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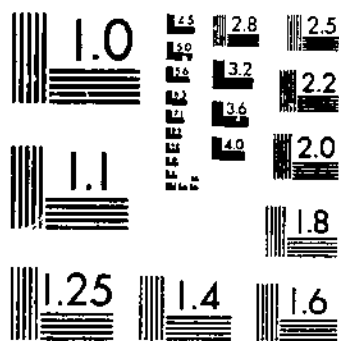
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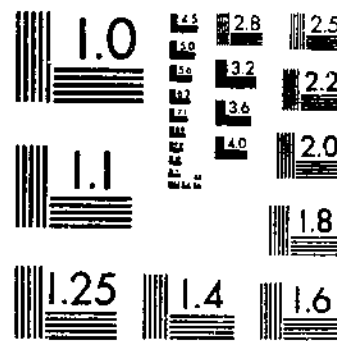
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INFLUENCE OF FERTILIZERS ON GROWTH RATES, FRUITING HABITS, AND FIBER
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UNITED STATES
DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

Influence of Fertilizers on Growth Rates, Fruiting Habits, and Fiber Characters of Cotton¹

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NUMEROUS FERTILIZER experiments with cotton have been conducted in the Southern States. In the majority of these experiments such criteria as yields, lint and boll characteristics, disease tolerance, or similar factors have been used to determine optimum fertilizer practice for a particular soil type or region. The results are considered applicable to areas where like conditions prevail.

Other studies have compared growth rates and fruiting habits of the cotton plant as influenced by varieties, fertilizer treatments, and various cultural practices; these plant responses have been correlated

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with yields or quality factors. These experiments have a somewhat wider range of applicability.

The experiment described in this bulletin was conducted at the United States Cotton Field Station, at Greenville, Tex., from 1937 to 1941, inclusive. It involved a study of the effects of nitrogen, phosphoric acid, and potash, each alone and in combinations, on growth rates, fruiting habits, and certain fiber characters of a single variety of cotton. It was designed to determine the particular effects of fertilizers that contribute to higher yields and their concurrent effects on certain quality factors in fiber. The findings are here summarized.

SUMMARY

A strain of Acala cotton was grown on Hunt clay, at Greenville, Tex., for five successive years, both with and without fertilizer applications, and studies were made of the influence of the fertilizer treatments on growth rates and fruiting habits and on certain fiber characteristics. The fertilizers were applied at the rate of 600 pounds per acre and in five different ratios of nitrogen, phosphorus, and potassium, namely, 0-15-0, 3-9-3, 9-3-3, 0-0-15, and 15-0-0. Under the conditions of the experiment the 0-15-0 and 0-0-15 fertilizers exerted very little influence on the growth rates and fruiting habits, whereas the nitrogen-bearing fertilizers were generally effective.

Applications of nitrogen fertilizers influenced both early and late growth rates of the main stalk, the growth rate of fruiting branches, the number of flowers per plant, the distribution of flowers in the second to sixth week of the flowering period, the number of bolls per plant, and the yield of seed cotton. They did not influence the stage of development at the time of initiation of fruiting, the length of the boll-shed period, the percentage of flowers developing into mature bolls, or the length of the boll-maturation period.

The greatest effects of the fertilizer combinations on the fiber properties were observed in an increase of fiber length with high phosphate and high potash fertilizers and a decrease in length with combinations containing nitrogen. The growth rates and fruiting were very generally and, in some cases, markedly influenced by seasonal changes, as were also certain, but not all, of the fiber properties that were measured.

REVIEW OF LITERATURE

Field experiments on the blackland prairie soils have shown (1)² in a fairly definite manner the fertilizers best adapted for cotton on soils of the central Texas section and the degree of response that may be anticipated. McNamara, Hooton, and Porter (11) compared several varieties of cotton on the basis of their growth rates and their response to seasonal conditions at Greenville, Tex. The present study is similar to theirs, except that the comparisons here reported were made among fertilizer treatments rather than among varieties. The literature reviewed by the above authors (1, 11), a paper by Cook on shedding of cotton (4), and several papers dealing more particularly

² Italic numbers in parentheses refer to Literature Cited, p. 30.

with fertilizer effects are all pertinent to the present study, as they show the response of the cotton plant to its environment.

Williams (22) found that increasing the percentage of phosphate in a complete fertilizer substantially increased the percentage of the total yield obtained at the first picking. Similar increases in the percentage of nitrogen (ammonia) caused little or no change in this respect, and increases in potash reduced the percentage of total yield at first picking. These results were obtained on Cecil sandy loam of the Piedmont province and on Norfolk fine sandy loam of the Coastal Plain section of North Carolina.

Musgrave and Coe (13) found that increasing the nitrogen content of fertilizers from 4 to 6, 8, and 10 percent caused cotton to mature at later dates.

Warner (22) studied the effect of nitrogen, phosphoric acid, and potash on cotton growth on Orangeburg fine sandy loam at Florence, S. C. Increasing the percentage of phosphoric acid in a complete fertilizer caused general increases in the number of blooms set through the fifth week and in the proportion of total bolls for the season which these blooms comprised. The percentage of total yield at first picking varied in a general way with the bloom records. Ammonia (nitrogen) increased the number of blooms and prolonged the fruiting season; phosphoric acid tended to accelerate maturity, but it did not change the length of the boll-maturation period.

Ludwig (10) found that neither the quantity of nitrate applied as fertilizer nor the time of application had a perceptible effect on the length of the square or the boll period. He states that his result, in harmony with the findings of other investigators, "indicates that relative length of boll period is dependent upon hereditary characters."

Nelson and Ware (14) studied the effects of the three fertilizer constituents on fruiting of cotton on Pulaski very fine sandy loam in Arkansas. Nitrogen had the greatest effect for this soil. This element increased the number of squares, blooms, and bolls; the size of bolls; the lint in 100 bolls; and the yields, but not necessarily in proportion to the rate of application. Percentage of earliness, weight of seed, lint index, percentage of lint, and staple length were little affected by the nitrogen applications. Of the above characters the lowest application of phosphoric acid increased percentage of earliness, but this was not true of higher applications; phosphoric acid increased boll size. Potash appeared to increase slightly the numbers of squares, blooms, and bolls, also the yields and the percentage of earliness. These investigators found that shedding took place in proportion to the number of blooms that developed and that the proportion of shedding was not affected by any fertilizer.

Studies by Ewing (6) and Harland (7) indicate that the productivity of the soil does not greatly alter the percentage of shedding. Cook (4) stated that a genetic factor is plainly indicated in plants that abort all their buds while their neighbors mature good crops. Kearney and Peebles (9) also concluded that the shedding of flower buds and young bolls is determined partly by genetic factors.

Reynolds and coworkers (16, 17) studied the effect of fertilizers on the length of cotton fiber. They found some differences that, though statistically significant, either were not large enough to be

detected consistently in commercial classing or were caused by something other than fertilizer treatment. Their studies were conducted in Texas on Kirvin fine sandy loam, Lufkin fine sandy loam, and Lake Charles clay.

Youngblood (24), in a general study of the correlation between reported lint length and soil type, concluded that the longer lint came from the more fertile soils, but noted an exception in the case of the Piedmont and Coastal Plains soils. On the other hand, neither Armstrong and Bennett (2) nor Sturkie (21) found significant differences in length of lint in cotton of the same variety grown on good and poor soils.

From this review it would seem that fertilizer treatment and general environment altered such characters as time, rate, and extent of fruiting but affected other characters, probably genetic, little or not at all.

The manifestation of a fertilizer effect may not be immediate, as discussed by Balls (3), who found an inhibition in the growth of the stem of Egyptian cotton to be followed 29 days later by a decided break in the flowering curve. This interval agrees closely with the time between the first appearance of the square and its date of blooming. He concluded that the factors that control the flowering of any bud may have operated 29 days (under the conditions of his experiment) prior to flowering.

