Published March, 1984

Reduction in Number of Motes in Bolls of Interspecific Hybrid Cotton by Backcross Pollination[1]

Harbans L. Bhardwaj and James B. Weaver, Jr.[2]

ABSTRACT

Motes are cotton (*Gossypium* spp.) ovules that fail to ripen into mature seeds but develop into aborted structures. These aborted ovules represent a loss in yield and cause imperfections in yarn and cloth quality by causing neps. The number of motes (percentage of ovules that failed to develop into seeds) was studied in interspecific hybrids (ISH) of cotton, which have a higher number of motes, for 3 years (1980-1982). A cytoplasmic male sterile ISH was hand-pollinated with pollen from its counterpart fertile-ISH and strains of parental species (*Gossypium hirsutum* and *G. barbadense*). The number of motes in seed-cotton produced as a result of these hand-pollinations was compared in 1980 and 1981. The results indicated that the number of motes was dependent upon the male parent used to pollinate the CMS-ISH. Pollinations with strains of *G. hirsutum* or *G. barbadense* resulted in approximately a 50% reduction in number of motes as compared to pollination with counterpart fertile-ISH. These findings provide an indirect evidence of cryptic structural differentiation in tetraploid species of cotton. During 1982, *G. hirsutum* backcross plants (grown from seed produced by hand-pollination in 1981), a fertile upland hybrid, and genotypes of parental species, when grown under open-pollination, had significantly lower number of motes than fertile-ISH plants. Outcrossing to parental species was observed to greatly reduce the number of motes in fertile-ISH. This is as expected because outcrossing to parental species is similar to backcrossing, which masks the effects of cryptic structural differentiation.

Additional index words: Gossypium hirsutum L., *G. barbadense* L., Cryptic structural differentiation, Cytoplasmic male sterility, Hybrid cotton.

THE phenomenon of hybrid vigor for agronomic and fiber properties in cotton (*Gossypium* spp.) has been observed since the time Mell (1894) first studied controlled cotton hybrids. Davis (1978) reviewed the published reports of hybrid vigor in cotton and concluded that a high priority should be given to production of hybrid cotton. The range of hybrid vigor in interspecific and intraspecific hybrids was of similar magnitude. The interspecific hybrids (ISH) of cotton (*G. hirsutum* × *G. barbadense*) have many advantages over intra-*hirsutum* hybrids. Some of these advantages include greater seedling vigor, increased tolerance to insect pests, and better fiber quality. The interspecific hybrids have considerably more motes as compared to intraspecific hybrids or commercial cultivars (Weaver, 1979).

A mote is an ovule that fails to ripen into a mature seed and develops into an aborted structure that may vary in degree of fiber and embryo development (Pearson, 1949). Motes represent a loss in yield and cause imperfections in yarn and cloth quality by causing neps. In addition, motes are easily broken and crushed during ginning. Small fragments may escape into lint and lower the yarn quality. Observations made by Rea (1928, 1929), Afzal and Trought (1934), Porter (1936), Afzal (1937), Pearson (1949), and Hughes (1968) have established that variation in mote number depends upon the cultivar and environmental conditions. Shibuya and Sato (1951) reported that most motes result from defective development of fertilized ovules. Defective ovules and failure of the pollen tube to fertilize were relatively unimportant causes.

Stebbins (1945) suggested a term, cryptic structural differentiation (CSD), to cover the situations when

[1] Contribution from the Dep. of Agronomy, Univ. of Georgia, Athens, GA 30602. Part of a dissertation submitted by the senior author in partial fulfillment of the requirements for the Ph.D. degree. Received 20 June 1983. The reported research was supported by State and Hatch Funds and a grant from Cotton, Inc.

[2] Graduate student and professor, Dep. of Agronomy, Univ. of Georgia, Athens, GA 30602, respectively.

Table 1. Percentages of different types of motes in cotton as a result of hand pollinations during 1980 and 1981 at Athens, Ga.

