HERITABLE RELATIONSHIPS OF STORM RESISTANCE AND MATURITY IN THREE VARIETIES OF GOSSYPIUM HIRSUTUM

By

GORDON DAVID HINTZ

Bachelor of Science

Oklahoma Agricultural and Mechanical College

Stillwater, Oklahoma

1952

Submitted to the Faculty of the Graduate School of
the Oklahoma Agricultural and Mechanical College
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE

May, 1953

HERITABLE RELATIONSHIPS OF

STORM RESISTANCE AND MATURITY IN

THREE VARIETIES OF GOSSYPIUM HIRSUTUM

Thesis Approved:

John M. Green
Thesis Adviser

A. Murphy

R. C. McIntosh
Dean of the Graduate School

ACKNOWLEDGMENT

The writer wishes to express his appreciation to his major adviser, Dr. John M. Green, for his assistance and criticism.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
REVIEW OF LITERATURE	2
MATERIALS AND METHODS	4
Parental Varieties	4
Comparison of Parents	5
Rate of Squaring	5
Square Periods	6
Boll Growth Rates	6
Boll Periods	7
Inheritance of Boll Period	7
Production of Seed	7
Field Design and Planting	7
Tagging and Recording	8
Storm Resistance Classification	9
Analysis of Data	9
EXPERIMENTAL RESULTS	12
Comparison of Parents	12
Rate of Squaring	12
Square Periods	12
Boll Growth Rates	12
Boll Periods	22
Inheritance of Boll Period	22
Lankart 57 x Oklahoma Special	22
Lankart 57 x Stormproof #1	28
Oklahoma Special x Stormproof #1	28
Heritability of Boll Period	31
Segregation of Stormproof Boll Types	32

TABLE OF CONTENTS (Continued)

Page

Relationship of Storm Resistance and Boll Period 32

DISCUSSION 39

SUMMARY 42

LITERATURE CITED 44

LIST OF TABLES

Table Page

1. Numbers of Squares Occurring on 3 Varieties on 3 Successive Dates. Counts were Made in 3 Replications of 25 Plants Each at 5 Day Intervals Beginning with the Start of Squaring 14

2. Average Square Periods for 3 Varieties of Cotton in which Squares were Tagged on 3 Dates 10 Days Apart 14

3. Mean Weights of Green Bolls in Grams for 3 Varieties at Specified Number of Days After Tagging. Blooms were Tagged on July 20, 1951 17

4. Mean Weights of Green Bolls in Grams for 3 Varieties at Specified Number of Days After Tagging. Blooms were Tagged on July 30, 1951 17

5. Analysis of Variance of Green Boll Weights with 10 Bolls Harvested Per Plant Per Date for the First 4 Dates After Tagging on July 20, 1951 19

6. Analysis of Variance of Green Boll Weights with 5 Bolls Harvested Per Plant Per Date for the First 8 Dates After Tagging on July 20, 1951 19

7. Analysis of Variance of Green Boll Weights with 5 Bolls Harvested Per Plant Per Date for the First 6 Dates After Tagging on July 30, 1951 19

8. Per Cent of Total Number of Open Bolls Per Variety for 3 Varieties at Specified Numbers of Days After Tagging of Blooms 21

9. Frequency Distributions of Mean Boll Periods of Individual Plants in Indicated Populations 25

10. Two Way Classification for Earliness or Lateness of Individual Plants which have Normal, Lankart, or Intermediate Boll Types in Lankart 57 x Oklahoma Special 36

LIST OF TABLES (Continued)

Table | Page

11. Two Way Classification for Earliness or Lateness of Individual Plants which have Normal, Stormproof, or Intermediate Boll Types in Oklahoma Special x Stormproof #1 37

LIST OF ILLUSTRATIONS

Figure Page

1. Total Numbers of Squares Appearing on 75 Plants of Each of 3 Varieties on 3 Dates at 5 Day Intervals After the Beginning of Squaring 13

2. Mean Weights of Green Bolls of 3 Varieties Harvested at 5 Day Intervals from Blooming to Boll Opening. Blooms were Tagged July 20, 1951, Early in the Blooming Period . 15

3. Mean Weights of Green Bolls of 3 Varieties Harvested at 5 Day Intervals from Blooming to 30 Days After Blooming. Blooms were Tagged July 30, 1951 16

4. Frequency Distributions of Opening of Bolls Produced from Blooms Tagged on August 11, 1951, in 3 Varieties of Cotton 20

5. Frequency Distributions Showing the Boll Period in Number of Days from Tagging for Parents and F_1 of Lankart 57 x Oklahoma Special 23

6. Frequency Distributions Showing the Boll Period in Number of Days from Tagging for F_2 and One Backcross of Lankart 57 x Oklahoma Special 24

7. Frequency Distributions Showing the Boll Period in Number of Days from Tagging for Parents and F_1 of Lankart 57 x Stormproof #1 26

8. Frequency Distributions Showing the Boll Period in Number of Days from Tagging for F_2 and Backcrosses of Lankart 57 x Stormproof #1 27

9. Frequency Distributions Showing the Boll Period in Number of Days from Tagging for Parents and F_1 of Oklahoma Special x Stormproof #1 29

LIST OF ILLUSTRATIONS (Continued)

Figure | Page

10. Frequency Distributions Showing the Boll Period in Number of Days from Tagging for F_2 and One Backcross of Oklahoma Special x Stormproof #1 30

11. Typical Bolls of Lankart 57 and Stormproof #1 Parents and their F_1, F_2, and F_3 Hybrid Progenies 33

12. Typical Bolls of Lankart 57 and Oklahoma Special Parents and their F_1, F_2, and F_3 Hybrid Progenies 34

13. Typical Bolls of Oklahoma Special and Stormproof #1 Parents and their F_1, F_2, and F_3 Hybrid Progenies 35

INTRODUCTION

"Storm resistance", or the tendency for the locks to remain in the bolls for an extended period after maturity, is important in cotton being grown for stripper harvest. Since all the present commercial storm resistant varieties are relatively late maturing, it would be helpful to the cotton breeder to know if storm resistance and maturity are associated.

The objectives of this stury were to determine if a relationship existed between maturity and storm resistance; to study inheritance of storm resistance and to study earliness and its components. The components of earliness that were studied included rate of squaring, length of square period, boll growth rates, and boll period.

The work was carried on in 1951 and 1952 on the Perkins and Paradise experiment farms located in the southern part of Payne County, Oklahoma.

REVIEW OF LITERATURE

Problems dealing with storm resistant cotton are relatively recent. Maturity studies, however, have been carried on for some time, and therefore, more literature is available on this subject.

Consistent differences for square period, or the length of time between the appearance of a square and its subsequent blooming, were found in four varieties at Sacaton, Arizona, in 1921, by Martin, Ballard and Simpson (7).[1] In 1924 and 1925 at Sacaton, Arizona, Loomis (4) obtained similar results.

McNamara, Hubbard, and Beckett (10) observed that cotton which was not thinned had a longer square period than cotton which was spaced at 12 inches. However, Ludwig (5) concluded that spacing of plants had no appreciable effect on either the square period or the boll period.

Martin, Ballard, and Simpson (7) studied boll growth rates in Pima and Sea Island (<u>G</u>. <u>barbadense</u>) and Meade (<u>G</u>. <u>hirsutum</u>) cotton. They found that green weights of growing Pima bolls reached a maximum weight at the age of 40 days. However, the gain in weight was most rapid up to 25 days, after which time the gain was negligible. Differences were found between Sea Island and Meade in the rate of growth of green bolls and in the maximum green weight of the boll.

Boll period, or the length of time between flower opening and opening of the mature boll, has been studied by a number of investigators. McNamara,

---

[1]Figures in parenthesis refer to LITERATURE CITED, page 44.

Hooton, and Porter (9) stated that in most cases the thickness of carpel walls tends to be associated with boll period; bolls having thinner carpels had shorter boll periods and bolls with thicker carpels had longer boll periods. They also concluded that boll period is strongly influenced by seasonal differences in temperature and moisture. Buie (1) reported that droughty conditions shorten the boll period.

Buie (1), and Martin, Ballard, and Simpson (7) have found that the boll period progressively lengthens with the advance of the season. Keitt and Murray (2) as early as 1919, stated that the use of certain fertilizers may also delay or hasten boll maturity. There are numerous reports in the literature concerning the effect of fertilizers on maturity.

Loomis (4) reported differences in boll period in relation to nodal location. He found that the maturation date of bolls of the same flowering date was longer on the outer than on the inner nodes of the fruiting branches.

Buie (1) concluded that maturity can be altered by a high shedding rate of bolls.

A study of the stormproof boll type and its inheritance was reported by Lynn (6), who observed that stormproof bolls had rough and cracked carpel walls and a lesser degree of spread between the carpels at maturity. Stormproof bolls are extremely difficult to distinguish until after the boll is open from four to six weeks, according to Lynn. He also observed that the degree of stormproofness is affected by seasonal differences and that there are three good methods by which one can determine stormproofness, namely (a) appearance, (b) amount of "drag", and (c) the effect of weather. Drag can be defined as the resistance of a lock of seed cotton to removal from the bur. Lynn concluded that there is only one gene pair controlling storm resistance in most commercial cottons.

MATERIALS AND METHODS

Parental Varieties

Three commercial varieties of cotton, Lankart 57, Oklahoma Special (Acala 6566-18), and Stormproof #1, were used as parents in this study. For convenience, these varieties will be referred to as L. 57, O.S., and St. #1, respectively, in graphs and tables.

Data[2] are available on per cent of total seed cotton harvested at first harvest for two years from the same three locations each year. The following percentages were computed: Lankart 57, 47.8 per cent; Stormproof #1, 47.4 per cent; and Oklahoma Special, 60.6 per cent harvested at first harvest. Lankart 57 and Stormproof #1 are rather late maturing varieties, while Oklahoma Special is an early maturing variety.