EXPERIMENTAL PROCEDURE

In this experiment the effects of five fertilizer ratios on growth rates, fruiting habits, and certain lint characters of cotton were compared with plots that received no fertilizer. Fertilizer ratios used were 0-15-0, 3-9-3, 9-3-3, 0-0-15, and 15-0-0, each applied at 600 pounds per acre each year. These were selected key ratios from among those comprising the fertilizer triangle (19), which was used in preliminary investigations in the blackland section. Restriction of the ratios normally comprising the fertilizer triangle to the five here selected does not give a balanced system, but it does permit estimation of the effects of the three elements singly and of two widely differing nitrogen-phosphate ratios with the potash element constant.

These treatments were arranged in a 6 by 6 Latin square, and the experiment was conducted on the same area of Hunt clay at the U. S. Cotton Field Station, at Greenville, Tex., 1937-41, inclusive. A Shafter strain of Acala cotton was planted each year; for the first 3 years planting seed was from the same lot, while for the last 2 years new seed was obtained from the original source. Satisfactory stands were obtained each year.

The years 1937-39 were quite uniform, and climatic records reveal no outstanding departures from a normal season. This is reflected in the uniform cotton yields of unfertilized plots for these 3 years, and particularly for the first 2 years (see table 11). A wet period late in June and early in July and a dry summer occurred in 1940. The 1941 season was unusually wet. An extremely dry year was not encountered during the course of the experiment. Local station rainfall records for the 5-year period, recorded in cooperation with the United States Weather Bureau, are summarized in table 1.

TABLE 1.—*Rainfall recorded at the Cotton Field Station, Greenville, Tex., 1937-41*

Month	1937	1938	1939	1940	1941
	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>	<i>Inches</i>
January.....	4.41	7.31	3.67	0.68	1.47
February.....	.72	6.12	5.31	3.47	2.96
March.....	5.33	3.78	2.82	2.60	3.74
April.....	1.45	7.68	4.23	5.96	7.64
May.....	1.41	1.28	2.41	6.45	5.93
June.....	3.30	2.78	2.57	4.78	10.38
July.....	1.89	2.69	.77	4.12	3.17
August.....	5.68	.94	3.21	5.84	2.25
September.....	2.40	1.43	.25	.59	.45
October.....	4.16	.23	1.57	2.04	7.48
November.....	4.12	3.20	5.53	8.04	1.56
December.....	6.27	1.74	1.18	6.98	2.97
Total.....	41.14	39.18	33.52	51.55	50.00

Methods used in these studies for measuring and recording growth rates were devised by McNamara, Hooton, and Porter (11). Development attained during the fruiting stage was recorded from 5 representative plants, selected and tagged prior to flowering, in each of the 36 plots. Subsequent examinations of these tagged plants were made at intervals of 2 days or less, and records were made of the number of nodes below the first fruiting branch, date, and position on the plant of all flowers, shed bolls, and open bolls. A separate record sheet was kept for each plant, but in tabulating the data prior to statistical analyses a mean value for the 5 plants was calculated for each plot.

Lint studies were made on fibers from bolls that opened within the same 24- to 48-hour period and developed near the central part of the tagged plants.

Yield data were obtained from the entire group of plots after guard rows were eliminated.

Kearney and Harrison (8) found that early bolls of Pima cotton produced shorter fibers than bolls of the main crop. Porter (15) also found that in upland cotton midseason bolls produced longer lint than earlier or later bolls, and seeds in the central part of the lock produced longer and more representative average staple lengths than seed from either the base or tip of the lock. For these reasons, samples for fiber analyses were selected from bolls produced near the center of the plant and individual seed samples were taken from the central part of the locks.

All data were analyzed statistically by methods outlined by Snedecor (20). Although analyses for each year's data were made, maximum dependence is placed in the combined analyses of the 5-years' data and discussion is largely based on those records.

Field data give a complete record of the location on the plant of each form that developed beyond the flower stage and its subsequent history. From these records the length of various critical intervals that might conceivably be influenced by fertilizer can readily be cal-

culated and reduced to numerical data. The measurements discussed here are those deemed most appropriate to a characterization of plant development.

INFLUENCE OF FERTILIZERS ON GROWTH RATES AND FRUITING HABITS

NUMBER OF NODES AT EARLY DATES

Node counts provide a convenient means of characterizing the early development of the cotton plant. The two lowest nodes are opposite and mark the points of attachment of the cotyledon leaves. Successively higher nodes occur in a spiral arrangement around the main stalk; this permits rapid and accurate counting.

Node counts were made on 20 plants selected at random from each plot at several early dates in 1939, 1940, and 1941 (table 2). It is apparent that fertilizer did have a marked effect on early development.

In 1939 the 3-9-3 fertilizer stimulated development to the extent of 0.9 additional node by June 8, and plants fertilized with 9-3-3 averaged 0.5 of additional node. By June 15 all fertilizers containing nitrogen were similarly effective. In 1940 these same fertilizers stimulated the early development of additional nodes and the 0-15-0 and 0-0-15 fertilizers were included in this group as well. The effect of the all-nitrogen (15-0-0) fertilizer was not evident, however, until the second date of record. In 1941 the same three nitrogen-bearing fertilizers that were outstanding in the two preceding years accounted for the production of additional early nodes.

TABLE 2.—*Number of nodes¹ at early dates on cotton plants treated with different fertilizers, Greenville, Tex., 1939-41*

Treatments	1939		1940		1941	
	June 8	June 15	June 8	June 28	June 19	July 2
0-15-0	10.0	12.7	**8.8	**14.1	7.2	10.9
3-9-3	**11.0	**13.5	**9.0	**14.7	**7.9	**11.5
9-3-3	*10.6	**13.3	**8.8	**14.7	**8.1	**12.0
0-0-15	10.0	12.8	*8.5	**14.1	7.0	10.7
15-0-0	10.3	**13.2	8.3	**14.0	**8.1	**12.4
None	10.1	12.6	7.9	13.5	7.0	10.5
Least significant difference at--						
5-percent level	.54	.43	.60	.36	.48	.48
1-percent level	.74	.58	.83	.49	.65	.65
F value	**4.57	**6.94	*3.96	**14.55	**12.47	**22.50

¹ **=significant at 1-percent level; *=significant at 5-percent level.

NUMBER OF NODES BELOW THE FIRST FRUITING BRANCH

Normally the lowest nodes on the plant, including the cotyledon nodes, produce only leaves; hence while the plant is making this early

growth it might be considered in a formative stage of development. The plant passes into the fruiting stage with the appearance of the first floral bud, which usually is to be found on a fruiting branch developing at the seventh to ninth node, or from the axil of the fifth to seventh true leaf. This first floral bud marks the initial stage in the development of the first fruiting branch, and if it is retained by the plant it becomes the first boll of that fruiting branch. A count of nodes below the first fruiting branch on fertilized and unfertilized plants is thus capable of showing whether fertilizers influence the stage of development at which fruiting is initiated.

TABLE 3.—*Number of nodes below first fruiting branch as influenced by fertilizer treatments and by years, Greenville, Tex., 1937-41*

EXPERIMENTAL DATA

Treatments	1937	1938	1939	1940	1941	General mean ¹
0-15-0	6.8	7.5	7.5	7.4	7.9	7.41
3-9-3	6.3	7.3	7.6	7.5	7.3	7.21
9-3-3	6.7	7.5	7.3	7.3	7.3	7.23
0-0-15	6.8	7.3	7.5	7.1	8.4	7.42
15-0-0	6.9	7.2	7.4	7.6	6.9	7.19
None	6.7	7.6	7.4	7.6	8.1	7.50
General mean ¹	6.70	7.40	7.45	7.42	7.85	7.33

ANALYSIS OF VARIANCE

Source	Degrees of freedom	Sum of squares	Mean square	F values		
				Found ²	Required at—	
					5-per-cent level	1-per-cent level
Total	179	69.85				
Rows	5	.66	0.13			
Columns	5	.98	.20			
Treatments	5	2.60	.52	1.49	2.71	4.10
Error <i>a</i>	20	7.05	.35			
Years	4	18.39	4.60	**19.17	2.48	3.56
Years × rows	20	5.42	.27			
Years × columns	20	5.34	.27			
Years × treatments	20	10.18	.51	**2.13	1.70	2.11
Error <i>b</i>	80	19.23	.26			

¹ Least significant difference between general means:

At 5-per-cent level

At 1-per-cent level

² ** = significant at the 1-per-cent level.

