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AGRONOMY

Cotton Mote Frequency Under Rainfed and Irrigated Conditions

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INTERPRETIVE SUMMARY

The number of seeds per boll, one of the components of yield, is highly variable and affected by environmental conditions prior to flowering and during boll development. Motes are cotton ovules that were not fertilized or seeds in which embryo development prematurely ceased. Although many small short-fiber motes can be removed by lint cleaners, fiber and seed-coat fragments crushed during harvest and ginning can pass through the gin stream and be incorporated into bales. Fiber can be removed from large, long-fiber motes during ginning with or without crushing the mote. Fiber from long-fiber motes is less mature than fiber from normal seeds. Improvements in yield and quality can be achieved by increasing the number of ovules fertilized and decreasing seed abortion.

In the research described in this report, the frequency of mote production under rainfed and irrigated conditions was monitored throughout the flowering period. Motes were categorized by fiber length. Short-fiber motes had fiber shorter than one-half the length on normal seeds. Short-fiber mote production fluctuated from 4 to 14% of the total seed number during the second through the sixth week of flowering in rainfed and irrigated cotton. Long-fiber motes had fiber lengths longer one-half the length on normal seeds and weighed less than 60 mg. Irrigation reduced long-fiber mote frequency.

The location of seeds in a locule can be mapped in relation to the apex of the boll. The seed closest to the apex of a boll was designated seed Position 1, and seeds were numbered consecutively toward the pedicel. Seed locations in locules were ranked according to mote frequency. Some seed locations were more sensitive to environmental perturbations, and under rainfed conditions (in 1994 and 1995) mote frequency patterns emerged. Seed positions near the boll apex or pedicel had more long-fiber motes.

Factors that contribute to reduced weight gain per seed may affect seed abortion. Cotton seed weights varied from 60 to 190 mg per seed. Locules were categorized according to average seed weight. Long-fiber mote frequencies were greater in locules with low seed weights than in locules with high seed weights.

This research emphasizes that environmental fluctuations alter mote frequency. Understanding factors controlling seed abortion is of importance to physiologists, breeders, and producers.

ABSTRACT

Short-fiber motes in cotton (*Gossypium hirsutum* L.), which have fibers shorter than one-half the length of the fibers on normal seeds, are either unfertilized ovules or underdeveloped seeds in which embryo growth ceased shortly after fertilization. Increased numbers of short-fiber motes reduce yield. In long-fiber cotton motes (fiber lengths longer than one-half the length of fibers on normal seeds), termination of embryo growth occurs some time after fertilization. Increased numbers of long-fiber motes reduce yield and fiber quality because less secondary wall is deposited on mote fibers. The objective of this study, conducted in Corpus Christi, TX, was to: (i) determine the frequency of mote production under rainfed and irrigated conditions, (ii) rank seed positions in locules according to probability of growth termination, and (iii) examine possible relationships between seed weight and mote production. Irrigation increased yield. Short-fiber mote percentages were the same in rainfed and irrigated cotton in 1993, but not in 1994 and 1995. In low-yield years, long-fiber

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mote percentages in rainfed cotton increased as the season progressed. When differences in mote frequencies among seed positions occurred, higher mote frequencies were associated with seed positions near either the locule apex or the pedicel. Some seed locations may be more sensitive to environmental perturbations than others. High frequencies of long-fibered motes were associated with locules in which the average seed weight was 60 to 110 mg (the lowest seed weight category).

The number of seeds per boll is a component of both cotton yield and fiber quality and is a function of the number of locules (carpels) per boll and the number of ovules per locule (Stewart, 1986). Seed-setting efficiency has been used to designate the number of seed produced, compared with the number of ovules available for fertilization (Turner et al., 1977).

Variation in seed per boll is the result of either the lack of seed fertilization or post-fertilization termination of embryo growth. Both cultivar and environment contribute to the variation in the number of seeds per boll. Weather conditions affect ovule development, pollen fertility, and pollen dispersal (Powell, 1969; Fisher, 1973; Stewart, 1986).

