

EFFECTS OF LOCATION, RATIOS, AND PLANTING ARRANGEMENT ON  
NATURAL CROSSING IN COTTON

EFFECTS OF LOCATION, RATIOS, AND PLANTING ARRANGEMENT ON  
NATURAL CROSSING IN COTTON

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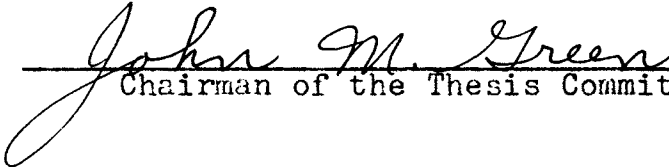
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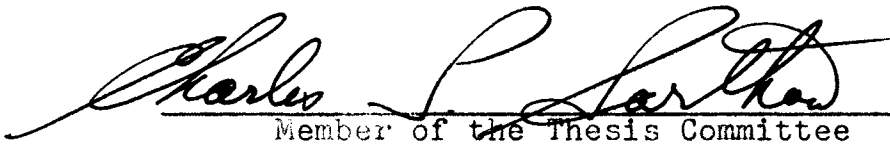
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## INTRODUCTION

One of the first studies on the natural crossing of cotton Gossypium hirsutum L., the results which were published in 1903, was conducted in South Carolina by Webber (23)<sup>1/</sup>.

Some of the problems in cotton breeding resulting from natural crossing are; difficulty in keeping strains of commercial varieties pure, increase and maintenance of breeding stock, and keeping genetically distinct lines pure. However natural crossing does offer some possibilities of value to the cotton breeder, including selection for recombinations within varieties, utilization of heterosis on a commercial scale and maintenance of variability within breeding material and in commercial varieties.

Objectives of this study were to determine the effects of (1) location in Oklahoma, (2) ratios of male to female plants, and (3) planting arrangement of males and females within a given ratio on the per cent of natural crossing occurring in cotton.

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<sup>1/</sup> Figures in parenthesis refer to "Literature Cited", page 18.

## REVIEW OF LITERATURE

Alternate Rows of Male and Female

Webber (23) reporting in 1903, was the first to publish results of natural crossing using alternate rows of male and female. His and later investigators' results on the amount of natural crossing occurring in alternate rows are recorded in Table 1.

Table 1.--Reports of natural crossing in cotton when males and females were planted in alternate rows.

Location	Investigators	Per cent Natural Crossing	
		Maximum	Minimum
South Carolina	Webber (23)	10.00	5.00
Egypt	Balls (5)	15.00	5.00
North Georgia	Allard (3)	20.00	----
North Georgia	McLendon (12)	2.00*	----
Mississippi	Ricks & Brown (15)	11.10	4.90
Arizona	Kearney (9)	11.00	5.00
Texas	Stroman & Mahoney (20)	0	0
North Arkansas	Ware (22)	40.90*	----
South Arkansas	Ware (22)	1.00	----
Oklahoma	Ligon (10)	15.90	5.10
China	Yu & Hsieh (24)	7.79*	----
Russia	Anonymous (4)	9.00	4.00
Texas	Richmond, Harper & Beasley (14)	9.00*	----
Tennessee	Pope, Simpson & Duncan (13)	27.20*	----
India	Afzal & Khan (1)	3.45	1.41
South Georgia	Turner (21)	34.00	11.00

\* Average figures

Ricks and Brown (15) in Mississippi, reported that a large number of the bolls produced no hybrid plants and the ones that did produced only a relatively small number per boll.

Kearney (9) working in Arizona was of the opinion that natural crossing rarely exceeded 20 per cent and was usually much lower. He was using Egyptian and upland types of cotton grown in alternate rows.

Allard (3) working in Georgia believed there were strong probabilities that approximately 40 per cent of the bolls contained hybrid seed. He was using Willett's Red Leaf Variety and green-leaf upland cotton in alternate rows.

#### Other Planting Arrangements

Other planting arrangements were adjacent plants, alternate plants, 90 per cent males, and more than 90 per cent males. The results reported by workers at various locations and the planting arrangements used are given in Table 2.

At Clemson College, Collings and Wallace (7) found 0.59 per cent natural crossing when a field of Red Leaf cotton was surrounded by green-leaf varieties. This was not set up as an experimental project. It was an observation of a field grown in the vicinity of the college.

A regional natural crossing testing program has been carried on since 1949. All tests were planted with a ratio of nine males to one female, the green female plants in adjacent rows being staggered so no green plant was adjacent to any other green plant. The locations and per cent of



natural crossing at each are presented in Table 3. (18).

Table 2.--Percentage of natural crossing in cotton where males and females were planted in arrangements other than alternate rows.