Years Treatments

0.23 0.32

.30 .43

A summary of node counts below first fruiting branch, as made in this study, is given in table 3. An analysis of each year's data was made separately, but these analyses are not reported. Significant differences occurred in only 1 year (1941), when the 3-9-3, 9-3-3, and 15-0-0 fertilizers caused the fruiting branches to develop from the lower nodes rather than on unfertilized cotton.

An analysis of variance of the 5 years' data is given in table 3. It is apparent that in this composite record no significant effects of fertilizers are indicated, leading to the conclusion that fertilizers do not consistently alter the stage of development at which fruiting is initiated. The significant years \times treatments interaction reflects the effectiveness of fertilizers in 1 year of the 5.

There were highly significant differences among the years with respect to the node number at which the lowest fruiting branch was borne. In this respect 1937 is particularly outstanding for the early stage at which fruiting was initiated. There were no significant differences among the 3 succeeding years, 1938-40, and fruiting was initiated at a somewhat later stage in 1941.

Thus, from the node counts it would seem that the five fertilizer combinations covered by this study did not consistently alter the stage of development requisite for the initiation of fruiting. The first fruiting branch appeared when the plant bore an average of 7.33 nodes. As noted under "Number of Nodes at Early Dates," certain fertilizers stimulated more rapid, early development and thus brought the plants to the stage requisite for initiation of fruiting at earlier dates. The three nitrogen-bearing fertilizers (3-9-3, 9-3-3, and 15-0-0) were most consistent in stimulating such early development.

INTERVAL BETWEEN FIRST FLOWERS ON SUCCESSIVE FRUITING BRANCHES

The interval (in days) between first flowers on successive fruiting branches has been found to be an accurate and readily measured index of the growth rate of the main stalk of a cotton plant (table 4). Analysis of variance by years, made separately but not reported here, shows that significant differences were confined to the first 3 years, although distinct trends are evident throughout the 5 years' results. In each of the first 3 years the 9-3-3 and 15-0-0 fertilizers caused more rapid development of nodes on the main stalk, and in 1938 the 3-9-3 ratio was also effective. The 0-15-0 and 0-0-15 fertilizers were not effective in any instance.

When all of the data are pooled, the 9-3-3 and 15-0-0 fertilizers significantly hastened the development of the main stalk. Their successive nodes were produced in an average of 2.68 and 2.66 days, respectively, compared with 2.82 days required by unfertilized cotton.

Growth rate differences were highly significant among the years. The rate for the first 2 years was slower than for the last 3, which showed little deviation in their growth rates.

An analysis of variance of the 5-years' results is presented in table 4. Highly significant differences between years are shown and significance between treatments, but no interaction of years \times treatments.

TABLE 4.—Interval in days between first flowers on successive fruiting branches as influenced by fertilizer treatments and by years, Greenville, Tex., 1937-41

EXPERIMENTAL DATA

Treatments	1937	1938	1939	1940	1941	General mean ¹
0-15-0	3.0	3.0	2.7	2.7	2.8	2.84
3-9-3	2.8	2.8	2.7	2.7	2.7	2.74
9-3-3	2.7	2.9	2.6	2.6	2.6	**2.68
0-0-15	2.8	3.0	2.7	2.8	2.5	2.76
15-0-0	2.7	2.8	2.5	2.6	2.7	**2.66
None	2.9	3.0	2.7	2.6	2.9	2.82
General mean ¹	2.82	2.92	2.65	2.67	2.70	2.75

ANALYSIS OF VARIANCE

Source	Degrees of freedom	Sum of squares	Mean square	F values		
				Found ²	Required at—	
					5-per-cent level	1-per-cent level
Total	179	11.20				
Rows	5	.40	0.08			
Columns	5	.49	.10			
Treatments	5	.73	.15	*3.75	2.71	4.10
Error a	20	.80	.04			
Years	4	1.33	.33	**6.60	2.48	3.56
Years × rows	20	1.35	.07			
Years × columns	20	1.07	.05			
Years × treatments	20	.78	.04		1.70	2.11
Error b	80	4.25	.05			

¹ Least significant difference between general means:

At 5-per-cent level Years 0.11 Treatments 0.11

At 1-per-cent level 0.14 0.15

² **=significant at the 1-per-cent level; *=significant at the 5-per-cent level.

INTERVAL BETWEEN SUCCESSIVE FLOWERS ON FRUITING BRANCHES

The interval (in days) between successive flowers on fruiting branches provides an index to the growth rate of a particular fruiting branch. A summary of these measurements and analysis of variance of the 5-years' data are given in table 5.

Based on the 5-year record the 3-9-3, 9-3-3, and 15-0-0 fertilizers reduced the number of days required for the production of a new node on the fruiting branches. Further, there was a progressive reduction in the length of time required for this development in the series, from 3-9-3 through 9-3-3 to 15-0-0 fertilizers. The difference in interval

required between 3-9-3 and 15-0-0 was significant. The 0-15-0 fertilizer increased the time required for the development of successive nodes while the 0-0-15 fertilizer had no consistent effect. As a general mean a new node was formed on the fruiting branches in 6.96 days.

There were some discrepancies among the years in the effect of fertilizers on the growth rate of fruiting branches. This is reflected in the significant years \times treatments interaction.

There were also highly significant differences among the years in the growth rate of fruiting branches. As was the case with growth rates of the main stalk, the most rapid growth occurred in 1939 and the slowest growth in 1938.

TABLE 5.—Interval (in days) between successive flowers on fruiting branches as influenced by fertilizer treatments and by years, Greenville, Tex., 1937-41

EXPERIMENTAL DATA						
Treatments	Years					General mean ¹
	1937	1938	1939	1940	1941	
0-15-0	6.9	7.8	6.5	7.6	8.0	**7.36
3-9-3	6.4	7.4	6.1	7.1	7.1	**6.82
9-3-3	6.5	7.4	6.1	6.5	7.0	**6.70
0-0-15	6.3	7.9	6.3	7.3	7.8	7.12
15-0-0	6.5	7.5	6.1	6.5	6.8	**6.68
None	6.7	7.7	6.4	7.4	7.3	7.10
General mean ¹	6.55	7.02	6.25	7.07	7.33	6.96

ANALYSIS OF VARIANCE						
Source	Degrees of freedom	Sum of squares	Mean square	F values		
				Found ²	Required at—	
					5-per-cent level	1-per-cent level
Total	179	77.71				
Rows	5	.14	0.09			
Columns	5	.63	.13			
Treatments	5	11.32	2.26	**32.29	2.71	4.10
Error a	20	1.45	.07			
Years	4	45.24	11.31	**87.00	2.48	3.56
Years \times rows	20	1.55	.08			
Years \times columns	20	1.75	.09			
Years \times treatments	20	5.29	.26	*2.00	1.70	2.11
Error b	80	10.04	.13			

¹ Least significant difference between general means:

At 5-per-cent level	Years	0.17	Treatments	0.14
At 1-per-cent level		.22		.19

² **=significant at the 1-per-cent level; *=significant at the 5-per-cent level.

PRODUCTION OF FLOWERS

Production of flowers is an index to the potential yielding capacity of cotton plants. A summary of total flower production by plants and an analysis of variance of the 5-years' data are given in table 6.

The three nitrogen-bearing fertilizers, which have previously been shown to have accelerated early development and growth rates, also increased flower production. The effect of the fertilizers in this respect increased through the series from 3-9-3 through 9-3-3, to the 15-0-0 fertilizer, paralleling their effect on the growth rate of fruiting branches. The 0-15-0 and 0-0-15 fertilizers did not have any significant effects. There were some inconsistencies among the fertilizer effects in different years, as shown by the significant years \times treatments interaction.

