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Changes in the Cellular Structure of the Cotton Peduncle Related to Water Transport and Boll Opening[1]

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ABSTRACT

Cell number per row and radial width of cells, walls, and cell lumina were measured in rows of cells containing vessels, tracheids, and parenchyma cells in cross sections of 7- and 42-day-old cotton (*Gossypium hirsutum* L.) peduncles to ascertain changes reducing water entry into the boll. Three positions in both ages of peduncle: (A) close to the stem, (B) midway between the boll and the stem, and (C) near the boll, were compared to relate anatomical and morphological characters of the peduncle to decreased water supply to older cotton bolls. In the 42-day-old peduncle close to the boll no rows containing only vessels were seen. Vessel rows were seen at this level of the 7-day-old peduncle, indicating that some cells of the vascular cambium after day 7 ceased producing rows of cells containing only vessels and shifted to tracheid production. Tracheid rather than vessel production would presumably reduce water transporting capacity in older peduncles due to the smaller lumen in tracheids. Overall, there was more vascular cross-sectional area for water conduction in 42-day-old peduncles than in 7-day-old ones.

Additional index words: *Gossypium hirsutum*, Boll opening, Boll decay, Boll rot, Water movement, Cellular structure.

Boll rots of cotton (*Gossypium hirsutum* L.) are caused by many species of microorganisms originating in the soil and contaminating the surface of the fruit during all stages of its development (5). One of the factors influencing possible microbial entry into the boll is the time of capsule dehiscence. If the time interval between the appearance of cracks in the sutural parenchyma of a boll and the complete opening of the boll could be reduced and the boll induced to open rapidly, the lint would dry rapidly. There would also be less time for microbial invasion and decay of the moist, sugar-containing lint. Once the carpel tissues have dried, they are a poor food source for rot-inducing organisms and further minimize the probability of boll rot.

Bolls, unlike leaves, do not abscise but rather are held on the plant. Water destined for the bolls is apparently withheld as the bolls approach maturity; the carpel walls dry, stresses are generated which pull the carpel walls apart, and the lint fluffs out exposing the seed. A recent report describes the vascular anatomy of the carpel wall relative to boll opening (6). Morris (3) related decreased water supply entering the mature boll to formation of tyloses in the xylem elements of the abscission zone of the peduncle. Both Morris (4) and Gubanov (1) related boll

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opening to decreased water entering the boll and subsequent drying of carpellary tissues. Pinckard and Baehr (5) have discussed boll opening as it relates to boll decay.

Because boll opening apparently is directly related to decreased water flow into the boll, followed by drying of carpel tissues, we looked for morphological or anatomical changes in the vascular tissue of the peduncle having a possible influence on water flow to the boll. These changes could include decreased cell number, reduced cell size, reduced cell lumen size, different cell types present, or increased cell occlusions. Fewer cells, reduced lumen size, and presence of cell occlusions would result in decreased water flow into the boll. Formation of tracheids, which have smaller lumina than vessels, rather than vessels would also presumably result in decreased water flow into the boll. Finally, if anatomical changes could not be found, decreased water flow could be a physiological response. Three areas of the peduncle were investigated in an attempt to locate the region showing the earliest changes indicating reduced capacity for water conduction.

MATERIALS AND METHODS

Seven- and 42-day-old bolls of cotton, cv. Delta and 'Pine Land-26' (DPL 16), were collected at the Red River Valley, Louisiana Branch Exp. Stn. Bolls were frozen for 24 hours until peduncle samples could be removed and fixed in formalin-acetic acid-alcohol. These tissues were dehydrated in ethanol-n-butanol and embedded in Paraplast.

The embedded tissue was sectioned at 10 μm with a rotary microtome and stained with a combination of safranin and fast green (2). Three regions in the peduncle were examined in both 7- and 42-day-old peduncles as follows: (A) signifies a position close to the stem, (B) midway between boll and stem, and (C) close to the boll (Fig. 1A). Cell measurements were made in the radial plane at a magnification of 420× using an ocular micrometer.

Cell rows were counted whenever a row of xylem cells could be followed from the pith to the cambium. A row not extending from the pith to the cambium was classified as incomplete. Approximately one-third of all xylem cells of a cross section were counted. Counts were made at three locations in each aged peduncle (Fig. 1A).

RESULTS

In cell rows containing both tracheids and vessels, at all three peduncle regions studied, there were more cells per row in the 42-day-old boll than in the 7-day-old boll (Table 1). For both peduncle ages, region A, nearest to the stem, contained the most cells per row (Fig. 1B, 2A). The number decreased through region B, halfway between the stem and boll (Fig. 1C, 2B), and the lowest number of cells per row was found in the region of the peduncle close to the boll, region C (Fig. 1D, 2C). The average radial cell diameter in xylem rows containing both tracheids and vessels decreased from a high in region A to a low in region C in both 7- and 42-day-old peduncles. Little variation occurred in wall thickness in the three regions of both ages of peduncles. The average lumen width values, measured in the radial plane, followed the average radial diameter measurements in the two ages of peduncles.

