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Agricultural Experiment Station

OF THE

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AUBURN.

RESULTS OF EXPERIMENTS ON COTTON IN ALABAMA.

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INTRODUCTION.

This bulletin has been prepared at the request of the Committee of the American Association of Agricultural Colleges and Experiment Stations which has in charge the collective exhibit of the Experiment Stations at the World's Fair in Paris in 1900. The Alabama Station has been engaged in the experiments on cotton since 1883 and a large amount of valuable material has accumulated in reference to its cultivation, chemistry, botany, diseases, entomology and physiology, and because of the variety of experiments conducted it was deemed appropriate for this station to prepare this work on cotton.

During the period covered by the experiments the following bulletins have been issued by the Station that relate to cotton:

In volume 1 there are 33 bulletins and 6 of these contain the results of experiments on cotton. 122 pages.

No. 5—Cotton experiments. 16 pages.

No. 13—Microscopic study of certain varieties of cotton. 20 pages.

No. 16—Fertilizer experiments with cotton. 20 pages.

No. 17—Dry application of Paris green and London purple for the cotton worm. 18 pages.

No. 21—A new root rot disease of cotton. 11 pages.

No. 22—Experiments with cotton. 24 pages.

No. 23—Co-operative tests of fertilizers on cotton. 61 pages.

No. 27—Black rust of cotton. 18 pages.

No. 33—Cotton. 1 2pages.

No. 34—Co-operative fertilizer tests on cotton. 46 pages.

No. 36—Some leaf blights of cotton. 32 pages.

No. 40—Cotton experiments. 15 pages.

No. 41—Some diseases of cotton. 65 pages.

No. 42—Co-operative soil tests of cotton. 34 pages.

No. 45—Insects of cotton. 5 pages.

No. 52—Cotton experiments. 2 pages.

No. 55—A new disease of the cotton; cotton boll rot. 13 pages.

No. 56—Experiments in crossing cotton. 51 pages.

No. 57—Fertilizers required by cotton as determined by the analysis of the plant. 16 pages.

No. 62—Cotton experiments. 7 pages.

No. 65—Co-operative seed tests. 4 pages.

No. 69—Fungus diseases of the cotton. 1 page.

No. 71—Experiments with foreign cottons. 12 pages.

No. 76—Cotton experiments. 23 pages.

No. 78—Co-operative fertilizer experiments with cotton in 1896. 48 pages.

No. 83—Hybrids from American and foreign cottons. 32 pages.

No. 91—Co-operative fertilizer experiments with cotton in 1897. 63 pages.

No. 99—Cotton rust. 31 pages.

No. 101—Experiments with cotton in 1898. 19 pages.

No. 102—Co-operative experiments with fertilizers on cotton in 1898. 75 pages.

Climatology of the cotton plant. Issued by the United States Weather Bureau. 70 pages.

The above list comprises 37 bulletins, containing a total of 986 pages.

In the prosecution of the work indicated by the above bulletins the following parties have been more or less intimately connected with and responsible for the results of the experiments:

W. H. Chambers, Agriculturist.
W. C. Stubbs, Chemist.
J. S. Newman, Agriculturist.
J. J. Barclay, Agriculturist.
N. T. Lupton, Chemist.
P. H. Mell, Botanist and Meteorologist.
G. F. Atkinson, Mycologist.
B. B. Ross, Chemist.
A. J. Bondurant, Agriculturist.
J. M. Stedman, Mycologist and Entomologist.
J. F. Duggar, Agriculturist.
F. S. Earle, Mycologist.
J. T. Anderson, Associate Chemist.
B. M. Duggar, Assistant Mycologist.
James Clayton, Assistant Agriculturist.
T. U. Culver, Assistant Agriculturist.
A. L. Quaintance, Assistant Entomologist.
T. D. Samford, Assistant Botanist.
George Clark, Assistant Botanist.
A. M. Lloyd, Assistant Botanist and Meteorologist.

A number of experimenters located in different parts of the State who had charge of the co-operative fertilizer tests on cotton have also contributed much valuable material.

P. H. Mell,
Director.

VARIETIES OF COTTON.

BY J. F. DUGGAR.

PURPOSES OF TESTS OF VARIETIES.

Variety tests of cotton have had a prominent place at nearly every experiment station in the Cotton Belt. Although these experiments have had some value, yet they do not afford a concise answer to the question so often asked "What is the best variety of cotton?"

Nor can we expect experimenters or farmers to be able to answer this question with a single name. Such an answer is up to this time impossible, for diligent search has failed to find any one variety of cotton which is universally superior to all other kinds. The variety which affords the largest yield on one soil is surpassed on a different soil by another kind. Even on the same soil, the relative productiveness of two given varieties differs, prevailing weather conditions perhaps favoring an early variety in one year, a late kind in another season. Conditions vary, and hence the list of most productive varieties changes from year to year.

Statements of results of variety tests will prove useful in proportion as they take careful account of the conditions under which each test was made, so that we may come in time to learn what class of varieties in normal seasons may be expected to yield more than other kinds on poor soil, what sort to head the list when the soil is fertile, what kinds to prefer for localities subject to early frosts, what varieties best respond to liberal fertilization, and so on.

Another promising field of investigation in variety testing is the study of the characters of each so called variety with a view to fixing a more definite standard of purity and uniformity, the data thus obtained being also useful in determining how many of the numerous so-called varieties of cotton stand for distinct types and how many are only useless and confusing synonyms. Our observations, made on 70 so-called varieties in 1899, with a view to ascertaining what varieties are distinct and what names are mere synonyms need to be repeated before publication.

PRODUCTIVENESS OF VARIETIES.

Tests of varieties of cotton have been made on the Station Farm at Auburn nearly every year during the past decade. The list of varieties varied from year to year, thus making difficult a comparison of the productiveness of the different kinds. An examination of all these lists shows that altogether 48 varieties have been tested at Auburn on plots large enough to determine the yield per acre. The usual size of plots in recent years has been one-sixteenth acre. In addition, the list of varieties tested in 1899 on plots too small to permit an accurate determination of yield per acre contains 45 new names, making a total of 93 so-called varieties tested by the Agricultural Department of this station.

In the following table is given only the data obtained in the field tests on the farm at Auburn. It indicates the rank of each variety in each test, as shown by the yield of lint cotton per acre. When the stand of plants is known to be defective, that variety is excluded from the table. The number 1 opposite any variety shows that in the test that year this variety produced more lint than any other; so the number 2 denotes second place in production of lint, and so on for other numbers.

Rank of Varieties of Cotton on the Basis of Yield of Lint Per Acre.

	1889	1890	1891	'91*	1892	1893	1896	1897	1898	1899
Allen Long Staple	2	....	8	....	21	....	....	14	....	....
Allen Hybrid L. S.	....	....	....	....	....	....	11	16	....	....
African..	....	....	....	....	....	....	....	....	....	1
Barnett...	4	....	3	....	....	....	....	....	....	....
Bailey...	....	....	....	12	18	....	....	....	....	....
Cherry Cluster.. ..	6	....	4	....	17	....	....	....	....	....
Colthorp Pride.. .	....	....	....	....	11	7	....	....	....	....
Colthorp Eureka..	....	....	....	....	14	4	....	....	....	....
Cook, J. C.......	....	....	12	....	....	....	....	....	....	....
Cook, W. A........	....	....	4	....	24	1	....	....	....	....
Common..	....	....	....	10	....	....	....	....	....	....
Crossland..	....	....	....	....	9	....	....	....	....	....
Dalkeith Eureka..	....	....	....	....	15	10	....	....	....	....
Dearing	....	....	....	....	....	....	....	4	2	14
Dickson..	....	....	2	....	20	....	3	12	....	....
Duncan..	....	....	....	....	....	....	9	6	....	13
Ellsworth..	12	....	....	....	....	....	....	....	....	....
Gold Dust..	....	....	7	....	22	....	....	....	....	....
Griffin..	....	....	....	....	....	....	....	2	....	....
Hawkins Improved	9	....	9	....	16	....	8	3	....	3
Herlong..	....	....	6	....	23	6	13	....	....	....
Hunnicutt.	....	....	1	....	14	....	12	13	....	....
Hutchinson.. .. .	....	....	....	....	....	....	1	7	7	....
Jones Improved...	5	....	10	....	....	....	10	5	8	7
Jones Long Staple	....	....	11	....	19	5	14	....	....	....
Jones No. 1.......	....	....	....	....	17	....	....	....	....	....
Keith...	....	....	5	....	11	....	....	....	....	....
King...	10	....	....	6	8	....	5	....	....	10
Lowry...	....	....	....	....	....	....	....	....	....	12
Matthews L. Staple	....	....	....	....	7	11	....	....	....	....
Okra..	9	....	....	13	12	8	....	....	....	....
Peeler...	....	....	....	7	8	....	....	....	....	....
Peerless...	7	1	....	4	6	....	4	11	....	....
Peterkin.	....	2	....	5	1	....	7	8	3	4
Petit Gulf..	....	....	....	3	3	....	17	....	....	....
Rameses..	8	....	....	9	....	....	....	....	....	....
Russell..	....	....	....	....	....	....	....	....	1	8
Southern Hope. ..	....	5	....	8	5	....	....	....	....	....
Storm Proof.. ...	....	4	....	15	2	....	....	....	....	....
Smith Improved..	....	....	....	....	....	....	....	....	4	....
Strickland.	....	....	....	....	....	....	....	....	....	11
Truitt..	1	3	....	2	4	....	2	9	5	2
Tyler...	....	....	....	....	....	....	6	15	....	9
Texas Oak...	....	....	....	....	....	....	....	1	6	6
Welborn..	3	....	....	11	13	2	15	....	....	5
Whatley Improved	....	....	....	....	....	9	16	10	....	....
Wonderful..	....	....	....	14	16	1	....	....	....	....
Zellner..	11	....	....	1	10	....	....	....	....	....
No. varieties in test....	13	5	13	15	29	11	17	16	8	14

Size of Seed.—The data showing size of seed were obtained by taking the average of three samples of seed, each sample from a different plant.

Examining, in the above table, the records of those varieties which have been tested four or more times, we find the following facts:

The best records are apparently those of Peterkin and Truitt. Peterkin made the largest yield of lint in one test, ranked not lower than fifth in all except two tests, and never lower than eighth.

Truitt ranked from first to fifth except in one test, where it occupied the ninth place.

Inasmuch as these two varieties rank high in most tests and have been more frequently tested than any others, it is convenient to regard one of them as a standard to which the records of other varieties may be referred for comparison.

To determine which of the above named varieties shall be used in these pages as a standard, it is necessary that we examine more in detail the records made by each of these varieties in the seven expriments in which both entered:

Comparison of Varieties Peterkin and Truitt on Basis of Yield of Lint in Seven Years.

YEAR WHEN TEST WAS MADE.	Yield of lint cotton per acre.	
	Peterkin	Truitt
1890	786	783
1891	465	489
1892	338	302
1896	320	384
1897	246	245
1898	339	330
1899	427	442
Average for 7 years	417	425

The difference in the average yields of the two varieties is only 8 pounds of lint per acre, an amount too small to demonstrate that one variety is distinctly better than the other, as regards production of lint.

Both may be counted safe varieties, having never failed in our tests to make fair to excellent records.

The value of the total product is greater with Truitt, which affords a larger percentage of seed than does Peterkin. For this reason we shall use Truitt as the standard of comparison in this article.

Comparing Jones' Improved with Truitt, we find that both varieties are common to five tests, in four of which the rank of Truitt is higher than that of Jones.

Hawkins was compared with Truitt in five tests, and in four of these was defeated. Dickson invited comparison with the standard in three tests, in all of which it was surpassed. King and Truitt were compared five times, and in every instance the yield of lint was in favor of Truitt. Peerless was six times compared with this standard and only once was Peerless superior. In each of five tests Welborn was surpassed in yield of lint by Truitt. Allen Long Staple, Herlong, Hunnicutt and Jones Improved were each twice in competition with Truitt and in all cases they were beaten by this last named variety.

Each of the varieties mentioned in the preceding paragraph has one or more excellent qualities, and no one of them is unproductive. It is quite probable that under some conditions each of these would prove more productive than either of those which have made the best average at Auburn. Nor do these tests imply that Truitt and Peterkin are superior to some of the best of the recently introduced varieties, for example Russell, which, however, has been tested here only twice, or not often enough to definitely determine its value in comparison with older varieties.

VARIETIES STUDIED IN 1899.

It is extremely desirable that varieties should be classified according to their natural relations. A satisfactory classification should be of practical benefit to the farmer in protecting him against the purchase of old varieties under new names and at high prices. It would undoubtedly reduce the number of so-called varieties, of which the writer has found more than 150 mentioned in agricultural publications. The importance of the end to be attained seems to justify an endeavor to classify the varieties in the fact of the almost insuperable obstacles. The difficulties are formidable, and among them may be mentioned:

(1) The tendency of even a pure variety to vary with its environment;

(2) The multiplication of names, especially local names, of varieties; and

(3) The relatively small amount of descriptive and statistical data on record showing the character of the so-called varieties.

In 1899 the writer grew a large number of varieties with a view to obtaining correct descriptions of each and additional data regarding the characteristics of all kinds tested.

The collection consisted of 70 sorts, the seed in most cases being procured from the originator or from parties supposed to be most interested in furnishing seed pure and true to name. Nevertheless there was in a number of varieties great diversity as between individual plants. To overcome this, as far as possible, selection was made in each variety of those plants which showed decided similarity in habit of growth and form of stalk, and which evidently represented the prevailing type. Later, from this number of selected plants were chosen the best three plants, as nearly as could be judged by the eye; these three twice-selected plants furnish the data as to size of plants, bolls, seed, etc., and the most representative of the three was photographed for use in this article.

With the small plots,—which were necessitated by the large number of varieties,—and with the small number of selected plants, it was impracticable to secure any reliable data relative to the yield of each kind.

A part of the data obtained from the selected plants of each sort are recorded in the tables which follow. Frequently the three samples from which an average was in all cases made were not entirely accordant. When the failure to agree was considerable, the samples were re-weighed.

The data which appear in the following table represent the characteristics of the several varieties as they revealed themselves under the conditions of a test made here in 1899, on sandy upland soil, well fertilized with commercial fertilizers, and with the plants allowed ample space on every side. Weather conditions were unfavorable, drougth doing considerable injury. Planting was done at a late date, May 8. It is not necessarily true that in other years or under different soil and weather conditions the data secured would exactly correspond with those obtained in 1899. Such tests as this need to be several times repeated so as to obtain averages of maximum value.

Illustrations showing representative plants of nearly every variety grown here in 1889 may be seen in plates I to XII. The last plate shows the appearance and relative size of an average full-grown but unopened boll of each variety. The entire credit for all illustrations is due to the Director, P. H. Mell, who made all the photographs.

The following 24 varieties may be considered as having large bolls, that is, requiring only 50 to 65 bolls to make a pound of seed cotton:

Banks, Cheise, Christopher, Coppedge, Culpepper, Cummings, Drake, Duncan, Ellis, Griffin, Japan, Jones Improved, Lee, Maddox, Nancy Hanks, Peerless, Pruitt, Russell, Scroggins, Sprueill, Strickland, Texas Storm Proof, Thrash, and Truitt.

Weight of Seed Cotton in 100 Bolls and Number of Bolls Required to Make One Pound of Seed Cotton.

VARIETY.	Wght. 100 boll contents. Lbs	No. bolls per lb seed cotton	VARIETY.	Wgt. 100 boll contents. Lbs	No. bolls per lb. seed cotton
Cheise Improved	2.00	50	W. A. Cook...	1.37	73
Texas Storm Proof.....	1.97	50	Doughty....	1.37	73
Drake....	1.80	56	Big Boll..	1.33	75
Strickland..	1.80	56	Minor....	1.33	75
Banks....	1.77	57	Texas Oak..	1.33	75
Russell..	1.73	58	Mattis....	1.30	77
Lee Improved..	1.70	59	Hawkins..	1.30	77
Japan....	1.70	59	Hawkins Jumbo..	1.30	77
Christopher Improved..	1.67	60	Hilliard...	1.30	77
Culpepper..	1.67	60	Pinkerton....	1.30	77
Peerless..	1.64	61	Petit Gulf..	1.30	77
Thrash Select..	1.64	61	Allen Impd. L. S......	1.30	77
Truitt..	1.64	61	Bur...	1.27	79
Jones Improved (Alexander)..........	1.64	61	King...	1.23	81
			Lowry......	1.23	81
Jones Imp'd (Curry)..	1.60	63	Texas Wood....	1.23	81
Ellis....	1.60	63	Cobweb..	1.23	81
Duncan....	1.57	64	Improved L. S....	1.23	81
Scroggins Prolific.. ..	1.57	64	Jackson African (Alexander)........	1.23	81
Nancy Hanks..	1.57	64			
Norris..	1.57	64	Moon....	1.20	83
Pruitt Premium	1.57	64	Welborn..	1.17	86
Maddox..	1.57	64	Tyler Limb Cluster....	1.17	86
Cummings..	1.53	65	Allen Hybrid L. S.....	1.17	86
Sprueill..	1.53	65	No. 12 [(?) Herlong]..	1.13	89
Coppedge..	1.53	65	Borden Prolific..	1.13	89
Griffin....	1.53	65	Wise....	1.13	89
Parks Own..	1.50	67	Peterkin..	1.10	91
Grayson Big Boll......	1.47	68	Dickson..	1.07	94
Gunn....	1.47	68	Boyd Prolific....	1.07	94
Matthews L. S........	1.47	68	Shine Early..	1.07	94
Texas Bur..	1.40	71	Dearing..	1.07	94
Smith Improved..	1.40	71	Norris....	1.07	94
Jackson Limbless (U. S. Dept. Agriculture....	1.40	71	Bates Poor Land.. ...	1.03	96
			Excelsior......	.87	111
Herndon Select..	1.40	71	Sea Island....	.77	130

The following 21 varieties have bolls of medium size, from 65 to 80 being required to make one pound of seed cotton:

Allen Improved, Big Boll, Bur, W. A. Cook, Doughty, Grayson Big Boll, Gunn, Hawkins, Hawkins Jumbo, Herndon, Hilliard, Jackson Limbless, Matthews Long Staple, Mattis, Minor, Parks, Petit Gulf, Pinkerton, Smith Improved, Texas Bur and Texas Oak.

The small boll varieties, or those requiring from 80 to 130 bolls to make a pound of seed cotton, numbered 22, and were as follows:

Allen Hybrid, Bates Poor Land, Borden, Boyd, Cobweb, Dearing, Dickson, Excelsior, No. 12 (the so-called Herlong), Improved Long Staple, Jackson African, King, Lowry, Moon, Norris, Peterkin, Sea Island, Shine Early, Texas Wood, Tyler, Welborn and Wise.

SIZE OF SEED.

The data showing size of seed were obtained by taking the average of three samples of seed, each sample from a different plant.

Average weight of cotton seed of each variety.

Variety	Grams.	Variety	Grams.
Duncan	16.64	Nancy Hanks	12.42
Banks	15.98	Cummings	12.34
Texas Storm Proof	15.98	Jones	12.34
Russell	15.74	Sprueill	12.34
Allen Improved	15.64	Cobweb	12.32
Thrash	15.52	Griffin	12.10
Drake	15.30	Bur	11.98
Ellis	15.20	Moon	11.70
Maddox	15.12	Allen Hybrid	11.56
Strickland	15.08	Lowry	11.54
Cheise	14.82	Minor	11.24
Culpepper	14.78	King	10.96
Christopher	14.50	Mattis	10.86
Coppedge	14.32	Petit Gulf	10.78
Lee	14.32	Jackson (African) from Alexander	10.54
Scroggins	14.18	Jackson Limbless from U. S. D. A.	10.46
Matthews L. S.	14.06	Texas Oak	10.34
Truitt	13.78	Hawkins	10.30
Sea Island	13.74	Shine	10.16
Jones	13.62	Peterkin	10.08
Peerless	13.54	Borden	10.04
Grayson	13.44	Welborn	10.04
Japan	13.44	No. 12 (? Herlong)	9.96
(?) Pruitt Premium	13.44	Dickson	9.94
Doughty	13.26	Pinkerton	9.74
Texas Wood	12.96	Boyd	9.54
Hilliard	12.96	Dearing	9.50
Cook (W. A.)	12.80	Peterkin	9.24
Gunn	12.70	Excelsior	9.10
Improved Long Staple	12.68	Texas Wood	8.72
Parks	12.66	Tyler	8.36
Smith Improved	12.64	Wise	8.28
Norris	12.62	Bates (Poor Land)	8.16
Texas Bur	12.52		
Big Boll	12.48		
Hawkins Jumbo	12.44		

If we would describe the seed as large, medium and small, an arbitrary division of varieties becomes necessary. The first 25 varieties in the above list, having seed weighing more than 13 grams per hundred, may be regarded as having large seed. Seed weighing 10.5 to 13 grams per 100 may be classed as medium in size, and those weighing 8 to 10.5 grams per hundred as small seed.

PROPORTION OF LINT TO SEED COTTON.

The following table gives the percentage of lint in the seed cotton of each variety. The figures are average results obtained by carefully handpicking samples of seed cotton from three plants of each variety and weighing the lint and seed on chemical balances.

VARIETY.	Per cent. lint.	VARIETY.	Per cent lint.
Pinkerton	38.6	Dickson	32.1
Bates (Poor Land)	37.6	Lowry	31.9
Borden	37.5	Scroggins	31.9
Wise	37.0	Lee	31.7
Thrash	36.2	Gunn	31.6
Peterkin (26 S.)	35.[illegible]	Shine	31.6
Texas Wood	35.4	Mattis	31.5
Peterkin (26 N.)	35.1	Jones Improved	31.4
Hawkins	35.0	Jones Improved	31.3
Jackson	34.5	Norris	31.2
Jackson	34.4	Russell	31.2
Minor	34.4	Cummings	31.1
No. 12 (? Herlong)	34.1	Ellis	31.1
Cheise	33.7	Hawkins Jumbo	31.1
Pruitt Premium (?)	34.0	Grayson	30.8
Sprueill	33.8	Petit Gulf	30.7
Parks	33.7	Banks	30.6
Nancy Hanks	33.6	Smith Improved	30.5
King	33.3	Drake	30.3
Tyler	33.2	Truitt	30.3
Maddox	33.1	Duncan	30.0
Texas Storm Proof	33.1	Texas Bur	29.9
Boyd	33.0	Cobweb	29.7
Welborn	32.9	Japan	29.7
Peerless	32.9	(?) Dearing	29.6
Bur	32.8	Strickland	29.6
Excelsior	32.8	Griffin L. S.	29.2
Hilliard	32.8	Herndon	29.1
Coppedge	32.8	Improved Long Staple	28.3
Moon	32.7	Doughty L. S.	28.2
Culpepper	32.5	Allen Hybrid L. S.	26.9
Christopher	32.4	Allen Improved L. S.	26.7
Texas Oak	32.4	Matthews L. S.	27.6
Big Boll	32.1	Sea Island	25.9
		Cook (W. A.) L. S.	25.8

In the list of varieties having at least 35 per cent. of lint there are only 9 names, all of these except Thrash being closely related varieties and in many respects resembling Peterkin. Only 14 names occur in the list of those having less than 30 per cent. of lint, most of these being long staple kinds. This leaves two-thirds of the varieties here tested in the class that has 30 to 35 per cent. of lint.

NUMBER OF FORMS PER PLANT AND TIME OF MATURING OF VARIETIES.

In order to ascertain the relative earliness of the varieties grown here in 1899, a count was made Oct. 9-11, of all bolls then open and also of all immature "forms," including blooms and unopened bolls of all sizes. The following table gives the data obtained by counting the "forms" on three plants of each variety, the percentage of open bolls being obtained by taking the total number of mature and immature forms as 100:

Average number of blooms, bolls and open burs and percentage of open bur, October 9–11, 1899.

VARIETY.	No forms per plant.	Per cent open bolls	VARIETY.	No forms per plant.	Per cent. open bolls
Nancy Hanks	47	100	Peterkin (26 N.)	44	80
Texas Wood	40	100	Dickson	48	79
Borden	36	97	Grayson	38	79
Griffin	40	97	Pinkerton	43	79
Parks	34	97	Banks	32	78
(?) Dearing	37	95	Culpepper	30	77
Boyd	55	94	Duncan	38	77
Norris	32	94	Jones Impd. (from Alexander)	29	76
Smith	32	94	Mattis	63	76
Shine	48	92	Excelsior	52	75
Texas Bur	24	92	Hilliard	40	75
Hawkins Jumbo	34	91	Russell	35	75
Peterkin (26 S.)	46	91	Maddox	39	74
Moon	31	90	Wise	39	74
Bur	34	89	Improved Long Staple.	49	73
Lowry	36	89	Herndon	41	71
Minor	47	89	Hawkins	33	70
No. 12 [(?) Herlong]	28	88	Texas Storm Proof	26	70
Gunn	28	86	Peerless	43	69
Texas Oak	29	86	Cook (W. A.)	52	67
Drake	40	85	Matthews	36	64
Coppedge	48	85	Sprueill	31	64
Pruitt Premium	34	85	Thrash	39	62
Ellis	25	84	Welborn	55	62
Big Boll	37	84	Cummings	62	58
Cheise	25	84	Strickland	23	56
Allen Hybrid	54	84	Tyler	35	50
Bates (Poor Land)	38	83	Jackson African (Alexander)	43	42
King	43	82	Lee	45	36
Jones Impd. (from Curry-Arrington)	40	82	Christopher	39	35
Truitt	33	82	Jackson Limbless (U. S. D. A.)	51	29
Japan	37	81	Sea Island	95	23
Cobweb	54	80			
Doughty	40	80			

Not only was the proportion of mature and immature fruit determined by counting, but field notes were made indicating the earliness of the variety as judged by appearances only. These notes show that the data in the tables do not constitute safe guides for dividing varieties into groups of early, medium and late maturity; the table is of greater use in showing what varieties would be most injured by early frost, which under the conditions of this test would have been those that occupy a position low down in the table. For example Welborn, although an early variety (in the sense of affording a heavy picking early in the season) had nevertheless about one-third of its forms in immature condition on October 11. A still more notable instance of large proportion of immature forms as late as October 11 is afforded by the Jackson.

An examination of this table shows that the following 27 varieties averaged 40 or more mature and immature forms per plant, those producing the largest number being placed first:

Sea Island, Mattis, Cummings, Welborn, Allen Hybrid, Boyd, Cook (W. A.), Cobweb, Excelsior, Jackson, Improved Long Staple, Shine, Coppedge, Dickson, Minor, Nancy Hanks, Peterkin, Lee, Peerless, King, Pinkerton, Herndon, Hilliard, Jones, Drake, Griffin and Texas Wood.

Those varieties on which the total number of forms averaged less than 30 were only 8, viz: Strickland, Texas Storm Proof, Cheise, Ellis, Texas Oak, Gunn, No. 12 (so-called Herlong), and Texas Bur.

More than half of the varieties in this test averaged from 30 to 40 blooms, bolls, and mature fruit on October 9-11, 1899.

Of course the number of fruit forms produced by the plant during the entire season of growth was much greater than the figures above would show, for the count did not include the large number of blooms and bolls which had been shed, as the result of very unfavorable weather conditions.

As judged by the eye the varieties were classed in the field with reference to time of maturity, as follows;

Very early.	*Early.*	*Early to medium.*	*Medium.*	*Medium to late.*	*Late.*	*Very late.*
Dickson,	Borden,	Cummings,	Griffin,	Big Boll,	Allen Hybrid,	Cheise,
Dearing,	Bur,	Drake,	Hawkins Jumbo,	Culpepper,	Banks,	Japan,
King,	Bates Poor Land,	Herndon,	Minor,	Hilliard,	Christopher,[1]	Thrash,
Lowry,	Hawkins,	Jackson African.	Texas Oak,[1]	Jones.	Coppedge,	Improved Long Staple,
Nancy Hanks,	Peerless,	Jackson Limbless,	Texas Bur,	Norris,	Cobweb,	Sea Island.
Parks.	Shine Early,	Sprueill.	Wise.	Peterkin Limb Cluster.	W. A. Cook,	
	Smith Improved,	Welborn,		Peterkin,	Duncan,	
	Texas Wood.			Pruitt,	Doughty L. S.	
				Truitt,	Excelsior,[1]	
				Tyler.	Ellis,	
					Grayson,	
					Gunn,	
					Jones Improved.	
					Mattis,	
					Maddox,	
					Moon,	
					Matthews L. S.	
					Pinkerton,	
					Petit Gulf,	
					Russell,	
					Scroggins,	
					Strickland,	
					Texas Storm Proof	

CORRELATION OF CHARACTERS IN VARIETIES OF COTTON.

One of the ends in view in making this detailed statistical study of varieties was to learn what qualities are correlated, or what characters we may expect to find combined in one variety and what qualities are antagonistic or usually not to be found united in the same variety. This question has a decidedly practical bearing for the conclusion reached by such studies should afford a means of correctly interpreting the results of variety tests. Knowledge of the characteristics of varieties should also enable the farmer more intelligently to choose the kind of cotton best suited to his conditions. A knowledge of qualities that may easily be united in the same plant and of those that are antagonistic should be of supreme value to the plant breeder who endeavors to intelligently originate varieties having certain definite characters.

A study of preceding tables shows that in general there is a fairly constant relation between the size (weight) of boll contents and the weight of 100 seed. Large seed are usually from varieties having large bolls, and *vice versa*. For proof of this assertion let the reader notice that of the 25 varieties classed as producing heavy seed, nearly all are also to be found in the list of large boll varieties. With one possible exception (Grayson) this is true of all short staple kinds under test. Apparently this law has little, if any, application to the long staple varieties, for Matthews, Doughty, Allen Improved and Sea Island,—all having long staple,—produce large seed though bearing bolls of medium or small size.

Further study of the tables shows that most small seed varieties, whether of Peterkin, Cluster, or other type, bear small bolls.

These investigations afford no answer to the question whether *within a given variety* the seeds average heavier in large bolls than in small. Is the superiority in weight of large bolls over small bolls of the same variety chiefly due to heavier, more completely developed seed or to their greater number? This question invites further study. Our work thus far leads to the conclusion that among short staple varieties those that bear large bolls are usually those that bear large seed.

The writer has compiled a table showing the percentage of lint afforded by every variety in the tests published by American Experiment Station prior to 1895. That compilation showed clearly that long staple varieties yield but a low percentage of lint. The results obtained in our collection of 70 varieties in 1899 affords additional evidence that great length of staple is antagonistic to a large proportion of lint. For example, all long staple varieties in this test yield less than 30 per cent. of lint, while only two or three of the short staple varieties tested show such a small proportion of lint.

Let us examine the several tables which precede this paragraph in order to ascertain whether the size of the seed has any relation to the percentage of lint. We are so accustomed to obtaining a large percentage of lint with Peterkin, a variety having very small seed, that we involuntarily associate small seed with great outturn of lint. This does seem to be the general rule, but there are possibly exceptions, as in the case of Thrash and the so-called Dearing of this test.

Small seed are usually an indication of a large percentage of lint.

PROVISIONAL CLASSIFICATION OF AGRICULTURAL VARIETIES.

Agricultural varieties of cotton are far from showing fixed characteristics. Moreover, the points of difference between any two extreme plants within one variety are

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often greater than the dissimilarity between the average plants of two closely related varieties. Hence the impossibility of accurately separating varieties according to single definite qualities, as form of stalk alone, size of bolls alone, etc.

Instead, it seems best to arrange the varieties into groups on the basis of general resemblance in several characters.

The following attempt to arrange the varieties grown here in 1899 is merely a provisional classification, to be modified as future investigations may suggest.

The short staple or upland varieties of cotton may conveniently be divided into six classes, and to these may be added the long staple upland varieties as a seventh. I would propose for each of these general classes a name giving, when practicable, an idea of the manner of growth of the plant, and with each class name would associate the name of some distinct and well known variety as a type or standard. I shall designate these classes as

(1) Cluster varieties, or Dickson type.
(2) Semi-cluster varieties, or Peerless type.
(3) Rio Grande varieties, or Peterkin type.
(4) Short Limb varieties, or King type.
(5) Big Boll varieties or Duncan type.
(6) Long Limb varieties, or Petit Gulf type.
(7) Long Staple Upland varieties, or Allen type.

The lines of demarkation between these groups are not always clear and distinct; one group often merges into another by almost imperceptible gradations, just as is the case with related varieties.

Below is given a list of the varieties (as grown here in 1899), which are included under these several groupings, and also a general description of the varieties composing each class. Varieties of which the classification, according to this scheme, is doubtful are named in a separate list, or are discussed in connection with the class to which they seem to bear the greatest resemblance. Further work will be done with a view to improving the classification and to more definitely determining the group to which each variety belongs.

CLASS I—CLUSTER VARIETIES, OR DICKSON TYPE.

The transition between this and the next succeeding class is so gradual that any other than arbitrary division is impossible. In this first class we include of the varieties grown here in 1899 only Dickson, Jackson (Jackson's African or Limbless) and Welborn.

With all these the most striking characters are (1) the absence of long wood limbs except at the base, and (2) the tendency of the bolls to grow in clusters, or in twos or threes from the same node of the stem or limb. The plants are usually tall, slender, and erect, though often bent down by the weight of bolls growing at the upper extremity of the main stem. The few base limbs are often long. The bolls and seed are usually small, but may be of medium size;—the seed are thickly covered with fuzz, which is usually whitish, with little or no brownish or greenish tinge.

As to the time of maturity these varieties must be classed as early, for though they sometimes make a second growth of bolls in the top of the plant which may fail to mature, they afford a large proportion of their total crop at the first picking. In earliness they are surpassed by the varieties of the King type (Class IV.)

In per centage of lint they present no striking peculiarity, seldom equalling in this respect the Rio Grands and usually ranging between 32 and 34 per cent. lint.

CLASS II—SEMI-CLUSTER VARIETIES, OR PEERLESS TYPE.

Here we include Boyd, Cummings, Drake, No. 28 N. (doubtfully labeled Dearing), Hawkins Prolific, Hawkins Jumbo, Herndon, Minor, Norris and Tyler.

These varieties have in less marked degree some of the qualities which distinguish Class I, being erect and having bolls more or less in clusters. Along the main stem are very short limbs above the base limbs, which latter are usually of medium length. In size of bolls and size of seed and percentage of lint there is considerable diversity among these varieties. The seed are usually of medium size, well covered with fuzz, except Tyler (which in this respect somewhat resembles Peterkin and may perhaps claim a place in Class III); fuzz of many shades, whitish, greenish, or brownish. These varieties are early or medium in time of maturity.

CLASS III—RIO GRAND VARIETIES, OR PETERKIN TYPE.

In this class we place Peterkin, Peterkin Limb Cluster, Texas Wood and Wise.

The characters which most distinctly mark this class are:

(1) The large proportion of lint, usually 35 per cent. or more of the weight of seed cotton, and

(2) Seeds that are bare of fuzz or nearly so, except at the tip end.

The plants are well branched, and usually, on upland soil, of medium size. The bolls are small and the nearly bare black seed are quite small. In time of maturing these varieties are usually neither very early nor extremely late.

The following varieties may perhaps be classed here to advantage, though in one or more respects they differ so widely from the type that they require further study before they can be positively assigned to this class:

Bates Poor Land, Borden, Excelsior, Pinkerton, Texas Oak, Tyler.

The low percentage of lint would seem to exclude all these except Bates, Borden and Pinkerton, and all six of the varieties in this list have fuzz, usually thin or brownish, on the seed. In small size and in the absence of any shade of green on the seed they all resemble Peterkin.

The following varieties have been mentioned in a work on cotton as related to Rio Grand, viz: Dearing and Shine, but in per cent. of lint and in some other respects they in 1899 differ widely from Peterkin, which we have taken as the type of this class.

CLASS IV—SHORT LIMB VARIETIES, OR KING TYPE.

King and Lowry constitute the basis of this group. Both are early, indeed the earliest varieties ever tested by the writer.

The plants are small and well branched near the top as well as at the base. The limbs are short, the bolls small, the seed medium in size, and thickly covered with fuzz, usually brownish, though a greenish shade is often visible. The percentage of lint is usually 32 to 34.

In the field Parks and the kind furnished us under the (probably incorrect) name of Herlong were not distinguishable from King, and we think that both these varieties belong here. Shine has some claims to a position in this group.

CLASS V—BIG BOLL VARIETIES, OR DUNCAN TYPE.

To this group we would assign:

Banks, Christopher, Coppedge, Culpepper, Duncan, Grayson, Jones Improved, Lee, Russell, Scroggins, Strickland, Texas Storm Proof, Thrash, Truitt and its equivalent, sent to us as Pruitt Premium.

The large bolls and large seed and late growth of Maddox seem to place it here, though its nearly bare seed are at variance with all the varieties above. The large bolls and seed characters of Sprueill and Japan would bring these two varieties to this group, but in 1899 these two matured too early to be ranked alongside of the late varieties in the list above.

The character which especially distinguishes this class is the large size of bolls, of which only 51 to 68 are required to yield a pound of seed cotton. Other specially notable qualities are late maturity and vigorous growth of stalk. The seed are large or very large, and covered usually (Maddox being an exception) with a thick fuzz, generally brownish white or whitish, a part of the seed of many of these varieties being covered with a deep green fuzz. The per cent. of lint often runs rather low and is usually between 30 and 33. The bolls are never clustered; in some varieties the upper limbs are so short as to give the top of the plant the erect, slender appearance which is common among semi-cluster varieties.

CLASS VI—LONG LIMB UPLAND VARIETIES, OR PETIT GULF TYPE.

Ellis, Gunn, and Petit Gulf find a place in this class. Cheise may be classed here, though it has also some of the qualities of the Big Boll group.

The varieties in this class grow to large size and have long limbs, the plants presenting a straggling appearance or marked want of compactness. The bolls and seed are both of medium to large size, the latter covered with fuzz of various shades. The per cent. of lint is low or medium. This class seems poorly suited to upland soils, and indeed, as grown here in 1899, does not impress one as pre-eminent in any specially valuable qualities.

CLASS VII—LONG STAPLE VARIETIES, OR ALLEN TYPE.

This group includes Allen Hybrid, Allen Improved, Cobweb, Cook (W. A.), Doughty, Griffin, Improved Long Staple (from Holloway), Matthews and Moon.

The length of staple is the distinguishing characteristic. The lint usually measures 1 3-16 to 1$\frac{3}{8}$ inches in length, or 30 to 35 millimeters. An almost invariable accompaniment to great length of staple is a low proportion of lint, which in all varieties of this class tested here, except Moon, has been less than 30 per cent.

The plants grow to large size, have limbs of great length, and usually present a straggling appearance, though in some varieties only the base limbs are long, the upper limbs bearing a number of bolls close to the main stem, and giving the upper portion of the plant the appearance of great prolificacy.

The bolls are not very large, but are long, slender, tapering to a sharp point. All of these long staple varieties are late in maturing a crop.

The seed are of medium to large size, usually densely covered with fuzz, from which all trace of green is absent, the color being almost pure white, or in some varieties of a brownish tint. In some varieties, as with all the seed of Cobweb and with a small proportion of the seed of Cook as grown here in 1899, the fuzz is absent, and the seed bare, these naked seeds being distinguishable from Peterkin by their larger size. If the length of staple in these long staple inland varieties were the results of hybridization between the Sea Island

and the ordinary short staple upland varieties we should expect the hybrid more frequently to inherit the naked or bare seed from its Sea Island parent.

LIST OF UNCLASSIFIED VARIETIES.

In addition to the varieties enumerated in the seven classes before named, we grew in 1899 the following varieties which must remain unclassified until the observations intended to ascertain their characteristics can be repeated:

Bur, Texas Burr, Big Boll (from Holloway), Japan, Mattis (a large boll straggling variety, with bare seed), Nancy Hanks and Smith Improved.

CHOICE OF VARIETIES.

No one variety can be universally recommended. A knowledge of the characteristics of each variety may sometimes aid a farmer in the selection of a kind suited to his conditions. For example, in the extreme northern portion of the cotton belt, where the growing season is short, earliness is one of the qualities desired. In addition to some good new varieties we find in the list of the very early, early, and medium early varieties on page 200 the names of the following well known kinds, King, Welborn, Dickson and Peerless, which are among the safe varieties for localities where the growing season is short.

For late planting, even in lower latitudes, early varieties are preferable.

Other qualities besides earliness which must be taken into consideration in choosing a variety are ease of picking, ability to withstand unfavorable weather without excessive shedding of forms, relative resistance to rust, tendency to produce a clean or trashy cotton, relative freedom from boll rot, etc. The writer's observation is that the varieties bearing bolls in clusters are apt to shed a larger proportion of their forms than those with a greater development of limbs. This probably implies that a grower of a cluster variety should be even more careful than other cotton planters to give frequent and thorough cultivation so as to avoid the excessive drying of the soil which occurs very rapidly while an unbroken crust covers the ground, and which condition of dryness often increases the tendency to shedding of forms.

Ease of picking is usually in proportion to the size of the bolls. Another factor is the character of the burs, which in some varieties offer special difficulties to clean and rapid picking. Varieties having this character are often termed "storm proof," in recognition of their relative resistance to the blowing out or beating out of the cotton by wind or rain. This quality is of doubtful advantage since it is directly opposed to ease of picking. Moreover, notes made on all these varieties in the field showed that the varieties offering considerable resistance to clean picking were by no means exempt from having a part of the seed cotton blown or beaten out by wind and rain.

As a rule, extreme length of limbs and want of compactness in the plant is undesirable. It is not the variety of straggling appearance that heads the list in productiveness.

For upland soils the long staple varieties are scarcely to be considered, for they require good, moist soil, are less productive than the short staples, and generally mature late.

Neither our tests nor those made elsewhere point to any one variety as absolutely the best. The farmer who would make use of our results can do so only by deciding for himself whether for his conditions he needs an early or late, a cluster or limbed, a large seed or small seed variety; and then, having decided on the kind of cotton he wishes, he should note all the varieties that we have included on previous pages in the class which he prefers. The rank of all the varieties of this class as regards productiveness or other qualities he can study with the aid of the tables given in this article. In nearly any class he may select he will find several varieties of about equal value, for the difference in productiveness between any two pure, well established varieties of the same type is far less than is generally supposed.

Let us consider carefully what particular characters or qualities are best adapted to a given soil and method of cultivation; then there is no danger of going far wrong, whichever one of the well established varieties of this class may be chosen.

EXPLANATION OF PLATES.

PLATE X—An accident caused the failure to present an illustration of the Truitt plant; however, see figure in Plate X, showing Pruitt Premium, which is identical with Truitt and which probably owes its name originally to an error in spelling.

2. Peerless.
3. Cummings.
4. Drake.
5. Mattis.
6. Dickson.
7. Boyd.
8. Lee.
9. Welborn.
10. Jackson Limbless, from U. S. Dept. Agr.
11. Jackson African, from Alexander Seed Co.
12. Seed incorrectly labeled Herlong.
13. Tyler.
14. Scroggins.
15. Christopher.
16. Herndon.
17. King.
18. Lowry.
19. Parks.
20. Sprueill.
21. Grayson.
23. Hawkins Prolific.
24. Hawkins Jumbo.
25. Nancy Hanks.
27. Peterkin Limb Cluster.
28. Dearing.
29. Texas Wood.
30. Wise.
31. Culpepper.
32. Strickland.

33. Norris.
34. Pinkerton.
35. Pruitt.
36. Ellis.
37. Jones Improved.
38. Bates Poor Land.
39. Bur.
40. Texas Bur.
41. Minor.
42. Smith Improved.
43. Petit Gulf.
44. Texas Oak.
45. Matthews Long Staple.
46. Griffin Long Staple.
47. Allen Hybrid Long Staple.
48. Allen Improved Long Staple
49. W. A. Cook Long Staple.
50. Doughty Long Staple.
51. Moon Long Staple.
52. Cobweb Long Staple.
53. Improved Long Staple.

26 S. Peterkin.
27 S. Gunn.
28 S. Excelsior.
29 S. Hilliard.
30 S. Shine.
31 S. Culpepper.
32 S. Banks.
33 S. Norris.
34 S. Pinkerton.
35 S. Pruitt Premium.
36 S. Big Boll.
37 S. Jones Improved.
38 S. Cheise.
39 S. Borden.
40 S. Maddox.
41 S. Coppedge.
42 S. Japan.
43 S. Sea Island.
44 S. Texas Storm Proof.

WHERE TO OBTAIN SEED.

As this Station has no seed for sale or distribution, the following list of parties supplying us with seed is given, so that intending purchasers may know where seed of each variety can be obtained:

Allen Hybrid, from J. B. Allen, Port Gibson, Miss.

Allen Improved, from J. B. Allen, Port Gibson, Miss.

Banks, from W. H. Banks, Newnan, Ga.

Bates Poor Land, from R. Bates, Jackson Sta., S. C.

Big Boll, from Holloway Seed & Grain Co. Dallas, Tex.

Boyd Prolific, from R. Frotscher, New Orleans, La.

Bur, from R. Frotscher, New Orleans, La.

Cheise, from Holloway Seed & Grain Co., Dallas, Tex.

Christopher, from R. H. Christopher, Asbury, Ga.

Cobweb, from W. E. Collins, Mayersville, Miss.

W. A. Cook, from W. A. Cook, Newman, Miss.

Coppedge, from C. S. Coppedge, Nyson, Ga.

Culpepper, from J. E. Culpepper, Luthersville, Ga.
Cummings, from T. A. Whatley, Opelika, Ala.
Dearing, from H. P. Jones, Herndon, Ga.
Dickson, from Curry-Arrington Seed Co., Rome, Ga.
Doughty, from Curry-Arrington Seed Co., Rome, Ga.
Drake Cluster, from M. W. Johnson Seed Co., Atlanta, Ga.
Duncan, from M. W. Johnson Seed Co., Atlanta, Ga.
Ellis, from G. B. Ellis, Palalto, Ga.
Excelsior, from C. F. Moore, Bennettsville, S. C.
Grayson Big Boll, from W. B. Grayson, Grayson, La.
Griffin, from John Griffin, Greenville, Miss.
Gunn, from C. S. Gunn, Temple, Miss.
Hawkins Improved, from W. B. Hawkins, Nona, Ga.
Hawkins Jumbo, from W. B. Hawkins, Nona, Ga.
Herlong, from Curry-Arrington Seed Co., Rome, Ga.
Herndon Select, from S. J. Thornton, Coldwater, Ga.
Hilliard, from W. A. Hilliard, Bowersville, Ga.
Improved Long Staple, from Holloway Seed & Grain Co., Dallas, Tex.
Jackson African, from Alexander Seed Co., Augusta, Ga.
Jackson Limbless, from Division of Botany, U. S. Dept. Agriculture.
Japan, from Holloway Seed & Grain Co., Dallas, Tex.
Jones Improved, from Alexander Seed Co., Augusta, Ga.
Jones Improved, from Curry-Arrington Seed Co., Rome, Ga.
King, from H. P. Jones, Herndon, Ga.
Lee Improved, from E. E. Lee, Wildwood, Ala.
Lowry, from J. G. Lowry, Cartersville, Ga.
Maddox, from J. S. Maddox, Orchard Hill, Ga.
Matthews Long Staple, from J. A. Matthews, Holly Springs, Miss.

Mattis, from C. F. Mattis, Learned, Miss.

Minor, from J. D. Minor, Meriwether, Ga.

Moon, from J. M. Moon, Peytonville, Ark.

Nancy Hanks, from Curry-Arrington Seed Co., Rome, Ga.

Norris, from H. H. Steiner, Grovetown, Ga.

Park's Own, from G. F. Park, Alexander City, Ala.

Peerless, from M. W. Johnson Seed Co., Atlanta, Ga.

Peterkin, from J. A. Peterkin, Fort Motte, S. C.

Petit Gulf, from H. C. Prevost, New Orleans, La.

Pinkerton, from H. R. Pinkerton, Eatonton, Ga.

Russell Big Boll, from G. F. Park, Alexander City, Ala.

Sea Island, from Alexander Seed Co., Augusta, Ga.

Scroggins Prolific, from J. T. Scroggins, Luthersville, Ga.

Shine Early, from J. A. Shine, Shine, N. C.

Smith Improved, from A. J. Smith, Conyers, Ga.

Sprueill, from A. M. Sprueill, Brompton, Ala.

Strickland, from Curry-Arrington Seed Co., Rome, Ga.

Texas Bur, from Alexander Seed Co., Augusta, Ga.

Texas Oak, from M. G. Smith, Lightfoot, Ga.

Texas Storm Proof, from W. J. Smiley, Baileyville, Tex.

Texas Wood, from D. F. Miles, Marion, S. C.

Thrash Select, from E. C. Thrash, Silvey, Ga.

Truitt, from Curry-Arrington Seed Co., Rome, Ga.

Tyler Limb Cluster, from Alexander Seed Co., Augusta, Ga.

Welborn Pet, from M. W. Johnson Seed Co., Atlanta, Ga.

Wise, from H. P. Jones, Herndon Ga.

PREPARATION AND CULTIVATION OF THE SOIL FOR COTTON.

BY J. F. DUGGAR.

The manner of preparing the seed bed for cotton varies greatly, being chiefly dependent on the amount of clay, sand, and vegetable matter in the soil. If commercial fertilizers are used preparation may be slightly different from that which is necessary for cotton receiving no fertilizer.

In clay or heavy loam soils receiving fertilizers, land on which there is much vegetable matter is usually broken broadcast (flushed) with a turn plow of some corresponding plow (half shovel, turn shovel, twister, scooter, etc.). Then the rows are opened, fertilizer placed in the row and a ridge or list formed over the fertilizer with two furrows. The proceedure is the same for sandy soils, and for clean land on which cotton is the preceding crop, except that the broadcast plowing is usually omitted. The row is completed by throwing two furrow slices on the list formed above the fertilizer, this bedding or "throwing out middles" being often delayed for several weeks after the formation of the original small ridge or list, which delay, though convenient, is of questionable wisdom on sandy soils. This question needs the exact investigation which it has not yet received. Presumably the narrow sharp ridges formed by balks or middles and lists dry out too rapidly in seasons of deficient rainfall.