Location	Investigators	Planting Arrangement	Per cent Natural Crossing	
			Maximum	Minimum
Texas	Shoemaker (16)	Excess of males**	10.90*	----
Texas	Stroman & Mahoney (20)	Adjacent plants	3.28	1.76
Mississippi	Brown (6)	90 per cent	81.00	57.00
Mississippi	Brown (6)	Adjacent plants	19.00*	----
India	Afzal & Khan (2)	Adjacent plants	2.28	1.91
Georgia	Turner (21)	90 per cent	33.50	25.80
Oklahoma	Ligon (10)	Alternate plants	25.20	21.60
Arizona	Kearney (9)	90 per cent	34.60	14.00

\* Average figures

\*\* The exact proportion of male to female could not be determined from the publication.

Table 3.--Summary of results of regional natural crossing tests in 1949 and 1950.

Location	Per cent Intermediate Red		
	1949	1950	2 Yr. Av.
Raleigh, N. C.	54.9	42.4	48.7
Knoxville, Tenn. (1st pick)	45.5	38.4	42.0
Knoxville, Tenn. (2nd pick)	----	44.5	----
Baton Rouge, La.	50.8	31.1	41.0
Perkins, Okla. (G H.)	----	33.1	----
Perkins, Okla. (Field)	----	35.3	----
Sacaton, Ariz. (1st pick)	29.0	36.6	32.8
Sacaton, Ariz. (2nd pick)	----	21.1	----
Tifton, Ga.	26.9	33.4	30.2
Athens, Ga.	----	27.4	----
Auburn, Ala.	29.4	23.7	26.6
Chickasha, Okla.	----	26.1	----
Experiment, Ga. (1st pick)	25.9	----	----
Experiment, Ga. (2nd pick)	24.5	----	----
Tipton, Okla.	----	24.1	----
Stoneville, Miss. (1st pick)	12.1	12.3	12.2
Stoneville, Miss. (2nd pick)	----	9.9	----
Hartsville, S. C.	12.0	----	----
State College, N. M.	11.6	11.7	11.7
Fayetteville, Ark. (1st pick)	----	10.5	----
Fayetteville, Ark. (2nd pick)	----	9.9	----
Greenville, Tex. (1st pick)	4.3	9.6	7.0
Greenville, Tex. (2nd pick)	30.4	30.4	30.4
College Station, Tex.	3.3	9.9	6.6

## MATERIALS AND METHODS

### Description of Parents

The two varieties of cotton used as parents in the natural crossing studies were DeRidder's Red Leaf, a red-leaf variety, and Empire, a green-leaf variety. They are upland types of cotton.

These two varieties were used because of the presence of anthocyanin pigment in the red-leaf and the absence of it in the green-leaf. The anthocyanin is apparent in two genotypes, the pure red or homozygous condition (RR) and dilute red in the heterozygous condition (Rr). The F<sub>1</sub> generation from a cross between red and green is dilute red. Both direct and reciprocal crosses produce the same ratio (12).

### Description of Planting

The varieties were planted in the spring of 1951 at three locations; on the Perkins, Lake Blackwell, and Chickasha experimental farms in Oklahoma.

The ratio of one red to one green was planted in the following manner on the Perkins farm; alternate rows, alternate plants in the same row, one red and one green plant in the same hill, and alternate blocks of five red and five green plants in the row. The plots containing the one to one ratios were 20 rows wide and 50 feet long. Row spacing was 42 inches within the plots.

Plots with a ratio of nine red to one green plant were grown at Perkins, Lake Blackwell, and Chickasha. The plots were 100 feet long and 20 rows wide. Row spacing within the plots was 42 inches.

All plots were thinned to one foot spacings in the rows during the fourth week following emergence.

#### Insect Control Program

A program of insect control was carried on through the growing season. This program consisted of spraying with the insecticides Toxaphane and Dicholoro diphneyl trichloroethane (DDT). Toxaphane was used July 13, 17, 21, 26, and August 17. Toxaphane plus DDT was applied on August 2, 13, and 22.

#### Method of Harvesting

All green plants at each location were tagged in July. This was done to facilitate identification at picking time since the leaves turned color and were shed with the first frost. At the time of tagging all plants were counted to determine actual ratios.

Each female plant was numbered and harvested separately from five green plant blocks where the planting arrangement was blocks of five red male alternated with blocks of five green female plants. From the other plots a bulked sample was taken from 20 green-leaf plants. Care was taken to choose only plants that were in a perfect stand. The two outside rows on each plot were discarded. No plants were taken within 10 feet of the end of a plot.

### Method of Determining Natural Crossing

After harvest the samples were ginned. The seeds were delinted with sulfuric acid.

