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Contributions of the Capsule Wall and Bracts to the Developing Cotton Fruit[1]

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ABSTRACT

Simultaneous exposure of sympodial leaf and fruit of cotton (*Gossypium hirsutum* L.) to $^{14}CO_2$ revealed that the bracts were 28% as efficient as leaves for CO_2 uptake on a unit-weight basis, or 20% on an area basis, while the capsule wall was less than 1% as effective as the leaf. Subsequent translocation to the fruit was much more rapid from the leaf than from the bracts. The capsule wall, on the other hand, served as a sink for photosynthate accumulation. Stomatal density was not limiting the uptake capacity of the bracts, since there were more stomata on the outside surface of the bracts (11,325/cm^2) than on the lower surface of the leaf (7,187/cm^2). Chlorophyll concentration was three times greater in the leaf than in the bract (2.28 mg, g fresh weight^{-1} compared to 0.83). Similarly, the comparatively low rate of CO_2 fixation by the capsule wall was not explained by the stomatal frequency on the capsule wall (4407/cm^2).

Additional index words: Gossypium hirsutum L., Translocation, Photosynthesis.

INTEREST in the contribution of the bract and the capsule wall of the cotton (*Gossypium hirsutum* L.) fruit to the nutrition of the developing capsule has been evident for many years, as shown by reports of Kearney (8), Morris (10), and Brown (6). They were able to show, although not unequivocably, that these parts are important to the developing capsule, but they were unable to separate and identify specifically what the contributions were and their importance. Morris (10), for example, showed that the removal of the bracts did not affect yield or lint quality, whereas shading the capsule wall or removing the bracts and shading the capsule wall together appreciably affected capsule size and lint quality. Brown (6), on the other hand, showed that bracts translocate photosynthate to the developing fruit. Recent observations by Benedict, Hall, and Kohel (4) indicated that bract photosynthate accounted for about 5% of the capsule constituents. Ashley (2) also has recently studied source-sink relationships in the cotton plant, but he did not include the bract in his studies. Benedict, Hall, and Kohel (3) recently reported on photosynthate incorporation into cotton capsules but did not study source relationships.

In view of these findings, it occurred to us that a radioisotope technique would be appropriate here to 1) determine specifically the relative uptake efficiencies of gaseous CO_2 by the leaf, bract, and capsule wall and 2) determine whether and to what extent incorporated CO_2 is translocated and assimilated into the developing fruit, especially from the capsule wall and the bracts.

MATERIALS AND METHODS

For these studies intact, 20-day-old cotton fruit from greenhouse-grown 'Stoneville 213' plants were used along with the adjacent leaf on the fruiting branch or sympodium (see ref. 5 or 11 for a discussion of cotton morphology). The leaf and fruit, including bracts, were enclosed in a Plexiglas[3] chamber 15× 20×8 cm. Approximately 5 μCi of $Ba^{14}CO_3$ (specific activity 1 mCi/mmol) was weighed into a small vial, 1 ml of water was added, and the $^{14}CO_2$ was released by adding 1 ml of concentrated perchloric acid through a serum stopper above the vial in the chamber. Exposure of the tissue was for 15 min from initial release, at which time the branch was severed from the plant. Parts were then separated, frozen, lyophilized, and ground to 40-mesh with a Wiley mill. The cotton fruits were frozen whole and broken down into separate parts after lyophilization. Four plants were treated in this way. A method similar to that of Eastin (7) was used for counting the tissue, except that only 4 mg was used, and the counting gel was Aquasol, a liquid scintillator that forms a high-efficiency counting gel with the addition of water. The sample-channels-ratio method was used for quench correction.

Translocation was estimated by allowing a 4-hour interval after exposure to $^{14}CO_2$. The fruit and leaf were exposed to $^{14}CO_2$ in combinations of leaf alone, capsule plus bracts, capsule without bracts, leaf plus capsule, and leaf plus capsule without bracts. Three plants were exposed for each treatment. Stomatal frequencies on leaves, capsule wall, and bracts were determined by applying Archer Adhesive to the tissue surface, stripping the adhesive off, and examining the sample under a microscope (9). At least 20 separate microscopic fields were counted for each tissue. Chlorophyll concentration was estimated by the procedure of Arnon (1) on seven separate samples each of leaf, capsule wall, and bracts. Leaf and bract area were estimated by planimeter tracings of the leaf and bract outlines drawn on paper.

RESULTS AND DISCUSSIONS

Simultaneous exposure of the leaf and fruit of cotton indicated that the leaf is, as expected, the primary organ for CO_2 uptake in cotton. The bracts were relatively efficient in CO_2 uptake, but the capsule wall took up a negligible amount (Table 1). The leaves had a higher specific leaf weight than the bracts (65.9 mg/cm^2 vs. 43.2 mg/cm^2). Therefore the bracts were only 20% as efficient on an area basis. By 4 hours after exposure to $^{14}CO_2$, both bracts and capsule wall had increased in ^{14}C- concentration relative to the leaf. Since the sympodial leaf has been reported to be the primary source of photosynthate for the boll at that node (2), the leaf should decrease in ^{14}C concentration as the boll increases.

