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Fiber Elongation and Dry Weight Changes in Mutant Lines of Cotton[1]

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ABSTRACT

Genetic variation in fiber elongation and secondary cell wall deposition in cotton (*Gossypium hirsutum* L.) was studied using three monogenic mutant lines (*Ligon lintless, Pilose,* and *immature fiber*) and two genetically diverse normal lines (Z2557 and Texas Marker-1). Because it has been shown that secondary cell wall deposition can begin before fiber elongation ceases, this experiment studied the genetic variability and interrelations between these two features of fiber development. The fiber development of these lines demonstrated that it is possible to alter, through genetic manipulation, either elongation or dry weight increase of the fibers without appreciably changing the other, thus demonstrating that fiber elongation and secondary cell-wall deposition are not necessarily controlled by the same genetic factors.

Additional index words: **Cellulose deposition, Lint dry weight per unit of length, *Gossypium hirsutum* L.**

BALLS (1915) observed in *Gossypium barbadense* L. that at about 21 days after anthesis, fiber elongation was complete and secondary wall thickening could be observed. Anderson and Kerr (1938) studied fiber elongation and secondary-wall thickening in *G. hirsutum* L. They reported that fiber elongation was complete about 21 days after anthesis and observed some indication of secondary wall deposition at 16 days, but concluded that the major secondary wall deposition took place after fiber elongation was complete. These reports formed the basis for establishing the concept that cotton fiber development is biphasic. Cotton researchers have followed the premise that during growth and development of fiber cells, elongation continues until 21 days after anthesis and secondary-wall deposition follows the completion of elongation. These events were considered mutually exclusive in timing, and many experiments studying cotton fiber development were designed around the concept of biphasic fiber development.

Benedict, Smith, and Kohel (1973) and Schubert et al. (1973) have shown that up to 59% of the total fiber dry weight can be present by the time fiber elongation has ceased. This weight represents secondary wall deposition. Hawkins and Serviss (1930) studied fiber elongation and wall thickening in 'Pima' and 'Acala' cotton. They concluded that no appreciable thickening of fiber walls began until fiber elongation was almost completed; however, inspection of their data reveals that by the time fiber elongation was completed, Pima had 60% and Acala 25% of their secondary wall thickening. These reports establish that fiber elongation and secondary wall deposition do not necessarily follow in a mutually exclusive sequence. We need to study the factors that influence these two aspects of fiber development and the variability and interrelations between them, with the ultimate goal of being able to apply this information to varietal development.

In the present paper we have chosen mutant lines as genetic tools to study fiber development because differences among cultivars may be too subtle to clearly distinguish between genetic and environmental variations and provide definitive results. Fiber development was compared in two normal lines and three lines with single gene mutations that result in unique fiber characteristics.

MATERIALS AND METHODS

The lines selected for this study were *Ligon lintless, Pilose, immature fiber,* Z2557, and Texas Marker-1. *Ligon lintless* is a simply inherited dominant mutant, which is characterized by distorted plant growth and short fiber (about 2 mm) (Kohel, 1972). *Pilose* is a mutant controlled by a single dominant gene and has short, dense plant hairs and short, coarse seed fibers (Simpson, 1947; Lee, 1964; Kohel, Lewis, and Richmond, 1967). *Pilose* was backcrossed into Texas Marker-1 for eight generations and then self-pollinated for two generations to isolate a true breeding line. The third line, *immature fiber,* has the characteristics of immature fiber, and it is controlled by a single recessive gene (McMichael, unpublished). Z2557 is a doubled haploid line that originated from a haploid plant found in the breeding nursery at the Texas A&M Agricultural Research and Extension Center, Lubbock, Texas. It has stormproof bolls and relatively short fibers. Texas Marker-1 is a long-term inbred line used as a genetic standard in the cotton genetics program at College Station. It is derived from 'Deltapine 14' and should have fiber development representative of delta-type cottons (Kohel, Richmond, and Lewis, 1970).