Genotypes	No. of bolls	Motes			
		Total	Large	Medium	Small
		%			
1980					
CMS-ISH × Fertile-ISH	81	53.97a†	8.77a	15.36a	29.47a
CMS-ISH × Paymaster 303‡	66	29.13b	4.36bc	10.10b	14.78b
CMS-ISH × E 4§	77	25.97bc	6.39b	8.78bc	10.79c
CMS-ISH × Coker 310‡	80	25.10c	3.91c	6.46c	14.73b
CMS-ISH × Pima S-5§	58	22.64c	5.28bc	6.81c	10.55c
1981					
Fertile-ISH ⊗	13	46.38a	2.92ab	1.28b	42.17a
CMS-ISH × Fertile-ISH	19	41.89a	2.96ab	12.38a	26.55b
CMS-ISH × UGA PR 1§	15	22.71b	1.31abc	6.15ab	15.25c
CMS-ISH × JBW 335‡	15	22.07b	0.45bc	2.17b	19.44bc
Fertile Upland Hybrid ⊗	8	18.88b	4.10a	2.31b	12.48c
UGA PR 1 (Pima Restorer) ⊗	12	17.49b	2.48abc	0.76b	14.26c
JBW 335 (Upland Restorer) ⊗	12	17.33b	0.00c	0.42b	16.91c

† The means followed by same letter within columns of the same year are not significantly different according to Duncan's Multiple Range Test (P = 0.05).
‡ *Gossypium hirsutum* male parent.
§ *Gossypium barbadense* male parent.

chromosomes of related species are not strictly homologous. Stephens (1950) observed that chromosomes of *G. hirsutum* and *G. barbadense* are not strictly homologous even though they are interfertile. Recombinations in later generations are accompanied by reduction in fertility and departures from expected Mendelian ratios.

The effect of CSD begins to show with the first segregating generation. The embryo developing on an F_1 plant is the beginning of the F_2 generation if selfing takes place. Cotton plants grown from F_2 seed of an ISH exhibit wide variation for all characters. The objective of this study was to observe the number of motes when an interspecific hybrid of cotton is backcrossed to either parent as compared to selfing.

MATERIAL AND METHODS

The experiments were conducted over a period of 3 years (1980-1982) at the Plant Sciences Farm, near Athens, Ga. Soil type was Appling Sandy loam, a member of clayey kaolintic thermic family of Typic Hapludult.

Hand Pollinations

In 1980 and 1981 a single row of CMS-ISH containing 20 plants was grown. The distance between plants was 0.97 m and plots were 1.94 m apart. The aim was to pollinate equal numbers of sterile flowers of CMS-ISH with each of five male parents, using a completely randomized design. The male parents were grown as single row plots of 10 plants each spaced 0.97 m. The sterile flowers on CMS-ISH were protected from outcrossing by closing the buds with gem clips 1 day before anthesis.

During 1980, a cytoplasmic male-sterile interspecific (*Gossypium hirsutum* × *G. barbadense*) hybrid (CMS 5-278 × 'Pima S-5' = CMS-ISH) was used as the female parent in hand pollinations. The male parents were: 1) fertile-ISH = 5-278 × Pima S-5 (*G. hirsutum* × *G. barbadense*), 2) Pima S-5 (*G. barbadense*), 3) E 4 (*G. barbadense*), 4) 'Paymaster 303' (*G. hirsutum*), and 5) 'Coker 310' (*G. hirsutum*). The CMS-ISH was used to avoid injury due to emasculation. The pollination of CMS-ISH with its fertile counterpart (fertile-ISH) was assumed to be identical to selfing in a fertile interspecific hybrid. During 1981, CMS-ISH (CMS 5-278 × Pima S-5) was pollinated with: 1) fertile-ISH (CMS GSA75 × UGA PR 1), 2) a Pima restorer (UGA PR 1), and 3) an upland restorer (JBW 335). In addition, some flowers were selfed on the three male parents. A fertile upland hybrid (CMS GSA75 × Dixie King Restorer) was also included in order to compare the number of motes in intra- and interspecific hybrids.