On the Station Farm the beds are completed as soon as fertilizers are applied. In applying fertilizers our practice differs from that of most farmers in that before the fertilizers are covered they are mixed with the soil by running a scooter plow through the line of fertilizer. This is probably necessary only when the fertilizer exceeds 200 pounds per acre. Fertilizers are drilled in the opening or center furrow over which the ridge or bed is formed.

Subsoiling.—No real subsoiling has been done on the Station Farm prior to 1900. Partial subsoiling, effected while the land was being flushed by running a scooter plow to a depth of about 4 inches in the bottom of a shallow turn plow furrow, was done on reddish loam land in January, 1896. The yield on the partially subsoiled land exceeded that on land not subsoiled by 139 pounds of seed cotton per acre in 1896. However, the next year, the same land, on which the subsoiling was not repeated, gave no increase that could be attributed to subsoiling. Partial subsoiling of the same field, as above, on Feb. 24, 1898, failed to increase the yield of cotton in 1898 to any appreciable extent.

Harrowing and rolling.—A defective stand of cotton plants is frequently the consequence of dry weather in April and May. The effects of dry weather at this season can be largely overcome by using the harrow before planting to break the surface crust whenever it forms, thus conserving moisture which may soon be urgently needed by the germinating seed and young plants. Another method of aiding germination on sandy soils that are very loose and dry at time of planting is by the use of the roller just after the seed are placed in the ground. The most convenient means of rolling is by the use of a very small but heavy roller attached to the planter. The wooden roller on some planters is often not heavy enough. In the dry spring of 1896 rolling of the land just after planting, either with an ordinary one horse roller, or with a narrow iron pulley, which packed only the drill, caused the seed to germinate promptly and thoroughly, while on unrolled ground few plants appeared until rain had fallen.

Cultivating implements.—The cultivation of the cotton crop after the young plants appear usually consists of hoeing two or three times and the use of some form of horse cultivation three to six times. The implement used by the best farmers on sandy and loam land is the heel scrape, which, properly regulated, can be made to do very shallow, and yet effective, cultivation. A practice which is deservedly falling into disuse is "barring off," accomplished by the use of the turn plow at the first cultivation of cotton. In "barring off" the young cotton plants are left, usually for several days,—in some cases for a week or more,—on a narrow ridge, which, drying rapidly, must check growth in dry seasons, especially as it is necessarily accompanied by severe root pruning. In wet seasons or on undrained land it may do no permanent harm, but even in such cases the turn plow should be run as shallow as possible and the hoeing should follow immediately, so that there may be no delay in throwing the dirt back against the roots.

We have been able to do equally as good work in siding with a heel scrape and have thus avoided the risks always incurred when a turn plow is used as a cultivating implement.

Cultivation with hell scrape should occur whenever a crust forms after a rain, the number of furrows per row being usually two, occasionally three, and sometimes towards the close of the season only one, in which case a 30 or 36-inch heel scrape is used.

Late cultivation.—An experiment to ascertain the effects of an extra late cultivation showed a slight gain in yield as the result of a cultivation given two weeks after the close of the usual cultivating season. A good general rule, which must be modified somewhat according to the presence or absence of weeds, is to practice late cultivation when the cotton stalks are small, and to stop at an earlier date in fields where there may be danger of excessive development of stems and foliage.

Depth of cultivation.—The depth of cultivation has been studied at this station, both by examination of the natural position of the roots in the soil and by noting the effect of both deep and shallow cultivation on the yield. The danger of severe mutilation of the roots may be inferred from the fact that most of the lateral roots were found to originate at a point only 1½ or 2 inches below the surface of the ground. Their position and direction was such that deep cultivation would unavoidably have broken a large proportion of the feeding roots. A single deep cultivation (at the second plowing, all other cultivation being shallow), reduced the yield of seed cotton in a test on prairie soil at Uniontown, Ala., by 85 pounds and on sandy soil at Auburn by 105 pounds of seed cotton per acre.

SELECTION OF SEED.

Old versus fresh seed.—The productiveness of a given seed is largely dependent, not only on the variety, but also on the individual character of that seed. Although unnecessarily large quantities of cotton seed are usually planted as the result of the low price of ordinary cotton seed, it is nevertheless important that the seed planted shall have a high germinative ability. This is especially important when high priced seed is employed. As a rule, those that are fresh germinate more completely than old seed, and unless there is a distinct advantage in the use of the latter the farmer should plant only fresh cotton seed, that is those from the crop of the preceding year.

However, at least one seed dealer has made the claim that old cotton seed are best, his idea being that in using old seed only the best seed germinate and that these should produce the most vigorous and productive cotton plants.

However, the average of three experiments made at Auburn in 1896 and 1897 showed no difference in yield that could be ascribed to the age of seed when all samples used had sufficient vitality to bring forth a full stand of plants.

Size and position of seed.—Size of seed, position of seed on parent plant, and environment under which the seed was produced, are also factors that probably influence the yield of the succeeding crop.

None of these subjects has been sufficiently investigated to permit of positive statements touching these points. Unpublished data obtained by the writer in 1896 indicated that under the conditions of those tests, seed from the top bolls afforded a smaller crop than seed from bolls growing low down on the cotton plant and that large seed produced a heavier crop of seed cotton than small seed of the same variety grown under identical conditions. The experiments pointing to the apparent superiority of seed from lower bolls, although partially confirmatory of a similar experiment in Arkansas, need to be repeated before we can safely assume that these results represent a general law. The same is true of the experiment in which large and small seed were compared. The superiority of large seed is generally acknowledged as a law applicable to many species of plants, and the superiority of large cotton seed, suggested by this experiment, is not surprising. But we must not jump at the conclusion that the larger the seed the greater the crop, for some of the most productive varieties, for example Peterkin, have small seed.

Effect of climate.—The effect of climate on cotton has received practically no attention. Several of the earliest varieties have originated near the northern limit of the Cotton Belt. This fact, together with the well known fact that seed of many cultivated plants as corn, garden peas, etc., grown in high latitudes produce plants which mature earlier than those from Southern seed, makes it probable that the season of growth of any variety could be shortened by having the seed grown for several years in the extreme upper limit of the Cotton Belt. As shown by our experiments in 1897, this increased earliness was not effected by the use of seed grown only one year in high latitudes. It would be necessary for several generations of seed to be produced in the cooler climate before the quality of early maturity would become pronounced.

Selection of seed as a means of improving cotton. In improving a variety of cotton by selection of seed, the most careful farmers select bolls that open early and that grow on the lower portion of the plant. Since the lower bolls average larger in size and earlier in maturity, this practice is commendable, provided choice is not made of the undersized bolls, some of which at the extreme lower portion of the plant are among the first to open. The whole subject of selection of seed of the cotton plant, the relative importance of size of seed, position and size of bolls, and climatic and soil conditions environing the parent seed,—are worthy of extended investigation at the Southern Experiment Stations.

The danger of drawing the supplies of seed from a common pile at a public gin without regard to the character of the seed cannot be too strongly emphasized. Cotton degenerates easily and it also improves rapidly under careful selection. Hence every cotton farmer should have each year at least one small field of cotton, grown from pure and carefully selected seed, the seed of this field to be used in planting the entire area of cotton the following year.

Best distance between cotton plants.—In 1886 the yield of cotton was nearly constant for distances of 1, 2, or 3 feet between plants in the drill; when the distance was increased to 4 feet the yield was reduced. These results were obtained with cotton in rows 4 feet apart and on low rich soil only recently brought into cultivation. The maximum yield was about 1,200 pounds of seed cotton per acre. The name of the variety used is not on record.

The results above are in essential accord with those obtained in 1887 on rich prairie slough land at Uniontown, Ala. In that test cotton in rows four feet apart made practically identical yields, whether the distance between plants was 1, 2, 3, or 4 feet, all yields being about 900 pounds of seed cotton per acre. At Auburn in 1889, on land which produced about 1,000 pounds of seed cotton, there was no material difference in yield when the distance between plants were 1, 2, 3, and 4 feet in the drill, the rows in all cases being 4 feet apart.

In 1890, with heavy fertilization and rows four feet apart, a distance of two feet afforded a larger yield (1,131 pounds of seed cotton per acre), than did distances of 1, 3, or 4 feet between plants. With rows 3 feet apart the yield of cotton was greater when the plants were spaced 3 feet apart in the row than with closer planting. These narrow rows (3 feet wide) afforded a smaller yield than rows 4 feet wide.

In 1891, both a cluster variety and a long-limbed variety were used in a distance experiment, with rows 4 feet apart. The cluster variety, Welborn, devoid of spreading limbs, was benefited by close planting, giving its maximum yield of 2,519 pounds of seed cotton per acre when the plants stood 1 foot apart in the drill, the decrease in yield being great when the distance was increased to 2, 3 or 4 feet between plants. Peeler, the variety having long spreading limbs, gave its maximum yield, 1,983 pounds, when the plants were spaced 2 by 4 feet, at which distance the yields of the cluster and long-limbed variety were practically equal.

In 1896 the variety used in testing the best distance for planting cotton was Peerless, a variety which does not occupy much space. In 1897, Truitt, a variety with long limbs, was used. The rows were $3\frac{1}{2}$ feet apart, with Peerless, $3\frac{1}{3}$ with Truitt. The following table shows the results in pounds of seed cotton per acre, each figure being the average for at least two plots:

Best distance for cotton, 1896 and 1897.

Distance between plants.	Peerless, 1896.	Truitt, 1897.
	Lbs.	*Lbs.*
12 inches	770	922
18 "	804	912
24 "	673	918
30 "	544	878
36 "	530	853

The above table shows that with Truitt cotton in narrow rows there was practically no difference in yield between distances of 12, 18 and 24 inches in the drill. When the space was increased to 30 inches a decided reduction in yield followed. When the distance became 36 inches a further reduction occurred, which, however, was only slight. The yield per plant increased rapidly as the space allowed to each was enlarged.

It should be remembered that the Truitt variety makes a large growth, and that its originator recommends thin planting for this variety. With Peerless, a smaller variety, planted in 1896 on a more sandy soil, best results were obtained by spacing either 12 or 18 inches in rows 42 inches apart.

The average percentages of the whole crop that were obtained at the first picking, August 26, 1897, were as follows: 42 per cent. for plants 12 inches apart; 38 per cent. for plants spaced 18 inches; 30 per cent. for plants 24 inches apart; 26 per cent. for plants spaced 36 inches apart. These averages suggest that thin planting retarded opening and that very thick planting decidedly hastened the maturity of the plants. However, different plots planted at identical distances varied considerably in the percentage of the total crop which was open at the time of the first picking.

Undoubtedly much of the cotton grown in Alabama is unduly crowded in the row and in many localities the rows are too narrow for economical cultivation. With almost any variety on medium or fair soil it is probably safe to allow a distance of 18 inches between plants in the drill. To increase this distance beyond two feet is doubtless unwise except when the variety is long-limbed, and in this case considerable risk of reducing the yield is incurred if the distance approaches or exceeds 3 feet. For erect and short-limbed varieties we feel safe in recommending a distance of 18 inches on good land and 12 inches on poor land. The richer the land the greater the spread of the limbs and the greater the area demanded by each cotton plant.

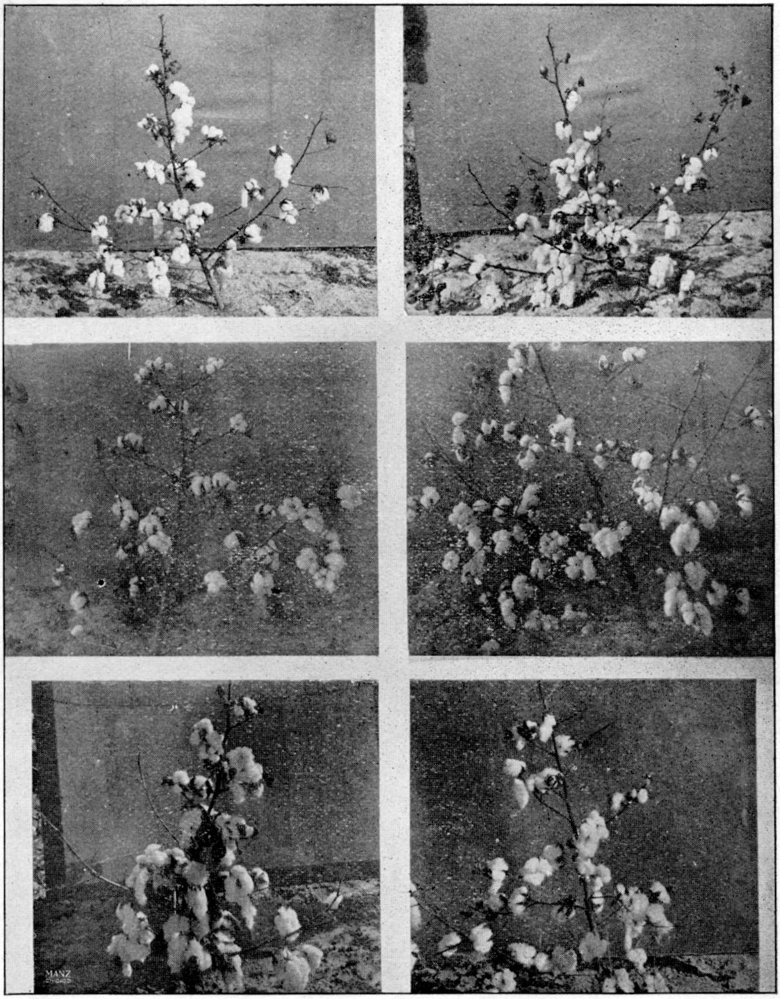
If in some exceptional soils there is such a tendency towards producing a large cotton stalk as to require more than 10 square feet per plant, the crop will usually be most conveniently cultivated if the needed space is afforded by widening the row to 4, 4½, or even 5 feet, leaving the space between plants in the drill not greater than 3 feet. Labor is economized by spacing the plants as far apart as is consistent with maximum yield, but on the average cotton lands of Alabama, with ordinary fertilization, a distance of 12 to 18 inches is safer than wider spacing.

Topping.—This operation, which is not often practiced at the present time, consists in the removal of a few inches of the extreme top of the cotton stalk, late in summer. The idea was probably to check the upward growth of the plant and to favor the more complete development of the bolls already formed.

Our tests here failed to show any advantage from topping, either on rich bottom land in 1886 or on rather poor up-land in 1897. In the latter experiment the Truitt variety was used and the yield of seed cotton per acre was, on the plots not topped at all 946 pounds; topped August 19, it was 906 pounds; and only 710 pounds when topping was performed as early as July 22.

Our experiments and those made at several other stations, agree in showing that ordinarily no advantage results from topping cotton.

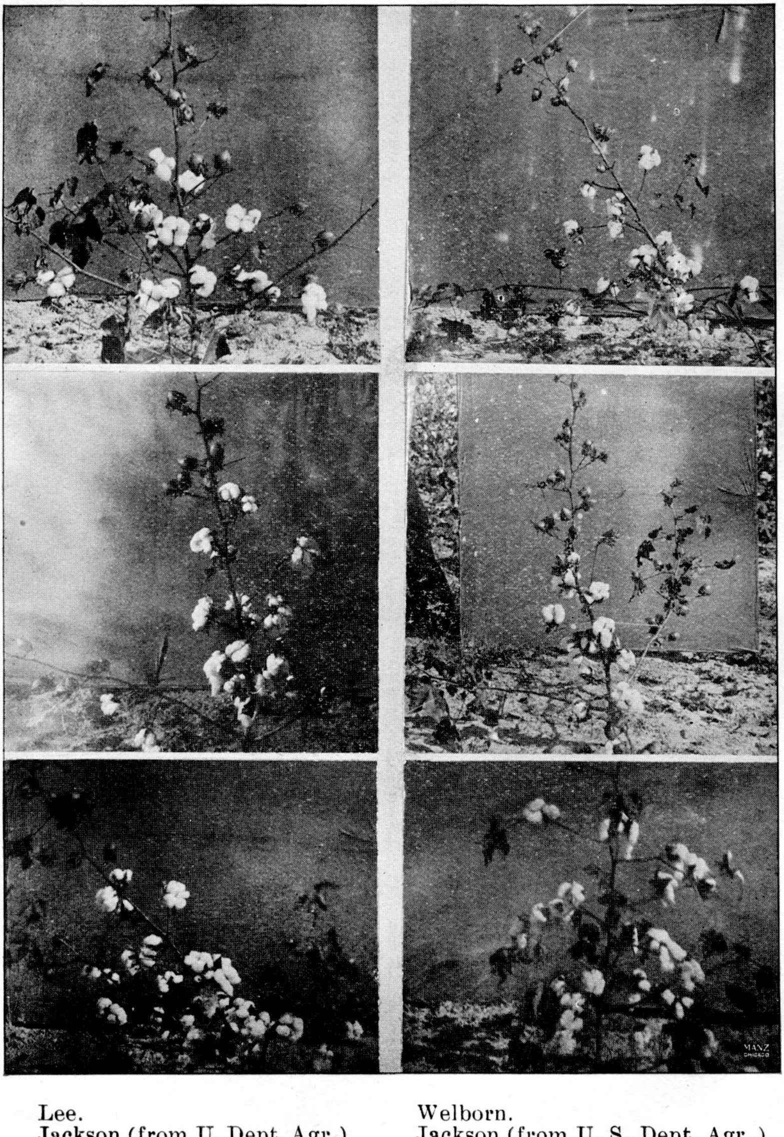
PLATE I.



Peerless.
Drake.
Dickson.

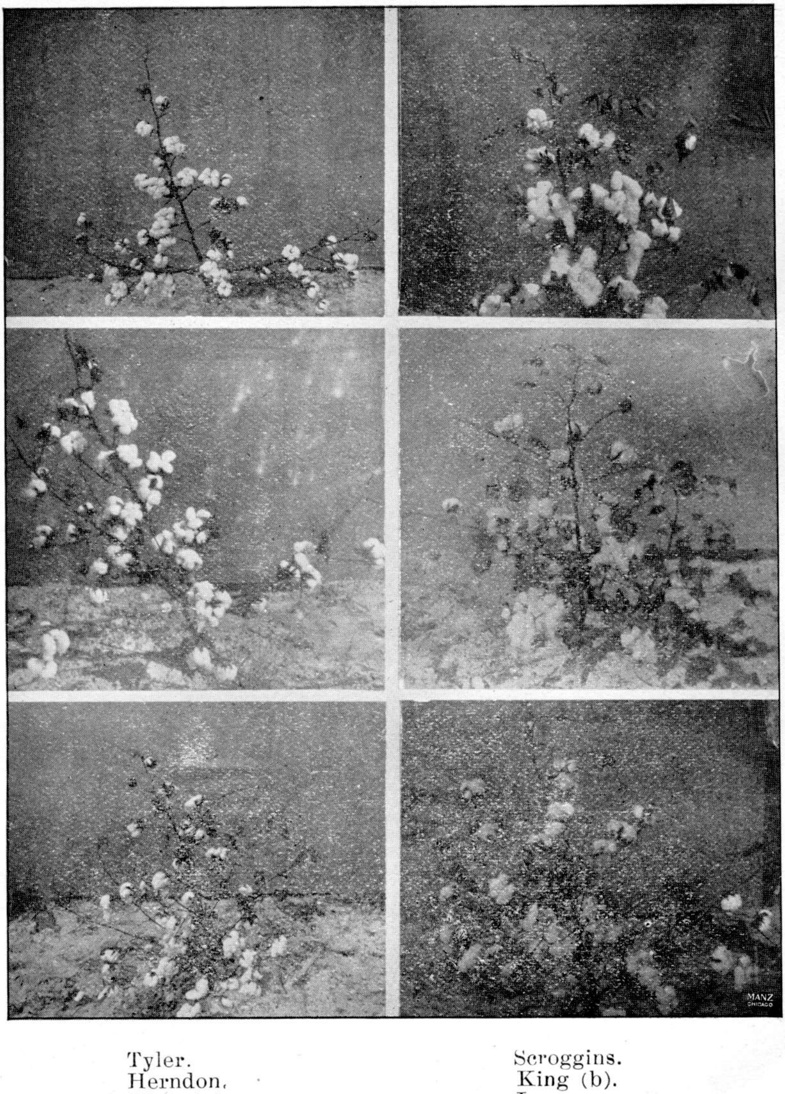
Cummings.
Mattis,
Boyd.

PLATE II.



Lee.
Jackson (from U. Dept. Agr.)
Jackson (from Alexander).

Welborn.
Jackson (from U. S. Dept. Agr.)
12 B (so-called Herlong.)

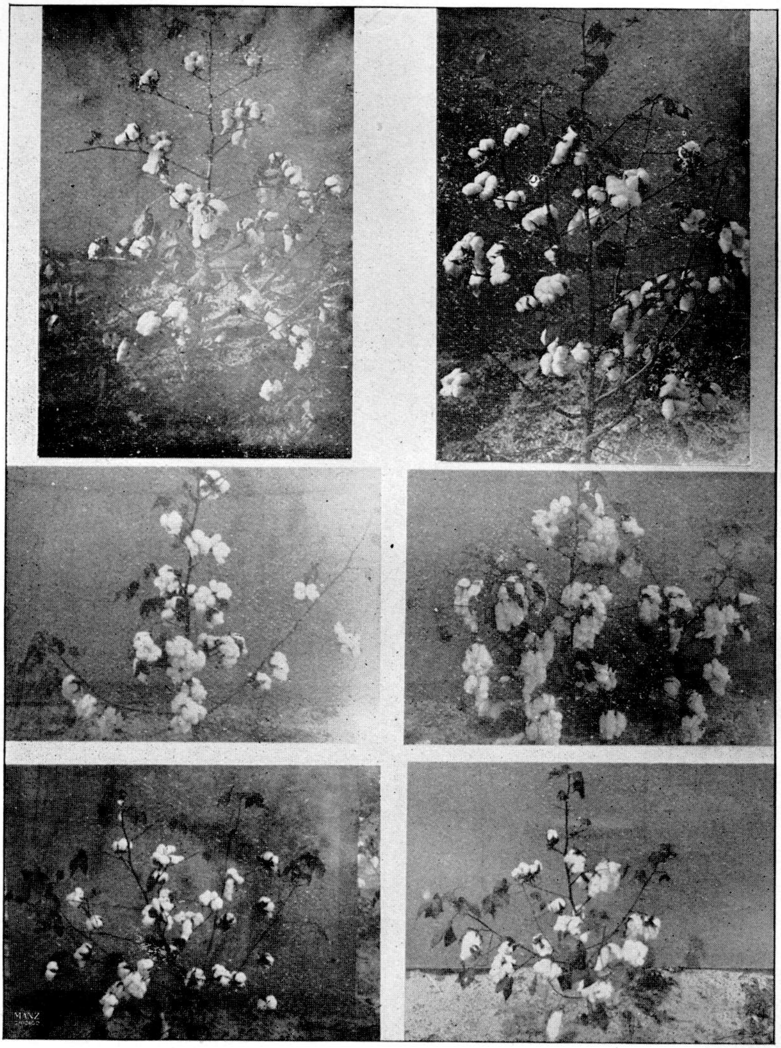


Tyler.
Herndon.
King (a).

Scroggins.
King (b).
Lowry.

Parks. Grayson.
Hawkins Prolific. Hawkins Jumbo.
Sea Island. Nancy Hanks.

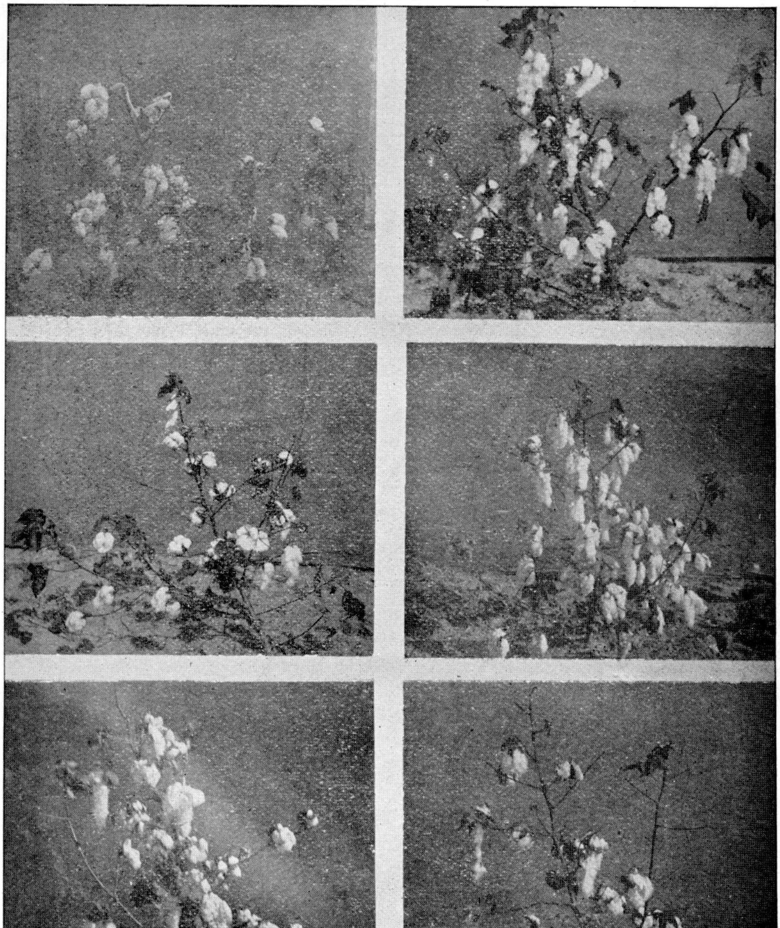
PLATE V.



Peterkin Limb Cluster (b.)
Dearing.
Wise.

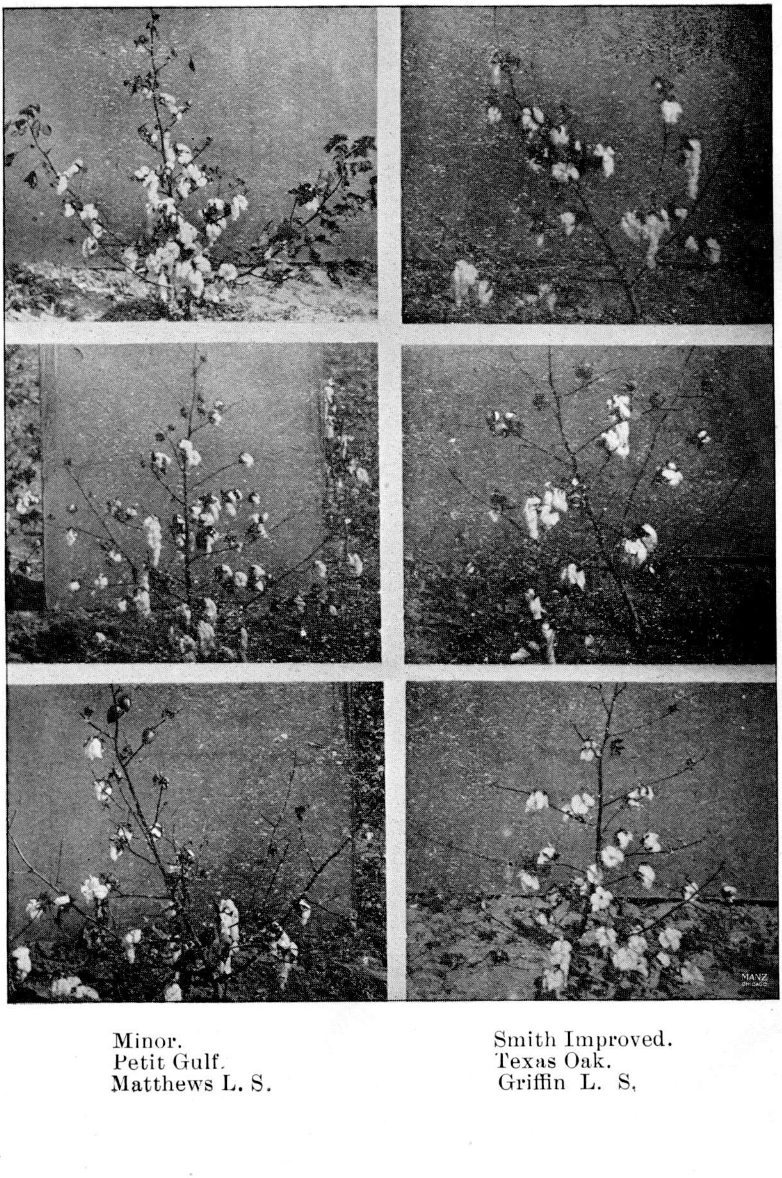
Peterkin Limb Cluster (c.)
Texas Wood.
Culpepper.

PLATE VI.



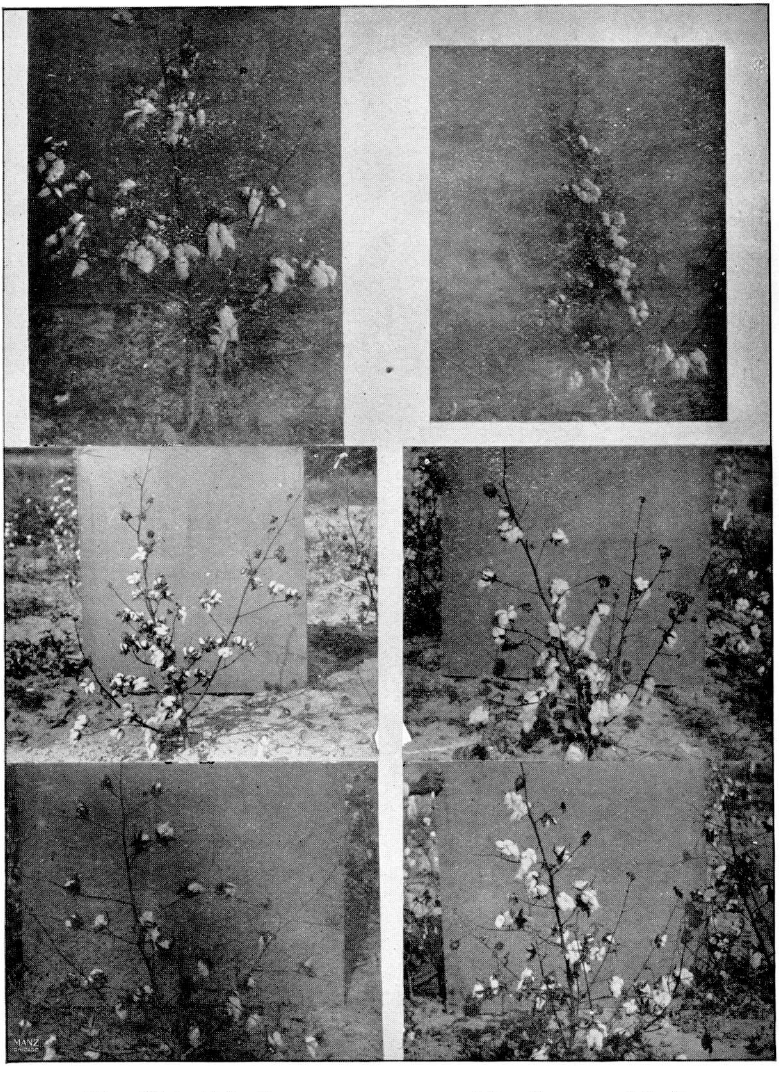
Duncan.	Russell.
Jones Improved (N. 37 C.)	Bates Poor Land.
Bur.	Texas Bur.

PLATE VII.



Minor.
Petit Gulf.
Matthews L. S.

Smith Improved.
Texas Oak.
Griffin L. S,



Allen Hybrid L. S.
W. A. Cook L. S.
Moon L. S.

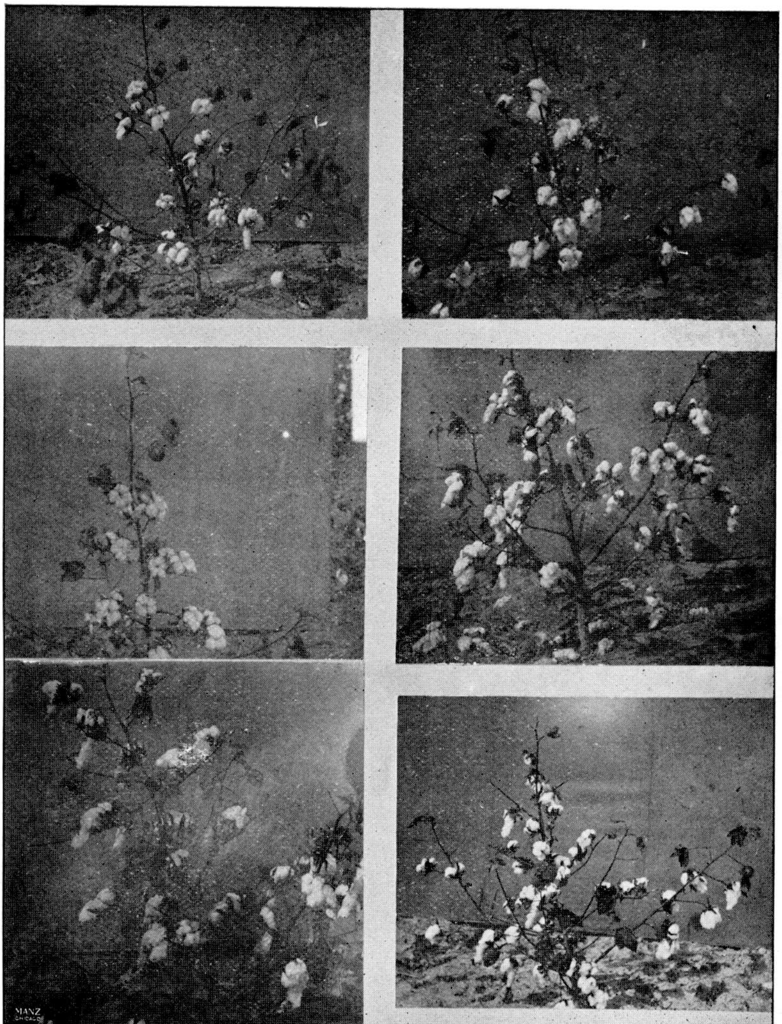
Allen Improved L. S.
Doughty L. S.
Cobweb L. S.

PLATE IX

Improved Long Staple.
Gunn.
Hilliard.

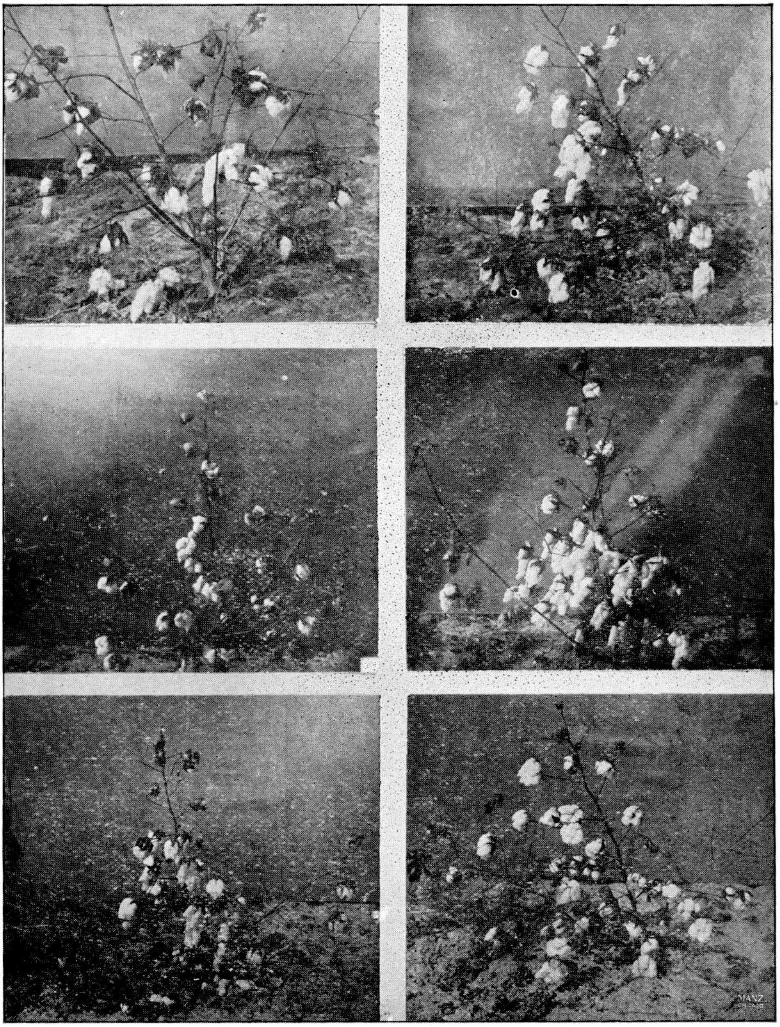
Peterkin.
Excelsior.
Shine.

PLATE X.



Thrash. Banks.
Norris. Pruitt Premium.
Big Boll. Jones Improved (S. 37 C.)

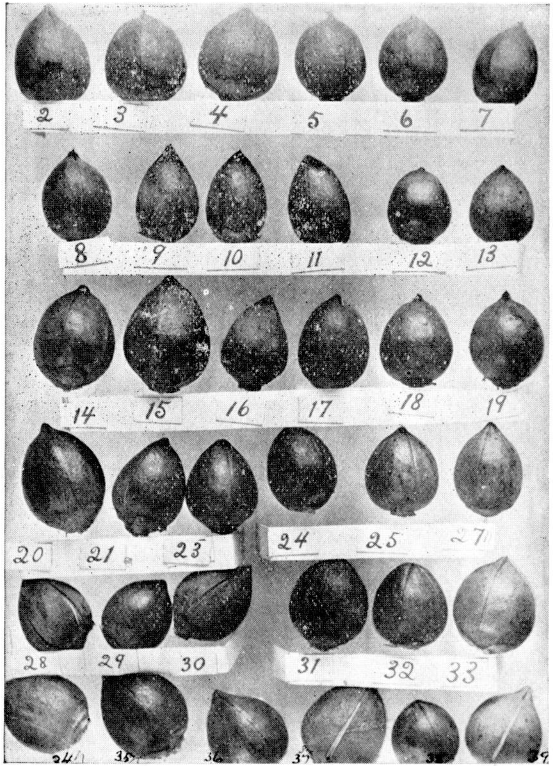
PLATE XI.



Cheise.
Maddox.
Japan.

Borden.
Coppedge.
Texas Storm Proof.

PLATE XII.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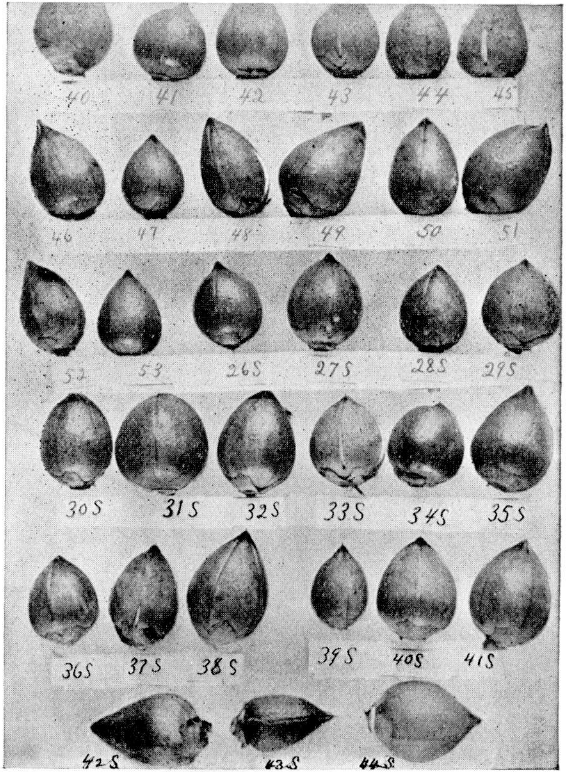
28 29 30 31 32 33


40 41 42 43 44 45
46 47 48 49 50 51
52 53 26S 27S 28S 29S
30S 31S 32S 33S 34S 35S
36S 37S 38S 39S 40S 41S
42S 43S 44S

THE MANURING OF COTTON.

BY J. F. DUGGAR.

THE EXTENT OF THE USE OF COMMERCIAL FERTILIZERS.

No statistics have been gathered to show what percentage of the area planted in cotton in Alabama is fertilized. A few decades ago practically the entire cotton crop of Alabama was grown without manuring, the use of commercial fertilizers being rare and the manures produced on the farm being more frequently used for food crops than for cotton. It still remains true that other crops than cotton have the first claim on the too-limited supplies of home-made manures. But the use of commercial fertilizers, or chemical manures, has been steadily and rapidly extending, especially during the last two decades.

The statistics furnished by the Commissioner of Agriculture of Alabama show that the following number of fertilizer tags have been sold during the past three years, the figures opposite representing the number of tons of commercial fertilizers (exclusive of cotton seed meal) sold annually in Alabama:

	No. of tags sold.	Equivalent to tons of fertilizer.
For the crop of 1897	1,101,830	110,183
For the crop of 1898	1,210,444	121,044
For the crop of 1899	993,480	99,348
Average for three years	1,101,918	110,192

There are no means of ascertaining the amount of cotton seed meal used as fertilizer in this State, but 10,000 tons per annum would probably be a low estimate. The cotton crop receives by far the larger portion of these commercial fertilizers. If we assume 105,000 tons as the average quantity of chemicals and cotton seed meal annually applied to the cotton fields of Alabama and if we assume 150 pounds per acre as the average amount applied, we have a calculated area of 1,400,000 acres of cotton annually receiving an application of commercial fertilizers. It is probably safe to say that in Alabama more than half of the land on which cotton is grown is fertilized with purchased materials.

There is no means of ascertaining the average selling price of commercial fertilizers, which, though chiefly consisting of goods sold until recently at $11.00 to $16.00 per ton, include also cotton seed meal and other fertilizers that cost considerable more than $16.00 per ton. The cost of the commercial fertilizers (including cotton seed meal) used by the cotton farmers of Alabama, either for cotton or for other crops on cotton plantations, must aggregate between $1,700,000 and $2,000,000 per annum.

The figures used above give some idea of the importance of the fertilizer question in cotton culture and justify the large amount of attention which the Alabama Experiment Station has given to investigations designed to aid the farmer in any part of the State in the selection of the most profitable fertilizer for the particular soil on which he grows cotton.

Not for all soils, nor indeed fully for any soil, has this problem been solved, but the lessons already learned as the results of these multitudinous experiments can be so used as to guide the farmer in many parts of the State in his choice of fertilizers and to materially increase the profits of cotton culture.

Do Fertilizers pay when Cotton is Five Cents per Pound?

We may in part answer this question by showing the average amount of increase in yield of seed cotton per acre attributable to different fertilizers. The following table (from Ala. Sta. Bul. 102) gives the *average* results for 22 co-operative fertilizer tests in 1897, and for 30 in 1898, made on a great variety of soils. The price assumed for a pound of seed cotton, $1\frac{5}{9}$ cents, is the *net* price of increase, or value of the seed cotton after paying 33 cents per 100 pounds for picking, and is equivalent to a gross price of 5 cents per pound for lint and $6.67 per ton for seed. At prices obtained for the crop of 1899 the profits would in many cases be double those shown in the table below.

Average increase in seed cotton per acre over unfertilized plots in 1897 and 1898.

Fertilizers.				Average 22 tests in 1897		Average 30 tests in 1898	
Plot No.	Amount per acre.	Kind.	Cost of fertilizers.	Increase over unfertilized plots.	Profit from fertilizers.	Increase over unfertilized plots.	Profit from fertilizers.
	Lbs.			*Lbs.*		*Lbs.*	
1	200	Cotton seed meal...........	$ 1.90	**113**	$—.15	**205**	$ 1.29
2	240	Acid Phosphate...........	1.50	**194**	1.51	**230**	2.08
3	00	No fertilizer...............	......	......	......	......	......
4	200	Kainit.....................	1.38	**144**	.86	**97**	.13
5	200 240	Cotton seed meal......... Acid phosphate...........	3.40	**339**	1.87	**375**	2.43
6	200 240	Cotton Seed meal......... Kainit...................	3.28	**282**	1.10	**258**	.73
7	200 200	Acid phosphate........... Kainit...................	2.88	**287**	1.58	**283**	.88
8	00	No fertilizer...............	......	......	......	......	......
9	200 240 200	Cotton seed meal......... Acid phosphate........... Kainit...................	4.78	**419**	1.73	**392**	1.32
10	200 240 100	Cotton seed meal......... Acid phosphate........... Kainit...................	4.08	**372**	1.79	**435**	2.84

This table shows that fertilizers, even when used indiscriminately, or without any attempt to suit the fertilizer to the soil were, as judged by *average* results, moderately profitable.

Averages, however, do not do full justice to the amount of increase which fertilizers afford when selected with special reference to their suitability for the soil on which they are to be applied. The detailed results from which the preceding table is made up, show that in a number of localities, the complete fertilizer, the meal and phosphate mixture, or even the phosphate applied by itself afford profits of more than $5 per acre after paying for cost of picking the increased yield due to the fertilizer, and this, too, when lint cotton was worth only 5 cents per pound. At the higher prices current in the winter of 1899-1900, each one of fertilizers or mixtures named in the above table would show a very satisfactory profit.

The absolute necessity for using fertilizers in the regions where they are now in general use can also be inferred from the small yields obtained in most tests on the plots that received no fertilizer. In our 52 conclusive tests in 1897 and 1898, the average yields *without fertilizers* were respectively 474 and 506 pounds of seed cotton per acre. Excluding all tests where the unfertilized plots produced 500 pounds or more of seed cotton per acre, we find that 11 soils in 1897 averaged without fertilizers only 281 pounds, and 17 soils in 1898 averaged, when unfertilized, only 299 pounds of seed cotton per acre, the entire product, including seed, being worth less than $6 per acre, at the low prices then prevailing.

To many minds even more conclusive in proving that commercial fertilizers are profitable than the results of any experiments is the fact that their use is constantly increasing. Both experience and experiment show that on many soils commercial fertilizers are indispensable to profitable cotton culture.

They have been occasionally charged with being largely responsible for the impoverished conditions of the cotton fields and the scant profits of the cotton grower. They are acquitted of the first charge by those who know the real causes of the deterioration of Southern soils. The exhaustion of the fertility of the cotton fields is due chiefly to leaching, washing, and loss of vegetable matter as the result of continuous clean cultivation. For the scant profits obtained in the culture of five-cent cotton, many causes are responsible, not least of which are impoverished soil, purchased supplies, unintelligent use of fertilizers, and the failure to master the principles which underly a rational system of farming. What we should condemn is not the *use,* but the *abuse,* or purposeless use, of commercial fertilizers.

KINDS OF FERTILIZER GENERALLY FOUND ON THE MARKET.

At the outset the farmer must choose whether he will buy a fertilizer already mixed, paying the fertilizer factory for the cost of mixing and for its profit, or whether he will buy the simple ingredients and do his own mixing on the farm. Of the ready mixed, or "manipulated" fertilizers, to which the name guano is so commonly applied, there are numerous varieties or brands on every important market, so that the farmer has the choice among brands that vary considerably in composition. He can buy phosphate with potash, or ammoniated phosphate with potash, and can choose between brands representing various proportions and percentages of nitrogen, phosphoric acid and potash.

As a general rule the complete manipulated guanos contain from 2 to 4 per cent. of nitrogen, 7 to 10 per cent. of available phosphoric acid, and 1 to 3 per cent. of potash.

If the farmer decides to buy the separate materials and do his own proportioning and mixing, (thus getting his fertilizing material at a lower price), he usually purchases cotton seed meal, acid phosphate, and kainit.

On the larger markets he has a choice from among a number of other simple fertilizers, as nitrate of soda, dried blood, muriate of potash, etc. On the farm of the Alabama Experiment Station no manipulated fertilizers are used, as we find it cheaper and more satisfactory to do our own proportioning and mixing.

The main consideration in buying fertilizers is to obtain available phosphoric acid, nitrogen and potash at the lowest cost per pound of each. This implies the necessity of buying according to analysis of the material under consideration and requires some figuring by simple arithmetical methods. A low price per ton of fertilizer is often accompanied by a high cost per pound of the nitrogen, phosphoric acid and potash, which it contains, especially where freight rates from the centers of fertilizer production are high. It frequently happens that the cheapest fertilizer is the dearest or least economical, and that low grade goods are poor investments.

In most of our experiments we have used in recent years chiefly Edisto High Grade acid phosphate, guaranteed to contain 14 per cent. of available phosphoric acid. The cotton seed meal and kainit used have been of average composition.

BEST FORMS OF NITROGENOUS FERTILIZERS.

The forms in which the cotton farmer may most conveniently purchase his supplies of nitrogen for purposes of fertilization are barn manure, cotton seed, cotton seed meal, and nitrate of soda. To this list might also be added sulphate of ammonia and various slaughter-house products, as dried blood and tankage. Of these cotton seed and cotton seed meal are most extensively used. At Auburn, as at nearly every experiment station in the Cotton Belt, tests have been made to determine the relative values of the nitrogen in these materials.

The number of comparisons made here of dried blood and sulphate of ammonia has not been sufficient to definitely establish their relative values for the soils of this region. However, the few experiments made suggest that the nitrogen in these materials is scarcely equal, and certainly not superior, to that in cotton seed meal.

Cotton seed meal versus nitrate of soda.—It is of greater importance to know the relative values of the nitrogen in cotton seed, cotton seed meal, and nitrate of soda. Let us first compare cotton seed meal and nitrate of soda.