Small motes are defined as ovules that have not been fertilized or underdeveloped seed in which embryos ceased growth shortly after fertilization (Pearson, 1949; Davidonis et al., 1996). Saranga et al. (1998) defined small motes as being 1 to 2 mm in width and up to 3 mm in length with fibers shorter than 1 mm while medium motes were 1 to 3 mm in width and 3 to 5 mm in length with fibers less than 10 mm long. Nonfertilized motes can be categorized as those in which embryo sac formation was defective and those in which the embryo sac was normal, pollen entered the ovule but fertilization was not accomplished (Sato, 1954). Small *G. hirsutum* motes weigh from 1 to 30 mg and have fiber less than half the length of fiber from normal seeds (Davidonis et al., 1996).

Post fertilization termination of embryo growth produces large motes with long fiber. Long-fiber motes weighing 35 to 60 mg have thin fiber cell walls with micronaire (micronafis) values less than 3.0 (Davidonis et al., 1996). Short-fiber motes are generally removed during lint cleaning while fiber from long-fiber motes is ginned from the motes and is incorporated into bales. The presence of six or more long-fiber motes per boll reduces the fiber quality of normal seeds within bolls (Davidonis et al., 1996). Thus, the presence of long-fiber motes both directly and indirectly alters fiber quality.

Pearson (1949) found no differences in short-fiber mote percentages that could be related to the early, middle, or late portions of the flowering period. Early-set bolls had more small motes than later set bolls in *G. barbadense* (Hughes, 1968). In one year of a 3-yr study, late-set bolls had more small motes than bolls set mid-season (Hughes, 1968). Small and medium mote frequencies were similar in early- and late-set bolls while large-mote frequencies were greater in late-set bolls than in early-set bolls (Saranga et al., 1998).

The occurrence of short-fiber motes has been linked to rainfall and temperature changes (Pearson, 1949). More short-fiber motes were formed on days in which a considerable amount of rain fell before noon and on days in which the maximum air temperatures were near 38 °C (Pearson, 1949). In contrast to Pearson (1949), Hughes (1968) stated that small-mote frequency was not related to rain falling on open *G. barbadense* flowers. A comparison of the number of small and medium motes obtained from bulk seed cotton samples revealed that irrigation reduced the number of small motes in *G. hirsutum* and *G. barbadense* (Saranga et al., 1998). Irrigation decreased the frequency of large motes in *G. barbadense* but not in *G. hirsutum* (Saranga et al., 1998).

The cotton plant can be described as a collection of carbohydrate sinks, all requiring supply from mature exporting leaves. Seeds have been described as high-priority sinks (Minchin and Thorpe, 1996). Environmental perturbations can lead to alterations in source-sink interactions. Translocation responses to water stress include reduction of source strength by reduction of photosynthetic rate and reduction of sink strength by growth inhibition (Hsiao, 1973). Irrigation-related increases in seed cotton and lint yields have been correlated with increases in seed index (the weight, in grams, of 100 seeds) (Spooner et al., 1958; Marani and Amirav, 1971; Shimshi and Marani, 1971).

Cotton and pea (*Pisum sativum* L.) may manifest similar source-sink interactions in terms of seed weight even though cotton has multilocular fruits and pea has single-locule fruits. Pod development can be divided into two phases. Seeds can abort during the course of the first phase of pod development. A simulation model was proposed in which assimilates produced are allocated to pods in proportion to their biomass (first phase of development) or to their seed number (second phase, during which almost no seed abortion occurs). The model was validated under field conditions (Jeuffroy and Devienne, 1995). A decrease in seed-setting efficiency, related to fertilization and embryo abortion, reduces the number of seeds per boll, which in turn, may alter assimilate partitioning.

Pearson (1949) found that small and large motes tended to be concentrated at the stigma (apex) and the pedicel (basal) regions of locules. Others reported a progressive increase in motes from the apex to the base of the boll (Rea, 1928; Porter, 1936). Hughes (1968) concluded that the basal ovules were the least likely to be fertilized and that there was no progressive increase in small motes from the apex to the base in *G. barbadense*. We show in this paper a differential sensitivity hypothesis that may account for some of the conflicting reports of seed-setting efficiency as related to the location of motes in locules.

