Ascorbic Acid Turnover, Carbohydrates and Mineral Nutrients in the Cotton Plant (*Gossypium hirsutum* L.)[1]

J.G. Bhatt, R. Renganayagi***

ABSTRACT

Turnover of ascorbic acid has been studied for the first time in developing bolls of the cotton plant. The levels of free ascorbic acid and its enzymic utilization were higher during early stages of boll growth and declined progressively. The large quantities of ascorbic acid were in bound form and followed the same trend as free ascorbic acid. The complexing of ascorbic acid with macromolecules was also at higher levels during the early stages but decreased as the boll developed. The excision of main stem leaf subtending the sixth sympodium from below upward in var. LRA 5166 (*Gossypium hirsutum* L.) decreased ascorbic acid turnover, total sugars and starch in seed cotton and carpels of the bolls developing on first and second nodes of this sympodium. The reduction in bound form of ascorbic acid and its capacity to combine with macromolecules was comparatively more than in free ascorbic acid and its enzymic utilization. The treatment also decreased nitrogen, phosphorus, potassium and calcium contents of bolls, particularity in carpels which appear to retranslocate nutrients for the growth of seed and lint. The disturbed ascorbic acid and carbohydrate turnover, and the decreased transport of nutrients, significantly reduced the dry weight of seeds and lint in mature bolls.

COMPENDIO

En esta investigación se estudia por primera vez el contenido de ácido ascórbico en bellotas de algodón en desarrollo. Los niveles de ácido ascórbico libre y de su utilización enzimática son más altos en las primeras fases del crecimiento de la bellota pero declinan progresivamente. Se encontró gran cantidad de ácido ascórbico fijado que siguió la misma tendencia que el ácido ascórbico libre. Los niveles más altos de los complejos de ácido ascórbico y macromoléculas, también, se dieron al inicio del crecimiento, declinando conforme el desarrollo de la bellota. La poda del tallo principal a la altura del sexto simpodio a partir de la base en la variedad LRA 5166 (*Gossypium hirsutum* L.), bajó el contenido de ácido ascórbico, los azúcares totales y los almidones en las semillas y en los carpelos de las bellotas del primer y segundo nudos de este simpodio. La reducción del ácido ascórbico fijado y su capacidad para combinarse con macromoléculas fue comparativamente mayor que el efecto sobre el ácido ascórbico libre y su utilización enzimática. El tratamiento también bajó los contenidos de nitrógeno, fósforo, potasio y calcio en las bellotas, particularmente en los carpelos, lo que indicaría un desplazamiento de nutrimentos hacia semillas y fibras. También se redujo significativamente el peso seco de las semillas y la fibra de las bellotas maduras.

INTRODUCTION

Though the sympodial leaf in the axil on which the cotton boll develops is the main source of assimilate supply, the main stem leaf subtending the sympodium meets 21% to 28% of its carbon requirements (12). The excision of the main stem leaf has been found to significantly reduce the boll weight irrespective of the species of cotton (2). Periodic changes in carbohydrate, nitrogen and mineral contents of the developing bolls have been reported by several workers but the effect of leaf excision on these changes is not known (4, 11, 13). Though ascorbic acid has been reported to play an important role in growth and differentiation in other plants, to date no information is available on its turnover in growing bolls of cotton except that the abscising bolls contained significantly low quantities of ascorbic acid (6, 7, 17).

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* Plant Physiologist, Research Student, Central Institute for Cotton Research, Regional Station, Coimbatore 641003, India.

** Research Student, Central Institute for Cotton Research, Regional Station, Coimbatore 641003, India.

MATERIALS AND METHODS

The cotton cv. LRA 5166 (*G. hirsutum* L.) was grown in the field under irrigation. The main stem leaf subtending the sixth sympodium from below upwards was excised when the flower on the first node of this sympodium opened. For collecting plant material at regular intervals, over 150 uniform plants were selected and leaves were excised on the same day. A similar number of plants where main stem leaves were not excised served as the control.