The varieties also differ in storm resistance. Oklahoma Special has a normal fluffed-type boll with little or no drag between the locks and the burs. Stormproof #1 is a small-bolled stormproof variety. The locks are tightly held in the bur and a knitting effect is very evident, as is shown in the example of the Stormproof #1 boll in figure 11. Lankart 57 is a large-bolled stormproof variety. The locks tend to protrude from the bur and a knitting effect is not evident. Knitting is the stretched appearance of the lint between the carpel tips.

---

[2]1949 Annual Report of the Cotton Breeding Research Program, Okla. Agr. Exp. Sta.

These three varieties also differ in rate of blooming and per cent bolls set. The following information was obtained at Chickasha, Okla., in 1949.[3]

	Total Blooms Per Plant	Per cent Bolls Set	Bolls Per Plant
Lankart 57	18.26	55.0	10.0
Oklahoma Special	30.19	48.6	14.7
Stormproof #1	21.67	65.7	14.2

Although Oklahoma Special produced the most blooms, it had the lowest percentage of bolls set. Lankart 57 produced the fewest blooms per plant and its per cent bolls set was not high. Blooming curves for the three varieties all reached a peak between 20 and 25 days after the start of blooming, but Stormproof #1 did not bloom as extensively as the other two varieties during the first ten days of blooming.

Comparison of Parents

The three parent varieties were examined for the rate of squaring, square period, boll growth rates, and boll period. Boll growth rates were determined on material planted at the Perkins Agronomy farm; the other characters were studied in a planting in the Paradise field.

Rate of Squaring

In studying the rate of squaring, 50-foot rows of each variety were replicated three times. The first 25 plants in each row were used and squares were counted on individual plants three times at five day intervals. The number of squares per plant was recorded for each date.

---

[3]Unpublished data of the Cotton Breeding Research Program, Okla. Agr. Exp. Sta.

Square Periods

Three replications of each variety were used with two 50-foot rows per replication. A pair of ordinary calipers was set at 3/32 of an inch. On three dates, at ten day intervals, all squares of this size (excluding bracts) were tagged. A different colored string was used for each date. When the tagged squares began blooming, the number of blooms opening each day was recorded.

Boll Growth Rates

Four replications of five 25-foot rows per variety were planted, the varieties being randomized within replications. Plants were thinned to one per foot and weeds were kept at a minimum.

When blooming was well under way, 100 blooms were tagged on the middle three rows of each variety. The remaining two rows served as border rows and were not tagged so that border effects would not enter into the results. Blooms were tagged on three dates at ten day intervals. Tags used were circular cardboard disks with a metal rim and a string securely fastened to the tag. A different colored tag represented each date of tagging. The tags were hung around the pedicel of each bloom used.

At five day intervals after tagging, ten young tagged bolls of each variety were harvested at random from all the plots. After four weighings, only five bolls were harvested per variety per date because sufficient bolls were not available to complete the boll period if ten bolls were harvested. The bracts and pedicel of each boll were removed by means of a razor blade and the bolls were weighed individually immediately after removal to prevent error due to water loss. Weighing was carried out to 0.01 gram and these weights were recorded for each boll of each variety.

Boll Periods

Bloom tagging was accomplished in the same manner as for the boll growth rate studies. Six replications of each variety were used with two 50 foot rows per replication. One hundred blossoms were tagged on each of two dates. The date of boll opening was recorded as the number of bolls opening per variety per date. Bolls were considered open when two carpels were spread at least 1/4 inch apart.

Inheritance of Boll Period

Production of Seed

During the 1951 season in which the parents were studied, crosses were made among the three varieties at the Perkins Farm. In 1950, F_1 seed had been produced and this F_1 seed was used to produce the F_2 and backcrosses. Some F_2 seed was sent to Mexico during the winter of 1951-52 and F_3 seed was produced. The F_1's were remade so that parents, F_1's, F_2's and backcrosses could all be studied the same year under similar conditions. Parental seed stocks were from commercial sources in all three years. It was originally planned to study boll growth rates in F_3, but because of the small number of plants per F_3 family, this was not possible.

Field Design and Planting

All seeds were planted in flats in the greenhouse. This was done with the intent of obtaining uniform germination and perfect stands in the field. After the seedlings were well established, they were transplanted to the field.

The original field design called for 20 replications of each of the pedigrees, but due to poor germination in the greenhouse, only nine replications of 12 pedigrees and six replications of one additional pedigree were studied. Two backcrosses were lost as a result of failure to germinate.

Each field replication contained one row of ten plants of each pedigree. Rows were 42 inches apart, and the plants were spaced 18 inches apart in the row. The whole test was bordered on all sides and no alleys nor skips were allowed within the test area in order to eliminate border effects. The rows in each replication were assigned at random. The 18 inch plant spacing within rows was based on the results of previous workers (5, 10).

Tagging and Recording

All blooms on every plant were tagged on 15 consecutive days. To minimize writing on the tag, the first day was assigned number 1, the second day number 2, and so on, up to 15 days. Tagging was started on July 24. The daily tagging was done to assure five tagged bolls per plant, considering that only about one-half of the blooms could be expected to produce mature bolls.

Each plant was visited once every other day and all tagged open bolls were recorded for each plant for that date. Tags were removed when open bolls were recorded to prevent confusion on later days. The number on the tag was recorded together with the date of opening of each boll. The boll period could then be calculated by the difference between the date of tagging and the date of opening. Recording was stopped on each plant either when five tagged bolls had been recorded or when all tagged bolls on that plant had been used. Plants with a minimum of three recorded bolls were used in the analysis.

Storm Resistance Classification

Each plant was classified for storm resistance by appearance and amount of drag. Classification was delayed until late in the season in order to let weathering have its effect. There were four classes of storm resistance used, namely (a) normal fluffed boll type found in Oklahoma Special, (b) Lankart boll type, (c) stormproof boll type as found in the Stormproof #1, and (d) boll types intermediate between any two parents.

Analysis of Data

Variances of the parental and hybrid populations were determined by pooling within replication variances for each pedigree. Differences in mean length of boll period of the parents were tested for significance by the "t" test (11).

Analysis of variance was used to determine if the three parent varieties differed in boll growth rates. The "F" test was used to test for significance (11).

The Chi-square test (3) for independence was used to determine if association existed between boll period and storm resistance. Chi-square tests were also made to determine if differences existed among the parents in their rate of squaring.

Heritability was estimated using the observed variances of the F_2 and backcross populations as proposed by Mather (8). Use of this method is valid when the scale used satisfies two criteria, (a) additivity and (b) independence of environment and genotype.

The data from the cross Lankart 57 x Stormproof #1, the only cross of which both backcrosses survived, were tested for additivity of the scale using the following formulae from Mather in which the letter B indicates backcross, P indicates parent, and F indicates filial generation:

Boll period means		Variance of boll period
$A = 2\bar{B}_1 - \bar{P}_1 - \bar{F}_1$		$V_A = 4V\bar{B}_1 + V\bar{P}_1 + V\bar{F}_1$
$B = 2\bar{B}_2 - \bar{P}_2 - \bar{F}_1$	and	$V_B = 4V\bar{B}_2 + V\bar{P}_2 + V\bar{F}_1$
$C = 4\bar{F}_2 - 2\bar{F}_1 - \bar{P}_1 - \bar{P}_2$		$V = 16V\bar{F}_2 + 4V\bar{F}_1 + V\bar{P}_1 + V\bar{P}_2$

To test the second criterion, it is necessary to have two or more genotypes showing different mean values. Each mean value must be made up of a number of individuals in which non-heritable variances can be measured. The variances can be compared by variance ratios. Significant differences will show that the non-heritable variance is not independent of the genotype.

Heritability of boll period was estimated using the method proposed by Mather and further illustrated by Warner (12). In this method the letter D indicates additive genetic effects, H indicates non-additive genetic effects, and E indicates environmental effects. The following are the formulae used:

Within variance of	Variance components
F_2	$(1/2)\,D + (1/4)\,H + E$
$2\,(F_2)$	$D + (1/2)\,H + 2E$
$(B_1 + B_2)$	$(1/2)\,D + (1/2)\,H + 2E$
$2\,(F_2) - (B_1 + B_2)$	

$$\text{Heritability} = \frac{(1/2)\,D}{V\,F_2}$$

There are certain basic assumptions in estimating heritability by components of variance. Warner (12) states these assumptions as "additivity of genic effects, locus to locus (no epistasis), and independent of genotype and environmental variance".

Warner also states, "an additional assumption is necessary to the effect that the environmental components of variance of the F_2 and of the two backcrosses are of comparable magnitude".

EXPERIMENTAL RESULTS

Comparison of Parents

Rate of Squaring

Differences were found among the numbers of squares produced by the three parent varieties. Figure 1 shows that Oklahoma Special put on more squares than the other parents, Lankart 57 and Stormproof #1, which appeared to be nearly alike in the number of squares produced. A comparison of the three parents (Table 1) gave a significant Chi-square with a probability range of 0.02 to 0.05. This indicates a significant difference among varieties in rate of squaring. Figure 1 showed a marked difference between Oklahoma Special and the other two varieties in the rate of squaring. A comparison of Lankart 57 and Stormproof #1 gave a significant Chi-square with a probability of less than 0.01 indicating that all three varieties differ in rate of squaring. The lower probability of the latter Chi-square was most likely due to a reversal between the first two dates (Figure 1) and the fewer degrees of freedom.

Square Periods

No significant differences in square period were obtained among the parents. Differences among varieties were less than one day for each date studied, as shown in table 2.

Boll Growth Rates

Figures 2 and 3 and tables 3 and 4 show the boll growth curves for the three parent varieties. At five days after tagging, all three varieties appear to be similar. From five to fifteen days, Lankart 57 showed

Fig. 1. Total numbers of squares appearing on 75 plants of each of 3 varieties on 3 dates at 5 day intervals after the beginning of squaring.