The order of entry of pollen tubes into ovules does not depend on ovule position within a locule because ovules near the stigma are not necessarily the first ones to be fertilized (Iyengar, 1938). Therefore motes formed as a result of defective pollen would be expected to occur randomly. If incomplete ovule development occurs randomly, then motes formed as a result of incomplete ovule development would occur in a random manner.

If some seed locations were more likely to manifest atypical ovule or seed development, then motes could be expected to occur more frequently at those seed locations. Final embryo weight can serve as an indicator of the ability of a seed to attract assimilates.

Embryo weight, ranked by seed location, showed that seeds in the middle of locules had the highest embryo weights, while seeds near the stigma had the lowest embryo weights, and pedicel region seeds had intermediate embryo weights (Iyengar, 1941). If seeds in the stigma and pedicel regions of locules have reduced abilities to attract assimilates, then environmental perturbations affecting assimilate distribution could promote embryo abortion in those seed regions to a greater degree than seeds in the middle of locules.

The objectives of this research were to (i) determine the frequency of short- and long-fiber mote production under rainfed and irrigated conditions, (ii) rank seed locations in locules for their propensity to form short- or long-fiber motes, and (iii) determine if seed weight and locules per boll were related to mote production.

MATERIALS AND METHODS

Plant Material and Growing Conditions

‘Deltapine 50' seeds were sown in mid-March (1993–1995) at the Texas A&M University Agricultural Research and Extension Center, Corpus Christi. Soil type was Victoria clay (fine, smectitic, hyperthermic Udic Pellusterts).

Each year before planting, cotton residues were shredded and 30-cm-tall beds were formed. Trifluralin (2,6–dintro–N,Ń–dipropyl –4–(trifluoromethyl) benzenamine) was applied preplant for weed control. Plots were cultivated twice during the growing season. Row spacing was 96 cm with an average of 11 plants per meter of row (1993–1995). Insect control was accomplished using pesticides and rates recommended by the Texas Agricultural Extension Service. Each plot was 12 rows wide and 15 m long.

Treatments were rainfed plots and plots that received supplemental irrigation in addition to rainfall. The drip irrigation system consisted of 3.8 L h^{-1} emitters spaced 0.8 m apart. Lines were placed at every other row. Each treatment was replicated in four plots in a completely randomized design.

First-position bolls (bolls nearest the main stem) were tagged on the day of anthesis. Plants were tagged once a week, with tagging (two rows per plot) beginning the second week after first bloom and continuing at 7-d intervals for 5 wk. Ethephon (2–chloroethyl phosphoric acid) was applied (1.24 kg a.i. ha^{-1}) at 60% open bolls. Carmichael et al. (1998) found no reduction in seed quality or micronaire when harvest aid chemicals were applied at various stages of boll opening. Seven to 10 d after ethephon treatment, all bolls from two center rows of each replicate plot were hand picked for yield determinations. The two tagged rows in each plot were hand-picked for locule mapping.

Locule Mapping

Tagged bolls were collected at harvest and locules were spread apart by hand. Bolls were not used if they were damaged, diseased, or missing locules. Three-, four-, and five-locule bolls were collected. Seeds in a locule were numbered with the seed closest to the apex of a boll designated Seed 1, and other seeds numbered consecutively toward the pedicel (Rea, 1928). Each seed position was scored as a seed, short-fiber mote, or long-fiber mote (locule mapping). Short-fiber motes were defined as having fibers less than half the length of fibers from normal seeds within the same locule. Long-fiber motes had fiber longer than half the length of fibers from normal seeds within the same locule and weighed less than 60 mg (seed and fiber).

Using maps, locules were sorted according to the presence or absence of motes. The percentage of locules with motes was determined. Locule maps were also used to choose locules that had only one mote (short or long fiber).