TABLE 6.—*Number of flowers per plant as influenced by fertilizer treatments and by years, Greenville, Tex., 1937-41*

EXPERIMENTAL DATA						
Treatments	1937	1938	1939	1940	1941	General mean ¹
0-15-0.....	19.2	19.4	19.0	13.9	8.5	16.00
3-9-3.....	21.6	22.6	21.3	16.4	10.2	**18.42
9-3-3.....	22.9	24.3	20.9	22.3	15.8	**21.24
0-0-15.....	22.1	19.1	18.9	14.6	10.7	17.08
15-0-0.....	22.7	21.1	22.8	21.2	20.2	**22.20
None.....	19.8	21.0	18.3	13.4	10.8	16.66
General mean ¹	21.38	21.75	20.20	16.97	12.70	18.60
ANALYSIS OF VARIANCE						
Source	Degrees of freedom	Sum of squares	Mean square	F values		
				Found ²	Required at—	
					5-per-cent level	1-per-cent level
Total.....	179	4,374.56				
Rows.....	5	52.90	10.58			
Columns.....	5	32.02	6.40			
Treatments.....	5	974.00	194.80	**24.38	2.71	4.10
Error a.....	20	159.83	7.99			
Years.....	4	2,079.95	519.99	**83.60	2.48	3.56
Years \times rows.....	20	71.83	3.59			
Years \times columns.....	20	110.31	7.02			
Years \times treatments.....	20	365.82	18.29	**2.94	1.70	2.11
Error b.....	80	497.90	6.22			

¹ Least significant difference between general means:

At 5-percent level..... Years 1.17 Treatments 1.52

At 1-percent level..... Years 1.55 Treatments 2.08

² **=significant at the 1-percent level; *=significant at the 5-percent level.

The larger number of flowers in cotton fertilized with 3-9-3, 9-3-3, and 15-0-0 mixtures is probably a logical sequence to the more rapid early development and accelerated growth rates caused by these same fertilizers.

There were highly significant differences among the years in number of flowers per plant. The numbers were remarkably uniform in the first 2 years, and were significantly lower in 1939. There was a highly significant drop from that level in 1940, and a further highly significant decline in 1941. As a general mean each plant produced 18.60 flowers.

To further characterize the effect of fertilizers on flower production, the data were segregated by weeks and are summarized in table 7. Data in this case are reported as numbers of flowers on five plants. There were only a few flowers in the first week of the flowering period, which began with the appearance of the first flower. The numbers increased to a maximum in the third or fourth week and then declined until there were only occasional flowers after the sixth week.

As with total flowers, the production of flowers by weeks was affected principally by the nitrogen-bearing fertilizers. Further, there is evidence of a progression in the effect of these fertilizers. The 3-9-3 fertilizer increased the number of flowers in the second and third weeks, following which there was a decline, and fewer flowers were produced on 3-9-3 fertilized plants than on those with no treatment in the fifth and sixth weeks. The 9-3-3 fertilizer caused highly significant increases in number of flowers in the first, second, third, and fourth weeks, while the 15-0-0 fertilizer increased production of flowers throughout the flowering period. Thus, through the series from the 3-9-3 to the 9-3-3 and the 15-0-0 ratio, the stimulating effect of the fertilizer was prolonged progressively further into the flowering period.

TABLE 7.—*Mean production of flowers¹ (by weeks) as influenced by fertilizer treatments, Greenville, Tex., 1937-41*

Treatments	Number of flowers on 5 plants produced in—					
	First week	Second week	Third week	Fourth week	Fifth week	Sixth week
0-15-0	3.00	10.83	20.77	21.63	**16.07	5.60
3-9-3	3.30	**14.47	**26.63	25.43	*17.17	**3.93
9-3-3	**1.23	**14.57	**27.50	**29.77	21.97	6.83
0-0-15	3.33	11.20	21.73	24.50	21.03	8.60
15-0-0	**1.23	**13.67	**26.47	**28.30	**28.17	**12.97
None	2.47	9.97	20.20	23.07	21.10	7.50
Least significant difference at						
5-percent level	.95	1.58	2.11	2.79	2.91	2.21
1-percent level	1.24	2.16	2.88	3.81	3.97	3.02
F value	**1.70	**14.13	**21.60	**10.85	**18.77	**17.07

¹ **=significant at the 1-percent level; *=significant at the 5-percent level.

BOLL-SHED PERIOD

Each of the study plants shed an average of 13.3 bolls. The interval in days between the date of flowering and the date the boll was shed was recorded as the boll-shed period (table 8).

The mean boll-shed period on unfertilized plants in this experiment was 5.28 days. None of the fertilizers caused a significant deviation from this value when the 5 years' data were pooled. Analysis of variance of each year's data show that significant differences occurred only in 1938, which were attributed to the high value on 9-3-3-treated plants. In view of the lack of effects in other years this would seem to be a vagary, although it is reflected in the highly significant years \times treatments interaction.

TABLE 8.—*Boll-shed periods (in days) as influenced by fertilizer treatments and by years, Greenville, Tex., 1937-41*

EXPERIMENTAL DATA						
Treatments	1937	1938	1939	1940	1941	General mean ¹
0-15-0	5.3	5.6	4.5	5.2	6.3	5.38
3-9-3	5.5	5.8	4.3	5.3	5.3	5.24
9-3-3	5.2	6.5	4.6	5.4	5.3	5.40
0-0-15	5.4	5.5	4.3	5.4	5.0	5.12
15-0-0	5.4	5.7	4.4	5.5	5.5	5.30
None	5.3	5.9	4.3	5.1	5.8	5.28
General mean ¹	5.35	5.83	4.40	5.32	5.53	5.29

ANALYSIS OF VARIANCE						
Source	Degrees of freedom	Sum of squares	Mean square	F values		
				Found ²	Required at—	
					5-per-cent level	1-per-cent level
Total	179	82.73				
Rows	5	.44	0.09			
Columns	5	1.12	.22			
Treatments	5	1.91	.38	1.90	2.71	4.10
Error <i>a</i>	20	3.96	.20			
Years	4	41.16	10.29	**49.00	2.48	3.56
Years \times rows	20	3.58	.18			
Years \times columns	20	4.23	.21			
Years \times treatments	20	9.61	.48	**2.29	1.70	2.11
Error <i>b</i>	80	16.72	.21			

¹ Least significant difference between general means:

At 5-percent level

At 1-percent level

² **—significant at the 1-percent level.

Years

Treatments

0.21

.28

0.24

.33

There were highly significant differences among the years in length of the boll-shed period. The extremes were represented by 1939 with the shortest period and 1938 with the longest period. As a general mean, bolls were shed 5.29 days after the flower opened.

BOLL-MATURATION PERIOD

The length of the period from date of flowering to the time the boll opened was recorded for all bolls and is termed the boll-maturation period. The pertinent data are summarized in table 9.

The average period required for the maturation of bolls on unfertilized plants was 40.48 days, and no fertilizer caused a significant deviation from this period. Treatments did not cause significant differ-

TABLE 9.—*Boll-maturation periods (in days) as influenced by fertilizer treatments and by years, Greenville, Tex., 1937-41*

EXPERIMENTAL DATA						
Treatments	1937	1938	1939	1940	1941	General mean ¹
0-15-0	38.7	39.7	38.2	44.9	41.1	40.62
3-9-3	39.1	39.8	38.2	44.1	40.9	40.42
9-3-3	38.9	39.7	38.6	43.5	40.8	40.30
0-0-15	38.9	39.8	38.4	44.9	40.9	40.58
15-0-0	38.8	39.9	38.0	44.4	40.4	40.30
None	38.7	39.2	38.3	44.9	41.3	40.48
General mean ¹	38.85	39.68	38.28	44.45	40.90	40.43

ANALYSIS OF VARIANCE

Source	Degrees of freedom	Sum of squares	Mean square	F values		
				Found ²	Required at—	
					5-per-cent level	1-per-cent level
Total	179	955.38				
Rows	5	2.10	0.42			
Columns	5	3.23	.65			
Treatments	5	1.98	.40			
Error a	20	9.89	.49		2.71	4.10
Years	4	865.55	216.39	**515.21	2.48	3.56
Years × rows	20	8.68	.43			
Years × columns	20	17.11	.86			
Years × treatments	20	13.28	.66	1.57	1.70	2.11
Error b	80	33.56	.42			

¹ Least significant difference between general means:

At 5-per-cent level

At 1-per-cent level

² **=significant at the 1-per-cent level.

Years
0.30
.40

Treatments
0.38
.51

ences in any of the years, the consistency of the data being attested by the low years \times treatments interaction. Apparently, fertilizers had no effect on the length of time required for the development and opening of the bolls.