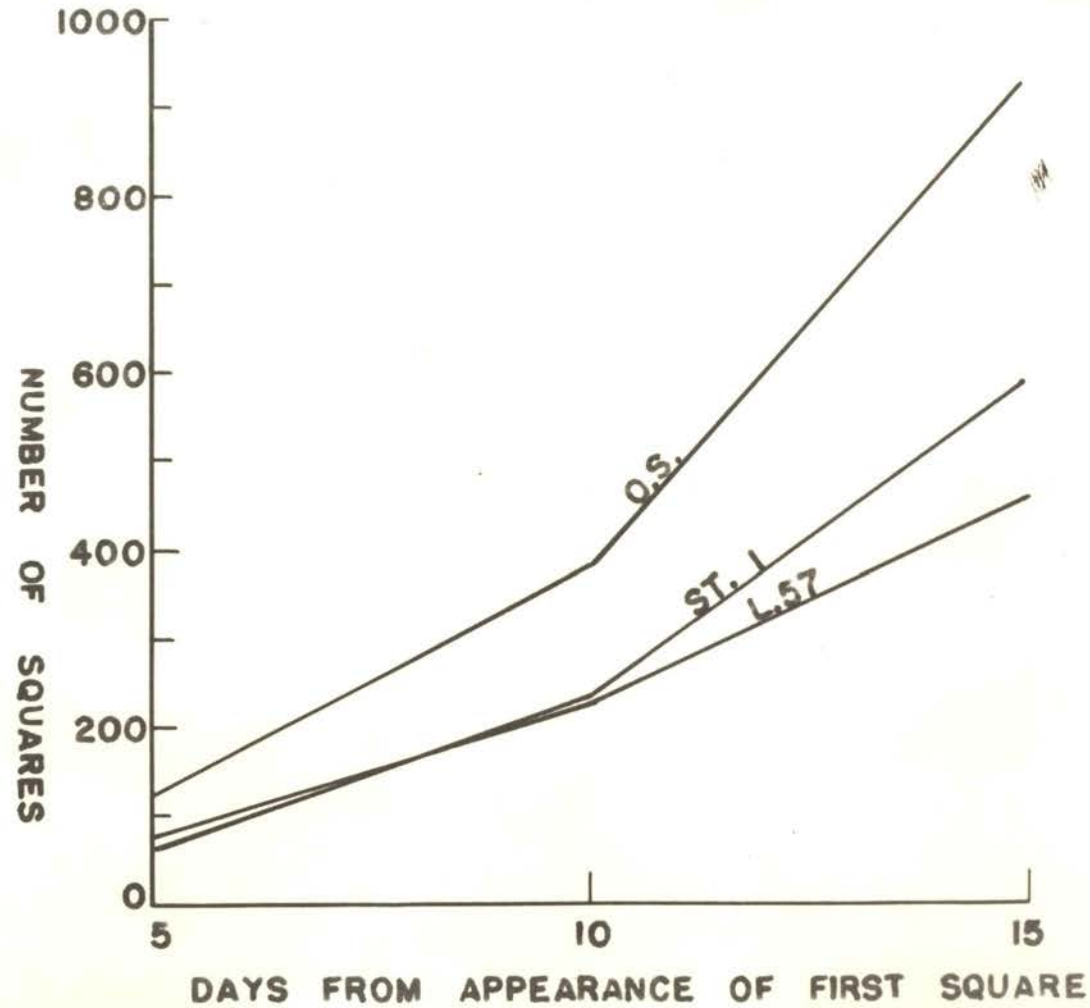

1000
800
600
400
200
0
NUMBER OF SQUARES
O.S.
ST. 1
L.57
5
10
15
DAYS FROM APPEARANCE OF FIRST SQUARE

Table 1. Numbers of squares occurring on 3 varieties on 3 successive dates. Counts were made in 3 replications of 25 plants each at 5 day intervals beginning with the start of squaring.

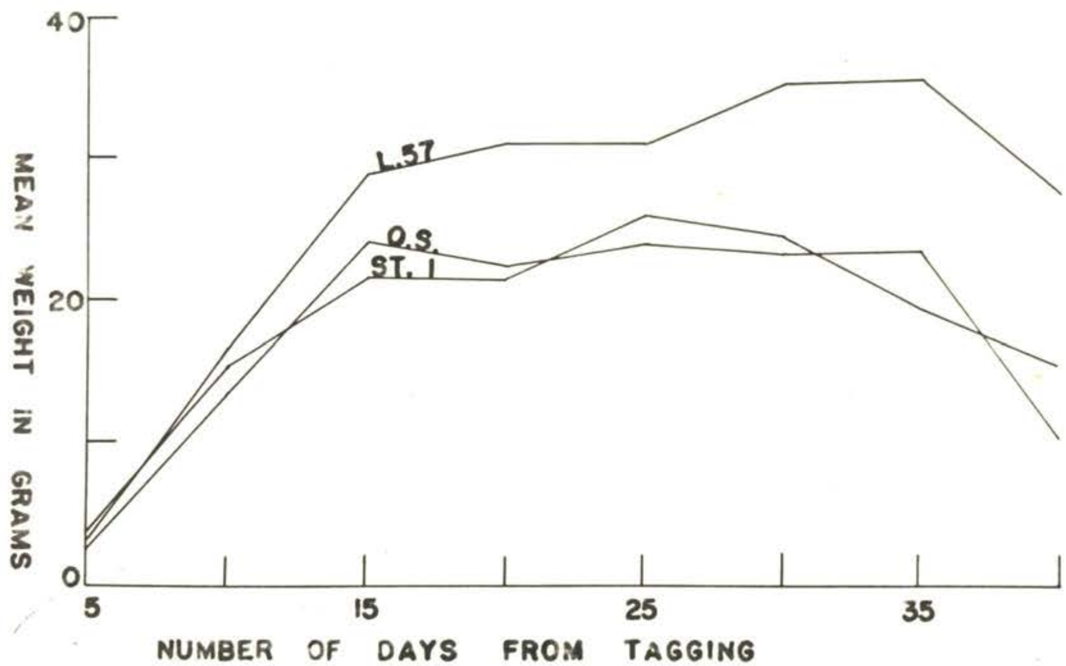
Variety	Days from appearance of 1st square			
	5	10	15	Total
Lankart 57	76	225	452	753
Oklahoma Special	121	380	931	1432
Stormproof #1	61	228	587	876
	258	833	1970	3061

Comparison of 3 varieties: $x^2 = 10.6161$, $P = 0.02-0.05$
Comparison of Lankart 57 and Stormproof #1: $x^2 = 9.9728$, $P =$ less than 0.01

Table 2. Average square periods for 3 varieties of cotton in which squares were tagged on 3 dates 10 days apart.

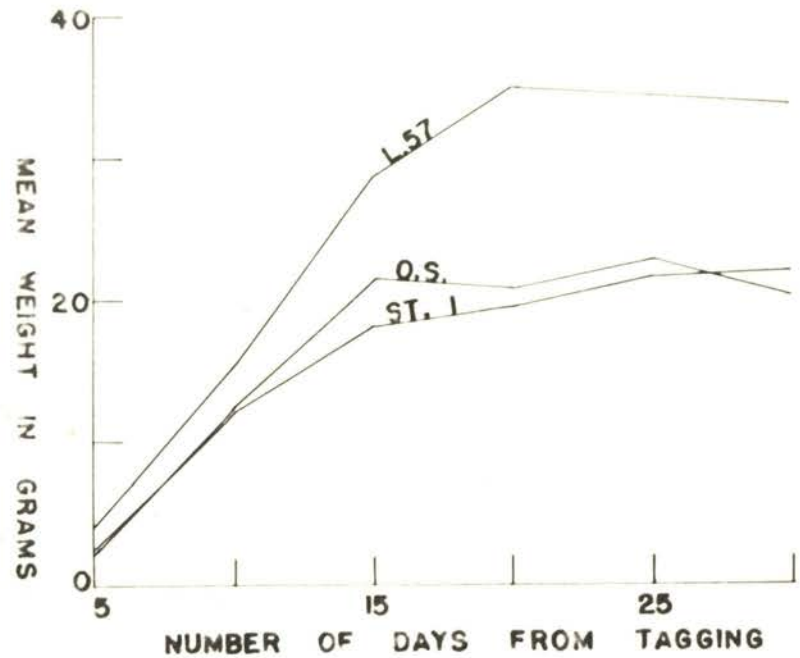
Variety		Days from squaring to blooming		
	Date tagged:	July 18	July 28	August 7
Lankart 57		17.88	17.95	19.33
Oklahoma Special		18.18	18.26	19.54
Stormproof #1		18.56	18.05	19.54

Fig. 2. Mean weights of green bolls of 3 varieties harvested at 5 day intervals from blooming to boll opening. Blooms were tagged July 20, 1951, early in the blooming period.



40
20
0
MEAN WEIGHT IN GRAMS
L.57
O.S.
ST. 1
5
15
25
35
NUMBER OF DAYS FROM TAGGING

Fig. 3. Mean weights of green bolls of 3 varieties harvested at 5 day intervals from blooming to 30 days after blooming. Blooms were tagged July 30, 1951.



40
20
0
MEAN WEIGHT IN GRAMS
L.57
O.S.
ST. 1
5
15
25
NUMBER OF DAYS FROM TAGGING

Table 3. Mean weights of green bolls in grams for three varieties at specified number of days after tagging. Blooms were tagged on July 20, 1951.

Variety	Number of Days from Tagging							
	5	10	15	20	25	30	35	40
Oklahoma Special	2.81	13.26	24.08	22.35	24.14	23.24	23.39	10.28
Stormproof #1	3.67	15.29	21.65	21.45	25.95	24.58	19.36	15.61
Lankart 57	2.95	16.55	29.04	31.13	31.14	35.36	35.88	27.70

Table 4. Mean weights of green bolls in grams for three varieties at specified number of days after tagging. Blooms were tagged on July 30, 1951.