Average Seed Weight

Seeds in Position 4 provided an accurate estimate of average seed weight per boll. Seed weights were recorded for each seed position (1–8) for a total of 9335 seeds from 1995 rainfed cotton and 12 969 seeds from 1995 irrigated cotton. The difference between seed weight averages at a given seed position and the boll's average seed weight were compared. This difference can be notated by $d_{ij} = \mu_{i\bullet} - \mu_{\bullet j}$; where μ_i = average seed weight at the i^{th} seed position, with dot notation indicating the average was across all bolls, and $u_{\bullet j}$ = the average seed weight of seeds in the j^{th} boll. Confidence intervals around these average differences, $\mu_{di\bullet} \pm t_{\alpha = 0.05} \bullet se_{di\bullet}$ for the i^{th} seed position, all excluded zero; with the exception of the fourth seed position.

Seed/Mote Sampling

Short- and long-fiber mote percentages were calculated in 4- and 5-locule bolls from rainfed and irrigated cotton during the growing season. The probability of a mote occurring at a specific seed location was based on the total number of seeds and motes at that location. Statistical procedures used in determining mote frequency at a specific seed location in a locule required that at least five motes occur at that seed location in the study populations. However, five motes were not found at all seed locations, and comparisons of all seed locations within a treatment could not be made.

Statistical Methods

The weighted-least-squares estimates (Grizzle et al., 1969) of the proportion of motes to the total seeds and motes in each category were calculated using the catmode procedure of SAS (SAS Institute, 1989). Contrast statements were then constructed to compare treatments for mote occurrence frequency using generalized Wald test statistics (Wald, 1943). For statistical analysis, a minimum of 10 bolls per category (week of flowering) was used.

RESULTS

Water Input Patterns

Water input, coupled with soil-water status at planting, and soil characteristics all contribute to plant growth. Fluctuations in seasonal rainfall amounts and irrigation provide a range of water input patterns that might be related to mote frequency (Table 1). Rainfall patterns revealed that 1993 had the highest May-through-July rainfall

Table 1. Nitrogen and water inputs for cotton production research conducted at Corpus Christi, TX.

	Nitrogen			Rainfall			Irrigation†		
Planting date	**Preplant**	**Post plant (rainfed)**	**Post plant (irrigated)**	**May**	**June**	**July**	**May**	**June**	**July**
		KgN ha^{-1}			**mm**			**mm**	
11 Mar 1993	**34**	**90**	**106**	**173**	**172**	**0**	**0**	**25 (1)**	**104(7)**
23 Mar 1994	**34**	**90**	**107**	**39**	**81**	**18**	**66 (2)**	**58 (4)**	**155 (22)**
31 Mar 1995	**36**	**85**	**112**	**81**	**57**	**16**	**18 (2)**	**89 (4)**	**140 (6)**

† Number of irrigations per month in parenthesis.

amounts, 1994 had the lowest rainfall amounts. Rainfed cotton lint yields were 1343 ± 94 kg · ha^{-1} for 1993, 895 ± 77 kg · ha^{-1} for 1994, and 1120 ± 188 kg · ha^{-1} for 1995. Total water input for irrigated cotton was greater than 390 mm each year and resulted in lint yields of 1586 ± 56 kg · ha^{-1} for 1993, 1537 ± 40 kg · ha^{-1} for 1994, and 1572 ± 49 kg · ha^{-1} for 1995.

Mote Frequency

In 1993, rainfed cotton short-fiber mote percentages did not differ significantly between rainfed and irrigated cotton (Table 2). Short-fiber mote frequency in rainfed cotton was 7.9% in 1994 for the fourth week of flowering and 13.9% in 1995 for the fifth week of flowering (Table 2). In irrigated cotton (1994 and 1995), short-fiber mote frequency varied during the season. Irrigation increased short-fiber mote frequency both of those years (Table 2).