In 1886 and again in 1887, on extremely poor soil, there was a decidedly larger yield of cotton where 420 pounds of cotton seed meal per acre was used than where 210 pounds of nitrate of soda was employed. This result is perfectly natural in view of the fact that these fertilizers were applied alone, the cotton supplied with nitrate of soda thus receiving only nitrogen, while with the 420 pounds of cotton seed meal were necessarily supplied the 12 pounds of phosphoric acid and the 7.4 pounds of potash contained in the meal.

In other tests here in 1886 and 1887, the above quantities of nitrate of soda and of cotton seed meal were again compared, this time in connection with a heavy application of floats. In this case the plants on both plots had a large amount of phosphoric acid at their disposal, and were thus able to make as good use of the nitrogen in nitrate of soda as in that of cotton seed meal. The yields were practically equal.

In 1897 and 1899 at Auburn, 75 pounds of nitrate of soda afforded a larger yield of cotton than did 216 pounds of cotton seed meal,—acid phosphate and kainit being used in connection with both nitrogenous fertilizers.

The co-operative experiments that were conducted in 1891 and 1892 under the direction of this station, afford a large number of comparisons between nitrate of soda and cotton seed meal. The quantity of nitrate of soda was 96 pounds per acre, in contrast with 240 pounds of cotton seed meal, the amounts of nitrogen in these two applications being practically equal. With both forms of nitrogenous fertilizer there was also applied 240 pounds of acid phosphate per acre.

The results of 49 co-operative tests are summarized in the following table:

	Yield seed cotton per acre.		
	1891. (27 tests.)	1892. (22 tests.)	Average of 49 tests.
Average yield with cotton seed meal.....	814	879	844
" " " nitrate of soda	824	863	841

These results show the practical equality of nitrogen from these two sources, cotton seed meal and nitrate of soda. And to this conclusion we are also led by the majority of the experiments made at Auburn.

Taken as a whole, the experiments conducted by this Station on a number of soils, justify the recommendation that the farmer purchase nitrogen in whichever of these two forms a pound of nitrogen costs least. This is usually in cotton seed meal.

Cotton seed versus cotton seed meal.—The determination of the relative fertilizer values of cotton seed and cotton seed meal was the aim of a number of co-operative experiments conducted under the writer's direction in 1896. The tests were made on 14 different soils. The seed were crushed before being used, and hence were probably more quickly available and of greater value to the crop to which they were applied than uncrushed seed would have been. Cotton seed meal was used at the rate of 200 pounds per acre, crushed seed at the rate of 472 pounds. The following extract from Bulletin No. 78 of this Station, summarizes the results of these 14 tests:

"In deciding on the amounts of cotton seed and meal to be compared, quantities of each were employed which would afford equal amounts of nitrogen, as indicated by the analyses then available. A more nearly complete compilation of analyses published since this experiment was planned indicates that it would have been more strictly accurate to have used 434 pounds of cotton seed per acre instead of 472.

Seven experiments give larger yields with cotton seed and seven afford heavier crops with cotton seed meal. Combining the results of these 14 experiments we find that crushed cotton seed afforded an average of 10 pounds per acre of seed cotton more than did the meal. This difference in yield in favor of the seed is amply sufficient to counterbalance the fact that there was used as fertilizer 38 pounds per acre of crushed cotton seed in excess of what was necessary to supply the required amount of nitrogen. After making this allowance, we find that cotton seed and cotton seed meal were on an average equally effective when such quantities of each were compared as contained equal amounts of nitrogen.

A pound of nitrogen was just as valuable in one as in the other.

But the market prices of cotton seed and meal are not governed wholly by the relative amounts of essential fertilizer ingredients in each. Whether it is more profitable to sell seed and buy meal, or apply seed to the land, depends on the relative prices of these two materials. The average figures for 14 experiments in 1896 showed that one ton of crushed seed was equal to an amount of meal containing a like quantity of nitrogen, which we find to be 922 pounds of meal; from this it follows that 1 pound of meal was equal to 2.06 pounds of seed. Hence we get the price per ton of seed at which the farmer could afford to swap seed for meal by dividing the price of meal by 2.06 ($2\frac{1}{16}$). For example, assuming a price of $20 per ton for cotton seed meal and dividing this by 2.06 we have $9.22 per ton as the relative fertilizer value of seed. Of course, to this price of seed should be added the cost of getting the seed to the oil mill. To put the average results of fourteen tests made in 1896 into still another form, we may say that a ton of crushed cotton seed was worth on the farm as fertilizer 46 per cent. of the fertilizer value of a ton of cotton seed meal.

The preceding are only average results, and individual soils and crops may be more responsive to the one or to the other source of nitrogen. For example, or certain compact clay or prairie soils deficient in vegetable matter, cotton seed may be the more valuable because of its effect on the mechanical condition of the soil. On the other hand we can scarcely doubt that cotton seed meal has some advantage under conditions when it is necessary that the fertilizer should exert its effect quickly. In this connection attention is called to the fact that the fertilizers for this test were applied later than is customary, the great majority of them being put in the ground in April, while in a few cases they were not applied until May. This may have been a greater disadvantage to the cotton seed than to the meal."

A discussion of this subject necessarily turns largely on the chemical composition of the materials compared. Hence, the following figures calculated from many analyses compiled in Bulletin No. 33 of the Office of Experiment Stations, U. S. Department of Agriculture, are added:

	Nitrogen. Lbs.	Phosphoric Acid. Lbs.	Potash. Lbs.
2,000 lbs. of cotton seed contains.	62.6	25.4	23.4
922 lbs. of c. s. meal contains..	62.6	26.5	16.3

A comparison of cotton seed and cotton seed meal as fertilizers for cotton has been made at Auburn during each of the past four years, using such amounts of each as would supply equal quantities of nitrogen. The cotton seed has either been crushed or rotted. One test was inconclusive; in one test the seed afforded the larger yield, and in two experiments the nitrogen in cotton seed meal was more effective.

In some years and on some soils the nitrogen in cotton seed meal proves more available than that in cotton seed, while under different climatic conditions or on other soils the advantage is with the seed.

The average of 14 experiments mentioned above showed that one pound of meal was equal to $2\frac{1}{16}$ pounds of crushed seed; since uncrushed seed would be less quickly available, it would doubtless require a larger amount of these, perhaps $2\frac{1}{2}$ to 3 pounds, to equal one pound cotton seed meal, as regards the effect exerted on the crop to which it is immediately applied.

The exact value of cotton seed meal in terms of cotton seed is by no means determined by the experiments thus far made; indeed, though further investigation is needed, a universal mathematical relation between the fertilizing values of cotton seed and cotton seed meal cannot be expected, since the relation between them will vary with the kind of soil and with some other environments.

Cotton seed versus stable manure.—This comparison was made in many localities in Alabama in 1890, 1892, and 1893, under the direction of this Station. In 1890 the amount of cotton seed employed was 795 pounds; in 1891 and 1892 it was 848 pounds per acre. In every test there was used 5 pounds of stable manure as a substitute for each pound of cotton seed, the amounts of manure being respectively 3,975 and 4,240 pounds per acre. The term "green cotton seed" implies that this fertilizing material was used without being crushed or rotted. In this condition it decomposes more slowly than if crushed or rotted, exerts a smaller effect the first year, and doubtless leaves in the soil a larger unused residue of fertilizing material for the use of the next crop.

No description of the barn manure is given, but it was almost certainly manure from horse or mule stables. As it was obtained from a great number of farms we may assume that its composition did not greatly differ from the average published analyses of horse manure, viz: $\frac{1}{2}$ per cent. nitrogen, $\frac{1}{4}$ per cent. phosphoric acid, and $\frac{1}{2}$ per cent. potash.

The following table summarizes the results of seventy experiments, omitting only the few tests that are obviously incorrect. It refers only to the plots on which stable manure (3,975 or 4,240 pounds per acre) or cotton seed (795 or 848 pounds per acre) were used alone, and to the nearest unfertilized plot.

FERTILIZER.	Pounds seed cotton per acre.				Averege per cent. increase in crop.
	1990. (21) tests.	1891. (27) tests.	1892. (22) tests	Aver'ge of (70) tests.	
	Lbs.	*Lbs.*	*Lbs*	*Lbs.*	
Average yield unfertilized plots, seed cotton	4?4	400	425	**436**	
Average yield with stable man're	922	828	906	**880**	**101**
Average yield with cotton seed.	782	679	723	**724**	**64**
Increase in yield due to stable manure	428	424	481	**444**	
Increase in yield due to cotton seed	288	279	298	**288**	
Stable manure more effective by	140	145	183	**156**	

From this condensation of the results of the 70 tests it appears that 5 pounds of stable manure exerted during the year when applied a greater influence on the yield of cotton than did one pound of green cotton seed used as fertilizer; that the yield was increased by 101 per cent. when stable manure was used and by 64 per cent. when cotton seed was used; and that to obtain an increase of one pound in the yield of seed cotton there was required 3 pounds of cotton seed or nearly 10 pounds of stable manure.

To put the evidence in another form, it may be said that in 79 per cent. of these tests the yield was greater with stable manure than with cotton seed.

The quantity of stable manure used contained a larger amount of vegetable matter than did the smaller application of cotton seed. Both seed and manure undoubtedly left in the soil large amounts of unused fertilizing material for the benefit of subsequent crops.

LEGUMINOUS PLANTS AS FERTILIZERS FOR COTTON.

Nearly every cotton farmer is aware of the fact that the cowpea is a valuable fertilizing plant. Yet there are few who use cowpeas or other legumes to the extent that they may be employed as fertilizers. In the past few years a special effort has been made by the Agricultural Department of this Station to determine the values of cowpeas, velvet beans, and other legumes as fertilizers, not only for cotton, but also for corn, oats, wheat, and sorghum.

The experiments in which cotton was used to measure the fertilizing value of legumes are mentioned below.

Velvet beans and cowpeas as fertilizers.—At Auburn the yield of seed cotton in 1899 on a plot where wonderful cowpea vines,—grown in 1898 in drills,—had been plowed under after being picked was greater than on a plot cropped in cotton in 1898, the peas and cotton having been fertilized alike in 1898. The actual difference in yield of seed cotton was 157 pounds per acre, or making allowance for the fact that on the green-manured plot there was only 89 per cent. of a perfect stand, the difference in the yields thus corrected was 367 pounds of seed cotton per acre in favor of the plot previously cropped in cowpeas. The soil was fertile.

In 1898 in a poorer field there were grown on adjacent plots cowpeas, velvet beans, and cotton, all fertilized alike with acid phosphate and kainit. The cowpeas and velvet beans were planted thickly in drills, using per acre 112 pounds of cowpeas and 120 pounds of velvet beans. The variety of cowpeas used was the Unknown or Wonderful. Both cowpeas and velvet beans were picked and removed from the field, though the latter did not fully mature. The vines were turned under in March, 1899, and all plots were planted to cotton; each plot of cotton was fertilized at the rate of 240 pounds of acid phosphate and 96 pounds of kainit per acre.

The yield of seed cotton per acre in 1899 was 1,533 pounds following cowpeas, 1,373 pounds following velvet beans, and 837 pounds following cotton.

These figures show that the increased yield of seed cotton attributable to manuring with cowpea vines was 696 pounds per acre; the gain apparently due to the fertilization with velvet beans was 546 pounds per acre. In percentage the increase is 83 and 64 per cent. respectively. Valuing seed cotton at 2½ cents per pound (which is equivalent to 6¾ cents per pound of lint and $7.50 per ton of seed), the gain with cowpeas and velvet beans is worth respectively $17.40 and $13.65 per acre.

Surely it was more profitable to grow cotton every alternate year at the rate of a bale per acre rather than to grow continuous cotton crops of about one-half bale per acre. If there be any doubt of this it should certainly be dispelled by the fact that one of these plots afforded in 1898 a yield of 18¼ bushels of peas per acre, besides increasing the cotton crop of the following year to the extent of $17.40 per acre.

It is but fair to state that in a rotation experiment begun in 1896 and which cannot be expected to afford positive results for several years yet, the increase in the yield of cotton following cowpeas (sown broadcast) has considerably less than the gains noted above. The smaller fertilizing effect of cowpeas in this incomplete rotation experiment is possibly due in part to want of uniformity in the plots, but is probably due chiefly to the fact that all cotton plots in the rotation experiment are fertilized with 120 pounds of cotton seed meal per acre, while in the experiments previously noted and in those detailed in the following paragraphs, no nitrogenous fertilizer was used, the plowed-in legume being the sole source of the nitrogen supply.

Vines and stubble of velvet beans as fertilizers for cotton.—On poor soil at Auburn an effort was made in 1898 and 1899 to ascertain the manurial value of the vines and stubble of velvet beans (*Mucuna utilis.*)

In 1898 cotton was grown on certain plots and velvet beans on others. The fertilization of all plots in 1898 was not identical, but for a given fertilizer applied to cotton there was a plot of velvet beans receiving the same fertilizer. The velvet beans grew in drills 3½ feet apart; the vines formed a dense net of vegetation, but did not mature seed. In March, 1899, velvet beans and cotton stalks were plowed in and soon afterwards all plots were fertilized alike with a mixture of 240 pounds of acid phosphate and 40 pounds of muriate of potash per acre.

Russell cotton was planted in 3½ feet drills on all plots on April 21. From midsummer forward there was a remarkable difference in the appearance of the two sets of plots, the cotton plants being much larger, greener, and more luxuriant on the plots where velvet beans had grown the year before.

The following table gives such of the results as bear on the fertilizing value of velvet beans:

Value of velvet beans as a fertilizer for cotton.

Fertilizers used the previous year.	Plot No.	Preceding crop.	Seed cotton per acre in 1899.	
			Yield.	Increase due to velvet beans.
			Lbs.	*Lbs.*
Acid phosphate used in 1898	6	Velvet beans in 1898	1502	622
	1	Cotton in 1898	880	
Raw phosphate used in 1898	7	Velvet beans in 1898	1570	602
	2	Cotton in 1898	968	
No phosphate used in 1898	8	Velvet beans in 1898	1661	755
	3	Cotton in 1898	906	
Average increase attributable to velvet beans				**660**

The above table shows that the average increase attributable to velvet beans used as a fertilizer was 660 pounds of seed cotton per acre, a gain of 72 per cent. as compared with the average yield on plots where the preceding crop had been cotton. At 2½ cents per pound of seed cotton (equivalent to 6¾ cents per pound for lint and $7.50 per ton for seed) this increase is worth $16.50 per acre. Moreover, experiments with other plants indicate that the fertilizing effect of legumes is not all felt the first year, so that there undoubtedly still remains in the soil to the credit of the velvet-bean manuring a considerable proportion of unused fertilizing materials available for future crops.

In the same field the velvet beans on one plot were cut for hay October 12, 1898. The stubble and roots were plowed in at the same time as the vines on the other plots referred to above.

Cotton on the plot where only roots and stubble were plowed in yielded in 1899 an amount of seed cotton which was 510 pounds greater than the yield on the corresponding plot previously cropped in 1898 in cotton.

Following roots and stubble the yield of seed cotton was 112 pounds less than on a comparable plot where the entire growth of velvet beans had been plowed under as fertilizer.

Experiments here and at other Southern Experiment Stations prove that it is generally more profitable to utilize the legumes for hay, plowing under only the roots and stubble as fertilizer, than to turn under the entire growth.

Cowpeas as fertilizer on lime land.—A co-operative fertilizer experiment nearly parallel to the above was conducted for this Station by Capt. A. A. McGregor on lime land at Town Creek, in North Alabama. In his experiment the cowpea was the legume employed.

In 1898 cowpeas were grown on certain plots and cotton on others. The cowpea vines, on which no fruit had matured, were plowed under in the spring of 1899. Cotton was planted on plots which had borne a crop of cotton in 1898 and on others which had grown cowpeas for fertilizing purposes, as above indicated. All cotton plots referred to in this paragraph were unfertilized in 1899, and the fertilization of cowpeas and cotton in 1898 had been identical, only phosphate being used with either crop.

The weather was exceedingly unfavorable in 1899, so that the full measure of the fertilizing value of cowpeas is not revealed in this test.

Value of cowpeas as fertilizer for cotton at Town Creek, Ala.

Fertilizers used the previous year	Plot No.	Preceding crop.	Seed cotton per acre in 1899. Yield.	Increase due to cowpeas.
			Lbs.	*Lbs.*
Acid phosphate used in 1898..	6	Cowpeas in 1898.......	468	140
	1	Cotton in 1898...........	328	
Raw phosphate used in 1898..	7	Cowpeas in 1898........	316	152
	2	Cotton in 1698	164	
No phosphate used in 1898..	8	Cowpeas in 1898........	228	84
	3	Cotton in 1898..........	144	
Average increase attributable to cowpeas				125

In this case the average increase in the yield of seed cotton, which we may attribute to the cowpea vines is, even under very adverse conditions, 125 pounds, worth at $2\frac{1}{2}$ cents per pound, $3.92 per acre. Doubtless future crops will also be benefited by the fertilization with cowpeas.

The importance of the teachings of these experiments can scarcely be over-estimated. The figures show that the first cotton crop following a leguminous plant, as the cowpea and velvet bean, was much larger than was obtained on plots where the preceding crop was cotton.

According to these figures a farmer can reasonably expect to obtain an increase of 300 to 600 pounds of seed cotton per acre by plowing under the entire growth of a leguminous plant, when conditions are favorable and when the legume grows luxuriantly and is the sole nitrogenous fertilizer. The gain is somewhat less when only the stubble of the legume is used as fertilizer, or when the legumes make a poor growth or occupies only a portion of the land, as occurs when cowpeas are drilled between the corn rows. But under all these conditions leguminous plants augment the yield of the following cotton crop to a profitable extent.

In the writer's opinion *the most promising means for increasing the yield of cotton per acre and the profits of cotton culture is by a more general use of leguminous plants as fertilizers.* These invaluable allies are by some farmers utilized and appreciated, but their use might be increased twentyfold with advantage to the current crop, to the permanent upbuilding of the soil, and to the filling of the farmer's pocket. It is putting the case very mildly to say that the average yield of cotton per acre in Alabama might be increased by at least fifty per cent. through the general use of legumes as fertilizers.

The limits of this article preclude a discussion of the best means of utilizing the legumes as fertilizers and of the best kinds to employ under varied local conditions. However the section headed "Rotation on Cotton Farms" affords a suggestive outline of one method of making the valuable leguminous plants tributary to profitable cotton planting, and numerous bulletins published by this Station deal with those leguminous plants that are most available to the farmers of the Cotton States.

RESIDUAL EFFECTS OF NITROGENOUS FERTILIZERS.

Few experiments have been made here or elsewhere in the South to determine the extent to which cotton may be benefitted by applications of fertilizers made to previous crops.

A test made in 1888 suggested that compost (composition or constituents not given) exerted no effect on the second crop when the amount of compost used was only 840 pounds per acre. Certainly larger amounts of compost,—and on some soils, the quantity mentioned above,—would prove beneficial to the second as well as to the first crop of cotton.

In one experiment it was thought that cotton seed meal, used in large quantity, exerted some residual effect, but the data were not entirely conclusive.

At Auburn in 1899 the increase in the yield of seed cotton attributable to 720 pounds of rotted cotton seed applied the preceding year, was in one case 28 pounds, and in another instance 35 pounds, an average increase of only 32 pounds of seed cotton per acre.

In a similar experiment, conducted under the direction of this Station by Capt. A. A. McGregor at Town Creek in 1898, the increase in the yield of seed cotton apparently attributable to the use of 720 pounds per acre of heated or rotted cotton seed was 84 pounds, when used in connection with acid phosphate, and 120 pounds when used in combination with raw phosphate. The average increase due to the seed was in the first crop 101 pounds of seed cotton per acre.

The second crop, viz., the crop of 1899, grown on the same plots without additional fertilization, showed no favorable effect from the application the preceding year of this amount of heated seed.

It is not safe to conclude that cotton seed will usually show practically no residual effect, for the very unfavorable weather conditions of 1899 may have been responsible for the above mentioned negative results. With larger amounts of seed, and on other soils observation has shown that cotton seed do exert a marked residual or "second-year" effect.

As a general rule we may safely assume that the coarser, less concentrated, and less soluble the nitrogenous fertilizer the larger the percentage of its manurial value fails to be appropriated by the first crop and remains in the soil for the use of subsequent crops. Hence in permanency of effect we should expect stable manure and leguminous plants to rank first, followed by green cotton seed, and then by crushed or rotted cotton seed. Cotton seed meal is very largely, if not entirely, utilized or wasted the first year, while from nitrate of soda we can expect no perceptible residual effect.

A RATIONAL SYSTEM OF FERTILIZATION.

Considering permanency of effect, as well as influence on the crop immediately following, the cowpea and other leguminous plants must be ranked as a cheaper source of nitrogen than is any nitrogenous material which may be bought as commercial fertilizers. The aim of the cotton farmer should be to grow such areas of legumes as will enable him to dispense with the purchase of nitrogenous fertilizers for cotton, using the funds thus saved to purchase increased amounts of phosphates or other necessary non-nitrogenous fertilizers. The money that would have been necessary to purchase one pound of nitrogen will buy about three pounds of phosphoric acid, or of potash, which larger purchases of phosphate and potash will enable the farmer to grow heavier crops of legumes. And heavier crops of legumes trap larger amounts of otherwise unavailable atmospheric nitrogen and result in further soil enrichment and in increased amounts of forage, enabling the cotton planter to maintain more livestock and to save more barn manure.

RAW VERSUS ACID PHOSPHATE.

On the College Farm at Auburn in 1882, the increase attributable to acid phosphate was 182 pounds of seed cotton per acre, while the increase ascribed to an equal weight of raw phosphate averaged 91 pounds, both phosphates having been used in connection with cotton seed meal.

In 1884, in the presence of 360 pounds of cotton seed meal per acre, raw phosphate was practically as effective as acid phosphate. In 1885 the results bearing on this question were inconclusive by reason of want of uniformity in the soil of the plots. In 1886 the results show that in the absence of nitrogenous fertilizers, neither raw nor acid phosphate at the rate of 420 pounds per acre was greatly advantageous, the yield being slightly in favor of the raw phosphate.

In 1887, in the presence of 210 pounds of cotton seed meal per acre, the yield was greater with raw than with acid phosphate (210 pounds of either), while in the absence of organic fertilizers the yields were practically identical with these two forms of phosphate.

In 1888, in connection with 400 pounds of cotton seed meal per acre, floats and acid phosphate afforded nearly equal yields of seed cotton.

In 1896 at Auburn, acid phosphate afforded a larger yield of seed cotton than did Florida soft phosphate, both being applied in the presence of cotton seed meal.

In 1897 high grade acid phosphate was compared with Tennessee (raw) phosphate and with (raw) Florida soft phosphate. In all cases, whether rotting vegetable matter (in the form of cotton seed meal) was present or absent, the acid phosphate afforded the larger yield.

The single instance in the experiments of recent years in which raw phosphate afforded a larger yield than acid phosphate, was when in 1897 equal quantities of each were composted with 1,500 pounds per acre of horse manure. Under these conditions the yield was 44 pounds greater with raw that with acid phosphate.

ACID PHOSPHATE VERSUS RAW PHOSPHATE.

In the co-operative experiments conducted under the direction of this Station on many different classes of soils, numerous comparisons of acidulated and raw phosphate have been made.

In 1890 the comparison was between 195 pounds of dissolved bone and 300 pounds of floats per acre, 90 pounds of sulphate of ammonia per acre being used with each. In 20 tests the average yield of seed cotton per acre was 904 pounds when the acidulated phosphate was used and only 780 pounds with floats. The difference in favor of dissolved bone was 124 pounds of seed cotton per acre.

In 1891 and 1892 the comparison was between equal weights of acid phosphate and floats, 240 pounds per acre, both being used in connection with 96 pounds of sulphate of ammonia per acre.

The average of 27 tests in 1891 shows a yield per acre of 824 pounds of seed cotton with acid phosphate and of only 609 pounds with floats. The difference in favor of acid phosphate was 215 pounds of seed cotton per acre.

The average of 22 tests in 1892 shows that the yield of seed cotton per acre was 863 pounds with acid phosphate and only 703 pounds with floats. The superior effect of the acidulated phosphate is measured by the difference of 160 pounds of seed cotton per acre.

It is of interest to note that in 27 tests in 1891 a mixture of cotton seed and 240 pounds of floats per acre afforded an average yield of seed cotton which exceeded the yield obtained with an application of cotton seed alone by only 64 pounds of seed cotton per acre. Likewise in 22 tests in 1892 the addition of floats to cotton seed increased the average yield by only 76 pounds of seed cotton per acre. In these tests the amount of seed used as fertilizer was about 800 pounds per acre.

Thus, under conditions favorable to raw phosphate, (that is, in the presence of decomposing vegetable matter), it was able to increase the yield only to the extent of 64 or 76 pounds of seed cotton per acre. On the basis of the prices prevailing in 1897 and 1898, the cost of the raw phosphate was greater than the value of the increased yield attributable to this fertilizer.

Not only was the average yield much smaller with raw than with acid phosphate, but in 58 of these tests, that is, in 88 per cent. of the separate experiments, the acid phosphate afforded the larger yields.

In the co-operative experiments of 1896 a comparison was made between equal weights of high grade acid phosphate (16.2 per cent. available phosphoric acid) and Florida soft phosphate, the latter containing 29.2 per cent. of total phosphoric acid, nearly all being in an insoluble form. With both phosphates kainit was used and also 200 pounds per acre of cotton seed meal.

In 14 tests the average yield of seed cotton per acre was 43 pounds greater with acidulated than with raw phosphate. The superiority of the acid phosphate was shown by the higher yields with this fertilizer in each of 11 experiments, or in 79 per cent. of the tests.

A series of experiments planned to throw light on the immediate and residual effects of raw and acid phosphate and cotton seed and on the value of green manuring was begun in 1898 at Auburn and in co-operative tests under our direction in other localities. The data relative to cotton seed and cotton seed meal and green manuring have been briefly discussed elsewhere in this article. For various reasons most of these experiments were not continued as planned, hence the following table is somewhat fragmentary, showing only such data as directly bear on the relative values of acid phosphate and Tennessee phosphate. Equal quantities of the two phosphates were used, 240 pounds per acre.

Yield in pounds of seed cotton per acre; acidulated vs. raw (Tennessee) phosphate in 1898.

Plot No.	Fertilizer per acre.	Blountsville. Yield.	Blountsville. Increase due to phosphate	Town Creek. Yield.	Town Creek. Increase due to phosphate.	Notasulga. Yield.	Notasulga. Increase due to phosphate.	Auburn.	Average increase due to phosphate.
	No vegetable matter (1898).	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*		
1	240 lbs. acid phosphate	960	696	544	304	552	136		279
2	240 lbs. raw phosphate	512	248	244	4	506	46		99
3	No phosphate	264		240		416			
	Vegetable matter in cotton seed (1898).								
4	240 lbs. acid phosphate 720 lbs. cotton seed	1280		628		1020			
5	240 lbs raw phosphate 720 lbs. cotton seed	811		360		796			
	Abundance of vegetable matter in 1899, from cowpea vines of 1898.								
8	Cowpea vines No phosphate								
9	Cowpea vines 240 lbs. acid phosphate			356	128			1390	
10	Cowpea vines 240 lbs. raw phosphate			256	28			1184	

At Town Creek and Blountsville, on lime soils, and at Tuskegee and Auburn on sandy soils, the results point to a common conclusion, to decided preference of the cotton plant for the acidulated form of phosphate.

It has been claimed that raw phosphate is as effective as acid phosphate when used in connection with large quantities of organic fertilizers or on land containing much vegetable matter. The rotting vegetable matter is thought to convert a part of the insoluble phosphoric acid into a soluble form.

The records in the above table do not show an equality of the two classes of phosphates even under these favorable conditions. Raw phosphate was decidedly less advantageous than acid phosphate even when applied to land on which a few months before a heavy growth of cowpea vines had been incorporated with the soil. Notwithstanding the assumed favorable effect of the vegetable matter in increasing the availability of the raw phosphate, the yield, under these conditions, was, with acid phosphate, greater by 100 pounds of seed cotton in one case and by 206 pounds in another instance.

When vegetable matter was not thus supplied the superiority of acid phosphate was still more marked, the differences in yield in its favor being respectively 448, 300 and 90 pounds of seed cotton, an average excess of 279 pounds per acre.

While a few of the earlier tests made at Auburn were thought at the time to indicate the possibility of the economical substitution of the cheaper raw phosphate for the most costly acidulated material, our hundred or more experiments bearing on this question, taken as a whole, declare emphatically that under ordinary conditions and present prices it is more profitable to fertilize cotton with acidulated than with raw phosphate. When the latter is employed at all it is best to use in connection with it some form of organic nitrogenous material as stable manure, cotton seed, or even cotton seed meal.

REVERTED VS. SOLUBLE AND INSOLUBLE PHOSPHORIC ACID.

At Auburn in 1882, 1886, 1887 and 1897, phosphate in which the phosphoric acid existed in reverted or citrate-soluble form was compared with raw and with acid phosphate.

In the two earlier tests reversion was caused by the addition of slaked lime to double its weight of acid phosphate, the resulting mixture being compared with the same amount of acid phosphate as had been used in the preparation of the reverted phosphate.

In 1882, in the presence of cotton seed meal, the increase in yield attributable to the reverted phosphate was 106 pounds of seed cotton per acre, against an increase of 182 pounds with acid phosphate and 91 pounds with raw phosphate. In 1884, in the presence of very large amounts of cotton seed meal, reverted, raw, and acid phosphate gave practically identical results. In 1886, in the absence of vegetable matter, the yield with 420 pounds of reverted phosphate per acre (source and method of manufacture not indicated) was greater than with an equal weight of English acid phosphate or of raw phosphate. In 1887 the results were inconclusive.

In 1897 the reverted phosphate was prepared as follows:

Equal quantities of acid phosphate and Florida soft phosphate were thoroughly mixed and moistened about one month before being applied to the soil. The mixture was then allowed to dry thoroughly, after which it was pulverized as thoroughly as practicable. This was done in order that reverted phosphate might be formed from some of the phosphoric acid previously existing in an insoluble form in the Florida soft phosphate.

The raw, reverted, and acid phosphate was each used at the rate of 240 pounds per acre, and with each was cotton seed meal and kainit.

With a mixture of these two kinds of phosphates the yields were larger than with an equal weight of Florida soft phosphate, but smaller than with an equal weight of acid phosphate.

The experiments made at this Station are not entirely conclusive as to the value of reverted phosphate as a fertilizer for cotton. On the whole they afford no proof that citrate soluble phosphoric acid is decidedly inferior to the water soluble form; they strongly suggest the superiority of reverted phosphoric acid to the insoluble form.

SOLUBLE PHOSPHORIC ACID FROM DIFFERENT SOURCES.

From the results of experiments conducted at Auburn in 1883 and 1884, Prof. J. S. Newman drew the conclusion that "the cotton plant has no choice between soluble phosphoric acid from bone and from phosphate rock."

RESIDUAL EFFECTS OF PHOSPHATES.

In 1888 cotton was grown without fertilizers on plots which both in 1886 and 1887 had been fertilized with 420 pounds per acre of either raw, reverted, or acid phosphate. The results are scarcely conclusive; the yields show no greater residual effect from raw phosphate than from reverted phosphate and apparently little if any advantage of raw over acid phosphate in its second-year or residual effects. Indeed there was apparently but little increase in yield on most plots as the result of the application of large doses of any of the several forms of phosphate.

The results bearing on the relative residual effects of raw and acid phosphate obtained in three experiments in 1898 and 1899 are given in the table below. In 1898 high-grade acid phosphate and Tennessee raw phosphate, without nitrogen, were used in fertilizing cotton on adjacent plots, a third plot being unfertilized in 1898. In 1899 all three plots were unfertilized.

Pounds seed cotton per acre in 1899 on plots fertilized in 1898 with raw and acid phosphates.

	Yield in 1899.	Auburn	Town Creek.	Average Yield.	Average increase due to 2nd year effect of phosphate.
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*
P. 1	240 lbs. acid phosphate in 1898	1156	328	742	....
P. 2	240 lbs. Tenn. (raw) phosphate in 1898	1100	164	632	....
P. 3	No fertilizer in 1898	820	144	382	....
	Increase in yield in 1899, due to fertilizers of 1898				
P. 1	240 lbs. acid phosphate in 1898	336	184	....	260
P. 2	240 lbs. Tenn. (raw) phosphate in 1898	280	20	....	150
P. 3	No fertilizer in 1898	....	....	....	....

Both in the test conducted on sandy and on lime land, at Auburn and on the farm of A. A. McGregor, at Town Creek,—the yield of cotton was greater in 1899 on land which the year previous had been fertilized with acid phosphate than on that previously fertilized with raw phosphate. These two experiments indicate plainly that acid phosphate, applied to cotton at the rate of 240 pounds per acre, is not necessarily exhausted the first year, but may extend its beneficial effect to the crop of the second year. They contradict the supposition that raw phosphate, by reason of its slow solubility must necessarily have a greater residual or second-year effect than an equal amount of acid phosphate.

Taking into consideration all experiments made by or under the direction of this Station, there seems to be abundant reason for preferring the acidulated to the raw phosphate, and little ground for expecting the raw phosphate to show a superiority to acid phosphate in the years subsequent to that in which the application is made.

Acid phosphate now is, and is likely to remain, the cotton planter's most economical source of phosphoric acid.

BEST FORM OF POTASH.

Of the several forms of potash kainit is most used by the cotton planter. Its effects in restraining black rust have been often noted in the publications issued both by the Biological and Agricultural Departments of the Alabama Experiment Station. But inasmuch as this subject is discussed at length by the Biologist, it is only necessary here to refer to it.

In our fertilizer experiments two facts relative to kainit and rust are noticeable, viz: (1) the usual favorable effect of kainit in checking rust, and (2) its occasional failure on some soils and in some seasons to reduce the injury resulting from this disease.

An example of the very effective use of kainit in checking rust occurred on the farm of this Station on sandy soil in 1898; on the other hand in 1899 there was little benefit from kainit in restraining rust, this negative result being obtained on the same soil which had the previous year gratefully responded to applications of potash.

An experiment conducted by the writer in 1898 showed that a pound of potash in the form of muriate was as effective in checking rust as when an equal amount was applied in the form of kainit. A comparison of potash in the form of kainit, muriate, sulphate and silicate was made in 1889 on light sandy soil on the farm of J. Binford, near Auburn. The results were inconclusive except in showing that under the unfavorable conditions of soil and weather no form of potash was decidedly advantageous.

In our co-operative fertilizer experiments 100 pounds of kainit per acre has been repeatedly contrasted with 200 pounds, both being used in connection with cotton seed meal and acid phosphate. The smaller as well as the larger amount has exerted a noticeable effect in checking rust. In 1898 on the Station Farm 200, 100, and 60 pounds of kainit per acre were compared, each forming part of a complete fertilizer. The larger amount was most marked in its restraining effect upon rust, while 60 pounds exerted a slightly favorable influence. If kainit is used to prevent rust it seems advisable to use at least 100 pounds per acre, and quantities much smaller than this can scarcely be expected to have much effect on rust, though in a general way they may be beneficial.

Usually potash can be purchased at a cheaper rate in muriate of potash or kainit than in the sulphate, or in other forms. In deciding between muriate and kainit the farmer should remember that it is slightly less convenient to apply muriate of potash; for as this is four times as strong as kainit, it is advisable to use only 25 to 50 pounds of the muriate per acre, which small amount necessitates extreme care in pulverizing and evenly distributing this fertilizer.

Aside from this slight consideration of convenience, the farmer should buy that one of these materials in which a pound of potash delivered at his farm costs him least. Where the freight rate or cost of hauling is high the muriate will be the cheaper source of potash; near seaport cities, or where freight rates are low, kainit may be the cheaper form of potash.

Where very large doses of kainit are employed it is doubtless preferable that the kainit be placed in the soil at least several weeks before the seed are planted. In using 200 pounds of kainit per acre, carefully incorporated with the soil by running a scooter plow in the drill, we have been able to detect no injury from applying this fertilizer immediately in advance of planting, though our preference is to apply all fertilizers some weeks in advance so as to insure their diffusion through the soil and to permit the ridges or beds to become moderately compact before planting.

BEST POTASH FERTILIZERS.

In 1898 and 1899 comparison was made of several kinds and of varying amounts of potash fertilizers. The experiment was continued for two years on the Station Farm. The plots were located on the crest of a hill, where the soil was a deep, white or gray sand, and very poor. This spot was selected because of its extreme liability to cause cotton growing on it to suffer from rust, a disease for which kainit has often been recommended as a preventive.

In 1898 muriate of potash at the rate of 50 pounds per acre was at least as effective as 200 pounds of kainit in restraining rust and in augmenting the yield. Black rust was very severe on the plots receiving no potash and on the plot to which had been applied in large quantity an insoluble form of potash,—native potash feldspar rock. In checking rust 200 pounds of kainit per acre was better than 100 pounds, and this latter amount was slightly more effective than 60 pounds of kainit per acre.

The results of tests made in 1899 on this poor field are given below; the basal mixture referred to consisted of 120 pounds of cotton seed meal and 240 pounds of acid phosphate per acre.

Yield of seed cotton obtained with the use of different forms of potash.

Plot No.	Fertilizers. Am't per acre.	Fertilizers. Kind.	Yield of seed cotton per acre.
	Lbs.		*Lbs.*
1	200	Kainit and basal mixture	678
2	100	Kainit and basal mixture	592
3	60	Kainit and basal mixture	526
4	......	No potash; only basal mixture	272
5	1000	Potash feldspar in 1898; only basal mixture in 1899	244
6	50	Muriate of potash and basal mixture	768

Although there was some rust in 1899, the amount was much less than in the preceding year. Potash only moderately increased the yield in 1898, and to an extent by no means commensurate with its effect in checking rust and causing the plants to retain their leaves late into the season. In 1899, on the other hand the yield with potash was at least double that of the plots receiving none of this material, but little of which increase can be attributed to the rust-restraining effect of potash. Even the small amount of 60 pounds of kainit per acre was highly beneficial, 100 pounds still more advantageous, and 200 pounds of kainit or 50 pounds of muriate afforded a large increase in the yield of cotton.

A special potash experiment made by Mr. R. Neighbors, near Auburn, for this Station, was inconclusive by reason of want of uniformity in the soil.

In 1899 a special potash experiment was made under the direction of the writer by Mr. John Binford, on his farm two miles southeast of Auburn. This soil is a gray sand. On the plots receiving full rations of potash, such an amount of the several fertilizers was used as would supply equal quantities of potash. On one plot common salt was substituted for kainit. There was some little rust, but in this respect there was no very great difference among the several plots, though it was noted August 18th, that rust was most abundant on the plot receiving neither potash nor salt and that it was least abundant on the plot fertilized with silicate of potash.

The basal mixture referred to in the following table consisted of 200 pounds of cotton seed meal and 240 pounds of acid phosphate per acre. The stand of plants was good on all plots. The results of the special potash experiment on Mr. Binford's farm are shown in the following table:

Results of special potash experiment in 1899.

Plot No.	Amount per acre.	FERTILIZER.	Yield seed cotton per acre.
	Lbs.		*Lbs.*
1	200	Common salt (NaCl) and basal mixture...	576
2	50	Muriate of potash and basal mixture......	608
3	....	Only basal mixture......................	584
4	200	Kainit and basal mixture................	624
5	60	Kainit and basal mixture................	524
6	100	Kainit and basal mixture................	492
7	28	Sulphate of potash and basal mixture.....	672
8	32	Silicate of potash and basal mixture......	612

In no form was potash notably advantageous, for the higher yields of Plots 7 and 8 were apparently due to want of perfect uniformity in the soil.

The three experiments referred to above, together with data obtained incidentally from other experiments at Auburn and numerous co-operative fertilizer tests seem to warrant the following conclusions relative to the use of potash fertilizers with cotton:

(1) Not only kainit, but other soluble forms of potash, as the muriate, sulphate, and silicate may, under suitable atmospheric conditions, restrain the spread of black rust.

(2) The minimum amount required to exert a notably beneficial rust-restraining influence is not yet determined, but is between 50 and 100 pounds of kainit per acre, and apparently nearer the latter figure.

EFFECTS OF LIME ON COTTON.

Few experiments have been made at the Alabama Experiment Station or elsewhere in applying lime to cotton. Those made here, are mentioned below.

In 1885, 300 pounds of floats (raw phosphate) per acre used alone afforded an average yield of 337 pounds of seed cotton per acre. An adjacent plot fertilized with the same amount of floats and also with 150 pounds of air slaked lime per acre yielded 442 pounds, an increase of 105 pounds of seed cotton per acre.

In 1886, and again in 1887, air slaked lime at the rate of 420 pounds per acre was applied to cotton in connection with an equal quantity of floats and also on other plots with an equal amount of acid phosphate. There was no increase in yield on the plots receiving lime, either during the year when applied, or in the succeeding year.

In 1896, air slaked lime was applied broadcast in January at the rate of 640 pounds per acre to our stiffest grade of land, in addition to a complete fertilizer applied in the drill. The plot receiving lime afforded in 1896 practically the same yield as the check plot. However, the cotton crop in 1897, growing on a plot where a similar dressing of lime had in 1896 been applied to cowpeas, afforded an increase of 91 pounds of seed cotton per acre in comparison with the yield of the check plot.

In short, light applications of lime in four experiments failed to increase the yield of cotton; in two experiments a moderate increase in yield of cotton accompanied the use of lime. These favorable effects seem to be exceptional and may be due in the one case to the effect of lime in changing insoluble into soluble potash in the soil, and in the other to the action of lime in hastening the rotting of the cowpeas which had recently been plowed into the soil.

On our upland soils at Auburn there appears to be no advantage in applying lime. However, on this farm is one reclaimed swamp, with a poorly drained acid soil. Probably on soils of this nature cotton would respond to applications of lime.

Nor should it be assumed that a sour or acid condition is found only in low-lying, poorly drained fields. On the flat sandy top of the Little Mountain in Lawrence county, in the northern part of the State, the writer tested a number of samples of cultivated, apparently well drained soils, and in most cases they showed an acid reaction. In the extreme southern part of the State sour soils are frequently to be found. The writer found a number of such tracts near Brewton and Prof. F. S. Earle has noted their occurence near Citronelle, in the same part of the State.

We know that many plants are intolerant of acid soils and that others are indifferent. It is not known to which class of plants cotton belongs, but on all soils which show an acid reaction,—indicated by the moist soil turning blue litmus paper to a pink or reddish tint, —there is a probability that lime will be helpful to most cultivated plants.

BARN MANURE.

Only an inconsiderable proportion of the acreage in cotton is fertilized with barn manure. In explanation it must be said that the number of livestock maintained on most cotton farms is entirely inadequate to furnish barn manure for any large acreage. Often this consists of little more than the teams necessary to cultivate the crop, or one mule for each 15 to 25 acres of cotton. A large proportion of the manure obtained from work teams is applied to corn and other food crops.

An increase in the number of head of livestock maintained on cotton farms would do much towards bringing prosperity to cotton planters. * At prices recently prevailing there is little if any profit in growing cotton except on land naturally fertile or on well manured soil. It is probably a conservative estimate if we regard only half the acres that the *average* farmer cultivates in cotton as returning a profit, the other half barely paying expenses or incurring a loss. The conversion of these poorer areas, at present unprofitably cultivated in cotton, into pastures on which to maintain an increased number of livestock, offers obvious advantages both in direct and indirect profits. Thus utilized, poor soils are renovated, and the livestock maintained on them would also afford a home market for the cotton seed produced on the farm, checking this drain upon the fertility of the soil, and manufacturing manures that can in large part take the

* These statements refer to a price of 5 to 6 cents per pound of lint cotton.

place of purchased chemical fertilizers.

This is said with a due recognition of the fact that on many cotton farms there are, at present, conditions that make it impracticable for their owners to engage in the growing of livestock on an extensive scale. In such cases the main reliance for the permanent improvement of cotton soils must be the use of leguminous plants as direct fertilizing agencies. When the system of growing leguminous plants (the cowpea, vetch, and their kin) for plowing under as fertilizers becomes established on any farm, many of the obstacles in the way of stock raising will have been overcome and it will be relatively easy to make the further advance step of keeping animals to consume the legumes, thus getting the food value of these plants, with very slight diminution of their fertilizing properties.

COMPOSTING.

As the word compost is used by the cotton planter it usually refers to a mixture of stable manure, cotton seed, and acid phosphate, which after being brought together are allowed to ferment 4 to 10 weeks. Other coarse materials and also other chemical fertilizers often enter into a compost. The theory underlying the making of composts is that during the fermentation materials previously insoluble are decomposed and converted into a soluble condition.

Our experiments with composts have been concerned with the question of relative profits from composts and from the use of the same fertilizers in their fresh or unfermented condition.

In 1896 a compost made up of 1 part (by weight) of acid phosphate, 1 part of crushed cotton seed, and 4 parts horse manure, was compared with the same materials applied in the drill March 17, in their unfermented condition. The compost was allowed to ferment under shelter for four weeks, being meanwhile kept moist, and was applied in the drill April 14. The yield of seed cotton was greater by 222 pounds per acre on the plot receiving the fresh materials than on the compost plot. This result may have been due, entirely or in part, to the greater looseness of the seed bed incident to the late application of compost.

To eliminate this condition of uneven looseness of the seed bed, the compost and the corresponding fresh materials were applied on the same day, April 16, in 1897. The compost had been made four weeks before, and had been kept under most favorable conditions. It consisted chiefly of stable manure, supplemented by acid phosphate and cotton seed meal. The difference in the yields was 54 pounds of seed cotton per acre in favor of the fresh materials.

In 1899 a compost of 1 part acid phosphate and 7 parts horse manure afforded a yield of 1,384 pounds of seed cotton, against a yield of 1,237 pounds with the corresponding fresh materials, a difference of 147 pounds in favor of the compost, when compost and fresh materials were applied the same day.

In plots which adjoined those just referred to Tennessee raw phosphate and horse manure, in proportions as above, gave practically the same yield when applied fresh as when made into compost.

Taken as a whole, these four experiments offer no arguments in favor of composting such materials as cotton seed, fine stable manure, cotton seed meal, and phosphate. Nor do the experiments along this line made at other experiment stations sustain the claim that these materials can usually be profitably composted for cotton, when the price of this staple is as low as it has been in recent years.

Composting involves a large amount of labor, in return for which it offers the advantage of being more quickly available to the plant than are the corresponding raw materials. Hence composting is advisable where quick action of a fertilizer is desired, as in truck farming, where earliness is an important consideration. With cotton it has not been shown that an immediately available fertilizer is as desirable as it would be on truck crops. On the contrary the long growing season of the cotton plant allows a long period for nitrogenous fertilizing materials to decompose and become soluble.

In applying the fertilizers referred to above, the coarser constituents have been drilled in the center furrow, the acid phosphate being applied last and mixed with the barn manure by the use of a scooter plow.

It is not contended that either our experiments or those at other stations have definitely settled the question against composting stable manure and cotton seed. Their teachings, as we interpret them, are that convenience and cost of labor should be the chief consideration in determining whether the composting of *fine* stable manure, cotton seed, and acid phosphate is advisable. The case is quite different when coarse litter of any sort, as oak leaves, pine needles, or coarse manure is obtainable at slight outlay for labor. And there is a good argument for placing in the compost heap such cotton seed as cannot be applied in the drill early enough to prevent germination, many farmers finding composting a convenient means of killing the seed that are to be applied late in the season. On theoretical grounds there should be some advantage in composting raw phosphates instead of placing them directly in the soil. But it will scarcely be contended that composting effects any improvement in the availability of acid phosphate, for the phosphoric acid in this is in a soluble condition when purchased.

METHODS OF APPLYING FERTILIZERS.

Fractional or intercultural application of fertilizers. The question is often asked whether it is best to apply all of the commercial fertilizer before planting or to reserve a portion of it to apply at a later date. To aid in the solution of this question numerous experiments have been made here. In two of these tests a part of the phosphate was reserved for use in the early summer. In neither case did this procedure result in a larger crop than when all of the phosphate was applied before planting in the usual manner.

In one experiment a mixture of equal parts of acid phosphate and cotton seed meal was applied in the center furrow in the usual way before planting, and at the rate of 420 pounds of the mixture per acre. In comparison with this, other plots received half of this mixture before planting and the other half either at the time of the first, second, or third plowing. Thus the amount of fertilizer was the same on all plots, but the distribution of half of it varied. The yields of seed cotton per acre were 1603 pounds when all was employed before planting, 1425 pounds when half was reserved until the first plowing; 1385 pounds when half was used at the time of the second plowing, and only 1357 pounds when half the fertilizer was not applied until the third plowing.

Dividing the fertilizer and applying part of it as above during the growth of the plant necessitates additional expense. The three experiments referred to above, which are the ones giving plainest testimony on this point, indicate that dividing the fertilizer failed to increase the crop. In none of our intercultural experiments with cotton is there clear evidence of advantage resulting from fractional applications of acid phosphate, kainit, or cotton seed meal. Since the usual method is cheaper and the dividing of the fertilizer fails to increase the yield, we must regard it as generally more profitable to apply all the fertilizer before planting.

The preceding statements do not imply that fertilizers are ineffective if employed after the plant comes up. On the other hand our tests afford some evidence that nitrate of soda applied as late as the middle of July and cotton seed meal used as late as the latter part of June may exert a favorable effect on the yield of cotton when the supply of nitrogenous fertilizer used before planting is inadequate. In other words we may increase the yield by an addition of nitrogenous fertilizer as late as July, but the augmentation in yield is greater in proportion to the earliness of application, and the extra amount of fertilizer is apparently in most cases most beneficial if it also is placed in the soil before the seed. In a test to determine the latest date at which fertilizers can be applied, it was found that neither 200 pounds of cotton seed meal per acre nor a like amount of kainit was at all effective when employed as late as August 13 on plots liberally fertilized with cotton seed meal and phosphate at the time of planting.