Variety	Number of Days from Tagging					
	5	10	15	20	25	30
Oklahoma Special	2.46	12.68	21.43	20.85	22.87	20.11
Stormproof #1	2.63	12.50	18.01	19.37	21.84	21.95
Lankart 57	4.13	15.54	28.84	34.98	34.23	33.81

a faster rate of gain than the other two varieties. Oklahoma Special and Stormproof #1 remained approximately the same throughout the boll growth period. Lankart 57 continued to increase in weight up to 35 days, whereas Oklahoma Special and Stormproof #1 did not appreciably gain after 15 days. Lankart 57 weighed 35.82 grams per boll at its maximum weight. Oklahoma Special and Stormproof #1 weighed 24.14 and 25.95 grams per boll, respectively, at their maximum weights.

Analyses of variance were run on the boll weights for both the first and second dates of tagging (Tables 5 and 6). Four dates of harvest with ten bolls harvested per plant per date were included in the analysis in table 5, and eight dates with only five bolls per harvest date were included in the second analysis (Table 6). Significant differences among varieties were found in both analyses. Therefore, five bolls harvested per plant per date provided a large enough sample for comparing these varieties.

As previously stated, the boll growth rates of Oklahoma Special and Stormproof #1 were much the same. It is assumed, therefore, that differences between Lankart 57 and the other two varieties accounted for most of the variance due to varieties.

A third analysis of variance was run on five bolls per weighing for the first six dates in the second tagged group (Table 7). Highly significant differences also occurred in this analysis showing that differences in dates of blooming had little or no effect upon varietal differences in boll growth rates.

The number of bolls per weighing and the total number of weighings varied because of a shortage of bolls caused by boll weevil infestation.

Table 5. Analysis of variance of green boll weights with 10 bolls harvested per plant per date for the first 4 dates after tagging on July 20, 1951.

Source of variation	D.F.	Net S.S.	M.S.	F
Dates	3	10259.0476		
Varieties within dates	8	1000.9185	125.1148	10.43**
Plants within varieties within dates	108	1295.7061	11.9973	
Total	119	12555.6722		

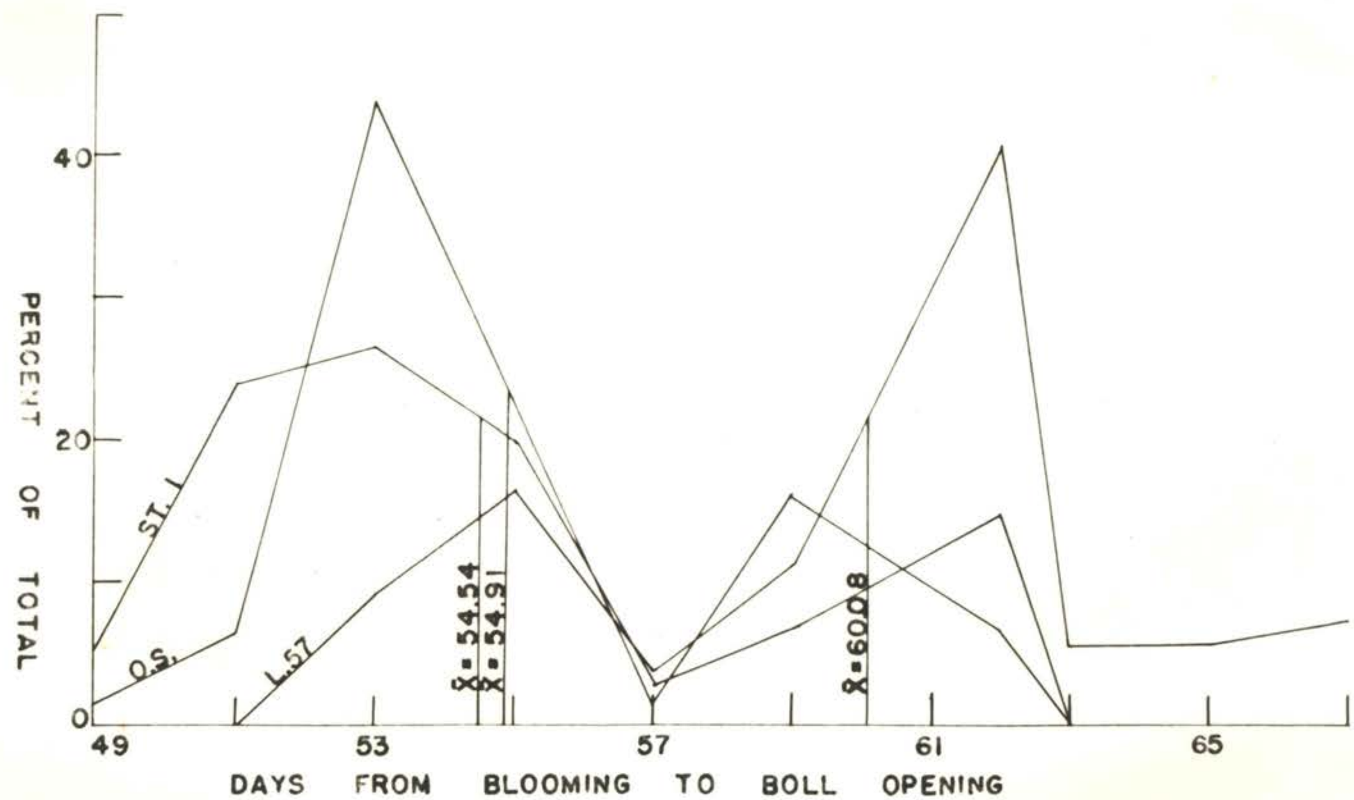
Table 6. Analysis of variance of green boll weights with 5 bolls harvested per plant per date for the first 8 dates after tagging on July 20, 1951.

Source of variation	D.F.	Net S.S.	M.S.	F
Dates	7	7571.2860		
Varieties within dates	16	2569.4323	160.5895	11.25**
Plants within varieties within dates	96	1370.2236	14.2732	
Total	119	11510.9419		

Table 7. Analysis of variance of green boll weights with 5 bolls harvested per plant per date for the first 6 dates after tagging on July 30, 1951.

Source of varistion	D.F.	Net S.S.	M.S.	F
Dates	5	6394.9560		
Varieties within dates	12	2111.7234	174.9770	18.15**
Plants within varieties within dates	72	697.9541	9.6938	
Total	89	9204.6335		

Fig. 4. Frequency distributions of opening of bolls produced from blooms tagged on August 11, 1951, in 3 varieties of cotton.



PERCENT OF TOTAL
40
20
0
49
53
57
61
65
DAYS FROM BLOOMING TO BOLL OPENING
ST. 1
O.S.
L.57
X̄ = 54.54
X̄ = 54.91
X̄ = 60.08

Table 8. Per cent of total number of open bolls per variety for 3 varieties at specified numbers of days after tagging of blooms.

Variety	Number of days from tagging										
	49	51	53	55	57	59	62	63	65	67	Total
Oklahoma Special	1.6	6.6	44.2	23.0	1.6	16.4	6.6	0	0	0	100.00
Stormproof #1	5.3	24.0	26.6	20.0	2.7	6.7	14.7	0	0	0	100.00
Lankart 57	0	0	9.2	16.7	3.7	11.1	40.7	5.6	5.6	7.4	100.00

Boll Periods

Marked differences were found in the length of boll periods of the parents. Figure 4 (Table 8) shows the frequency distributions of per cent bolls opening per variety on the indicated number of days after blooms were tagged. Mean boll periods for Oklahoma Special and Stormproof #1 were approximately the same, differing only 0.37 days. However, the difference between these varieties and Lankart 57 was 5.17 days and 5.54 days, respectively. Stormproof #1 was known to be later maturing than Oklahoma Special. The difference in maturity was not due to a difference in boll period.

Frequency distributions for all varieties were bimodal. The low saddle between the two peaks was due to a severe cold wave which brought precipitation and low temperatures for about a three day period to this section of Oklahoma. Bolls failed to open during this period.

Inheritance of Boll Period

Each of the crosses, Lankart 57 x Oklahoma Special, Lankart 57 x Stormproof #1, and Oklahoma Special x Stormproof #1 will be discussed separately.

Lankart 57 x Oklahoma Special

Mean lengths of boll period for Lankart 57 and Oklahoma Special (Figs. 5 and 6, Table 9) were 44.9 and 40.9 days, respectively. A "t" value of 15.66** was obtained indicating that only once in 100 times, under similar conditions, observed differences obtained would be due to chance. F_1 and F_2 means were both 42.6 days, closely approximating the arithmetic mean of the parents, 42.9. Seed of only one backcross

Fig. 5. Frequency distributions showing the boll period in number of days from tagging for parents and F_1 of Lankart 57 x Oklahoma Special.