No rows containing only vessels were seen in the 42-day-old peduncle at region C (Fig. 2C). All other 7-and 42-day-old peduncle regions contained rows with vessels only. Since vessels are wider than tracheids and have a wider lumen than tracheids, identification of a tracheid as a vessel is most unlikely. Region C of the 42-day-old boll contained no complete rows in which all cells were large enough to be vessels.

In the 7-day-old peduncle there was a decrease in number of cells per row from region A (Fig. 1B) to B (Fig. 1C) but little difference between regions A (Fig. 2A) to B (Fig 2B) in the 42-day-old peduncle. The average radial width of cells decreased from region A to C in the 7-day-old peduncle but increased from A to C in the 42-day-old peduncle.

Average wall thickness in these cells showed little variation. The values for average lumen width reflected the changes seen in average radial width of these cells.

Parenchyma cell rows were seen only at region A, close to the stem, in both 7- and 42-day-old peduncles (Fig. 1B, 2A). The average number of cells per row increased from the 7- to 42-day-old peduncles (compare Fig. 1B and 2A, 1C and 2B, 1D and 2C). The average radial width, wall thickness, and lumen width were similar for the two ages. Some of these rows of parenchyma cells extended through the phloem. Some 7- and 42-day-old

Table 1. Average number of cells in the vascular rows, radial cell width, wall thickness, and lumen width in relation to the age and the position in the peduncle.

Age of peduncle	Peduncle region	Average no. cells/ row	Average cell radial width	Average wall thickness	Average lumen width
days			μm		
Rows from pith to cortex containing both tracheids and vessels					
7	A†	8.75	2.04	0.34	1.35
42	A	15.63	2.11	0.32	1.47
7	B‡	7.40	2.02	0.36	1.32
42	B	12.78	1.71	0.37	0.99
7	C§	7.08	1.82	0.36	1.11
42	C	11.53	1.89	0.34	1.23
Rows from pith to cortex containing vessels only					
7	A	10.50	1.74	0.31	1.14
42	A	16.00	2.06	0.34	1.36
7	B	7.73	2.22	0.33	1.56
42	B	11.60	1.94	0.41	1.13
7	C	7.70	1.89	0.34	1.21
42	C	No rows of vessels present			
Rows from pith to cortex containing tracheids only					
7	A	8.96	1.58	0.32	0.98
42	A	16.27	1.62	0.31	1.00
7	B	7.16	1.58	0.31	0.97
42	B	11.26	1.42	0.36	0.73
7	C	5.46	1.49	0.29	0.90
42	C	10.18	1.54	0.32	0.93
Incomplete rows					
7	A	3.70	1.33	0.35	0.69
42	A	5.71	1.01	0.34	0.48
7	B	3.96	1.33	0.37	0.65
42	B	4.80	1.07	0.38	0.43
7	C	3.00	1.13	0.32	0.57
42	C	4.88	1.23	0.33	0.60
Rows from pith to cortex containing parenchyma cells only					
7	A	5.17	2.40	0.27	1.87
42	A	11.36	2.46	0.27	1.90

† Peduncle cross section near stem.
‡ Peduncle cross section halfway between stem and boll.
§ Peduncle cross section near boll.

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parenchyma cells contained a dense precipitate. A similar precipitate was seen in vascular branches in the bolls in the 42-day-old peduncle.

In cell rows containing only tracheids, the average cell number per row decreased in both 7- and 42-day-old peduncles from region A to C. The average radial width of tracheids decreased in the 7-day-old peduncle from region A to C. The 42-day-old peduncle showed a decrease in average radial width of tracheids from region A to B but an increase from B to C. There was little variation in wall thickness in these cells in both 7- and 42-day-old peduncles. The average lumen width showed a variation similar to that of the average radial cell width.

These data are presented in Table 1.

DISCUSSION

The increase in the average number of cells from a 7-day-old peduncle to a 42-day-old peduncle was expected because of additional vascular cambial divisions, which occurred in the 42-day-old peduncle. Since the older peduncle regions, nearest to the stem, produce more cells than the younger peduncle regions, near the boll base, the presence of more cells per row in regions near the stem was also expected. These results rule out reduced cell number in decreasing water supply to older bolls. Increased cell numbers in 42- vs. 7-day region B rows overcome the decrease in cell and lumen width and result in increased conducting area in the 42-day peduncles at region B. Thus, reduced cell and lumen size are not involved in decreased water supply to older bolls.

