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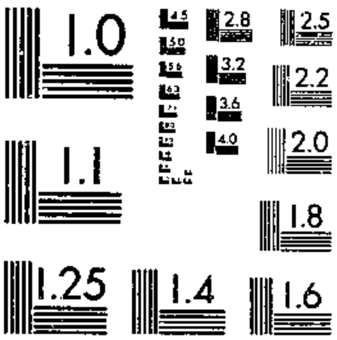

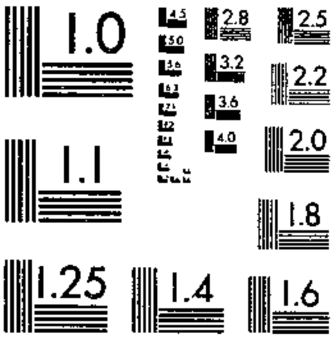

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TECHNICAL BULLETIN No. 710 — JUNE 1940

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

DIFFERENTIAL GROWTH RATES IN COTTON VARIETIES AND THEIR RESPONSE TO SEASONAL CONDITIONS AT GREENVILLE, TEX.[1]

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INTRODUCTION

Differential growth rates between varieties of cotton are recognized, but the determining morphological factors causing these differences are not well understood. With specific information lacking, logical inquiry naturally would include the particular characteristics that contribute to earliness and production. Information as to the number of nodes to first fruiting branch, rate of appearance of first flowers on successive fruiting branches, rate of appearance of successive flowers on fruiting branches, shed period, boll period, thickness of burs, and the location on the plant where bolls are most likely to be set or to be shed, are all fairly definite characteristics that may be evaluated and reduced to rather exact terms. These values are important not only from the standpoint of breeding and production, but they also have direct bearing on problems of plant nutrition or of insect control, especially as related to the proper time or condition of growth for applying control measures.

A better understanding of plant behavior should be helpful to cotton producers, crop reporters, cotton statisticians, and others. This information may be of value in estimating the response that might be expected from certain combinations of characters in genetics

[1] Submitted for publication March 30, 1939.

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work, or in considering factors that should be sought in selection and breeding work.

Plant responses in a given season frequently show that there may be greater or more consistent differences in the reactions of a variety to seasonal conditions than are found between two dissimilar varieties. This behavior may account for much current misinformation on varieties traceable to some unusual seasonal response peculiar to the variety.

The studies reported herein were begun in 1929 at Greenville, Tex., and continued for a 5-year period through 1933. The field data obtained in 1929 and 1930 were lost by fire in 1931, and results for only 3 years are available. The similarity of data obtained in 1929 and 1930 to that of succeeding seasons leads to the opinion that data for the 3 years presented reflects with reasonable accuracy the general varietal behavior that may be expected under conditions as existing in this locality.

The consistent behavior of varieties relative to the number of days between the appearance of fruiting branches, the number of days between flowers on fruiting branches, shed period, boll period, etc., presents tangible differences of the more important factors influencing growth rates in cotton.

As a further aid in understanding growth rates between varieties and the effects of seasonal conditions, a statistical analysis has been made of the more important data.

REVIEW OF LITERATURE

During the past 25 to 30 years a number of investigators have studied the morphology of the cotton plant.

Cook (*5*),[2] in writing of dimorphic branching of tropical crop plants, pointed out that cotton has two kinds of branches, axillary and fertile. They are now commonly known as vegetative and fruiting branches. Cook and Meade (*7*) described the arrangement of parts in the cotton plant and discussed certain morphological relations. Ewing (*8*), reporting from Mississippi where he worked with 27 varieties, observed varietal differences in rates of flower production, boll shedding, and boll period, as well as the influence of soil and rainfall on these phenomena. McClelland (*19*), in 1916, pointed out a striking occurrence of regularity in blooming of cotton plants, and later McClelland and Neely (*20*) reported more detailed studies of plants grown at Fayetteville, Ark., in 1923, and at Fayetteville and Marianna, Ark., in 1929. These investigators studied the growth rates in several varieties of cotton and found that the vertical order of blooming was generally within 2.3 to 2.8 days and that the horizontal interval fluctuated closely around 6 days. These data are in close agreement with those obtained from other varieties at Greenville.

King (*13*), in discussing water stress in Pima Egyptian cotton in Arizona, found the mean boll period in *Gossypium barbadense* L. to be 68 days, with a mean difference in time required from flowers blooming in July and in September to be 27 days. He reported that the interval from flowering to shedding was approximately 10 days, and observed that "a heavy rain materially shortened the shed period." King also found that plants producing the greatest vegetative growth

[2] Italic numbers in parentheses refer to Literature Cited, p. 42.

appeared to suffer most frequently from "water stress," remained longer in a wilted condition between irrigations, and showed an earlier recurrence of wilting after irrigation. Ewing (*8*) reported that the "period between flowering and shedding is longest when shedding first begins and shortest at the close of the season." In a later report, King (*14*) stated that bolls from plants affected by water stress often were greatly reduced in size, contained fewer seeds, and were frequently deformed and off-type for the variety. Plants suffering from water stress were usually found to produce fiber that was "weaker, less abundant, shorter, and more uneven in length than that developed under favorable conditions."

From an irrigation experiment in Arizona, Martin and Loomis (*23*) reported that the shedding of young Pima Egyptian cotton bolls was greatest 4 to 14 days after flowering, with an average of 10.8 days for all shed bolls. Martin, Ballard, and Simpson (*22*), in studying the growth of fruiting parts in cotton grown in Arizona, Texas, and South Carolina, concluded that "the average number of days between the production of successive fruiting branches was approximately 3 days, with none of the varieties showing significant differences." All of the varieties under the conditions represented showed an average of about 6 days between the appearance of squares on the fruiting branch. Consistent differences were noted by these investigators in the square period of Pima and Meade as compared with that of Acala, Durango, and Lone Star. They also observed a slight increase in the square period for successive fruiting branch nodes in Pima and a lengthening of the boll period with the advance of the season.

McNamara, Hubbard, and Beckett (*21*) studied growth rates in several varieties of cotton in Texas and for different dates of planting and different spacings. They found the mean interval between the appearance of first flowers on successive fruiting branches to be 2.4 days as compared to 6.2 days for successive flowers on fruiting branches. The time from planting to the appearance of first squares ranged from 58 days in an April 2 planting to 19 in plantings made July 24 and August 15. In another similar experiment in 1925, the period ranged from 68.5 days in a March 16 planting to 25.6 in a June 15 planting, which indicated that the length of time from planting to first square may be very materially affected by seasonal conditions. These investigators also showed that the intervals between the formation of successive fruiting branches and the appearance of successive squares on fruiting branches were consistently longer in unthinned cotton than in thinned cotton.

Barre (*1*) states that the "lack of sufficient soil moisture is the principal factor in causing cotton shedding." Hawkins et al. (*10*), in studying shedding in cotton under irrigation in Arizona, concluded that the amount of available soil moisture, through its influence on food conditions within the plants, is a major factor in regulating fruiting behavior. Hawkins also stated that extremely high osmotic pressures induced by severe reductions in soil moisture, or low osmotic pressures, were usually followed by increased shedding. Lloyd (*15*) recognized that abscission was inhibited during anthesis, and states that "The maximum numbers fall on the second day, though high rates persist till the fifth day." He also observed that "Rain, if it falls in the late forenoon and probably early afternoon, causes a high degree of shedding of bolls through its destruction of pollen." Buie

(*4*), reporting studies of the fruiting habits of the cotton plant in South Carolina, found that an average of 48.3 percent of the flowers produced bolls and that of flowers of the first 3 weeks more than 85 percent developed into open bolls. Buie's data also showed that environmental conditions played an important part in relation to boll period and that the boll period progressively lengthened with the advance of season. He noted "that few of the upper branches produced flowers and fewer still produced bolls."

Beckett (*2*), in studying the growth rates in Garo Hill (*Gossypium cernuum* (Tod.)), an Asiatic cotton, found that the mean number of days between the appearance of successive fruiting branches in this species was 2.31 ± 0.177 days and the number of days between the appearance of successive squares on the fruiting branches was 6.50 ± 0.167, which closely correspond to the same rates in upland cotton, but that the mean boll-shed period was 3.85 days as compared to 6.10 days for Lone Star, an upland variety. He also found that the boll period lengthened with the advance of the season.

Beckett and Hubbard (*3*) reported that there was a decided tendency toward a higher rate of shedding of five-lock than of four-lock bolls and that the percentage of the former was more subject to environmental or cultural conditions than of the latter.

Loomis (*16*) found the mean square period for Pima cotton to be slightly over 33 days and for Acala 28 and 29 days. He also determined that Acala bolls matured in about 5 days less time than Pima and that the severity of boll shedding increased progressively from basal or inner nodes to those farther out on the branches. Loomis also determined that the boll period on the second node was lengthened by the presence of a boll on the first node.

Ludwig (*18*), working in South Carolina, found that spacing of plants had no appreciable effect on either the square period or the boll period, and stripping forms from the plants had no perceptible effect on the square period. In another report Ludwig (*17*) studied late defoliation and concluded that the yields, both in size and number of bolls, were reduced by defoliation if carried out long enough before maturity. Late defoliation also caused the death of most of the twigs and many of the plants where the soil was moist, but no such result followed if the soil were dry or defoliation occurred earlier, and such early defoliation delayed maturity rather than hastened it.

Cook (*6*) observes that—

> a genetic factor is plainly indicated in plants that abort all of their buds, while their neighbors mature good crops. Egyptian cotton may retain nearly all of its buds and young bolls while upland varieties in adjacent rows are shedding nearly all of their buds.

Kearney and Peebles (*11*), in studying the heritability of different rates of shedding in cotton, found a consistently higher rate of boll shedding in Acala than in Pima Egyptian. There was a lower mean percentage of bud shedding in both the first and second generation hybrids than in either parental population, while the mean percentage of boll shedding of the hybrid in both generations was between the mean percentages of the parental types.

In a later report on Pima Egyptian × Acala upland crosses, Kearney and Peebles (*12*) concluded that—

> the shedding of flower buds and young bolls is determined partly by genetic factors. Conclusive evidence that such is the case was afforded by third genera-

tion progenies of F_3 plants which had shown, respectively, a high, intermediate, and low rate of shedding.

EXPERIMENTAL METHODS

Six upland types, represented by commercial strains of Acala, Lone Star, Rowden, Delfos, Half and Half, and Kekchi were selected for study. These varieties differ widely with respect to length and percentage of lint, lint index, seed index, size and fuzziness of seed, size and shape of boll, stormproofness, drag, size and shape of leaf, plant type, growth habit, productiveness, etc. The varieties are classified according to their relative differences in table 1. It will be noted that there is a wide range of differences among them, especially in the percentage and length of lint.

TABLE 1.—*Classification of varieties according to their relative differences for several characters*

Characteristics	Acala	Lone Star	Rowden	Delfos	Half and Half	Kekchi
Seed:						
Large			X			
Medium	X	X				X
Small				X	X	
Seed coat:						
Very fuzzy	X		X			
Medium fuzzy						
Fuzzy		X		X	X	X
Seedlings:						
Normal		X	X		X	X [1]
Vigorous	X			X		
Type of growth	Erect	Semierect	Erect	Spreading	Erect	Spreading
Growth habit:						
Determinate				X		
Normal		X	X		X	X
Indeterminate	X					
Leaves:						
Large		X				
Medium			X		X	X
Small	X			X		
Leaf lobe:						
Wide		X	X			
Medium	X				X	X
Narrow				X		
Boll shape:						
Pointed				X		X
Medium	X	X	X			
Round					X	
Bolls per pound of seed cotton:						
45 to 60		X	X			
60 to 75	X					X
75 to 100				X	X	
Percentage of lint:						
30 to 32				X		
33 to 34			X			X
35 to 36		X [1]				
37 to 38	X					
39 to 40						
41 to 42						
43 to 44					X	
Length of lint (inches):						
¾					X [1]	
⅞						
15/16			X			
1		X				
1 1/32	X					
1 1/16						
1 3/32				X		
1 1/8						X

[1] Plus.

The procedure followed in this study has been developed as a practical and reliable method resulting from 10 years' observations of growth and fruiting of cotton plants. The individual plants were selected from variety test rows in close proximity to each other in 1931 and 1932, but included in a separate planting in 1933. They were grown on very uniform soil which had been classified by the Bureau of Chemistry and Soils as a low-lime phase of Houston clay.

Prior to flowering, 25 normal plants of each variety were selected for observation and numbered from 1 to 25 consecutively. From this number, final data were recorded on only 20. The 5 extra plants provided sufficient safeguard for such contingencies as terminal bud abortion or development of other characteristics not typical of the variety. Examinations were made at intervals of 2 days or oftener throughout the growing season, and data recorded of the number of nodes to first fruiting branch, date and position on the plant of all flowers, shed bolls, open bolls, and thickness of burs. Main stalk nodes were tagged at one or two points on each plant which facilitated the recording of data during the latter part of the season.

A separate record sheet for each plant was prepared for this study. It was compact in design and provided sufficient space for recording all necessary information. Consecutive numbers were used to indicate the date on which various changes occurred, and convenient symbols were employed to express such occurrences as aborted fruiting branches, small square shedding, exotic vegetative branches, and diseased or insect-damaged bolls. Bolls showing abnormal development, diseased conditions, or insect damage were not included in calculations.

Every mature boll from each plant was collected and its position by plant node recorded. These bolls furnished material for studying any possible relationship that might exist between the date of flower and open boll and the position on the plant at which the bolls were borne, as well as the influence of growth conditions on the fiber.

STATISTICAL TREATMENT

The data for each of the principal characteristics covered by this study have been examined by means of the analysis of variance, as developed by Fisher (*9*) and described in systematic form by Snedecor (*25*). The number of nodes to the first fruiting branch, rate of appearance of first flowers on successive fruiting branches, rate of appearance of successive flowers on fruiting branches, boll-shed period, and boll-maturation period data are presented and analyzed. For each characteristic the original field data are shown in tabular form followed by tables including (1) an analysis of variance, (2) a summary of means and mean differences together with their "*t*" values for varieties, and (3) similar determinations for yearly means.

The first analytical table shows the source of variation, the number, of degrees of freedom, values for sum of squares, mean square, and "F" value (*25, p. 15*) as found and as required for the probabilities P–0.01 and P–0.05, or the 1 and 5 percent levels of signficance, for varieties, years, interaction: varieties × years, and error. Since many of the observed F values are considerably higher than is required for significance at the 5 percent level, estimates of the significance of differences may be based principally on the values required at the 1 percent level. The standard error of the mean difference is calculated by use of the formula:

$$S.\ E._{\text{M. D.}}=\frac{\sigma}{\sqrt{n}}\times\sqrt{2}$$

The second and third tables are adapted from similar ones presented by Pope (*24*), and are alike except that one is based on varietal means for 3 years combined and the other on yearly means when all varieties are considered as a single group. The standard error of the mean difference, and the values of t at the 1- and 5-percent levels of significance, or odds of 99:1 and 19:1, respectively, are placed at the bottom of the table. Analyses of single varieties for each year are not shown, since a single year's results are generally considered to be unreliable for interpretation of data. In each of these tables the varieties or years, as the case may be, are listed in descending order from left to right at the top, and from top to bottom at the left margin, according to the values of the means for the character under discussion. Each table is bisected by a diagonal line of asterisks, above and to the right of which are placed the actual differences between the mean value directly above and the one directly to the left. The corresponding figures below and to the left of the asterisks are obtained by dividing the mean difference by the standard error of the mean difference. These figures are known as t values and serve as a guide to the degree of significance of the actual mean differences shown above and to the right of the asterisks. All values of t greater than that given at the bottom of the table as required for significance at the 1-percent level, corresponding to odds of 99:1, may be considered as highly significant.