The character of the season materially affected the length of the boll-maturation period, as shown by the highly significant variance among years. Each year differed from each of the others in this respect. The range was from 38.28 days in 1939 to 44.45 in 1940. The mean interval from date of flowering to dates of boll opening was 40.43 days. It is known that late-season bolls require a longer time for maturation than those that develop earlier in the season. This is

TABLE 10.—*Number of bolls per plant as influenced by fertilizer treatments and by years, Greenville, Tex., 1937-41*

EXPERIMENTAL DATA						
Treatments	1937	1938	1939	1940	1941	General mean ¹
0-15-0	5.6	6.4	4.3	4.4	2.5	4.64
3-9-3	6.7	7.8	4.3	4.9	3.1	***5.36
9-3-3	6.6	8.9	4.5	6.0	4.7	**5.96
0-0-15	6.2	6.2	4.0	4.5	3.5	4.88
15-0-0	6.7	8.0	4.4	5.6	5.6	**6.06
None	5.4	6.6	4.1	4.4	3.4	4.78
General mean ¹	6.20	7.17	4.27	4.97	3.80	5.28

ANALYSIS OF VARIANCE						
Source	Degrees of freedom	Sum of squares	Mean square	F values		
				Found ²	Required at—	
					5-per-cent level	1-per-cent level
Total	179	468.34				
Rows	5	5.25	1.05			
Columns	5	5.93	1.19			
Treatments	5	57.26	11.45	**20.09	2.71	4.10
Error a	20	11.46	.57			
Years	4	280.02	70.01	**87.51	2.48	3.56
Years \times rows	20	6.11	.31			
Years \times columns	20	10.13	.51			
Years \times treatments	20	28.33	1.42	*1.78	1.70	2.11
Error b	80	63.85	.80			

¹ Least significant difference between general means:

	Years	Treatments
At 5-per-cent level	0.42	0.41
At 1-per-cent level	.56	.55

² ** = significant at the 1-per-cent level; * = significant at the 5-per-cent level.

confirmed by the data from this study. It is possible that the pronounced variance among the years in length of the boll-maturation period is partly due to the differing proportions of early-, medium-, and late-season bolls.

NUMBER OF BOLLS

A summary of the number of bolls produced on plants studied, expressed as annual treatment means and as general means by treatments and by years, together with analysis of variance of the 5-years' data, is given in table 10.

The 3 nitrogen-bearing fertilizers increased the number of bolls over those borne on untreated plants. As a general mean each untreated plant bore 4.78 bolls, and the advantages due to 3-9-3, 9-3-3, and 15-0-0 fertilizers were 0.58, 1.18, and 1.28 bolls per plant, respectively. Based on the prevailing stand (1 plant per foot, or 13,756 plants per acre) these increases calculated to an acre basis aggregate 7,978 bolls for the 3-9-3, 16,232 bolls for the 9-3-3, and 17,608 bolls for the 15-0-0. The 0-15-0 and 0-0-15 fertilizers did not have a significant effect on number of bolls per plant. There were small discrepancies among the data for the individual years, as shown by the years \times treatments interaction, which was significant at the 5-percent level.

There were highly significant differences among the years. The smallest number of bolls per plant, 3.80, was produced in 1941, which was a wet year unfavorable for cotton production. The largest number, 7.17 bolls per plant, was produced in 1938.

PERCENTAGE OF FLOWERS PRODUCING BOLLS

As a general mean each plant produced 18.60 flowers, of which 5.28, or 28 percent, developed into mature bolls. Fertilizer treatments caused only small differences in the percentage of flowers that developed into mature bolls, while seasonal conditions apparently had a much greater controlling influence. This is shown by the pertinent data given in table 11.

A factor of greater importance in determining the fate of a flower is the time within the flowering period in which it is produced. When the flowering period was segregated by weeks on all treatments, as shown in table 12, it was found that 59 percent of the flowers produced in the first week developed into mature bolls, followed by 51, 34, 17, 16, and 11 percent in the second to sixth week, respectively. These data, which confirm many already published, are a natural consequence of the prevailing climatic conditions. During the early part of the season soil moisture is usually adequate for normal boll development, but during the hot dry summers the cotton is frequently placed under severe stress, resulting in profuse shedding of small bolls, squares, and even leaves.

A knowledge of this seasonal sequence in the hazards associated with early and late bolls is valuable to the cotton breeder in developing strains that will be productive under conditions of insect infestation. It is of value in planning insect-control measures where these are a factor, because of the special importance of protecting the early bolls. Further, it is correlated with variations obtained in response to ferti-

lizers on the blackland prairie soils. The greatest response to fertilizer ordinarily will accrue in years when soil moisture is fully adequate, but not excessive, during the early part of the fruiting season.

YIELDS OF SEED COTTON

The yields of seed cotton are summarized and an analysis of variance of the 5 years' data are given in table 13.

In each of the 5 years and as general means, the three nitrogen-bearing fertilizers increased yields by highly significant margins. In 1937 the 0-0-15 fertilizers also increased the yield by a highly significant margin, but this was not true in any other year, nor was it evident

TABLE 11.—Percentage of flowers that developed into mature bolls as influenced by fertilizer treatments and by years, Greenville, Tex., 1937-41

EXPERIMENTAL DATA						
Treatments	1937	1938	1939	1940	1941	General mean ¹
0-15-0	29.82	32.70	22.62	32.99	28.55	29.24
3-9-3	31.19	34.43	20.34	29.97	31.15	29.41
9-3-3	28.69	32.88	21.78	26.90	29.67	27.98
0-0-15	28.39	32.62	21.29	31.13	33.05	29.30
15-0-0	29.94	33.28	19.40	26.52	27.93	27.41
None	27.58	31.34	22.14	34.07	32.41	29.51
General mean ¹	29.18	32.87	21.26	30.26	30.46	28.81

ANALYSIS OF VARIANCE						
Source	Degrees of freedom	Sum of squares	Mean square	F values		
				Found ²	Required at—	
					5-per-cent level	1-per-cent level
Total	179	5,451.46				
Rows	5	78.80	15.76			
Columns	5	72.48	14.50			
Treatments	5	116.97	23.39	1.69	2.71	4.10
Error a	20	276.59	13.83			
Years	1	2,823.62	705.91	**12.89	2.48	3.56
Years × rows	20	116.91	5.85			
Years × columns	20	225.87	11.29			
Years × treatments	20	123.58	21.18	1.29	1.70	2.11
Error b	80	1,316.61	16.46			

¹ Least significant difference between general means:

At 5-per-cent level

At 1-per-cent level

² **=significant at the 1-per-cent level.

Years	Treatments
1.00	2.00
2.52	2.73

TABLE 12.—*Percentage of flowers developing into mature bolls, segregated by weeks, as influenced by fertilizer treatments and by years, Greenville, Tex., 1937-41*

Year	Flowers opening in—					
	First week	Second week	Third week	Fourth week	Fifth week	Sixth week
1937.....	72	52	31	12	1	0
1938.....	90	83	33	20	20	3
1939.....	34	40	23	8	22	12
1940.....	50	23	51	26	10	17
1941.....	50	53	39	30	24	16
Mean.....	59	51	34	17	16	11

in the mean yield for the 5-year period. This inconsistency caused a highly significant years \times treatments interaction. The 0-15-0 fertilizer did not have a significant effect on yields in any year.³

The increases in yield from the 3-0-3, 9-3-3, and 15-0-0 fertilizers amounted to 161, 269, and 290 pounds seed cotton per acre, respectively, showing a progressive advantage through this series. Considering the individual years, however, the 9-3-3 fertilizer was optimum in each of the first 3 years, and the 15-0-0 fertilizer was optimum in the last 2.

There were highly significant differences in yields among the years. The range in mean yields was from 935 pounds of seed cotton per acre in 1940, characterized by a wet period in late spring and a dry summer, to 375 pounds in 1941, which was an abnormally wet year. Between the extremes, the 3 earlier years differed significantly among themselves, but the yields were relatively stable.

RÉSUMÉ OF FERTILIZER EFFECTS ON GROWTH RATES AND FRUITING

Certain fertilizers caused relatively large increases in yield in this experiment. There were concomitant changes in certain plant characters and growth-rate intervals, while others were largely unaffected. Thus, the data contribute to an understanding of the fundamental factors that are responsible for the larger yields due to fertilizers.