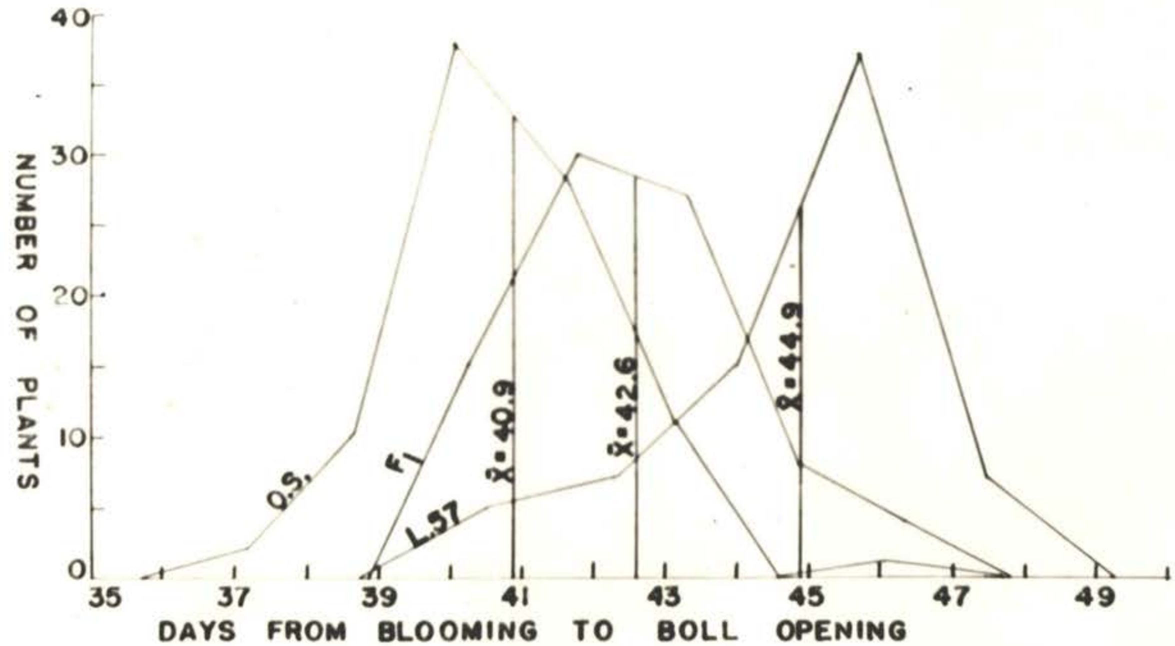
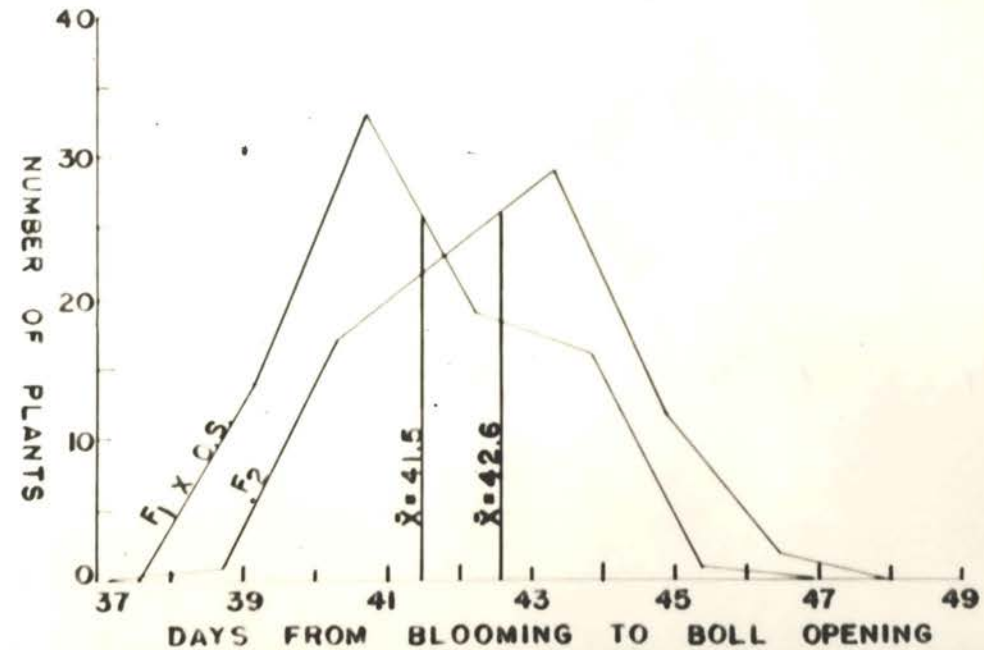

40
30
20
10
0
NUMBER OF PLANTS
35
37
39
41
43
45
47
49
DAYS FROM BLOOMING TO BOLL OPENING
O.S.
F1
L.57
X̄=40.9
X̄=42.6
X̄=44.9

Fig. 6. Frequency distributions showing the boll period in number of days from tagging for F_2 and one backcross of Lankart 57 x Oklahoma Special.

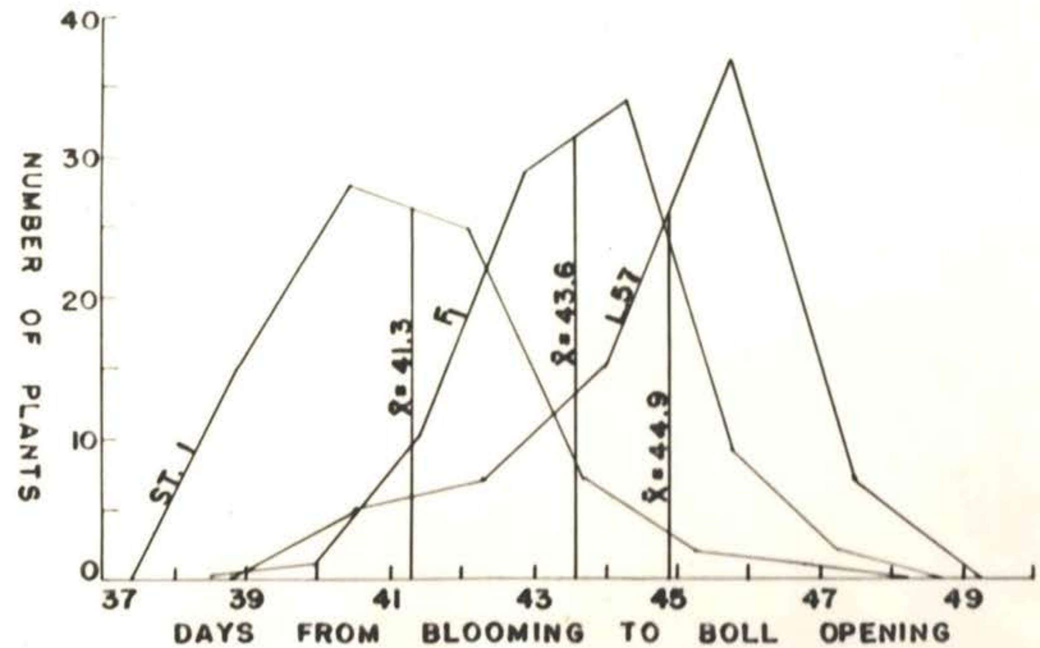


NUMBER OF PLANTS
40
30
20
10
0
37
39
41
43
45
47
49
DAYS FROM BLOOMING TO BOLL OPENING
F1 X C.S.
F2
X̄=41.5
X̄=42.6

Table 9. Frequency distributions of mean boll periods of individual plants in indicated populations.

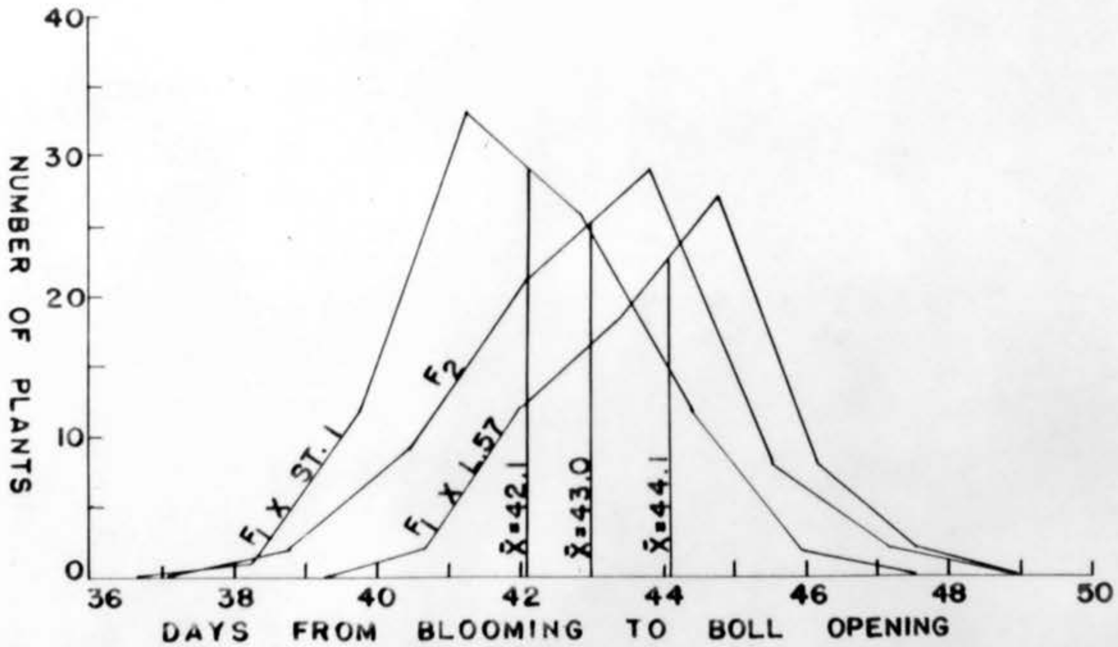
Pedigree	Class centers: standard deviations above or below mean							Total No. of Plants	Mean and Standard Deviation
	-3	-2	-1	+1	+2	+3	+4		
Lankart 57	5	7	15	37	7			71	44.9 ± 1.721
Oklahoma Special	2	10	38	28	11		1	90	40.9 ± 1.457
Stormproof #1		15	28	25	7	2	1	78	41.3 ± 1.553
L. 57 x O.S. F_1		15	30	27	8	4		84	42.6 ± 1.479
L. 57 x St. #1 F_1	1	10	29	34	9	2		85	43.6 ± 1.441
O.S. x St. #1 F_1	2	3	28	16	8			57	40.5 ± 1.269
L. 57 x O.S. F_2	1	17	23	29	12	2		84	42.6 ± 1.517
L. 57 x St. #1 F_2	2	9	21	29	8	2		71	43.0 ± 1.665
O.S. x St. #1 F_2	1	16	30	24	9	4	1	85	40.7 ± 1.411
(L. x O.S.) O.S.		14	33	19	16	1		83	41.5 ± 1.536
(L. x St. #1) L.	2	12	18	27	8	2		69	44.1 ± 1.354
(L. x St. #1) St. #1	1	12	33	26	12	2		86	42.1 ± 1.518
(O.S. x St. #1) O.S.	2	10	35	27	12	2		88	40.9 ± 1.463

Fig. 7. Frequency distributions showing the boll period in number of days from tagging for parents and F_1 of Lankart 57 x Stormproof #1.