NUMBER OF NODES TO FIRST FRUITING BRANCH

The two axillary buds at the base of the cotyledons represent two main stalk nodes, and the first true leaf appears at the third main stalk node. After seedlings develop an average of six or eight true leaves, they may be considered as having passed the juvenile stage and entered the fruiting stage of development.

When the fruiting stage has been reached, the uppermost leaf will be found subtending a tiny square, which, if it remains on the plant, will form the first boll on the fruiting branch arising from that node. The number of true leaves on the seedlings, therefore, may be taken as an index to the stage of development at which the plants begin producing floral buds. Upland varieties would be expected to begin fruiting with the sixth to eighth true leaf. In a very few cases the first fruiting branch will not appear until the tenth or eleventh true leaf is formed, and occasionally first squares may be found behind the fourth or fifth true leaf.

In observing varieties in the field there often appears to be rather pronounced differences in the height at which plants begin fruiting. Cotton growers frequently refer to a cotton as one that "fruits high" or "fruits low." This difference apparently is more closely associated with internode length than with node number. In other words, short main-stalk internodes will give a plant the appearance of fruiting low while longer internodes make it appear to fruit higher, although both types may be producing the first fruiting branch at the same node number. The main-stalk node at which the first fruiting branch is borne offers a convenient basis for comparison between varieties or types and is the first character discussed in this report.

Considering the diverse types represented in the six varieties studied, there were surprisingly small differences in mean main-stalk nodes on which the first fruiting branches were borne. Even the growth rates in the juvenile stage were more uniform than would be expected.

The greatest difference in mean height to first fruiting branch was only 0.78 of a node, and this occurred between the Lone Star and Rowden varieties. The greater part of this difference occurred during the season of 1931 when several of the Rowden plants showed the first fruiting branch on the tenth and eleventh main-stalk nodes, which is unusually high. In 1933 these two varieties produced their first fruiting branches at exactly the same mean position of 8.55 nodes. The mean nodes to first fruiting branch of Kekchi and Lone Star were practically the same, the Kekchi branches being only 0.05 of a node higher than Lone Star, which was 7.92. Delfos and Half and Half produced their first fruiting branches at 8.33 and 8.55 nodes, respectively. The mean nodes to first fruiting branch of Acala and Rowden were practically the same, being 8.68 and 8.70 nodes. Both varieties were erect in their habits of growth. The number of nodes to the first fruiting branch, together with the yearly mean and the mean for the 3-year period, for 20 plants of each variety, are shown in table 2.

TABLE 2.—*Nodes to first fruiting branch on 20 plants each of 6 varieties of cotton, for the 3-year period 1931–33, at Greenville, Tex.*

Plant No.	Acala			Lone Star			Rowden			Delfos			Half and Half			Kekchi		
	1931	1932	1933	1931	1932	1933	1931	1932	1933	1931	1932	1933	1931	1932	1933	1931	1932	1933
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
1	8	8	9	8	7	9	9	10	8	7	8	7	9	8	9	8	8	7
2	8	10	11	7	7	9	10	9	8	9	8	9	9	8	8	9	9	9
3	9	8	9	7	9	9	9	9	8	11	7	8	8	10	8	8	8	7
4	9	9	8	7	7	8	8	7	9	9	8	8	9	9	8	8	7	8
5	9	10	8	6	7	11	9	7	9	9	8	9	9	9	9	7	7	9
6	9	10	8	8	7	8	8	9	8	8	8	9	11	8	8	10	9	9
7	8	8	9	8	8	9	9	9	9	9	8	8	9	8	8	9	6	8
8	8	10	9	7	8	8	10	9	7	9	8	9	8	8	9	8	8	8
9	8	9	11	7	7	9	10	9	8	8	8	10	9	7	9	7	7	8
10	9	8	9	8	7	8	9	9	9	9	9	8	7	8	8	8	7	7
11	9	8	8	9	9	7	9	8	8	10	8	10	10	7	10	8	7	9
12	7	8	9	7	8	8	10	9	7	9	9	9	9	9	7	8	9	8
13	9	8	8	10	8	7	7	9	9	9	6	8	10	9	9	10	8	8
14	9	9	9	7	7	9	10	6	8	9	7	8	9	8	8	9	7	8
15	9	7	9	8	6	9	11	10	10	10	7	7	9	8	9	7	7	8
16	9	7	9	7	7	8	10	8	9	7	8	7	7	8	7	9	8	8
17	10	9	9	9	8	9	9	9	9	8	8	8	10	7	9	7	7	8
18	9	8	8	8	7	9	8	8	10	8	9	9	8	8	11	8	9	8
19	9	8	10	7	10	8	9	7	10	8	7	8	9	8	9	9	7	8
20	8	8	8	7	8	9	9	7	8	7	9	10	9	8	9	9	6	8
Total	173	170	178	152	152	171	183	168	171	173	158	169	178	163	172	166	151	161
Mean	8.65	8.50	8.90	7.60	7.60	8.55	9.15	8.40	8.55	8.65	7.90	8.45	8.90	8.15	8.60	8.30	7.55	8.05
3-year mean		8.68			7.92			8.70			8.33			8.55			7.97	

An analysis of variance of the number of nodes to the first fruiting branch is shown in table 3.

TABLE 3.—*Analysis of variance of the number of nodes to the first fruiting branch in 6 varieties of cotton at Greenville, Tex., 1931–33*

Variance	Degrees of freedom	Sum of squares	Mean square	*F* value		
				Found	Required	
					P=0.01	P=0.05
Total	359	352.7750	0.9827			
Varieties	5	36.4917	7.2983	8.95	3.08	2.25
Years	2	21.0500	10.5250	12.91	4.68	3.03
Interaction: varieties × years	10	16.4833	1.6483	2.02	2.57	1.97
Error	342	278.7500	.8151			

The observed values of *F* for varieties and years are approximately three times the requirement for significance at the 1-percent level, while the *F* value for interaction: varieties×years falls between the values required for significance at the 1- and 5-percent levels.

Analyzing the data for each variety separately, it was found that Half and Half and Kekchi produced their first fruiting branches at significantly lower nodes in 1932 than in 1931, and Lone Star produced its first fruiting nodes significantly lower in 1931 and 1932 than in 1933. No significant differences between seasons were found in Acala, Rowden, and Delfos, indicating that they were less susceptible to early seasonal conditions than Lone Star, Half and Half, and Kekchi.

Combining the 3 years' data, Lone Star, Kekchi, and Delfos produced their first fruiting branches significantly lower than Acala and Rowden. The first fruiting branches were also lower in Lone Star and Kekchi than in Half and Half and Delfos. The level of significance of the differences between means of varieties are indicated in table 4.

TABLE 4.—*Mean number of nodes to first fruiting branch, actual mean differences between varieties, and t values of mean differences in 6 varieties of cotton at Greenville, Tex., 1931–33*

Variety	Mean	Rowden (mean, 8.70)	Acala (mean, 8.68)	Half and Half (mean, 8.55)	Delfos (mean, 8.33)	Kekchi (mean, 7.97)	Lone Star (mean, 7.92)
Rowden	8.70	*	0.02	0.15	0.37	0.73	0.78
Acala	8.68	0.12	*	.13	.35	.71	.76
Half and Half	8.55	.87	.75	*	.22	.58	.63
Delfos	8.33	2.14	2.03	1.28	*	.36	.41
Kekchi	7.97	4.23	4.12	3.36	2.09	*	.05
Lone Star	7.92	4.52	4.41	3.65	2.3[illegible]	.29	*

0.1725 = *S. E.* $_{M.\ D.}$ between means of varieties.
1.966 = *t*, required, odds 19:1.
2.588 = *t*, required, odds 99:1.

In 1931 the mean node number at which the first fruiting branch was borne was significantly lower in Lone Star, Kekchi, Acala, and Delfos than in Rowden; it was lower in Lone Star and Kekchi than in Half and Half; and lower in Lone Star than in Acala and Delfos. In 1932 the mean node number of the first fruiting branch was significantly lower in Lone Star, Kekchi, and Delfos than in Acala and Rowden, and in Lone Star and Kekchi than in Half and Half, whereas in 1933 it was lower in Kekchi and Delfos than in Acala and lower in Kekchi than in Half and Half, Lone Star, and Rowden.

When all of the varieties were combined, the mean node number at which the first fruiting branch was borne was significantly lower in 1932 than in 1931 and 1933, as is shown in table 5.

TABLE 5.—*Mean number of nodes to first fruiting branch, actual mean differences between years, and t values of mean differences in 6 varieties of cotton considered as a single group, 1931–33*

Year	Mean	1931 (mean, 8.54)	1933 (mean, 8.52)	1932 (mean, 8.02)
1931	8.54	*	0.02	0.52
1933	8.52	0.16	*	.50
1932	8.02	4.18	4.02	*

0.1244 = S. E. $_{M. D.}$ between means of years.
1.966 = t, required, odds 19 : 1.
2.558 = t, required, odds 99 : 1.

RATE OF APPEARANCE OF FIRST FLOWERS ON SUCCESSIVE FRUITING BRANCHES

Data were obtained on the rate at which new fruiting branches were formed along the main stalk, by recording the interval in days between first flowers on successive fruiting branches. This method was used because previous studies at Greenville indicated the feasibility of such procedure, since the square period was found to fluctuate very little within a season.

During the 3-year period, a total of 2,362 growth intervals was recorded. They are summarized by variety and by year in table 6. The mean interval for all varieties was 2.65 days. Slight differences appeared in the mean interval for different varieties, although the widest fluctuations were between seasons. It will be noted that the interval was considerably longer in 1933 than for the 2 previous years. Delfos and Half and Half showed a slightly shorter interval between first flowers on successive fruiting branches than the other varieties. Usually there was a definite tendency for the interval between successive fruiting branches to lengthen between the higher nodes near the top of the plants. There was also a definite tendency for this period to be shortest within the region where the greatest number of bolls were set. This, of course, indicates that while moisture was ample and good growing conditions prevailed, a majority of the bolls were set rapidly. The mean interval in days between first flowers on successive fruiting branches by main-stalk nodes is shown in table 7.

TABLE 6.—*Cases and mean interval between appearance of first flowers on successive fruiting branches in 20 plants of 6 varieties of cotton, at Greenville, Tex., 1931–33*

[These data are a reliable indicator of the rates of growth and fruiting of the different varieties]

Variety	Cases				Mean interval			
	1931	1932	1933	Total	1931	1932	1933	1931–33
	Number	*Number*	*Number*	*Number*	*Days*	*Days*	*Days*	*Days*
Acala	108	118	151	377	2.93	2.39	3.17	2.83
Lone Star	79	133	117	329	2.70	2.37	3.14	2.74
Rowden	77	152	177	406	2.45	2.45	2.85	2.58
Delfos	121	178	164	463	2.33	2.51	2.83	2.55
Half and Half	79	138	166	383	2.58	2.22	2.85	2.55
Kekchi	93	139	172	404	2.38	2.48	3.01	2.63
Total				2,362				
Mean of all varieties								2.65

TABLE 7.—*Mean interval between first flowers on successive fruiting branches at specific main-stalk nodes for 6 varieties of cotton during the 3-year period 1931–33*

Fruiting branch No.	Mean interval																	
	Acala			Lone Star			Rowden			Delfos			Half and Half			Kekchi		
	1931	1932	1933	1931	1932	1933	1931	1932	1933	1931	1932	1933	1931	1932	1933	1931	1932	1933
	Days	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*
27													4.3					
26	8.0												3.0					
25													3.0					
24	4.5						4.0					4.0	3.0	3.0				4.0
23	2.0			4.0	3.3		3.5		5.0	3.0			3.0	3.0	4.0			
22	3.7	2.5	6.0	3.0	2.3		4.0		3.0	3.5		4.3	2.5	2.1	4.0		2.0	3.0
21	3.1	2.7	3.3	2.0	2.0		2.7	2.7	3.5	5.0	3.1	3.5	2.2	1.8	2.0	3.0	2.7	
20	3.2	2.2	5.1	3.0	2.3		2.2	2.8	3.3	2.6	2.8	4.0	2.5	2.4	4.0	3.0	2.9	7.0
19	2.6	2.8	4.6	2.8	2.4	3.0	2.4	3.3	4.6	2.8	2.9	3.7	2.4	1.8	3.8	2.7	2.4	4.7
18	3.1	3.0	4.3	2.7	2.8	4.4	2.7	2.5	4.7	2.8	2.9	4.4	1.8	2.5	4.1	2.6	2.6	4.9
17	3.2	2.3	4.1	2.6	3.0	4.5	2.9	2.5	3.7	3.2	2.5	4.5	3.0	2.2	3.4	2.0	2.7	4.2
16	2.4	2.3	3.2	2.7	2.2	3.9	2.8	2.3	3.3	2.5	2.1	3.4	2.5	2.2	3.9	2.6	2.1	3.3
15	2.9	2.7	2.7	2.8	2.5	3.2	3.2	2.7	3.6	2.0	2.6	3.6	2.8	1.8	3.2	3.1	2.6	3.1
14	1.1	2.0	2.0	3.3	2.4	2.7	3.0	2.3	2.3	1.9	2.3	2.3	1.7	2.2	2.4	2.6	2.5	2.2
13	2.7	2.8	2.1	2.6	2.6	2.7	2.7	2.5	2.2	2.2	2.9	2.6	2.6	2.0	2.3	2.3	2.7	2.5
12	1.0	2.1	2.4	2.5	2.3	2.0	1.4	2.3	1.8	1.8	2.1	1.9	1.9	2.3	1.9	2.4	2.2	2.1
11	2.5	2.6	2.0	2.3	2.8	2.3	2.9	2.4	2.3	1.9	2.4	2.1	2.6	2.8	2.2	2.9	3.0	2.4
10	1.6	2.0	2.4	1.6	2.3	1.7	1.3	2.0	1.6	1.4	2.4	2.0	1.7	2.5	2.4	2.0	2.1	2.4
9	.5	2.0	2.5	2.7	1.7	1.7	2.0	1.5	1.6	1.7	2.0	1.9		2.5	1.5	1.0	3.0	1.9
8	2.0			1.0	.7	2.0		1.3	2.0		1.5	2.0			2.5	3.0	3.0	
7					3.0											1.0	2.0	

An analysis of variance of the interval between the appearance of first flowers on successive fruiting branches is shown in table 8.