Minimal long-fiber motes were produced during the second week of flowering in all years for rainfed cotton (Table 3). Long-fiber mote frequency in rainfed cotton increased as the season progressed. In 1993 irrigation was terminated on 19 July (the tagging date for the sixth week of tagging was 15 July) and a dramatic rise in long-fiber mote percentage was seen in bolls beginning with the sixth week of flowering. The last irrigation date in 1994 was 28 July and the last tagging date (sixth week of flowering) was 5 July. The last irrigation date in 1995 was 24 July and the tagging date for the fifth week of flowering was 28 June. Irrigated cotton (1994, 1995) had a lower frequency of long-fiber motes than did rainfed cotton for the third and fourth weeks of flowering (Table 3).

Factors that contribute to reduced weight gain per seed may affect seed abortion. Cotton locules were categorized by average seed weight and mote number. The category composed of locules with one mote was chosen for further analysis. The occurrence of single-mote locules in a population can be illustrated by comparing three flowering dates in 1995 rainfed cotton. Twenty-five percent of the locules from the second and third weeks of flowering and 17% of the locules from the fourth week of flowering were single-mote locules while 15, 25, and 31% of the locules had more than one mote for the second, third, and fourth weeks of flowering, respectively.

Table 2. The percentages of short-fiber motes found in 4-locule bolls from rainfed and irrigated cotton (DPL 50) during the growing season.

Treatment	Year	Week of flowering				
		2	3	4	5	6
		Short-fiber motes (%)				
Rainfed	1993	8.0 a†	6.4 ab	5.4 b	5.4 ab	5.9 ab
Irrigated	1993	6.6 a	7.2 a	5.3 a	5.8 a	6.9 a
Rainfed	1994	5.5 *b	5.9 *a	7.9 *a		
Irrigated	1994	9.6 a	10.1 a	5.2 bc	3.8 c	5.6 b
Rainfed	1995	3.7 c	6.4 *b	4.9 *bc	13.9 *a	
Irrigated	1995	4.1 c	8.2 a	6.0 b	4.3 c	

† Means within a column followed by an * indicate significant differences (*P* = 0.05) between rainfed and irrigated mote percentages. Means within a row followed by the same letters are not significantly different at *P* = 0.05. Means within a column were not compared across years.

Table 3. The percentages of long-fiber motes found in 4-locule bolls from rainfed and irrigated cotton (DPL 50) during the growing season.

Treatment	Year	Week of flowering				
		2	3	4	5	6
		Long-fiber motes (%)				
Rainfed	1993	2.4 c†	7.7 * ab	7.8 * ab	9.5 *a	5.3 * b
Irrigated	1993	2.4 c	3.0 bc	4.4 b	1.0 d	9.9 a
Rainfed	1994	2.2 c	8.5 * b	14.8 * a		
Irrigated	1994	2.2 b	0.6 c	1.4 c	3.5 a	0.8 c
Rainfed	1995	5.3 * c	8.3 * b	15.2 *a	14.7 * a	
Irrigated	1995	3.4 b	2.0 c	1.5 c	5.0 a	

† Means within a column followed by an * indicate significant differences (*P* = 0.05) between rainfed and irrigated mote percentages. Means within a row followed by the same letters are not significantly different at *P* = 0.05. Means within a column were not compared across years.

A comparison was made to determine if seed weight range was related to the probability that the one mote in a single-mote locule was a long-fiber mote (only locules with one mote either short- or long-fiber were selected for this analysis). In the 60-to-110 mg seed weight range, around 30% of the total number of single-mote locules contained one long fiber mote (Fig. 1). As average seed weight increased, the percentage of single-mote locules having a short-fiber mote increased so that at the 171-to-190 mg seed weight range, about 95% of the single-mote locules had a single short-fiber mote (Fig. 1).