In both years, open flowers on all plants of CMS-ISH on a particular day were randomly selected for pollination with each of the male parents. Equal numbers of male sterile flowers were pollinated with each male parent.

During 1980 and 1981, bolls resulting from hand crossing were harvested individually. During 1981, the bolls on the male parents and the fertile upland hybrid resulting from self-pollination also were harvested individually. The seed cotton in each boll was examined for number of motes and seeds. Motes were classified as large, medium, or small, based on their size (Table 1). The smallest motes were approximately as small as a pin head and the largest as large as mature seeds. The large motes were differentiated from mature seeds as explained by Pearson (1949). The fibers on large motes have a silky appearance and the seed coat is easily crushed between the thumb and forefinger.

Table 2. Percentages of different types of motes in cotton bolls resulting from open pollination during 1982 at Athens, Ga.

Genotypes	Motes			
	Total	Large	Medium	Small
	%			
PD 695‡ × Pima S-5§ (Fertile—ISH)	31.38a†	3.50a	13.90a	13.98a
CMS-ISH × UGA PR 1§ (BC_1)	22.22ab	3.30a	9.81ab	9.10ab
CMS-ISH × JBW 335‡ (BC_1)	17.77bc	2.85a	7.81bc	7.11ab
Coker 315‡ (cultivar)	12.07bc	1.10a	6.28bcd	4.69b
UGA PR 1§	10.66c	2.43a	2.23de	6.00b
Pima S-5§ (cultivar)	9.58c	0.62a	1.29e	7.66ab
JBW 335‡	9.04c	0.63a	6.34bcd	2.07b
Fertile upland hybrid (PD 695 × BW 72-35601)	8.84c	0.45a	4.64cde	3.74b

† Means followed by the same letter within columns are not significantly different according to Duncan's Multiple Range Test (P = 0.05).
‡ *Gossypium hirsutum.*
§ *Gossypium barbadense.*

Open-Pollinated Genotypes

During 1982, a replicated test was conducted with eight entries (Table 2). The backcross plants of CMS-ISH × UGA PR 1 and CMS-ISH × JBW 335 were grown from the seed obtained from hand pollinations in 1981. Each entry was planted in a single-row plot (4.6 m long spaced 0.97 m apart) in a randomized complete block design with three replications. Five random plants were selected from each plot and three open-pollinated bolls from each plant were harvested individually. The seed cotton from these bolls was examined for number of motes and seeds. Based on size, motes were classified as large, medium, or small.

Data from all 3 years on total number of motes expressed as percentage of total number of ovules (total number of motes and seeds) were analysed separately. During 1980 and 1981, the number of bolls resulting from hand pollination was not equal for all the male parents due to insect injury, shedding, etc. We treated each boll as a replication. The problem of unequal number of replications was handled by using general linear models procedure for analysis of variance. The least square means were not different from arithmetic means; therefore, arithmetic means were used

for comparisons of backcrossed and selfed bolls. During 1982, the material was grown in a randomized complete block design with three replications and data were analysed using the analysis of variance. The means were compared using Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Motes in Hand-Pollinations

In 1980 the percentage of ovules that developed into motes depended upon the male parent used to pollinate the CMS-ISH (Table 1). Pollination of CMS-ISH with fertile-ISH resulted in 54% of the ovules developing into motes. This was the highest percentage we observed and significantly greater than that with any other male parent. The percentages of total ovules that developed into motes for all other male parents were approximately one half of that for fertile-ISH. Pollination with Paymaster 303 (*G. hirsutum*) gave a significantly higher number of motes than pollination with the other *G. hirsutum* cultivar, Coker 310. There were no significant differences in number of motes when pollinated with the male parents Pima S-5, E 4, or Coker 310. Pollination with *G. hirsutum* generally resulted in lower percentages of large motes as compared to *G. barbadense*. The large motes cause more problems since they have spinnable fibers which can break during manipulations and readily tangle into neps.