TABLE 8.—*Analysis of variance of the interval between the appearance of first flowers on successive fruiting branches in 6 varieties of cotton at Greenville, Tex., 1931–33*

Variance	Degrees of freedom	Sum of squares	Mean square	F values		
				Found	Required	
					P=0.01	P=0.05
Total	354	129.3859	0.3655			
Varieties	5	3.8053	.7612	2.56	3.08	2.25
Years	2	20.7937	10.3968	34.91	4.68	3.03
Interaction: varieties × years	10	4.4235	.4423	1.49	2.57	1.97
Error	337	100.3829	.2978			

The F value for varieties lies between the required values for significance at the 1- and 5-percent levels, and the F value for years is of very high significance, while interaction: varieties × years exerts little influence on the rate of appearance of first flowers on successive fruiting branches.

In 1931 the differences between means of varieties were not significant; in 1932 the mean interval was significantly less in Half and Half than in Delfos; and in 1933 it was less in Delfos than in Lone Star, and less in Delfos, Half and Half, and Rowden than in Acala.

When totals for the 3-year period are considered, there were no highly significant differences between varieties in regard to the appearance of first flowers on successive fruiting branches, though the differences between Acala and Delfos and Half and Half approached the 1-percent level and Rowden differed from Acala at a value somewhat above the odds of 19:1, as is shown in table 9.

TABLE 9.—*Mean number of days between appearance of first flowers on successive fruiting branches, mean differences between varieties, and t values of the mean differences, in 6 varieties of cotton at Greenville, Tex., 1931–33*

Variety	Mean	Acala (mean, 2.83)	Lone Star (mean, 2.74)	Kekchi (mean, 2.63)	Rowden (mean, 2.58)	Delfos (mean, 2.55)	Half and Half (mean, 2.55)
Acala	2.83	*	0.09	0.20	0.25	0.28	0.28
Lone Star	2.74	0.82	*	.11	.16	.19	.19
Kekchi	2.63	1.83	1.00	*	.05	.08	.08
Rowden	2.58	2.28	1.46	.46	*	.03	.03
Delfos	2.55	2.56	1.74	.73	.27	*	.00
Half and Half	2.55	2.56	1.74	.73	.27	.00	*

0.1095 = *S. E. M. D.* between means of varieties.
1.968 = t, required, odds 19:1.
2.592 = t, required, odds 99:1.

The mean interval in days between the appearance of successive fruiting branches was significantly less in Acala, Lone Star, and Half and Half in 1932 than in 1933, and less in Rowden, Delfos, and Kekchi in 1931 and 1932 than in 1933.

Combining all varieties, the mean intervals in days between the appearance of successive fruiting branches were significantly less in 1931 and 1932 than in 1933, indicating again the influence that season may exert on varietal behavior. The interval between 1931 and 1932, however, was barely significant. The degree of significance of the mean differences are shown in table 10.

TABLE 10.—*Mean number of days between appearance of first flowers on successive fruiting branches, actual mean differences between years, and t values of mean differences, in 6 varieties of cotton considered as a single group at Greenville, Tex., 1931–33*

Year	Mean	1933 (mean, 2.97)	1931 (mean, 2.56)	1932 (mean, 2.40)
1933	2.97	*	0.41	0.57
1931	2.56	5.72	*	.16
1932	2.40	7.95	2.23	*

0.0717 = *S. E.* $_{M.D.}$ between means of years.
1.966 = *t*, required, odds 19 : 1.
2.588 = *t*, required, odds 99 : 1.

RATE OF APPEARANCE OF SUCCESSIVE FLOWERS ON FRUITING BRANCHES

A third quantitative character exerting an influence on earliness and productiveness in cotton is the time interval between the formation of successive bolls on fruiting branches. This interval was recorded as the number of days between successive flowers on fruiting branches, and the mean ranged from 6.34 for Half and Half to 7.57 for Rowden. All varieties followed the same general trend for seasons. Considering the mean interval for 1931, all varieties were lower in 1932 and higher in 1933. There were a number of reversals between varieties for different seasons, but with a definite tendency for shorter intervals in both Half and Half and Delfos, with Rowden showing the longest. The highest mean interval was found in Acala for 1933, which was 8.43 days and rather high for this variety.

The number of cases by variety for each year, the mean interval by year, and the 3-year mean are shown in table 11.

In most of the varieties, shorter intervals were recorded for branches rising from the eleventh to the fifteenth nodes, showing a tendency for them to shorten at the point of maximum fruiting-branch development. The interval was usually longer on the first or second fruiting branches than for those just above them, with a tendency to lengthen as the extremities of the plant were approached. This difference in growth rate was less pronounced in Acala and Rowden than in the other four varieties. Apparently growth of the plants was more rapid when conditions were most favorable for setting the greatest number of bolls (table 12).

TABLE 11.—*Cases and mean interval between successive flowers on fruiting branches in 6 varieties of cotton, at Greenville, Tex., 1931–33*

[These data also indicate the rate of fruiting of the different varieties]

Variety	Cases				Mean interval			
	1931	1932	1933	Total	1931	1932	1933	1931–33
	Number	*Number*	*Number*	*Number*	*Days*	*Days*	*Days*	*Days*
Acala	133	198	200	531	6.66	6.41	8.43	7.18
Lone Star	109	238	176	523	6.69	6.35	7.93	6.99
Rowden	116	235	205	556	7.46	7.01	8.23	7.57
Delfos	191	260	225	676	6.21	5.71	7.13	6.35
Half and Half	113	313	198	624	5.92	5.38	7.71	6.34
Kekchi	115	259	276	650	7.56	6.33	7.72	7.20
Total				3,560				
Mean of all varieties								6.94

TABLE 12.—*Mean interval between successive flowers on fruiting branches for 6 varieties of cotton at Greenville, Tex., 1931–33*

Fruiting branch No.	Mean interval																	
	Acala			Lone Star			Rowden			Delfos			Half and Half			Kekchi		
	1931	1932	1933	1931	1932	1933	1931	1932	1933	1931	1932	1933	1931	1932	1933	1931	1932	1933
	Days	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*
27													7.0					
26													7.0					
25													6.0					
24													6.5					
23							7.0						5.9					
22	7.0						6.0						5.0	5.3				
21	8.2		10.0	9.0	5.5				9.0	6.0			6.5	5.1				
20	7.3		7.0	8.0	5.0	8.0	5.5	6.0	8.3	6.9	5.0		5.0	5.5	8.0	8.0		10.0
19	7.1	6.4	9.7	5.0	5.5		5.3	6.0	7.0	5.3	5.7		4.9	5.9	6.6		6.0	9.1
18	7.1	6.2	10.8	6.0	6.3	8.0	5.7	6.2	8.5	6.1	5.8	7.0	6.0	5.1	7.7	6.7	5.7	9.3
17	5.2	6.0	9.9	6.0	5.9	8.6	6.2	6.5	9.0	6.2	6.2	8.0	5.0	5.4	7.5	6.3	5.8	9.7
16	6.0	6.3	9.1	5.7	6.0	9.0	6.0	6.4	8.5	5.6	5.9	8.4	4.7	5.4	7.7	5.9	6.2	8.5
15	5.8	6.2	10.4	5.5	5.6	8.0	6.6	6.5	9.4	6.1	5.6	7.8	4.5	5.4	8.1	5.9	5.6	9.0
14	6.3	6.3	8.9	6.0	5.9	8.4	6.9	7.1	8.7	6.2	5.9	6.9	5.6	5.1	8.1	5.6	5.7	8.5
13	6.3	6.3	8.2	5.4	5.5	8.4	7.6	6.8	8.9	5.7	5.0	7.2	5.4	4.9	7.7	6.9	5.7	7.8
12	6.2	6.1	8.9	5.9	6.1	7.6	6.6	6.8	9.2	6.0	5.7	6.9	6.8	5.4	8.8	6.3	5.9	7.1
11	8.1	6.7	9.1	6.7	6.3	6.7	7.7	7.5	9.6	6.5	5.6	7.7	6.2	6.2	7.5	6.6	6.7	7.4
10	6.4	7.4	8.1	7.0	6.6	8.4	7.7	7.7	8.5	6.0	5.8	7.0	7.1	6.0	7.9	7.6	6.3	9.1
9	6.8	7.2	8.5	7.0	7.0	7.8	8.7	8.5	8.2	6.2	5.9	7.7	7.6	6.4	8.2	8.8	6.8	7.9
8	7.7	6.5		6.2	7.2	7.3	10.0	7.4		7.5	5.9	6.0		7.0	6.0	8.5	7.3	9.8
7	7.0			8.7	6.7			8.0			7.0			6.3	8.0	6.9	7.5	12.0
6								8.0										

An analysis of variance, presented in table 13, shows that the observed values of F are highly significant for varieties and years, and barely significant for interaction: varieties × years.

TABLE 13.—*Analysis of variance for the appearance of successive flowers on fruiting branches in 6 varieties of cotton at Greenville, Tex., 1931–33*

Variance	Degrees of freedom	Sum of squares	Mean square	F values		
				Found	Required	
					P=0.01	P=0.05
Total	355	493.4479	1.3900			
Varieties	5	73.2240	14.6448	21.98	3.08	2.25
Years	2	172.1754	86.0877	129.20	4.68	3.03
Interaction: varieties × years	10	22.8440	2.2844	3.43	2.57	1.97
Error	338	225.2045	.6663			

In considering each year as a unit, in 1931 the intervals between the appearance of successive flowers on fruiting branches in Delfos and Half and Half were significantly shorter than in Kekchi and Rowden; in 1932 the intervals in Delfos and Half and Half were shorter than in Kekchi, Acala, and Lone Star, and the intervals in all these were shorter than in Rowden; while in 1933 the intervals were shorter in Delfos, Half and Half, and Kekchi than in Acala, and shorter in Delfos than in Rowden and Lone Star.

When means for the 3 years are considered, the intervals in Delfos and Half and Half were shorter than in Acala, Kekchi, and Lone Star, and shorter in Delfos, Half and Half, and Lone Star than in Rowden, the degree of significance being shown in table 14.

TABLE 14.—*Mean number of days between appearance of successive flowers on fruiting branches, actual mean differences between varieties, and t values of mean differences in 6 varieties of cotton at Greenville, Tex., 1931–33*

Variety	Mean	Rowden (mean, 7.57)	Kekchi (mean, 7.20)	Acala (mean, 7.18)	Lone Star (mean, 6.99)	Delfos (mean, 6.35)	Half and Half (mean, 6.34)
Rowden	7.57	•	0.37	0.39	0.58	1.22	1.23
Kekchi	7.20	1.85	•	.02	.21	.85	.86
Acala	7.18	1.95	.10	•	.19	.83	.84
Lone Star	6.99	2.90	1.05	.95	•	.64	.65
Delfos	6.35	6.10	4.25	4.15	3.20	•	.01
Half and Half	6.34	6.15	4.30	4.20	3.25	.05	•

0.2011 = *S. E. M. D.* between means of varieties.
1.968 = t, required, odds 19 : 1.
2.592 = t, required, odds 99 : 1.

Acala, Lone Star, Rowden, Delfos, and Half and Half gave significantly shorter intervals between the appearance of successive flowers on fruiting branches in 1931 and 1932 than in 1933. In addition, the intervals were shorter in Half and Half in 1932 than in 1933, and shorter in Kekchi in 1931 than in both of the other years.

Combining all varieties, the intervals in 1931 and 1932 were significantly shorter than in 1933, and shorter in 1932 than in 1931. Differences between means of years, together with the significance of these differences, are shown in table 15.

TABLE 15.—*Mean number of days between appearance of successive flowers on fruiting branches, actual mean differences between years, and t values of mean differences in 6 varieties of cotton considered as a single group at Greenville, Tex., 1931–33*

Year	Mean	1933 (mean, 7.86)	1931 (mean, 6.74)	1932 (mean, 6.20)
1933	7.86	*	1.12	1.66
1931	6.74	9.11	*	.54
1932	6.20	13.50	4.39	*

0.1230 = $S.E._{M.D.}$ between means of years.
1.966 = t, required, odds 19:1.
2.588 = t, required, odds 99:1.

LOCATION OF BOLLS

Considering the location and number of fruiting positions on which bolls are set, it appears that the first few floral buds on the plant are confronted with more hazards than those that immediately follow them. Aphis, cotton flea hopper, and other insects are responsible for the loss of some of the first squares that are produced, while others are destroyed by wind, rain, and hail.

While many bolls were borne on the lower fruiting branches, the first and second did not, as a rule, set as many bolls as those immediately above them. This is true for practically all six varieties, although Delfos set more bolls on the second fruiting branch than did any of the other varieties. All six of the varieties failed to set as many bolls on the first two fruiting branches as on the next two that follow (see figs. 1 to 6). Of course, quite a number of the first fruiting branches suffer from terminal abortion at the second node, which further reduces the chances of maturing bolls on those branches.

A significant and interesting point developed from this study shows that more than one-half of the total crop matured was produced on the first node of the fruiting branches. Figures 1 to 6 represent a composite illustration of total flower and boll production on 20 plants. The behavior of the varieties in this respect was quite uniform, and the variations found did not occur between the most widely divergent types as might be expected. Rowden, a large-bolled, erect plant, was found to be in almost perfect agreement with Delfos, a small-bolled spreading plant with much more open foliage. This relationship therefore appears to be a morphological expression independent of variety or type.

The number and percentage of bolls set on the first, second, and third fruiting branch nodes, together with those set on all other nodes for each year, are shown in table 16.

TABLE 16.—*Bolls set on different fruiting-branch nodes on 20 plants each of 6 varieties of cotton, 1931–33*

Variety	Fruiting-branch node	Bolls set							
		1931	1932	1933	1931–33	1931	1932	1933	1931–33 [1]
		Number	*Number*	*Number*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*
Acala	First	65	51	45	161	63.73	54.26	45.00	54.32
	Second	18	36	30	84	17.65	38.30	30.00	28.64
	Third	8	7	18	33	7.84	7.44	18.00	11.09
	All others	11	0	7	18	10.78	0	7.00	5.92
Lone Star	First	57	50	33	140	65.52	50.51	37.93	51.31
	Second	14	27	30	71	16.09	27.27	34.48	25.94
	Third	8	13	16	37	9.20	13.13	18.39	13.57
	All others	8	9	8	25	9.20	9.09	9.20	9.16
Rowden	First	65	59	46	170	63.11	62.11	51.11	58.77
	Second	22	31	23	76	21.36	32.63	25.56	26.51
	Third	10	4	10	24	9.71	4.21	11.11	8.34
	All others	6	1	11	18	5.82	1.05	12.22	6.36
Delfos	First	89	113	74	276	55.63	70.63	50.68	58.98
	Second	53	38	32	123	33.12	23.75	21.93	26.26
	Third	12	8	19	39	7.50	5.00	13.01	8.50
	All others	6	1	21	28	3.75	.62	14.38	6.25
Half and Half	First	75	104	83	262	53.57	52.00	61.94	55.83
	Second	34	56	38	128	24.29	28.00	28.36	26.87
	Third	16	28	12	56	11.43	14.00	8.95	11.45
	All others	15	12	1	28	10.71	6.00	.74	5.81
Kekchi	First	43	66	52	161	63.24	64.08	44.44	57.24
	Second	14	26	37	77	20.59	25.24	31.62	25.81
	Third	6	9	14	29	8.82	8.74	11.97	9.84
	All others	5	2	14	21	7.35	1.94	11.97	7.08

[1] Average of percentages.