None of the fertilizers used had a consistent effect on (1) the stage of development at the time fruiting is initiated, as measured by node counts below first fruiting branch; (2) the length of the boll-shed period; (3) the percentage of flowers that develop into mature bolls; or (4) the length of the boll-maturation period.

³The experiment described here was designed to test effects of each of the primary plant food elements—nitrogen, phosphorus, and potassium. As a matter of fact, however, only effects from additions of nitrogen should be considered as effectively brought out by the experiment as conducted. The soil of the Greenville station is so well supplied with available phosphoric acid and potash that additions of these constituents as fertilizers did not increase yields of seed cotton. This means that some other soil would have to be selected for the experiment in order to get reliable information concerning probable effects of additions of these elements upon the various properties of the cotton plant studied.

TABLE 13.—*Total yields (in pounds) of seed cotton per acre as influenced by fertilizer treatments and by years, Greenville, Tex., 1937-41*

EXPERIMENTAL DATA						
Treatments	1937	1938	1939	1940	1941	General mean ¹
0-15-0.....	642	602	573	786	213	563
3-9-3.....	775	884	670	955	372	² **731
9-3-3.....	839	953	702	1,175	525	**839
0-0-15.....	784	669	587	751	237	606
15-0-0.....	800	932	698	1,196	673	**860
None.....	642	646	587	748	228	570
General mean ¹	748	781	636	935	375	695

ANALYSIS OF VARIANCE						
Source	Degrees of freedom	Sum of squares	Mean square	F values		
				Found ²	Required at—	
					5-per-cent level	1-per-cent level
Total.....	179	4,868.00				
Rows.....	5	13.99	2.80			
Columns.....	5	17.48	3.50			
Treatments.....	5	1,285.98	257.20	**113.30	2.71	4.10
Error <i>a</i>	20	45.34	2.27			
Years.....	4	2,970.72	742.68	**728.12	2.48	3.56
Years × rows.....	20	53.41	2.67			
Years × columns.....	20	41.87	2.24			
Years × treatments.....	20	354.92	17.75	**17.40	1.70	2.11
Error <i>b</i>	80	81.29	1.02			

¹ Least significant difference between general means:

At 5-per-cent level..... Years 21.6 Treatments 37.2

At 1-per-cent level..... 28.8 50.8

² **=significant at the 1-per-cent level.

The first, third, and fourth of these characters are related to critical periods in the reproductive process and are possibly controlled by genetic factors. All are influenced by seasonal conditions. McNamara, Hooton, and Porter (11) found differences among varieties with respect to all of these measurements, and there were differences among years, both in their experiment and in the present study. It would seem, therefore, that while these characters differ with variety and seasonal conditions, they are not readily susceptible to change by varying the fertilizer treatment.

Fertilizers did cause significant changes in (1) early growth rate as measured by early node counts; (2) the growth rate of the main stalk as measured by the interval in days between first flowers on successive

fruiting branches; (3) the growth rate of fruiting branches as measured by the interval in days between successive flowers on fruiting branches; (4) the number of flowers per plant; (5) the distribution of flowers among the second to sixth week of the flowering period; (6) the number of bolls per plant; and (7) the yield of seed cotton.

These measurements are related to growth rates and probably affect the fruiting capacity of the plant. It is in this category of response that fertilizer effects seem to be exerted. There were significant differences among years with respect to all of these characters, thus demonstrating that they are susceptible to change with seasonal conditions as well as with fertilizer treatment.

On this Hunt clay the 0-15-0 and 0-0-15 fertilizers caused such few changes that they may be regarded as of no practical importance. In contrast, the three nitrogen-bearing fertilizers accelerated growth rates and increased fruiting capacity by practically all standards of measurement. In general, their effectiveness increased through the series from 3-9-3 through 9-3-3 to 15-0-0 ratios.

Based on the data, hypothetical composite plants from unfertilized plots and those treated with 3-9-3, 9-3-3, and 15-0-0 fertilizers may now be described. Salient characteristics of such plants are given in table 14.

INFLUENCE OF FERTILIZER TREATMENTS ON FIBER CHARACTERS

Material for examinations on the influence of fertilizer treatments on certain characteristics of cotton fibers was obtained from the same plants used for the first part of this report and consisted of 1 boll from each of 5 plants in each plot of the experiment. Thus, each treatment and the no-treatment check furnished 30 bolls, aggregating a total of 180 bolls for the whole experiment each year. Each season's bolls were produced in the central part of the plant from flowers that opened within the same 24- to 48-hour period. One seed from the middle of one lock of each boll was selected for arraying on a McNamara-Stutts fiber sorter, according to the procedure outlined by the authors (12) and Cook (5).

The length of each "pull" of fibers from the machine was measured and the weight of each length group determined by means of a milligram balance. The resulting data were examined by analysis of variance for the following characteristics: (1) Percentage of fibers less than one-half inch in length; (2) total weight of arrays; (3) maximum length; (4) upper quartile length; (5) mean length of that part of the arrays greater than one-half-inch in length; and (6) weight percentage of the length group in which the upper quartile length is located.

PERCENTAGE OF FIBERS LESS THAN ONE-HALF INCH IN LENGTH

A summary of the percentages of fibers less than one-half inch in length is presented in table 15. The general mean for treatments shows that all fertilizer combinations increased the percentage of fibers less than one-half inch in length. The found *F* value for treatments, 1.61, indicates a lack of significance between the various fertilizers for this characteristic, but application of the *t* test reveals a significant increase in short fibers attributable to the 0-15-0 and 3-9-3 combinations.

TABLE 14.—Salient characters of hypothetical composite plants from unfertilized plots and plots fertilized with 3-9-3, 9-3-3, and 15-0-0 fertilizers, Greenville, Tex., 1937-41

Treatment	Characters not consistently affected by fertilizers					Characters affected by fertilizers										Yield of seed cotton per acre
	No. of leaves for fruit	Boll shed period	Flowers developing into mature bolls	Boll maturity period	Nodes on early dates	Formation of new nodes on main stalk	Formation of new nodes on fruiting branch	Distribution of flowers on fruit of plants during flowering period			Flowers per plant	Bolls per plant	Pounds			
	Number	Days	Percent	Days	Number	Days	Days	Second week	Fourth week	Sixth week	Number	Number	Number	Number	Pounds	
3-9-3	7.21	6.21	29.41	40.12	**16.2	2.71	**6.82	**14.47	25.43	**3.03	*18.42	**5.36	**731			
9-3-3	7.62	6.49	27.38	40.31	**13.3	**2.53	**6.70	**14.57	**29.77	0.82	*21.31	**5.46	**839			
15-0-0	7.19	6.36	27.41	40.30	**13.2	**2.66	**6.68	**13.97	**28.30	**12.97	*22.59	**9.04	**860			
None	7.60	6.28	29.51	40.48	12.2	2.82	7.10	9.97	23.07	7.50	16.66	4.78	570			

* = significant at the 5-percent level; ** = significant at the 1-percent level.

† Mean for June 15, 1939; June 28, 1940; July 2, 1941.

When the general mean for years was considered, the lowest general mean percentage (8.49) was obtained in 1937 and the next lowest (10.81) in 1940, the difference between the two being highly significant. The highest percentage (14.36) was obtained in 1941, and it is separated from all the other years by highly significant differences.

Thus, it may be seen that climatic or seasonal conditions have a greater influence than fertilizer treatments on the percentage of fibers less than one-half inch in length.

The inconsistency of the results from one year to another is indicated by the highly significant years \times treatments interaction shown by the found F value in table 15.