There is room for further investigation to determine whether kainit or other potash salts will exert a restraining effect upon black rust if applied after the first symptoms of rust have appeared.

With this possible exception, and the further possible exception of nitrate of soda, we may safely conclude that the best time to apply commercial fertilizers (in usual amounts) to cotton is before the seed is planted.

Reserving part of the fertilizer for application in the seed drill.—In three experiments, made at Auburn in 1896 and 1897, this matter was under test. A complete fertilizer, made up of acid phosphate, cotton seed meal and kainit, was used at the rate of 420, 560, and 635 pounds per acre, these unusually large amounts being employed in order to emphasize any difference in yield that might be obtained. The greater portion of the fertilizer was placed in the center or "marking off" furrow in the usual manner before the beds or ridges were formed. Either one-third or one-fourth of the total amount of fertilizer was reserved and applied at the time of planting in immediate contact with the seed.

In all three experiments the yield was slightly less on plots where the fertilizer was applied in this manner than on comparable plots receiving all of the fertilizer in the center furrow according to the usual custom.

FERTILIZING IN CENTER FURROW VERSUS IN LISTING FURROWS.

In 1898 a complete fertilizer, consisting of acid phosphate, cotton seed meal, and kainit was applied just before planting either (1) all in the center furrow as usual, or (2) one-third in center furrow and one-third in each listing (side) furrow, or (3) one-half in each listing furrow. No special pains were taken to incorporate fertilizer with the soil except on the plots where all the fertilizer was applied in the center furrow, in which case a scooter plow was used to mix the large amount of fertilizer with the soil.

The results of this single experiment showed that there was a loss in placing all of the fertilizer in the listing furrows. Comparing only those plots which have since given proof of uniformity in natural fertility we find little or no advantage in dividing the fertilizer equally between the center and the two listing furrows as compared with placing all of the fertilizer as usual in the center furrow. Possibly the former method may be found advantageous when amounts of commercial fertilizer considerably exceeding 500 pounds per acre to be employed.

In using less than 500 pounds of fertilizer per acre there seems to be no advantage in dividing it between center and list furrows. If 300 pounds or more of commercial fertilizer is applied in the center furrow, it is desirable to mix this with the soil by the use of a scooter plow.

DEPTH AT WHICH FERTILIZERS SHOULD BE APPLIED.

In 1885 a fertilizer called Tinsley's Standard was drilled at the rate of 300 pounds per acre in center furrows which were 2 and 4 inches deep. The resulting yields were practically identical and apparently uninfluenced by the variations in the positions of the fertilizer.

CO-OPERATIVE FERTILIZER TESTS MADE BY FARMERS.

In recognition of the fact that the soils of the Experiment Station Farm at Auburn represent a comparatively small area of the cotton lands of the State, local fertilizer experiments, conducted by farmers under the direction of the Alabama Experiment Station, were begun in 1889. The weighing and mixing of fertilizers has been done at Auburn, and the separate packages for each plot, properly labeled, have been shipped to the local experimenters. Detailed directions as to choice of land, dimensions of plots, methods of securing uniform stand of plants, and precautions to be taken in harvesting the crop, have each year been furnished to each experimenter; uniform blank forms for reporting results have been supplied, and in the last three years these blank forms have been so designed that when filled out by the local experimenters they may afford detailed information regarding the nature of the original forest growth, nature of the soil, history and previous cropping of the land, and details of cultivation, etc.

The following list indicates the large amount of data thus far obtained as the result of these local fertilizer tests, or "soil tests" with cotton:

Year.	No. tests.	Reported in	Under direction of
1889	3	Alabama Sta. Bul. 12...	J. S Newman.
1890	24	Alabama Sta. Bul. 23...	do.
1891	43	Alabama Sta. Bul. 34....	do.
1892	36	Alabama Sta. Bul. 42....	A. J. Bondurant.
1896	21	Alabama Sta. Bul. 78....	J. F. Duggar.
1897	30	Alabama Sta. Bul 91....	do.
1898	36	Alabama Sta, Bul. 102....	do
1899	22	....	do
	215		

This list of 215 separate tests, requiring in the aggregate 2,766 plots, does not include a number of special fertilizer tests made by farmers for this Station in the past three years to determine the best forms of phosphate and of potash for cotton. Nor does it include any fertilizer tests on other crops than cotton, and it excludes all tests not reported in full to the Agricultural Department of the Experiment Station.

The size of plots during the first two years of these tests was one-fifteenth acre, and subsequently one-sixteenth acre; in 1896 and in all later experiments the size was increased to one-eighth acre.

The number of plots in each test, which at first was 15, was reduced when, for the sake of greater accuracy, the size of plots was increased.

The experiments of 1896 were directed especially towards a comparison of different forms of phosphatic and nitrogenous fertilizers, and only incidentally have they a value as soil tests.

The co-operative fertilizer experiments of 1897, 1898, 1899 and those arranged for in the present year are on a uniform plan. In each of these experiments there are 10 plots, 2 of which are unfertilized, In determining the increased yield on the plots lying between the two unfertilized plots, the yields on both of the latter are used, giving to each a weight inversely proportional to its distance from the plot under comparison.

The tenth plot of each test is not really a part of the regular soil test, but is added to ascertain the economy and rust-restraining influence of a half ration of kainit in a complete fertilizer.

The following table shows the general plan of the series of co-operative fertilizer experiments now under way, and gives the kind and amount of each fertilizer and the number of pounds of nitrogen, phosphoric acid, and potash in each formula:

Pounds per acre of fertilizers, nitrogen, phosphoric acid, and potash used and composition of each mixture.

Plot No.	Fertilizers. Amount per acre.	Fertilizers. Kind.	Mixture contains Nitrogen.	Mixture contains †Available phosphoric acid.	Mixture contains Potash.
	Lbs.		*Lbs.*	*Lbs.*	*Lbs.*
1	200	Cotton seed meal	13.58	5.76	3.54
		In 100 *lbs. c. s. meal**	6.79	2.88	1.77
2	240	Acid phosphate	....	36.12	....
		In 100 *lbs. acid phosphate*	....	15.05	....
4	200	Kainit	....	....	24.60
		In 100 *lbs. kainit*	....	....	12.30
5	200 240	Cotton seed meal Acid phosphate	13.58	41.88	3.54
		In 100 *lbs. above mixture*	3.09	9.52	.80
6	200 200	Cotton seed meal Kainit	13.58	5.76	28.14
		In 100 *lbs. above mixture*	3.39	1.44	7.03
7	240 200	Acid phosphate Kainit	....	....	....
		In 100 *lbs. above mixture*	....	8.21	5.59
9	200 240 200	Cotton seed meal Acid phosphate Kainit	13.58	41.88	28.14
		In 100 *lbs. above mixture*	2.12	6.54	4.39
10	200 240 100	Cotton seed meal Acid phosphate Kainit	13.58	41.88	15.84
		In 100 *lbs. above mixture*	2.59	7.75	2.93

* Average of many analyses.

† Counting all of the phosphoric acid in cotton seed meal as available.

The choice of cotton seed meal as the best nitrogenous fertilizer for these tests was made after careful weighing of its advantages and disadvantages as compared with sulphate of ammonia and nitrate of soda, which had been used in the earlier tests. The one disadvantage of cotton seed meal in fertilizer experiments is the fact that it contains, in addition to nitrogen, small amounts of phosphoric acid and potash. The arguments for its use, in spite of this disadvantage, were these: Cotton seed meal is a cheap source of nitrogen and by far the most generally used form of purchased nitrogenous fertilizer, hence farmers will immediately make use of any formulas that may be found best in experiments with cotton seed meal, while they might be slow to avail themselves of even the best formulas, if they contained an unfamiliar material, not always easily obtained, like nitrate of soda or sulphate of ammonia. It was thought best in these tests, which were intended as popular demonstrations, as well as local investigations, to use only materials to which the farmers are accustomed, and which, if they proved desirable, could be easily obtained in any market. In other words, it was thought to be more necessary to ascertain whether cotton seed meal was a profitable fertilizer for a given soil than to answer the nearly equivalent question whether that soil demanded nitrogen.

In the space at hand it is not possible to present in detail the results of several hundred fertilizer tests, nor even to include the results of the soil tests made in 1899, which have not yet appeared in print.

Hence data for only a few tests can be published in this article. Choosing only those experiments which have been conducted under a uniform plan for three years on the same farm, and in which each year the results have apparently been fairly conclusive, we find that the only tests which up to date have complied with these strict conditions are those made in Monroe, Chambers, Henry, Clarke, and Randolph counties.

The following table shows the increased yield of seed cotton per acre attributable to the use, under four different conditions in each of three years, of either 200 pounds of cotton seed meal, or 240 pounds of high grade acid phosphate, or 200 pounds of kainit per acre.

Increase in pounds of seed cotton per acre attributable to 200 lbs. cotton seed meal, 240 lbs. acid phosphate and 200 lbs. kainit per acre, respectively.

Locality.	Year.	No. year.	*Increase* by adding c. s. meal					*Increase* by adding phosphate					*Increase* by adding kainit				
			To nothing.	To phosphate.	To kainit	To phosphate and kainit	Average due to meal	To nothing.	To meal.	To kainit	To meal and kainit	Average due to phosphate.	To nothing.	To meal.	To phosphate.	To meal and phos.	Average due to kainit.
			Lbs	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs*	*Lbs.*	*Lbs.*	*Lbs.*
Burnt Corn.	1897.		40	94	239	132	126	208	262	210	144	206	51	250	53	132	122
	1898		292	6	151	341	198	344	158	92	282	219	—13	—154	—265	70	—90
	1899		216	223	266	155	215	299	310	438	320	342	27	77	173	394	93
	Av.	3	183	108	217	209	180	284	210	247	249	255	22	58	—13	99	42
Cusseta.	1897.		104	202	235	253	199	160	258	84	114	156	29	150	—45	6	36
	1898.		120	228	115	– 33	107	152	260	261	117	175	—8	—13	107	—156	—15
	1899		104	38	142	164	112	264	198	305	327	274	—45	—7	—4	122	17
	Av.	3	109	156	164	128	139	192	239	217	189	202	—8	43	15	– 9	10
Dothan.	1897		80	—39	91	120	63	152	33	132	161	120	234	245	214	373	267
	1898.		32	22	32	228	78	40	30	20	216	76	136	136	116	322	178
	1899.		248	110	119	123	150	208	70	227	231	184	106	—23	125	138	87
	Av.	3	120	31	81	157	130	133	44	126	153	104	159	119	152	278	177
Jackson.	1897.		170	103	247	—64	114	150	83	182	—129	72	22	99	54	—113	16
	1898.		8	152	—32	320	112	272	416	160	512	340	136	96	24	192	112
	1899		136	—90	—146	500	103	336	110	—7	639	269	115	—167	—228	362	21
	Av.	3	105	55	23	252	109	353	203	112	341	227	91	9	—52	147	49
Kaylor.	1897.		228	35	131	170	141	352	159	28	67	152	114	17	—210	—75	—39
	1898		312	98	155	271	209	368	154	222	338	270	107	—50	—39	134	38
	1899.		112	278	183	274	212	72	238	133	224	167	49	120	110	106	96
	Av.	3	217	137	156	238	187	264	184	128	210	197	90	29	—80	54	31

Tests at Burnt Corn, Monroe County.—These tests were conducted by J. P. and J. C. Watkins on a farm two miles north of Burnt Corn. The soil is described as gray, sandy, and stony, with red clay subsoil at a depth of 6 to 8 inches from the surface. The original growth was short leaf pine, sweet gum, and red and white oaks. The land had been in cultivation about thirty years. The yields without fertilizers were, in the three years of the test, 333, 398, and 236 pounds of seed cotton per acre.

Taking the average results for three years, 200 pounds of cotton seed meal per acre applied alone afforded an increase of 183 pounds of seed cotton per acre, and applied under four different conditions in each of three years, the average increase was 180 pounds. This is sufficient to pay the cost of the cotton seed meal and to leave some profit.

Examining next the increased yield of seed cotton attributable to the use of 240 pounds of high grade acid phosphate per acre, we find that it is, when applied alone, 284 pounds; when employed under four different conditions in each of three years the average increase is 255 pounds of seed cotton; in every combination its use is highly profitable.

Kainit (200 pounds per acre), applied alone, was practically useless; in combination with the other fertilizers it was seldom decidedly beneficial; and the average increase attributable to kainit under all conditions was only 42 pounds of seed cotton per acre, which result would entail a loss from the use of kainit on this soil and in years when rust was not prevalent.

Tests at Cusseta, Chambers County.—These tests were made by T. T. Meadows on his farm one-half mile north of Cusseta, on land from which the growth of oak, hickory, and pine had been cleared about 50 years ago.

The soil, which is representative of considerable areas of the Metamorphic Region of East Alabama, is shallow, stony and red, with a subsoil of the same color. Whatever may be its deficiencies as regards composition, it is evident that it is in poor mechanical condition, and that it needs vegetable matter.

The yields, without fertilizers in the three years of the tests were respectively 84, 300, and 204 pounds of seed cotton per acre.

Cotton seed meal at the rate of 200 pounds per acre, applied alone, has given quite uniform results in the three years, the average increase being 109 pounds of seed cotton per acre, thus leaving little or no profit from the use of cotton seed meal applied alone. In all combinations its results are somewhat better, the increased yield of seed cotton averaging under all conditions 139 pounds per acre, or sufficient to yield but a small profit.

With 240 pounds of high grade phosphate per acre the gain is much greater, averaging 192 pounds of seed cotton when the phosphate was applied alone and 202 pounds as the result of using phosphate under many different conditions. This leaves a moderate or fair profit from the use of phosphate.

It is clear that kainit was not needed on this soil, for alone it failed to afford any increase and its average gain under many conditions was only the inconsiderable amount of 10 pounds of seed cotton per acre.

Other tests reported in previous publications of this Station show that phosphate is indispensable to profitable cotton culture on the soils of this region.

The more difficult problem is the determination of the proper proportion of cotton seed meal for use with the phosphate. The small size of the plant on the red soils around Cusseta indicate a need for nitrogen, but Mr. Meadow's results show gains too small, I think, to justify the use of 200 pounds of cotton seed meal per acre on soils in such poor mechanical condition and so liable to disaster from drought. One-third cotton seed meal and two-thirds phosphate is probably a safer, because cheaper proportion. And yet one hesitates to recommend as a permanent policy the expenditure necessary for even 100 pounds of cotton seed meal per acre, in view of the fact that vegetable matter is so obviously needed by these stiff red soils as a defense against injury from drought, and in view of the further fact that by choosing cowpeas or other legumes to supply this vegetable matter all necessary nitrogen would be supplied in abundance.

It would seem advisable in the cultivation of this soil to aim at putting it in such condition by the use of an occasional leguminous crop in the rotation, as to require only the purchase of acid phosphate for cotton.

Tests at Dothan, Henry County.—These tests were made by T. M. Borland, on his farm adjoining the town of Dothan. The soil is a gray sand, level, rather more subject to excessive moisture than to special injury from dry weather. The land was cleared less than 10 years ago of the growth of long leaf pine. This soil is typical in texture and moisture conditions of large areas of land in the southern tiers of counties in Alabama. Rotting of bolls in 1898 reduced the yields. The yields of seed cotton per acre in the three years of the test were 356, 268, and 584 pounds respectively. No report of marked injury from rust has been made by the experimenter.

Cotton seed meal has been beneficial to the extent of giving an average increase for all condition of 130 pounds of seed cotton per acre, which leaves a small profit. The comparative freshness of the land and the amount of vegetable matter which it still contains account for the rather slight increase with cotton seed meal, which will doubtless become more necessary as the soil remains longer in cultivation and parts with more of its original vegetable matter.

Phosphate has been beneficial, but its effects have been less marked than in most other parts of the State, possibly as a result of local weather conditions at Dothan during 1898.

Kainit has been more distinctly beneficial at Dothan than in any other locality where an equal number of tests have been made in recent years. The increase attributable to 200 pounds of kainit per acre was, when it was applied alone, 159 pounds of seed cotton per acre; averaging all the figures bearing on the use of kainit under four different conditions in each of three years, we find the average increase attributable to kainit to be 177 pounds of seed cotton per acre. Here is margin for a fair profit, and for a profit greater than that due either to cotton seed meal or to phosphate. This favorable effect of kainit is especially interesting as occurring under conditions where we cannot, apparently, attribute the benefit either to the hypothetical power of kainit to increase the moisture supply in the soil or to its rust-restraining tendency. The cause apparently lies in a deficient supply of available potash in the soil; but in the absence of chemical analysis of this soil the true cause of the good effect of kainit cannot be positively determined.

TESTS AT JACKSON, CLARKE COUNTY.

These experiments were conducted by J. L. Ballard, on the farm of the Southwest Alabama Agricultural School. The soil is described as red, with red clay subsoil. The original growth of oak, sweet gum, dogwood, and long and short leaf pine was removed about 10 years ago. The soil is naturally in good condition as shown by the yields on the unfertilized plots which, during the three years of the experiment, were respectively 735, 1,048 and 896 pounds of seed cotton per acre.

The average increase attributable to cotton seed meal was 109 pounds of seed cotton, or enough to allow little if any profit. But it should be noted that this land is still comparatively fresh.

Except in the very dry season of 1897 the returns from acid phosphate have generally been satisfactory; the increase in the yield of seed cotton per acre was 253 pounds when it was applied alone, and averaged 227 pounds when phosphate was used under many conditions. This gives a good profit. Kainit was seldom very beneficial and the gain attributable to kainit, used under all conditions, was 49 pounds. Apparently this soil did not need kainit, was not in its comparative freshness very responsive to applications of cotton seed meal, and was greatly benefitted by the use of phosphate.

TESTS AT KAYLOR, RANDOLPH COUNTY.

This series of experiments was conducted by Judge T. J. Thomason, near Kaylor and two miles south of Ranburne, on gray soil with yellow subsoil, rather retentive of water. The original growth was oak, hickory, and long leaf pine. That the soil was naturally rather fertile or in good mechanical condition is suggested by the fact that the unfertilized plots averaged in 1899, 944 pounds, and in 1897, 722 pounds of seed cotton per acre. In 1898 the unfertilizer plots yielded only 364 pounds.

The increased yield with cotton seed meal was in every case sufficient to afford a moderate profit, the average increase under all conditions being 187 pounds of seed cotton per acre.

With acid phosphate the results were decidedly favorable; the average increase in yield attributable to acid phosphate was, when it was used alone, 264 pounds, and as the average of all conditions, 197 pounds of seed cotton per acre.

The effect of kainit was irregular and in no case markedly beneficial. The average increase, under all conditions, was only 31 pounds of seed cotton, an amount entirely insufficient to pay the cost of this fertilizer.

Having considered somewhat in detail the results of 15 tests made in five localities, there still remain the corresponding data for 200 other tests, of which more than half merit consideration as conclusive so far as they go, and as affording valuable aid in the choosing of fertilizer formulas for certain soil belts.

Valuable as are these results just referred to when considered separately and in their local bearing, they cannot be chiefly summarized. The results obtained in the uniform tests of the last three years have been arranged in accordance with the following scheme of classification, in which completeness (especially as regards the effects of nitrogen) has been sacrificed for the sake of simplicity.

GROUP I. Phosphate much more important than kainit; latter not needed or used at financial loss.

GROUP II. Phosphate much more important than kainit; latter of secondary importance.

GROUP III. Phosphate and kainit both important and about equally effective.

GROUP IV. Kainit more important than phosphate; latter of secondary importance, but needed.

GROUP V. Kainit much more important than phosphate; latter not needed, or used at financial loss.

GROUP VI. Only cotton seed meal very important; phosphate and kainit of slight or no benefit.

GROUP VII. No fertilizer used very effective.

The following table practically summarizes the soil tests of the past three years, the Roman numerals referring to the number of the group which furnishes an explanation of the result of each test. Thus in all tests in which the Roman number 1 occurs, the benefit from phosphate is marked and the use of kainit unsatisfactory. The number II shows also that phosphate was of prime importance, and that in addition kainit was beneficial, but to a less extent than phosphate. In the same way the other numbers in the table may be understood by referring to the explanation of the corresponding group, which is to be found on page 280.

In brief it may be said that the predominant need indicated by the first and second group is for phosphate, in the fourth and fifth for kainit, and in the third for both in equal degree. Tests in which cotton seed meal (as well as one or both mineral fertilizers) is exceedingly beneficial, may occur in any of these first five groups. The sixth group is intended to embrace only those tests in which cotton seed meal was the sole very effective fertilizer.

Locality.	County.	(1897) *Group.*	(1898) *Group.*	(1899) *Group.*
1. Town Creek	Lawrence	I.	....	....
——:——				
2. Blountsville	Blount	....	I.	....
3. Larimore	DeKalb	....	I.	II.
——:——				
4. Snow Hill	Wilcox	....	(?) I.	(?)II.
——:——				
5. Dillburgh	Pickens	....	II.	....
6. Gordo	Pickens	....	II.	I.
7. Sulligent	Lamar	....	I.	....
——:——				
8. Clanton	Chilton	II.	....	....
9. Marvyn	Russell	....	II.	VII.
10. Prattville	Autauga	II.	....	....
11. Tuscaloosa	Tuscaloosa.	II.	II.	....
12. Notasulga	Macon	....	I.	I.
13. Vick	Bibb	....	....	VI.
——:——				
14*a*. Auburn (Sta. farm)	Lee	IV.	IV.	VII.
14*b*. Auburn (Foster farm)	Lee	....	....	VI.
15. Cusseta	Chambers	I.	I.	I.
16. Kaylor	Randolph	I.	I.	II.
——:——				
17. Brewton	Escambia	I.	III.	....
18. Burnt Corn	Monroe	II.	I.	II.
19. Dothan	Henry	IV.	IV.	II.
20. Garland	Butler	....	....	II.
21. Hartford	Geneva	....	VII.	....
22. Jackson	Clarke	VII	II.	I.
23. Lumber Mills	Butler	II.	II.	....
24. Newton (unpublished.)	Dale	....	II.	....
25. Wilson	Escambia	III.	....	I.
——:——				
26. Berneys	Talladega	III.	I.	?
27. Bevil	Choctaw	....	III.	VII.
28. Calhoun	Lowndes	....	....	I.
29. Coosa Valley (bottom)	St Clair	....	V. (rust)	....
30. Coatopa	Sumter	IV.	I.	....
31 Cullman	Cullman	....	....	VII.
32. Greensboro'	Hale	VI.	VI.	?
33. Hurtsboro	Russell	....	I.	....
34. LeGrand	Montgom'y.	III	III.	....
35. Maple Grove	Cherokee	....	....	(?)VI.
36. Naftel	Montgom'y.	IV.	IV.	....
37. Rutledge	Crenshaw	III.	....	....
38. Sterrett	Shelby	I.	III.	VII.
39. Thomaston	Marengo	IV. (rust)	VI.	....
40. Union Springs	Bullock	IV.	VI.	?

The first twenty-five localities in the above table are so arranged as to bring together those which, according to the map prepared by the State Geologist, Dr. E. A. Smith, are in the same or closely related geological formations. It is not intended to convey the idea that the soil is exactly similar in each group of localities. Personal inspection and chemical and mechanical analyses of each soil are needed before we can very positively assign the soils represented in these experiments to their proper position and before a very useful soil map of the State can be prepared.

The soils on which the first four tests in the above table were made are all calcareous, but of dissimilar origin.

Numbers 5 to 7 inclusive are localities which come within the area mapped by Dr. Smith as the "Oak, Hickory and Short Leaf Pine Region;" numbers 8 to 13 inclusive come within the region of "Gravelly Hills, with Long Leaf Pine;" numbers 14 to 16 inclusive embrace localities in the "Gray Isinglass and Red Clay" soil belt of the central portion of East Alabama; the "Long Leaf Pine Region" of South Alabama is represented by numbers 17 to 25 inclusive; numbers 26 to 40 stand for soils which for the present must remain unclassified even tentatively.

The soil tests referred to in the above table, supplemented by numerous other experiments which it is not now practicable to condense into tabular form, constitute the basis for the deductions drawn in the following paragraphs.

I. With the probable exception of most of the soils of the Central Prairie Region (calcareous), all soil belts on which tests have been made by this Station show benefit from acid phosphate applied to cotton. Indeed acid phosphate may be said to be a fertilizer universally advantageous to cotton on Alabama soils, with the single exception noted above.

II. Kainit (at the rate of 200 pounds per acre) is less frequently needed than either acid phosphate or cotton seed meal, and a considerable proportion of the soils on which it has been most advantageous lie in the southern part of the State. On soils especially liable to "black rust" in all parts of the State, and in seasons when that disease is especially injurious, kainit is at its best. On many soils, especially on those containing clay, it can be profitably dispensed with. Where needed, an application of 100 pounds per acre is often sufficient for cotton.

III. Cotton seed meal is highly beneficial to cotton on a large proportion of the cultivated area of every soil belt in Alabama. Apparently it is universally needed on uplands except on (1) new grounds and (2) on soils containing considerable vegetable matter, as the result of proper rotation with cowpeas or other humus-forming crops. Though cotton seed meal is almost invariably beneficial, it is not always *profitable* when applied to cotton at the rate of *200 pounds per acre*. Poor mechanical condition of the soil, resulting in a scarcity of moisture in summer, is the greatest hindrance to the profitable use of large doses of cotton seed meal. But even with poor mechanical condition of the soil it is usually profitable on soils where the stalk is small to use cotton seed meal. A better method of fertilizing with nitrogen through the use of leguminous plants is pointed out elsewhere in this article.

IV. On old soils, as a rule, it is more profitable to employ for cotton a mixture of acid phosphate and cotton seed meal, or of these two and kainit, than to use an equal money value of any one of them alone.

V. The universal basis for a fertilizer formula for cotton in regions where commercial fertilizers are employed should be acid phosphate; of which 100 to 240 pounds should be used per acre, in addition to cotton seed meal as necessary.

VI. The proper proportion of cotton seed meal to acid phosphate in a fertilizer formula for cotton depends more on the recent chopping and manuring of the field than on the character of the rocks from which the soil is derived. An intelligent decision on this point can be reached by a judicious application of the following facts:

(a) Small stalks, (if not due to climatic influences, poor cultivation, etc.), are usually an indication that nitrogen (as in cotton seed meal) is needed.

(b) Excessive stalk or "weed growth" of cotton is an indication that nitrogen can be dispensed with, wholly or partially.

(c) Phosphate hastens maturity and may aggravate the injury from black rust.

(d) The fresher the land the less the need for nitrogen.

(e) A luxuriant growth of cowpeas just preceding cotton dispenses with the necessity for cotton seed meal, as does also a recent heavy dressing with stable manure or cotton seed.

(f) The flat lands of the Southern Long Leaf Pine region probably require a smaller proportion of cotton seed meal than the soils of the central part of the State; this may be due to the former having been, as a rule, in cultivation for a shorter period of time, or it may be attributable to a more constant supply of soil moisture in the first mentioned region, with consequent ample development of the cotton stalk.

VII. The amount of commercial fertilizer per acre that yields the largest net profit varies with a multitude of conditions, as soil, season, amount of cash or capital, cost of labor and fertilizers and price of cotton. Generally moderate to large applications pay best when the season is favorable, but involve the risk of loss should climatic conditions be extremely unfavorable. To ren- as safe as possible intensive fertilization, the soils on which it is employed should be in good mechanical condition, especially as regards drainage and power to retain sufficient moisture during drougth, which latter condition may usually be brought about by a rotation that affords an abundance of vegetable matter and by judicious preparation and cultivation. On soils needing the following materials it seems generally advisable to apply them at the rate per acre of 100 to 240 pounds for acid phosphate, 60 to 200 pounds for cotton seed meal, and 60 to 100 pounds for kainit.

VIII. In response to requests for recommendation of definite fertilizer formulas for cotton on different soils, the writer would tentatively suggest the following,—to be modified somewhat when the facts mentioned in paragraph VI seem to require it;—(a) For calcareous clays or clay loams in North Alabama; for the red clay lands occupying a triangular area in the central portion of East Alabama (for the most part north of the Western Railroad and east of the Coosa River)—; and for the stiffer non-calcareous soils of the northwestern and western part of the State:

80	to	120	pounds cotton seed meal per acre.
160	to	240	pounds acid phosphate per acre.
240	to	320	pounds total per acre.

(b) For sandy soils in the eastern and central part of the State:

80	to	120	pounds cotton seed meal per acre.
160	to	240	pounds acid phosphate per acre.
40	to	60	pounds kainit per acre.
280	to	420	pounds total per acre.

(c) For the level lands of the Southern Long Leaf Pine Region:

60 to 120 lbs. cotton seed meal per acre.
120 to 240 lbs. acid phosphate per acre.
60 to 80 lbs. kainit per acre.

240 to 440 lbs. total per acre.

(d) For any well drained soil in any part of the State on which cotton is known to be especialy liable to black rust:

120 to 160 lbs. cotton seed meal per acre.
80 to 120 lbs. acid phosphate per acre.
80 to 120 lbs. kainit per acre.

280 to 400 lbs. total per acre.

IX. The formulas suggested above contain approximately the following percentages of nitrogen, (and its equivalent in ammonia), available phosphoric acid, and potash, using phosphate containing 12½ per cent of avalable phosphoric acid:

Formula	Per cent. nitrogen.	Per cent. ammonia	Per cent. available phos. acid.	Per cent. potash.
(*a*). For certain red lands, etc.	2 3	2 8	9.3	0.6
(*b*). For certain sandy lands..	2.0	2 4	8 0	2.3
(*c*). For low, long leaf pine lands....................	1 9	2.3	7.6	2.8
(*d*). For "rusting" soils	3.0	3.6	4.8	4.3

X. The lime soils of the Central Prairia Region have usually failed to make profitable use of commercial fertilizers. It is a generally accepted belief that commercial fertilizers on these soils are unprofitable, and so they have proved on good prairie soil at Uniontown, Ala. As a rule prairie soils are in poor mechanical condition and need vegetable matter rather than commercial fertilizers. Their improvement is especially marked when a leguminous crop, as mellilotus or cowpeas, is plowed in. Some of the best of these soils need drainage rather than fertilization. On the poorer soils, observation indicates that cotton seed meal is advantageous, and the few experiments made on bald prairie suggest that phosphate may increase the yield of cotton there.

The acid condition of certain soils found in many parts of the State may render ineffective commercial fertilizers that may be applied to them. For acid soils, which, when moistened and brought in contact with blue litmus paper, change the paper to a reddish color, the remedy is usually to be found in drainage or in the application of lime or marl, supplemented by the usual fertilizers.

To make commercial fertilizers afford a maximum profit it is desirable to use them on soils which are in good mechanical condition, especially as regards the supply of moisture in periods of drougth. Generally the cheapest means of accomplishing this improvement in the mechanical condition of a soil is by the growth of humus-forming crops, and especially by the growth of leguminous plants as food for stock or fertilizer for the soil, or for both purposes combined.

DISEASES OF COTTON.

BY F. S. EARLE.

The systematic investigation of cotton diseases was first undertaken at this station on the appointment of Dr. Geo. F. Atkinson as Biologist in the Fall of 1889. It has been continued as opportunity offered by the various officers filling this position up to the present time. Six bulletins* have been published dealing exclusively with the diseases of cotton besides minor notes in a number of the other publications of the Station.

The article on Diseases of Cotton (pp. 279-316) in the treatise on The Cotton Plant published as Bulletin 33, of the Office of Experiment Stations, United States Department of Agriculture, was written by Dr. Atkinson after severing his connection with this Institution, but it was based almost entirely on work done while here, and it may be considered as his final summing up of the results obtained while here.

In the following pages a brief account will be given of the present state of our knowledge of each of the diseases of cotton that has been detected in this State, drawing freely on the matter already published, but also incorporating the results of my own study and observation during the past four years.

In studying the diseases of cotton it has seemed desireable to prepare a Bibliography giving the title, place and time of publication, and where possible, a brief outline of the contents of the papers that have been published on this subject in different parts of the world.

*For a detailed statement of the contents of these bulletins see chapter on Bibliography p. 324.

Diligent search has discovered a surprisingly meager literature considering the great importance of cotton as an agricultural crop. This Bibliography is appended as a part of this paper. It is probable that some titles have been omitted especially as library resources have been limited, but the fact is evident that almost nothing has been published outside of the United States; and that of our own Experiment Station, only two have given the subject serious attention. The United States Department of Agriculture has from time to time, published papers and notes on cotton diseases. The first noteworthy one was the paper by Townend Glover on "Accidents and Diseases of the Cotton Plant," in the Annual Report for 1855, and the last is the admirable monograph on "The wilt Disease of Cotton, Watermelon and Cowpea," by Dr. Erwin F. Smith, just issued as Bulletin No. 17, of the Division of Vegetable Physiology and Pathology. It is gratifying to learn that during the past Summer one of the members of this Division has been assigned to special work on cotton diseases.

In volumes 5 and 6, of the Tenth Census, which are devoted to the cotton industry of the United States there are chapters devoted to diseases for each of the cotton States which contain much valuable information on distribution.

A list of the fungi that have been detected as growing on cotton or on the cotton plant in any part of the world has been prepared and is added as a part of this paper. Many of the species named are saprophytes and are probably of little or no economic importance; but since so many supposed saprophytes have the power under certain conditions of becoming partial or facultative parasites it is thought best to include them in this list.

In taking up the different diseases as a matter of convenience those will be considered first that more obviously affect the root and stem, second, those affecting the leaves, and third, those affecting the bolls. Under the first heading we have Root Knot, Sore Shin, Wilt, and Anthracnose of the Stem. The diseases of the leaves are Rust, Red Rust, Angular Leaf Spot, Leaf Blight and Mildew. The diseases of the bolls are Anthracnose, Boll Rot and Shedding. Under each of these diseases reference will be made by number to the more important papers bearing on it that are mentioned in the bibliography.

ROOT KNOT.*

Syn. Root Galls.

In common with many other cultivated plants at the South the roots of cotton are subject to the attack of a microscopic nematode worm, *Heterodera radicicola* (Greef.) Muell. The larval nematodes invade the tissues of the rootlets where they become encysted, and their presence causes a gall like swelling of the root. The gravid females are large enough to be seen with a hand magnifier when the fresh galls are broken open. Each female produces from 100 to 200 eggs, and the life cycle is completed in about one month, thus allowing seven or eight generations during the growing season. Under favoring conditions they therefore increase very rapidly. The galls or knots are usually about the size of a pea, but by confluence they may become much larger. If only a few are present no great damage is done, though the part of the root below the knot usually after a time rots away. If the knots are very numerous the nutrition of the plant is seriously deranged, growth is feeble or ceases entirely, and finally the rotting of the roots causes the premature death of the plant.

Cotton is less seriously affected by "root knot" than

* Bibliography, Nos. 4, 10, 13. See also Ala. Sta. Bull. 9.

many kinds of vegetables and some kinds of fruit trees. The cotton farmer therefore has less cause to dread it than the orchardist or trucker to whom it is often a veritable scourge. It however injures the cotton quite seriously, and it is so widely distributed, occurring more or less in most of the sandy and alluvial soils of the Gulf States that its total injury to the cotton crop must be very considerable. As Atkinson has pointed out, its greatest injury to cotton takes place when it occurs, as it often does, in the same fields with the fungus producing cotton wilt (see p. 296), since the breaking down of the root tissue by the nematode serves to aid the wilt fungus in obtaining an entrance.

Numerous experiments have been conducted at this Station during the past four years with the hope of finding some means of freeing the soil from this pest. The organism seems to be remarkably resistant, and so far the experiments have largely given only negative results. It has been suggested* that kainit and lime applied to soils would greatly reduce the injury from root knot. A number of tests were made with these substances without result. In one case both lime and kainit were applied to a plot at the rate of 2000 lbs of each per acre. The plot was planted to okra and every plant developed root knot.

With the soil in pots in the green house carbon di sulphid has given encouraging results. When 10 c. c. have been injected into 12 in. pots before planting the percentage of root knot has been greatly reduced. It has not been found safe to inject it near the roots of living plants either in pots or in the field. Some field experiments have been tried with it but with less marked

* J. C. Neal—The Root Knot Disease of the Peach, Orange and other Plants in Florida, U. S. Dept. of Agr. Div. of Entomology, Bull. 20.

results. In 1899 two plots were treated with it. On one plot 10 c. c. were injected once in two feet in each direction and in the other a like quantity was injected once a foot. Both plots and a check plot were planted to cow peas and okra. The place selected chanced to be rather free from the nematodes as but few of the plants on the check plot were affected. Well developed cases were found however on all three of the plots in about equal proportions. No benefit could be detected from the treatment. It is to be noted however, that the workman in injecting the carbon di sulphid carelessly left the holes made by the injector open so that part of the fumes probably escaped.

In 1899 plots were also prepared with varying quantities of sulphur broadcasted and plowed in two weeks in advance of planting. The amount of sulphur used varied from two to sixteen pounds per square rod. All of the plots were planted to cowpeas and okra. The okra failed to germinate when more than 4 lbs. of sulphur per rod was used. The cowpeas were not affected, germinating and growing well on all of the plots. Where the heaviest applications were made the fumes of the sulphur could be detected easily, when the sun was hot, at any time during the summer. None of the cowpeas in this experiment suffered seriously from the nematodes. It did not prove to be a good plant for the experimental work, but well developed cases of root knot were found on all the plots. In fact it so happened that the plot receiving 16 lbs. of sulphur developed more cases than some of the checks. It is also interesting to note that root tubercles developed freely on this heavily sulphured plot and that on one of the plants underground perithecia developed of the fungus causing the cowpea wilt, *Neocosmospora vasinfecta tracheiphila*, E. F. Smith.

The only soil treatment that has proved at all efficacious in reducing the numbers of this pest has been a perfectly clean fallow continued through two growing seasons. During the summer of 1896, certain plots were given perfectly clean cultivation, no growth of any kind being allowed on them. In the spring of 1897, a portion of these plots were planted in okra and other vegetables. Root Knot developed on all of them but in only about half the normal quantity. On the other plots the clean fallow was continued throughout the Summer of 1897, till September, when celery plants were set out on them. Celery is the most susceptible of all vegetables to the nematode root knot disease, but the plants remained entirely free from the trouble. An absolutely clean fallow extending over two Summers is hardly a practical remedy on account of the cost, and on account of the injurious effect on the soil. Probably equally good results would be secured by allowing only such plants to grow on the land as are known to be entirely free from the nematodes. None of the grasses or small grains are known to harbor them, so by planting to wheat, oats or rye in the Fall and following with German millet or sorghum in the Summer, and continuing this for two or three years it seems that the land should be quite thoroughly cleaned of them. It would be necessary to take great care to keep down all succulent rooted weeds that might serve to harbor the nematodes. This style of cropping would prove very exhausting on most of our cotton lands, and on the lighter of them it would not be practicable. It is unfortunate that our best known soil improving plant, the cowpea, should prove a nurse plant for the nematode but such is the case, and its frequent use cannot be advised on soils known to be infested by them. The velvet bean, (*Mucuna utilis*), a new soil improving plant that has attracted much attention during the past few years, it is claimed is nearly or quite exempt from its attack. If this claim proves to be well founded, and there is strong evidence in its favor, then oats followed by velvet beans for two seasons will not only practically rid the land of nematodes but will vastly increase its fertility.

SORE SHIN.*—DAMPING OFF.

Young cotton plants are sometimes observed to fall over and die. This is known as damping off. It usually occurs in wet, unfavorable weather. Atkinson has shown that this disease is caused by a fungus that penetrates the young stems just below the surface of the soil, causing their tissue to become soft and decomposed. In some cases, especially as the plants get a little older, only one side of the plant becomes affected. The stem is not cut off, but an ulcerous depression is formed. Such plants may ultimately recover, though their growth is retarded. This is the condition sometimes known as Sore shin. From the fact that the fungus causing this trouble has not been found to produce spores or other fruit bodies, Atkinson called it the "Sterile Damping Off Fungus," to distinguish it from other fungi that cause the damping off of young seedlings. He found similar sterile mycelia attacking many other plants besides cotton and that they are widey distributed as damping off agents. One of these sterile fungi has since been studied by B. M. Duggar as causing a serious disease of the sugar beet, and by F. C. Stewart as causing a stem rot of carna. tions. These investigators agree in placing these sterile fungi in the form genus *Rhizoctonia,* but their studies have not yet progressed sufficiently far to admit of assigning specific names to the different forms. Their observations and experiments suggest liming the soil as a possible remedy.

* Bibliography, Nos. 10, 12, 13, 19, 29, 81.

The *Rhizoctonia* of cotton is very widely distributed. It probably occurs in every cotton field in the State. During wet, unfavorable springs it kills a great many plants, and yet owing to the habit of very heavy seeding and of only chopping to a stand after the plants begin to form rough leaves, it is doubtful if the disease often causes serious loss. Atkinson claims that, like the nematode root knot, it sometimes does harm by aiding the wilt fungus to gain an entrance into the stem of the cotton plant.

The suggestion for liming the land will doubtless be useful in all cases where the soil is acid, as in the case with many of our sandy lands. We have no direct observations, however, as to its effect on this disease in the cotton field. Running the smoothing harrow obliquely across the rows as soon as the ground can be stirred after each rain while the plants are small, will tend to check the disease by quickly drying the surface layer of the soil in which the *Rhizoctonia* is most active. On lands that are free from rocks and trash such harrowings will not injure the stand, but will prove the cheapest and most efficient form of cultivation.

COTTON WILT.*

Syn. Frenching.

This disease has sometimes been called "Frenching," but it is best to drop this meaningless term, especially as it has not come into general use. There are a number of closely related diseases of cultivated plants, as of the bean, the cow pea and the watermelon that are known by the expressive name of "Wilt," and it seems best to make the usage uniform.

The disease is caused by a fungus parasite, *Neocosmospora vasinfecta* (Atk). E. F. Smith, that lives in the

*Bibliography, Nos. 10, 13, 39, 40, 41.

soil and gains entrance to the vascular bundles of the stem through the roots. The disease may be present in the plant for some time before it becomes externally manifest, except in the somewhat dwarfed growth, but its presence can be easily detected by splitting open the stem. In the healthy stem the internal tissue is white, but when the wilt disease is present it becomes stained a dark brown. This staining of the tissues, particularly of the vascular bundles, is always present, but the external symptoms are somewhat variable. In typical cases when the disease is progressing rapidly the growth of the fungus plugs up the ducts, thus cutting off the water supply from the leaves, causing them to suddenly wilt. At first this wilting may only be noticed on certain branches. In some cases the branches on one side of the plant wilt and die, while those of the other side remain green and possibly even mature their crop. Usually the whole top becomes involved within a few days after the wilting is first noticed and the plant soon dies. Instances have been observed where nearly all the plants in fields several acres in extent have died in this manner by mid-summer. At other times the disease seems less active. The leaves do not wilt, but gradually die and fall off, beginning with the lowest ones. The margins of the leaves first turn yellow and then brown, the color changes extending down between the main veins in V shaped areas. The green color may persist along the veins for some time, but the leaf finally falls. New shoots will sometimes start from near the base of the plant after the top is quite badly diseased, for the fungus seems to grow upward from the point of attack much more rapidly than it does downwards so that the roots remain comparatively healthy, excepting the ones by which the fungus first entered the plant.

The fungus found in the tissues of these wilted plants belongs to the form genus *Fusarium*, and it was described by Atkinson, who first detected it as *Fusarium vasinfectum*. Within the tissues it produces only minute oval spores, but on culture media it develops the curved septate spores characteristic of this genus. Dr. Erwin F. Smith first detected the perfect, ascigerous form of the fungus which consists of bright red, minute, Nectriaceous perithecia, thickly or thinly scattered over the underground part of the stem and the larger roots. The Ascospores are nearly spherical, one celled and at maturity dark brown, with a thick and more or less roughened epispore. These characters do not admit of placing it in any of the previously described genera of the *Nectriaceae* so that Dr. Smith has described it as a new genus under the name *Neocosmospora*.

The fungi causing the wilt of cowpeas and of watermelons are so similar in structure to the cotton wilt fungus that after much careful study Dr. Smith is unable to separate them specifically. The failure of cross inoculations, and the results of field tests and observations, all show that, though so closely alike in form, the fungus from one of these hosts is not able to infect either of the others. He therefore considers the watermelon and cowpea fungi as being physiological varieties of the cotton fungus.

This disease is a very serious one. It lives over in the soil from year to year, and when once established in a field it continues to spread and grow worse as long as cotton is planted on the land. No remedy is known, and it becomes necessary to discontinue growing cotton on lands where the disease makes its appearance. How long the disease will persist in the soil is not known. Few direct experiments on this very important point have been made, but instances have been reported by intelligent farmers where fields infested with this disease have been planted in other crops as corn or oats for two seasons, and yet when again planted to cotton on the third year the disease still made its appearance, though not so bad as before the change of crop. Some melon growers claim that five to seven years' rest is necessary for infested lands, if indeed, it is ever safe to plant again where melons have once wilted.

So far as known, the cotton wilt attacks no other plant except okra. The fact that it is at least physiologically distinct from the wilts of cowpeas and watermelons is an important one practically since it admits of planting cowpeas as a restorative crop on lands infested with the cotton wilt. If the disease was communicable from one of these plants to the other as was at one time feared this would not be permissible. Dr. Smith's opinion of their physiological distinctness seems to be well founded. It is fully supported by some field observations of my own. In July, 1898, I was called to investigate an outbreak of this disease on the farm of Mr. James Hall at Midway, Bullock Co., Ala. In a field of about three acres three-fourths of the cotton was dead or dying. Mr. Hall said that it had been dying for two months, and in order not to leave the ground entirely vacant he had been replanting with cowpeas. At the time of my visit the peas were growing luxuriantly among the dying cotton without showing the slightest sign of disease. Mr. Hall wrote me in the fall that the peas remained healthy to the end of the season, showing that in this case at least they did not contract the disease from the cotton.

A certain garden lot in Auburn, belonging to Mr. C. E. Little was planted to cowpeas, following oats, during 1897 and 1898. In both seasons nearly all of the peas died from wilt, showing the land to be thoroughly infested with the cowpea wilt fungus. In 1899 Mr. Little kindly allowed me to plant some cotton in this garden, as well as cowpeas, snap beans and velvet beans. Half or more of the cowpeas and a few plants of the snap beans contracted the wilt, but the cotton and the velvet beans remain entirely healthy.

Sound, healthy cotton roots seem to have a certain power of resistance to the wilt fungus. It is not uncommon to find plants that have evidently been attacked through a single root only. It is possible that the fungus usually gains entrance through injured roots, as where they are broken by the plow. The injury caused by nematodes and the ulcers caused by the *Rhizoctonia* or "sore shin" fungus also seem to serve to enable the wilt fungus to attack the plants.

This disease is quite widely scattered. It is known to occur in Arkansas, South Carolina, Alabama and Florida. In this State it is widely distributed throughout the southern half. It has been found in Montgomery and in the south edge of Lee county, but so far it has not been reported north of a line drawn through these two points with the exception of an isolated outbreak at Athens, in the Tennessee valley.

The most important practical point remaining to be learned in connection with this disease is the length of time the fungus can exist in the soil if no cotton or okra is planted. The fact that the similar cowpea wilt (See p. 293) developed on a plot that had received at the rate of more than 1,500 pounds of sulphur per acre does not make experiments for destroying the fungus in the soil seem encouraging.

ANTHRACNOSE OF THE STEM.*

The fungus causing Anthracnose of the bolls, *Colletotrichum Gossypii* South, sometimes attacks the

*See Bibliography, Nos. 5, 6, 8, 10, 13.

stems, causing a blighting of the bark over extensive areas. The term anthracnose is usually associated with diseases producing little sunken pits or ulcers as in the case of the anthracnoses of the grape and the raspberry. There is no such appearance in this case. The bark at first turns a uniform reddish brown and finally dies. The foliage soon shows the effect of the disease, yellowing and finally dying and falling much as with the rust. The latter disease, however, does not usually affect the stems. They remain green and frequently put out new leaves after the old ones have all fallen. This stem blight often occurs in connection with the rust, but again it may occur on vigorous plants and on soils where the rust does not occur. This disease is rather prevalent, though it has attracted but little attention, its effects being usually confounded with those of the rust. No remedies can be suggested.

This fungus is an active parasite, attacking at various times nearly all parts of the cotton plant. It has been known to damp off seedlings, it develops on the seed-leaves, on the bark, on the leaves and bracts and especially on the bolls. It is a serious pest and annually causes much loss.

RUST.*

Synonyms: Black Rust, Yellow Leaf Blight, Mosaic Disease.