The mean percentage of bolls set on first fruiting-branch nodes for all six varieties ranged from 51.31 for Lone Star to 58.98 for Delfos. The number of bolls set on the second node is approximately one-half that on the first node. The mean percentages ranged from 25.81 for Kekchi to 28.64 for Acala. On the third fruiting-branch node there was greater variation where the number of bolls matured ranged from about one-half to about one-third of those on the second node. The percentage of bolls matured on all other nodes ranged from 5.81 for Half and Half, to 9.16 for Lone Star. From the table it will be noted that bolls borne on the second node have about one-half the chance to mature as those on the first node. Bolls borne on the third node have about one-half to one-third the chance as those on the second node, and so on. There was a progressive decrease in the number of bolls borne on succeeding fruiting-branch nodes. This is another reason why it is possible for closely spaced plants to make larger crops of cotton under conditions where moisture is deficient as well as in more humid regions under weevil infestations. With closely spaced plants it is not possible to have long fruiting branches. The growth of the plants is usually erect with fruiting branches of only a few nodes.

The percentage of hybrid or selfed bolls that may be set during a certain period may be high or low, depending upon the stage of fruiting of the plant when such work is performed. If most of the first fruiting-branch nodes have flowered before the work of selfing or hybridizing is begun, the chances of obtaining a set of bolls are reduced about 50 percent under Greenville conditions. Ordinarily, chances of a crop are greatest on the lower fruiting branches, i. e., the first 10 to 12 branches. Above the twelfth fruiting branch the possibility of obtaining a crop of bolls becomes increasingly smaller. On the first 10 or 11 fruiting branches most of the bolls were produced on the first three or four fruiting-branch nodes, while on the twelfth fruiting branch or above, most of the bolls were borne on the first or second fruiting-branch node.

When a plant sets but one or two bolls early in the season, it does not reach as mature a stage as do those that set more bolls and is therefore able to make a correspondingly greater recovery when favorable conditions occur. Frequently such plants may be observed with a larger number of late bolls than those that have set a heavier crop earlier in the season and undergone a longer period of water stress. The tendencies of the cotton plant to respond in this manner allow fair crops to be set following an abatement of insect injury or other unfavorable conditions for the setting of bolls. This behavior may be frequently observed in experimental plots where low yields at first picking will be followed by high yields in the second picking.

A study of climatic records during July, the period of maximum flower production for the 3 years, shows that on the third day following an abrupt drop in the mean temperature, particularly if it is accompanied by rains and cloudy weather, there also is marked reduction in the number of flowers produced and bolls set.

In cotton-breeding work, this behavior is important and indicates the most opportune time for selfing and emasculating flowers with the greatest odds in favor of obtaining a good set of bolls.

PERCENTAGE OF BOLLS SET

The percentage of squares or flowers that may survive and grow into mature cotton bolls is of interest, and relates more directly to environment than to the cotton plant itself. Where conditions for growth are ideal and insects and disease avoided, it is possible for a cotton plant to set a perfect crop of bolls. These conditions are rarely encountered, although they are frequently approached. In the blacklands of Texas the actual number of bolls per plant that are set and matured is rather small, notwithstanding the fact that it is one of the great cotton-producing areas of the world.

In table 17 is shown the total number of flowers, the number of bolls shed, and number of bolls matured on 20 plants of 6 varieties each during the 3-year period 1931–33. No continuous record was made of small-square shedding, but in all probability there were as many floral buds (squares) shed as there were flowers produced. In most seasons the number of floral buds or squares shed may even exceed the number of flowers. Considering the total number of flowers produced by each variety and the number of bolls shed and matured, it was observed that the varieties which produced the greatest number of flowers also matured the greatest number of bolls.

Although there was a wide difference in the number of flowers produced by the same variety in different seasons, there was not a very wide fluctuation in the percentage of bolls set. About 25 percent less boll shedding occurred in Delfos and Half and Half, which are small-bolled varieties, than in the larger bolled varieties. In variety tests conducted during the same 3 years, the highest yields were also obtained from the smaller-bolled varieties. This behavior clearly indicates that smaller-bolled varieties are able to set more bolls during a given period than larger-bolled varieties, and also suggests the possibility of breeding for production with less emphasis on boll size than has been customary in the western Cotton Belt. On the other hand, there have been definite objections to very small bolls on the part of the western cotton growers. As a rule, small-bolled varieties have not been stormproof, and in dry seasons may be difficult to pick.

TABLE 17.—*Flowers, shed bolls, and bolls matured on 20 plants each of 6 varieties of cotton for the 3-year period 1931–33 at Greenville, Tex.*

Variety and year	Flowers	Bolls shed	Bolls matured	
	Number	*Number*	*Number*	*Percent*
Acala:				
1931	373	271	102	27.3
1932	324	230	94	29.0
1933	368	268	100	27.2
Total	1,065	769	296	27.8
Lone Star:				
1931	306	219	87	28.4
1932	372	273	99	26.6
1933	295	208	87	29.5
Total	973	700	273	28.1
Rowden:				
1931	334	232	103	30.8
1932	368	273	95	25.8
1933	380	290	90	23.7
Total	1,082	795	288	26.6
Delfos:				
1931	397	237	160	40.3
1932	423	263	160	37.8
1933	370	224	146	39.5
Total	1,190	724	466	39.1
Half and Half:				
1931	342	202	140	40.9
1932	440	240	200	45.5
1933	347	213	134	38.6
Total	1,129	655	474	42.0
Kekchi:				
1931	265	197	68	25.7
1932	314	211	103	32.8
1933	440	323	117	26.6
Total	1,019	731	288	28.3

In order to compare the ability of the different varieties to set and mature early bolls, the flowering period was divided into four weekly intervals, beginning with the appearance of the first flower for each variety. The percentage of bolls set for each week was calculated from the number of flowers produced during that particular time.

The percentage of bolls set from flowers during the first 4 weeks for the six varieties for 3 years and the percentage of the total crop set are shown in table 18.

While the high mortality of the first few floral buds on the lower fruiting positions has been already discussed, table 18 shows that as a rule the first flowers produce the highest percentage of mature bolls, with the percentage of bolls set showing a weekly decline during the period of maximum flower production. There were several cases in which the percentage of bolls set was less for the first week than for the second. The means for the 3-year period all showed a steady weekly decline except in Acala. Delfos conformed very closely to this order, the only variations being in 1931 and 1933. In 1931 the percentage for the second week was slightly higher than for the first; however, during both weeks the percentages were unusually high. In 1933 the percentage of bolls set was a trifle higher the third week than it was the second week. In all other cases the percentage of bolls set has declined each week, with the greatest drop occurring in the fourth week. In 1932, where the decline in Delfos was most gradual, the variety set its entire crop within 4 weeks.

TABLE 18.—*Bolls set at weekly intervals for 4 weeks from all flowers produced on 20 plants of 6 varieties of cotton for the 3-year period 1931–33, and total crop set during the same period, at Greenville, Tex.*

Variety and year	Bolls set from flowers produced in the—				Total crop set
	First week	Second week	Third week	Fourth week	
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Acala:					
1931	71.43	70.00	17.14	8.60	75.49
1932	15.79	36.76	27.97	20.16	91.49
1933	17.65	21.24	31.03	15.09	62.00
Mean	36.84	42.78	26.18	15.17	76.01
Lone Star:					
1931	79.31	38.18	16.36	25.00	82.76
1932	18.75	34.67	27.83	11.38	73.74
1933	21.74	35.71	18.28	20.00	77.01
Mean	40.48	36.02	21.63	17.80	77.66
Rowden:					
1931	63.16	69.05	22.64	25.53	74.76
1932	40.74	36.36	16.79	5.56	95.79
1933	31.25	21.05	23.48	8.18	63.33
Mean	43.82	37.28	20.40	12.12	78.13
Delfos:					
1931	86.11	88.89	48.91	13.43	98.75
1932	83.33	60.62	44.44	13.56	100.00
1933	74.19	32.00	33.04	17.82	76.03
Mean	81.44	60.80	41.74	14.56	92.06
Half and Half:					
1931	80.00	86.96	50.00	43.04	80.71
1932	66.67	84.44	54.00	37.14	77.00
1933	70.00	41.27	50.00	18.10	82.84
Mean	72.73	67.53	51.60	32.41	79.75
Kekchi:					
1931	70.37	44.68	10.00	9.09	75.00
1932	33.33	52.83	25.93	18.40	86.41
1933	32.26	30.36	30.33	9.30	73.45
Mean	43.84	40.78	24.48	13.54	77.43

The behavior of Half and Half was similar to that of Delfos in that a higher percentage of bolls was set during the first and second weeks than in the larger-bolled varieties. The mean percentage of bolls set during the first week for Half and Half was about 9 less than for Delfos; the percentage for the fourth week was nearly 18 greater for Half and Half. These two varieties were outstanding in the percentage of flowers that developed into mature bolls during the first 4 weeks of flowering. Early maturing bolls can come only from flowers produced early in the season.

The other four varieties, Acala, Lone Star, Rowden and Kekchi, did not set as high percentages of bolls as Delfos and Half and Half, except during the fourth week when Acala and Lone Star slightly exceeded Delfos. Of these varieties, Acala set the lowest percentage during the first week, but the highest during the second and the third weeks. All other varieties set the highest percentage of bolls during the first week of flowering when flower production was low, but as flowering increased the percentage producing mature bolls decreased.

During the 3-year period the mean percentage of the crop set in the first 4 weeks of flowering ranged from 76.01 for Acala to 92.06 for Delfos. This range clearly shows the earliness of Delfos and its determinate habit of growth as compared with the slower fruiting of Acala and its more indeterminate growth habits. The other varieties were intermediate in their behavior between these extremes.

The more determinate varieties would be expected to set a higher percentage of bolls early in the season than those less determinate in habit. Other factors being equal, a variety that would continue to set bolls during the latter part of the season would have some advantage over one that did not, although late bolls usually encounter insect hazards in addition to unfavorable weather conditions.

BOLL-SHED PERIOD

The mean boll-shed period for all six varieties was remarkably uniform, considering the diversity of the plant types represented. There appears to be a negative correlation between boll-shed period and size of boll. Although the maximum mean difference in boll-shed period was only 0.72 of a day between Acala and Kekchi, there was a definite tendency for the heavier bolls to have a shorter shed period than the lighter bolls.

It is recognized that there may be other causes for these differences that do not relate to boll size and that may be independent of other varietal characters. One such cause is the manner in which the abscission layer is formed. This layer of cells forms at the base of the pedicel and serves as a partition, separating the boll from the fruiting branch. There is also a rather common deformity of boll pedicels known as decurrent pedicels, in which the pedicel attachment extends for some distance along the internode, often ranging an inch or more in length. When this condition is present, the blasted boll or square may hang on the plant indefinitely. In this study, recognition of such a condition was taken into consideration, and when abscission became complete at the base of the pedicel, the boll was recorded as shed, even through complete separation had not taken place.

From a total of 4,374 shed bolls, the mean boll-shed period for all varieties was 5.16 days with a minimum mean period of 4.75 for 769 Acala bolls and a maximum mean period of 5.47 for 731 Kekchi bolls. The boll-shed data for the 3-year period is summarized in table 19, which shows the total number of bolls shed by variety for each year, together with the mean period by year and combined for the experiment. The location on the plant from which the bolls were shed is shown graphically in figures 1 to 6 and also indicated in figure 7, the last figure being the basis for the discussion of the topic Zonate Shedding of Bolls and Squares (p. 24).

TABLE 19.—*Shed bolls and mean boll-shed period for 20 plants of 6 varieties at Greenville, Tex., 1931–33*

Variety	Bolls shed				Mean boll-shed period			
	1931	1932	1933	Total	1931	1932	1933	1931–33
	Number	*Number*	*Number*	*Number*	*Days*	*Days*	*Days*	*Days*
Acala	271	230	268	769	5.06	4.67	4.55	4.75
Lone Star	219	273	208	700	5.33	5.07	5.20	5.20
Rowden	232	273	290	795	5.14	4.92	4.81	4.95
Delfos	237	263	224	724	5.42	5.29	5.30	5.34
Half and Half	202	240	213	655	5.49	5.04	5.28	5.27
Kekchi	197	211	323	731	5.67	5.29	5.47	5.47
Total				4,374				
Mean boll-shed period								5.16

The shed period for Garo Hill cotton has been reported to be 3.85 days, as compared with 6.10 days for Lone Star, an American upland type. The Garo Hill bolls are much smaller than Lone Star bolls. The mean boll-shed period for Pima Egyptian cotton was found to be 10.8 days in one experiment and 10.3 days in another. Pima and Garo Hill are of a different species from the upland varieties reported in this bulletin, and both have smaller bolls, one with a very much shorter shed period and the other with a much longer period than the upland cottons. All of the work referred to above was done in California and Arizona under irrigation.

An analysis of variance of the boll-shed period is shown in table 20.

The observed value of F indicates that mean differences between varieties and between years are significant, but interaction: varieties × years is too small to be significant.

TABLE 20.—*Analysis of variance for boll-shed period in 6 varieties of cotton at Greenville, Tex., 1931–33*

Variance	Degrees of freedom	Sum of squares	Mean square	F values		
				Found	Required	
					P=0.01	P=0.05
Total	353	192.7452	0.5460			
Varieties	5	20.3917	4.0783	8.34	3.08	2.25
Years	2	6.0510	3.0255	6.19	4.66	3.03
Interaction: varieties × years	10	2.0201	.2020	2.42	3.91	2.54
Error	336	164.2824	.4889			

In 1931 the differences between varieties were not significant, but in 1932 the shed period for Acala was significantly less than for Delfos and Kekchi, and in 1933 it was significantly shorter in Acala and Rowden than in Kekchi, and in Acala it was less than in Delfos, Half and Half, and Lone Star.

Over the 3-year period, Acala and Rowden gave significantly shorter boll-shed periods than Delfos and Kekchi, and Acala had shorter periods than Half and Half and Lone Star. The significance of mean differences between varieties is shown in table 21.