The first sample for chemical analysis was taken on the fourth day after anthesis and the subsequent samples at six or seven days interval until the carpels of the bolls showed symptoms of drying. The bolls were collected in the morning and seed cotton and carpels were analysed separately.

The procedure described by Chinot *et al.* (9) was followed to determine free ascorbic acid (AA), bound ascorbic acid or ascorbigen (ASG), enzymic utilization capacity of ascorbic acid (AAU), and combining capacity of ascorbic acid with macromolecules (AA-MM). Total sugars were estimated by the Somogyi method (16), and starch according to the procedure of

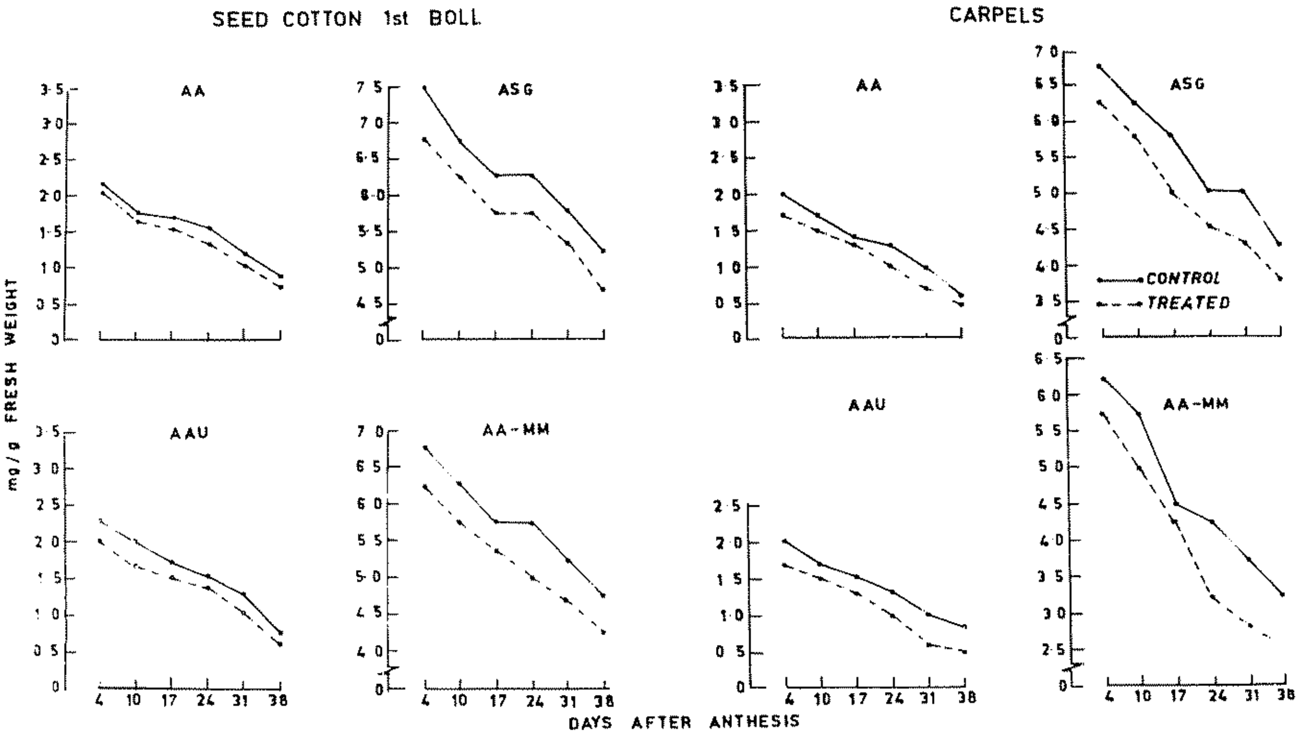

Fig. 1. Effect of leaf-excision on the turnover of ascorbic acid in seed cotton and carpels of developing bolls.

Pucher *et al.*(15). Nitrogen and phosphorus were estimated by standard colorimetric methods, potassium by flame photometer and calcium by the of Cheng and Bray method. The boll at the first node on the sixth sympodium, and subsequently the boll at the second node on this sympodium, were analysed. Since the results for both the bolls were similar, those for the first boll alone are given.