Seed Location

The total mote percentages (all seed locations), recorded in Tables 2 and 3, were broken down into

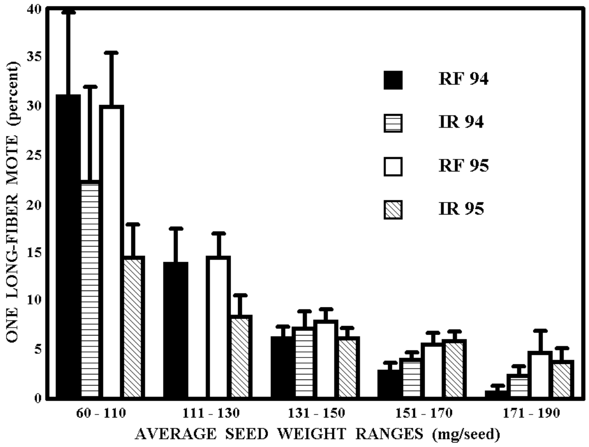

Fig. 1. Percent of locules containing one long-fiber mote in the total locule population containing only one mote (either a short or long fiber mote). Data are presented in relation to the average weight of the middle seed in the locule containing the mote. RF = rainfed, IR = irrigated.

Table 4. Short-fiber mote occurrence in relation to seed location within a locule in DPL50.

Seed location in a locule†		Second week of flowering		
		1993	1994	1995
		Short-fiber motes (%)		
Rainfed	1	5.4 a‡	5.1 a	2.9 ab
	2	6.2 a	5.0 a	4.9 a
	3	10.7 a	5.3 a	4.5 ab
	4	6.2 a	5.3 a	2.7 b
	5	10.7 a	5.0 a	4.5 ab
	6	6.2 a	6.3 a	2.9 ab
	7	9.8 a	4.5 a	3.7 ab
	8	8.4 a	7.4 a	3.6 ab
Irrigated	1	3.0 b	4.8 c	3.0 a
	2	6.1 ab	7.2 bc	4.8 a
	3	5.3 ab	8.2 bc	5.6 a
	4	3.0 b	10.1 b	4.0 a
	5	9.1 a	9.1 bc	4.8 a
	6	7.6 ab	9.1 bc	2.8 a
	7	7.7 ab	12.0 ab	4.3 a
	8	10.8 a	16.7 a	3.5 a

† The seed nearest the pedicel is designated no. 8.

‡ Means within a column followed by the same letter are not significantly different at *P* = 0.05. Data based on 4-locule bolls.

mote percentages by seed location. In some cases the number of short-fiber motes found at a specific seed location was too small for statistical analysis (see Materials and Methods). No strong relationship was found between seed position and percent short-fiber motes (Table 4). When differences were found (1993, 1994 irrigated) the Seed 1 location had fewer short-fiber motes than did the Seed 8 location.

Table 5. Long-fiber mote percentages within a locule and across the growing season DPL 50, rainfed.

1994	Week of flowering		
Seed location in a locule†	2	3	4
	Long-fiber motes (%)		
1	2.0 a‡	11.7 a	27.0 a
2	2.4 a	9.4 a	20.0 ab
3	1.8 a	6.2 b	6.0 c
4	1.6 a	9.7 a	11.1 bc
5	1.5 a	5.0 b	11.1 bc
6	2.0 a	7.8 ab	13.1 bc
7	3.1 a	7.1 ab	16.1 ab
8	2.7 a	11.1 a	13.8 bc

1995	Week of flowering			
Seed location†	2	3	4	5
	Long-fiber motes (%)			
1	8.6 a‡	10.4 ab	13.9 bc	17.9 ab
2	8.0 a	5.2 b	13.9 bc	9.5 b
3	3.8 bc	8.8 ab	11.6 c	8.3 b
4	2.6 c	5.2 b	10.5 c	11.9 ab
5	4.3 bc	6.2 ab	12.8 bc	16.7 ab
6	4.6 b	10.4 ab	16.9 bc	13.1 ab
7	5.2 b	11.5 a	19.3 b	19.0 ab
8	5.8 ab	8.9 ab	23.4 a	21.5 a

† The seed nearest the pedicel is designated no. 8.

‡ Means within a column followed by the same letter are not significantly different at *P* = 0.05. Data based on 4-locule bolls.