Table 1. Efficiency of capsule wall and bracts of cotton fruit for uptake of CO_2 when exposed simultaneously with a leaf to $^{14}CO_2$. (Relative to the leaf, taken as 100%).

	15 minutes after exposure				4 hours after exposure			
	DPM/mg	SE	Total†	SE	DPM/mg	SE	Total	SE
Leaf	100.0%*		100%		100.0%		100.0%	
Bracts	28.1	3.60	7.1	1.05	109.4	26.61	25.2	6.70
Capsule wall	0.8	.12	1.7	.50	23.2	6.51	47.8	10.29

* Disintegrations per min per mg of leaf tissue 15 min after exposure was 6,556 and after 4 hr, 2,436. † DPM/mg times total weight of the tissue.

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[3] Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by USDA and does not imply its approval to the exclusion of other products that may also be suitable.

Table 2. Percent of recovered counts located in the indicated branch portion 4 hours after exposure to $^{14}CO_2$.

	Leaf	SE	Capsule & leaf	SE	Capsule, bracts, and leaf	SE	Capsule & bracts	SE	Capsule	SE	C/CB†
Presentation leaf	45.4	7.3	21.4	2.20	25.3	3.13					
Bracts	0.2	0.04	--		6.4	2.46	25.4	3.37			
Other leaves, etc.	0.5	0.3	--		--		4.9	0.25	21.4	12.54	
Branch stem	6.5	2.3	4.7	1.01	4.1	0.53	3.5	2.01	5.0	2.55	
Peduncle	3.3	0.7	5.1	1.51	4.1	1.28	5.7	1.45	5.6	1.43	0.32
Capsule wall	9.9	3.7	13.3	3.68	12.1	2.58	19.5	2.53	29.2	6.60	0.56
Endocarp	5.7	1.0	16.5	7.86	7.7	2.83	6.0	0.77	6.2	1.89	0.38
Seed	16.8	8.4	11.1	1.54	12.6	4.43	12.4	0.39	10.8	1.63	0.25
Lint	11.7	0.05	27.9	4.65	27.6	3.14	22.7	3.42	22.2	2.41	0.29
% Recovery*	53.02	17.31	29.9	3.09	31.8	7.11	5.4	1.43	2.3	1.00	

* % Recovery is the percent of total radioactivity released that was recovered and accounted for within the plant. The low recoveries of capsule and leaf and capsule, bracts and leaf reflect the strained juxtaposition necessary to enclose both the boll and leaf in the chamber simultaneoulsy. † Ratio of DPM's in the capsule alone treatment to those in the capsule and bracts treatment.

The data in Table 2, however, indicate that, although the capsule wall was a sink for the radioactivity incorporated by the leaf, the bracts were not. Apparently, then, the relative accumulation by the capsule wall was from translocation out of the leaf into the capsule wall, whereas the accumulation by the bracts was the result of their slower rate of assimilation and translocation relative to the leaf during this time period. This is not to say that the bracts do not contribute to the developing fruit. The ratio of DPM's in the capsule parts in the capsule-alone treatment, compared to the capsule-plus-bract treatment (Table 2), show that such internal organs as seed and lint have 3 to 4 times as many counts in the treatment with bracts as in the one without. Evidently the increased radioactivity was the result of bract assimilation and translocation.

The apparent contradiction of data from Table 1, which shows a nonstatistically significant increase of ^{14}C in the bracts with time and of data from Table 2, which shows translocation by bracts into the capsules by the C/CB ratio, is probably the result of sampling error. The large standard error (26.61, Table 1) would seem to indicate this sampling error. Other possible explanations include an injury effect from removing bracts and the possibility that bracts function both as a sink for the leaf and as a source for the fruit.

Examination of the bracts and capsule wall for stomata and chlorophyll concentration (Table 3) show that bracts have a surprisingly large number of stomata compared to the leaf, and even the capsule wall has more stomata per unit area than the inside of the bract or the top surface of the leaf. Chlorophyll concentrations are, however, 3 and 13 times higher in the leaf than in the bract or capsule wall, respectively. Although stomata number is not limiting, chlorophyll concentration is limiting, and it is the determinative factor for CO_2 fixation by these organs.

These data confirm and expand the early reports on the utility of the bracts and the capsule wall for assimilate production. Although the bracts photosynthesize and provide some photosynthate to the developing capsule, their contribution is small in relation to leaf photosynthesis. The value of the capsule wall as a photosynthate source is not clear, since it fixes very little CO_2 and contains little chlorophyll (Table 3). In fact the capsule wall imports photosynthate from other sources; yet whenever it is shaded, as some experiments by Morris and by Kearney have shown, the yield and lint quality are significantly affected. Further research is needed on the role of the capsule wall in seed and fiber development.

Table 3. Stomatal frequency and chlorophyll concentration of bracts, capsule wall, and leaf of cotton.

	Stomata		Chlorophyll	
	No./cm²	SE	mg/g fresh wt	SE
Bract				
Outside	11,325	269	0.83	0.03
Inside	3,965	147		
Capsule wall	4,407	57	0.17	0.03
Leaf				
Top	2,727	86		
Bottom	7,187	74	2.28	0.10

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