TABLE 15.—Percentage of fibers less than one-half inch in length as influenced by fertilizer treatments and by years, Greenville, Tex., 1937-41

EXPERIMENTAL DATA						
Treatments	1937	1938	1939	1940	1941	General mean ¹
0-15-0	11.30	10.25	11.31	10.61	14.65	11.62
3-0-3	7.78	11.85	10.77	11.97	14.74	11.42
9-3-3	7.07	13.53	10.78	11.37	13.63	11.28
0-0-15	7.05	12.00	10.71	11.25	14.67	11.14
15-0-0	10.08	11.76	11.65	9.37	13.29	11.23
None	7.69	8.51	11.29	10.31	15.19	10.60
General mean ¹	8.49	11.32	11.09	10.81	14.36	11.21

ANALYSIS OF VARIANCE						
Source	Degrees of freedom	Sum of squares	Mean square	F values		
				Found ²	Required at—	
					5-percent level	1-percent level
Total	179	1,157.58				
Rows	5	8.04	1.61			
Columns	5	1.69	.34			
Treatments	5	17.98	3.60	1.61	2.71	4.10
Error a	20	44.61	2.23			
Years	4	929.69	157.42	**68.15	2.48	3.56
Years \times rows	20	24.07	1.20			
Years \times columns	20	36.04	1.80			
Years \times treatments	20	210.66	10.53	**4.56	1.70	2.11
Error b	80	184.80	2.31			

¹ Least significant difference between general means:

At 5-percent level

At 1-percent level

² ** = significant at the 1-percent level; * = significant at the 5-percent level.

	Years	Treatments
At 5-percent level	0.71	0.81
At 1-percent level	.94	1.10

TOTAL WEIGHT OF ARRAYS

The total weight of arrays is the sum of all fibers pulled from one side of the seeds in each treatment. These weights have been summarized for the 5 years in table 16 and show that this characteristic did not vary significantly between fertilizer treatments, but the interaction of years \times treatments is highly significant, as indicated by the found F value of 4.48. In other words, fertilizer treatments did not significantly influence this character, but seasonal weather conditions caused it to vary in a highly significant manner.

TABLE 16.—Total weight of arrays (in milligrams) as influenced by fertilizer treatments and by years, Greenville, Tex., 1937-41

EXPERIMENTAL DATA						
Treatments	1937	1938	1939	1940	1941	General mean ¹
0-15-0	26.89	29.67	27.31	27.14	23.32	26.86
3-9-3	26.72	29.15	29.49	24.20	22.13	26.34
9-3-3	26.29	26.64	30.01	24.15	22.83	25.99
0-0-15	27.21	29.79	28.82	26.22	22.17	26.84
15-0-0	26.87	31.08	26.15	27.13	22.09	26.66
None	23.45	32.34	26.37	25.81	24.27	26.45
General mean ¹	26.24	29.78	28.02	25.78	22.80	26.52

ANALYSIS OF VARIANCE

Source	Degrees of freedom	Sum of squares	Mean square	F values		
				Found ²	Required at—	
					5-per-cent level	1-per-cent level
Total	179	1,842.77				
Rows	5	22.87	4.57			
Columns	5	16.57	3.31			
Treatments	5	16.98	3.40		2.71	4.10
Error a	20	87.45	4.37			
Years	4	983.77	245.91	**70.88	2.48	3.56
Years \times rows	20	72.17	3.61			
Years \times columns	20	54.50	2.73			
Years \times treatments	20	310.76	15.54	**4.48	1.70	2.11
Error b	80	277.70	3.47			

¹ Least significant difference between general means:

At 5-percent level

At 1-percent level

² ** Significant at the 1-percent level.

Years

Treatments

0.88

1.13

1.16

1.54

MAXIMUM LENGTH OF ARRAYS

The maximum length of an array is taken to be that one-eighth inch group in which the longest pull of fibers is located, and in this experiment the maximum length was not affected significantly by any fertilizer treatment as compared with the no-treatment check (table 17). In comparisons of fertilizer combinations the difference between the 0-3-3 and 3-0-3 combinations was barely significant, whereas a highly significant difference was obtained between the 0-3-3 and 0-15-0 ratios.

TABLE 17.—*Maximum length of arrays (in inches) as influenced by fertilizer treatments and by years, Greenville, Tex., 1937-41*

EXPERIMENTAL DATA

Treatments	1937	1938	1939	1940	1941	General mean ¹
0-15-0	1.275	1.337	1.281	1.287	1.313	1.290
3-0-3	1.294	1.369	1.256	1.231	1.313	1.293
0-3-3	1.250	1.350	1.231	1.231	1.319	1.276
0-0-15	1.241	1.344	1.281	1.269	1.306	1.289
15-0-0	1.275	1.356	1.263	1.225	1.331	1.290
None	1.244	1.337	1.275	1.281	1.306	1.289
General mean ¹	1.261	1.349	1.265	1.254	1.315	1.289

ANALYSIS OF VARIANCE

Source	Degrees of freedom	Sum of squares	Mean square	F values		
				Found ²	Required at—	
					5-per-cent level	1-per-cent level
Total	179	122.15				
Rows	5	.67	0.13			
Columns	5	2.61	.52			
Treatments	5	2.06	.41	1.86	2.71	4.10
Error a	20	4.36	.22			
Years	4	61.80	15.45	**48.28	2.48	3.56
Years × rows	20	4.48	.22			
Years × columns	20	8.19	.41			
Years × treatments	20	12.05	.60	*1.87	1.70	2.11
Error b	80	25.03	.32			

¹ Least significant difference between general means:

At 5-per-cent level

At 1-per-cent level

² ** Significant at the 1-per-cent level; *—significant at the 5-per-cent level.

Years	Treatments
0.016	0.016
.022	.022

When all treatments were combined, the greatest maximum length, 1.349 inches, occurred in 1938, the increase over the other 4 years being highly significant. The maximum length (1.315) in 1941 was greater than for 1937, 1939, and 1940 by highly significant mean lengths.

The F value, 1.87, found for the years \times treatments interaction in the combined analysis of variance (table 17), is significant at the 5-percent level.

TABLE 18.—Upper quartile length of arrays (in inches) as influenced by fertilizer treatments and by years, Greenville, Tex., 1937-41

EXPERIMENTAL DATA

Treatments	1937	1938	1939	1940	1941	General mean ¹
0 15 0	1.182	1.231	1.132	1.201	1.184	1.186
3 9 3	1.173	1.237	1.113	1.140	1.185	1.170
9 3 3	1.167	1.212	1.097	1.124	1.193	1.159
0 0 15	1.128	1.245	1.129	1.175	1.211	1.178
15 0 0	1.173	1.253	1.118	1.144	1.187	1.175
None	1.152	1.253	1.094	1.170	1.202	1.174
General mean ¹	1.163	1.239	1.114	1.159	1.195	1.174

ANALYSIS OF VARIANCE

Source	Degrees of freedom	Sum of squares	Mean square	F values		
				Found ²	Required at—	
					5-percent level	1-percent level
Total	179	0.513804				
Rows	5	.006231	0.001246			
Columns	5	.007534	.001507			
Treatments	5	.012417	.002483	2.64	2.71	4.10
Error <i>a</i>	20	.018794	.000940			
Years	4	.307269	.076817	**85.84	2.48	3.56
Years \times rows	20	.020352	.001018			
Years \times columns	20	.031568	.001578			
Years \times treatments	20	.041253	.002063	**2.41	1.70	2.11
Error <i>b</i>	80	.068386	.000855			

¹ Least significant difference between general means:

At 5-percent level

At 1-percent level

² **=significant at the 1-percent level.

Years

Treatments

0.014

0.017

.018

.023

UPPER QUARTILE LENGTH

The upper quartile length is approximately the length determined by commercial classification, and is defined by Richmond and Fulton (18) as "the length of the group at that point on the array which includes 75 percent by weight of the fibers, beginning with the shortest groups." They also found a close correlation between the combing length in general use by cotton breeders and the upper quartile length, indicating that the upper quartile length is a fair standard of length for any particular sample.