This disease has attracted more attention than any of the others affecting cotton. It causes the premature falling of the leaves, thus preventing the proper maturing of the crop. It occurs very commonly in the older cotton growing States, usually, though not always, on the thinner sandier lands. The losses occasioned by it when present vary from 5 per cent. to 50 per cent. or more of

* Bibliography Nos 5 6, 9, 10, 13, 18, 20—25, 26, 29, 31, 32, 33, 34.

the crop, and as it is so widely distributed the total loss is very great. The disease is a complex one, depending in part on unfavorable soil and weather conditions, and in part on the attacks of several species of fungi. None of these seem to be able to grow on perfectly vigorous, rapidly growing cotton foliage, but during hot, showery weather they develop rapidly on any leaves where there is reduced vitality from any cause, as where the foliage has prematurely ripened from the effects of drouth or of a poor sterile soil. The disease is really a remarkable one as illustrating the marked effect of soil conditions and the general vigor of the host plant in enabling it to resist the attacks of a certain class of parasites. It may be safely asserted that this disease cannot attack a cotton plant that is in full, vigorous growth, but that a sudden checking of growth and lowering of the vitality from any cause will render it liable to serious injury if the weather conditions favor the growth of these fungi. The species of fungi usually connected with this disease are *Macrosporium nigricantium* Atk., an undescribed species of *Alternaria, Cercospora gossypina* Cke. and *Colletotrichum Gossypii* South. The exact course of the disease varies with the weather conditions. In some cases the leaves of affected plants first exhibit a more or less mottled yellow color. This is the condition that suggested the name of "Mosaic Disease" that Dr. Atkinson applied to it in his later publications. When a period of warm summer rains suddenly follows a long drouth in July or August, this mosaic condition will be hardly apparent, but the seemingly healthy leaves will be seared and blackened by the rapid growth of these various fungi. Under these conditions the leaves often wither and fall very quickly, leaving the stalks entirely bare. In such cases a second crop of leaves is sometimes produced so that fields that were quite bare in early September become green again in October, but such leaves are produced at the expense of reserve food material that should go to developing the bolls, and they are an injury rather than a help to the crop, as frost usually comes before the new leaves have had time to elaborate a new food supply. It more often happens that the leaves do not all fall at first, but that many of them, though badly blotched and spotted by the fungi, still hang on for some time and assist in ripening the more advanced bolls. Of course such plants do not set a top crop so that even if all the formed bolls on the plant when it is attacked ripen, the crop is seriously reduced. The quality of the fiber, too, is often injured on badly rusted plants. It is light and chaffy and the same bulk of it weighs less than cotton from healthy plants.

It seems certain that the damage done by this complex disease is mainly due to the growth of the associated fungi. These attack and destroy the tissues of leaves that would otherwise continue to perform their functions. The physiological disturbances due to drouth or other unfavorable conditions would disappear with the advent of more favorable weather, and the plant would resume its normal growth but for these fungus attacks. On the other hand it is equally certain that perfectly vigorous plants have the power to resist these fungus attacks, and that when the soil is in the proper condition of tilth and fertility the cotton plants will pass unharmed through conditions of weather sufficiently unfavorable to induce serious outbreaks of rust on less favorable soils. This has been forcibly illustrated for several years past in the sandy fields south and west of Auburn. Owing to the passage of a stock law the fences have been removed and the old fence rows have been grubbed out and plowed and planted with the rest of the fields. These fence rows are practically new land.

The soil is rich from the accumulation of vegetable matter for many years, and its mechanical condition is such that it resists drouth and keeps the plant constantly growing. The old fields on the other hand have been cropped in cotton year after year for many years till their vegetable matter and other elements of fertility have been exhausted. These soils are in no condition to resist drouth, and with the advent of hot dry weather in mid-summer growth ceases and the foliage hangs limp and wilted during the noon-day heat. Now when rains occur the fence row cotton grows with increased vigor, while that in the poor, worn-out fields soon shows the unsightly spots of rust, and for the past three years it has been bare of leaves and practically dead by the middle of September, while that of the bordering fence rows, subjected to identically the same climatic conditions, has remained green and vigorous to the end of the season.

The obvious remedy then for cotton rust lies in ameliorating unfavorable soil conditions, and securing a state of fertility that will support continued vigorous growth of the plant. Judging from a wide series of observations and an extended correspondence the usual inciting cause of cotton rust is the inability of the soil to withstand drouth. In other cases the cause is just the reverse and rust is induced by lack of drainage. Cotton roots require a well areated soil, and they are quickly affected by standing water or by too great a rise of the water-table. In such cases drainage would prove an efficient remedy. There are still other classes of soils with abundant vegetable matter and where the mechanical conditions all seem favorable where cotton rusts badly in ordinary seasons. In these cases the trouble seems to come from a lack of sufficient potash in the soil, and applications of kainit or other potash fertilizers remedy the trouble. In fact the good effect of potash has often been so marked that kainit has come to be considered as almost a specific for this disease. It has been held that this favorable effect of kainit might be due to the effect of the salts it contains on the hydrostatic pressure and surface tension of the soil moisture. Recent experiments seem to show that it is rather the specific effect of the potash since muriate, sulphate and other potash salts are found to be effective about in proportion to the per cent. of potassium they contain. Thus 50 pounds of muriate is fully as effective as 200 pounds of kainit per acre in enabling the plants to resist rust. On drouthy soils applications of potash alone will often prevent rust during favorable seasons, but at other times its effects will be much less marked. On the Station Farm during 1896 and 1897 potash fertilizers gave almost no effect in preventing rust. In 1898 its effect was very markedly beneficial. In 1899 its good effects were plainly visible but were much less marked than in the previous year. On these drouthy soils the mechanical conditions need ameliorating in addition to supplying the needed chemical elements. This is best done by plowing under leguminous soil improving crops. Of these the cowpea is the best known, and on most soils it is exceedingly satisfactory. For the southern half of the State, and especially on sandy soils where the nematode root knot trouble prevails, the recently introduced velvet bean promises to be a marked improvement. On very poor soils both of these crops should be liberally fertilized with acid phosphate and potash, as otherwise the growth obtained will be too small to accomplish much in the way of soil improvement. It is not necessary to apply nitrogenous fertilizers, since these crops have the power of gathering nitrogen from the atmosphere, which accounts for their great usefulness in increasing soil fertility. For growing either of these crops it is necessary to miss growing one crop of cotton on the land. The peas can usually be most economicaly grown after a crop of wheat or oats, but the velvet bean requires a long growing season in which to reach full development, and it will pay best to give up the land to it during an entire season.

There are two other leguminous crops, Hairy Vetch and Crimson Clover, that make their growth during the winter and early spring. By sowing these seeds between the standing cotton stalks in October and cultivating them in lightly, the growing crops will occupy the land during the winter, thus preventing the leaching and washing away of fertility by the winter rains. They will be ready to cut for hay by the first of May in time to put in a late cotton crop on the stubble, or if preferred they may be plowed down in April and the cotton can be planted at the usual time. In either case the soil will be gradually improving year by year and the loss from rust will be decreasing, and that without losing the use of the land for a single cotton crop. Under the practice now usually prevailing exactly the reverse of this is the case. The soils are being rapidly depleted of their fertility and the losses from rust are becoming heavier and heavier. Of these two crops vetch is for several reasons decidedly preferable and its greatly extended use cannot be too strongly urged. Directions for seeding and for the soil inoculation that is necessary for success with this crop will be found in Bulletins 87, 96, and 105 of this Station.

Our knowledge of this much discussed and complex disease may be summarized as follows:

Cotton rust is a composite disease, being due partly to physiological derangements caused by improper soil conditions, and partly to the attacks of a number of facultative fungus parasites, among which the most important are *Macrosporium nigricantium* Atk. *Alternaria sp., Cercospora gossypina* Cke. and *Colletotrichum Gossypii* South.

The plants would largely recover from the physiological derangement on the advent of more favorable weather if it were not for the attacks of the fungi.

On the other hand the fungi are not able to attack plants that are in a vigorous growing condition.

In some cases the lack of vigor that permits these fungus attacks is due to too much standing water in the soil. Such cases can be remedied by drainage.

In other cases it is due to the lack of some chemical element in the soil, usually potash, when the remedy consists in supplying the needed element in the fertilizer.

In the great majority of cases lack of vigor is due to the exhaustion of the soil humus thus greatly reducing its water holding and drouth resisting capacity. In such cases the potash is also usually exhausted. The remedy consists in restoring the vegetable matter needed to form humus by plowing in leguminous crops and in supplying the needed mineral fertilizers.

RED RUST.*

This name is usually applied to a peculiar reddening of cotton foliage due to the attacks of a mite, *Tetranychus telarius,* which resembles the "red spider" of greenhouses in its habits and causes very similar injuries. It is of rather common occurrence in North Alabama, usually on newly cleared lands, and it has been observed doing conspicuous injury in a few fields near Auburn. Judging from the older accounts of cotton diseases, it occurs quite widely in most of the cotton growing

* Bibliography, Nos. 1, 2, 5, 6, 9, 10, 13, 29, 31.

States. Its injuries are often confounded with those produced by other causes. It seldom invades entire fields, but is usually confined to limited patches or areas. The mite multiplies rapidly during hot dry weather, but it is held in check by rains. While locally troublesome it can only be classed among the minor enemies of the cotton plant. So far no remedial measures have been tried. Judging from experience with the allied greenhouse pest the prospects for finding a practicable remedy are not flattering.

The suffused reddening of the foliage due to premature ripening so often seen on sterile rocky hillsides can hardly be called a disease. It is simply starvation and can be promptly remedied by ameliorating the soil conditions.

According to Atkinson* the term Red Rust is sometimes applied to certain stages of the true or black rust when the fungus spots on the leaves are surrounded by a reddish border. This is certainly not a common use of the term. In my experience farmers employ it almost exclusively for the injury caused by mites.

LEAF BLIGHT.†

When the fungus, *Cercospora gossypina* develops alone on the leaves the resulting condition may properly be called leaf blight. The fungus occupies deadened whitish areas 1-2 c. m. in diameter. These are usually surrounded by an indistinct reddish border. Scattered spots of it may appear at almost any stage of the growth of the plant. When acting alone it is usually a disease of minor importance, but it is very widespread and it frequently merges into the rust for this is one of the fungi associated with that disease.

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* Ala. Bull. 27:6.

† Bibliography Nos. 5, 6. 7, 9, 10, 13, 38.

The perfect or ascus bearing stage of this fungus was first detected by Atkinson, who called it *Sphaerella gossypina*. As has been recently pointed out * the generic name *Sphaerella* is not tenable for this group of fungi as it had been previously employed for a different class of plants and the name *Mycosphaerella* has been proposed instead. Our cotton fungus, therefor, will have to be called *Mycosphaerella gosspyina.* The so-called *Cercospora* is only the early or immature conidial stage of the fungus, but, as in so many other cases, it is in this stage that the injury is done.

COTTON MILDEW. †

In late summer and fall the under surface of the leaves of cotton growing in moist places is often covered by white frosted areas. These are usually rather small and angular, being bounded by the veinlets of the leaf, but sometimes they become confluent, covering the entire leaf surface. This frosted appearance is due to the growth of a fungus, *Ramularia areola* Atk. It results in the rather premature falling of the affected leaves, but as it usually only occurs on rank plants in low moist places this partial defoliation coming so late in the season does no appreciable damage.

No remedies have been tried for this disease. If it should ever be worth the while it could doubtless be held in check by spraying with fungicides, but the spraying of a field crop like cotton is a task that will seldom be undertaken.

ANGULAR LEAF SPOT. ‡

In the first stages of this disease clear watery spots are seen in the leaves. These are usually bounded by the

* See Engler-Plantl. Nat. Plantz. Fam 1:1:423.

† Bibliography Nos. 3, 10, 13. Syn. Areolate Mildew.

‡ Bibliography Nos. 5, 6, 10, 13.

veins and are thus somewhat angular. Sometimes these transparent spots are confluent along both sides of one of the larger veins or ribs. At this stage of the disease these spots are swarming with bacteria. Later the spots become bounded by a blackish border, the leaf tissue of the spot becomes dry and dead, and often finally breaks away, leaving a jagged hole. This disease is very widely distributed. It is doubtful if there is a cotton field in the State entirely free from it. It usually first appears in June or early July or from two to six weeks earlier than the rust, though it is often found in connection with that disease, when it contributes not a little to the defoliation of the plants. When acting alone it seldom involves a sufficiently large portion of the leaf surface of the plant to prove very detrimental, but it doubtless aids in lowering the vitality of the plant and thus paves the way for the attacks of the rust fungi.

In his earlier accounts of the disease Atkinson attributed it to the action of the bacteria that always accompany it in its early watery stages. Later, owing to the failure of some inoculation experiments he seems to have changed his views for he includes it among the diseases due primarily to physiological causes. My own observations favor the former theory as the disease is by no means confined to plants that are lacking in vigor, and it usually appears at the season of the year when the cotton is making its most vigorous growth. I am of the opinion that the disease is directly due to the action of the accompanying bacteria, that they are able to develop in vigorous healthy leaf tissues, and that in many cases, at least, the cotton aphis is instrumental in spreading the contagion. These views, however, require confirmation, as the disease greatly needs further study. No remedies have been proposed.

COTTON BOLL ROT.*

The rotting of the unripe bolls often causes serious loss to the cotton grower. During the wet Fall of 1898 there were instances where almost the entire crop of some fields was lost, and there were considerable areas in different parts of the State where the percentage of loss was very heavy. Owing to the prevailing dry weather the loss during 1899 has been comparatively small. Like the rust this seems to be a composite trouble that cannot be traced to any one uniform cause. Unlike the rust, however, it is not as a rule the poor, worn out lands that suffer from it. It causes its worst injury on the richest lands where the growth of the cotton is rankest and most vigorous. Although it has been observed since the early years of the century our knowledge of this disease is very fragmentary. The following remarks regarding it must largely be taken as suggestions of probabilities rather than as statements of proven facts. Stedman, who studied the disease, thought that he had discovered the cause in a germ that he called *Bacillus gossypina.* His results have not been fully confirmed. In 1897 C. F. Baker investigated a serious outbreak of boll rot near Dadeville, Ala. He came to the conclusion (not before published) that the primary cause of the disease, at least in the case under investigation, was the puncture of the boll by one of the small leaf hoppers sometimes known as "sharpshooters." †

He found these insects very abundant in the infested fields, and brought back numerous specimens of the

* Bibliography Nos. 13, 15, 29, 31, 37, 43 45,

†In a recent letter Mr. Baker says: "The Tettigonid "sharpshooters" most conspicuous in the work at Dadeville were two species of the genus *Diedrocephala* as that genus has been recognized by American entomologists. These two occurred in greatest numbers, but a few others, Jassids and Tettigonids were also involved.

bolls in all stages from the fresh puncture to complete rottenness. In the Laboratory various organisms were isolated from these rotting bolls, including at least three species of *Bacillus, Colletotrichum Gossypii, Fusarium sp., Alternaria sp., Rhinotrichum macrosporum* and *R. tenellum.* One of the bacilli was the red pigment producing *B. prodigiosus.* Most of these organisms were doubtless mere saprophytes feeding on the broken-down tissues of the boll. Which one or ones it was that first invaded the insect punctures and started the rot could not be determined with certainly. Field inoculations were made with the different bacilli, but without success. The inoculation punctures in the bolls dried down without producing rot. This, perhaps, should have been expected as the weather was by this time dry and the bolls inoculated were on rather small, feeble plants. The rot only occurs in nature during wet weather or on plants that are so rank as to fully shade the ground thus preventing the drying off of the dew and maintaining a moist atmosphere. It was impossible to decide whether either of the germs was the one isolated by Stedman.

Whether the organisms that produce rot are always dependent on insect punctures for gaining an entrance to the boll is perhaps an open question. There is some evidence that when the plants are rank and the weather wet insect punctures are not always necessary. *Colletotrichum Gossypii,* at least, among the species eumerated above as developing on the rotting bolls, is known to be an active parasite. Quite possibly its attacks on the carpels may so injure the tissue as to admit the other organisms to the immature lint which seems to furnish so favorable a nidus for their growth. On the other hand Stedman's hypothesis of an actively parasitic germ, able in some unknown way to gain entrance to the bolls unaided, may in some cases be the correct one. The whole subject is very obscure and there is great need for farther careful investigation. The disease has not been prevalent in the fields near Auburn which has rendered study of it difficult.

In any event the fact seems well established that it is the rankest, most luxuriant cotton that is most subject to boll rot. This suggest the following practical recommendations for lessening its injuries. 1st to avoid as far as possible planting cotton on lands that produce an excessive growth of stalk or "weed." Such lands are usually more valuable for corn and hay. 2nd. If necessary to plant on such lands give more space between the rows than is the common practice. This will give better circulation of air and will tend to dry the plants more quickly. 3rd. On such lands use acid phosphate freely and no other fertilizer. Even on soils so rich that no fertilizer is ordinarily used the acid phosphate will be profitable on account of its well known tendency to promote fruitfulness and early maturity rather than a rank growth of stalk. Nitrogenous fertilizers should particularly be avoided on such soils. 4th. Plant the short growing, early maturing varieties, rather than the rank long-limbed late kinds. In other words, the treatment where boll rot is feared should be largely the reverse of that indicated for combating rust. In that case we want to promote vigor of stalk and foliage by all possible means, here the object should be to reduce over-luxuriance and provide for the free circulation of air and the rapid drying off of the plants.

ANTHRACNOSE OF THE BOLL.*

The fungus *Colletotrichum Gossypii* is an active parasite of the cotton plant in all stages of its growth. It attacks the stems of young seedlings near the ground,

* Bibliography Nos. 8, 10, 13, 27, 42.

causing death, much as in damping off. It produces characteristic lesions on the margin of the seed leaves, especially where the latter are caught and impeded in growth while trying to escape from the hull. It develops on the leaf—scars on the stem, and on feeble or injured leaves being one of the fungi associated with rust. It causes a blight of the bark of the twigs and larger stems, but its most conspicuous injuries are to the bolls. It is very common in all cotton fields to see the bolls when approaching maturity lose their green color and assume, especially on the side exposed to the sun, a dull red or bronzed color. This change in color is due to the growth of the mycelium of this fungus in the carpels. If the invasion has not taken place till the boll is nearly mature and the weather is not too wet the fungus may not reach the fruiting stage, or at least it will produce spores sparingly and inconspicuously, and the boll may open quite normally, so that no material damage results. This is very frequently the case. At other times the fungus causes a premature dying of the tissues of the carpels, causing them to crack open, thus exposing the immature lint which may rot in consequence. If too mature to rot, the carpels do not open freely, making the lint hard to pick. It is only under conditions especially favorable to it that the fungus produces the peculiar spotting, and the pustules filled with pink spores, that have been figured as characteristic of the disease. In very many cases bolls and stems are affected by the fungus that do not show these symptoms at all.

It has been found by Atkinson that scalding the seed before planting prevented the appearance of this fungus on seedlings grown for experimental purposes in the greenhouse, probably by destroying spores that were lodged on the lint, and he has suggested this treatment of the seed as a possible remedy for the disease under field conditions. The proposed remedy has not been tried in the field, and in fact it gives little promise of success since the plant is liable to infection at any stage of its growth ,and the crop is so universally grown that any treated area would almost inevitably become infested from neighboring plantations before the close of the season. No other remedy has been suggested. The disease causes in the aggregate very serious losses.

SHEDDING OF BOLLS.*

Young cotton bolls often fall as the result of injury by the boll worm or other insects, but the term "shedding" is usually applied to a falling of the bolls that is not caused by insect or fungus injuries. It seems to be entirely a physiological trouble and to be dependent on soil and weather conditions. The trouble has not been sufficiently studied to admit of any definite statements as to the predisposing causes. Some varieties or classes of varieties seem to be more subject to shedding than others. The texture and moisture holding capacity of the soil doubtless has a considerable influence. In some cases the character of the fertilizer used has a marked effect on shedding. † Probably, however, the character of the season and the abundance or absence of rainfall has more to do with shedding than any other factor. During a period of seasonable rains the plant puts on as many bolls as it could carry to maturity if these favorable conditions were to continue. If now a period of drouth comes on the lessened water supply in the soil

*Bibliography Nos. 10, 13, 29, 31.

† See Ala. Bull. 99:304. On very poor sandy land plots with only phosphate and with phosphate and kainit shed the bolls of the top crop badly, while those with complete fertilizer set and carried a full top crop.

prevents the taking in by the roots of a sufficient quantity to meet the needs of the crop, and as a measure of self-protection the plant throws off part of its load. Again a plant may be carrying a good crop of bolls during a comparatively dry period in which case growth of stalk will have largely ceased, and the food elaborated by the leaves is practically all going to develop the fruit. If now rains come on, a rapid new growth of stalk may be induced that will divert the prepared food from the bolls, and thus cause some of them to fall, or if the rains are very heavy and prolonged the soil may become so water-logged as to cause the dying of some of the feeding rootlets and root hairs, thus deranging the nutrition of the plant. At the same time, the continued dark, cloudy weather would interfere with the normal action of the leaves. Whatever the physical explanation it is a frequently observed fact that sudden changes in weather conditions either from wet to dry or from dry to wet will affect the plant unfavorably and cause shedding. Of course these conditions of weather are beyond our control and in so far as they are the active cause of shedding it will be impossible to avert the trouble. Such a system of soil preparation, cultivation and fertilization as will tend to keep the plant in the best possible condition of thrift and vigor will do much to minimize the bad effects of unfavorable weather.

The trouble is a serious one, often causing the loss of a considerable percentage of the crop. It should be studied until the effect on fruitfulness of each of the factors constituting the environment is fully understood.

List of Fungi Recorded as Growing on Cotton or the Cotton Plant.

Aecidium Desmium B. & Br. Fungi of Ceylon No. 850 Sacc. Syl. Fung. 7:782.

On leaves of *Gossypium*, Island of Ceylon.

Aecidium Gossypii E. & E. Erythea 5:6—1897.

On leaves of *Gossypium*, Lower California.

Alternaria sp.

An undetermimed species mentioned by Atkinson as one of the fungi associated with cotton rust in Alabama. Bot. Gazette 16: 61-65. Ala. Exp. Sta. Bull. 27:6-10.

Alternaria tenuis Nees. Syst. d. Pilze 2:72. Sacc. Syl. Fung. 4:545. On leaves and stems of various plants in Europe and North America. Said by Gasparrini to be associated with a disease of cotton in Italy known as "Palagra."

Bacillus gossypinus Stedman. Ala. Exp. Sta. Bull. 55:6. Apr. 1894. In rotting cotton bolls in Alabama. Figured and described as causing a boll rot of cotton.

Bacillus prodigiosus.

Mentioned in this publication, p. 312, as isolated from rotting cotton bolls in Alabama.

Botryosphaeria Berengeriana DeNot. Sfer. Ital. 82. Fig. 90. Sacc. Syl. Fung. 1:457. On various trees and shrubs in Europe and America. Atkinson, Bull. Cornell Uni. 3:11 refers to this species, on the authority of Dr. Massee who examined the specimens, his No. 2354 on capsules of *Gossypium herbaceum* from Alabama. Ellis, N. A. Pyrenomycetes p. 546 gives this as a synonym for *Botryosphaeria fuliginosa* (M. & N.) E. & E. while Saccardo, Syl. Fung. 1:456 gives *Sphaeria fuliginosa* M. & N. as a synonym for *Botryosphaeria Quercuum* (Schw.) Sacc.

Botryosphaeria horizontalis (B. & C.) Sacc. Syl. Fung. 1:463.

Syn. *Melogramma horizontalis* B. & C. Grev. 4:98.

On stems of cotton from South Carolina, Ravenel No. 1892.

Botryosphaeria subconnata (Schw.) Cke. Grev. 13:101.

Syn. *Sphaeria subconnata* Schw. Syn. N. A. Fungi No. 1443. *Thuemenia valsarioides* Rehm. Thuem. Myc. Univ. No. 2166.

On stems of cotton, Carolina, Schweinitz; Georgia, Ravenel.

Cercospora gossypina Cke.

See Mycosphaerella gossypina (Cke.) Earle.

Cercosporella Gossypii Speg. Guar. 1;162.

Sacc. Syl. Fung. 10:565. On cotton leaves, Brazil.

Chaetomium olivaceum C. & E. Grev. 6:96.

Sacc. Syl. Fung. 1:225, on dead stems of *Erigeron* New Jersey. Atkinson refers here specimens on dead stems of cotton from Alabama. Bull. Cornell Uni. 3:6.

Cladosporium herbarum (Pers.) Lk.

Developing on cotton roots killed by *Ozonium* and placed in a moist chamber. Pammel Tex. Exp. Sta. Bull. 7:20.

Cleistotheca papyrophila Zuk. Mykol. Mitheil, p. 4. (Bot. Zeitsch). Sacc. Syl. Fung. 11:270. On cotton fiber, Austria.

Colletotrichum gossypii South. Jour. of Myc. 6:101. Sacc. Syl. Fung. 10:469. Also Atkinson in Jour. of Myc. 6:175, Ala. Exp. Sta. Bulls. 17:8 and 41:40. Abundant in Alabama and other Southern States causing anthracnose of the bolls and stems, also on the leaves associated with rust.

Dyplodia gossypina Cke. Grev. 7:95. Sacc. Syl. Fung. 3:366. On dead capsules of cotton, Bombay, India, and Washington, U. S. A. Atkinson, Bull. Cornell Uni. 3:29 refers here to specimens from Alabama.

Diplodia herbarum (Corda) Lev. Ann. Sci. Nat. 1846, p. 292.

Syn. *Sporocadus herbarum Corda*, Ic. 3, fig 63.

Sacc. Syl. Fung. 3:370. On dead stems of various plants including cotton, Europe, Algeria, North America.

Diplodiella Cowdelli (B. & Br.) Sacc. Syl. Fung. 3:377.

Syn. *Diplodia Cowdelli B. & Br.* Ann. N. H. No. 406.

On cotton paper, England.

Doassansia Gossypii Lagh. Jour. of Myc. 7:49. Sacc. Syl. Fung. 11:235. On leaves of *Gossypium*, Ecudor.

Dothiorella botryosphaerioides Sacc. Mich 1:145. Sacc. Syl. Fung. 3:242. On stems of *Gossypium* South Carolina, (Ravenel).

Eurotium sp.

Atkinson, Div. of Exp. Sta. U. S. Dept. of Agr. Bull. 33:307, mentions this as appearing in cultures from diseased cotton roots from Texas.

Fusarium sp.

Atkinson, Div. of Exp. Sta. U. S. Dept. of Agr. Bull. 33:307, common on cultures from diseased cotton roots from Texas.

Fusarium aurantiacum (Lk.) Sacc. Syl. Fung. 3:720.

Syn. *Fusisporium aurantiacum Lk.* Obs. 1:17.

Mentioned in Sacc. Syl. Fung. 13:538 [Host Index] as occurring on stems of *Gossypium herbaceum.*

Fusarium oxysporum Schlecht. Fl. Berol. 2:139. Sacc. Syl. Fung. 4;705. Specimens on bolls of *Gossypium herbaceum* from Alabama are referred to this species by Atkinson. Bull. Cornell Uni. 3:49.

Fusarium vasinfectum Atk.

See Neocosmospora vasinfecta (Atk.) E. F. Smith.

Gibberella pulicaris (Fr.) Sacc. Mich. 1:43.

Syn. *Sphaeria pulicaris Fr.* Syst. Myc. 2:417. Given by Sydow in Host Index Sacc. Syl. Fung. 23:538 as occurring on *Gossypium herbaceum.*

Licea Lindheimeri Berk? Grev. 2:68.

Mentioned by Atkinson as occurring in cultures from diseased cotton roots from Texas. Div. of Exp. Sta. U. S. Dept. of Agr. 33:307.

Macrosporium gossypinum Thuem, Herb. Myc. oeconom. No. 513. Sacc. Syl. Fung. 4:526. On dead stems of *Gossypium herbaceum,* South Carolina, (Ravenel).

Macrosporium nigricantium Atk. Bot. Gazette, 16:62. Ala. Exp. Sta. Bull. 27:8; Sacc. Syl. Fung. 10:676 (under the name *M. nigricans* Atk). Abundant on living or languishing cotton leaves throughout the Gulf States associated with the disease called rust.

Mucor Mucedo L.

Reported by Atkinson, Div. of Exp. Sta. U. S. Dept. of Agr. 33:107 as occurring in cultures of diseased cotton roots from Texas.

Mycosphaerella gossypina (Cke.) Earle, this publication, p. 309. Syn. *Cercospora gossypina* Cke. Grev. 12:21.

Sphaerella gossypina Atk. Bull. Torr. Bot. Cl. 18:300.

The *Cercospora* stage of this fungus is common on cotton leaves in the Gulf States causing leaf blight. It is also associated with rust.

Neocosmospora vasinfecta (Atk.) E. F. Smith. Div. of Veg. Pys. and Path. U. S. Dept. of Agr. Bull. 17:46. 1899.

Syn. *Fusarium vasinfectum Atk.* Ala. Exp. Sta. Bull. 41:26. The conidial stage is parasitic within the stem of the cotton plant causing wilt. Frequent in the Gulf States.

Oedocephalum echinulatum Thax. Bot. Gaz. 16:17.

Sacc. Syl. Fung. 10:522. Reported by Atkinson, Div. of Exp. Sta. U. S. Dept. of Agr. 33:307 as occurring in cultures of diseased cotton roots from Texas.

Olpitrichum carpophilum Atk. Bot. Gaz. 19:244.

Sacc. Syl. Fung. 11:594. On rotting cotton bolls in Alabama.

Ophiobolus porphyrogonus (Tode) Sacc. Syl. Fung. 2:338.

Syn. *Sphaeria porphyrogona Tode* Meckl. 2;12.

On many herbaceous stems Europe and America. Specimens on dead cotton stems from Alabama are so determined by Atkinson, Bull. Cornell Uni. 3:8.

Ozonium sp.

Pammell, Texas Exp. Sta. Bulls. 4 and 7. Atkinson, Bot. Gaz. 18:16–19. Div. of Exp. Sta. U. S. Dep. of Agr. Bull. 33, 300–308, causing a serious root rot of cotton and other plants and trees in Texas. Pammel referred it provisionally to the species *O. auricomum Lk.* Atkinson decides that it cannot be that species. No fruiting forms have been observed.

Penicillium candidum Lk.

Penicillium Duclauxi Delacr.

Penicillium glaucum Lk.

All three of the above species of *Penicillium* developed in cultures of diseased cotton roots from Texas. Atkinson, Div. of Exp. Sta. U. S. Dept. of Agr. Bull. 3.:307.

Pestalozziella gossypina Atk. Cornell Uni. Bull. 3:38. On dead stems of cotton from Alabama.

Phlyctaena Gossypii Sacc. Mich. 2:144 (as *Septoria*). Sacc. Syl. Fung. 3:595. On stems of cotton, Carolina, Ravenel; Alabama, Atkinson, Cornell Uni. Bull. 3:30.

Phoma corvina Rav. Grev. 17:75. Sacc. Syl. Fung. 10:171. On branches of *Gossypium*, South Carolina.

Phoma Gossypii Sacc. Mich. 2:144. Syl. Fung 3:121. On stems of *Gossypium*, Carolina, Ravenel; Alabama, Atkinson, Cornell Uni. Bull. 3:30.

Phyllosticta gossypina Ell. & Martin. Jour. of Myc. 2:129. Sacc. Syl. Fung. 10:130. On fading leaves of cotton, F. L. Scribner; Alabama, Atkinson, Cornell Uni. Bull. 3:31.

Pleospora nigricantia Atk. Cornell Uni. Bull. 3:9. On fallen leaves of *Gossypium herbaceum* that were attacked by *Macrosporium nigricantium*.

Polyporus (or Trametes) sp.

On cotton roots, developing on a brown mycelium quite distinct from the *Ozonium*. Pammel, Tex. Exp. Sta. Bull. 7:18.

Pyrenophora hyphasmatis Ell. & Ev. Jour. of Myc. 4:77 (or as quoted by Saccardo owing to error in pagination 4:65) Sacc. Syl. 9:805. On exposed cotton cloth, Louisiana.

Ramularia areola Atk. Bot. Gazette, 15:166. Ala. Exp. Sta. Bull. 41:55-58. On living cotton leaves in the Gulf States causing mildew.

Rhinotrichum macrosporum Farl. Mich. 2:148. Sacc. Syl. Fung. 4:91. On rotten wood. Mass. On dead capsules of *Gossypium herbaceum*, Alabama, Atkinson, Cornell Uni. Bull. 3:39.

Rhinotrichum tenellum B. & C. Grev. 3:109. Sacc. Syl. Fung. 4:91. On rotten onions So. Car.

On dead capsules of *Gossypium herbaceum*, Alabama, Atkinson, Cornell Univ. Bull. 3:39.

Rhizoctonia sp.

Sterile damping off fungus, Atkinson, Ala. Exp. Sta Bull. 41:30-39. Cornell Exp. Sta. Bull. 94:265-268. Duggar, Cornell Exp, Sta. Bull. 163:330-352. Causing a damping off of cotton seedlings, and the disease known as sore shin.

Rhizopus nigricans Ehrb. De Mycetog, Nova Acta. 19:108. Sacc. Syl. Fung. 7:212. A common mould.

On tissues of cotton seedlings that have died from damping off. Atkinson, Ala. Exp. Sta. Bull. 41:31.

Saccharomyces sp.

Atkinson, Div. of Exp. Sta. U. S. Dept. of Agr. Bull. 33:307 mentions a "pink yeast" as occurring in cultures of diseased cotton roots from Texas.

Sclerotium sp. An undetermined species causing Rolf's "Sclerotium Wilt" of various plants. Mentioned by E. F. Smith, Div. of Veg. Phys. & Path. U. S. Dept. of Agr. Bull. 17:44, as causing a wilt of cotton in Florida.

Septoria gossypina Cke. Grev. 12:25

Sacc. Syl. Fung. 3:516. On leaves of *Gossypium*, Carolina, Ravenel.

Sphaerella gossypina Atk.

See Mycosphaerella gossypina (Cke) Earle.

Sporotrichum chlorinum Link. Obs. Myc. 2:35.

Sacc. Syl. Fung. 4:112. Occurring in cultures from diseased cotton roots from Texas. Atkinson, Div. of Exp. Sta. U. S. Dept. of Agr. Bull. 33:307.

Thielavia basicola Zopf. Verhand, Bot. Brand, p. 101. Sacc. Syl. Fung. 1:39. Making wounds in cotton stems beneath the surface of the earth, E. F. Smith, Div. of Veg. Phys. & Path. U. S. Dept. of Agr. Bull. 17:38.

Torula incarcerata Cke. Grev. 1:90.

Sacc. Syl. Fung. 4:258. Causing a disease of cotton seeds in India.

Tricothecium roseum (Pers.) Lk. Obs. Myc. 1:16.

Syn. *Trichoderma roseum* Pers. Syn. Fung. p, 231.

Sacc. Syl. Fung. 4:178. On decaying carpels of *Gossypium*, Atkinson, Cornell Uni. Bull. 3:39.

Uredo Gossypii Lagh. Jour. of Myc. 7:48.

Sacc. Syl. Fung. 11:224. Causing a destructive rust of the foliage of *Gossypium* in Ecudor.

Valsa gosspinay Cke. Valsei of U. S. p. 115 (in Proc. Phil. Acad. Sci. 1877). Sacc. Syl. Fung. 1:127.

On branches of cotton, Carolina, Ravenel.

Verticillium Rexianum Sacc. Mich. 2:577.

Sacc. Syl. Fung. 4:153, occurring in cultures of diseased cotton roots from Texas, Atkinson, Div. of Exp. Sta. U. S. Dept of Agr. Bull. 33:307.

Zignoella funicola (Ell.) Sacc. Syl. Fung. 2:217.

Syn. *Sphaeria funicola* Ell. Bull. Torr. Bot. Club, 8:90.

On exposed cotton cord in a grape trellis, New Jersey.

This makes a total of 61 species reported as growing on Gossypium.

Species Excludende.

In examining Mycological literature for cotton inhabiting fungi references have been found to the following species as occurring on *Gossypium* which on investigation prove to be erroneous. These errors have mostly occurred through a misunderstanding on the part of foreign botanists of our popular use of the of the term "cottonwood" for the different species of *Populus.*

Amphisphaeria separans Ell. & Ev. Bull. Torr. Bot. Club 24:130. "On an old cottonwood shingle." This is mentioned by Sydow. Host Index Sacc. Syl. Fung. 13:548 as occurring on wood of *Gossypium.*

Diplodiella striispora Ell. & Barth. Erythera 41:24. "On cottonwood stump." Mentioned by Sydow l. c. as on trunk of *Gossypium.*

Gloeosporium carpigenum Cke. & Hark. Grev. 13:113.

"On capsules of cottonwood." This is given in Sacc. Syl. Fung. 10:453 as "*in capsulis Gossypii arborei.*" Miss E. A. Southworth in her article on Anthracnose of cotton, Jour. of

Myc. 6:100, says, "When this fungus [*Colletotrichum Gossypii*] was first brought to our notice some immature specimens were sent to Mr. Ellis who afterward sent them to Mr. Cooke; both agreed that they were identical with *Gloeosporium carpigenum* Cke. & Hark. and the fungus was distributed in Ellis North American Fungi under that name. Through the kindness of Mr. Harkness I have been able to compare it with type specimens of *G. carpigenum* and find it quite distinct from this fungus."

It may be mentioned in this connection that *Gloeosporium carpigenum* Cke. & Hark. on capsules of cottonwood is antedated by *Gloeosporium carpigenum* Cke. Grev. 7:109 on fruits of *Aesculus*, California. As the spore measurements in the two descriptions do not agree it is to be supposed that they are two distinct species, in which case the one on "cottonwood" is without a name.

Hyponectria Gossypii (Schw) Sacc. Syl. Fung. 2:456.

Syn. *Sphaeria Gossypii* Schw. Fung. Car. No. 207. Dr. Erwin F. Smith has conclusively shown, Div. of Veg. Phys. & Path. U. S. Dept. of Agr. Bull. 17:51, that this should be considered *nom. excludendum* as it was founded on a misconception, the type specimen showing only a wrinkling of the capsule, no fungus at all being present.

Macrosporium nigricans Atk. Sacc. Syl. Fung. 10:674. This seems to be a missprint for *Macrosporium nigricantium* which see.

Ozonium auricomum Lk.

Pammell so called the fungus causing root rot of cotton in Texas, but Atkinson decides after farther study of the fungus that it cannot be this species. See *Ozonium sp.*

Sphaeria Gossypii Schw.

See Hyponectria Gossypii (Schw.) Sacc.

Bibliography of Cotton Diseases.

In the following pages the attempt has been made to bring together the titles of all the papers that have been published on cotton diseases. Owing to limited library facilities the list is necessarily incomplete and the writer will be greatly obliged for notes on any omitted articles. The papers are arranged alphabetically by authors and as far as possible chronologically under each author. No attempt has been made to list reviews or compilations, but only such papers as give the results of original observation and study. Papers in the agricultural press* or other transient publications are not included.

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1. **Atkinson, Geo. F.—The Cotton Worm and other Enemies of the Cotton Plant.** So. Car. Dept. of Agr. Monthly Rept. Oct. 1888, p. 91. Mention is made of Red Rust as caused by mites, *Tetranychus tetarius.*

2. **Atkinson, G. F.**—So. Car. Exp. Sta. Bull. 4:60. Jan. 1889. Mentions the Red Rust caused by mites.

3. **Atkinson, G. F.—A New Ramularia on Cotton.** Bot. Gazette 15:166-8. July, 1890. A description of the botanical characters of the fungus *Ramularia areola* causing mildew of cotton.

4. **Atkinson, G. F.—A New Root Rot Disease of Cotton.** Ala. Exp Sta. Bull. 21, p. 1-11, Dec. 1890. Describes the attacks of the nematode, *Heterodera radicicola* on cotton roots.

5. **Atkinson, G F.—Black Rust of Cotton; a Preliminary Note.** Bot. Gazette, 16:61-5, Mch. 1891 A paper read before the Assoc. of Agr. Col. & Exp. Sta's. at Champaign, Illinois, Nov. 1890, giving a brief discussion of the characteristics of the disease and of the fungi accompanying it He describes as new *Macrosporium nigricantium* and mentions a bacterial leaf disease [angular spot].

6. **Atkinson, G. F.—Black Rust of Cotton.** Ala. Exp. Sta. Bull. 27, pp. 1-16, with two plates, May, 1891. A more extended discussion of the matter presented in the preliminary paper.

7. **Atkinson, G. F.—Sphaerella Gossypina n. sp.—the Perfect Stage of Cercospora Gossypina Cke.** Bull. Torr. Bot. Club, 18:300-301 with plate, Oct. 1891, a botanical description of the fungus.

8. **Atkinson, G. F.—Anthracnose of Cotton.** Jour. of Myc. 6:173-8 with two plates, 1891

Read before the Assoc. of Agr. Col. & Exp. Sta's. Champaign, Ills. Nov. 1890.

Describes the occurrence of the fungus *Colletotrichum Gossypii* South on different parts of the cotton plant, and its behavior in artificial cultures.

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* A long list of references to newspaper articles on the Texas root rot, of cotton and other plants is given by Pammel at the end of Texas Exp. Sta. Bull. No 7.

9. **Atkinson, G. F.—Some Leaf Blights of Cotton.** Ala. Exp. Sta. Bull. 36, pp. 1-32, with two plates, March 1892. Describes rust, under the name of "Yellow Leaf Blight," calls attention to its being, primarily a physiological disease, gives history of kainit as a preventive of the disease and discusses the effect of humus. Makes brief mention under the name of "Red Leaf Blight" of a reddening of the leaves, often seen on poor lands, due to poor nutrition.

10. **Atkinson, G. F.—Some Diseases of Cotton.** Ala. Exp. Sta. Bull. 41, pp. 1-65, with numerous figures, Dec. 1892. This was prepared by Dr. Atkinson before severing his connection with the Ala. Exp. Station as a summary of his studies on cotton diseases. It includes a somewhat full discussion of the following topics: General Nature of Cotton Diseases, p. 5. Yellow Leaf Blight or Mosaic Disease [Rust], p. 9. Frenching [Wilt], p. 19. Damping Off or Sore Shin, p. 30. Anthracnose, p. p. 40. Shedding of Bolls, p. 50. Angular Spot of Cotton, p. 54. Areolate Mildew of Cotton, p. 55. Cotton Leaf Blight, p. 58. Root Galls, p. 61.

11. **Atkinson, G. F.—Methods for Obtaining Pure Cultures of Pammel's Fungus of Texas Root Rot of Cotton.** Bot Gazette, 18:16-19, Jan. 1893. Read before Amer. Assoc. Agr. Coll. & Exp. Sta's, New Orleans, Nov. 1892. Describes methods of baiting the fungus.

12. **Atkinson, G. F.—Damping Off.** Cornell Exp. Sta. Bull 94:265-8. Discusses the sterile damping off fungus [*Rhizoctonia*] which is the cause of sore shin in cotton.

13. **Atkinson, G. F.—Diseases of Cotton.** The Cotton Plant, Office of Exp. Sta. U. S Dept. of Agr. Bull. 33, pp. 279-316, with numerous cuts, 1896. This gives a detailed account of all cotton diseases known to occur in North America. It is largely the result of the author's work while connected with the Ala. Exp. Station. The diseases discussed are Mosaic Disease or Yellow Leaf Blight [Rust], Red Leaf Blight [Red Rust in part], Shedding of Bolls, Angular Leaf Spot, Frenching [Wilt], Sore Shin, Damping Off or Seedling Rot, Anthracnose, Root Rot (Ozonium), Cotton Leaf Blight, Areolate Mildew, Cotton Boll Rot, Root Galls of Cotton.

14. **Atkinson, G. F.—Some Fungi from Alabama.** Cornell Uni. Bull. Vol. 3, No. 1, pp 1-50, June. 1897. This mentions among others, 20 species of fungi as occurring on cotton in Alabama, two of which are described as new.

15. **Comstock, J. Henry—Report upon Cotton Insects.** U. S. Dept. of Agr. 1879. Appendix II, p. 384. Mentions cotton boll rot. Dr. Lee reporting from Lowndes Co., Ala , says "From 1825 to 1832 the crop was cut off very much by an infection called 'the rot.' The bolls which were not matured became diseased and sour."

16. **Cooke, M. C.—Blights of Tea and Cotton**, Grevillea, 1:90. Dec 1872. Describes a disease of Cotton seeds in India caused by the fungus *Torula incarcerata* Cke.

17. **Curtis, Geo. W.**—Tex. Exp. Sta. Bull. 22:211-216. Sept. 1882. Discusses a root rot of alfalfa found to be the same as the cotton root rot [*Ozonium*]. Reports experiments that suggest salt as a possible remedy.

18. **Dabney, Chas W.**—Ann. Rept. N. Car. Exp. Sta. for 1882, pp. 68-73. In discussing kainit as fertilizer for cotton he refers at some length to its effect in preventing rust and the shedding of bolls.

19. **Duggar, B. M.—Three Important Diseases of the Sugar Beet.** Cornell Exp. Sta. Bull 163:329-352. Feb. 1899. Discusses the sterile fungus of cotton sore shin in connection with a similar fungus causing a disease of beets and refers it to the genus *Rhizoctonia*.

20. **Duggar, J. F.—Experiments with Cotton**. Ala. Exp. Sta. Bull. 76:22. Jan. 1897. Mentions the failure of kainit in moderate quantity to resist rust in experiments during 1896. With 600 lbs. per acre there was a noticeable effect.

21. **Duggar, J. F—Co-operative Fertilizer Experiments with Cotton in 1896**. Ala. Exp. Sta. Bull. 78. Feb. 1897. On pp. 63 and 66 are brief notes on the effect of fertilizers on rust.

22 **Duggar, J. F.—Experiments with Cotton**. Ala. Exp. Sta. Bull. 89. Jan. 1898. On pp 4 and 20 are notes on the effect of kainit on rust.

23 **Duggar, J. F.—Co-operative Fertilizer Experiments with Cotton in 1897**. Ala Exp Sta, Bull. 91 Feb. 1898, p. 44. "Kainit greatly reduced the injury from leaf diseases in 61 per cent. of the experiments." There are numerous notes on the effect of kainit in controlling rust

24. **Duggar, J. F.—Experiments with Cotton in 1898**. Ala. Exp. Sta. Bull. 101, Jan. 1899, pp. 3, 16 and 17 give result of special potash experiments showing marked effect of kainit and muriate of potash in decreasing the amount of rust.

25. **Duggar, J. F.—Co-operative Fertilizer Experiments with Cotton in 1898**. Ala. Exp. Sta Bull. 102, Feb. 1899. Many brief notes on rust and some mention of boll rot.

26. **Earle, F. S.—Cotton Rust**. Ala. Exp. Sta. Bull 99 pp. 281-309, Dec. 1898. A report on farther investigations of this disease. Atkinson's views are in the main confirmed. Attention is especially called to the necessity for soil improvement in combatting this disease. It is shown that muriate of potash is as effective as kainit in controlling it.

27. **Galloway, B. T.—Anthracnose of Cotton**. Ann. Rept. U. S. Dept. of Agr. 1890, pp, 407-8 with colored plate. A brief account of the disease.

28. **Gasparrini,—Observationi sopra una Malattea del Cottone, &c.** Insti. D'Incorag, Napoli, 1865. Describes a disease known as

Pelagra. *Alternaria tenuis* Nees, and other moulds are associated with it.

29. **Glover, Townend—Accidents and Diseases of the Cotton Plant.** Ann. Rept. U. S. Dept. of Agr. 1855, pp 230-234. Gives an account of the following diseases: "Sore Shin," attributed to careless hoeing, also to twisting by the wind. "Frenching," a name applied to plants with variegated leaves. "Effects of Bad Subsoil," the sudden dying of plants near Tallahassee, Fla. [evidently cotton wilt]. "The Rust." [The author seems to confuse Rust, Red Rust, and probably anthracnose under this term.] "Shedding of Young Buds or Bolls," caused by wet weather. "The Rot," quotes a very full description by Mr. Thorp in American Farmer [no date given].

30. **Lagerheim, G.—Observations on New Fungi from North and South America.** Jour. of Myc 7:44-50. Sept. 1891. Describes *Uredo Gossypii* as a new species causing a serious disease of cotton in Ecudor. Mentions a disease reported from Cuenca under the name of "Cancha" cause not known and describes *Doassansia Gossypii*.

31. **Loughridge, R. H.**—Tenth Census, Vols. 5 and 6. Under the heading "Diseases of Cotton" a brief resume is given of reports from most of the counties in each of the cotton States. The diseases mentioned are Shedding, Boll Rot, Rust, Blight, and Sore Shin. In Texas the term blight evidently refers to Root Rot. In Florida it seems to refer to Wilt. In the other States the terms rust and blight seem to include all leaf diseases of cotton. Read in the light of our present knowledge of cotton diseases these reports are exceedingly interesting and throw much light on geographical distribution.

32. **Lyman, Jos. B.—Enemies of the Cotton Plant.** Ann. Rept. U. S. Dept. of Agr 1866, p. 199. Mentions rust, states it is worse on soils of moderate depth that have been long in cultivation. "Rotation of crops and a liberal application of manures, especially those rich in potash and phosphoric acid will in nine cases out of ten give relief."

33. **Newman, J. S.—Experiments with Cotton.** Ala. Exp Sta. Bull. 22:19, Jan. 1891. Calls attention to the effect of kainit in preventing leaf blight [rust].

34. **Newman, J. S.—Co-operative Soil Tests of Fertilizers.** Ala. Exp. Sta. Bull. 23. Feb 1891. Brief notes on rust.

35. **Pammel, L. H—Root Rot of Cotton or Cotton Blight.** Texas Exp. Sta. Bull. 4, pp. 1-18, Dec. 1888. Discusses geographical distribution, characteristics, and the various theories to account for it. Ascribes it to the growth on the roots of the fungus *Ozonium auricomum* Lk. as determined by Dr. W. G. Farlow.

36. **Pammel, L. H.—Cotton Root Rot.** Texas Exp. Sta. Bull. 7, pp. 1-30, with 5 plates, Nov. 1899. A fuller discussion than in previous paper Gives list of host plants for *Ozonium* in Texas and suggests rotation with the serials as the most promising remedy. Mentions Seedling Rot or Sore Shin, p. 7.

37. **Riley, C. V.** 4th Rept. U. S. Ent. Com. p 357, 1885. Describes Boll Rot. Thinks Steele mistaken in attributing it to work of boll worm, states that it has been destructive at times since 1814.

38. **Scribner, F. Lamson.—Cotton Leaf Blight.** Ann. Rept. U. S. Dept. of Agr. 1887, p. 355 with colored plate. Describes *Cercospora gossypina* Cke. States that it is "distinct from the dreaded cotton rust.... and in comparison is of little consequence."