No consistent patterns involving time were seen from the second through the sixth week of flowering when short-fiber motes were monitored at specific seed locations (data not shown). Long-fiber mote frequencies were determined for seed locations in a locule during the 1994 and 1995 growing seasons (Table 5). Long-fiber motes occurred less frequently in irrigated cotton and sufficient numbers per treatment were not found for seed location analysis. In 1994, there were no differences in long-fiber mote frequencies related to seed location in early-set bolls, while in later-set bolls the percentages of long-fiber motes at the Seed 1 location were significantly different from the percentages of long-fiber motes at the Seed 3 location (Table 5). Middle seeds (Seed 3 and 4 locations) had lower mote frequencies than did the Seed 8 location in bolls set during the fourth and fifth week of flowering (Table 5). The largest mote percentage found in irrigated cotton was for the sixth week of flowering in 1993 (Table 3). The percentage of long-fiber motes found at the Seed 4 location was significantly less than the percentages of motes found at the Seed 1, 2, 7, and 8 locations (data not shown).

Locule Number and Mote Frequency

Mote percentages were calculated for four- and five-locule bolls categorized by week of flowering and water input. The percent of short-fiber motes in four- and five-locule bolls from rainfed plants was the same in bolls set the second week of flowering (1993–1995, Table 6). In 1993 and 1995, five-locule bolls from plants grown under irrigated conditions had more short-fiber motes than four-locule bolls set during the second week of flowering. There was no difference in long-fiber mote percentage between four- and five-locule bolls set during the second week of flowering (1993–1995) (Table 7). A comparison of small short-fiber mote percentages for four- and five-locule bolls showed that mote percentages were similar while the percentage of locules with no small short-fiber motes was greater in four-locule bolls than five-locule bolls (Pearson, 1949).

Table 6. Short-fiber mote frequency in 4- or 5-locule bolls (DPL 50).

Treatment	Year	Week of flowering	Number of locules	
			4	5
			Short-fiber motes (%)	
Rainfed	1993	2	8 a†	8 a
Rainfed	1993	3	6 a	7 a
Irrigated	1993	2	7 b	12 a
Irrigated	1993	3	7 a	8 a
Rainfed	1994	2	6 a	5 a
Rainfed	1994	3	6 b	7 a
Irrigated	1994	2	10 a	6 a
Irrigated	1994	3	10 a	12 a
Rainfed	1995	2	4 a	4 a
Irrigated	1995	2	4 b	7 a
Irrigated	1995	3	8 b	17 a

† Means within a row followed by the same letter are not significantly different at the 0.05 probability level. Means within columns across years were not compared.

Table 7. Long-fiber mote frequency in bolls composed of 4- or 5-locule bolls (DPL 50).

Treatment	Year	Week of flowering	Number of locules	
			4	5
			long-fiber motes (%)	
Rainfed	1993	2	3 a†	3 a
Rainfed	1993	3	8 a	4 b
Irrigated	1993	2	2 a	1 a
Irrigated	1993	3	3 a	2 a
Rainfed	1994	2	2 a	2 a
Irrigated	1994	2	2 b	6 a
Rainfed	1995	2	2 a	2 a
Irrigated	1995	2	2 a	3 a
Irrigated	1995	3	2 a	2 a

† Means within a row followed by the same letter are not significantly different at the 0.05 probability level. Means within columns across years were not compared.

DISCUSSION

Mote Frequency

Differences in short-fiber mote frequency related to boll location were found in 1994 and 1995, but not in 1993, in rainfed and irrigated cotton (Table 2). Pearson (1949) and Saranga et al. (1998) did not find differences related to boll location while Hughes (1968) found differences. The discrepancies in mote frequencies may be related to environmental fluctuations during the growing season rather than to any inherent propensity of certain boll locations to produce large numbers of short-fiber motes.

Irrigation increased short-fiber mote percentages in four- and five-locule bolls (Tables 2, 6). The relationship between irrigation and short-fiber motes remains unclear. Saranga et al. (1998) categorized motes by mote percentage of total seed potential (number of seed and motes of all sizes) and number of motes per gram of lint obtained from a 40-g sample. The effect of irrigation on small and medium mote frequency (number per gram of lint) was analyzed using seed cotton from all boll locations.