Seeds were germinated in peat pellets in the gneenhouse, and transplanted to the field 3 weeks later. Each entry per replication consisted of a plot of 20 plants spaced 45 cm in the row and 102 cm between rows. The experiment consisted of four replications.

To minimize variability in boll development, flowers were removed from the plants until feak blooming was reached. Flowers were then tagged on the day of anthesis. All samples for analysis were taken from bolls tagged on the same day, except bolls from *Ligon lintless* samples. *Ligon lintless* plants produced too few flowers and bolls on any given day to fit precisely into the scheme of stratification used.

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Measurements were taken from a single boll from each plot every seventh day. The fresh boll sample was weighed and separated into boll wall and seed locules; these components were then weighed. A single locule was weighed and used to determine the remaining measurements. The number of ovules was determined by counting the number of funiculi attachments. Fiber length was measured by placing the locule in boiling water to separate the seeds; then individual seeds were placed on the convex surface of a watch glass and the fibers were allowed to stream out under running water (Morris, 1962; Gipson and Joham, 1969). The length of the fiber was determined on five seeds. The fiber and seeds were separated, oven-dried, and weighed.

RESULTS

Seed Development. The main object of this study was to study fiber development, but we did measure and analyze differences in ovule number, seed number, and seed dry weight to make sure that these factors did not bias our results. There were no statistically significant differences for these characters. The average number of ovules was 8.75 per locule. There was an occasional locule with 7 or 10 ovules, but most locules contained 8 or 9 ovules. The average number of ovules per locule that matured to form seeds was 8.20. The range was from 6 to 10. The average mature seed weight was 0.0896 g and ranged from 0.0825 to 0.0939 g. These data establish that seed development did not differ among the lines under investigation and that differences in fiber development were not a consequence of unusual seed development.

Fiber Development. Differences in fiber length among the entries were statistically significant at all dates throughout the experiment, as anticipated. (Fiber elongation does not start until after anthesis, therefore, fiber determinations could not be recorded on the day of anthesis.) Fiber dry weight per boll differences were statistically significant among entries at 21, 28, and 35 days after anthesis, and fiber dry weight per seed differences were significant at 28 and 35 days. Differences among entries were obvious and consistent at the other dates, but not large enough for statistical significance. When fiber development was expressed as the ratio of dry weight per unit of fiber length, the entries were significantly different from 14 days after anthesis to maturity.

The above results of our statistical tests present the general trends that were observed in this experiment. The following data present specific features of the individual entries. We have chosen to present the data graphically to convey the developmental sequence that was recorded. In each figure the mean fiber length is presented. To eliminate any variability that might be associated with seed number, the fiber dry weight is expressed as the average per seed. The dry weight per unit of length is presented because we felt that it was a useful means of determining when the increase in fiber weight reflected secondary wall deposition. The ratio of weight to length should be constant when only elongation is taking place. The data were recorded for weekly intervals until maturity (49 days after anthesis, all the bolls had opened).

Texas Marker-1. Texas Marker-1 was included as a control to show normal delta-type cotton fiber development (Fig. 1A). Maximum elongation was reached by 28 days after anthesis, after which there was variability in fiber length determination. This result was observed in most of the entries in this and other experiments. We could not determine whether this variability was associated with sampling technique or with environmental factors that affected fiber length. However, two fairly consistent trends were noted. The fiber length measurements taken from mature open bolls (49 days after anthesis) were shorter in all but one entry, and 35 days after anthesis there was a decline in fiber length and dry weight. This effect was noted also in other experiments where the bolls were at a different stage of development. We assume that this was a moisture-temperature response because it occurred during the last week of July when moisture requirements from supplemental irrigation were in the greatest demand.

The dry weight of the fibers increased rapidly from 14 days after anthesis onward and reached maximum at 42 days. There was a decrease in dry weight at maturity, which was accompanied by the decrease in length. Expressing fiber dry weight per unit of fiber length aided in interpreting some of the changes in fiber development. Dry weight/length did not change from the 7- to the 14-day measurements. This lack of change indicates that differences in dry weight were caused by elongation and not by secondary wall deposition. However, by 21 and 28 days after anthesis (the period when fiber elongation reached its maximum), 32 and 74%, respectively, of the fiber final dry weight was present. The plateau in dry weight/length between days 42 and 49 suggest that the decreases in fiber length and weight were caused by sample variation, rather than by environmental factors that changed the fibers.