39. **Smith, Erwin F.—The Watermelon Wilt and Other Wilt Diseases due to Fusarium.** Proc. A. A. A. Sci. 44:190, May, 1896. Mentions cotton wilt and the discovery of the ascigerous form of the fungus causing it, considers it probably identical with the wilts of the watermelon and the cowpea.

40. **Smith, Erwin F.—The Spread of Plant Diseases.** Trans. Mass. Hort. Soc. 1897, pp. 128-9. Mentions cotton wilt incidentally as an example of a disease infesting soils. Cites a sea-island cotton grower who has abandoned 15 acres of his best land on account of it

41. **Smith, Erwin F.—Wilt Disease of Cotton, Watermelon and Cow Pea.** U. S Dept. of Agr. Div. of Veg. Phys. & Path. Bull. 17, pp. 1-53, with 10 plates, Nov. 1899. A very full description of the fungus causing the wilt disease of cotton, *Neocosmospora vasinfecta* (Atk.) Smith, with extended culture experiments. He considers it the type of a new genus in the *Nectriaceae*. The forms on watermelon and cowpea are physiological varieties since they do not seem capable of transmission from one host to another, although structurally indistinguishable. An exceedingly valuable paper.

42. **Southworth, Miss E. A.—Anthracnose of Cotton.** Jour. of Myc. 6:100-105 with 1 plate, 1890. A description of the fungus, *Colletotrichum Gossypii* South, which is considered a new species, with notes on the damage to cotton crop and on geographical distribution.

43. **Stedman, J M.—Cotton Boll Rot.** Ala. Exp. Sta. Bull. 55, pp. 1-12 with 2 plates, Apr. 1894. Describes a disease of cotton bolls which he considers of bacterial origin and ascribes to the growth of *Bacillus gossypina* Sted. Cultural notes and inoculation experiments are recorded.

44. **Stelle, J. P.—Cotton Blight.** 4th Rept. U. S. Ent. Com. App. III, p. 25. 1885. Says the disease is also known in Texas as Stalk Rust and Root Rot. Gives a fairly good description, decides it is not due to insects and suggests rotation of crops.

45. **Stelle, J. P.—Boll Rot,** l. c. p. 26. Observes the cotton boll worm to frequently bite into bolls that they do not enter and considers these injuries as the cause of boll rot.

46. **Wailes, B. C. L.—The Cotton Plant; Its Origin and Varieties and its Enemies and Diseases.** Agriculture and Geology of Mississippi, 1st Rept. 1854, pp. 146-148. Not seen.

47. **Watts.—Dictionary of Economic Products of India.** In the chapter on cotton several diseases are mentioned under their native names. They are mostly ascribed to unfavorable weather conditions, but they do not seem to have been scientifically studied.

CLIMATIC CONDITION OF COTTON BELT.*

BY P. H. MELL.

THE GENERAL CLIMATIC FEATURES PREVAILING IN THE SOUTHERN UNITED STATES DURING THE PREPARATION OF THE LAND FOR THE PLANTING OF THE SEED.

The winters of the South are seldom severe, and the temperature rarely reaches zero except in the more northern latitudes of the cotton region, and not often even there. It is a well recognized fact among cotton planters that in those portions of the country where the changes of temperature are sudden and the fall reaches zero during every winter and sometimes frequently during the same winter, the period is too short between frosts to enable the cotton plant to perfect its growth and mature its fruit. Many efforts have been made to force the plant to produce fiber in the northern portions of Kentucky and the colder regions in west and northwest Texas, but all such efforts have proved total failures, even though the general conditions of the soil in those sections of the country are of a nature well suited for the cultivation of cotton.

The following table of winter temperatures at those stations in the cotton region, giving continuous records for ten years or more, is given to bring out the above conclusions in regard to the growth of cotton. A careful study of this table will show that wherever the altitude or latitude causes the temperature to range low during the winter and spring months the cultivation of cotton is correspondingly reduced to a minimum:

*Condensed from "Climatology of Cotton Plant." P. H. Mell, Bulletin 8 U. S. Weather Bureau.

TABLE I.—*Winter minimum temperatures at stations of the cotton belt of the Southern States.*

Stations.	Length of record.	Minimum.	Month and year.	Mean minimum. December.	Mean minimum. January.	Mean minimum. February.	No of times min. was down to zero and below.
Northern portion.	*Years.*	°		°	°	°	
Atlanta, Ga.	13	— 2	Jan., 1886	37.6	35.4	39.7	2
Charlotte, N. C.	13	— 5	Dec., 1880	35.5	33.8	37.4	2
Chattanooga, Tenn.	13	— 7	Jan., 1886	35.6	34.0	37.7	2
El Paso, Tex.	14	— 5	Dec., 1880	32.9	30.7	35.8	2
Fort Davis, Tex	11	— 3	Jan., 1886	33.2	30.1	34.8	2
Fort Elliott, Tex.	10	—14	Jan., 1888	25.6	18.7	24.2	12
Fort Smith, Ark.	10	— 7	Jan., 1886	33.8	26.8	32.3	3
Knoxville, Tenn.	21	—16	Jan., 1884	32.3	30.6	34.2	7
Little Rock, Ark.	13	— 5	Jan., 1886	38.5	33.7	38.0	1
Memphis, Tenn	20	— 8	Jan., 1886	38.1	32.8	37.7	2
Nashville, Tenn	21	—10	Jan., 1884	33.9	30.5	34.1	9
Middle portion.							
Auburn, Ala.	14	3	Jan., 1884	39.7	38.2	44.8	0
Augusta, Ga.	20	6	Jan., 1886	39.0	38.8	42.0	0
Charleston, S. C	20	10	Jan., 1886	44.8	44.5	46.2	0
Green Springs, Ala.	27	2	Jan., 1886	......	......	......	0
Hatteras, N. C.	17	8	Dec., 1880	42.0	39.3	41.9	0
Kittyhawk, N. C	17	5	Feb., 1886	40.1	36.6	39.4	0
Montgomery, Ala	19	5	Jan., 1886	40.6	40.1	44.4	0
Palestine, Tex.	10	0	Jan., 1886	42.6	38.3	43.8	1
Shreveport, La.	20	1	Jan., 1886	41.6	38.2	43.1	0
Union Springs, Ala.	24	8	Jan., 1886	......	......	......	0
Vicksburg, Miss	20	3	Jan., 1886	42.7	39.9	44.2	0
Wilmington, N. C.	21	9	Jan., 1884	39.9	38.9	41.5	0

Winter minimum temperatures, &c.—Continued.

STATIONS.	Length of record	Minimum.	Month and year	Mean mini'um December	Mean mini'um January.	Mean mini'um February.	No. of times min was down to zero and below.
Southern portion.	*Years.*	°		°	°	°	
Brownsville, Tex...	16	18	Dec., 1880 / Jan., 1881	53.5	50 0	55 2	0
Cedar Keys, Fla...	10	15.5	Jan., 1886	51.4	51.0	54.9	0
Galveston, Tex....	21	11	Jan., 1886	51.5	47.4	52.9	0
Indianola, Tex	14	12	Jan., 1886	50.1	43.8	49.9	0
Jacksonville, Fla...	20	15	Jan. 1886	49.1	47.5	50.8	0
Mobile, Ala	21	11	Jan., 1886	44.4	43.6	47.6	0
New Orleans, La...	21	15	Jan., 1886	48.7	47.3	51.2	0
Pensacola, Fla.....	12	15	Jan., 1886	47 3	46 3	51.0	0
Rio Grande City, Tex	15	19	Jan., 1881	50.5	47.7	54.2	0
San Antonio, Tex...	15	6	Jan., 1886	45.2	41.0	46.8	0
Savannah, Ga......	21	12	Jan., 1886	44.4	43.7	46.9	0

The months of February and March are spent by the planters in preparing the land for the planting of the seed, and the season is very well adapted for such work. The weather is not often so severe as to prevent outdoor work, and the ground is seldom so hard frozen as to impede the progress of the plow.

In the lower half of the Southern States, the fall of snow is very unusual, and even in the more northern limits it scarcely covers the ground above a few inches and remains only a few days at the most. It is possible, therefore, under these conditions, for the farmers to work almost continually during the winter months. The lands are generally plowed broadcast in the winter so that the rains and the frosts may disintegrate the soil and render the ingredients available to the demands of the plants. The plowing usually begins about the 1st of February and continues until planting of the seed in

April or May, depending, of course, upon the locality of the farm. In winter the rains are frequent and the soil is often soaked. The freezing of this water at night and quick thawing under the influence of the noonday sun cause great changes to take place in the chemical and physical conditions of the soil.

THE CLIMATE OF THE SEED-PLANTING SEASON.

The heavy frosts in the South have generally ended by the 15th of April, and there is little danger of the young cotton plant becoming killed if it is planted so as to germinate about the 1st of May. It is customary, therefore, to put the seed in the ground from April 1 to May 10, the time depending largely upon the locality in the cotton belt. With the exception of the extreme south the cotton that is planted before the 15th of April is apt to become reduced in its vitality by cool nights that prevail during the first half of April. In most sections of the cotton belt light frosts, with occasional killing frosts, frequently retard the growth of vegetation during the first weeks of April, particularly in the northern limits of the region. It is therefore customary in those portions of the belt to delay the planting until the first week in May so as to escape this period of cool weather.

During the months of April and May the weather is seldom so cold as to entirely destroy the tender cotton plant just after it reaches the surface of the ground when it is most susceptible to the influence of cold. Very rarely does the thermometer record temperatures lower than 33°. The maximum temperature sometimes goes as high as 98°, but the range is generally between 80° and 95°, thus supplying a large percentage of heat rays for the warmth of the soil. As far south as Mobile, during a period of 21 years, the temperature ranged above 40° as often as 18 years and above 45° as often as

10 years. At Augusta, Ga., in the middle area of the cotton belt, the minimum temperaure, throughout a period of 19 years, ranged above 40° nine times, and fell below 35° only twice. At Montgomery, Ala., in the central belt, and on the edge of the great prairie region, the minimum temperature ranged above 40° 13 years out of a record of 19 years. These facts indicate a remarkably fair season for the planting of the seed, and show that the soil is not so chilled as to prevent the rapid germination of the plant. It is therefore customary among the farmers throughout the extent of this southern area to plant a week, and in some places two weeks, earlier than in that portion of the cotton belt located north of Montgomery and Augusta.

By the first of May cotton planting is about completed throughout the entire area of the cotton belt. After the close of the second week in May frost is not likely to occur, and, although there may be a few cool nights, the cotton plant in its young, tender condition, stands a very fair chance in all sections of the country under consideration. The mean minimum for May ranges above 52° at all stations, and at the majority it is above 60°. The minimum temperature, even at the extreme northern stations, never falls below 35°, and at twenty-five out of thirty-one stations furnishing continuous records, the minimum is never lower than 40°.

THE GROWING PERIOD OF THE PLANT, AND ITS WEATHER CONDITIONS.

This period might be properly termed the season from "chopping out" to the appearance of the first boll. In the central portions of the cotton belt this time is generally from the first of June to the first of August. The first bloom opens early in June and the first boll matures early in August. During this period in the life of the plant there must be a large supply of sunshine, and only so much moisture as will furnish the plant with what it needs, and at the same time not make the soil so damp as to cause too rapid multiplication of surface roots nor cause too great a growth of what farmers term "weed," that is, rapid development of stalk and branches to the detriment of flowers and fruit.

During the months of June and July rains are not ordinarily heavy, and floods occur only at long intervals. The greatest normal rainfall is 6.83 inches for June at Cedar Keys, Fla., and for July it is 8.68 inches at the same place. The largest number of rainy days that occur during the two months usually take place at stations along the Atlantic and Gulf coasts. At stations in the interior the rain is not so frequent, but with the exception of some of the stations in Texas, there is never less than ten normal rainy days in each month, thus furnishing ample moisture for all the demands of the cotton plant while in its blooming season. Much rain during this period is decidedly injurious to the plant because the flowers are so singularly constituted that if water accumulates in the cup formed by the petal and sepals rapid decay will take place, caused by fermentation of the gelatinous substance generated at the base of the flowers, and the forms will shed off and the yield of the plant be correspondingly decreased. These flowers open in the early morning, just after the sun rises above the horizon, and remain expanded to the sun's rays until late in the evening, when the petals close and remain so until next morning, when they open again.

At this stage of their development the color changes from a delicate cream to a light red. At the close of the second day the petals fall off, leaving a small boll surrounded by the green sepals. Now, if the rains are frequent during this period the petals have their sensitive organisms greatly dulled, and the absence of the sunlight, so necessary for their activity, causes them to stick to the forming boll and decay rapidly follows. Much cloudy weather during this period is almost as injurious as continual rains, because the cotton plant is a sun plant.

This plant can stand a much longer drought while blooming than almost any other vegetation, and hence the fall of rain should not be more frequent than once in three or four days, and the showers should be very light, permitting as much as possible the largest amount of sunshine. The number of days on which rain is apt to fall during these two months does not exceed 51 per cent. at any point in the entire region of the cotton belt, and at most places it generally does not exceed 40 per cent. The average number of sunny days during June and July is 56 per cent. At many of the statons, however, the percentage of perfectly clear days is greater than that given above for the entire region. For instance, at Memphis, Tenn., it is 59 per cent.; at Vicksburg, Miss., it is 68 per cent.

CHARACTER OF WEATHER BEST SUITED FOR THE PRODUCTION OF FIBER.

The first boll generally opens early in August, the interval from the first bloom to the first boll being about 40 to 50 days, the shorter interval being required later in the season. The plant continues to bloom during the month of August and until the latter part of September, but its powers in this regard are steadily reduced as the vitality goes more and more into growing the already formed bolls and bringing them to maturity. In the Southern States the cotton plant is decidedly an annual, whatever may have been its condition in its original form, and the work of perfecting its seed completes its life.

During this period in the history of the cotton plant there must be an abundance of sunshine and a small amount of moisture. At this time the plant has reached its full height and the largest share of its vitality must go towards making seed and developing fiber. If much rain occurs at this stage in its life three deleterious results will take place: First, the "weed" or stem, leaves, and branches will begin rapidly to multiply to the detriment of the fruit. The plant will stop blooming and the squares already formed will shed because of the too rapid growth of the parts of the branches to which they are attached. Second, the bolls already formed will begin to decay, caused by the surplus water absorbed by them, and thus rendered unable to open, since it takes a large per cent. of warmth and sunlight to cause the bolls to open, they will be destroyed. Third, the fiber in the bolls already opened, when the rain season begins will be beaten out on the ground and lost or badly stained. It is therefore best for the condition of the cotton plant that much dry weather prevails during the months of August and September.

Although droughts occur frequently during the months of July and August, still the normal results indicate for the entire cotton felt 43.5 per cent. of cloudy days while the probability of rainy days is 34.5 per cent. The sun is likely, under these conditions, to shine unclouded 56.5 days in the 100. This character of the season is most propitious for the plant in its flowering and boll-forming period.

In September the probability of rain in the northern section of the cotton belt is as 1:4, or one day in four may produce rain. The normal rainfall for this month in the same region of the cotton belt is 3.03 inches. So that the eight days of precipitation may produce on an average 0.38 of an inch each day. This indicates a dry month in its normal condition, and therefore very favorable for gathering the staple. The large per cent. of sunshine, 61 per cent., causes the bolls to open rapidly and preserves the fiber in its purest whiteness. This character of weather continues through October; thus furnishing two months of fine season for gathering the crops. In the central portion of the belt we find a similar condition in the cast of the sky. The probability of rain in September is 27 per cent. out of 100; and the per cent. of cloudy days is 44, or 66 per cent. of sunshiny weather. The normal rainfall for this section for September is 4.74 inches, or 0.59 of an inch for each of the eight days of rain. There is more rain throughout the southern belt than in either of the other two. The normal is 5.72 inches, the probability of rain is 1:3, or 33 days in 100 may produce rain. The per cent. of cloudy days is 44.8. So that during September there is a probability of 55 days of sunshiny weather in 100.

THE PICKING SEASON AND ITS WEATHER.

The months of autumn are spent in gathering the staple, and by the end of November, if the season is favorable, almost the entire crop will be picked. All that the cotton planters desire during this period of the year is that frost will be delayed as late as the last week in November, and that after the middle of September heavy rainstorms will not occur, but that showers, if they come at all, shall be light and not frequent. This condition of the atmosphere wil enable the pickers to gather the cotton as fast as it opens, in all its beautiful whiteness, unsullied by dampness, mold, or dirt. It is not often in the South that heavy rains occur in autumn, and monthly averages seldom go above 3.50 inches, but more frequently fall below 2.00 inches. The winds are also generally light so that the cotton is not greatly damaged by being driven out on to the ground and stained.

In the extreme southern portions of the belt the frost will come later than in the more northern parts of the section under consideration. For instance, frosts may be expected along the coasts of Georgia and Alabama any time after November 15, while at Atlanta, Vicksburg, Starkville, and Palestine, killing frosts will come generally as soon as November 1. At Charlotte, Chattanooga, and Nashville it is as early as October 15.

THE IMPROVEMENT OF THE COTTON BY HYBRIDIZATION AND SELECTION.

BY P. H. MELL.

These experiments have been conducted at the Alabama Experiment Station for the past six years, and during that period several bulletins have been issued on the subject of the improvement of the cotton fiber. In the development of this work the first step attempted was the determination of the number of varieties then in cultivation throughout the cotton belt, and which ones of these furnished the best results in maturity of the fiber, its length and the largest yield. The second year was devoted to blending by crossing those varieties which yielded the best fiber in the largest quantity, in order to secure a plant approaching nearest the perfect cotton plant. During the second year also a third step was taken in the cultivation of a number of foreign cottons, the seeds of which were secured from India, Egypt, Mexico, South America and the Fiji Islands, with the hope that something might be accomplished to counteract the tendency to purchase Egyptian cotton now so steadily growing with some of the manufacturers in the New England mills. The new plants secured by the first step and the seeds obtained from these foreign cottons from the first season's planting were cultivated another year in order that the properties of the American hybrids might be rendered stable, and that the foreign cotton plants might be acclimated. After accomplishing these ends the fourth step was taken, viz: to blend the new American types with the foreign acclimated plants with the hope that the resulting plant would contain within itself the best properties of the two parents. The discussion that follows will determine whether this desirable end has been reached or no.

I—THE NUMBER OF VARIETIES IN CULTIVATION IN THE COTTON BELT.

To determine this question the following so-called varieties of cotton were cultivated the first season and a careful study was made in the field and under the microscope of all portions of the plant:

Allen's long staple, Bailey, Barnett, Cherry's cluster, W. A. Cook, J. C. Cook, Gold dust, Hawkins' improved, Herlong, Hunnicutt, Jones' improved, Jones' long staple, Keith, T. J. King, Okra leaf, Peeler, Peerless, Peterkin, Petit Gulf, Rameses, Rust proof, Southern hope, Truitt, Welborn's pet, Wonderful, Zellner.

After conducting many experiments in the field and in the laboratory, extending over the entire season, the following classification was adopted:

(1) Short staple forms, under 1.2 inches:
Bailey, Barnett, Cherry's cluster, J. C. Cook, Dixon, Gold dust, Hawkins' improved, Herlong, Hunnicutt, Jones' improved, Keith, King, Okra leaf, Peeler, Peerless, Peterkin, Petit Gulf, Rust proof, Rameses, Southern hope, Storm proof, Truitt, Welborn's pet, Zellner.

(2) Long staple, 1.3 inches and above:

Allen's long staple, W. A. Cook, Jones' long staple, Wonderful.

(3) Prolific forms:

Allen's long staple, Bailey, Barnett, Cherry's cluster, W. A. Cook, Dixon, Gold dust, Hawkins' improved, Herlong, Hunnicutt, Jones' improved, Keith, King, Okra leaf, Peerless, Truitt, Welborn's pet, Wonderful.

(4) Non-prolific:

J. C. Cook, Jones' long staple, Peeler, Peterkin, Petit gulf, Rust proof, Southern hope, Zellner.

(5) Those forms which have leaves alike:

Allen's long staple, Cherry's cluster, Dixon, Jones' improved, Jones' long staple, Gold dust, Hunnicutt, Keith, King, Peeler, Truitt, Wonderful, Zellner. (Three to five lobed leaves.)

W. A. Cook, Hawkins' improved, Peerless, Petit Gulf, Southern hope, Rust proof, Welborn's pet. (Four to five lobed leaves.)

(6) Long limbed forms:

Allen's long staple, J. C. Cook, Gold dust, Herlong, Hunnicutt, Jones' long staple, King, Peeler, Peerless, Peterkin, Petit Gulf, Rameses, Southern hope, Truitt, Wonderful, Zellner.

(7) Short lmbed forms:

Bailey, Barnett, Cherry's cluster, W. A. Cook, Dixon, Hawkins' improved, Jones' improved, Keith, Okra leaf, Rust proof, Welborn's pet.

(8) Clustered varieties:

Cherry's cluster, Herlong, Peerless, Welborn's pet.

(9 Large boll varieties:

Allen's long staple, W. A. Cook, Hawkins' improved, Hunnicutt, Jones' long staple, Wonderful.

(10) Medium and small varieties:

Bailey, Barnett, Cherry's cluster, J. C. Cook, Dixon, Gold dust, Herlong, Jones' improved, Keith, King, Okra leaf, Peeler, Peerless, Peterkin, Petit Gulf, Rameses, Southern hope, Rust proof, Truitt, Welborn's pet, Zellner.

(11) The dark, smooth seed forms:

Bailey.

(12) The furry, dark and small seed forms:

J. C. Cook, Petit Gulf.

(13) The large light brown, furry seed forms:

Allen's long staple, W. A. Cook, Gold dust, Hawkins' improved, Hunnicutt, Jones' long staple, Keith, King, Peeler, Peerless, Rameses, Southern hope, Rust proof, Trutt, Welborn's pet, Wonderful, Zellner.

(13) The small, light brown, furry seed forms:

Barnett, Cherry's cluster, Dixon, Herlong, Jones' improved, Okra leaf.

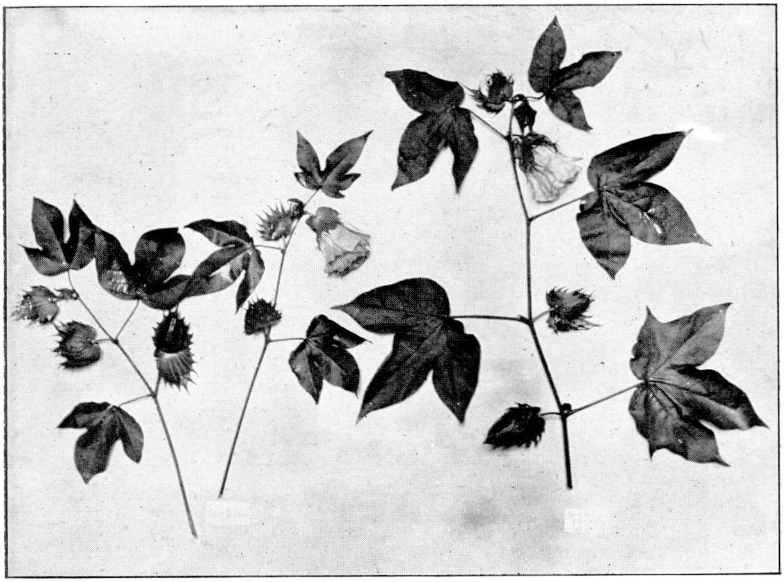
Selecting from the above classfication those forms which have features alike, we may rearrange our plants into the following seven groups:

1. Allen's long staple, W. A. Cook, Hunnicutt, Jones' long staple, Wonderful.
2. Bailey, Okra leaf.
3. Cherry's cluster, Herlong, Peerless, Welborn's pet.
4. J. C. Cook.
5. Barnett, Dixon, Hawkins' improved, Jones' improved, Keith, King, Rameses, Truitt.
6. Gold dust.
7. Peterkin, Peeler, Petit Gulf, Rust proof, Southern hope, Zellner.

It may not be far wrong to assert that each of the many so-called varieties now on the market belong to one of these groups; and, in a number of instances, coming under the observation of the writer, the "new cotton" has no right to a new name, but is only an improved production of seed under an excellent system of cultivation and selection from year to year.

In this connection an effort was also made to determine the scientific names of these varieties of cotton, or in other words, what species of the genus *Gossypium* were involved in the development of these varieties. This undertaking was much more difficult than the first attempt, viz. the classification of the varieties. Cotton has been cultivated in the South for so long a period, and so many kinds of seeds have been planted in such

1 2



(Photographed by P. H. Mell)

Fig 1. 1—Sea Island Cotton,
2—Sea Island Crossed on Upland Cotton.

close proximity to each other, every opportunity has been presented for favorable hybridization, and, in the repeated replanting of these seeds year after year, the types have been well established and many of the distinctive properties of the original parents have been hopelessly obliterated. It becomes, therefore, a difficult problem to determine the names of the species from which the varieties have been derived. We may say, however, that indications point to the presence of the following species at least:

Gossypium herbaceum, L.; *Gossypium roseum*, Tod.; *Gossypium maritimum*, Tod.; *Gossypium hirsutum*, Mill.

The illustrations of leaves given herewith furnish the character of foliage usually found on the cotton plants grown in the cotton belt. Some of these leaves are thickly covered with hairs with the lobing so characteristic of the *Gossypum hirsutum;* while others are smooth and are deeply lobed like those produced on Sea Island forms or the *Gossypium maritimum.*

II—CROSSING THE VARIETIES.

In the experiments the "W. A. Cook" and "Peerless" varieties were selected to carry the female function, because these plants had distinctive and desirable features which were strongly marked; and a stable basis was thus offered upon which to develop the future improved bolls.

Having succeeded in raising strong and healthy plants of all the varieties mentioned under the first step, a number of flowers on the best plants of the W. A. Cook and Peerless were prepared in the following manner, on an evening just before sundown, when there was no indication of rain for at least forty-eight hours:

The buds on the most mature limbs were selected, the petals of which would fully expand during the early hours of the next morning, and by means of small scissors these petals were cut off just above their bases, thus exposing the stamens and pistils fully to view. The stamens were then carefully removed by means of a pair of forceps, without bruising the pistil. Thus denuded of all male organs the pistil was covered with a thin paper bag, as a protection against the wind and insects, and left until next morning, by which time it was fully developed with all its functions ready for the reception of the pollen. A healthy flower from a plant of another variety was plucked next morning and carried to the flower prepared the afternoon before, and, by means of a small soft brush, the pollen was dusted on the stigma of the pistil. The bag was replaced and carefully fastened around the limb so as to prevent any possibility of pollen from any other source being introduced upon the pistil. A tag, properly labeled, was suspended at the base of the flower for future reference. After two or three days the bag was taken off and the new boll left to grow under the influence of the sun's rays. Many hundreds of these bolls were grown, the fiber gathered and the seed carefully selected and planted the third season. The fiber of the last planting was then subjected to the most rigid examination under the microscope and submitted to severe tests to determine its valuable and weak properties.

From the many hundred hybrids secured by the crossing of the American varieties the following were found to be the most desirable forms and all of the other hybrids were dropped from the future experiments:

BOTANICAL CHARACTERISTICS OF AMERICAN CROSSED PLANTS.

Allen's long staple crossed on Peerless produces a boll of medium size gradually tapering to the end, and also one rather blunt pointed and cylindrical. The involucre covers about one-half of the boll and is cut into lobes extending $\frac{1}{4}$ the depth of the involucre; the surface is covered with fine hairs; the bases are slightly united. The flower is pale yellow white; the petiole is short and hairy. The plant grows to the height of 5 to 6 feet with long branches. Prolific. Leaves large and 3-lobed; covered with hairs. Seeds large, furry and light brown.

Barnett crossed on Cook produces a plant 4 to 5 feet high with branches of medium length and numerous, 5 to 8 bolls to each branch. Leaves 3-lobed and covered with hairs. Flowers light yellow with petiole about length of boll. Boll nearly cylindrical and large with involucre length of boll and deeply lobed. Seeds furry, light brown and medium sized.

Cherry's cluster crossed on Cook.—Plant 6 to 7 feet high and prolific. Branches of average length and numerous, with 5 to 9 bolls to each. Leaves 3-lobed, covered with hairs. Flower pale yellow with petiole length of flower. Boll large and ends with an erupt point; involucre length of boll with deep lobes, and free at base.

Wonderful crossed on Peerless.—A prolific plant, 4 to 6 feet high, 3-lobed leaves, limbs long, bolls medium size, 2-3 to each limb, pointed; all parts of plant covered with hairs, seeds light brown, furry. Flowers light yellow with petiole about length of petals; seed light brown; fiber long. Plant matures at average date.

Petit Gulf crossed on Peerless.—Bolls walnut shaped and acute conical, the first usually five and the second four celled. Stem triangular, leaves long petiolate, upper surface except veins glabrous, lower surface pubescent, 3 to 5 lobed; corolla nearly twice the length of the bracts, pale yellow, turning red after flowering, calyx large toothed, pale green, spotted, nerved; anther column almost covered with stamens; petiole about length of blade; peduncle about two inches in length.

Truitt crossed on Cook.—Bolls conical pointed, 4-celled, small plant, non-prolific; leaves three, four, and five lobed; limbs long, numerous; medium sized bolls; large, light brown, furry seeds, long fibre; maturity about average time.

Petit Gulf crossed on Cook.—Bolls ovate conical, 4-celled, 3 to each branch; leaves 3-lobed, smooth above except veins, pubescent below; stem somewhat pubescent, younger portions woolly, triangular in section; 4 feet in height; branches long; seed dark brown; fiber short. Late in maturing.

Rust Proof crossed on Peerless.—Boll conical, 4-celled medium sized, 4-6 to each limb; seeds large, light brown and furry; fiber long; leaves 3 to 5-lobed; long limbs; stem 4-5 feet. Average time in maturing.

The Sea Island species belongs to *Gossypium maritimum,* which is fully identified as follows:

G. maritimum.—Glabrous, stem erect, branched, tall; branches graceful, spreading, subpyramidal ascending, and later recurving; leaves rotundate ovate, subcordate, 3-5 lobed, sometimes intermingled with other entire leaves, lobes ovate, ovate-lanceolate, or lanceolate-oblong, depressions between lobes subrotundate; single peduncle above the axis of leaf and stem, an inch long during flowering period, but afterwards elongating; bracts broadly ovate, cordate adhering at middle of base with calyx, but not coalescing among themselves, deeply cut into lobes, lobes near base slightly broader, lanceolate, terminating with an elongated point; corolla longer than bracts, petals yellow, or pale sulphur color, not entirely expanded during the flowering period; lower part of style free from stamens and equal in length to another bearing column; style somewhat three parted; boll ovate conical, acute, three to four celled, 6-9 seeded; seeds beaked at hilum, black, smooth and covered with long silky fibre.

TABLE I.

Comparison between the original plants and 9 of the best improved forms.

Number.	NAME OF PLANT.	Number seed in boll.	Wt. seed in grammes.	Wt. lint in grammes.	Per cent. seed.	Per cent. lint.	Length of fiber in millimeters.	Diameter of fiber in millimeters.	Character of twist.	Max. strain for breaking one strand in grammes.	Min. strain for breaking one strand in grammes.
14	**Cherry's Cluster on Cook**	**36**	**4 326**	**1.979**	**68.6**	**31.4**	33.	**0 020**	Excellent	**14.20**	**12.31**
	Cook, W. A.,	42	5.675	2.740	67.4	32.6	38	0.020	Good.		
	Average	**42**	**4.796**	**2 465**	**65 5**	**34.6**	30.	**0.018**			
	Cherry's Cluster,	42	3.917	2 190	63.5	36 5	23.	0.017	Fair.		
56	**Petit Gulf on Peerless**	**44**	**4.276**	**3.214**	**57.1**	**42.9**	23.	**0 018**	Good.	**13.71**	**11.75**
	Peerless,	42	3.217	1.751	64.8	35.2	22.	0.020	Very good		
	Average	**42**	**4.557**	**2 251**	**66.5**	**33 5**	24.	**0.020**			
	Petit Gulf,	42	5.897	2.751	68.2	31.8	26.	0 020	Very good		
58	**Rust Proof on Peerless**	**33**	**4.608**	**2 396**	**65.8**	**34.2**	26.	**0 022**	Very good	**13.10**	**12.10**
	Peerless,	42	3.217	1.751	64.8	35 2	22.	0.020	Very good		
	Average	**41.5**	**4 279**	**2 229**	**65.6**	**34.0**	....	**0 017**			
	Rust Proof,	41	5 340	2 706	66 3	32.7	......	0.014	Fair.		
71	**Truitt on Cook**	**43**	**5.670**	**2 554**	**68.9**	**31.1**	30.	**0.014**	Excellent	**12.35**	**9.68**
	Cook, W. A.,	42	5.675	2 740	67.4	32.6	38.	0.020	Good.		
	Average	**37 5**	**5 352**	**2.580**	**67.5**	**32.5**	30.	**0.017**			
	Truitt,	33	5 029	2.419	67.6	32.4	23.	0.014	Poor.		
11	**Barnett on Cook**	**35**	**5.175**	**2.090**	**71.2**	**28.8**	35.	**0.020**	Good.	**11.01**	**8.85**
	Cook, W. A.,	42	5.675	2 740	67 4	32.6	38.	0 020	Good.		
	Average	**34.5**	**4.395**	**2 239**	**65.8**	**34.2**	32.	**0 020**			
	Barnett,	27	3.115	1.737	64.2	35.8	36.	0.020	Fair.		
76	**Wonderful on Peerless**	**34**	**5 010**	**2 575**	**64.7**	**35.3**	30.	**0 020**	Excellent	**14.48**	**11.22**
	Peerless,	42	3.217	1.751	64 8	35.2	22.	0.020	Very good		
	Average	**42**	**4.316**	**2.087**	**66 9**	**33.1**	28.	**0.019**			
	Wonderful,	42	5.415	2.423	69.0	31.0	34.	0.018	Very fair.		

Table I.—Continued.

Comparison between the original plants and 9 of the best improved forms.

Number.	Name of Plant.	Number seed in boll.	Wt. seed in grammes.	Wt. lint in grammes.	Per cent. seed.	Per cent. lint.	Length of fiber in millimeters.	Diameter of fiber in millimeters.	Character of twist.	Max. strain for breaking one strand in grammes.	Min. strain for breaking one strand in grammes.
55	**Petit Gulf on Cook**	**43**	**4 216**	**2.507**	**62.7**	**37 3**	23.	**0.016**	Good.	**15.30**	**9.25**
	Cook, W. A.,	42	5.675	2.740	67.4	32 6	38.	0.020	Good		
	} Average..................	**42**	**5.786**	**2.746**	**66 8**	**32.2**	32.	**0.020**			
	Petit Gulf,	42	5 897	2.751	68 2	31 8	26.	0 020	Very good		
2	**Allen's Long Staple on Peerless**	**34**	**4.540**	**2.194**	**67 4**	**32.6**	33.	**0.020**	Very good	**12.25**	**11.77**
	Peerless,	42	3.217	1 751	64 8	35 2	22.	0.020	Very good		
	} Average	**43.5**	**3.469**	**1 893**	**64 8**	**35.2**	28.	**0 020**			
	Allen's Long Staple,	45	3.722	2 035	64.7	35 3	33.	0.020	Fair.		
135	**Sea Island on Wonderful & Peerless**.....	......	**5.380**	**1.743**	**67.6**	**32 4**	38.	**0 018**	Excellent	**15 42**	**14.77**
	Sea Island.	15	2.023	0.658	75.5	24 5	38.	0 017	Very good		
	} Average......	33	**3.552**	**1.611**	**69 8**	**30 2**	31.	**0 018**			
	Wonderful,	42	5.415	2 423	69 1	30.9	34.	0 018	Very fair.		
	Peerless,	42	3.217	1.751	64.8	35.2	22.	0 020	Very good		

III—CULTIVATION OF THE FOREIGN COTTONS.

Within recent years much attention has been attracted to foreign cottons, especially those of India and Egypt, because of the yearly increased importation of the staple into this country. It is claimed by a few experts that the fiber, in some respects, is superior to the ordinary "upland" varieties grown in the South, and that there is danger of the importaton increasing to such an extent as to seriously injure the trade in American cottons. The Indian cotton is generally noted for its rich creamy color, its ready adaptability for certain dyes and the property the thread has of swelling in the process of bleaching, so that the cloth made of it becomes more substantial than that manufactured from the coarser grades of American cottons. These foreign staples are also used in the United States for mixing with the low grade American fibers to improve their color and the quality of the cloth.

Several of the Experiment Stations in the South have cultivated some of the varieties of the cotton from India and Egypt in order to compare their properties with our native forms, but, so far as the knowledge of the writer goes, there have been no regular systematic experiments conducted in any State extending over a period of several years, except at the Alabama Station. Of course nothing definite can be determined about any foreign plant until it has become acclimated by several years careful cultivation. The experiments at Auburn have been planned to accomplsh first this result.

The first step taken in these investigations was, therefore, to acclimate the plants; secondly, to secure the best results possible in health of plant, maturity of fiber and the yield of lint that the conditions of the soil and climate would permit.

In conducting these experiments the following so-called varieties were secured from India, Egypt and Mexico, and most of them were first planted in 1894. (Three of the varieties, however, viz: Mit Afifi, Bamieh, and Mannoah were first planted in 1893):

Bajwara (India),	Mirzapore (India),
Bamieh (Egypt),	Mit Afifi (Egypt),
*Bani,	"Mexican resists drought,"
*Bombay,	"Mexican,"
Broach (India),	"Mexican",
*Bourbon,	*"Nagpur jari,
‡Creula,	Narma (India),
Deshi (a broach cotton from India),	Nadam (Madras cotton),
Goghari (India),	Nimari bani (India),
*Guchard,	*Painaa,
Herbucco,	‡Roji,
Indrepur,	Surat Kupas (India),
*Jari,	*"Tree cotton" (Mexico),
Jakko (Egypt)	"Upland Georgian" (Mexico),
Mannoah (Egypt),	*Wagaria Wadhwan.

The following items in reference to the derivation of the local names of these cottons may be of interest:

Broach, Baroach or *Bharuch*, is a comprehensive term and is used to indicate the finer grades of cotton. It is the name of a district in India.

Manuah, Mannoah or *Jettooee*, in its native clime yields one-eighth of the cotton sold in the markets, but it is cultivated with other crops. It requires nearly a year to mature.

Miduopore or *Mirzapore* is the largest cotton mart in India.

Nadam is an inferior grade of cotton and is grown in

*These failed to germinate.

‡ Requires two years for maturing balls.

the district of the same name in India not for exportation, although it is used for adulterating the best grades which are sent to other countries. It is a triennial and poor bearer, and the fiber is cleaned with difficulty.

Narma or *Nurma,* sometimes also called *Deo-Kupas,* is a fine silky cotton. It is the name of a section in India. The plant bears ten to twelve years in its native country. The fibre is more than one inch long, and is used for the manufacture of the finest linens. It is cultivated near the temples for making the robes of priests.

Surat Kupas is named after an important seaport town through which most of the cotton from one district is shipped. This term is often used in a general sense for cotton coming from *Surat, Broach,* and *Berar* districts. *Kupas* signifies clean cotton, or ginned.

Wagaria, Wagriah or *Wadhwan* is also the name of a district in India and represents an annual cotton growing to the height of 2 or 3 feet with a single tapering stem. The bolls do not open wide, but remain closed except a crack at the apex. There is considerable trouble necessary to force them open and extract the fiber. The bolls are gathered from the plants and afterwards opened by children. This cotton is suitable for the manufacture of only the coarser grades of cloth.

The other names mentioned in the list are local rather than descriptive.

BOTANICAL CLASSIFICATION.

A careful examination of the foreign cottons under consideration would classify them as follows:

1. *Gossypium herbaceum* var *microcarpum* Tod: Broach, Goghari.

2. *G. Wightianum* Tod: Nadam, Deshi, Jakko, Roji, Nimari bani.

3. *G. roseum* var *albiflorum.* Tod: Indrepur, Goghari., Surat Kupas., Mirzapore., Roji.

4. *G. hirsutum* var *album* Tod: Indrepur, Herbucco, Surat Kupas, Mirzapore.

5. *G. maritimum* Tod: Jakko, Mannoah, Mit Afifi.

6. *G. maritimum* var *polycarpum* Tod: Bamieh.

7. *G. Brazililiense* Macf: Guchard, Creulo.

The seed, when delivered at Auburn in 1893 and 1894, were badly mixed, rendering it difficult in most instances, to determine which plant represented the local name given on the package. It will thus be noted that in the above seven species and varieties the same local name has been repeated. After gathering the first year's crop the seeds were carefully assorted, however, and the classification made as above stated. (See plates XIII and XIV.)

A detailed description of these species is given in accordance with "Relazione sulla Cultura dei Cotoni—Monografia del Genere Gossypium" by Agostino Todaro.

Gossypium herbaceum, Tod. Stem erect, covered with long soft hair; branches spreading; slightly pyramidal; leaves 3-5 lobed, rarely 7 lobed, lobes rotundate obtuse, apex minutely mucronate; stipules linear lanceolate, acuminate very short; peduncle erect and nearly equal to half of peteole; bracts ovate cordate, with sharp cut teeth, general outline of bract leaf rotundate, bases united; coralla longer than the bracts, obovate, unequally wedge shaped, yellow, marked at base with purple spots, after flowering the outside surface turns reddish; bolls small ovate, hardly subrotundate, apex deeply hollowed out, 4-5 celled, cells 6-7 seeded; seeds ovate, short mucronate at hilum, covered with thick closely adhering fiber, in some cases white ash-gray, short, in other cases rather long and white.

Broach, Goghari and Deshi are varieties of this species. Professor Middleton seems to think that Goghari is a cross between Wagaria and Broach Deshi, and states that a good crop of this cotton in India will produce from 400 to 500 lbs. of seed cotton per acre. It is considered to be a high grade staple in its native country.

Gossypium hirsutum, Tod. Stem erect, branches spreading slightly ascending, pyramidal, hairy; leaves ovate rotundate cordate, 3-5 lobed, those found at end of branches are at times acute and entire, lobes truncate-semiovate, subtriangular, acute or acuminate, the middle lobes larger and longer, at fold acute plicate; stipules ovate lanceolate (unequalateral, sharp, rigid pointed, the other portion lanceolate), acuminate; bracts large ovate, acuminate, in the upper portion deeply cut into many narrow lobes, in the lower part simply dentate, the clefts are elongate linear produced at the apex into an attenuated point; corolla large, longer than bracts, during flowering period considerably expanded, petals pale sulphur color, afterwards rolling up and turning red; style long, exserted; boll large, walnut shaped, generally four celled, apex rotundate, terminating abruptly into a sharp point; seeds ovate covered with short white fiber firmly adherent.

Bajwara, Herbucco, Indrepur, Mirzapore and Surat kapas are evidently varieties of this species. They resemble very closely Todaro's *G. hirsutum var. album*, the Indrepur, however, has a large boll rapidly tapering to a point, while the Mirzapore contains one more nearly the shape of a walnut and generally four celled. The shape of boll on the Indrepur type would indicate features of *G. glabratum, Tod.*

The three forms known by the vernacular names of "Jakko," "Mannoah," and "Mit Afifi," are varieties of

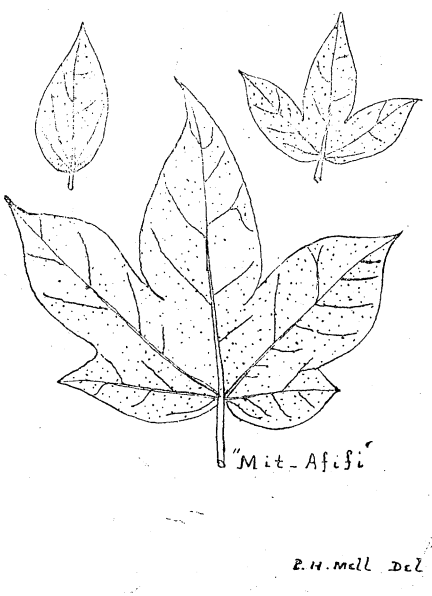


FIG. 2.

G. maritimum, Tod., the same species to which the sea island cotton is referred. These cottons are grown in different parts of Egypt and produce very superior grades of fiber. The yield is large also, averaging in its native country 350 pounds of lint per acre. An illustration of the leaves of this species of cotton is given in figure 2.

Gossypium maritimum var *polycarpum,* Tod. Stem erect, simple; 1-3 peduncles in the axis of each leaf; few if any branches.

The plant grows to the height of 7-8 feet and is glabrous throughout. The few branches, if present at all, spring from near the roots. Generally branches are wanting. The leaves are large, deep green and free from hairs. The surfaces are dotted with darker green spots. The bolls grow in clusters from the axis of the leaf and main stem. The petals of the large conspicuous flowers are bright yellow with a deep or purple spot at the base on the inside. The involucre is nearly the size of the petal, bright green and smooth.

Figure 3 is a good representation of the leaf, petal involucre and pistil of this plant.

FIG 3.—Bamieh. (P. H. Mell.)

Narma is probably a hybrid produced by blending the species *G. arboreum* Linn. and *G. Indicum*, Lam. The leaves, as well as all other surfaces, are covered with short shoft hairs. Stem is somewhat shrubby and dotted with red spots; cordate leaves are 5-lobed, lobes broadly lanceolate and terminated with a bristle, sometimes a small rounded lobe is found between the other lobes; petiole dotted with red; petals bright yellow with red extending over fully one-third of the outside surface; a red spot is found also at the base of the petal inside, inner surface covered with minute hairs; bracts are small, very nearly entire, or at least apex slightly indented, hairy outside and adhering at base; peduncles are short and hairy; calyx entire and dotted green; stamens extend as far as the stigma; boll small ovate acuminate 3-4 carpels; seeds small, 8 in each cell; fiber short and brown.

Gossypium Wightianum Tod. Stem erect and covered with soft hairs; branches spreading, slightly ascending, leaves rather rotundate, obscurely obcordate, 3-5 lobed, lobes ovate, obtuse with bases drawn together or wrinkled, the depressions between the two lobes obtuse with small dentiformed lobes now and then interjected, stipules semiovate, somewhat sickle shaped, otherwise linear lanceolate, all acuminate; peduncles erect during the blooming period but recurved during fruiting; bracts ovate, very small, base united, cordate, acute, small serrated; corolla longer than bracts, obovate, unequally shaped, yellow, base spotted dark purple, but after flower opens, petals turn red; bolls very small, ovate, 8-seeded; seeds small ovate-subrotundate, densely covered with fiber; fiber short and closely adhering and white.

Nadam. Nimari.

Professor Middleton classifies Nimari as a hybrid from *G. roseum* Tod. and *G. neglectum,* Tod. The plant cultivated at the Auburn Station, however, produced a yellow flower with a red spot at the base of the petal, while the plant described by Professor Middleton yields a white flower and resemble Todaro's *G. roseum var albiflorum.* Nadam cotton may be a variety of *G Wightianum* Tod. with a strain of *G. indicum.* Lamk. Todaro's *Wightianum* closely resembles Linneus' *G. herbaceum* and there seems to be no good reason for introducing a new species with so little, if any difference from the older form.

Professor Middleton makes the following pertinent comments in a valuable pamphlet on "Indian Cultivated Cottons," page 4, on the effects produced in cotton plants by transferring them from one country to another where the conditions in climate and soil may be materially changed. The experiments conducted at the Alabama Station so fully corroborate these conclusions of Professor Middleton they are copied into this bulletin:

"*Habit.*—Soil affects the size and general appearance of the cotton plant to a very great extent. On sandy loams and well drained land most cottons are tall, lax in habit, with long, weak, spreading branches; on clay and badly drained soils they are small bushes with short branches.

"*Hairs.*—These are not perceptibly affected in the first season by a change of soil and climate.

"*Stems, Petioles and Peduncles* are affected in size by a change in habit, but are not otherwise altered by a change of soil.

"*Leaves, Stipules and Branches* are greatly affected in size, and the first and last to some extent in conformation, by change of climate. These leafy organs are very different in a moist atmosphere from what they are in a dry, and herbarium specimens may be misleading if e. g., some are made in the monsoon and others in the dry season. The sinuate character of the leaf of the *G. herbaceum* series of cottons is only marked in the monsoon, and the more marked during this season than it is afterwards. The braceteoles of the annual and shallow rooted cottons diminish markedly in size as the hot season advances.

"*Flowers.*—These do not alter perceptibly in form or color by transference to a new district. If the plant is healthy the flowers will be normal; but like the bracteoles they diminish in size late in the season.

"*Bolls.*—The bolls also become smaller, especially on light soils, as the hot season advances, but those that form early in the season should be true to kind whether grown on clay or sandy soil.

"*Seeds.*—In those bolls which mature well, the size or number of seeds is not affected during the first season by a change of soil and climate.

"*Lint.*—The fiber, more than anything else, is injuriously affected by change."

TABLE II.

The following table shows the results of microscopic examination of the foreign cottons. Three of the best varieties of the American cottons are also given for the purposes of comparison.