Although plugging of xylem cells by tyloses would reduce water entry into the boll, large numbers of tyloses were not found in this investigation. A second possible mechanism of water restriction could be the formation of tracheids rather than vessels by the vascular cambium in older peduncles. Because of their smaller lumina width

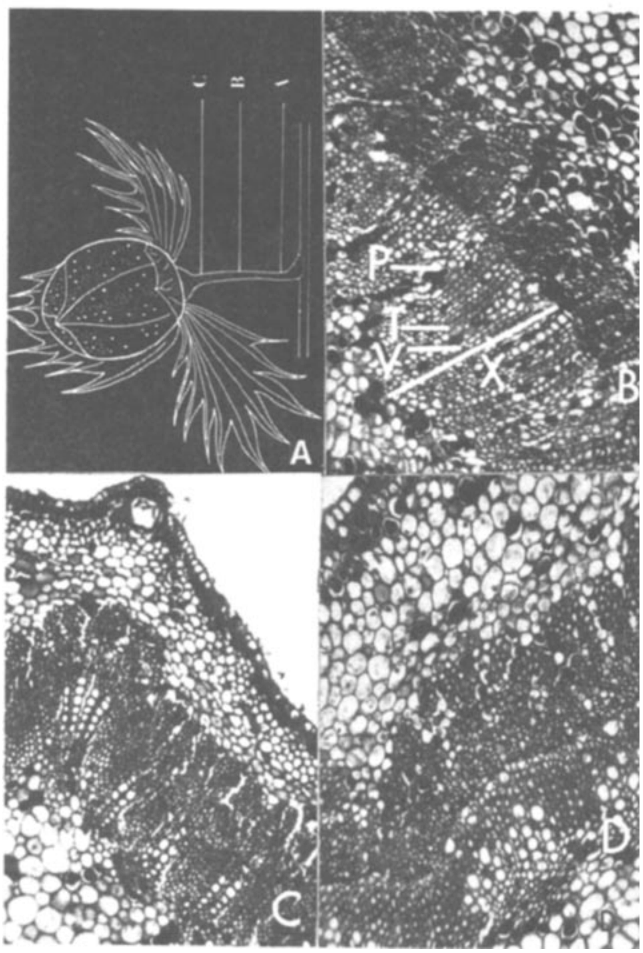

Fig. 1. A. Diagram indicating peduncle regions sampled. B. A representative segment of a cross section from a 7-day-old DPL 16 peduncle near the stem, region A (× 175). C. A representative segment of a cross section from a 7-day-old peduncle midway between the boll and the stem, region B (× 150). D. A representative segment of a cross section from a 7-day-old peduncle close to the boll, region C (× 250).
X = xylem, V = vessel, T = tracheid, P= parenchyma.

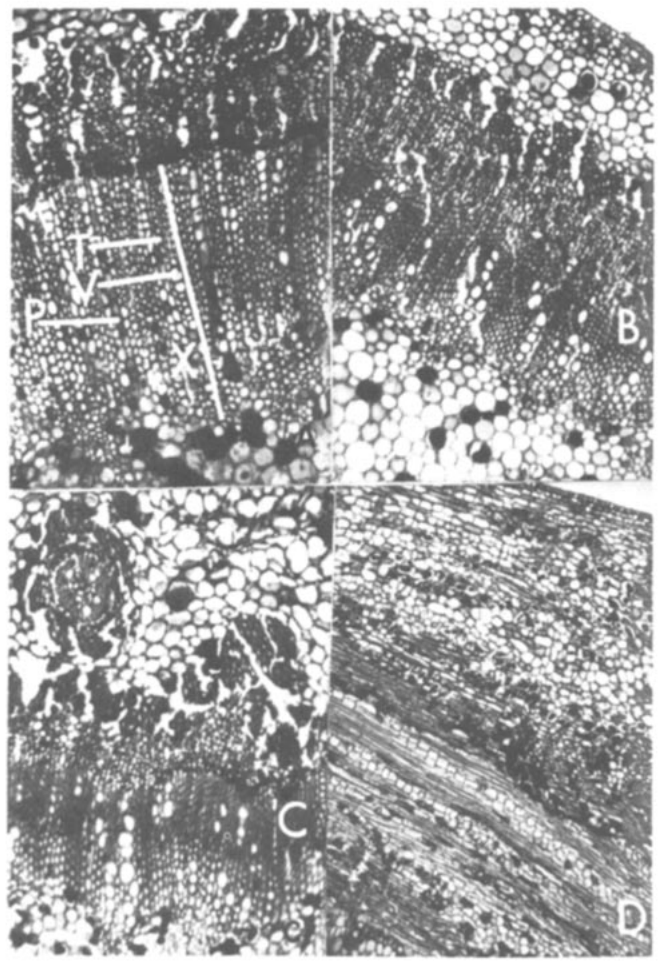

Fig. 2. A. A representative segment of a cross section from a 42-day-old DPL 16 peduncle near the stem, region A (× 200). B. A representative segment of a cross section from a 42-day-old peduncle midway between the boll and the stem, region B (× 200). C. A representative segment of a cross section from a 42-day-old peduncle close to the boll, region C (× 200). D. A representative segment of a longitudinal section from a 35-day-old DPL peduncle near the stem, region A (× 125).
X = xylem, V = vessel, T = tracheid, P = parenchyma.

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and less porous ends, tracheids are capable of transporting much less water than could vessels occupying the same cross-sectional area. Tracheid production rather than vessel production in older peduncles could reduce the water-transporting capacity of the peduncle below what it would be if vessels were continually produced.

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