TABLE 21.—*Mean boll-shed period (days), actual mean differences between varieties, and t values of mean differences in 6 varieties of cotton at Greenville, Tex., 1931–33*

Variety	Mean	Kekchi (mean, 5.47)	Delfos (mean, 5.34)	Half and Half (mean, 5.27)	Lone Star (mean, 5.20)	Rowden (mean, 4.95)	Acala (mean, 4.75)
Kekchi	5.47	*	0.13	0.20	0.27	0.52	0.72
Delfos	5.34	1.01	*	.07	.14	.39	.59
Half and Half	5.27	1.56	.54	*	.07	.32	.52
Lone Star	5.20	2.10	1.09	.54	*	.25	.45
Rowden	4.95	4.04	3.03	2.49	1.94	*	.20
Acala	4.75	5.60	4.59	4.04	3.50	1.56	*

0.1286=*S. E. M. D.* between means of varieties.
1.968=*t*, required, odds 19:1.
2.592=*t*, required, odds 99:1.

The interval from flower to boll shed for each variety considered separately did not vary significantly from year to year, but when all varieties were combined the shed period was significantly lower in 1931 than in 1932 and 1933. The differences between mean of varieties, together with the significance of each difference, are shown in table 22.

TABLE 22.—*Mean boll-shed period (days), actual mean differences between years, and t values of mean differences in 6 varieties of cotton considered as a single group at Greenville, Tex., 1931–33*

Year	Mean	1931 (mean, 5.35)	1933 (mean, 5.10)	1932 (mean, 5.05)
1931	5.35	*	0.25	0.30
1933	5.10	2.65	*	.05
1932	5.05	3.18	.53	*

0.0942=*S. E. M. D.* between means of years.
1.966=*t*, required, odds, 19:1.
2.588=*t*, required, odds, 99:1.

ZONATE SHEDDING OF BOLLS AND SQUARES

In addition to the physiological or genetic relationships that have been reported by investigators on boll shedding in cotton, a morphological relation exists which definitely influences the number of bolls that may reasonably be expected to set at different locations on the plant.

Cotton plants form new floral buds or shed squares and small bolls in adjusting themselves to their water supply. When moisture was abundant early in the season, the plant set a crop of bolls and, in addition, produced a large number of squares and flowers, but their chances of reaching maturity were remote. As the plants' need of water became more acute, the young bolls were shed. There was a strong tendency for the squares to develop into flowers and then shed as young bolls, rather than for the large squares to shed. Within a week or two after the first small-boll shedding began, the plants usually entered a period of stress in which they wilted during the day and small-square shedding began. When the shortage of moisture continued, buds on the ends of the fruiting branches aborted or failed to develop, and further growth of the plants was arrested. The plants then entered a mature or senile stage, evidenced by a lighter-colored foliage and shedding of some of the primary leaves. After the lower bolls had opened, the plants usually put out new terminal and axillary growth from which the late bolls or "top crop" developed. Top bolls seldom reached maturity before frost at Greenville, and none of the late-formed bolls from plants in this experiment opened normally.

The actual number of bolls that were set on the plants, together with the number that were shed, are shown in figures 1 to 6, by main-stalk and fruiting-branch node for each variety for the 3-year period of the experiment.

From these figures it will be seen that the fruiting period of cotton in the blacklands of Texas is relatively short, and a majority of the bolls are set early in the season.

One point in particular is emphasized in the diagrams for 1933 (figs. 1–6, *C*). As the plants were approaching the full development of a normal boll set, and some shedding of small bolls had begun to take place, a good rain fell which renewed plant growth and permitted squares to remain on the plants and produce flowers that otherwise would have been shed. With the moisture supply replenished, these flowers resulted in a scattered set of later bolls farther out on the branches. Similar conditions are frequently encountered during seasons of heavy cotton flea hopper injury when the small squares are destroyed. When there are few or no bolls on the plants, owing to insect damage, later flowers have a better chance of maturing bolls on such plants than on heavily fruited plants, if the insect invasion wanes or diminishes or can be controlled.

In the normal growth of the plants there was a succession of zones in which the plants fruited and defruited themselves in adjusting their crop and growth to the available water supply. The zone in which the early-set bolls were found may be termed the "fruiting zone." This zone is followed by the "small-boll shedding zone," which in turn is followed by the "small-square shedding zone." After the bolls open, or late-season moisture is provided, plant growth is renewed and the top crop is set, either at the plant extremities or from the development of axillary buds. A diagram showing the relation of fruiting zones to zones of shedding is shown in figure 7.

Even in the driest years, renewed late-season growth often took place without additional moisture, after the bolls on the plants had opened. This was especially true on the more fertile plots and with the more indeterminate varieties. Observation of cotton on soils of low fertility and low moisture showed that late-season growth was sometimes delayed even after moisture had been supplied. Renewed late growth of the plants therefore depended upon the state of maturity they had reached under the prolonged stress conditions. Varieties of a more determinate habit of growth set a larger crop of bolls during a hot dry period, but were much slower in recovering.

Other observations in a nearby date-of-planting experiment indicated that the stage of boll development as the plants encountered stress periods also had an important bearing upon their ability to withstand periods of stress. Where a majority of the bolls were less than 2 weeks old, both the loss and stress were found to be more severe than where the bolls were older and required less moisture for development. This behavior has frequently been observed in plantings made on the same soil type, but on different dates. Late plant-

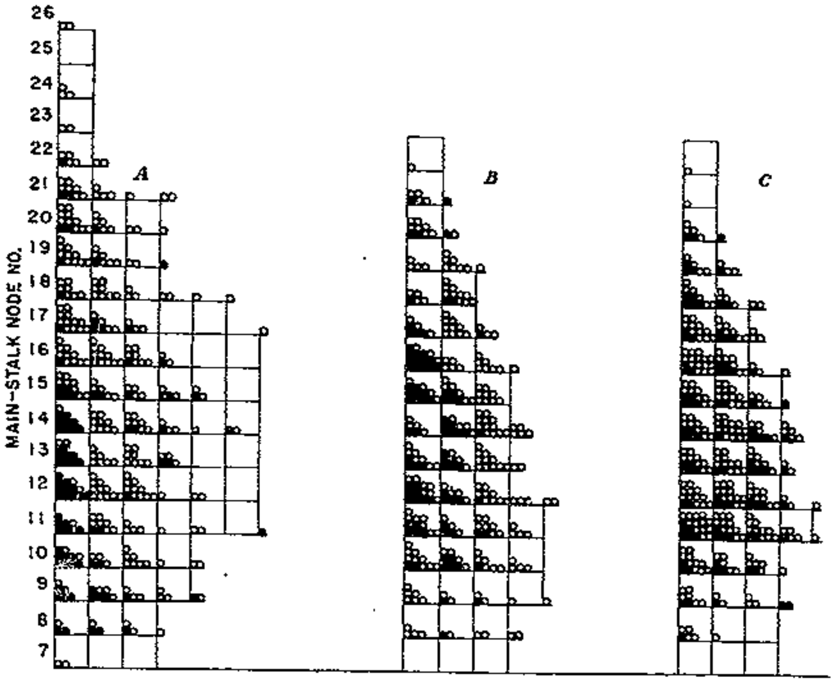


FIGURE 1.—Diagram for Acala cotton plants for 1931 (*A*), 1932 (*B*), and 1933 (*C*), showing each main-stalk and fruiting-branch node represented by a square, and the location on the plant of all matured bolls and shed bolls. Matured bolls are shown as solid black circles and shed bolls as hollow circles. Only 27 to 29 percent of all flowers produced matured bolls.

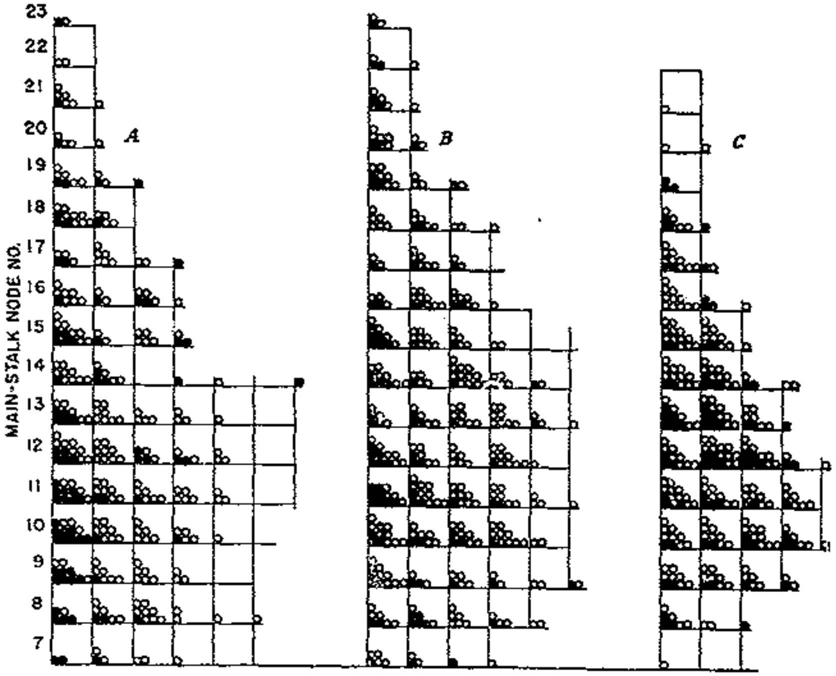


FIGURE 2.—Diagram for Lone Star cotton plants for 1931 (*A*), 1932 (*B*), and 1933 (*C*), showing each main-stalk and fruiting-branch node represented by a square, and the location on the plant of all matured bolls and shed bolls. Matured bolls are shown as solid black circles and shed bolls as hollow circles. Only 26 to 29 percent of all flowers produced matured bolls.

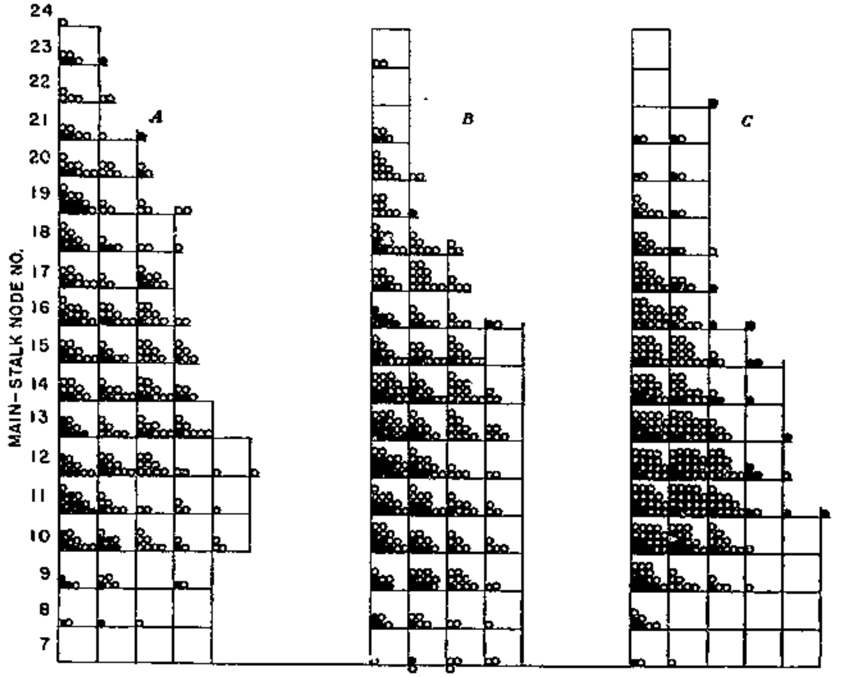


FIGURE 3.—Diagram for Rowden cotton plants for 1931 (*A*), 1932 (*B*), and 1933 (*C*), showing each main-stalk and fruiting-branch node represented by a square, and the location on the plant of all matured bolls and shed bolls. Matured bolls are shown as solid black circles and shed bolls as hollow circles. Only 23 to 30 percent of all flowers produced matured bolls. Rowden, one of the largest bolled varieties, set the smallest percentage of bolls of any of the six varieties.

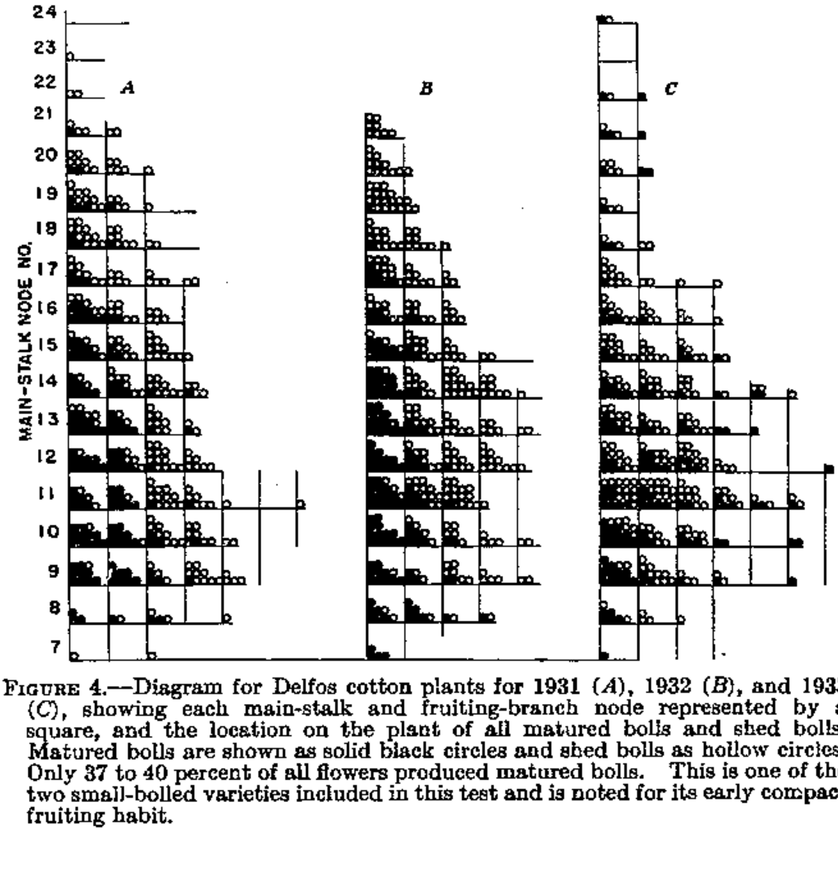


FIGURE 4.—Diagram for Delfos cotton plants for 1931 (*A*), 1932 (*B*), and 1933 (*C*), showing each main-stalk and fruiting-branch node represented by a square, and the location on the plant of all matured bolls and shed bolls. Matured bolls are shown as solid black circles and shed bolls as hollow circles. Only 37 to 40 percent of all flowers produced matured bolls. This is one of the two small-bolled varieties included in this test and is noted for its early compact fruiting habit.