RESULTS AND DISCUSSION

In seed cotton of the normal boll, free AA was at a higher concentration until about the half boll maturation stage and then declined (Fig. 1). Large quantities of AA were in the bound form. Enzymic utilization of AA was greater during early stages of boll growth and followed the pattern of free AA. The combining ability of AA with macromolecules was also high until the half boll maturation stage.

The level of free AA in the carpels of the normal boll was as high as in seed cotton during the first 10 days but decreased at a slightly faster rate. In the carpels, maximum quantities of AA were as ASG and declined rather more rapidly than in seed cotton, whereas the trend in AAU was similar to free ascorbic acid. The decline in AA-MM was sharp during early stages, and though the levels were lower than in seed cotton, the fall after the twenty-fourth was at the same rate.

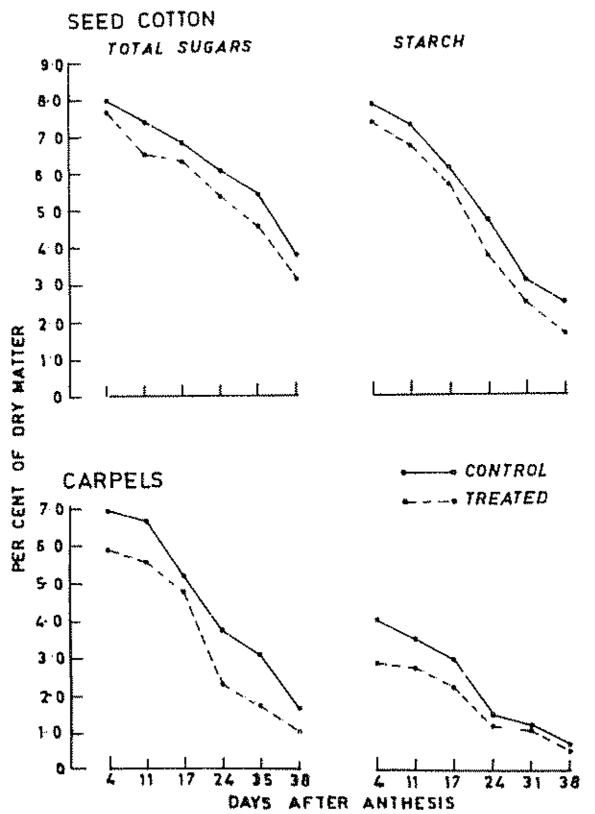

Fig. 2. Effect of leaf-excision on the changes in total sugars and starch in seed cotton and carpels of developing bolls.

After excision of the main stem leaf, AA turnover in the boll was considerably disturbed (Fig. 1). In seed cotton and carpels the quantum of reduction in AA and AAU was similar. Similarly more ASG appeared to be released in the seeds and carpels up to the seventeenth day, when compared with the control. The levels of AA-MM in seed cotton and carpels were lowered substantially during the later period of boll maturation. The fall in the carpels after the seventeenth day was steeper than in the control.

The excision of the main stem leaf also lowered total sugar and starch contents of seed cotton (Fig. 2). At several stages total sugars in carpels were reduced by over one per cent. The reduction in starch content during early stages varied from 0.5 to 1.0 per cent.

The occurrence of AA is known to generally coincide with high metabolic activity. Its rate of production and utilisation has been reported to govern the rates of development and it is also acted upon by a number of enzymes present in the plant system (10, 14). The excision of the main stem leaf lowered AA turnover considerably during boll development. Though the sympodial leaf is the primary source of supply for photosynthate and nutrients, excision of the main stem leaf did affect the normal requirement of the boll as total sugars and starch decreased at all stages of development. Hexose sugar is the unit from which AA is formed (1). The reduction in starch content of the carpels indicates the internal adjustment to divert more sugars for the growth of seeds and lint. Perhaps a portion of free sugars and/or that released through

