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Relationship between Fiber-Length Increase and Seed-Volume Increase in Cotton (*Gossypium hirsutum* L.)[1]

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ABSTRACT

Three cultivars of *Gossypium hirsutum* L. were chosen for wide differences in fiber length and seed volume: 'Stoneville 213,' 'Paymaster 54B,' and 'Acala 1517-D.' Increases in fiber length and seed volume were measured from boll ages of 8 to 17 days. During this period the relationship of fiber length to seed volume in each cultivar fit the model $L = \beta V^{\alpha}$ with $R^2 = 0.99$, where L = fiber length, V = seed volume, and α and β are the growth parameters. The α value in each was near 0.5, indicating that seed volume was increasing as the square of fiber length. This relationship suggests that biological partitioning of available resources within the cotton plant controls some agronomically important parameters.

Additional index words: **Growth relation, Allometric equation, Lint percent.**

THIS paper is concerned with the relative growth of the lint and seed in upland cotton (*Gossypium hirsutum* L.), i.e. the relative increase in volume of the seed to the elongation of the lint hairs. Understanding this relationship should help to understand variations in lint length, lint percent, and the relation between these two properties. First, it is necessary to consider the various factors that contribute to lint percent and then to see how these may vary during fruit development.

Lint percent = lint index/ (lint index + seed index) where seed index equals weight of 100 seeds and lint index equals weight of lint on 100 seed.

Lint index/100 = (number hairs/seed) × (average weight/hair)

Average weight/hair = (average length × (weight/unit length)

Seed index/100 = (average volume/seed) × (dry weight/unit volume)

Lint hairs, single-celled outgrowths of the epidermis of the seed coat, arise on the surface of the ovule on the day of flowering or the day after (7). This accounts for the number of hairs per seed in the equation above. Under good growing conditions, the lint hairs elongate for some 16 to 21 days after flowering to reach their final length (3, 5, 8). The hairs elongate as long as the seed is increasing in volume and the fruit is enlarging (1, 2).

Endosperm development within the seed parallels the increase in size of the maternal tissue of the seed (9). For approximately 25 to 30 days after the boll has reached its mature dimensions, there is a maturation phase of fruit development. The embryo grows at the expense of the endosperm (6) and secondary wall deposition takes place in the lint hairs and in various layers of the seed coat (3, 5, 6).

Since the fibers and the main body of the seed are increasing in size at the same time, differentials in the rate of enlargement could affect lint percent according to the relations outlined above. In this paper we report preliminary results describing the relationship of fiber-length increase to seed-volume increase in the first stage of development. Studies on the maturation stage of development where weight changes are the primary concern will be reported at a later time.

MATERIALS AND METHODS

The three cotton cultivars, 'Stoneville 213,' 'Acala 1517-D,' and 'Paymaster 54B,' were grown at Jackson, Tenn., in randomized blocks with four replicates of 16 rows spaced 1 m apart and 18 m in length with about 100 plants/row. First bloom occurred July 4, and flowers were tagged July 15. Developing bolls were harvested each day, exclusive of weekends, from boll age 8 to 17 days. Each day's harvest of 10 bolls/replication was stored frozen until measurements were made.

The procedure for determining fiber length was similar to published methods (5, 8). The frozen bolls were peeled, and the seed masses were dropped into boiling water and agitated to separate the seeds. At least 20 seeds were taken from each boll for subsequent fiber length and seed volume measurements. For fiber measurement the hairs were straightened with a fine stream of water on a microscope slide (and gently brushed when necessary). Fiber lengths were measured from the chalazal end of the seed to the edge of the fiber "halo" with a millimeter rule. The average seed volume in a boll was determined by carefully dissolving the fibers of all the seeds measured for fiber length in concentrated sulfuric acid and measuring the water displacement of the delinted seeds in μliters. The resulting data were submitted to statistical analysis by the nonlinear regression analysis of Zar (10).

RESULTS AND DISCUSSION

Seed volumes, fiber lengths, and lint percents of the mature seed and lint of the three cultivars are given in Table 1. Hawkins and Serviss (3) reported that fiber length decreased on drying, so maximum length of the undried fibers should be slightly longer than the dried fibers. Also, in this experiment the maximum seed volumes measured during growth were much greater (approx. 60%) than the volumes of the mature dry seed. The values in Table 1, therefore, give only a relative range of volumes and lengths since different cultivars may respond differently to drying. No apparent correlation was seen between

Table 1. Seed volume, lint length, and lint percentage of the mature dry seed for the cotton cultivars studied.

Cultivar	Seed volume	Lint length	Lint percent
	μliters	mm	
Stoneville 213	91.2	26.2	40.1
Paymaster 54B	100.4	22.6	38.8
Acala 1517-D	120.2	29.0	34.1

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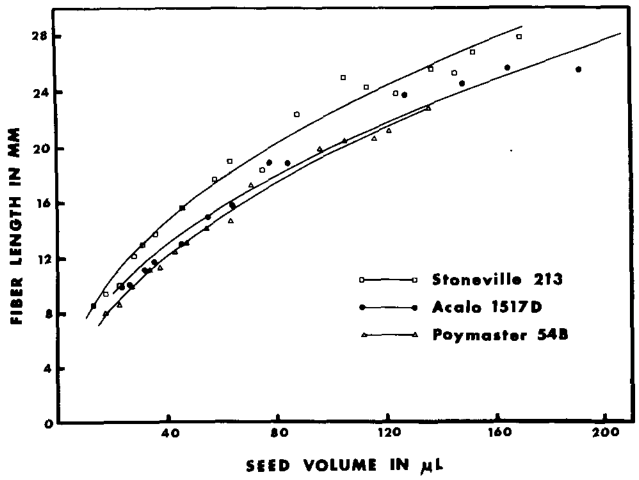

Fig. 1. Relation of fiber length to seed volume during the rapid-growth period for three cotton cultivars. The points are average according to increments of volume. Each line represents the calculated best fit of each cultivar to the relation $L = \beta V^{\alpha}$.

final seed size and fiber length of the mature seeds, but lint percent was negatively correlated to the seed size of these three cultivars.