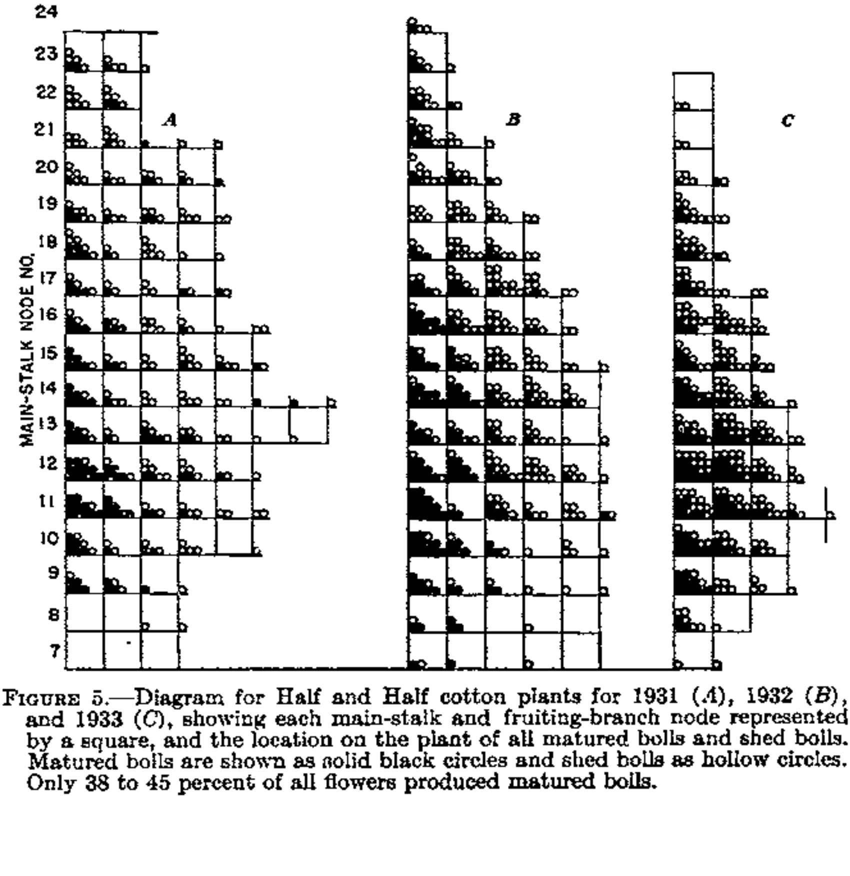


FIGURE 5.—Diagram for Half and Half cotton plants for 1931 (*A*), 1932 (*B*), and 1933 (*C*), showing each main-stalk and fruiting-branch node represented by a square, and the location on the plant of all matured bolls and shed bolls. Matured bolls are shown as solid black circles and shed bolls as hollow circles. Only 38 to 45 percent of all flowers produced matured bolls.

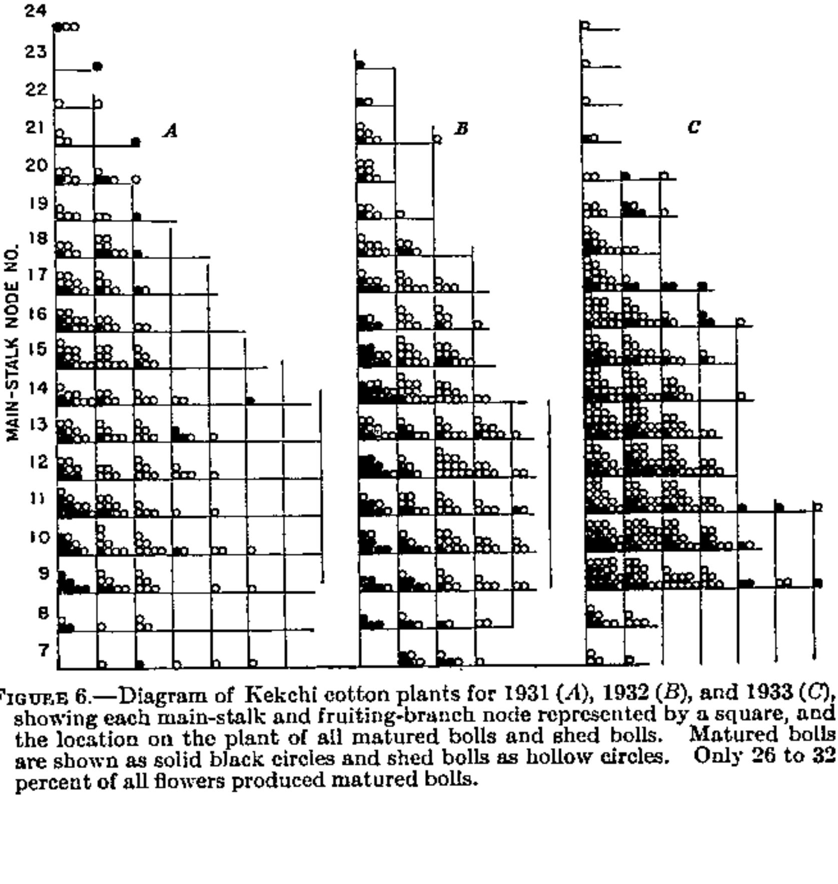


FIGURE 6.—Diagram of Kekchi cotton plants for 1931 (*A*), 1932 (*B*), and 1933 (*C*), showing each main-stalk and fruiting-branch node represented by a square, and the location on the plant of all matured bolls and shed bolls. Matured bolls are shown as solid black circles and shed bolls as hollow circles. Only 26 to 32 percent of all flowers produced matured bolls.

ings, as a rule, are not so productive as early plantings; they usually enter a stress period later and therefore fail to reach as mature a stage as early plantings; consequently, they recover more promptly than the earlier plantings.

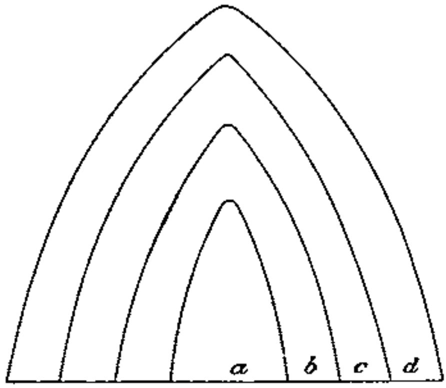


FIGURE 7.—Schematic diagram of a cotton plant showing successive zones of fruiting and physiological defruiting. *a*, Normal fruit zone; *b*, small-boll shedding zone; *c*, small-square shedding zone; *d*, late-season growth.

TERMINAL ABORTION OF FRUITING BRANCH BUDS

Fruiting branches of cotton plants are simply reproductions and elongations of the floral-branch internodes with their complementary parts. A tiny bud deeply embedded in the terminal growth of a cotton plant may within a few weeks transform into a fruiting branch of several nodes, leaves, bolls, flowers, and squares. So long as the terminal bud remains on the branch, this process continues indefinitely. When the terminal bud is lost, normal growth cannot continue and any new growth must take place from a dormant axillary bud. This growth from the axillary bud is usually in the form of a single vegetative node which in turn forms a new fruiting branch, and growth again proceeds normally. In the Blackland Belt of Texas the two major factors that cause terminal-bud abortion are insects and water stress. After the plants have encountered stress conditions so severe as to cause the shedding of terminal buds, new growth is likely to be delayed for several weeks, unless adequate moisture is promptly provided. Even then it may be slower than would be expected, and if the moisture supply is not maintained, such renewed growth may not contribute to an increase in the crop, since nearly a month is required for the square to produce a flower, and an additional period of 6 to 8 weeks is needed for the flower to mature a boll.

In 1933 a record was kept of all terminal-bud abortions on the plants under study. The number of cases of terminal abortion at the first node was greater in Delfos and Half and Half than in the larger boll varieties. These data have been tabulated in a scattergram showing the main-stalk nodes and the fruiting-branch nodes on which the terminals were aborted (fig. 8). A good rain at the time when the greatest amount of shedding might have normally been expected delayed much of the shedding, as may also be seen in figures 1 to 6, which show locations of bolls matured and shed. The distribution of terminal-bud abortion therefore shows a greater range in both directions than might normally be expected. However, a very high percentage of the branches on which the greatest number

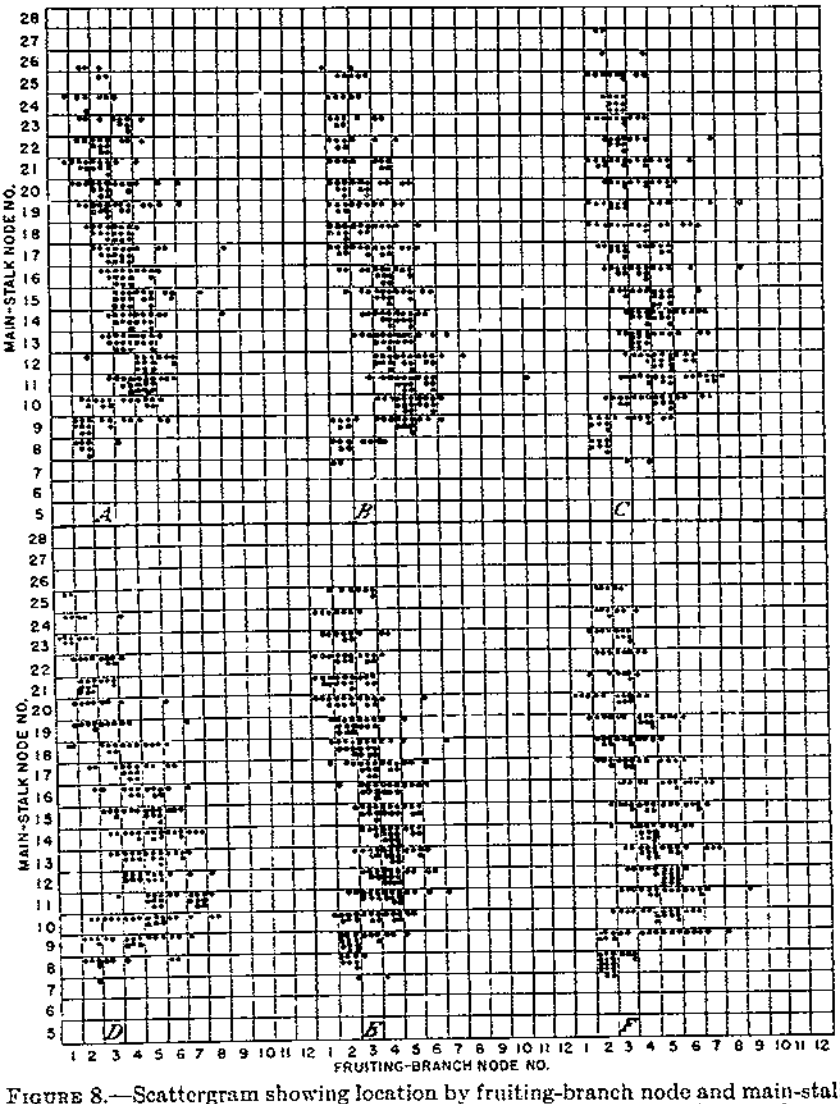


FIGURE 8.—Scattergram showing location by fruiting-branch node and main-stalk node, the number of cases of abortion of terminal buds of the fruiting branch on 20 plants of 6 varieties of cotton in 1933: *A*, Acala; *B*, Lone Star; *C*, Rowden; *D*, Delfos; *E*, Half and Half; and *F*, Kekchi. Abortion of terminal buds at the first node was greater in Delfos and Half and Half than in the larger boll varieties.

of bolls were set shed their terminal buds and failed to make further growth. Acala, Lone Star, and Rowden, all of which are large- or medium-bolled varieties, showed very few cases of terminal abortion at the first node. Kekchi, having a medium-sized boll, behaved differently and showed six cases of terminal abortion at the first fruiting-branch node. Delfos showed 14 such cases and Half and Half 21, the greatest number. There was a general tendency toward an increase in terminal abortion at the first fruiting-branch node in progressing from the larger-bolled to the smaller-bolled varieties. The scattergram patterns show some rather wide differences between these varieties.

In Acala there was a gradual and progressive increase from the second to the fifth fruiting-branch nodes on the lower five fruiting branches. From the thirteenth to the sixteenth main-stalk nodes the greatest terminal abortion took place at the fourth fruiting-branch node, while on fruiting branches above the sixteenth main-stalk node there was a gradual retreat to where the greatest number of cases were found at the fourth fruiting-branch node or earlier. The Rowden variety showed a much more erratic behavior with less tendency for concentration of terminal abortion to take place at any given node. The Lone Star variety, while showing rather widely scattered distributions, had neither the spread of Rowden nor the regularity found in Acala. Delfos showed much less grouping for given nodes than either Acala or Half and Half, both of which show the greatest concentration of abortion for given nodes. Again, considering the widely divergent types represented in this study, all but Rowden taper off rather uniformly at the twenty-sixth main-stalk node. Rowden showed two cases one node higher.

BOLL PERIOD

The boll period, or the number of days required from flower to open boll, showed the most consistent differences between varieties of any characteristic studies. The number of normal bolls matured each year on 20 plants of each variety are shown in table 23, together with the mean yearly boll period and the mean for the 3 years. The mean boll period ranged from 40.80 days for Half and Half to 47.12 for Rowden. In addition to these varietal differences, seasonal influence is also shown. In 1933 the boll period for all varieties was from 2 to 3 days longer than in 1932. Climatic influence may be operative early in the season or any other time, and find expression in either hastening or retarding maturity of the bolls. Late-season bolls, which develop during a period of shorter days and usually with more abundant moisture and moderate temperatures, required a progressively longer period for maturity.

Considering mean boll size in relation to boll period, as shown in table 23, Delfos produced the smallest bolls, followed in order by Half and Half, Kekchi, Acala, Rowden, and Lone Star. Half and Half showed a consistently shorter boll period each year than Delfos, but the bolls averaged about 9 percent larger (table 23). This behavior indicates that there are factors other than size that influence boll period. There is a distinct difference in boll shape of the two varieties. Half and Half bolls are very bluntly pointed, while Delfos bolls are long and sharply pointed. Illustrations of typical bolls of these two varieties are shown in plates 1 and 2.

Acala showed a slightly shorter boll period than Delfos in 1931 and 1933, although the Delfos bolls required less time in 1932. The mean boll period for the 3 years places Acala about midway between Half and Half and Delfos. Acala averaged 68 bolls of seed cotton to the pound compared with 89.4 for Delfos and 80.3 for Half and Half. Notwithstanding the fact that Acala bolls were much larger than the Delfos, the boll period was somewhat shorter. The behavior of the Acala boll period indicates, therefore, the presence of an inherent factor that is not directly associated with boll size or thickness of carpel. The size and shape of Acala bolls are shown in plate 3. Delfos bolls ranked third in boll period with a mean of 42.13 days, but had the smallest bolls of any of the six varieties. Lone Star, which might be considered as the largest bolled variety, produced practically the same size boll as Rowden, but ranked fourth in boll period each year, ranging from an average of 44.12 days in 1932 to 46.89 in 1933, with a mean of 45.49 days for the 3-year period. A group of Lone Star bolls are shown natural size in plate 4.

