.3	4.1	3.7	5.6	2.6	2.7	4.0	3.2		
F	*	NS	*	NS	*	*	*	*		

* Significant at the 0.05 level. NS = not significant.

maturity can be attributed to genetic gains in earliness in the newer cultivrs. The remainder or earliness, reported by Bridge and McDonald (1987) to be 2 to 3 wk, should probably be attributed to other changes in management of cotton production.

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