40
30
20
10
0
NUMBER OF PLANTS
37
39
41
43
45
47
49
DAYS FROM BLOOMING TO BOLL OPENING
ST. 1
X̄ = 41.3
F1
X̄ = 43.6
L 57
X̄ = 44.9

Fig. 8. Frequency distributions showing the boll period in number of days from tagging for F_2 and backcrosses of Lankart 57 x Stormproof #1.



NUMBER OF PLANTS
40
30
20
10
0
36
38
40
42
44
46
48
50
DAYS FROM BLOOMING TO BOLL OPENING
F1 X ST. 1
F2
F1 X L.57
X̄=42.1
X̄=43.0
X̄=44.1

germinated, F_1 x Oklahoma Special. The mean of this backcross was 41.5 days. The midpoint of the F_1 and Oklahoma Special was 41.75 days. The observed results agree closely with those expected with additive gene expression.

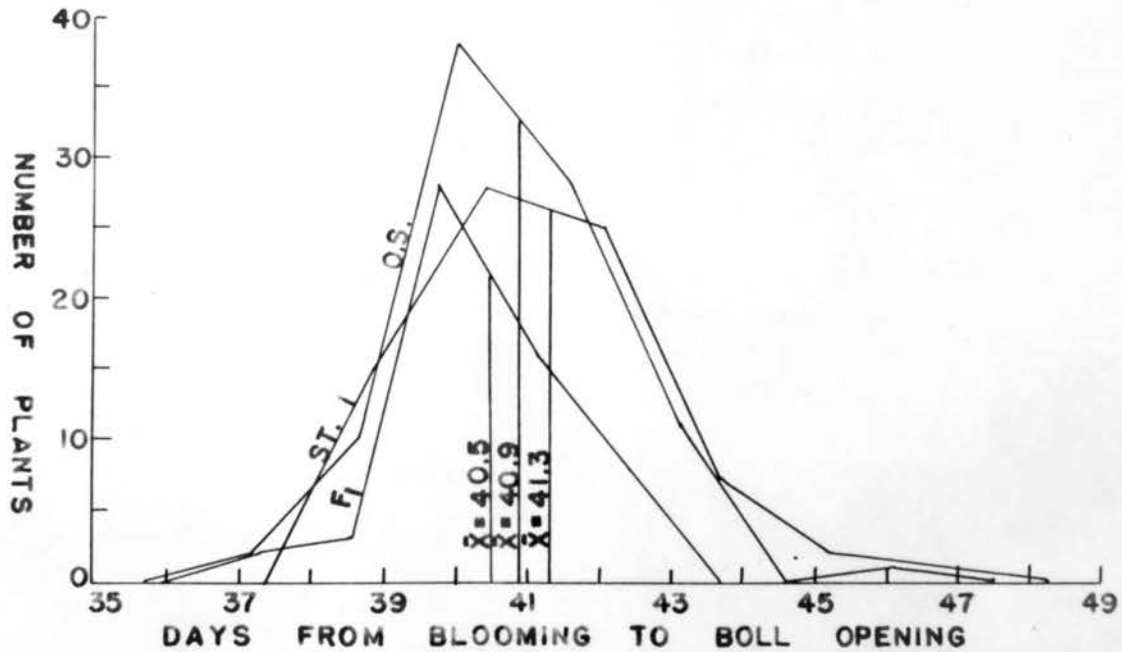
<u>Lankart 57 x Stormproof #1</u>

Mean lengths of boll period for Lankart 57 and Stormproof #1 (Figs. 7 and 8, Table 9), were 44.9 and 41.3 days, respectively. This difference was also highly significant, giving a "t" value of 13.36**. The F_1 and F_2 means were 43.6 and 43.0 days, respectively, closely approximating the arithmetic mean of the parents, 43.1. The mean of the backcross, F_1 x Lankart 57, was 44.1 days, the midpoint of the F_1 and Lankart 57 being 44.25 days. The mean for the other backcross, F_1 x Stormproof #1, was 42.1 days, whereas the midpoint of the F_1 and Stormproof #1 was 42.45 days. The observed results of the F_1, F_2, and backcrosses agree closely with those expected with additive gene expression.

<u>Oklahoma Special x Stormproof #1</u>

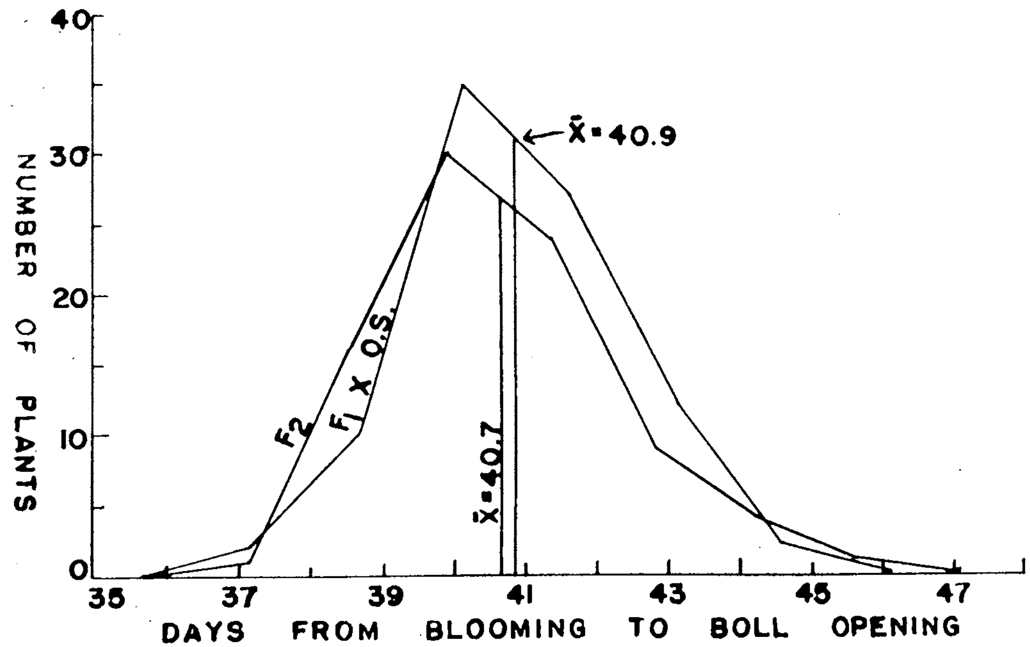
In the cross Oklahoma Special x Stormproof #1 (Figs. 9 and 10, Table 9), the difference between parents was only 0.4 days. The parental difference was not significant, giving a "t" value of 1.71. Mean values observed were: for Oklahoma Special, 40.9; Stormproof #1, 41.3; F_1, 40.5; F_2, 40.7; and F_1 x Oklahoma Special, 40.9 days. Since the parents did not differ significantly in respect to boll period, it appears that the maturity differences between Oklahoma Special and Stormproof #1 were due to some factor other than length of boll period.

Fig. 9. Frequency distributions showing the boll period in number of days from tagging for parents and F_1 of Oklahoma Special x Stormproof #1.



NUMBER OF PLANTS
DAYS FROM BLOOMING TO BOLL OPENING
0
10
20
30
40
35
37
39
41
43
45
47
49
O.S.
ST.
F_1
$\bar{X}$ = 40.5
$\bar{X}$ = 40.9
$\bar{X}$ = 41.3

Fig. 10. Frequency distributions showing the boll period in number of days from tagging for F_2 and one backcross of Oklahoma Special x Stormproof #1.



40
30
20
10
0
NUMBER OF PLANTS
35
37
39
41
43
45
47
DAYS FROM BLOOMING TO BOLL OPENING
F2
F1 X O.S.
X̄ = 40.7
X̄ = 40.9

Heritability of Boll Period

Substituting observed values for Lankart 57 x Stormproof #1 into the formulae for testing additivity of the scale gave the following results:

Boll period means	Variance	Standard error
A = -0.3	V_A = 12.574	3.54
B = -0.7	V_B = 13.709	3.70
C = -1.4	V_C = 58.013	7.61

In this scaling test, 0 indicates complete additivity, and plus or minus deviations indicate non-additive gene effects. The deviations of -0.3 to -1.4 were all exceeded by their standard errors, indicating non-significant deviations from additivity.

The second criterion of scaling, independence of environment and genotype, could not be tested since the parental varieties were open pollinated and were not considered homozygous.

The per cent of heritability for the same cross was calculated by using the method proposed by Mather (8) and further illustrated by Warner (12). Substituting observed values into the formulae, the following results were obtained:

Pedigree	Variance components	Observed variance
F_2	(1/2) D + (1/4) H + E	2.771
2 (F_2)	D + (1/2) H + 2E	5.542
(B_1 + B_2)	(1/2) D + (1/2) H + 2E	4.139
2 (F_2) - (B_1 + B_2)	(1/2) D	1.403

$$\text{Heritability} = \frac{(1/2)\ D}{V\ F_2} = \frac{1.403}{2.771} = 0.506 \text{ or } 50.6\%$$

Other methods of estimating heritability could not be used since the parental varieties were open pollinated and were not considered homozygous.