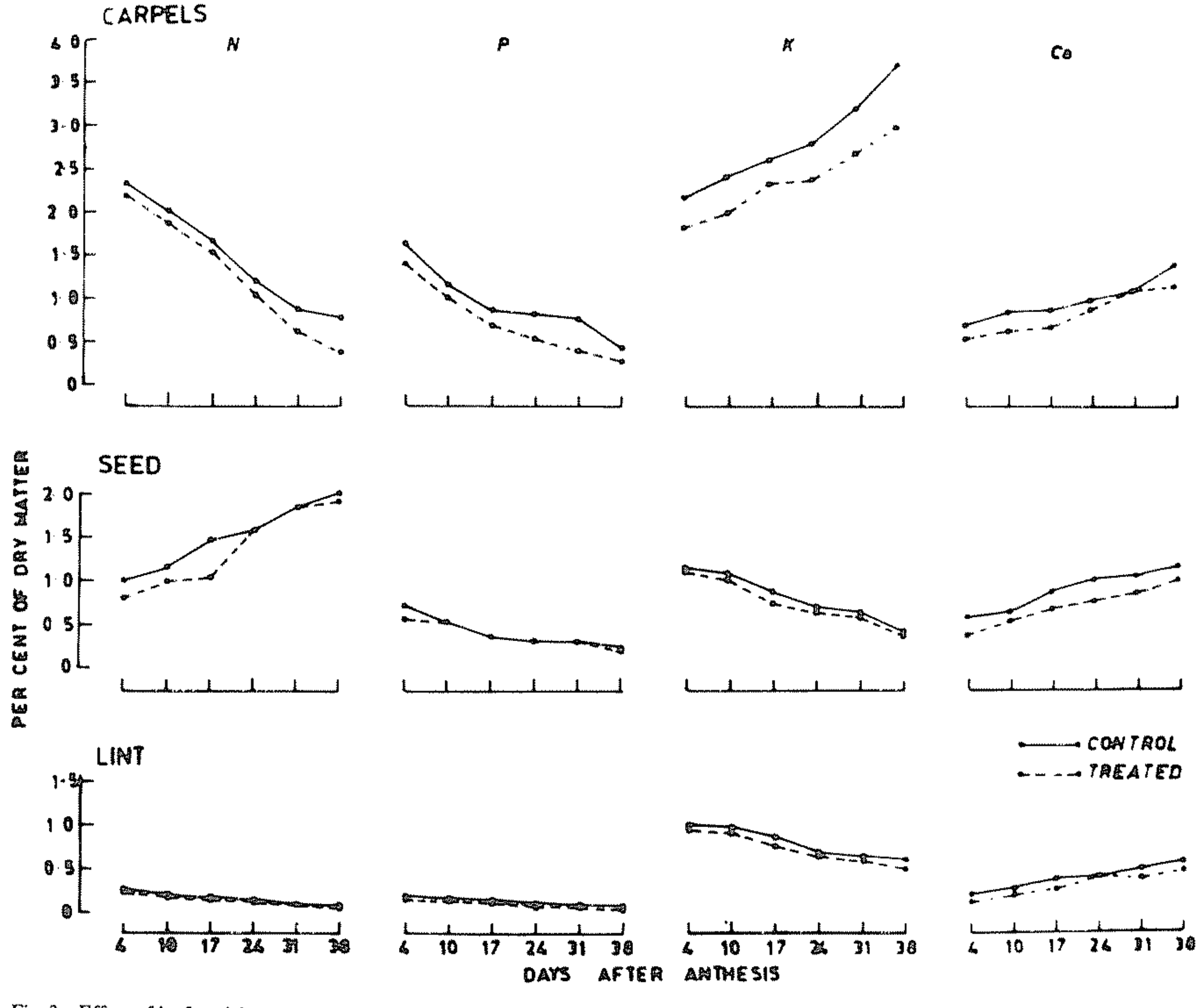

Fig. 3. Effect of leaf-excision on the changes in nitrogen, phosphorus, potassium and calcium contents in carpels, seeds and lint during boll development.

starch hydrolysis is converted to AA and stored as ASG. The possible role of AA in boll development is indicated by comparatively greater decrease of ASG and lowered levels of AA-MM both in seed cotton and carpels after leaf excision. Ascorbic acid complexes with macromolecules like DNA and RNA when a free radical of AA is generated in the medium, and the process goes on continuously in all active centres of growth (8).