The highest long-fiber mote frequencies were recorded for rainfed cotton in 1994 and 1995 (Table 3). During most of the season (week 3–5 of flowering) rainfed cotton had higher long-fiber mote percentage than did irrigated cotton. Although Saranga et al. (1998) reported that the number of large motes in rainfed cotton was greater in late-set bolls, irrigation did not decrease large mote frequency in *G. hirsutum*.

Early termination of irrigation in 1993 had a pronounced effect on long-fiber mote formation (Table 3). Individual pea seed weight variations have been attributed to seed growth rate and, in turn, seed growth rate was correlated to cotyledon cell number, leading to the conclusion that variations in seed growth rate depend on growing conditions during the period between flowering and the beginning of seed filling (Munier-Jolain and Ney, 1998). The seed-filling period for cotton begins around 21 d post anthesis with the embryo accumulating protein, followed by oil accumulation beginning at 25 d post anthesis (Stewart, 1986). Maximum embryo length is attained at 25 d post anthesis (Stewart, 1986). Therefore, dramatic environmental fluctuations prior to 21 d post anthesis would be major contributors to long-fiber mote formation. This is in agreement with the findings of Sato (1954) that the period between 15 d post anthesis and boll opening contributed a 1% increase in mote percentages, while during the period from 7 to 15 d post anthesis mote percentages increased from 5.7 to 13.4%.

Weight Gain

If weight gain per seed expressed as final seed weight was considered to be a reflection of available assimilates and/or of sink strength, then low-seed-weight bolls have a greater propensity than do high-seed-weight bolls for long-fiber mote production (Fig. 1). Regression analysis showed that the decrease in *G. barbadense* boll weight with increasing numbers of small motes was less than that predicted from the loss of seeds (Hughes, 1968). This indicates that some compensation in seed weight occurred (Hughes, 1968).

If assimilates are allocated to young bolls in a manner similar to pea pods, then early boll biomass in relation to boll load and boll location on plant may prioritize assimilate allocation. This prioritization may result in a boll with fewer seeds and many small motes receiving the same amount of assimilate as a boll with few small motes and many seeds. Embryo development (cells per embryo) may be more extensive in bolls with few seeds, thus laying the foundation for greater weight gain during the filling period.

Over 3 yr, three patterns of mote frequency related to seed location were seen. First, all seed locations had similar mote frequencies; second, Seed 1 location had a lower short-fiber mote frequency than did Seed 8 location; and third, middle-seed locations had lower long-fiber mote frequencies than did seed locations in the apex or pedicel regions. If, during ovule and seed development, certain seed locations are inherently more sensitive to factors that promote atypical ovule development or embryo abortion, then changes in the physiological status of a plant would cause shifts in mote location patterns.

The different mote frequency patterns reported by Rea (1928), Porter (1936), Pearson (1949), and Hughes (1968) may be reconciled by the differential sensitivity hypothesis. High temperatures and water stress alter the physiological status of a plant, and the consequences of the change in physiological status may alter development of pollen, ovule, or seed. The critical developmental period for short-fiber motes is 2 to 3 wk prior to anthesis when atypical pollen or ovule development occurs (Stewart, 1986). For long-fiber motes this critical period runs from fertilization through embryo growth and development.

CONCLUSIONS

Further elucidation of the differential sensitivity hypothesis requires a more precise delivery of environmental perturbations to developing pollen, ovules, and seeds. The formation of long-fiber motes may depend on the timing, intensity, and duration of stress. In 1995, June rainfall was lower than in the two preceding years. All flowering weeks were in June. Differences in long-fiber mote percentages for rainfed and irrigated bolls were manifest during the second week of flowering (Table 3). Middle-seed positions had the lowest mote percentages (Table 5). An increase in the severity of the stress may lead to more long-fiber motes per locule, culminating in most of the seed positions within a lock occupied by long-fiber motes. The relationship between stress and short-fiber mote frequency is more complicated because short-fiber motes are the result of defective pollen, incomplete ovule development, and embryo abortion shortly after fertilization.

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