Segregation of Stormproof Boll Types

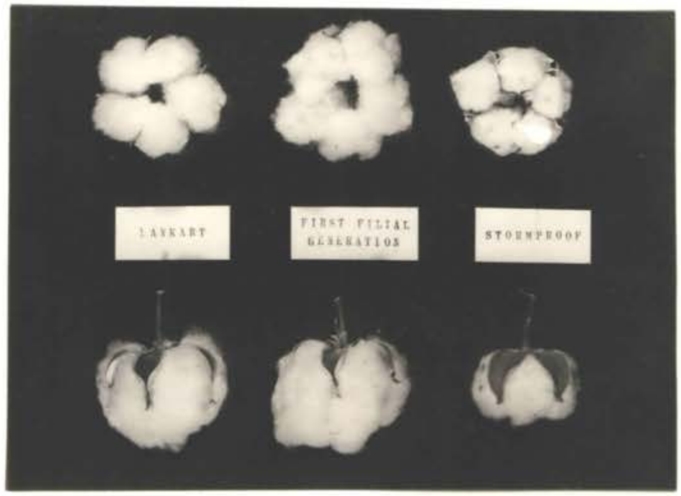
Storm resistance classifications in hybrid progenies of Lankart 57 x Stormproof #1 were difficult. Figure 11 shows the varying degrees of boll types and fluffiness observed. Differences were more distinct in segregating generations of Lankart 57 x Oklahoma Special (Figure 12) and Oklahoma Special x Stormproof #1 (Figure 13). However in all progenies several intermediate types occurred indicating either a large number of genes influenced storm resistance, or environmental effects were great. It seems likely that both Stormproof #1 and the Lankart 57 types of storm resistance were inherited quantitatively since Lankart 57 was uniform in boll type.

Relationship of Storm Resistance and Boll Period

Chi square tests for independence and association were made to determine the relationship of storm resistance and boll period. Chi square tests were made on crosses of Lankart 57 x Oklahoma Special and Oklahoma Special x Stormproof #1. No test for independence nor association was run on crosses of Lankart 57 x Stormproof #1 because of the difficulty in classification for storm resistance. A Chi square test was also made on the Stormproof #1 parent because of the variability of this parent in boll types.

Tables 10 and 11 show the Chi squares and probability ranges for all crosses on which the test for association was made. In no case was any

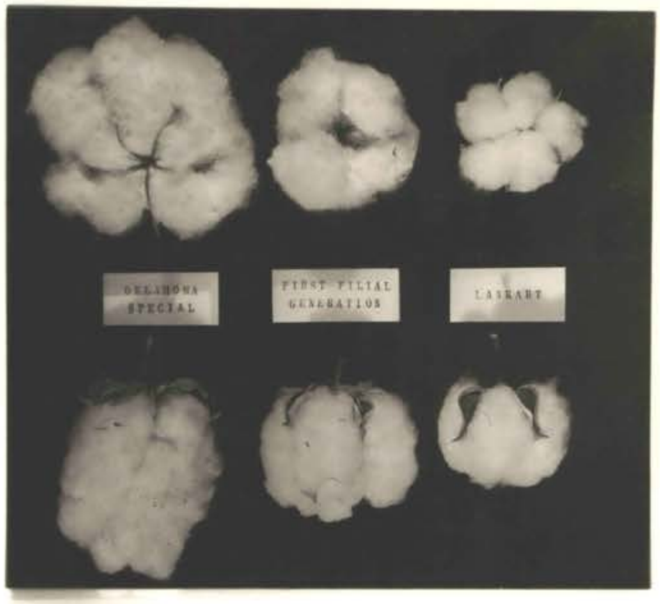
Fig. 11. Typical bolls of Lankart 57 and Stormproof #1 parents and their F_1, F_2, and F_3 hybrid progenies.

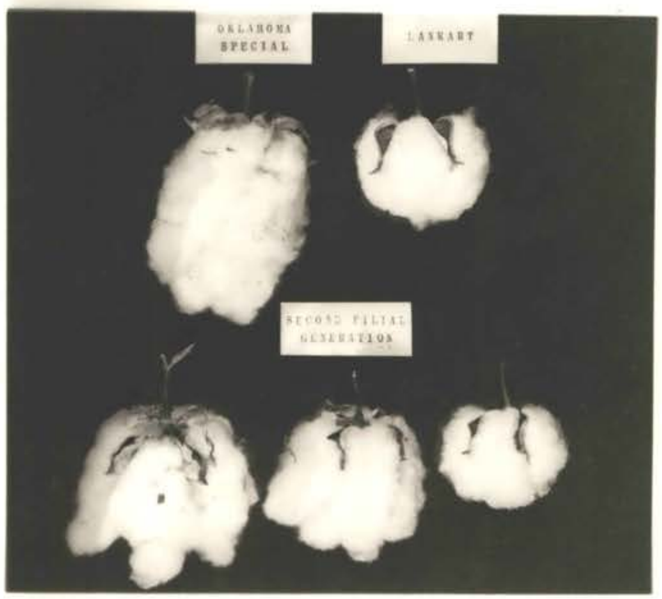

LANKART
FIRST FILIAL
GENERATION
STORMPROOF


LANKART
STORMPROOF
SECOND FILIAL
GENERATION


THIRD FILIAL
GENERATION

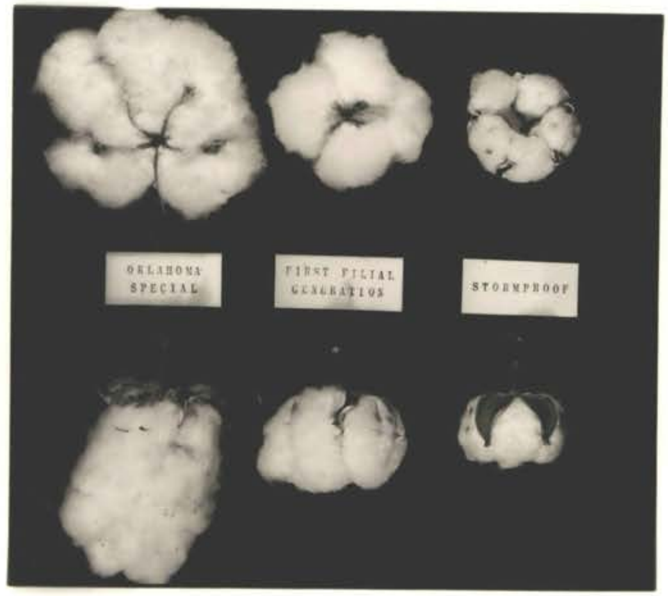
Fig. 12. Typical bolls of Lankart 57 and Oklahoma Special parents and their F_1, F_2, and F_3 hybrid progenies

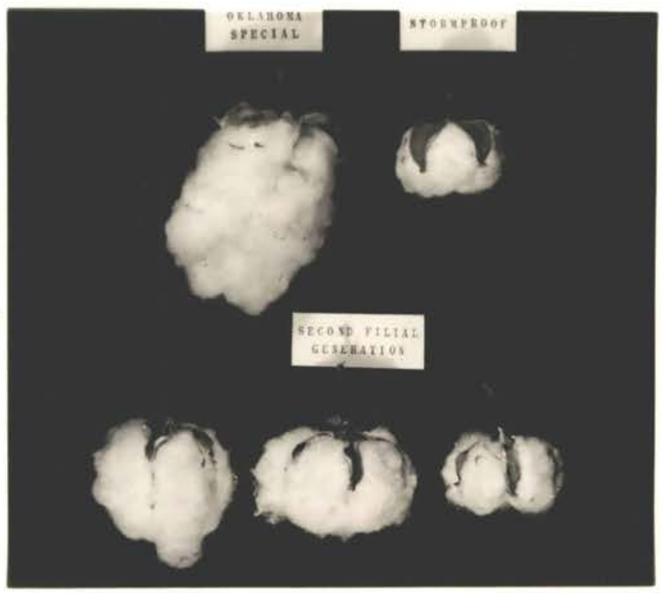

OKLAHOMA SPECIAL
FIRST FILIAL GENERATION
LANKART


OKLAHOMA SPECIAL
LANKART
SECOND FILIAL GENERATION


THIRD FILIAL GENERATION

Fig. 13. Typical bolls of Oklahoma Special and Stormproof #1 parents and their F_1, F_2, and F_3 hybrid progenies.


OKLAHOMA SPECIAL
FIRST FILIAL GENERATION
STORMPROOF


OKLAHOMA SPECIAL
STORMPROOF
SECOND FILIAL GENERATION

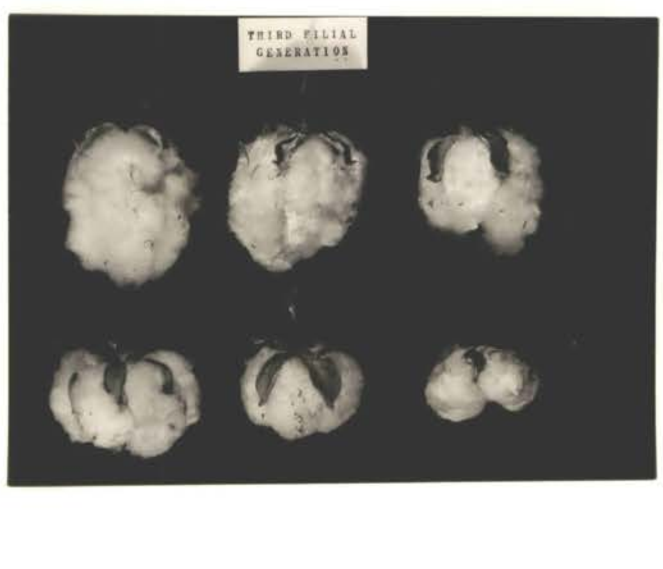

THIRD FILIAL GENERATION

Table 10. Two way classification for earliness or lateness of individual plants which have normal, Lankart, or intermediate boll types in Lankart 57 x Oklahoma Special.