The seeds were grown in a germinator in the laboratory. To develop the red color of the hybrids an ultra-violet lamp was placed behind the trays in the germinator. The light was turned on for ten minutes the second day after the seeds were placed in the germinator. This was done each day until all seedlings were removed. Counts were made by removing the red seedlings each day until all seeds were germinated.

The per cent of natural crossing was determined by dividing the total number of seeds germinated into the number of hybrids produced.

### Analysis of Data

Data from 9:1 ratios, alternate rows, alternate plants in the row, and one red and one green plant in the same hill were not susceptible to statistical analysis. In these cases means were compared from the data. Five plant blocks were analyzed according to Fisher's (8) analysis of variance technique.

## EXPERIMENTAL RESULTS

### Actual Ratios Obtained

The experimental designs used in this study were planted so that expected ratios of red male plants to female green plants would be 1:1 and 9:1. Due to seeds not germinating, errors in thinning, and plants dying after thinning the actual ratios were different from expected ratios. The actual ratios observed in each planting arrangement are given in Table 4.

Table 4.--The expected and actual ratios of red male plants to green female plants in each planting arrangement.

Arrangement of red and green parents	<u>Expected ratios</u> red : green	<u>Actual ratios</u> red : green
Alternate rows	1.00 : 1.00	1.13 : 1.00
Alternate plants in row	1.00 : 1.00	1.00 : 1.16
Both in same hill	1.00 : 1.00	1.00 : 1.00
Alternate 5 plant blocks	1.00 : 1.00	1.26 : 1.00
Perkins*	9.00 : 1.00	9.45 : 1.00
Lake Blackwell*	9.00 : 1.00	13.59 : 1.00
Chickasha*	9.00 : 1.00	8.77 : 1.00

\* Nine red to one green at these locations.

### Natural Crossing with a 1:1 Ratio

The per cent of natural crossing when DeRidder's Red Leaf and Empire cotton were planted in 1:1 ratios using different planting arrangements of red male and green female

plants are given in Table 5. The arrangement that resulted in the largest amount of natural crossing was alternate rows with 36.00 per cent. Apparently the proximity of male plants to female plants did not determine the per cent of natural crossing. Where both male and female plants were in the same hill 21.88 per cent natural crossing occurred, which was the lowest. There was very little difference in the amount of natural crossing occurring when the planting arrangement was alternate male and female plants in the row or alternate blocks of five male and blocks of five female plants in the row. Alternate male and female plants resulted in 26.77 per cent while alternate blocks of five male and five female resulted in 26.41 per cent.

Table 5.--Observed percentage of natural crossing occurring in 1:1 ratios planted in different experimental designs.

Arrangement of red and green parents	Number of plants			% Natural Crossing
	Rr	rr	Total	
Alternate rows	1145	2035	3180	36.00
Alternate plants in row	920	2516	3436	26.77
Both in same hill	449	1603	2052	21.88
Alternate 5 plant blocks	821	2288	3109	26.41

The percentages of natural crossing occurring on individual plants from the five plant blocks are given in Table 6. The average per cent of all plants was 26.41 while the per cent for individual plants ranged from a high of 42.85 to 15.96 for the lowest. It was expected that end plants within blocks would have the highest per cent of

natural crossing but the results did not prove this to be true as shown by the analysis of variance (Table 7) of these data. The variance for blocks was highly significant while the variance for plants within blocks was not significant. From the analysis it is apparent that differences existed among localized areas within the field. This could have been due to the nature of insect activity.



Table 6.--Observed percentages of natural crossing occurring on individual green plants from alternate five red and five green plant blocks.

Plant* No.	Block No.					Mean
	1	2	3	4	5	
1	26.79	24.43	28.57	17.91	37.50	27.00
2	31.32	35.84	29.50	17.02	33.30	29.40
3	26.27	27.27	26.63	15.96	22.72	23.80
4	21.85	42.85	27.70	19.46	28.08	27.50
5	27.85	30.64	29.22	18.39	33.76	28.00
Mean	26.80	32.20	27.90	17.70	31.10	

\* All plants within the blocks were numbered in the same direction.

Table 7.--Analysis of variance of green blocks and plants within blocks.

Source of Variation:	D/F	Net sum of squares	Mean square	F
Blocks	4	650.75	162.68	7.96**
Plants within blocks	4	86.63	21.66	1.06
Remainder	10	327.17	20.45	
Total	24	1064.47	44.35	

\*\* F value significant at the 1 per cent point.

Natural Crossing with a 9:1 Ratio

The locations and per cent of natural crossing resulting from plantings of nine red male plants to one green female plant are presented in Table 8.