Z2557 and Pilose. These two lines will be discussed together because their performance was similar (Fig. 1, B and C). Although their fiber development was similar, the genetic factors controlling fiber development were not the same. Z2557 does not contain the *Pilose* gene. *Pilose* should have essentially the same genes controlling fiber development that are present in Texas Marker-1, except that *Pilose* has the dominant alleles at a single locus, which modifies fiber development.

Z2557 and *Pilose* reached their maximum fiber elongation by 21 days after anthesis. Not only was the maximum length reached earlier but the rate of elongation was slower than those of Texas Marker-1. Fiber length at 7, 14, and 21 days was shorter for these two lines than for Texas Marker-1.

Dry weight increased more rapidly in Z2557 and *Pilose* than in Texas Marker-1, and the final dry weight produced was greater. Inspection of the dry weight per length of fiber curve reveals that it was increasing at day 14, so secondary wall development had begun. At 21 days, 42 and 31% of the final dry weight had been deposited for Z2557 and *Pilose*, respectively. It is particularly noteworthy that dry weight and dry weight per unit length continued to increase through the entire developmental period.

Immature fiber. Fiber elongation of the *immature fiber* line appeared to be normal (Fig. ID). It grew as rapidly as Texas Marker-1 but reached its maximum by 21 days. Thus, its fibers were not as long. It had been crossed to Texas Marker-1 only once, and we do not know the fiber length of its parental line.