TABLE 23.—*Bolls matured, mean boll period for all bolls, and mean number of bolls per pound of seed cotton on 20 plants each of 6 varieties of cotton from 1931–33*

Variety	Bolls				Mean boll period				Mean bolls per pound of seed cotton
	1931	1932	1933	Total	1931	1932	1933	1931–33	
	Number	*Number*	*Number*	*Number*	*Days*	*Days*	*Days*	*Days*	*Number*
Acala	102	94	100	296	41.11	40.44	43.16	41.59	68.0
Lone Star	87	99	87	273	45.48	44.12	46.89	45.49	60.4
Rowden	103	95	90	288	47.67	45.13	48.56	47.12	60.6
Delfos	160	160	146	466	42.18	39.63	44.59	42.13	89.4
Half and Half	140	200	134	474	40.84	39.51	42.05	40.80	80.3
Kekchi	68	103	117	288	46.95	44.71	48.10	46.54	72.7
Total				2,085	44.04	42.26	45.56		
Mean of all varieties								43.95	71.9

Kekchi, which ranked fourth in boll size, was fifth as to boll period. For boll size it consistently held fourth place each year with a mean boll size for the 3 years of 72.7 bolls per pound of seed cotton. Here again the boll period is not correlated with boll size. Kekchi bolls are rather long and tapering, with characteristically beaked or blunted points (pl. 5). Kekchi and Delfos are the two varieties included in this study that have long tapering pointed bolls. Both varieties also have a longer boll period than might be expected in relation to their size.

Rowden had the longest boll period with a mean for the 3 years of 47.12 days. It was consistently the slowest in opening with boll periods ranging from 45.13 in 1932 to 48.56 in 1933. It was included in this test because of its large bolls and large fuzzy seed. In 1931 and 1932 its bolls were slightly larger than Lone Star, but in 1933 the Lone Star produced the larger bolls. For the 3-year period the boll size of these two varieties is about equal. Rowden, however, has a longer and somewhat more pointed boll than Lone Star. Lone Star and Rowden bolls are illustrated in plates 4 and 6, respectively.

While there was no definite correlation between boll size and boll-maturation period, there was a rather general tendency for the smaller bolls to have a shorter boll period. Since boll shape and other factors were involved, close correlations could hardly be expected.

An analysis of variance, as calculated for the boll period, is shown in table 24.

TABLE 24.—*Analysis of variance for the boll period in 6 varieties of cotton at Greenville, Tex., 1931–33*

Variance	Degrees of freedom	Sum of squares	Mean square	F values		
				Found	Required	
					P=0.01	P=0.05
Total	342	3,396.9225	9.9325			
Varieties	5	2,182.2633	436.4527	281.47	3.08	2.25
Years	2	653.3481	326.6741	210.68	4.68	3.03
Interaction: varieties × years	10	57.3720	5.7372	3.70	2.57	1.97
Error	325	503.9391	1.5506			

Extremely high significance between means of varieties and of years is indicated by the F values. Interaction: variety × years is highly significant.

In 1931, Lone Star, Delfos, Acala, and Half and Half had significantly shorter boll periods than Rowden and Kekchi; Delfos, Acala, and Half and Half were less than Lone Star; and Half and Half alone was less than Delfos. In 1932, Acala, Delfos, and Half and Half were less than Rowden, Kekchi, and Lone Star. In 1933, Lone Star, Delfos, Acala, and Half and Half were less than Rowden and Kekchi; Delfos, Acala, and Half and Half were less than Lone Star; Acala and Half and Half were less than Delfos; and Half and Half was less than Acala.

When means of all years were considered as one group, the rank of the varieties was exactly the same as in 1931 and differed from 1933 only in that in the latter year Acala and Half and Half had shorter boll periods than Delfos. The significance of differences between means of varieties for the 3-year period as a whole is shown in table 25

TABLE 25.—*Mean boll-maturation period (in days), actual mean differences between varieties, and t values of the mean differences in 6 varieties of cotton at Greenville, Tex., 1931–33*

Variety	Mean	Rowden (mean, 47.12)	Kekchi (mean, 46.54)	Lone Star (mean, 45.49)	Delfos (mean, 42.13)	Acala (mean, 41.59)	Half and Half (mean, 40.80)
Rowden	47.12	•	0.58	1.63	4.99	5.53	6.32
Kekchi	46.54	1.67	•	1.05	4.41	4.95	5.74
Lone Star	45.49	4.70	3.03	•	3.36	3.90	4.69
Delfos	42.13	14.40	12.72	9.69	•	.54	1.33
Acala	41.59	15.95	14.28	11.25	1.56	•	.79
Half and Half	40.80	18.23	16.56	13.53	3.84	2.28	•

0.3466 = *S. E. m. n.* between means of varieties.
1.968 = *t*, required, odds 19 : 1.
2.592 = *t*, required, odds 99 : 1.

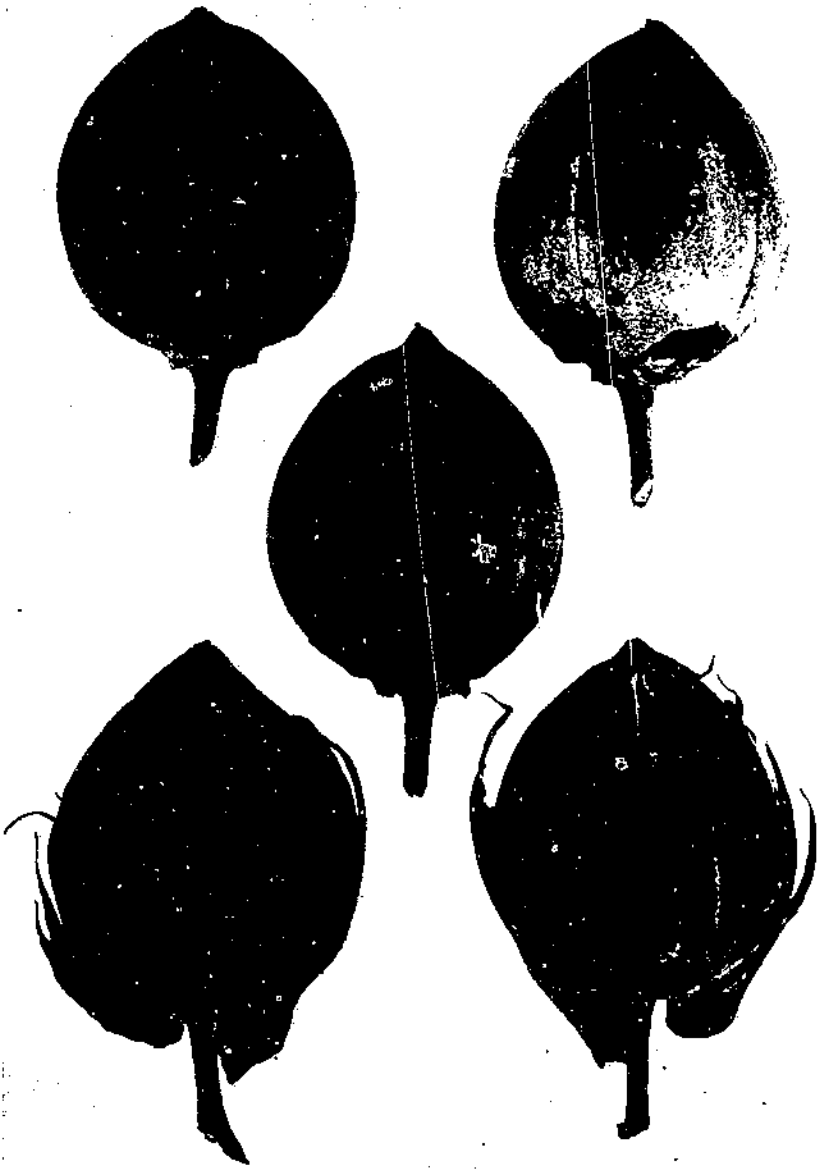
The boll period in Acala, Lone Star, Delfos, and Half and Half was significantly shorter in 1931 and 1932 than in 1933, and in Rowden and Kekchi it was shorter in 1932 than in 1931.

In analyzing means of all varieties as one group, 1931 and 1932 were significantly less than 1933, and 1932 was less than 1931, as is shown in table 26.

Typical Half and Half bolls that have reached their full development and are ready to open. Carpel-thickness measurements were made on these and other similar bolls. (Natural size.)

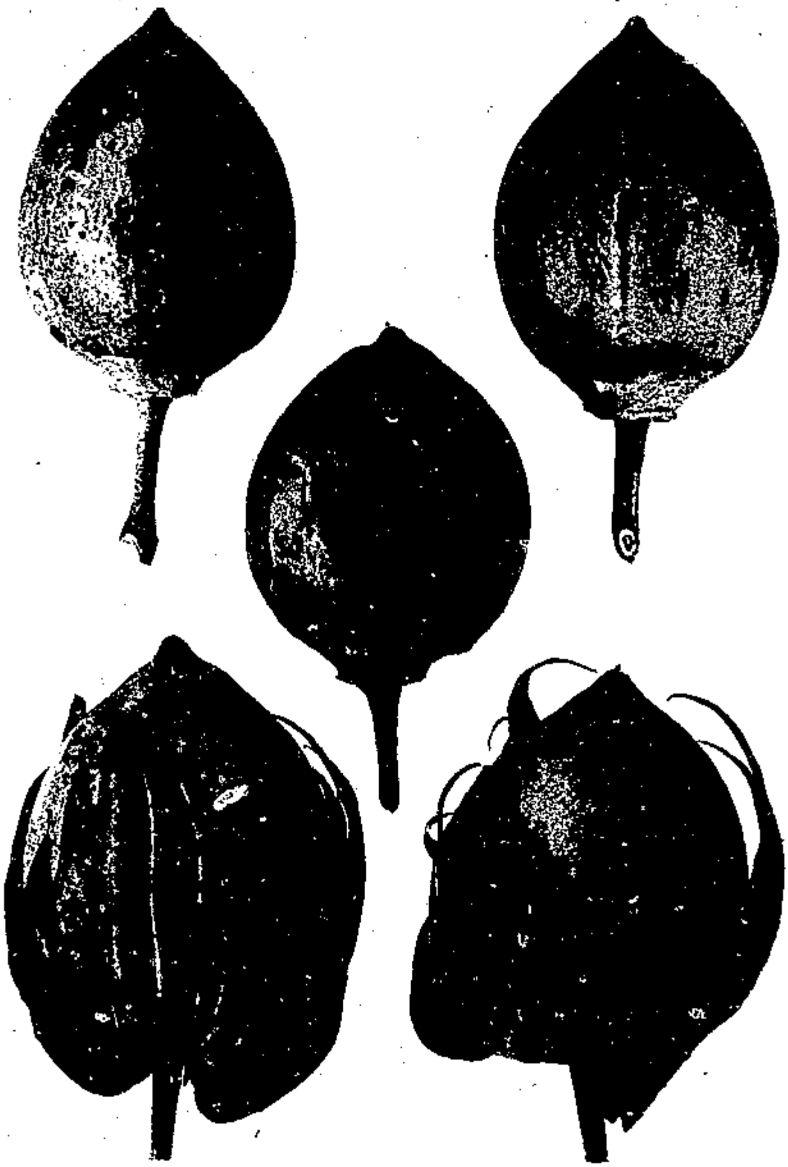
Typical Delfos bolls, as produced at Greenville, Tex. This was the smallest-bolled variety included in the study, although the boll period was somewhat longer than Half and Half and Acala. Compare with plates 1, 3, 4, 5, and 6 for size and shape. (Natural size.)

Mature Acala cotton bolls. Although these bolls were much larger than the Delfos bolls, and their carpel walls considerably thicker, the boll period for Acala is somewhat less than that for Delfos. Compare with plates 1, 2, 4, 5, and 6 for size and shape. (Natural size.)



Typical Lone Star bolls. For the 3-year period these bolls were the equal of Rowden in size, but they stood fourth in rank for boll period, the mean being 45.49 days. Lone Star and Acala both gave a shorter boll period than their size alone would indicate. (Natural size.)

Well-developed Kekchi bolls which ranked third for smallness of size and fifth for boll period. Kekchi showed the thickest carpels of the six varieties. The bolls are rather long and tapering, with irregular, rough, blunt, and somewhat beaked points. (Natural size.)



Typical Rowden bolls. Rowden is generally regarded as possessing the largest boll of the Texas big-bolled group. In this study the average size of Rowden and Lone Star bolls were practically equal. The Rowden carpels were somewhat thicker than the carpels of Lone Star and its boll period was the longest of the six varieties studied, being 47.12 days. (Natural size.)

TABLE 26.—*Mean boll-maturation period (in days), actual mean differences between years, and t values of the mean differences in 6 varieties of cotton considered as a single group at Greenvillle, Tex., 1931–33*

Year	Mean	1933 (mean, 45.56)	1931 (mean, 43.97)	1932 (mean, 42.26)
1933	45.56	*	1.59	3.30
1931	43.97	4.34	*	1.71
1932	42.26	9.00	4.66	*

0.3667 = S. E. M. D. between means of years.
1.968 = t, required, odds 19 : 1.
2.592 = t, required, odds 99 : 1.

BOLL PERIOD IN RELATION TO POSITION ON THE PLANT

Plant growth in the early fruiting stages was vigorous, but as fruiting progressed, vegetative growth became restricted. Since three-fourths of the crop was set within a period of 4 weeks, and fruiting began low on the plant and progressed upward and outward on the fruiting branches, most of the crop was set on the lower central part of the plant during the period of vigorous growth. As the number of bolls increased, water stress increased as each additional boll was set. This behavior was shown by a lengthening of the period between successive flowers on the fruiting branches, between first flowers on successive fruiting branches for the upper nodes, and by the lengthening of the boll period of the later set bolls. High temperatures and dry soil contribute to retarding plant development, and to the writers it appears that the slowing down of growth during midseason is more likely to be attributable to water deficiency than to any other one thing. Late-season bolls grown during shorter days, declining temperatures, and more abundant soil moisture required a longer time for maturity than early-season bolls, and in some cases, at least, would account for a longer boll period, as no doubt was partially the case in 1933, when more bolls were borne farther out on the branches.

The mean period for bolls borne on fruiting branches arising from main stalk nodes is shown by variety for the 3-year period in table 27, and illustrates the progressive changes that take place on a plant within a season and between seasons. From these figures it will be noted that there is a definite tendency for the boll period to lengthen as the nodes on the extremity of the plants are approached. While the growth of nodes on the first or second fruiting branches is rather slow, as a rule, the boll period for these few nodes does not follow the same trend near the base of the plants but does show a tendency to lengthen toward the terminals.

The mean period for bolls borne on the first node of the fruiting branches was shorter than the period on later nodes, for all varieties except Kekchi, where they were about the same. In the Kekchi variety, bolls borne on the first node required an average of one-tenth of a day longer to open than those borne on the second node. The shorter boll period for first-node bolls in the other varieties is all the more significant when it is realized that more than half of the bolls of all varieties were borne on the first nodes. The practical advantage of knowing that a majority of all bolls matured on cotton plants are borne on the first fruiting-branch nodes and that they open in less time than those borne farther out on the plants should be of great value to the grower in establishing proper cultural practices and carrying out insect-control measures.

The mean boll period by variety and year is shown for fruiting-branch nodes in table 28.