The average per cent of natural crossing for all locations was 50.91. Of the three locations studied, the planting at Perkins resulted in the highest per cent of natural crossing which was 54.27 compared with 48.51 at Lake Blackwell and 49.85 at Chickasha. The planting at Chickasha was harvested at different dates. The first picking was made 42 days earlier than the second picking. The seed harvested in the first picking had 53.35 per cent hybrids, the second picking had 46.35 per cent hybrids.

Table 8.--Observed percentage of natural crossing occurring in 9:1 ratios planted at three locations in Oklahoma.

Location	Number of Plants			% Natural Crossing
	Rr	rr	Total	
Perkins	3014	2540	5554	54.27
Lake Blackwell	996	1057	2053	48.51
Chickasha (1st pick)*	1661	1452	3113	53.35
Chickasha (2nd pick)**	1430	1625	3055	46.35

\* Picked October 11, 1952.

\*\* Picked November 21, 1952.

## DISCUSSION

The per cent of natural crossing of cotton did not vary greatly among the three locations studied. There was approximately 6 per cent difference between the highest and the lowest locations. The planting at Perkins resulted in 54.27 per cent, the highest, compared with 48.51 per cent at Lake Blackwell, the lowest. Two of the locations in this study were used in a similar study in 1950, and results reported show 9.2 per cent more natural crossing occurring at Perkins than at Chickasha (18). Percentages observed were considerably lower in 1950, indicating a large seasonal effect. Ware (22) reported a difference of 39.9 per cent in the amount of natural crossing between two locations studied in Arkansas. He was of the opinion that this difference was due to differences in insect populations.

A comparison of results for locations in Oklahoma with locations in other sections of the cotton belt shows the 54.27 per cent natural crossing occurring at Perkins in 1951 to be higher than any location reported in 1949 or 1950 except Raleigh, North Carolina which had 54.9 per cent in 1949 (18).

In 1950, the only year for which data for both Raleigh and Perkins are available, Raleigh had about eight per cent more crossing than Perkins.

The effect of ratios on the amount of natural crossing occurring in cotton was studied. Plantings of one male to one female plant and nine males to one female plant were used. In all plantings of the 9:1 ratio the per cent of natural crossing was higher than with the 1:1 ratio. There were about 14 per cent more hybrids produced with a 9:1 ratio than with a 1:1 ratio. This would be expected. Because of the higher proportion of male to female plants there would be more opportunities for natural crossing with the male parent. These results agree with the results of Kearney (9) and Brown (15), while the results reported by Turner (21) show that 1:1 ratios produced a slightly higher maximum percentage of natural crossing than did the 9:1 ratios, although the minimum percentages were lower in the 1:1 ratios. From the results of this study and the results reported by other workers it appears that when a large amount of natural crossing is desired in cotton a higher ratio of male to female plants is needed.

Four planting arrangements using a 1:1 ratio of male to female plants were compared. In all of these planting arrangements some natural crossing occurred, alternate rows being the highest with 36 per cent and both male and female plants in the same hill the lowest with 21.88 per cent. This difference may be accounted for in part by an excess of males in the alternate rows planting, the actual ratio being 1.13 to 1.00.

A higher per cent of natural crossing between alternate rows than alternate plants was reported by Afzal and Khan (1).

Ligon (10) observed 25.20 per cent of natural crossing between adjacent plants and 15.90 per cent between alternate rows. His per cent of natural crossing for adjacent plants is approximately the same as occurred in this study. The per cent of natural crossing observed by Ligon when alternate rows were used is 21.10 per cent lower than observed in this study.

Stroman and Mahoney (20) reported no natural crossing where alternate rows was the planting arrangement while they reported a maximum of 3.28 per cent natural crossing in plantings of adjacent male and female plants.

Natural crossing occurred at all locations, in all planting arrangements, and in both ratios studied. This is in agreement with the results reported by other workers; therefore cotton breeders should consider natural crossing when planning breeding programs and in handling breeding material in the field. Natural crossing under Oklahoma conditions is almost as high as at any location in the United States and higher than at most. In view of this fact, possibilities for utilization of heterosis resulting from natural crossing should be investigated in Oklahoma.

## SUMMARY

1. Two varieties of cotton, DeRidder's Red Leaf and Empire, were used as parents in natural crossing studies conducted in Oklahoma in 1951.

2. Ratios of 9 red males to 1 green female resulted in 54.27 per cent natural crossing at Perkins, 49.85 per cent at Chickasha, and 48.51 per cent at Lake Blackwell.

3. Two dates of harvest at Chickasha gave 53.35 and 46.35 per cent crossing for the first and second dates, respectively.

4. Four planting arrangements with a ratio of 1 red male to 1 green female at Perkins gave the following results; (a) alternate rows 36.00, (b) alternate plants in the row 26.77, (c) red and green plants in the same hill 21.88, and (d) alternate 5 plant blocks 26.41 per cent natural crossing.

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