When we measured the concomitant development of seed and fiber, we observed that there was a nonlinear correlation (Fig. 1). Subsequent nonlinear regression analysis showed that the growth of the fibers was related to seed-volume increase according to the allometric equation (4), $L = \beta V^{\alpha}$, where L = fiber length in mm, V = seed volume in μliters, and α and β are the growth parameters characteristic of a cultivar. Ideally, the relationship would be: $L = \beta_1 V_0 + \beta_2 V^{\alpha}$, since the cotton ovule has a finite volume, V_0, before the fibers begin to grow. However, V became so much greater than V_0 that the latter equation was not different from the allometric equation at the 0.05 probability level. Also, in practical terms V_0 was laborious to determine. Any difference in V_0 between cultivars was included in the β value of the allometric equation. The values of the growth parameters, with their standard errors, and the standard errors of estimate of the relation for each cultivar are given in Table 2. R^2 for each was greater than 0.99.

The log transformation of the allometric equation

$$\log L = \log \beta + \alpha \log V$$

yields a straight line (Fig. 2). The parameter α becomes the slope of the line, and log β becomes the intercept. In terms of growth, the α value represents how fast the fiber is elongating with respect to seed-volume increase. The β parameter is a measure of relative performance during very early growth and includes such factors as initial ovule size, time of fiber initiation, and relative rate of growth.

Table 2. Growth parameters of the allometric relation ($L = \beta V^{\alpha}$) of fiber-length growth to seed-volume growth. Determinations of fiber length and seed volume were made on the seed of 160 bolls, ranging in age from 8 to 17 days.

Cultivar	β	σ	α	σ	S. E. estimate	R^2
Stoneville 213	2.6908	0.1357	0.4597	0.0108	1.6052	0.994
Paymaster 54B	1.8205	0.0903	0.5152	0.0106	1.2804	0.995
Acala 1517-D	2.3434	0.1390	0.4647	0.0121	1.7422	0.993
All cultivars	2.3975	0.0911	0.4667	0.0080	1.9671	0.990

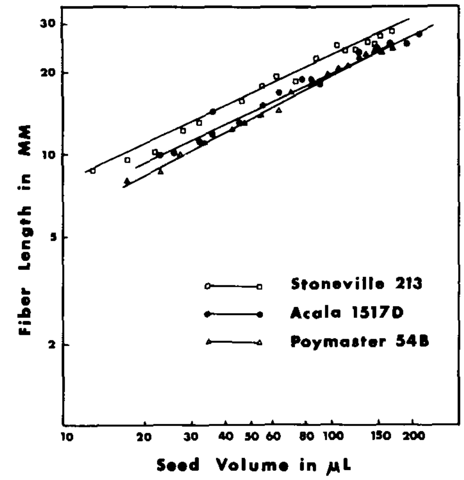

Fig. 2. Logarithmic transformation of the fiber-length and seed-volume determinations during growth.

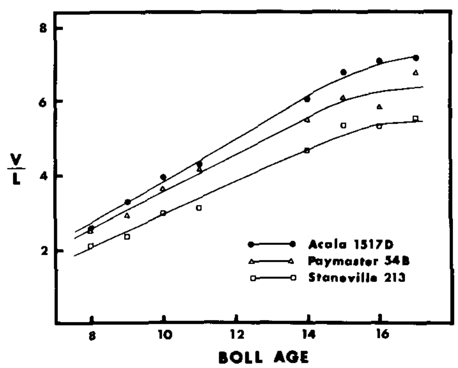

Fig. 3. Ratio of seed volume in μliters to fiber length in mm vs age of boll from flowering.

The α and β values of Paymaster 54B indicated that fiber development started slowly, then proceeded more rapidly compared to the other cultivars; with Stoneville 213, however, the inverse was true. For all three cultivars, β decreased where α increased; hence, these two parameters tended to counterbalance each other in comparison of growth curves. Considering the large differences in seed size and fiber length, the growth relations of volume to length did not appear to have major differences.

In practical terms, the interrelation of seed and fiber growth suggests that the time period required for maximum volume and length has a major influence on the final ratio of seed to fiber. In each case, volume increased roughly as the square of the fiber length. Under the assumptions that seed volume is directly related to seed index and that fiber length is a component of lint index (mean fiber length × wt per unit length × number of fibers), these results indicate that lint percent will decrease with increase in the time period of enlargement. When the ratio of seed volume to fiber length (V/L) was plotted against age from flowering (Fig. 3), it was evident that the ratio increased with age. Also, the ratio of increase with age was different for these three cultivars. Lint percentage (Table 1) was inversely related to V/L ratio.

Although three diverse cultivars each yielded a straight-line relationship for Log L vs Log V, we are aware of the limitations of 1 year-1 location studies. Questions such as the influence of environment or variety-environment interaction on the relationship were not answered. We are currently examining a wider array of cultivars grown under different environments and locations and will report these results at a later time.

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