During 1981, selfing of a fertile-ISH and pollination of CMS-ISH with its counterpart fertile-ISH had similar percentages of total motes (Table 1). Therefore, we assume that pollination of CMS-ISH with its counterpart fertile-ISH is identical to selfing in a fertile-ISH. Pollination of CMS-ISH with pollen from either of the parental species resulted in significantly lower percentages of motes. A reduction of nearly 50% of ovules that developed into motes was obtained by avoiding selfing in the ISH. The percentage of motes in intra-*hirsutum* hybrid was similar to *G. hirsutum* or *G. barbadense* cultivars.

The results of hand-pollination experiments conducted during 1980 and 1981 indicate that the number of motes in interspecific hybrids of cotton can be reduced significantly by growing a CMS-ISH instead of a fertile-ISH. The CMS-ISH can be pollinated with desirable strains from either of the parental species. The CMS-ISH and pollinator, however, would have to be grown in areas of high pollen vector activity.

Motes in Open-Pollinated Genotypes

During 1982, the percentages of ovules that developed into motes were observed in a replicated field test without selfing. The fertile-ISH had the highest percentage of ovules that developed into motes (Table 2). In all other entries, the percentages of motes were significantly lower except in CMS-ISH × UGA PR 1. In the upland cultivar, Coker 315, 12% of the ovules developed into motes. There were no differences in the percentages of large motes among entries. The overall percentage of motes in the open-pollinated fertile-ISH during 1982 was considerably less than expected based on 1980 and 1981 results. During 1980, approximately 54% of the ovules in the ISH developed into motes compared to 31% during 1982. We speculate that the reason for this difference is the exceptionally high level (50%) of outcrossing at Athens. A high degree of outcrossing would lower the number of motes as compared to selfing if pollen available for outcrossing came from *G. hirsutum* or *G. barbadense* cultivars. The 1982 test was surrounded by an upland (*G. hirsutum*) nursery. This apparently resulted in an overall reduction in number of motes in fertile-ISH since a high percentage of the developing embryos may be outcrosses to *G. hirsutum* instead of F_2 selfs.

Stephens (1950) presented convincing arguments for the presence of cryptic structural differentiation in tetraploid species of cotton. Due to this differentiation, selfing in interspecific hybrids results in most of the segregates resembling either parental species or the F_1 because the crossover gametes are at a selective disadvantage. This disadvantage results from duplications and deficiencies in the gametes due to cryptic structural differentiation. The embryos resulting from union of crossover gametes presumably abort in the early stages of development. Backcross of the F_1 hybrid to either of the parental species masks the duplications and deficiencies of crossover gametes because of the complete chromosome set of the recurrent parent. This results in lower embryo abortion. The present study gives indirect evidence of cryptic structural differentiation between *G. hirsutum* and *G. barbadense*. Selfing the ISH resulted in more motes whereas backcrossing with cultivars of parental species reduced the number of motes by 50%. Our data indicate that a high level of reversion to parental types in ISH begins on the F_1 plant when they are highly cross pollinated.

The results obtained in this study indicate that two planting systems could give a lower number of motes in interspecific hybrid cotton, provided there is good pollen vector activity. The first system involves planting alternate groups of four rows with fertile-ISH and upland or Pima cultivars. The outcrossing with parental-type pollen occurring on the ISH will result in a lower number of motes. The reduction in number of motes is directly related to the degree of outcrossing. In this system high pollen vector activity would be beneficial but the plants will produce seed and lint even if vector activity declines sharply. The second system involves planting CMS-ISH and a desirable fertile genotype as a pollinator in the same field. This system will result in fewer motes but will only be successful under conditions of high pollen vector activity.