TABLE 27.—*Boll period expressed as the mean for each fruiting branch arising from successive main-stalk nodes for 6 varieties of cotton for the 3-year period 1931–33*

Main stalk node No.	Mean boll period for each fruiting branch																	
	Acala			Lone Star			Rowden			Delfos			Half and Half			Kekchi		
	1931	1932	1933	1931	1932	1933	1931	1932	1933	1931	1932	1933	1931	1932	1933	1931	1932	1933
	Days	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*
28	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------
27	------	------	------	------	------	------	------	------	47.0	------	------	------	------	------	------	------	------	------
26	------	------	------	------	------	------	------	------	------	------	------	------	40.0	------	------	------	------	------
25	------	------	------	------	------	------	51.0	------	------	------	------	------	41.0	------	------	------	------	------
24	------	------	------	------	------	------	------	------	------	------	------	47.0	42.3	43.0	------	43.0	------	------
23	------	------	------	46.1	52.0	------	48.7	------	------	------	------	------	44.7	42.0	------	48.0	54.0	------
22	46.0	------	------	------	49.0	------	------	------	53.0	------	------	47.0	40.5	40.3	------	------	51.0	52.0
21	44.5	44.5	------	43.1	47.3	------	48.3	50.5	48.0	42.0	------	48.3	41.0	43.5	------	48.0	46.0	------
20	42.7	44.7	42.0	45.1	45.3	------	50.7	------	47.5	45.5	------	46.3	41.0	41.4	41.0	45.0	48.0	50.0
19	41.7	------	43.3	44.7	47.0	46.0	48.3	47.0	50.0	45.4	45.0	42.0	42.7	46.0	44.3	48.0	51.0	47.5
18	43.0	43.3	43.1	46.7	50.5	46.5	48.3	45.3	47.5	44.5	42.0	47.0	42.7	41.4	43.0	47.3	48.3	49.0
17	44.0	41.8	41.7	43.7	45.7	46.5	48.5	47.5	48.0	45.0	43.1	46.0	41.4	41.6	41.8	47.0	46.3	48.3
16	42.5	40.2	42.6	46.5	46.2	46.0	47.9	46.5	49.8	43.5	40.6	45.0	42.2	39.8	45.0	46.3	45.6	48.7
15	42.8	40.1	44.9	44.7	43.4	47.3	48.4	46.0	48.8	43.9	42.1	45.0	43.1	39.2	42.0	47.0	45.2	49.3
14	42.3	40.4	43.5	45.2	44.7	47.0	47.7	45.3	48.4	45.0	39.7	46.0	41.1	40.1	42.5	46.0	44.6	49.9
13	42.2	40.3	42.8	46.2	44.9	46.6	47.8	44.5	48.7	42.8	39.2	44.9	40.2	39.6	42.9	47.0	44.0	48.4
12	41.8	39.2	43.2	47.5	43.5	47.1	47.3	44.2	48.6	42.3	39.8	45.3	40.6	38.6	41.9	45.0	42.8	49.0
11	39.5	39.9	43.3	45.7	43.4	47.8	47.5	44.6	49.0	41.9	39.0	44.3	39.9	37.9	41.9	46.9	43.6	48.3
10	37.2	40.3	42.7	46.3	41.9	46.3	47.1	44.1	48.8	41.2	39.5	44.1	39.9	38.3	41.8	47.0	43.5	47.7
9	39.4	41.0	42.8	45.5	44.6	48.3	46.8	45.4	47.7	39.9	38.9	43.6	37.9	38.1	40.9	47.2	43.9	47.4
8	39.2	36.1	44.0	43.4	41.9	46.5	47.0	42.7	48.7	40.2	37.7	41.6	------	38.8	39.7	48.0	43.7	46.3
7	------	------	------	42.7	43.3	------	------	47.0	48.0	------	36.0	40.0	------	38.0	------	43.0	44.0	------

TABLE 28.—*Mean boll period by fruiting-branch node for bolls maturing on 6 varieties of cotton, 1931–33*

Variety and year	Period for fruiting-branch node indicated						
	First	Second	Third	Fourth	Fifth	Sixth	Seventh
Acala:	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*
1931	40.6	41.9	42.7	42.6	42.5	41.0	42.0
1932	39.8	41.1	42.0				
1933	43.4	43.2	42.3	43.1			
Mean	41.3	42.1	42.3	42.9			
Lone Star:							
1931	45.6	45.7	47.0	41.7			34.1
1932	43.9	44.4	44.7	44.0	50.5	51.0	
1933	47.2	47.2	46.1	46.6			
Mean	45.6	45.8	45.9	45.1			
Rowden:							
1931	47.6	48.4	48.4	48.3			
1932	44.4	45.6	47.7	56.0			
1933	48.8	48.8	47.8	48.9	47.5	47.0	
Mean	46.9	47.6	48.0	51.1			
Delfos:							
1931	41.7	43.3	43.3	44.5			
1932	39.3	40.4	40.6	42.0			
1933	44.0	45.3	46.1	44.0	46.4	45.0	47.0
Mean	41.7	43.0	43.3	43.5			
Half and Half:							
1931	40.4	41.5	40.3	43.2	42.3	42.0	46.0
1932	39.1	39.4	40.5	42.7	42.3	42.0	
1933	42.0	42.8	41.6	44.0			
Mean	40.5	41.2	40.8	43.3	42.3	42.0	
Kekchi: [1]							
1931	46.8	46.4	47.2	46.3		43.0	
1932	44.1	44.4	47.9	47.0	46.0		
1933	48.3	48.2	48.8	48.9	48.4	45.1	49.1
Mean	46.4	46.3	48.0	47.4	47.2	44.1	

[1] With the exception of Kekchi, the boll period for the first node is shorter than the second, with a tendency toward a progressive lengthening on the outer nodes.

THICKNESS OF CARPELS IN RELATION TO BOLL PERIOD

Thickness of boll carpels was measured on 50 full-grown green bolls of each variety just before they were ready to open. Preliminary observations indicated that more reliable and consistent measurements might be made at the thinnest portion of the carpel wall, which was found to be just below the point of greatest circumference, as the carpel walls become much thicker near the basal and apical ends. The measurements were made with an ordinary micrometer gage on thin longitudinal sections, which eliminated error due to curvature of the carpels. The mean measurements for each variety by year are shown in table 29, together with the general mean for the 3-year period.

There was fairly close agreement between the readings made in 1931 and 1932 for all varieties. In 1933 the plants were better supplied with moisture and the carpels were thicker. A heavier vegetative growth and slower growth rates were observed in all varieties in 1933. Half and Half showed consistently the thinnest carpel walls. In this variety, the thinnest carpel wall was associated with the shortest boll period.

TABLE 29.—*Mean thickness of boll carpels at the thinnest point as determined on 50 full-grown, well-matured green bolls of 6 varieties of cotton from crops of 1931, 1932, and 1933, at Greenville, Tex.*

Variety	Thickness			Mean thickness, 1931–33
	1931	1932	1933	
	Millimeters	*Millimeters*	*Millimeters*	*Millimeters*
Acala	1.99	1.83	2.89	2.237
Lone Star	1.97	1.86	2.84	2.223
Rowden	2.01	1.87	3.02	2.300
Delfos	1.67	1.57	2.65	1.903
Half and Half	1.52	1.50	2.45	1.823
Kekchi	2.07	1.88	2.98	2.310
Mean	1.87	1.75	2.80	2.143

Delfos carpel walls were only slightly thicker than the Half and Half. Acala and Lone Star were of practically the same thickness each year. Both varieties have much larger bolls than either Delfos or Half and Half, although the boll period for Acala was shorter than Delfos and only slightly longer than Half and Half. For carpel thickness, Rowden and Kekchi were very similar each year and show an average thickness of carpels of 2.300 and 2.310 mm., respectively. These two varieties, with the thickest carpels and the longest boll period, contrast with Half and Half with the thinnest carpels and the shortest boll period, and show a definite relationship between thickness of carpel and boll period.

SUMMARY AND CONCLUSIONS

The studies reported herein relate to rates of growth and fruiting in six different varieties of cotton (Acala, Lone Star, Rowden, Delfos, Half and Half, and Kekchi) possessing widely contrasted characters. The data presented cover the 3-year period 1931–33.

Half and Half and Kekchi produced first fruiting branches significantly lower in 1932 than in 1931. Lone Star produced its first fruiting branches significantly lower in 1931 and 1932 than in 1933. No significant differences between seasons were found in Acala, Rowden, and Delfos. When all varieties were combined as one group, the mean node number on which the first fruiting branch was borne was significantly lower in 1932 than in 1931 and 1933. The mean node number on which first fruiting branches were borne for the 3-year period was as follows: Acala, 8.68; Lone Star, 7.92; Rowden, 8.70; Delfos, 8.33; Half and Half, 8.55; and Kekchi, 7.97.

The mean interval in days between the appearance of first flowers on successive fruiting branches was found to be for Acala, 2.83; Lone Star, 2.74; Rowden, 2.58; Delfos, 2.55; Half and Half, 2.55; and Kekchi, 2.63 days. The differences between the means of varieties were not significant in 1931. In 1932 the mean interval was significantly less in Half and Half than in Delfos, and in 1933 it was less in Delfos than in Lone Star, and less in Delfos, Half and Half, and Rowden than in Acala. Considering means for the 3-year period, there were no significant differences between varieties. Combining varieties for the 3-year period, the interval was significantly less in 1931 and 1932 than in 1933, indicating a strong seasonal influence on this characteristic.

The mean interval between the appearance of successive flowers on fruiting branches for all varieties was 6.94 days. The 3-year mean ranged from 6.34 for Half and Half to 7.57 days for Rowden. In most of the varieties the intervals were shorter on the eleventh to fifteenth nodes, which were the points of maximum fruiting-branch development. Also the intervals were usually longer on the first two fruiting branches than those immediately above. There was a tendency for the interval to lengthen on the upper fruiting branches. The mean intervals were found to be highly significant for varieties and years, indicating that valid differences exist between varieties and that they may be significantly influenced by seasons.

An average of 56 percent of the bolls matured on all varieties were located on the first fruiting-branch nodes. Lone Star produced the lowest percentage of first fruiting-branch node bolls with a mean of 51.31 and Delfos the highest with 58.97 percent. The mean percentage of bolls produced on the second fruiting-branch nodes was about one-half the number produced on the first nodes, and the mean percentage produced on the third fruiting-branch nodes was slightly less than half that produced on the second nodes. This behavior clearly indicates that the greatest opportunity for setting bolls is on the first fruiting-branch nodes and that the chances of obtaining bolls on successive fruiting-branch nodes are reduced about one-half in each instance.

The varieties that produced the greatest number of flowers also matured the largest number of bolls. The medium- to large-bolled varieties matured bolls from 26 to 28 percent of their flowers. The small-bolled varieties, Delfos and Half and Half, set 39.1 and 42 percent of their flowers, respectively. The seasonal effect on the number of flowers produced, bolls shed, and bolls matured was not as great as might be expected. In fact, Acala and Lone Star showed a remarkably uniform behavior.

Approximately three-fourths of the total crop of bolls were set within 4 weeks after the appearance of the first flowers. The rapid fruiting of Delfos was outstanding over the other varieties. In 1932 Delfos set 100 percent of its crop in 4 weeks and showed an average of 92.06 percent for the 3-year period. All other varieties showed a mean percentage of 76 to 79 percent for the first 4 weeks.

The boll-shed period for all varieties was rather uniform, averaging 5.16 days for all varieties. It was highest in Kekchi with a 3-year mean of 5.47 days and lowest in Acala with a mean of 4.75. Rowden, one of the largest-bolled varieties, had a lower mean shed period than Half and Half or Delfos, the small-bolled varieties. Larger-bolled varieties had a tendency to shed in fewer days than the smaller-bolled varieties. An analysis of variance indicates that the mean differences in shed period between varieties and between years were significant. In 1931 differences between varieties were not significant, but in 1932 the shed period in Acala was significantly less than in Delfos and Kekchi, and in 1933 it was significantly shorter in Acala and Rowden than in Kekchi; and in Acala it was less than in Delfos, Half and Half, and Lone Star. This behavior indicates that significant varietal differences exist in boll-shed periods but may also be significantly influenced by seasonal conditions.

In the fruiting of the cotton plant a morphological relation exists that definitely influences the number of bolls that may be expected to set on different locations on the plant. Early in the season the plants set a crop of bolls on the lower and inner fruiting positions. As the demand for water becomes more acute, there follows a period of small-boll shedding. If the weather continues dry and hot, the period of small-boll shedding is followed by a period of small-square shedding. The plants thus fruit and defruit in successive zones. The zone of boll setting may be termed the "fruiting zone," which is followed by the "small-boll shed zone," and this zone is followed in turn by the "small-square shed zone." Each zone extends upward and outward from the base of the plant. Late in the season a top crop may develop on the extremities of the fruiting branches or from axillary buds on some of the inner nodes.

The branches on which the greatest number of bolls were set showed the greatest number of cases of terminal abortion. There was a marked tendency for the first two fruiting branches to abort at the second node, and the smaller-bolled varieties showed more cases of abortion at the first node.

The mean boll period for all varieties was 43.93 days and ranged from 47.12 days for Rowden to 40.80 days for Half and Half. Acala with 68 bolls to the pound of seed cotton showed a mean boll period of 41.59 days in comparison with Delfos with 89.4 bolls to the pound and a mean boll period of 42.13 days, clearly indicating that factors other than boll size may be associated with boll period. High significance between means of varieties and of years were indicated. The boll period in Acala, Lone Star, Delfos, and Half and Half was significantly shorter in 1931 and 1932 than in 1933, showing again the strong influence of season on this character.

The boll period on the upper and outer fruiting positions was usually somewhat longer than those on the inner and lower positions. The upper and outermost bolls were also the last bolls set and in 1933 were supplied with abundant moisture and more moderate temperatures, conditions which might be expected to prolong boll period. The mean boll period for bolls borne on the first nodes of fruiting branches was shorter than later nodes for all varieties except Kekchi and had a tendency to lengthen with progressive nodes. When it is understood that more than one-half of the crop is set on the first node, the importance of this behavior is apparent.

Thickness of boll carpel was determined on 50 fully grown green bolls. Carpel thickness was relatively uniform in 1931 and 1932 but was considerably thicker in 1933, a year of more abundant summer rainfall. Half and Half showed the thinnest carpel walls with a 3-year mean thickness of 1.823 mm. and likewise the shortest boll period. Delfos ranked second in thinness of carpel walls, with a 3-year mean of 1.963 mm. The other varieties ranked in the following order with little variation: Lone Star, Acala, Rowden, and Kekchi. Although the carpel thickness of Acala was 2.237, the boll period was less than Delfos and only slightly longer than Half and Half. Rowden and Kekchi, which possessed the thickest carpels, also had the longest boll period.

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U. S. GOVERNMENT PRINTING OFFICE: 1940

For sale by the Superintendent of Documents, Washington, D. C. - - - - Price 10 cents

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