LOCAL NAMES OF COTTON.	Length of fiber. Millimeters*.	Diameter of fiber. Millimeters*.	Maturity of fiber.	Condition of twist of fiber.	Rupture strain of fiber expressed in grammes*. Several trials to rupture a single strand.	Rupture strain of fiber expressed in grammes*. Average.
Bajwara	32.0	0.024 0.032	Medium	Fair	5.140, 5 875, 10.460	7.158
Bamieh	42 0	0 016. 0 018	Excellent	Excellent	16 700, 22 733	18.717
Broach	30 0	0.028, 0.032	Fair	Fair	5 810, 6 840, 15 600	9 413
Deshi	29.0	0 024	Irregular	Good	7 475, 8 775, 15 350	10 533
"Georgia Upland," India	36.0	0 032	Excellent	Excellent	13 600, 14 535	14.068
Goghari	38.0	0.016, 0.022	Excellent	Excellent	12 200, 14.460	13 330
Herbucco	36.0	0 016, 0 018	Excellent	Excellent	5.320, 9 830, 6.315, 12 575	8 610
Indrepur	38.5	0.032	Good	Good	4.110, 8 885, 9 335	7 443
Jakko	40 0	0.028, 0.032	Good	Good	14.260, 16 380	15.320
Mannoah	31.5	0.032	Good	Good	10 200, 12 750, 18 750	13.933
Mirzapore	38.4	0.032	Medium	Poor	6 250, 7 920	7 085
Mit afifi	42.0	0 016, 0 024	Excellent	Excellent	12.610, 10 335	11.472
Mexican	27.0	0.024, 0.048	Medium	Fair	2.925, 4.100, 6.705	6.865
Mexican	28 0	0.016, 0 048	Good	Good	9 250, 11.075	10.163
Narma	23 0	0 016, 0.032	Good	Good	9.585, 15.585	12 585
Nadam	33 0	0.016, 0.018	Excellent	Excellent	7.120, 9 780	8.450
Nimari bani	27.0	0 016, 0.032	Fair	Fair	10 055, 11.668	10 862
Surat Kupas	28 0	0.032	Fair	Good	6.750, 12 375	9 562
Cherry Cluster	22 4	0 019, 0 027	Excellent	Excellent	9.348, 17.608, 19 345	15.434
Cook, W. A.	38.7	0.020	Good	Good		7 590
Peerless	18.5	0.016, 0 024	Fair	Medium	5.811, 10.276, 14 022	10 055

* 1 Gramme is equivalent to 15.43 grains; 1 Millimeter is 0.03937 of an inch.

IV—THE HYBRIDS FROM AMERICAN AND FOREIGN TYPES.

The following American varieties of cotton improved by crossing (see first step) were selected, because of their superior qualities, to hybridize with the foreign varieties mentioned on page 352.

No. 14. Cross of Cherry's cluster and W. A. Cook.
2. Cross of Allen's long staple and Peerless.
79. Cross of Wonderful and Peerless.
58. Cross of Rust proof and Peerless.
55. Cross of Petit Gulf and W. A. Cook.
56. Cross of Petit Gulf and Peerless.
71. Cross of Truitt and W. A. Cook.
11. Cross of Barnett and W. A. Cook.
70. Cross of Truitt and Peerless.
43. Cross of King and W. A. Cook.
Sea Island.

The resulting hybrids gave the following distinguishing characteristics:

*Afifi x Cherry's x Cook (140).**—Some of the leaves have smooth surfaces above and hairy below, while others are covered with hairs, petiole and veins are dotted with black spots; petals bright yellow, in one flower red spot at base, red spot wanting in another, spotted with red on the upper margins ,those petals with red spot at base grow on the torus in a reversed position to others without the red spot, the latter are larger; involucre in one case slightly adheres at base, free in other flowers, the first are hairy on the outer surfaces and the latter are hairy only on the margins, the former is also larger than the latter; peduncle tinged red with three deep red spots just below the calyx cup.

Mannoah x Petit Gulf x Peerless (141).—Leaf with minute hairs over the under surface, all other surfaces smooth, petiole and veins dotted, only one kind of leaf

* The numbers in brackets refer to the records of experiments.

on the plants; petals in some flowers deeper yellow and larger than in others, red spot at base of all petals; involucre in some cases covered with short hairs, in others smooth, except on margins; calyx cup in those flowers with larger petals is more cleft than in the smaller flowers.

Truitt x Cook x Afifi (149).—One leaf is a decided Afifi type while others are decidedly Cook in shape (or *G. hirsutum*) and hairy surfaces; some of the flowers are more like the Afifi parentage while others resemble the *kirsutum* with the exception of a small red spot at the base of the petals.

Petit Gulf x Cook x Bamieh (153.)—The following illustrations give very clear ideas of this hybrid:

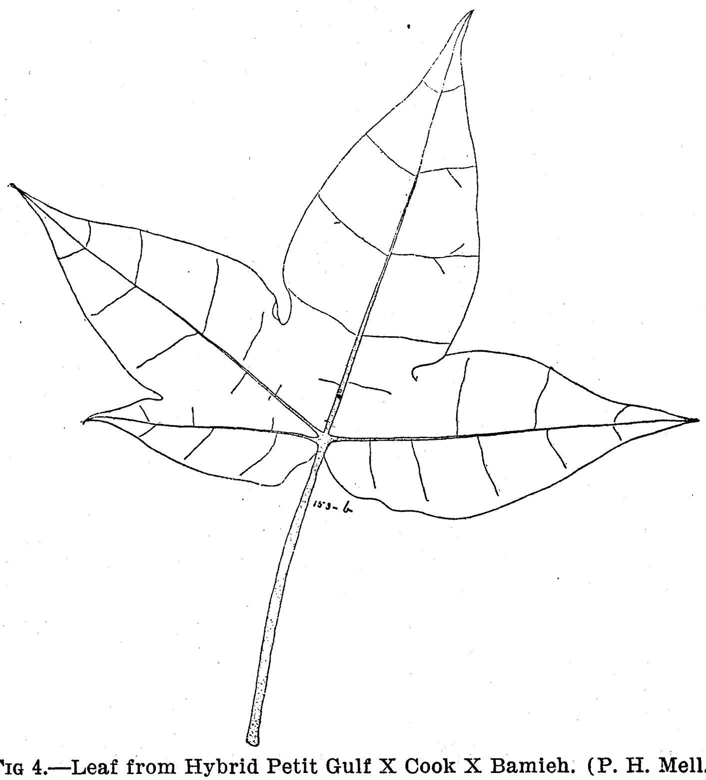


FIG 4.—Leaf from Hybrid Petit Gulf X Cook X Bamieh. (P. H. Mell.)

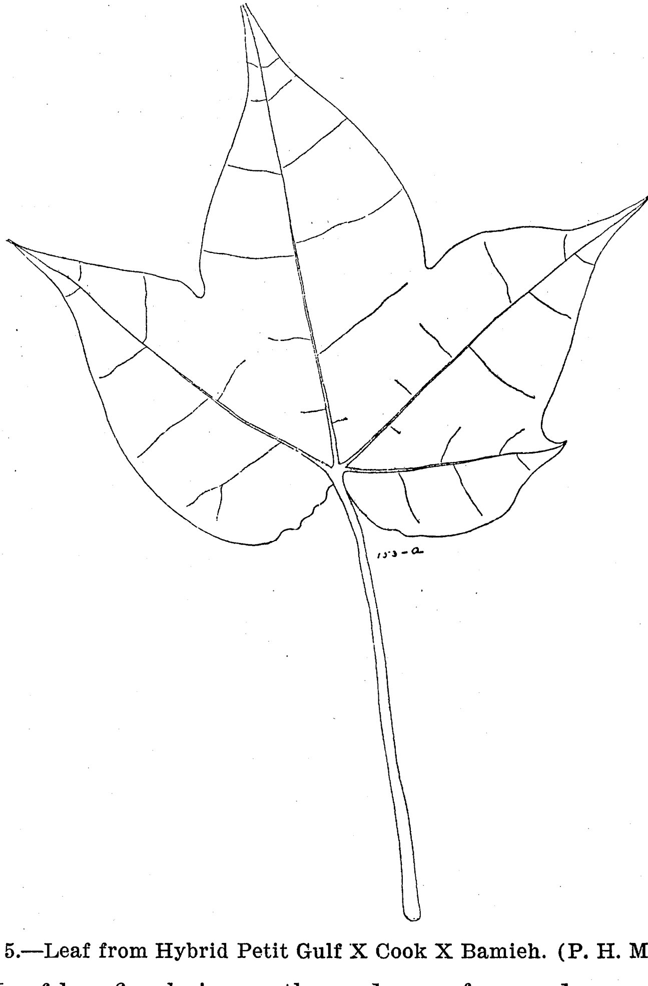


Fig 5.—Leaf from Hybrid Petit Gulf X Cook X Bamieh. (P. H. Mell.)

Leaf has fine hairs on the under surface and very few on the petiole and along the veins on the upper surface, spotted red, black dots on petiole, no hairs, petiole red-green, dotted black, contains a gland on the midrib, but this is wanting in other leaves on plant; petals bright yellow, red spot is retained at the base in some flowers, while in others it is absent; the upper half of the involucre is tinged red with a few hairs on the margins; the pistil is slender; some of the seeds are black with the staple slightly adhering, some deep green with fiber strongly adhering, some yellowish white with thickly adhering fiber.

Rust proof x Peerless x Afifi (157).—Leaves smooth on the upper surface, short hairs on the lower, petiole tinged red with dark spots over surface, also over the midrib, leaf very decidedly wrinkled; petals in some flowers bright yellow with red spot at the base, in others lighter yellow free of red spot, but in a reversed position on the torus; involucre on the bright yellow flower, large bright green tinged with red on the outer surface, spotted with darker green, only slightly joined at base, fringed with hairs, those on the lighter colored flowers about two-thirds the size and in other respects like the larger involucre; pistil in the bright yellow flowers with a long style and recurved stigma, the peduncle is as long as the involucre, the pistil in other flowers is shorter with a broader calyx cup, peduncle only one-third as long as in the other flower.

Table III.

Number of Experiment.	Names of Plants Crossed.	Seed cotton per plot—kilo.*	Seed per plot, kilo.*	Lint per plot, kilo.*	Number of plants to plot.	Per cent. of seed.	Per cent. of lint.	Length of fiber in m. m. †	Diameter of fiber, m m. †	Max. breaking strain, 1 strand, in gram. ‡	Min. breaking strain, 1 strand, in gram. ‡	Average breaking strain, 1 strand, in gram. ‡
117	**Cherry's Cluster X Cook X Miduopur**	**7.0**	**4.9**	**2.1**	**56**	**70.0**	**30.0**	**38.**	**0 016**	**18 11**	**4 86**	**7.62**
	Cherry's Cluster	1 6	1.1	0.5	13	68.7	31.3	23.	0 017	19 34	9.35	14.73
	Cook	3.1	2.2	0.9	12	70 9	29.1	38.	0.020	9 93	6.25	8.09
	Average of parents	.....	.....	.....	.....	**70.7**	**29 3**	**33.**	**0.023**	**15.79**	**7.28**	**9.97**
	Miduopur	12.8	8.8	3.7	97	72.4	27.6	38.	0.032	7 92	6.24	7.09
119	**Allen's Long Staple X Peerless X Afifi**	**5.4**	**3.7**	**1.6**	**40**	**68 5**	**31.5**	**40.**	**0.016**	**13 50**	**11.16**	**12.33**
	Allen's Long Staple	....	.....	.....	.....	69 8	30.2	33.	0.020	11.86	7 26	8.92
	Peerless	2.2	1.5	0.7	20	68 1	31.9	22.	0 020	14 02	5 81	10.42
	Average of parents	....	.....	.....	.....	**68 9**	**31.1**	**32.**	**0.019**	**12.83**	**7 80**	**10.27**
	Mit Afifi	2.9	2.0	0.9	63	69 0	31.0	42.	0.016	12.61	10.34	11.47
122	**Sea Island X Afifi**	**5 8**	**4.0**	**1.8**	**28**	**69.0**	**31.0**	**42.**	**0.020**	**14.02**	**9.83**	**12.13**
	Sea Island	4 5	3.3	1.2	54	73 3	26 7	38.	0.017	11.86	8.23	9.30
	Average of parents	....	.....	.....	.....	**71.2**	**28 8**	**40.**	**0.017**	**12 24**	**9 27**	**10 39**
	Mit Afifi	2 9	2.0	0 9	63	69.0	31.0	42.	0.016	12.61	10 34	11.47
129	**Allen's Staple X Peerless X Broach**	**3.3**	**2.2**	**1.1**	**25**	**66.7**	**33.3**	**40.**	**0.016**	**12 70**	**12.42**	**12.56**
	Allen's Long Staple	....	....	.....	.....	69.8	30 2	33.	0.020	11.86	7.26	8.92
	Peerless	2 2	1 5	0.7	20	68 1	31.9	22	0 020	14.02	5 81	10.42
	Average of parents	.....	....	.....	.....	....	....	**28.**	**0.023**	**10.49**	**6 29**	**9.58**
	Broach	.....	....	...		.....	.....	30	0 028	15 60	5.81	9.41

* Kilogram=2.204 avoidupois pounds.
† Millimeter=0.03937 of an inch.
‡ Gram=15.432 grains.

TABLE III—Continued.

Number of Experiment.	NAMES OF PLANTS CROSSED.	Seed cotton per plot—kilo.*	Seed per plot, kilo.*	Lint per plot, kilo.*	Number of plants to plot.	Per cent. of seed.	Per cent. of lint.	Length of fiber in m. m. †	Diameter of fiber, m. m †.	Max. breaking strain, 1 strand, in gram. ‡.	Min breaking strain, 1 strand, in gram. ‡.	Average breaking strain, 2 strand, in gram. ‡.
130	**Wonderful X Peerless X Afifi**	**5.9**	**4.2**	**1.7**	**56**	**71.2**	**28.8**	**38.**	**0.016**	**10.90**	**9 41**	**10.16**
	Wonderful	1.5	1.04	0 46	11	69.0	31.0	34.	0.018	5 46	5 00	5.23
	Peerless	2.2	1.5	0.7	20	68.1	31.9	22.	0 020	14 02	5 81	10.42
	Average of parents	....	....	....	....	**68.7**	**31.3**	**33.**	**0.018**	**10 70**	**7.05**	**9.04**
	Mit Afifi	2.9	2.0	0.9	63	69 0	31.0	42.	0.016	12.61	10.34	11.47
140	**Afifi X Cherry's Cluster X Cook**	**5.5**	**4.0**	**1.5**	**42.**	**72.7**	**27.3**	**42.**	**0.016**	**13.89**	**10.07**	**11.98**
	Cherry's Cluster	1.6	1.1	0 5	13	68.7	31.3	23.	0 017	19 34	9 35	14.73
	Cook	3.1	2.2	0.9	12	70.9	29.1	38	0 020	9.93	6.25	8.09
	Average of parents	....	....	....	....	**69.5**	**30.5**	**34**	**0.018**	**13 96**	**8.65**	**11.43**
	Mit Afifi	2.9	2.0	0.9	63	69.0	31.0	42.	0.016	12.61	10.34	11 47
141	**Mannoah X Petit Gulf X Peerless**	**4.9**	**3.3**	**1 6**	**42**	**65.3**	**34.7**	**42.**	**0.016**	**13.89**	**10.07**	**11.98**
	Petit Gulf	8.5	5.8	2.7	32	68.2	31.8	26.	0.020	.....	.....	.....
	Peerless	2.2	1.5	0.7	20	68.1	31.9	22.	0.020	14.02	5.81	10.42
	Average of parents	....	....	....	....	....	....	27	0.024	.....	.....	.....
	Mannoah	....	....	....	....	....	....	32.	0.032	18.75	10.20	13.9
146	**Mannoah X Rust Proof X Peerless**	**2 5**	**1.8**	**0.7**	**59**	**72.0**	**28.0**	**34**	**0 020**	**15.74**	**14.44**	**15 09**
	Rust Proof	....	....	....	....	70.8	29.2	40	0.014	9.40	6.62	8 03
	Peerless	2.2	1.5	0.7	20	68.1	31.9	22.	0.020	14.02	5.81	10.42
	Average of parents	....	....	....	....	....	....	**31.**	**0 022**	**14.07**	**7.54**	**10.79**
	Mannoah	....	....	....	....	....	....	32.	0.032	18.75	10.20	13.93

149	**Truitt X Cook X Afifi**	**4.8**	**3.4**	**1.4**	**43**	**71.4**	**28.6**	**44.**	**0 016**	**20.71**	**15.65**	**19 01**
	Truitt	1.5	1.02	0 48	9	68.0	32.0	23.	0.014	18 43	10.26	15.16
	Cook	3.1	2.2	0.9	12	70 9	29.1	38.	0 020	9.93	6.25	8.09
	Average of parents	....	....	....	....	**69 3**	**30.7**	**34.**	**0 017**	**13.66**	**8.95**	**11.57**
	Mit Afifi	2 9	2.0	0.9	63	69.0	31 0	42.	0.016	12.61	10 34	11.47
153	**Petit Gulf X Cook X Bamieh**	**5.6**	**4.0**	**1.6**	**49**	**71.6**	**28 4**	**38.**	**0.016**	**13.63**	**8.20**	**10.88**
	Petit Gulf	8.5	5.8	2 7	32	68.2	31.8	26	0 020	....	....	....
	Cook	3.1	2 2	0.9	12	70.9	29 1	38	0.020	9 93	6.25	8.09
	Average of parents	....	....	....	....	**68.8**	**31.0**	**35.**	**0 019**	....	....	....
	Bamieh	5.9	4.0	1.7	90	67.8	32 2	42	0.018	22.73	16 70	18 72
155	**Petit Gulf X Peerless X Bamieh**	**8.0**	**5 5**	**2.6**	**64**	**68.8**	**31 2**	**38.**	**0.016**	**12.44**	**9.30**	**11 12**
	Petit Gulf	8 5	5 8	2.7	32	68.2	31.8	26.	0 020	....	....	....
	Peerless	2.2	1.5	0.7	20	68.1	31 9	22.	0 0.0	14.02	5 81	10.42
	Average of parents		....	....	....	**68. 0**	**32 0**	**30.**	**0 019**	....	....	....
	Bamieh	5 9	4 0	1.7	90	67.8	32.2	42.	0 018	22.73	16 70	18 72
157	**Rust Proof X Peerless X Afifi**	**4.7**	**3 3**	**1.4**	**43**	**70.0**	**30 0**	**38.**	**0.018**	**9.83**	**6.26**	**7 72**
	Rust Proof	....	....	....	....	66.3	32.7	40.	0.014	9.43	6.62	8 03
	Peerless	2.2	1 5	0.7	20	68.1	31.9	22.	0.020	14 02	5 81	10 42
	Average of parents	....	....	....	....	**67.8**	**31 9**	**35.**	**0 017**	**12 02**	**7 59**	**9.97**
	Mit Afifi	2 9	2.0	0.9	63	69 0	31 0	42.	0.016	12.61	10.34	11.47
160	**Bamieh X Cherry Cluster X Cook**	**9.7**	**6.7**	**3.0**	**120**	**69.1**	**30 9**	**44.**	**0.008**	**13.68**	**9 48**	**11.58**
	Cherry's Cluster	1 6	1 1	0.5	13	68.7	31 3	23.	0.017	19 34	9 35	14.73
	Cook	3.1	2.2	0 9	12	70 9	29.1	38.	0 020	9.93	6 25	8 99
	Average of parents	....	....	....	....	**69 1**	**30 9**	**34.**	**0.018**	**17 33**	**10.77**	**13.85**
	Bamieh	5 9	4 0	1.7	90	67 8	32 2	42.	0 018	22.73	16 70	18 72
162	**Afifi X Allen's Staple X Peerless**	**5.6**	**3 9**	**1 6**	**120**	**70 5**	**29 5**	**44**	**0 008**	**13 68**	**9 48**	**11.58**
	Allen's Staple	....	....	....	....	69 8	30.2	33.	0.020	11 86	7.26	8.92
	Peerless	2.2	1.5	0.7	20	68.1	31.9	22.	0.020	14.02	5.81	10.42
	Average of parents	....	....	....	....	**69.0**	**31 2**	**32**	**0 019**	**12 83**	**7 80**	**10 27**
	Mit Afifi	2 9	2.0	0 9	63	69 0	31.0	42	0.016	12.61	10 34	11 47
165	**Barnett X Cook X Herbucco**	**7.8**	**5 4**	**2.4**	**61**	**69 2**	**30 8**	**36.**	**0.024**	**11 45**	**8.05**	**10 10**
	Barnett	....	....	....	....	67.9	32.1	26.	0.020	5.18	4.18	5.23
	Cook	3.1	2.2	0.9	12	70.9	29 1	38.	0.020	9.93	6.25	8.09
	Average of parents	....	....	....	....	**68.6**	**31.4**	**33.**	**0.019**	**9.23**	**5.25**	**7.31**
	Herbucco	10 9	7.3	3 6	82	67.0	33.0	36.	0.018	12.58	5.32	8.61

CONCLUSIONS:

1. The combination of the *Gossypium hirsutum* and *Gossypium maritimum* yield a cotton plant which produces fiber of the best grade in strength, maturity, twist, length, fineness and yield per acre.

2. The blending of small and large boll species is not desirable, as a rule, because the resulting forms are generally weak and inferior.

3. The *G. maritimum* is rather slow in maturing its bolls and frost is apt to catch the plant, in this climate, before 60 per cent. of the bolls are open. The hybrid procured by uniting *G. maritimum* and *G. hirsutum* is quicker in reaching maturity, and is more prolific.

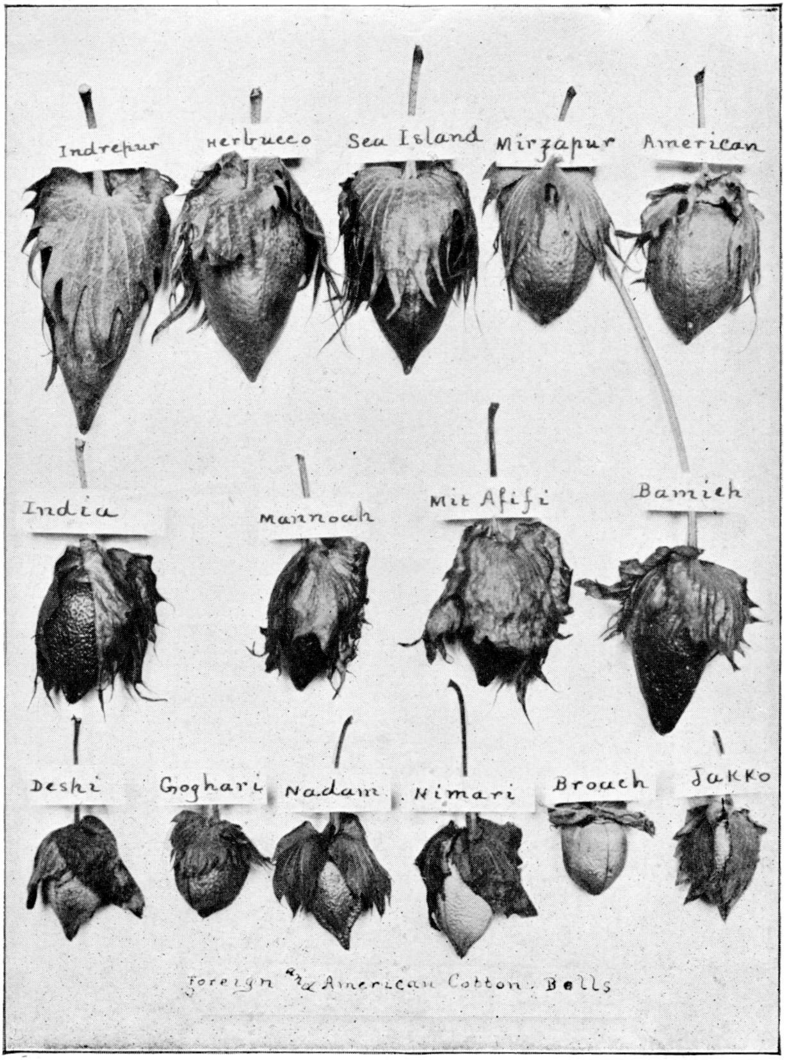
4. The black, smooth seeds are generally transferred into furry seeds of a dark brown color.

5. The Egyptian species are finer grades of cotton than those received from India, in length of strands, strength and texture. They unite, also more readily with the American species and the hybrids are generally equal to the parents in qualities.

6. The Sea Island cotton combines with the Afifi and Mannoah to produce superior grades of staple and the plant is rather prolific. There is a prospect in the present stage of the experiments of securing a variety which wlll be a healthy, long staple upland cotton.

7. Numbers 119, 122, 129, 146, 149 (see Table III), give the best results in length of fiber, per cent. of lint and in degree of strength, in each case yielding results above the average produced by the parents. With the exceptions of 117, 157 and 160 all of the hybrids represented in Table II yielded results in degree of strength above the averages of the parents; and in every instance the length of the fiber was increased over the average of the parents. There is practically but little difference in the yield of lint between the parents and the hybrids.

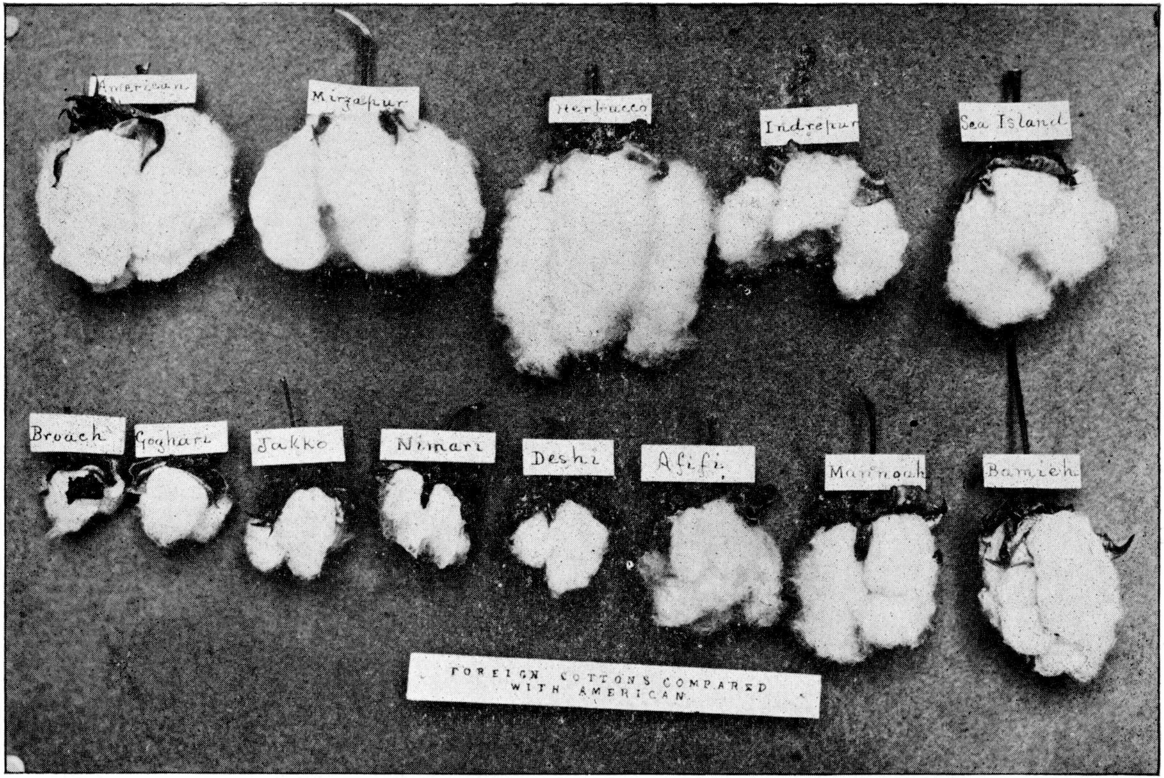
PLATE XIII.



(Photographed by P. H. Mell.)

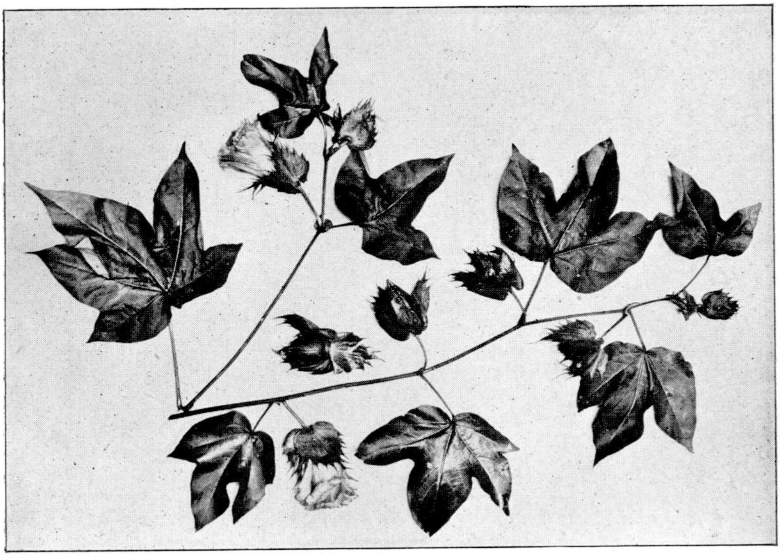
Foreign and American Cotton bolls exhibiting relative sizes and shapes. Reduced about ½.

PLATE XIV.



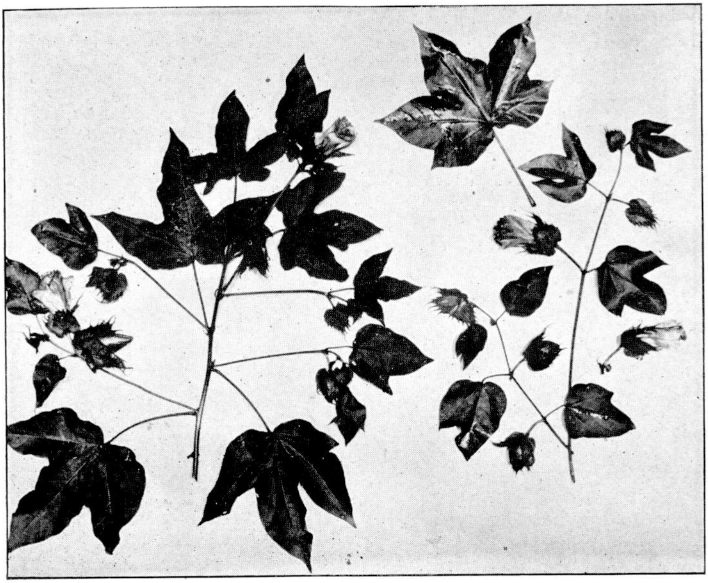
(Photographed by P. H. Mell.)

Open bolls of American and Foreign Cottons. Reduced about ⅓.



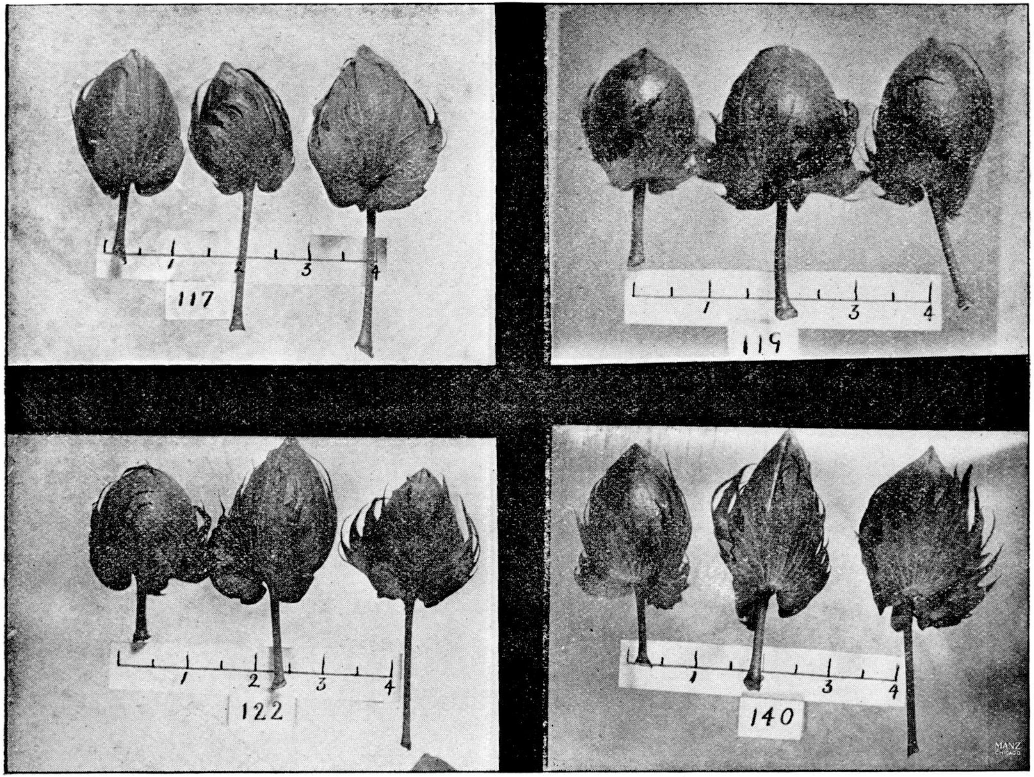
Mit Afifi or Egyptian Cotton.

1 2



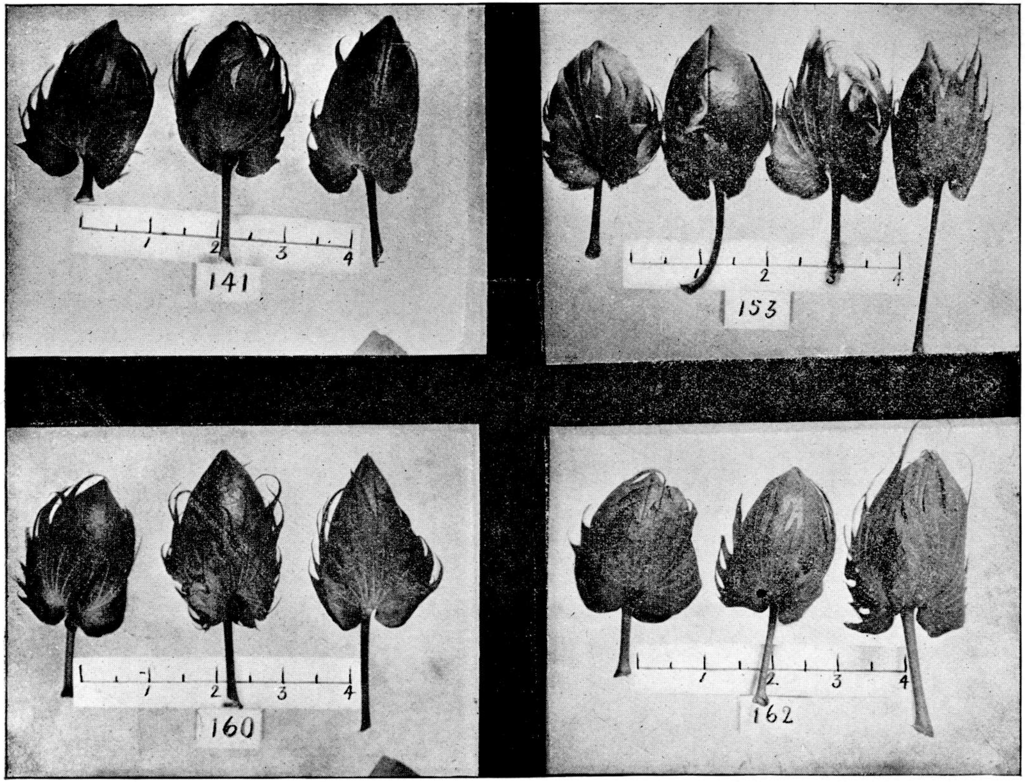
(Photographed by P H. Mell.)

1 Bamieh or Egyptian Cotton
2—Mannoah or Egyptian Cotton.



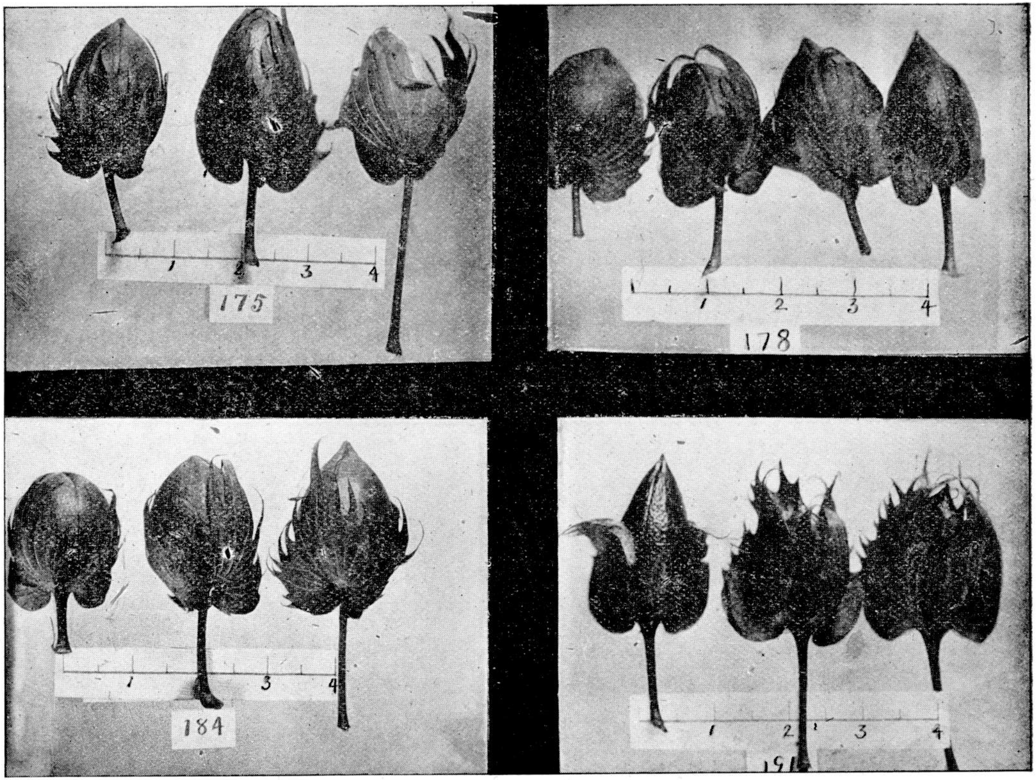
(Photographed by P. H. Mell.)

Each of the above groups represents bolls obtained from one plant. For explanation of numbers see table III, page 365. The scale is in inches.



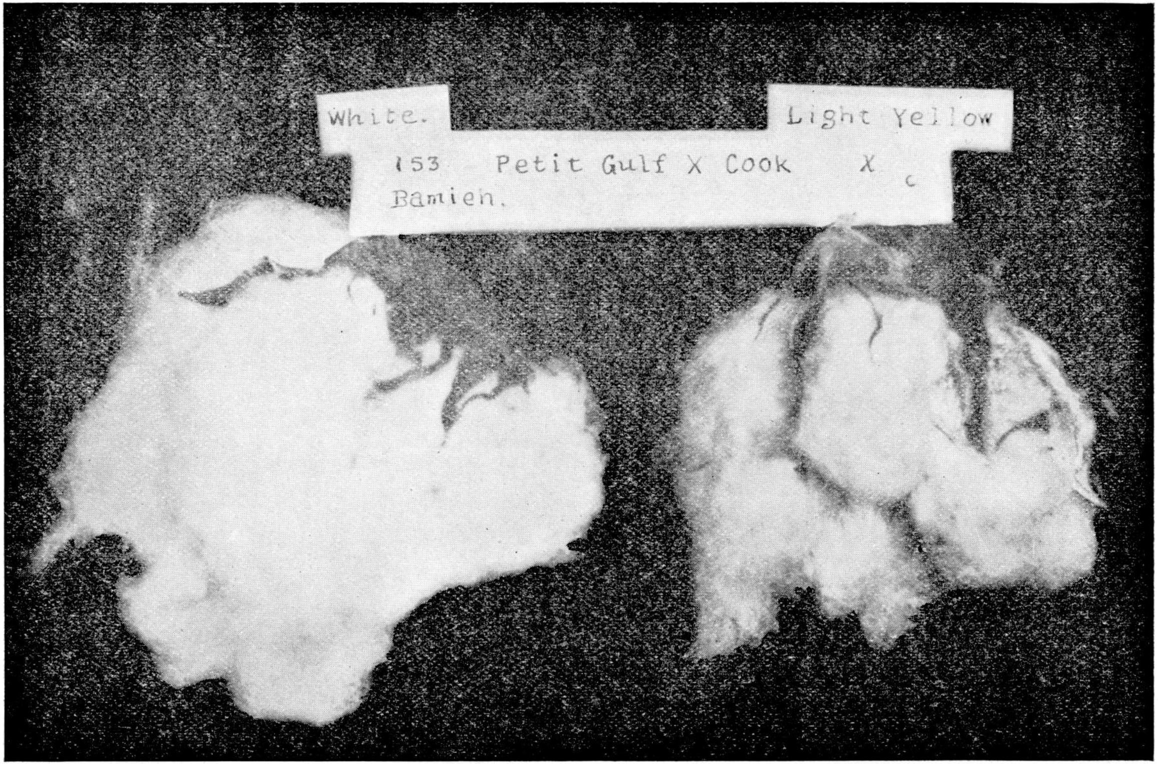
Each of the above groups represents bolls obtained from one plant. For explanation of numbers see table III, page 365. The scale is in inches. (Photographed by P. H. Mell.)

PLATE XVIII.

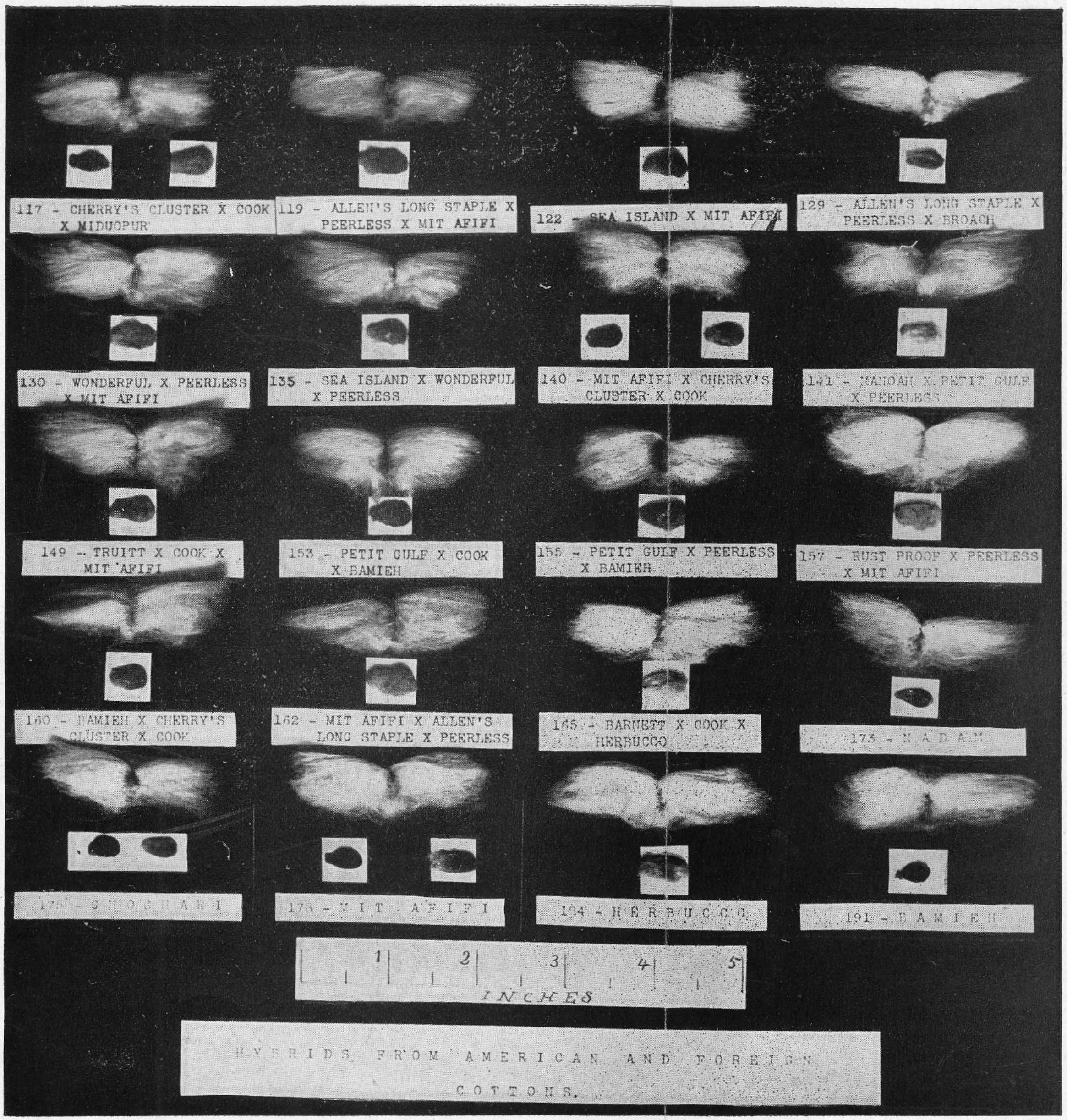


Each of the above groups represents bolls obtained from one plant For explanation of numbers see table III page 365 The scale is in inches

(Photographed by P. H. Mell.)



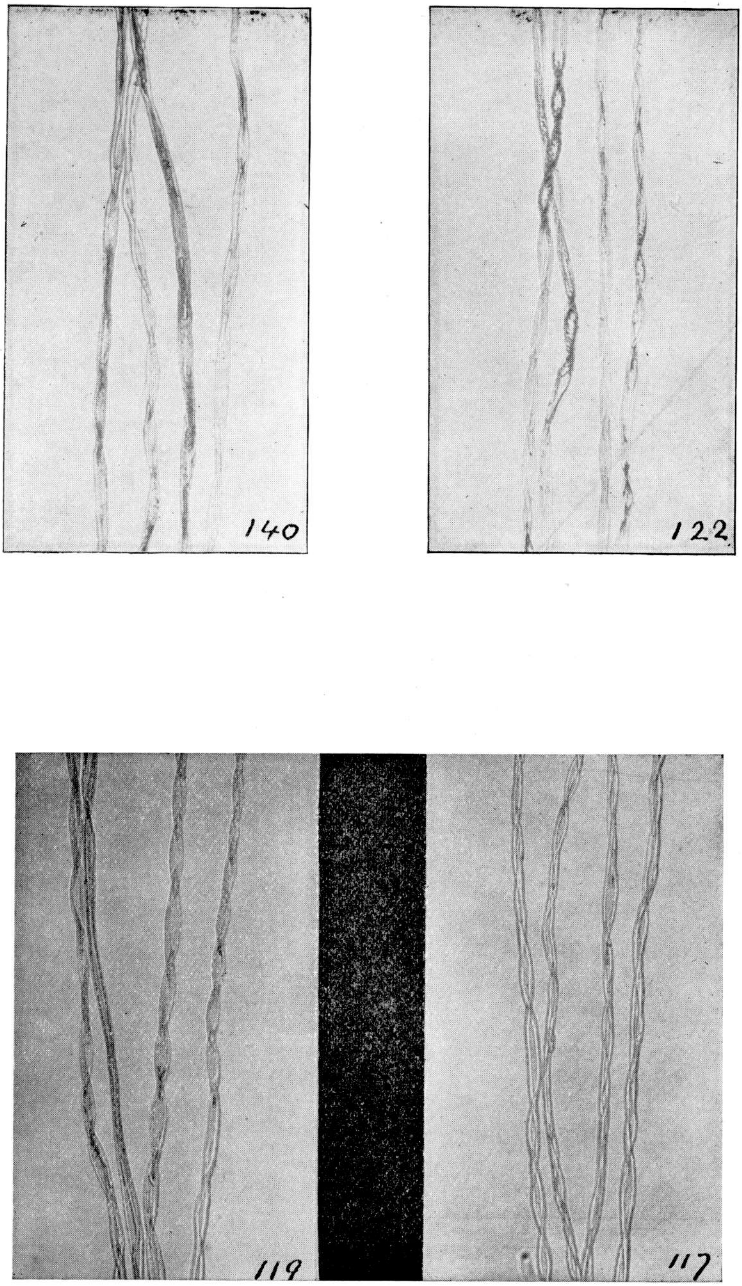
Open bolls obtained from the same plant Exhibiting both the Foreign and American parents.
Slightly reduced



Length and quantity of fiber produced by each seed resulting from hybridizing the American and Foreign Cottons. The illustrations show the seeds covered with fiber and also the seeds with the fiber extracted.

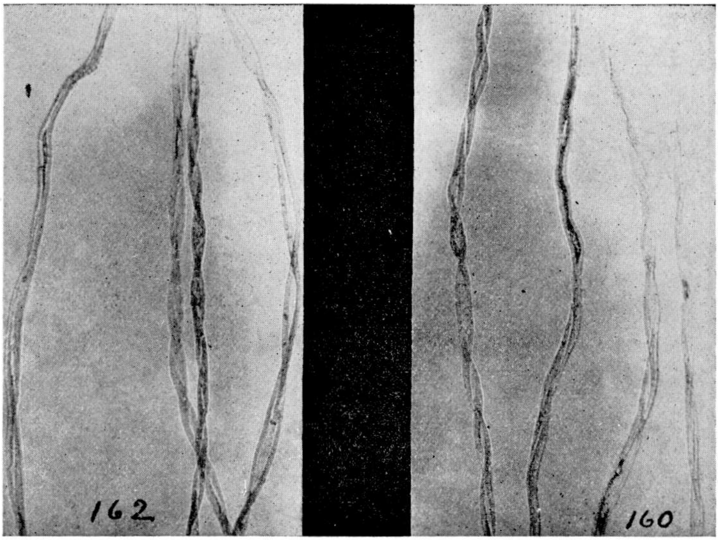
[Photographed by P. H. Mell.]

PLATE XXI.



Photomicrographs of Cotton fiber from hybrids. For explanation of numbers see table III, page 365. [Photographed by P. H. Mell.]

PLATE XXII.