Boll Type	Number of Plants			X^2	P
	Early[a]	Late[b]	Total		
F_1					
Normal	26	20	46		
Lankart	6	8	14		
Intermediate	15	9	24		
	47	37	84	1.1718	0.50-0.70
F_2					
Normal	18	19	37		
Lankart	3	3	6		
Intermediate	23	18	41		
	44	40	84	0.4473	0.70-0.80
(L. x O.S.) O.S.					
Normal	40	27	67		
Lankart	5	5	10		
Intermediate	2	4	6		
	47	36	83	1.7618	0.30-0.50

[a]Plants whose boll period was shorter than the mean of the sample studied.

[b]Plants whose boll period was longer than the mean of the sample studied.

Table 11. Two way classification for earliness or lateness of individual plants which have normal, stormproof, or intermediate boll types in Oklahoma Special x Stormproof #1.

Boll Type	Number of Plants			X^2	P
	Early[a]	Late[b]	Total		
Stormproof #1					
Normal	6	5	11		
Stormproof	9	10	19		
Intermediate	28	20	48		
	43	35	78	0.6634	0.70-0.80
F_1					
Normal	18	15	33		
Stormproof	1	0	1		
Intermediate	15	8	23		
	34	23	57	1.3315	0.50-0.70
F_2					
Normal	23	24	47		
Stormproof	1	1	2		
Intermediate	24	12	36		
	48	37	85	2.6422	0.20-0.30
(O.S. x St. #1) O.S.					
Normal	45	34	79		
Stormproof	0	0	0		
Intermediate	2	7	9		
	47	41	88	3.9176	0.10-0.20

[a]Plants whose boll period was shorter than the mean of the sample studied.

[b]Plants whose boll period was longer than the mean of the sample studied.

significant Chi square value found indicating that boll period and storm resistance were not associated with each other.

DISCUSSION

Components of earliness including rate of squaring, length of square period, boll growth rates, and boll period were studied in three varieties selected for parents because they differed in maturity and storm resistance.

The three parental varieties were found to differ in rate of squaring.

Previous workers (4, 7) found that cotton varieties differed in their square periods. In the present study, differences were not significant for length of square period, being less than one day among varieties.

The most rapid gain in green boll weights occurred during the first 15 days of boll growth. Highly significant differences among the parents were observed, substantiating the results of Martin, Ballard, and Simpson (7), who found differences in boll growth rates among cotton species and varieties. The differences in the size of the bolls are apparent to the naked eye, Lankart 57 having a larger and heavier boll. Lankart 57 sets fewer bolls than either of the other two varieties which very possibly accounts for the larger size and weight of its bolls, or vice versa.

Length of boll period was approximately equal in Oklahoma Special and Stormproof #1. These varieties had significantly shorter boll periods than Lankart 57. Previous workers (1, 9) have shown that seasonal differences occur in the length of boll period. Average boll periods for the three varieties in the present study were 14.15 days shorter in 1952 than in 1951. Varietal differences were consistent in the two years in spite of the more serious drought in the second year.

Although significant varietal differences were found to occur in rate of squaring, boll growth rates, and length of boll period, only boll period was studied in segregating generations. Since a large population was grown in 1952, time did not permit a study of the rate of squaring. Boll growth rates could not be studied on individual plants, so F_3 progenies were planted in order to provide several plants for boll growth rate study. However, because of the small number of plants per F_3 family, sufficient blooms were not obtained for tagging per day to permit completing this study.

In the crosses in which the parent differed, Lankart 57 x Oklahoma Special and Lankart 57 x Stormproof #1, boll period appeared to be inherited as a quantitative character with additive gene action indicated. Apparently additive gene effects in quantitative inheritance can result from (a) all genes having strictly additive effects, or (b) some genes being dominant for earliness and some genes being dominant for lateness, and their effects balancing each other.

The parents, crosses, and backcrosses of Oklahoma Special and Stormproof #1 did not differ significantly in the length of boll period.

The backcrosses which did not germinate well, (Lankart 57 x Oklahoma Special) x Lankart 57 and (Oklahoma Special x Stormproof #1) x Stormproof #1, were one-fourth Oklahoma Special. It is possible that a lethal condition was present with one-fourth Oklahoma Special parentage.

Heritability of boll period was studied in the cross Lankart 57 x Stormproof #1 since both backcrosses survived. The scale of measurement was found to be additive using the method proposed by Mather (8). An estimate of heritability in the material studied showed a heritability score of 50.6 per cent. The method for estimating heritability was obtained from previous workers (8, 12) and provides an estimate of the additive genetic portion of the variance. A heritability score of 50.6 per cent means that in selection for shorter or longer boll period in this material, one could expect to retain in the progeny of the selected sample 50.6 per cent of the difference between the mean of the original population and the mean of the selected sample.

In his work on the stormproof character, Lynn's (6) observations as to boll type of the "stormproof" varieties were found to be essentially the same in the material studied in this problem. However, Lynn concluded that storm resistance was inherited on the basis of one incompletely dominant gene. In this problem, it was shown that a number of degrees of boll types occur in the F_2 and F_3 segregations. Therefore, it can be concluded that storm resistance in this material is inherited on the basis of an unknown number of genes that interact to cause a quantitative effect.

Boll period and storm resistance were found to be independent in the crosses studied.

SUMMARY

The inheritance of storm resistance and maturity were studied in crosses of three commercial varieties of cotton: Lankart 57, Oklahoma Special, and Stormproof #1. Rate of squaring, square period, boll growth rate, and boll period of the parents were studied in 1951. Significant differences among varieties occurred in rate of squaring, boll growth rate, and boll period. In 1952, the parents, F_1's, F_2's, and backcrosses (two of which did not germinate) were planted and boll period data were taken along with storm resistance classifications.

Lankart 57 and Oklahoma Special behaved as expected, the former being later maturing and the latter early maturing. Stormproof #1 was previously shown to be approximately as late maturing as Lankart 57, but it was found to have the same boll period as Oklahoma Special. Differences in maturity were due to something other than boll period. In the crosses Lankart 57 x Oklahoma Special and Lankart 57 x Stormproof #1, significant differences were observed among the parents and the hybrid populations means. Heritability studies were made on the cross Lankart 57 x Stormproof #1. It appeared that a number of genes with a total additive effect were responsible for the determination of boll period. A heritability estimate of 50.6 per cent was obtained for the material studied. In the cross Oklahoma Special x Stormproof #1, no significant differences among parents and/or hybrid population means were observed.

Storm resistance was concluded to be inherited on the basis of an unknown number of genes that interact to cause a quantitative effect.

No association of boll period and storm resistance was observed in the parents or hybrid population.

LITERATURE CITED

1. Buie, T. S. Fruiting habit of the cotton plant. S. Car. Agr. Exp. Sta. Bul. 261. 1929.

2. Keitt, T. E. and Murray, A. W. The influence of certain factors on the time of opening of cotton. Ga. Agr. Exp. Sta. Bul. 130. 1919.

3. Leonard, W. H. and Clark, A. G. Field plot technique. Minneapolis, Minn.: Burgess Publishing Co., 271 pp., 1939.

4. Loomis, H. F. Development of flowers and bolls of Pima and Acala cotton in relation to branching. U.S.D.A. Dept. Bul. 1365. 1927.

5. Ludwig, C. A. Some factors concerning earliness in cotton. Jour. Agr. Res. 43:637-659. 1931.

6. Lynn, H. D. The inheritance of "stormproof" boll type in <u>Gossypium hirsutum</u>. Masters Thesis. A. & M. College of Texas. 1-39. 1949.

7. Martin, R. D., Ballard, W. W., and Simpson, D. M. Growth of fruiting parts in the cotton plant. Jour. Agr. Res. 25:195-208. 1923.

8. Mather, K. Biometrical genetics. London: Methuen & Co., 162 pp. 1949.

9. McNamara, H. C., Hooton, D. R., and Porter, D. D. Differential growth rates in cotton varieties and their response to seasonal conditions at Greenville, Texas. U.S.D.A. Tech. Bul. 710. 1940.

10. McNamara, H. C., Hubbard, J. W., and Beckett, R. E. Growth and development of cotton plants at Greenville, Texas. U.S.D.A. Dept. Cir. 401. 1927.

11. Snedecor, G. W. Statistical methods. Ames, Iowa: The Collegiate Press. Ed. 4, 485 pp. 1946.

12. Warner, John N. A method of estimating heritability. Agron. Jour. 44:427-430. 1952.

VITA

Gordon David Hintz
candidate for the degree of
Master of Science

Thesis: HERITABLE RELATIONSHIPS OF STORM RESISTANCE AND MATURITY IN THREE VARIETIES OF GOSSYPIUM HIRSUTUM

Major: Field Crops

Minor: Botany

Biographical and Other Items:
Born: October 29, 1930, at St. Louis, Missouri
Undergraduate Study: Oklahoma Agricultural and Mechanical College 1948-52.
Graduate Study: O.A.M.C. 1952-53
Experiences: Employed by business research firm, 1947-48; employed by Agronomy Department, 1950-53.

Member of Phi Kappa Phi, Phi Eta Sigma, Agronomy Club, Red Red Rose, and Newman Club.

Date of Final Examination: May 1953.

THESIS TITLE: HERITABLE RELATIONSHIPS OF STORM RESISTANCE AND MATURITY IN THREE VARIETIES OF GOSSYPIUM HIRSUTUM

AUTHOR: Gordon David Hintz

THESIS ADVISOR: Dr. John M. Green

The content and form have been checked and approved by the author and thesis advisor. Changes or corrections in the thesis are not made by the Graduate School office nor by any committee. The copies are sent to the bindery just as they are approved by the author and faculty adviser.

TYPIST: Dorothy Watkins