TABLE 19.—*Mean length of that part of cotton fiber arrays greater than an inch in length as influenced by fertilizer treatments and by years, Greenville, Tex., 1937-41*

EXPERIMENTAL DATA						
Treatments	1937	1938	1939	1940	1941	General mean ¹
0-15 0	0.989	1.043	0.947	1.007	1.035	1.004
3 0-3	.993	1.056	.924	.947	.998	.984
9-3 3	.992	1.019	.921	.933	1.013	.976
0-0-15	.963	1.064	.954	.994	1.027	1.000
15-0-0	.979	1.053	.933	.956	.984	.981
None	.977	1.052	.917	.983	1.017	.989
General mean ¹	.982	1.048	.933	.970	1.012	.989

ANALYSIS OF VARIANCE						
Source	Degrees of freedom	Sum of squares	Mean square	F values		
				Found ²	Required at—	
					5-per-cent level	1-per-cent level
Total	179	111.45				
Rows	5	1.73	0.35			
Columns	5	1.77	.35			
Treatments	5	4.85	1.00	*3.34	2.71	4.10
Error a	20	5.78	.29			
Years	4	70.08	17.52	**116.80	2.48	3.56
Years × rows	20	2.96	.15			
Years × columns	20	3.11	.16			
Years × treatments	20	8.96	.45	**3.00	1.70	2.11
Error b	80	12.21	.15			

¹ Least significant difference between general means:

At 5-percent level	Years	0.014	Treatments	0.018
At 1-percent level		.019		.025

² **=significant at the 1-percent level; *=significant at the 5-percent level.

Upper quartile lengths of arrays for this experiment, expressed as annual treatment means and as general means by treatments and by years, are given in table 18 and show no significant variations due to fertilizer treatments as compared with the no-treatment check. Between the fertilizer treatments themselves, however, the upper quartile length for the 0-15-0 fertilizer treatment was longer by a highly significant margin than for the 9-3-3 treatment.

The upper quartile length differences between years were highly significant, the mean varying from 1.239 inches in 1938 to 1.114 inches in 1939.

High significance is to be attached to the years \times treatments interaction, indicating that years had a definite effect on the way the upper quartile length reacted to different fertilizer treatments.

MEAN LENGTH OF THAT PART OF THE ARRAYS GREATER THAN ONE-HALF INCH IN LENGTH

The mean length of that part of the arrays greater than one-half inch in length showed no significant increase or decrease due to treatment when compared with the no-treatment check (table 19). The difference of 0.023 between the 0-15-0 and 15-0-0 fertilizers, however, is significant and the comparable difference of 0.028 between the 0-15-0 and 9-3-3 ratios is highly significant. These differences are comparable to those of the upper quartile length in which the 0-15-0 fertilizer treatment gave the longest fibers, whereas the 9-3-3 treatment produced the shortest, indicating that nitrogen fertilizers tend to shorten the staple length.

Differences between the mean lengths for years are highly significant, with 1938 showing the greatest mean length (1.048 inches) and 1939 the smallest (0.933 inch).

Highly significant interaction for years \times treatments is indicated in table 19 by the found F value of 3.00.

WEIGHT PERCENTAGE OF THE LENGTH GROUP IN WHICH THE UPPER QUARTILE LENGTH IS LOCATED

No significant differences between treatments, over the 5-year period, were obtained for the weight percentage of the length-group in which the upper quartile length is located. Highly significant differences between years were indicated, with extremes of 30.95 percent in 1937 and 24.98 percent in 1939 (table 20).

An analysis of variance of the weight percentage of the length-group in which the upper quartile length is located is given in table 20, in which the found F value indicates that high significance may be attached to the years \times treatments interaction.

SUMMARY AND CONCLUSIONS

The fiber characters studied in this section are supplemental to the plant development studies and are based on samples taken from the same plants.

TABLE 20.—*Weight percentage of the length-group in which the upper quartile length is located, as influenced by fertilizer treatments and by years, Greenville, Tex., 1937-41*

EXPERIMENTAL DATA						
Treatments	1937	1938	1939	1940	1941	General mean ¹
0-15-0.....	29.41	28.27	25.90	27.99	26.25	27.56
3-9-3.....	30.58	30.78	23.88	25.61	26.05	27.38
9-3-3.....	32.32	27.61	25.30	25.26	24.87	27.07
0-0-15.....	33.48	28.37	26.38	27.97	24.87	28.22
15-0-0.....	28.04	26.87	24.54	28.80	25.56	26.76
None.....	31.85	27.72	23.85	26.18	24.92	26.90
General mean ¹	30.95	28.27	24.98	26.97	25.42	27.32

ANALYSIS OF VARIANCE						
Source	Degrees of freedom	Sum of squares	Mean square	F values		
				Found ²	Required at—	
					5-percent level	1-percent level
Total.....	179	2,058.37				
Rows.....	5	23.67	4.73			
Columns.....	5	16.23	3.25			
Treatments.....	5	41.85	8.37	1.14	2.71	4.10
Error a.....	20	146.68	7.33			
Years.....	4	838.20	209.55	**37.62	2.48	3.56
Years×rows.....	20	161.83	8.09			
Years×columns.....	20	142.33	7.12			
Years×treatments.....	20	241.77	12.09	**2.17	1.70	2.11
Error b.....	80	445.81	5.57			

¹ Least significant difference between general means:

	Years	Treatments
At 5-percent level.....	1.11	1.46
At 1-percent level.....	1.47	1.99

² **=significant at the 1-percent level.

Fertilizer treatments increased the percentage of fibers less than one-half inch in length over no-treatment check, with the increases due to the 0-15-0 and 3-9-3 fertilizer treatments being significant. Highly significant differences were obtained between years, indicating that climatic conditions have a greater influence than fertilizer treatments on percentage of fibers less than one-half inch in length.

The total weight of arrays of fibers pulled from one side of the seeds in each treatment showed no significant differences between treatments. The interaction of years × treatments was highly significant and indicated a much greater seasonal influence on this characteristic than fertilizer treatments.

TABLE 21.—Summary of all fiber characteristics studied, together with the respective rank of each treatment, as influenced by fertilizer treatments and by years, Greenville, Tex., 1937-41

Treatment	Percentage of fibers less than $\frac{1}{8}$ inch in length		Maximum length		Upper quartile		Mean length		Weight percentage of the length group in which the upper quartile length is located		Total weight	
	Percent	Rank	Inches	Rank	Inches	Rank	Inches	Rank	Percent	Rank	Milligrams	Rank
None.....	10.60	1	1.289	4-5	1.174	4	0.989	3	26.90	5	26.45	4
0-0-15.....	11.14	2	1.289	4-5	1.178	2	1.000	2	28.22	1	26.84	2
15-0-0.....	11.23	3	1.290	3	1.175	3	.981	5	26.76	6	26.66	3
9-3-3.....	11.28	4	1.276	6	1.159	6	.976	6	27.07	4	25.99	6
3-9-3.....	*11.42	5	1.293	2	1.170	5	.984	4	27.38	3	26.34	5
0-15-0.....	*11.62	6	1.299	1	1.186	1	1.004	1	27.56	2	26.86	1
Mean.....	11.21	-----	1.289	-----	1.174	-----	.989	-----	27.32	-----	26.52	-----
Least significant difference at—												
5-percent level.....	.81	-----	.016	-----	.017	-----	.018	-----	1.46	-----	1.13	-----
1-percent level.....	1.10	-----	.022	-----	.023	-----	.025	-----	1.99	-----	1.54	-----

* = Significant at the 5-percent level.

The maximum length of arrays was not significantly affected by fertilizer treatments in comparison with the no-treatment check; however, highly significant increases in length were obtained in 1938 as compared to the other years.

No significant variations as a result of fertilizer treatments were found in the upper quartile length of arrays as compared with the no-treatment check, but the upper quartile length for the 0-15-0 fertilizer was longer by a highly significant degree than for the 9-3-3 fertilizer. There were highly significant differences between years, and significance also occurred in the years \times treatments interaction, indicating that the seasons had a definite effect upon the way the upper quartile length reacted to different fertilizer treatments.

No significant increase or decrease caused by treatment was found in the mean length of that part of the array greater than one-half inch in length, as compared with the no-treatment check. A significant increase in length was obtained in a comparison between the 0-15-0 and 15-0-0 fertilizers, and a highly significant increase was obtained in a similar comparison of the 0-15-0 and 9-3-3 ratios.

The weight percentage of the length group in which the upper quartile length is located likewise failed to produce significant differences between treatments, but the differences between years were highly significant. High significance, as indicated by the F value, may be attached to the interaction of years \times treatments.

A summary of the values of each treatment and their corresponding rank for each character is shown in table 21. The only character with significant differences between treatments compared with unfertilized checks was the increase in percentage of fibers less than one-half inch in length, attributable to applications of 3-9-3 and 0-15-0 fertilizers.

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