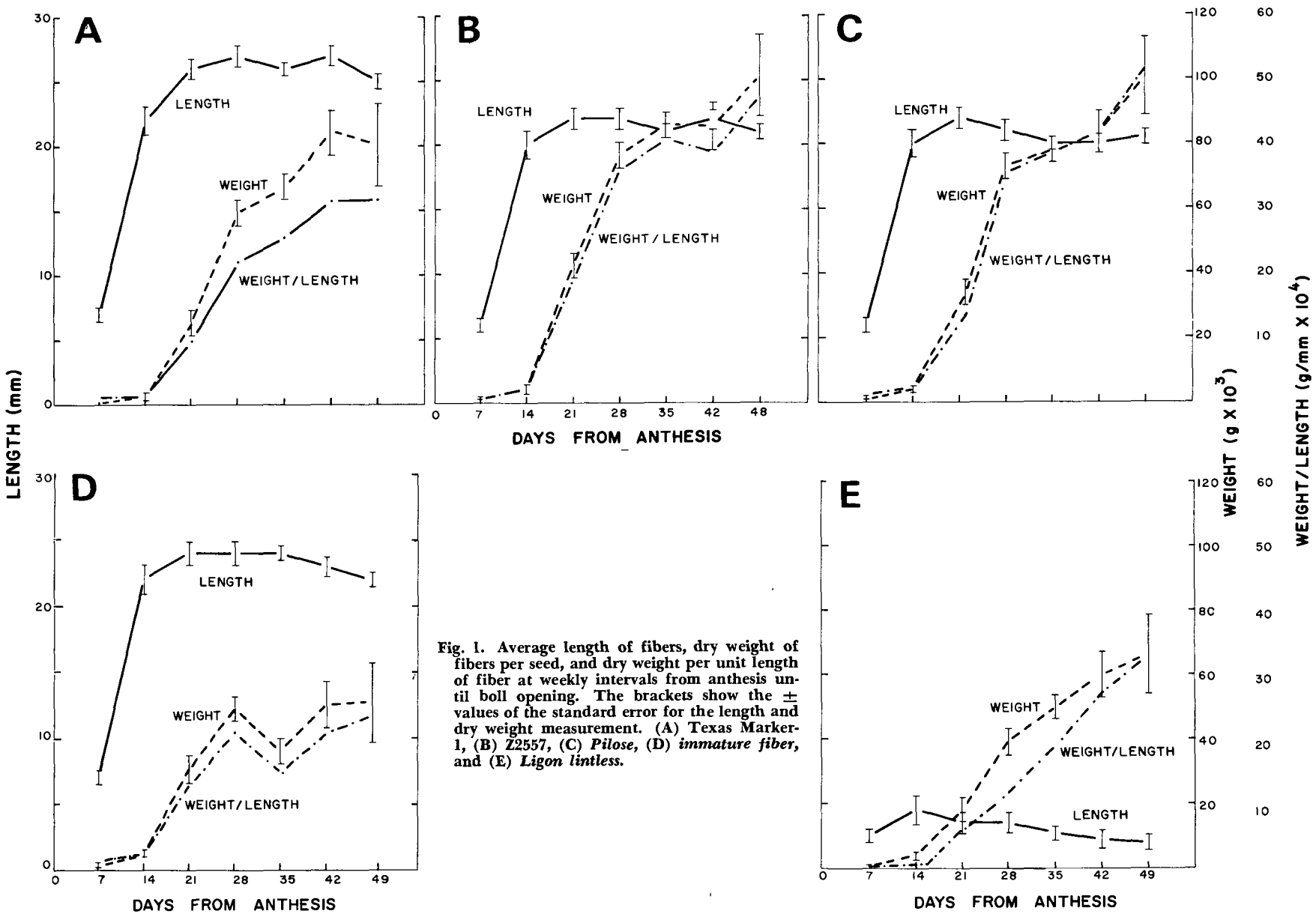

Fig. 1. Average length of fibers, dry weight of fibers per seed, and dry weight per unit length of fiber at weekly intervals from anthesis until boll opening. The brackets show the ± values of the standard error for the length and dry weight measurement. (A) Texas Marker-1, (B) Z2557, (C) *Pilose*, (D) *immature fiber*, and (E) *Ligon lintless*.

Fiber dry weight was the characteristic of this line that was altered. Dry weight accumulation began normally. At 7 days we observed only an increase in dry weight caused by fiber elongation, but at 14 days secondary cell wall deposition had started. At 21 days the increase in dry weight and dry weight/length were comparable to those observed in the other lines, but the increase slowed and reached maximum by 28 days.

Ligon lintless. Fiber elongation was altered in this line (Fig. 1E). The maximum elongation was reached in 14 days. The data indicate that what little elongation took place was at a slow rate, but it was difficult to evaluate this adequately because elongation was completed in such a short period. After 14 days, fiber lengths began to decrease. There is no obvious explanation for this, except that it may be as a consequence of continued secondary wall deposition.

In contrast to fiber elongation, fiber weight increase was essentially normal. The amount of dry matter accumulated in such a small fiber was remarkable, and undoubtedly physical limitations of the fiber caused some restriction on the increase of secondary wall. The plot of the dry weight per length data dramatically illustrates the deposition of secondary cell wall cellulose. When viewed in the light microscope, fibers of *Ligon lintless* appeared about the same diameter as a normal fiber, but they were not as extremely convoluted. It is possible also that a large number of cells elongate to form the short fibers.

INTERPRETATION

The fiber development of three mutant lines has been described and compared to that of the two control lines. With the *Pilose* mutant fiber elongation is slower and terminates sooner than in normal cotton. Fiber dry weight (secondary wall development) is not altered and is perhaps enhanced after cessation of fiber elongation. The result is a short coarse fiber similar to that of Z2557. The second mutant, *immature fiber,* has normal, or nearly normal, fiber elongation, but secondary cell wall deposition ceases at an early stage of development. The third type, *Ligon lintless,* has extremely short fiber, too short to be removed by conventional ginning procedures, and normal, or nearly normal, secondary cell wall deposition.

The mutant lines investigated demonstrate that genetic control of fiber elongation and secondary wall deposition can be dissociated. Fiber elongation can be curtailed while dry weight accumulation continues in a normal manner, and dry weight accumulation can be changed without altering fiber elongation.

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