The CMS-ISH could be planted in alternate rows with an upland fertility restorer strain. The seed harvested from the CMS-ISH would be the first backcross (BC_1) to upland and plants grown from this seed would be fertile. Yield tests conducted in Georgia indicate that these BC_1 plants may produce a lint yield equal to or better than the adapted cultivars and a slightly longer and stronger fiber (Weaver, 1982). The fiber produced on CMS-ISH for the production of BC_1 seed is more desirable than the fertile counterpart. This advantage is important as a large hectarage is required for hybrid seed production. Weaver

(1981) suggested that the use of these BC_1 plants will be desirable as they are expected to show better pollen fertility than CMS-upland × upland restorer hybrids.

Further studies need to be conducted for reducing the number of motes in interspecific hybrids of cotton. There is a variation among cultivars of both *G. hirsutum* and *G. barbadense* for number of motes (Pearson, 1949 and Hughes, 1968). It is possible that some upland cultivars may have more of the *G. barbadense* genome introgressed into them than others. Similarly, some *G. barbadense* cultivars may have more of the *G. hirsutum* genome introgressed into them than others. The ISH between two strains with least differences in chromosome homology should have a lower number of motes. Determining the number of motes in a group of F_1 interspecific hybrids should be done from bolls produced by self-pollination or under very low outcrossing conditions.

ACKNOWLEDGMENTS

The senior author is thankful to Punjab Agricultural University, Ludhiana (India) and Indian Council of Agricultural Research, New Delhi (India) for providing financial assistance in the form of an advance degree fellowship.

REFERENCES

1. Afzal, M. 1937. Motes in cotton. II. Punjab desi cottons. Indian J. Agric. Sci. 7:487–495.
2. ----, and T. Trought. 1934. Motes in cotton. I. Punjab american cottons. Indian J. Agric. Sci. 4:554–575.
3. Davis, D.D. 1978. Hybrid cotton—specific problems and potentials. Adv. Agron. 30:129–157.
4. Hughes, L.C. 1968. Motes in varieties of *Gossypium barbadense*. Emp. Cotton Grow. Rev. 45(3):266–280.
5. Mell, P.H. 1894. Experiments in crossing for the purpose of improving the cotton fiber. Ala. Agric. Exp. Stn. Bull. 56.
6. Pearson, N.L. 1949. Mote types in cotton and their occurrence as related to variety, environment, position in lock, lock size and number of locks per boll. USDA Tech. Bull. 1000.
7. Porter, D.D. 1936. Position of seeds and motes in locks and lengths of cotton fibers from bolls borne at different positions on plants at Greenville, Texas. USDA Tech. Bull. 509.
8. Rea, H.E. 1928. Location of motes in the upland cotton lock. J. Am. Soc. Agron. 20:1064–1068.
9. ----. 1929. Varietal and seasonal variation of motes in upland cotton. J. Am. Soc. Agron. 21:481–486.
10. Shibuya, T., and H. Sato. 1951. Embryological studies on the formation of abortive seeds or motes in cotton. Proc. Crop Sci. Soc. Jpn. 20:210–214.
11. Stebbins, G.L. 1945. The cytological analysis of species hybrids. II. Bot. Rev. 11:463–486.
12. Stephens, S.G. 1950. The internal mechanism of speciation in *Gossypium*. Bot. Rev. 16:115–149.
13. Weaver, J.B., Jr. 1979. Production and performance of interspecific hybrid cotton. p. 72–74. *In* J.M. Brown (ed.) Proc. Beltwide Cotton Prod. Res. Conf. Phoenix, Ariz., 7-11 Jan. 1979. Natl. Cotton Coun., Memphis, Tenn.
14. ----. 1981. Development of upland fertility restorer strains capable of adequate fertility restoration. p. 84–85. *In* J.M. Brown (ed.) Proc. Beltwide Cotton Prod. Res. Conf. New Orleans, La., 4-8 Jan. 1981. Natl. Cotton Coun., Memphis, Tenn.
15. ----. 1982. Recent significant observations on the development of hybrid cotton. p. 88–90. *In* J.M. Brown (ed.) Proc. Beltwide Cotton Prod. Res. Conf. Las Vegas, Nev., 3-7 Jan. 1982. Natl. Cotton Coun., Memphis, Tenn.