Changes in mineral nutrients in carpels, seeds and lint followed the same trends as in other *G. hirsutum* cultivars reported first by Dastur and Ahad (11) and confirmed later by Leffler and Tubertini (13). The excision of main stem leaf affected the nutrient content of carpels more than seeds and lint (Fig. 3). Though reduction in nitrogen and phosphorus was greater from the twenty-fourth and seventeenth days respectively, the reduction in potassium content of carpels was comparatively higher throughout. Except for the penultimate stage, calcium was uniformly lowered. Since seeds and lint receive their nutrient requirements from the carpels, the latter appeared to retranslocate nutrients to the former as a result of leaf excision. Even then, until the twenty-fourth day, nitrogen in seeds was reduced appreciably. The calcium content was also a little lower. The effect of excision of the main stem leaf lends experimental support to the conclusion that in a developing cotton boll retranslocation of nutrients between carpels, seeds and lint occur continuously.

The excision of the main stem leaf significantly reduced the dry weight of mature bolls (Table 1). There was little effect on the weights of carpels, but seed and lint weights decreased significantly.

RESULTS

Though ascorbic acid is known to play an important role in growth and differentiation in plants, no information is available on its turnover in growing bolls (fruits) of the cotton plant. In cultivar LRA 5166 (*G. hirsutum* L.) seeds of the growing boll had a higher concentration of free AA until when the boll was approximately half mature and then declined. The large quantities of AA were in the bound form. Enzymic utilization of AA as well as its combining capacity with macromolecules, remained at higher levels until the half boll maturation stage. Concentration of free AA in the carpels of the boll was as high as in the seeds during the first ten days after anthesis. The carpels also had maximum quantities of AA in the bound form. These two forms of AA, and its enzymic utilization and combining capacity with macromolecules, decreased at a comparatively faster rate in carpels than in the seeds.

When the main stem leaf subtending the sixth sympodium from below was excised after the flower opened on the first node of this sympodium, AA turnover in the growing boll was disturbed considerably. In

Table 1. Effect of excision of main stem leaf on the weight of boll components at maturity.

Treatment	Carpels	Seeds	Lint	Boll weight
		Boll at 1st node		
Control	0.92	1 72	1.22	2.95
Leaf excised	0.92	1 32	0.87	2.20
L.S.D. 5%	N.S.	0.290	0.159	0.275
		Boll at 2nd node		
Control	0.87	1 72	1 00	2.72
Leaf excised	0.87	1.25	0.77	2.02
L.S.D. 5%	N.S.	0.199	0.081	0.224
		Boll at 3rd node		
Control	0.95	1.37	0.95	2.32
Leaf excised	0.92	1.00	0.70	1.70
L.S.D. 5%	N.S.	0.152	0.159	0.200

N.S. = not significant.

seeds as well as carpels the quantum of reduction in free AA and its enzymic utilization was similar. The excision of the main stem leaf appeared to release more AA from its bound form in the seeds and carpels until the seventeenth day after anthesis. The combining capacity of AA with macromolecules was lowered substantially when compared with the normal boll. The total sugar and starch contents of seeds also decreased when the main stem leaf was excised. At several stages total sugars in carpels were reduced by over one per cent. The reduction in starch content of the carpels indicated that more sugars were diverted for the growth of seeds and lint. Perhaps a portion of the sugars released from starch is utilised for the formation of ascorbic acid. The comparatively greater decrease in the bound form of AA and lowered levels of its combining capacity with macromolecules suggests the possible role of AA in boll development.

The excision of the main stem leaf had a greater effect in reducing mineral nutrient content of carpels than seeds and lint. Though the nitrogen and phosphorus content of carpels was low after about 20 days of boll growth, potassium content was lower throughout. Since seeds and lint receive their nutrient requirements from carpels, it appeared that in a developing boll, retranslocation of nutrients between the boll components occurs continuously. The excision of the main stem leaf significantly reduced the dry weight of mature bolls.

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