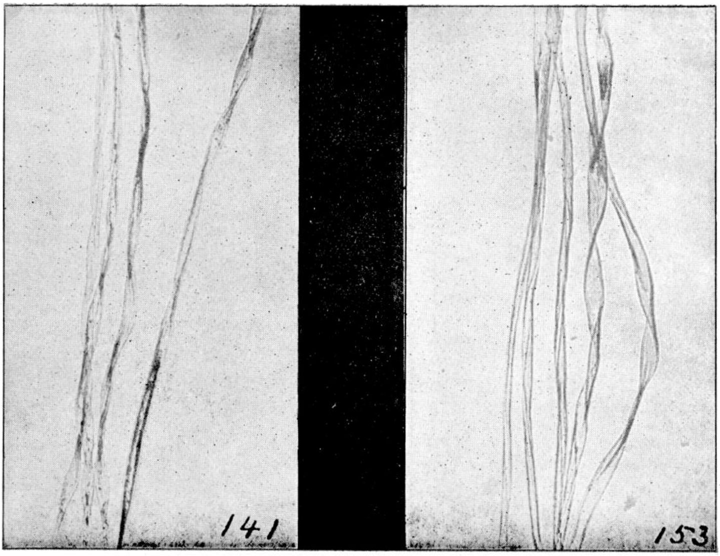


Photo Micrographs of Cotton fiber from hibrids. For explanation of numbers see table III, page 365. [Photographed by P. H. Mell.]

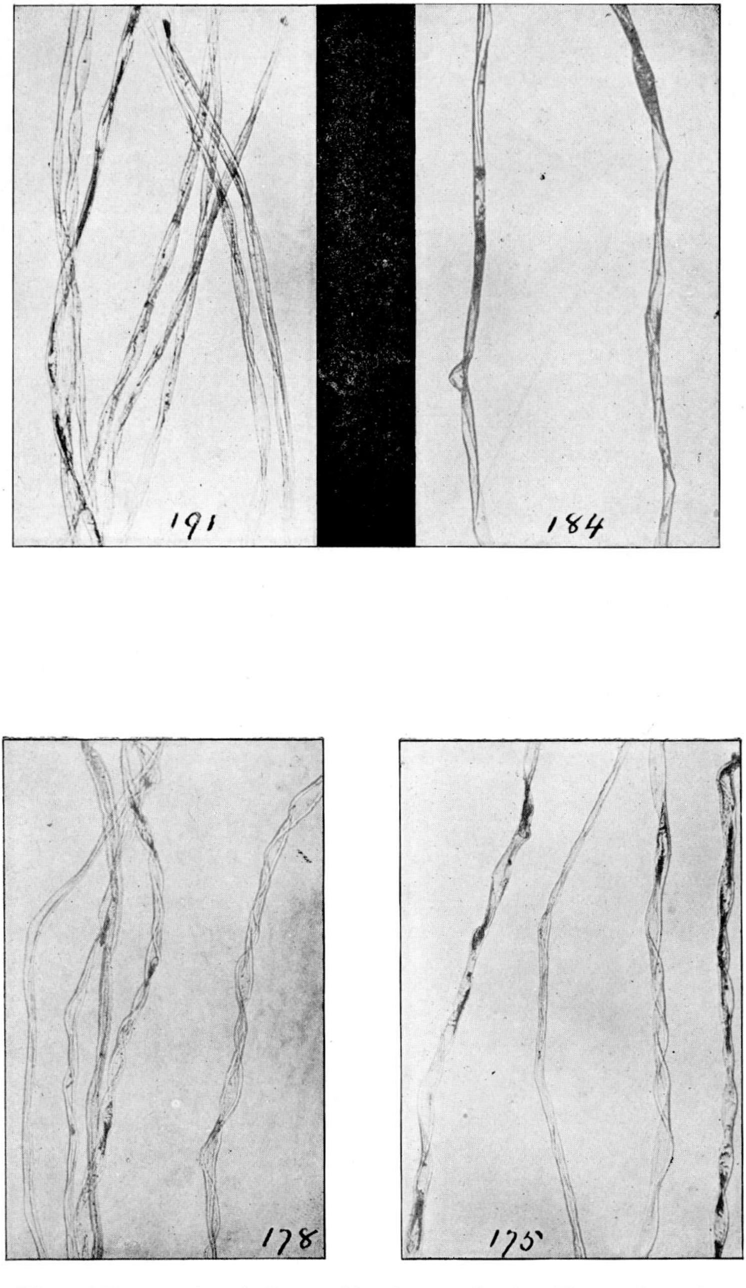


Photo-Micrographs of Cotton fiber from hybrids. For explanation of numbers see table III, page 365. [Photographed by F. H. Mell.]

THE COTTON PLANT CONSIDERED IN SOME OF ITS CHEMICAL RELATIONS.

BY B. B. ROSS.

ANALYTICAL STAFF:

DR. J. T. ANDERSON.

C. L. HARE.

J. Q. BURTON, JR.

THE COMPOSITION OF THE COTTON PLANT AT DIFFERENT STAGES OF GROWTH.

The importance of a careful and thorough study of the staple crops in their chemical relations has long since been appreciated and emphasized by the foremost agricultural scientists, and in recognition of this fact the chemical department of this station has given no little attention during the past few years to the study of the chemical composition of the cotton plant, its fertilizer requirements and other related questions of interest.

The work performed by this department in the study of the cotton plant in its chemical relations may be classified as follows:

A study of the chemical composition of the cotton plant at various stages of growth.

A study of the fertilizer requirements of the cotton plant as determined by the analysis of the plant grown on different soils by the aid of different fertilizing materials.

An investigation of the influence of cotton seed products in food rations upon the composition of butter.

Analyses of cotton seed products with reference to their fertilizing and feeding value.

Until a comparatively recent date, little chemical work of importance had been done with regard to the determination of the composition of the cotton plant at different periods of its growth, nor had there been made any very extended or accurate investigations as to the nutrition of the plant during various stages of its development.

In 1891, J. B. McBryde, of the Tennessee Experiment Station, published a bulletin in which were embodied the results of complete analyses of all parts of the cotton plant, the specimens examined being collected during the two preceding seasons. Up to the date of the appearance of this bulletin, the literature upon the subject of the composition of the cotton plant was exceedingly meagre, and little information of value was procurable outside of analyses by Ville of France, Dr. White of Georgia, and Prof. Jackson of Boston. The comprehensive contribution of Prof. McBryde to the stock of information relating to this subject was supplemented a year later by a bulletin issued by W. L. Hutchinson and L. G. Patterson, of the Mississippi Experiment Station, in which were reported results of analyses of all parts of the cotton plant collected at frequent intervals during the period of growth, and the value of the results were further enhanced by reason of the fact that the investigation extended over two seasons.

The analytical work reported included determinations of the proximate organic, as well as individual inorganic, constituents of the different parts of the plant, and much valuable information was secured with regard to the distribution of the plant constituents at different periods during the progress of growth of the plant.

According to the statement of the experimenters, the investigations at the Mississippi Station were made with a view to determining whether any peculiarities of nutrition existed in the cotton grown on the soils in that section of the State, as the plant, in general, showed an abnormal stalk and leaf development, while at the same time it was quite deficient in fruiting capacity.

In view of the abnormal growth and development of the cotton plant upon the Mississippi soils referred to, and on account of the fact that climate and season, as well as soils, may affect the composition of the plant, it was deemed desirable to conduct a series of experiments at this Station with a view to determining the composition of the cotton plant under the conditions of climate and soil existing in this section. These experiments, while conducted along different lines, were also designed to supplement, to a certain extent, the investigations conducted by Dr. J. T. Anderson, Associate Chemist, several years ago, in which the chief object in view was to determine the influence of varying quantities and forms of the chief fertilizing constituents upon the composition of the plant as regards these particular constituents. Owing to the limited time at the disposal of this department, it was impossible to make complete determinations of all individual constituents of the plant at all stages of its growth, but complete proximate analyses have been made of all portions of the plant and determinations were made of the chief fertilizing constituents, including nitrogen, phosphoric acid, potash and lime, while a complete analysis of all parts of the mature plant was also made.

The soil of the plots upon which the experiments were conducted was a light sandy one, with a somewhat thin subsoil, and was fairly typical of the upland soils in this immediate section. Owing to an unavoidable delay attendant upon the collection of the first sample of the plant for analysis, this particular sample was taken from a different plot from the remaining four samples, but the soil was also of a light sandy character and it is not believed that the composition of the young plant, as grown on this soil, would differ materially from that of the plant produced on the other soil.

Samples of the plant were taken at five different periods of growth, the earliest sample being taken five weeks after planting, and the latest sample being collected after fruiting had ceased.

The plants selected for analysis were as nearly representative as possible of the crop on the plat on which the experiments were conducted, and accurate weighings of the sample were made immediately after the individual plants had been collected. The plants were carried to the laboratory without loss of time, and were at once re-weighed, and any loss in weight noted. The different portions of the plant were now separated, carefully weighed and exposed to the air in thin layers in order to effect a thorough air-drying.

The drying of the material was completed in a large drying chamber by the heat of low pressure steam, and the samples were then reduced to a fine state of division by grinding.

In the first two experiments the plant was divided into three portions, for the purposes of analysis, the roots, stalks and leaves being analyzed separately, while in the case of the last three samples the bolls were also subjected to a separate analysis.

In the analysis of the sample representing the fifth stage of growth, complete analyses of roots, stalks, leaves, bolls, lint and seed are given, and the ratio of the weights of different parts of the plants to each other has been carefully noted. The loss in weight of the plants and their different parts during the process of drying was also accurately determined so that it is quite possible to arrive at the composition of the plant in its original fresh condition.

During the earlier and later stages of growth of the plants on the experimental plots, the weather was quite dry, but in the middle of the season there was a considerable amount of rain, and the growth of the plant between the times of collecting samples 3 and 4 was quite rapid and vigorous.

In reporting the results of analysis, the composition of all parts of the plant at all stages of growth is given, and in addition, the composition of the whole plant in both the fresh and dry condition is presented in tabulated form.

In the analysis of the different parts of the plant, and of the plant as a whole, the results reported are for the completely dried substance, except where specified to the contrary.

TABLE I.

Fertilizing constituents of cotton roots—
(in the water free substance.)

No. of Sample.	Ash	Nitrogen.	Phosphoric Acid.	Potash.	Lime.
I	8 32	1.82	0 50	3 26	1.70
II	4.34	1 06	0 41	1.82	0.43
III	4.18	0.93	0 38	1 53	0 43
IV	4.32	0 61	0 25	1 26	0.47
V	3.72	0 48	0.26	0 90	0.45

Proximate constituents of cotton roots.

No. of Sample.	Ash.	Protein.	Fibre.	Fats.	Carbo-hydrates.
I	8 32	11 38	43.68	1.50	27.80
II	4 34	6 63	39 06	2.31	47.66
III	4 18	5.81	38 47	2 92	48.62
IV	4.32	3.81	43.17	2 70	46.00
V	3 72	3 00	40 62	2 78	49 88

An examination of the figures showing the composition of the roots of the plant indicates a sharp falling off in the mineral constituents of the plant between the first and second periods of growth, and a very slight variation in the ash content during the remaining periods of the plant's development.

The lime and potash particularly show an abrupt decrease between samples 1 and 2, after which the content of the former becomes nearly constant, while the latter shows a gradual falling off up to the period of full maturity. The decline in the phosphoric acid content with the progress of the plant growth is more gradual than in the case of the lime and potash, while the nitrogen follows the potash closely in its ratio of decrease.

The fiber in the roots showed considerable variation during the various stages of growth, being unusually high in sample No 1, and exhibiting alternate decreases and increases in the remaining samples.

The fat shows a tendency to increase until the third period is reached, after which the proportion remains nearly constant, while the carbo-hydrate content exhibits a similar rate of variation.

TABLE II.

Fertilizing constituents of cotton stalks.

No. of Sample.	Ash.	Nitrogen.	Phosphoric Acid.	Potash.	Lime.
I	13 30	2 61	0.65	2.55	3 68
II	7.70	1 66	0.51	2.03	1.49
III	5.41	1.40	0.38	1.83	1.26
IV	5 65	0.82	0.28	1.67	1.35
V	3.09	0.64	0.21	0 85	0.78

Proximate constituents of cotton stalks.

No. of Sample.	Ash.	Protein.	Fibre.	Fat.	Carbo-hydrates.
I	13.30	16.31	38 70	1 43	30.26
II	7.70	10.38	35 41	1.13	45.38
III	5.41	8.75	39.51	0.93	45.40
IV	5.65	5.13	40 22	1.07	47.93
V	3.09	4.00	45 31	1.11	46 49

The composition of the stalks showed variations somewhat similar to those of the roots at the various stages of growth, there being a marked falling off in the proportions of mineral constituents in sample No. 2 as compared with sample No. 1, while the decrease from sample 2 to sample 5 was more gradual.

There is a somewhat sharp decline in the amount of total ash constituents in passing from sample 4 to sample 5, the decrease in the proportions of potash and lime in this period being particularly marked. The decrease in the phosphoric acid content as the growth of the plant progressed was quite gradual and uniform.

The falling off in the proportion of nitrogen is most noticeable in the second and fourth periods of growth the decline being quite gradual in the other periods.

The crude fiber showed a marked increase with the progress of the development of the plant, although a slight fluctuation was noted between the first and third periods of growth. The fat content after the first period showed little variation, but the proportion of carbohydrates showed a steady, though not regular increase, as the plant approached maturity.

TABLE III.

Fertilizing constituents of cotton leaves.

No. of Sample.	Ash.	Nitrogen.	Phosphoric Acid	Potash.	Lime.
I	21.60	5.11	1.04	4.68	8.81
II	16.63	4 33	0.78	2.66	7.40
III	15.98	3 60	0.57	2.27	6.42
IV	15.20	3.16	0.66	2.26	7.12
V	12.55	2 25	0.48	1.09	5 28

Proximate constituents of cotton leaves.

No. of Sample.	Ash.	Protein.	Fiber.	Fat.	Carbo-hydrates.
I	21.60	31.94	7.26	3.39	35.81
II	16.63	27.06	8.69	4.66	42.96
III	15.98	22.50	9.04	8.74	43.74
IV	15.20	19.75	8.99	8.33	47.73
V	12.55	14.06	8.71	9.49	56.19

A reference to the table of analyses of the leaves shows that this particular part of the plant contains a higher average proportion of fertilizing constituents than any other part, until the bolls commenced to mature. The large amount of fiber in the burrs and lint, of course, tended to decrease the proportions of phosphoric acid, potash, nitrogen, etc., in the whole boll, notwithstanding the fact that the seed contains good percentages of these constituents. The proportion of ash in the dry matter of the leaves decreased steadily as the growth of the plant progressed, the most abrupt declines being noted in samples 2 and 5, as compared with samples 1 and 2.

The potash content decreased somewhat in the same ratio as the proportion of ash, though more rapidly, while phosphoric acid and lime showed a more gradual, though not uninterrupted, decrease as the plant developed, there being a slight increase in the two latter constituents in the fourth period of growth.

Nitrogen decreased with comparative regularity during the different periods of growth, the most marked decline being noted in the last period. It will be noted that the potash content in sample No. 5 is less than one fourth that of sample No. 1, while the phosphoric acid content falls off only about one-half between the same periods.

The falling off of all of these constituents was much more marked than in the experiments reported from the Mississippi Station, there being an actual gain in phosphoric acid in the case of the Mississippi tests.

The fiber in the leaves showed a slight gain in the earlier stages of growth, and fluctuated very slightly during the remainder of the period covered by the experiments.

TABLE IV.

Fertilizing constituents of cotton bolls.

No. of Sample.	Ash.	Nitrogen.	Phosphoric Acid.	Potash	Lime.
III	9.15	3.24	1 06	2.25	2.16
IV	5.78	2.27	0 72	2.54	0.87
V	4.74	1 83	0.78	1 60	0.51

Proximate constituents of cotton bolls.

No of Sample.	Ash.	Protein.	Fiber.	Fat.	Carbohydrates.
III	9.15	20.25	23.09	3.29	44.22
IV	5.78	14.19	42.31	7.17	30.55
V	4.74	11.44	45 21	9.81	29.07

There was a marked increase in fat as the plant approached maturity, and there was quite a considerable increase in carbohydrates also, although the increments were not at all uniform.

The term "boll," as used in this connection, applies to the complete boll, including capsule, seed and lint, and is not restricted to the burrs, as is the case in some other bulletins relating to this subject.

Between the third and fourth periods of growth, there was a marked falling off in the ash constituents of the bolls, and a somewhat moderate decline in passing from the fourth to the fifth period. The phosphoric acid content showed a sharp decrease in the fourth period as compared with the third, and a very slight increase is noted in the last period of growth. Potash increased slightly in the fourth period and exhibited a marked falling off in the fifth period, while lime, on the other hand showed a very abrupt decrease in the fourth period, and a much smaller relative diminution in the last stage of growth.

Nitrogen also declined sharply in the fourth period, and exhibited a moderate decrease in the fifth period, of the plant's development.

Crude fiber increased very rapidly in the fourth period and showed only a fair increase in the last period, while carbohydrates showed a corresponding decrease.

The fat showed a marked increase in the fourth and fifth periods owing to the rapid formation of seed during that stage of the plant growth. In like manner, the large increase in fiber in the bolls is due to the accelerated production of lint as the plant approached maturity. The increase in these constituents of course, caused a decline in the relative proportions of several of the fertilizing constituents.

Analysis of Burrs—(water free.)

Ash.	Nitrogen.	Phosphoric Acid.	Potash.	Lime.
9.06	0.82	0.48	3.09	1.14

A reference to the above table of analysis of the burrs reveals the fact that in an air dry or water free condition, quite fair proportions of the essential fertilizing constituents are present, the proportion of potash being particularly high, while lime and nitrogen are also contained in good quantities.

COMPLETE ANALYSIS OF ENTIRE MATURE PLANT.

The following table gives the results of a complete analysis of the entire mature plant collected on October 3rd, 1899.

Under normal conditions, it would be expected that the water content would be somewhat lower in the plant at maturity than at the next preceding period of growth, but the weather for several weeks before the taking of this sample being extremely dry, there was quite a considerable falling off in the proportion of water as compared with sample No. 4. There was also noticed quite a considerable loss of leaves from the plant during the last period, the proportion of the weight of the leaves to the weight of the stalk being much lower than in any of the preceding samples.

Table No. V.

Complete analysis of the entire mature plant.

	Nitrogen.	Phosphoric Acid	Potash.	Lime.	Magnesia.	Oxide of Iron.	Soda.	Sulphuric Acid.	Silica.	Ash.	Protein.	Fiber.	Fat.	Carbohydrates.
Roots	0.48	0.26	0.90	0.45	0.44	0.25	0.44	0.14	0.64	3 72	3.00	40.62	2.78	49.88
Stalk	0.64	0.21	0.85	0.78	0.28	0.21	0.30	0 14	0 16	3.09	4.00	45.31	1.11	46 49
Leaves	2.25	0 48	1.09	5.28	0.94	0 43	0 66	1.05	1 70	12 55	14.06	8 71	8 49	56.19
Bolls	1 83	0.78	1.60	0.51	0.55	0.15	0 23	0.42	0.21	4.74	11 44	45.21	9.81	29 07
Seed	3.54	1.40	1.13	0.32	0.30	0.03	0 28	0 11	0.02	3.65	22 13	11.91	23 05	39 26
Lint	0.18	0.09	0.59	0.07	0 14	0 16	0 07	0 09	0 07	1 25	1.12	87.02	0.61	10 00

The following table shows the composition of the plant, as a whole, at the several stages of growth, the results being given for the thoroughly dried plant, as well as for the fresh plant at the time of taking the samples.

TABLE VI.

Analyses of plant for fertilizing constituents at different stages of growth.

A—Analysis of plant in water-free condition.

No. of Sample.	Ash.	Nitrogen	Phosphoric Acid.	Potash.	Lime.
I	18 09	4.12	0.88	3 96	6.74
II	11.53	2.85	0.63	2.30	4.15
III	8.70	2.24	0.55	1.98	2.68
IV	8.25	1.96	0.54	2.11	2.72
V	4 78	1.43	0 56	1 30	0.94

B.—Analysis of plant in fresh condition.

No. of Sample.	Ash.	Nitrogen.	Phosphoric Acid.	Potash.	Lime.
I	2.76	0 63	0 13	0.61	1.03
II	2.76	0.68	0 15	0 55	0.99
III	2 56	0 66	0.16	0 58	0.79
IV	1.81	0.43	0 12	0.46	0.60
V	1.85	0 55	0.22	0 50	0.36

These results were secured by consolidating the analytical data reported in the preceding tables, the proportional distribution of the different parts of the plant having been carefully determined.

A reference to Table No. VI-A shows a heavy decline in ash constituents in the second period, a somewhat less marked decrease in the third period, only a slight loss in the ash content in the fourth, and another large decline in the last stage of growth.

Nitrogen exhibits a steady and continued decrease from the first to the last period of growth, the largest decline being noted in the second period.

Phosphoric acid decreased up to the third period and then remains almost absolutely constant during the remainder of the growth of the plant. Potash and lime decline steadily up to the third period, a slight increase being noted in the fourth period, while a sharp falling off is observed in the last stage of growth of the plant.

The great decrease in the proportion of lime in the last period is no doubt due largely to the extensive shedding of leaves by the plant at this period, the leaves being particularly rich in this constituent at all stages of growth.

In Table No. VI-B, illustrating the composition of the plant in its original fresh condition, it will be noted that the variation in the proportions of the leading constituents is much less than in the table of results for the completely dried plant.

The ash content for the first two periods, on this basis, is the same, while a decline is noted in the third and fourth periods, after which it becomes nearly constant again. Nitrogen shows only slight fluctuations during the first three periods of growth, but exhibits a sharp falling off in the fourth period and an almost equally marked gain in the last stage of growth. Phosphoric acid exhibits only slight variations during the first four periods and markes a marked gain during the fifth period. In the case of potash, only slight variations are noted throughout the whole period of growth, while the lime content exhibits a continued but somewhat irregular decline, the most noteworthy decreases being observed in the third, fourth and fifth periods.

The falling off of nitrogen, phosphoric acid and potash in the fourth period is doubtless due largely to the fact that there had been an abundance of rain prior to the taking of this sample, in consequence of which the plant had grown rapidly and had taken up a large proportion of water, thus reducing the apparent proportion of the constituents named.

It was [illegible]d above that there had been a considerable loss of leaves from sample No. 5 prior to the collection of the plants for analysis, and on this account, it is deemed desirable to make compensation for this loss in calculating the composition of the plant taken as a whole. In sample No. 4, there had been only a slight loss of leaves, and the proportion of the weight of the dry matter of the leaves to the dry matter of the stems was .937 to 1. Assuming that this ratio would have continued to hold good in the case of sample No. 5, if no loss of leaves had occurred, we find that the weight of the dry matter of the leaves in sample No. 5 should have been 3.65 times greater than it actually was under the conditions obtaining at the time the sample was taken. Upon this basis the composition of the plant as a whole would be as follows, calculated to a water free condition, the composition of the plant being also given in the dry and fresh condition, without compensation for the leaves lost in the last period.

TABLE VII.

Analysis of entire mature plant.

Condition of Plant.	Ash.	Nitrogen.	Phosphoric acid.	Potash.	Lime.	Magnesia.	Oxide of iron.	Soda.	Sulphuric acid.	Silica.
Water-free........	4.78	1.43	0.56	1.30	0.94	0.49	0.19	0.30	0.37	0.33
Fresh............	1.85	0 55	0 22	0 50	0.36	0.19	0.07	0.12	0.14	0.13
Water-free, with compensation for loss of leaves.	6.07	1.56	0 55	1.26	1.65	0.56	0 23	0.36	0.48	0.56

From the data thus secured, it is easy to ascertain by calculation the amount by weight of the plant, and of the chief plant constituents required to yield a crop of 300 pounds of lint cotton per acre. It will be noted that the proportion of seed to lint in sample No. 5 is smaller than under normal conditions, owing to the fact that a considerable number of the bolls were not fully matured at the time the sample was taken. In the immature bolls, the proportion of lint to seed is generally above the normal, and in the case of this sample, the lint constituted 36.56 per cent. of the air dried seed cotton, a per centage much above the usual proportion of lint. Making due compensation for the loss of leaves from the plant in the fifth period, it is ascertained by calculation that the proportions of fertilizing constituents indicated in the following table would be required to produce a lint crop of 300 pounds per acre under the conditions governing the series of experiments described.

The weights of nitrogen, phosphoric acid, potash and lime contained in a crop producing 300 pounds of lint are given, and the relative distribution of these constituents through different parts of the plant is also presented. The weights of the different parts of the plant in a thoroughly dried condition are also given, and it will be noted that the total dry weight of the crop required to yield 300 pounds of lint is 2,470.9 pounds.

TABLE VIII.

Amounts of fertilizers constitueuts in pounds required to produce a crop of 300 lbs. of lint.

	Nitrogen.	Phosphoric acid.	Potash.	Lime.
Lint—300 lbs.	0.54	0.27	1.77	0.21
Seed—507.1 lbs.	17 95	7.10	5.73	1.52
Burrs—363.1 lbs	2.99	1.74	11.22	4.14
Leaves—566.2 lbs.	12 64	2.70	6.13	29.90
Roots—130.2 lbs.	0.62	0·34	1.17	0 59
Stems—604.2 lbs.	3.87	1.27	5.14	4.71
Total—2470.9 lbs.	38 61	13 42	31.16	41.07

It appears from this table that to produce 300 pounds of dry lint there are required 38.61 pounds of nitrogen, 13.42 pounds of phosphoric acid, 31.16 pounds of potash and 41.07 pounds of lime.

The total weight of the crop is somewhat smaller than the weight of the crop in the experiments of McBryde, and the distribution of the various parts of the plant by weight varies considerably from the results reported by him.

The amounts of nitrogen and potash found in the crop required to produce 300 pounds of lint, are somewhat belowthe amounts given in the tables of McBryde, while the amount of phosphoric acid is slightly above the figures which he reports.

The plant is also less rich in fertilizing constituents than the plants reported in the Mississippi experiments, but this may be due to the fact that the past season was somewhat unfavorable to the growth and development of the plant, as well as to the fact that the soil upon which the crop was grown was not so fertile as the Mississippi soil.

Nevertheless, the yield of bolls and lint in proportion to the total weight of the plant was quite good, and it is quite possible that where considerably larger proportions of phosphoric acid, nitrogen and potash than those reported above, are found in the plant, the crop has taken up larger amounts of these constituents than are actually required for its normal development.

It is a well known fact that upon some soils the development of stalk and leaf is out of all proportion to the yield of fruit, and so it is not at all surprising that, upon soils where the stalk and leaf development is not so vigorous, and where, at the same time, the yield of lint in proportion to the weight of the whole plant is good, the amount of fertilizing constituents contained in the plant should be smaller than in the former case.

McBryde and others have called attention to the small amount of fertilizing constituents contained in the lint, and a reference to the tables previously given will show that 300 pounds of lint will remove only .54 pound of nitrogen, .27 pound of phosphoric acid, 1.77 pounds of potash and .21 pound of lime from the soil, and if the remainder of the plant and the seed were re-turned to the soil, the loss of fertilizing constituents would be almost inappreciable.

In actual practice, it would be quite difficult to secure the thorough incorporation of the plant into the soil, and yet a considerable amount of fertilizing material could be thus stored up and placed at the disposal of the next crop.

It will be noted that the amount of phosphoric acid in the fully matured plant is much less than that of nitrogen and potash, and this fact is of especial interest when it is considered that practically all cotton fertilizers supply much larger proportions of phosphoric acid than of nitrogen and potash. The fact that the quantities of phosphoric acid supplied in cotton fertilizers are relatively much larger than those of nitrogen and potash, notwithstanding the occurrence of smaller proportions of phosphoric acid in the plant, might warrant the conclusion that owing to the rapid reversion of soluble phosphates in the soil in the presence of oxide of iron and alumina, it becomes necessary to supply an amount of phosphoric acid largely in excess of the actual requirements of the plant.

The following table shows the relative distribution of the different portions of the plant at the various stages of growth, the results being given in percentages of the completely dried plant, as well as of the plant in its original fresh condition. In the column headed 5-a is given the results for the plant under the conditions obtaining at the time the sample was taken, while in column 5-b are presented the figures for the plant after making compensation for the leaves lost during the last period.

Table IX.

Percentage ratios of different parts of the plant to the whole plant during the different periods of growth.

A.—Plant in fresh condition.

	I.	*II.*	*III.*	*IV.*	*Va.*	*Vb.*
Roots............	7 27	11.61	10.85	4 67	5 45	4.61
Stems............	37.59	35.33	34 96	22.08	26.78	22.05
Leaves	55 14	53.06	24.10	21.87	7 51	22.88
Bolls............	....	....	30 09	51.38	60 17	50.46

B.—Plant in water free condition.

	I.	*II.*	*III.*	*IV.*	*Va.*	*Vb.*
Roots............	8.94	10 57	12.29	7.60	6.32	5.27
Stems............	27.95	42 55	43.13	29.71	29 34	24.46
Leaves...........	63.11	46 88	26 69	27.83	7.53	22.91
Bolls............	....	....	16 89	34 85	56 81	47.36
Lint.............	....	....	....	....	14 56	12.14
Seed.............	....	....	....	....	24.62	20.52
Burrs............	....	....	....	....	17 63	14.70

A reference to this table shows that in the fresh plant, that the percentage of roots to the weight of the total plant increases in the second period, and then declines throughout the remainder of the experiment. The leaves and stems fall off continuously in the proportion they bear to the weight of the whole plant, while the percentage weight of the bolls increases rapidly until in the last period, this part of the plant constitutes more than 60 per cent. of the weight of the entire plant.

The water content in the fresh plants in the various periods of growth was as follows:

1st period, 84.72 %; 2nd period, 76.08 %; 3rd period, 70.53 %; 4th period, 78.10 %; 5th period, 63.72 %.

FERTILIZER REQUIREMENTS OF COTTON, AS DETERMINED BY THE ANALYSIS OF THE PLANT.

Condensed from Bulletin 57, issued by Dr. J. T. Anderson.

Some years prior to the experiments just described, an extended series of experiments was conducted by Dr. J. T. Anderson, Associate Chemist of the Station, with a view to determining the influence of various fertilizer constituents upon the composition of the plant, and the substance of Dr. Anderson's report is herewith presented in a condensed form.

For the purposes of the experiments, two plots of ground were selected, whose soils were of the same general type, but widely different in point of fertility. One of the plots selected is designated the "Drake field," while the other plot was located in the Station garden. The soil of the Drake field was too poor for the profitable culture of cotton, while that of the Station garden had, by proper management, been brought to a high state of cultivation. The former plot had stood idle the preceding year, while the latter had produced two crops. In the preparation of the land, all the stubble and roots were removed as completely as possible after the ground had been thoroughly broken up.

Each piece of ground was divided into ten small plots, each 10x10, arranged in a continuous line, and a space four feet wide was left between the plots. Three of the plots in each strip were left unfertilized, while to the other seven the three chief fertilizing constituents were applied, singly and in combination, as is set forth in Table I.

Table 1.

Cotton plant in flowering stage.

Plots.	Fertilizers Used.	Drake Field. Per cent. potash.	Drake Field. Per cent. phosphoric acid.	Drake Field. Per cent. nitrogen.	Drake Field. Oz. seed cotton.	Station Garden. Per cent. potash.	Station Garden. Per cent. phosphoric acid.	Station Garden. Per cent. nitrogen.	Station Garden. Oz. seed cotton.
1	None	2.154	0.839	3.390	3.75	3.444	0.861	3 455	35.63
2	Nitrate soda	....	0.863	3.906	10.	3 287	0.829	3 976	73.43
3	Kainit	2.751	....	3 382	11 86	3 320	0.958	3 717	117.14
4	Acid phosphate	....	0.781	3.837	34.	3.227	0.914	3 896	124 29
5	None	2.034	0.934	3 488	9 29	3 178	0.862	3.825	130.83
6	Nitrate soda and kainit	2.137	0 627	3 855	30.	2.981	0.805	3 831	120.
7	Nitrate soda and acid phosphate	1.823	0 699	3.685	23.21	3.199	0.854	4.225	96 25
8	Kainit and acid phosphate	1.997	0 919	3 967	29.17	3.102	0.797	3 873	132 86
9	Nitrate soda, kainit and acid phosphate	2 547	0 830	3 645	37.50	3.611	0.860	4.347	145.34
10	None	2.238	0.886	3.645	12.50	3.106	0.805	4.149	141.25

The first set of samples for analysis was taken during the first week in June, when the plants were in the early flowering stage. The second set were drawn about the 1st of September, when the last blossoms were falling off, and the early bolls were beginning to open. The entire stalk above ground was taken, air dried, and prepared for analysis in the usual way.

In Table I will be found the percentages of potash, phosphoric acid, and nitrogen in the plant in the flowering stage. The figures given are the means of a number of determinations, and are calculated to the dry substance, the moisture of each sample having been carefully determined in the usual way, by separated heatings and weighings until no further loss of weight occurred. In the same table will be found the weight in ounces of the seed cotton gathered from each plot.

TABLE 1.

COTTON PLANT IN FLOWERING STAGE.

A glance at the figures in Table No. 1 will reveal several noteworthy facts. In the first place it will be observed that there is considerable divergence between the maximum and minimum percentages of two of the constituents. That the composition of the cotton plant, therefore, in relation to these ingredients at least, is subject to perceptible variation, cannot be doubted. For instance, the maximum percentage of potash in the Drake field is 50.8 % higher, and in the garden, 21.1 % higher, than the minimum in the same soil; while the maximum in the garden exceeds the minimum in the field by 98 %. The maximum nitrogen in the field is 17 %, and in the garden 25.8 % higher than the minimum in the same soil; and the maximum in the garden, 28.2 % higher than the minimum in the field. The *relative* variations between the extremes of phosphoric acid are greater than those in the case of nitrogen, but the absolute variations are small, and may possibly be traceable to accidental causes.

In the second place, we note that the character of the soil exercises a perceptible influence on the composition of the plant, at least as far as potash and nitrogen are concerned. Taking the means of the percentages of potash in the three unfertilized plots of each soil separately, we find that this mean in the garden soil is 51.4 % higher than the corresponding mean in the field soil. Making the same estimates for nitrogen, we find that the garden soil exceeds the field soil in this ingredient by 8.6 %.

To ascertain the effect of the addition of fertilizing constituents to the soil upon the relative proportions of these constituents in the plants themselves, a detailed reference to Table 1 is necessary.

In the results from the Drake field soil it is seen that the highest percentage of potash is in plot 3, and the next highest in plot 9, to both of which plots potash was added. On the other hand, the second lowest percentage is in plot 8, which also was fertilized with potash. It will be noticed that this plot seems eccentric in another particular—in that it contains the highest percentage of nitrogen, when no nitrogen was applied to it. With this exception, the highest percentage of nitrogen is found in plot 3, which has nitrogen fertilization, and the lowest percentage where nitrogen was used, is higher than the average of those where no nitrogen was added, even when the high percentage of plot 8 is included in the estimate. As has already been noted, the variation in phosphoric acid seems to obey no rule, the percentages in the two soils being practically the same.

The Station garden soil being in a high state of cultivation to begin with, it was to be expected that the influence of fertilizers here, both on the composition of the plant, and on the yield of seed cotton, would be less strongly marked than in the poorer soils. While this is the case, it is also true that by fertilization with potash and nitrogen the percentages of these constituents even here are increased. This is notably true in plot 9, where all three fertilizers were applied and where are found the highest percentags of these ingredients.

An average of the experiments in which potash was supplied to the Drake field plots, shows a considerable gain for the potash content of the plants grown thereon, as compared with the plots to which potash was not furnished, and a slight gain is noted in the Station garden plot. The average of the phosphoric acid plots in the Drake field shows a slight decrease in the phosphoric acid content of the plant as compared with that of the plant grown on plots from which phosphoric acid was withheld, and only a slight increase is noted in the case of plants grown on phosphoric acid plots in the Station garden. Plants grown on nitrogen plots, both in the Drake field and Station garden, show quite a fair increase in the nitrogen content, as compared with the plant grown on plots to which nitrogen manures were not supplied.

The results that have hitherto been considered were obtained from the analysis of the plant in the early flowering stage. It was deemed expedient to analyze the plant in a later stage, also, and so about three months after the first samples were taken, when the plant was full of unopened bolls, the second lot was drawn. One of the purposes of this investigation was to see if the percentages of potash, phosphoric acid, and nitrogen in the plant did not increase with the yield of cotton. This could hardly be otherwise, if the seed were ground up with the stalk, inasmuch as the seed are a reservoir, so to speak, in which these constituents accumulate. Hence it was thought best not to include the young, immature seed in the sample for analysis, and they were accordingly rejected. The results of the analysis are given in Table 2 following, which is constructed after the model of Table 1. Here, as in the other, the results are calculated to the dry substance.

Table 2.

Analysis of plant in the bolling stage.

Plots.	Fertilizers Used.	Drake Field. Per cent. potash.	Drake Field. Per cent. phosphoric acid.	Drake Field. Per cent. nitrogen.	Drake Field. Oz. seed cotton.	Station Garden. Per cent. potash.	Station Garden. Per cent. phosphoric acid.	Station Garden. Per cent. nitrogen.	Station Garden. Oz. seed cotton.
5	None	1 256	.788	1.883	9.29	2 538	.758	2.352	130.83
6	Nitrate soda and kainit	2 123	345	1 969	30.	2 026	741	2.436	120
7	Nitrate soda and phosphoric acid	1 051	.537	1 883	23.21	1 494	.688	2 064	96 25
8	Kainit and phosphoric acid	2 119	.488	1.841	29 17	2.751	.900	2 442	132 86
9	Nitrate soda, kainit and phosphoric acid	2.562	.557	1 833	37.50	3.054	696	2.339	145.34
10	None	......	......	......	12 50	2 683	.724	2 273	141 25

A conspicuous fact observable in the above table is that the figures here are smaller than the corresponding figures in the first table. This was to be expected. The plant at this stage of growth is nearing maturity, and the three important constituents are being rapidly stored up in the seed.

A reference to the table shows that in the Drake field, the lowest percentages of potash in the plant are in 5 and 7, where potash was not supplied, while the highest potash content is in No. 9, where there is complete fertilization, and where there is, also, the highest yield of cotton. In this plot, however, the plant has quite a low nitrogen content, but the other nitrogen fertilized plots bring up the average to a point above that of the nitrogen content of plants grown on non-nitrogen plots.

In the case of the garden plot, it is noted that the average effect of the potash fertilization is to increase the percentages of potash, while a similar increase in the nitrogen content does not follow from the application of nitrogenous fertilizers.

This would seem to indicate that the garden soil contains a deficiency of potash, but a sufficiency of nitrogen.

The results on phosphoric acid are worthy of special attention. With a single exception, the percentages of this constituent in the Drake field in the bolling stage, are decidedly lower than the corresponding ones in the flowering stage, while no such marked change is observable in the garden percentages. It would seem, therefore, that there is a deficiency of available phosphoric acid in the Drake field, which was not shown by the analysis at the earlier stage, and further, that there is no such deficiency in the garden soil. The exceptional case referred to is in 5, where the percentage of phosphoric acid is only a little smaller than the average found in the earlier stage. This fact, taken in connection with that of a high percentage of nitrogen and a low yield of cotton, might suggest the possibility of a case of arrested development. It will be observed that with rare exceptions the percentages of all the constituents are higher in the garden than they are in the field, and from this the conclusion may be drawn that there is a deficiency of potash, phosphoric acid, and nitrogen in the field. The smaller yield of cotton in the field strengthens this conclusion.

While, as a rule, the percentages of fertilizing constituents are smaller in the bolling stage than in the flowering stage, it will be noted, that on plots 6, 8 and 9, in the Drake field, where potash was supplied, there is in the first case only a slight decrease in potash and in Nos. 8 and 9 there is a slight increase in the potash content, the largest yields of cotton being obtained from these plots.

From this it would seem that in the potash-fertilized plots there is a sufficiency of that constituent under the circumstances here existing. On the other hand, comparing the field and garden, we find that while the latter has much higher percentages of potash to begin with, it has at the same time larger per cents of decrease than the potash-fertilized plots in the field, ranging from 11.3 % in plot 8 to 53 % in plot 7. In other words, with a larger supply there is a smaller excess of potash over the demands for that constituent.

The decrease in the percentages of phosphoric acid and nitrogen between the flowering and bolling stage is quite marked, the decline in the amount of the latter constituent being particularly large.

A comparison of the figures in Tables 1 and 2 shows that where the plant has high percentages of two or more constituents in the flowering stage, and only a small decrease in those percentages in passing to the bolling stage, there is, as a rule, a large yield. With low, or medium percentages, in the early stage, followed by largely decreased percentages in the later stage, a relatively low yield is secured, and this would explain the low yield in plot 5, Drake field.

The soils upon which these experiments were conducted, while similar, from a geological standpoint, differ materially in composition, owing to the fact that the Station garden had been systematically improved, and an idea of the character of the soils can be secured from the following chemical analysis:

	DRAKE FIELD.	STATION GARDEN.
Moisture	.650	.825
Insoluble silica	94.790	93.097
Soluble silica	.532	.560
Alumina	1.153	1.873
Oxide iron	.850	1.093
Lime	.185	.260
Magnesia	.158	.122
Soda	.268	.315
Potash	.098	.087
Phosphoric acid	.087	.064
Nitrogen	.069	.086
Organic matter	1.550	2.195
Humus	.580	.863
Available inorganic matter	.647	.946
Humus silica	.[illegible]53	.353
Humus phosphoric acid	.020	.035

It will be noted that the proportion of Insoluble Silica in both of these soils is quite high, the field soil containing nearly two per cent. more than the garden soil. As regards lime, if the minimum limit assigned to this constituent in light sandy soils by writers on this subject be correct, both of these have a sufficiency of this valuable substance, the garden having 40.5 % more than the field. In both potash and phosphoric acid, on the other hand, the garden soil is poorer, about 1 % in the former and

26.4 % in latter. What has just been said applies to *total* phosphoric acid. The humus phosphoric acid, all of which is believed to be readily available to the plant, is 75 % higher in the garden than in the field. In total available inorganic matter—that which dissolves out with the humus—the garden soil is 46 % richer than the field soil.

It will thus be seen that the garden soil in the main is richer in the important inorganic constituents than the other soil; but it is believed that its superior fertility is chiefly due to its larger proportion of organic matter.

CONCLUSIONS.

The following conclusions were drawn by Dr. Anderson as the result of the above experiments:

"1. That the composition of the cotton plant in respect to potash, phosphoric acid, and nitrogen, is subject to decided variations under varying conditions.

"2. That the nature of the soil exerts a considerable influence on the composition of the plant, a rich soil giving higher percentages of the three important constituents than a poor soil.

"3. By fertilizing with either of the three constituents in soils not already containing a sufficiency of the same, it is possible to increase the percentage of that constituent in the cotton plant which is grown on such soil.

"4. That humus in the soil is of great value, not only in supplying organic constituents, but, also, in holding inorganic constituents in most available conditions."

A comparative study of the results of these experiments in connection with those conducted during the past season would warrant the further conclusion that where no percentage increase in fertilizing constituents of the plant occurs during the progress of its growth, and even where an actual decrease is noted, there is still a large absolute increase of these constituents, and the result of the application of fertilizers may be manifested in the increased bulk of the plant and in the augmented yield of the crop.

THE EFFECT ON BUTTER FROM FEEDING ON COTTON SEED AND COTTON SEED MEAL.

Condensed from a bulletin prepared by Dr. N. T. Lupton in 1891, the analytical work being performed by Dr. J. T. Anderson.

An investigation was undertaken several years since at the Alabama Experiment Station to determine the effect of cotton-seed and cotton-seed meal on the composition of the butter fat, especially on the volatile acids, the melting-point, and the specific gravity of the butter produced.

Several chemists of late years have called attention to changes produced by the use of the feed stuffs mentioned, notably Prof. Harrington, of the Texas Experiment Station, and Dr. Wiley, of the Department of Agriculture, Washington, D. C. This subject was thought to be of sufficient scientific and practical importance to justify an extended investigation. For this purpose a herd of registered Jerseys was divided into two groups, one consisting of ten cattle and the other of a single cow. The cattle of the first group were fed for a preparatory period of ten days on the customary ration used at the station, excluding cotton-seed meal and hulls; the single cow was fed on the same ration. At the end of the preparatory period, samples of milk and butter were taken for one week, on Monday, Wednesday, and Friday, and carefully analyzed. The milk of the ten cattle composing the first group was mixed and churned as a whole—that of the single cow was kept separate and churned by itself. The first preparatory period was for ten days; after that the experimental and preparatory periods extended over seven days each.

The daily rations for the different periods, representing the kind and quantity of food actually consumed are given in the right hand column of the table of results. The nutritive ratios for the first three periods were: 1:5.8; 1:3.75, and 1:5.08.

During the fourth period the cattle were confined exclusively to raw cotton-seed and cotton-seed hulls, and during the fifth period to cooked cotton-seed and cotton-seed hulls. They were allowed as much as they would eat. The nutritive ratios mentioned above are calculated from analyses made of the feed stuffs in use at the station. In compounding the rations, the object was not so much to conform with strictness to the German standard as to bring the cows gradually under the influence of cotton-seed, cotton-seed meal, and hulls without injury to their general health.

Samples of milk and butter were taken after each milking and churning, and subjected to a thorough and careful analysis. In the following table, however, analyses of milk are omitted, and no individual analyses of butter are reported, the results given being the averages of individual analyses for each period.

During the progress of these experiments it was noted that there was a marked falling off in the quantity of milk, and a corresponding increase in the amount of butter produced during the first three periods, as the cattle were getting more under the influence of the cotton-seed meal.

During the remaining periods the quantities of both milk and butter diminish, the ration being confined to cotton-seed and cotton-seed meal, without reference to having it well balanced as a milk ration.

Average composition of butter for each period.

Period. Group I	Volatile acids.	Melting-point.	Specific gravity at 100° C.	Rations.
I.....	29 8	35·6°	0·90284	5 lbs. each ground oats, ground corn, and bran.
II.....	30 5	36·1°	0·90280	Cotton seed meal 3 lbs.; ground oats, 4 lbs.; bran, 5 lbs. ensilage, 11 lbs.
III.....	27 5	37·4°	0.90194	Cotton seed meal, 4 lbs.; cotton seed hulls, 9 lbs.; ensilage, 4½ lbs
IV.....	22·1	43·6°	0 89899	Raw cotton seed meal and cotton seed hulls.
V.....	22·5	42·7°	0 90262	Cooked cotton seed meal and cotton seed hulls.
Group II.				
I.....	31·4	34·2°	0·90323	5 lbs. each ground oats, ground corn, and bran.
II.....	31·1	36·3°	0·90152	Cotton seed meal, 3 lbs; ground oats, 4 lbs.; bran, 5 lbs.; ensilage.
III.....	25·45	39·4°	0·89995	Cotton seed meal, 4 lbs.; cotton seed hulls, 9 lbs.; ensilage, 4½ lbs.
IV.....	20·4	42·5°	0·89854	Raw cotton seed meal and cotton seed hulls.
V.....	21·9	43·5°	0·89857	Raw cotton seed and cotton seed hulls.

The general effects of these valuable feed stuffs, when used in carefully prepared rations, will hereafter be investigated; at present we are concerned only, as previously stated, with their effects on the volatile acids, melting-point, and specific gravity of the butter fat produced under their influence. For these effects attention is called to the above tabular statements, from which the following conclusion is drawn:

Feeding on cotton-seed and cotton-seed meal increases in a marked degree the melting-point of butter, the increase reaching in these experiments eight or nine degrees, and diminishes to a corresponding extent the volatile acids, while the specific gravity remains virtually the same.

The richness of cotton-seed meal in albuminoids renders it of prime importance to mix it with one or more feed stuffs poor in this nitrogenous compound, such as ensilage, hay, or cotton-seed hulls.

It may be stated in this connection that no change was observable in the color of the butter from feeding cotton-seed and cotton-seed meal. The samples, still in the laboratory, are all of a beautiful golden yellow.

INFLUENCE OF COTTON SEED PRODUCTS UPON THE COMPOSITION OF MANURE OF CATTLE.

It is a well known fact that a very large proportion of the total fertilizing constituents of feed stuffs is found in the excrements of animals, the proportion of fertilizing constituents thus recovered being governed by the age and condition of the animal. In the case of fully grown animals the percentage of fertilizing ingredients thus recovered is much higher than in the case of young and growing animals, and by the employment of a feed rich in fertilizing, as well as nutritive constituents, it is possible to secure a manure much richer than that obtained from an ordinary feed. A mixture of cotton seed meal and hulls is much employed in fattening cattle for the market, and if the manures, both solid and liquid, are carefully collected and preserved, a considerable proportion of the value of the original feed stuff will be recovered in the manure.

To illustrate the superiority in fertilizing value of manure obtained as a result of feeding animals on cotton seed meal and hulls, analyses are given in the following table of manures resulting from an ordinary mixed feed and also from cotton seed meal and hulls.

Analysis of manure from different feeds.

	Manure from ordinary feed.		Manure from cotton seed meal and hulls.	
	Sample 1 Cow	Sample 2. Horse.	Sample 3. Cattle.	Sample 4. Cattle.
Phosphoric acid..........	0 28	0 46	0 96	0.67
Nitrogen..................	0 29	0.63	0 88	0.93
Potash....................	0.21	0 31	0.73	1.13

The analyses represent the composition of the manures in the fresh or nearly fresh condition, although samples 3 and 4 were slightly drier than sample No. 1 at the time of analysis.

A reference to the figures given in the above table will serve to emphasize the advantages of the employment of such high grade foods as cotton seed meal and hulls, where it is desired not only to furnish nutriment and flesh to animal, but fertilizing constituents to the soil as well.

Special acknowledgement is due to Dr. J. T. Anderson, Associate Chemist, and to Messrs. C. L. Hare and J. Q. Burton, Assistant Chemists, for the careful, painstaking and laborious attention given by them to the analytical work connected with the chemical portion of this bulletin, and also for valuable assistance rendered in the tabulation of results.

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