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Studies in Inheritance in Cotton

Improvement of Dharwar American Cotton by Hybridization

BY

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AND

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CONTENTS

LIST OF ILLUSTRATIONS

PLATES.

TEXT FIGURES.

STUDIES IN INHERITANCE IN COTTON.

The Improvement of Dharwar American Cotton by Hybridization.*

(Received for publication on the 23rd April 1928.)

I. Introduction.

Despite the many attempts to introduce and acclimatize American cotton in India between 1840 and 1870, there is only one area where it became and has continued to be a staple crop of the country. This is in that portion of the Bombay Presidency, and the neighbouring portions of the Nizam's Dominions, Madras and Mysore, which lies to the extreme south-east of the province and whose natural markets are Gadag and Hubli. Here New Orleans cotton was introduced by the then Collector of Dharwar (Mr. A. N. Shaw) in 1842.† The first crop was sown in August of that year, and yielded (near Hubli) at once a larger crop than was produced by the local *Kumpta* cotton with a higher ginning percentage (33·3 per cent. as against 24·2 per cent.). This experiment was, in fact, so successful that the matter was taken up seriously, an American cotton planter, Mr. Mercer, was stationed in this neighbourhood in 1843 and an experimental Farm was established at Kusugal in the Hubli Taluka. The result of many tests there with all kinds of exotic cottons was still in favour of New Orleans cotton, but owing to the prevalence of disease the experiments were soon after transferred to Gadag, where the crop grew much more healthily and gave a much higher yield.

The crop rapidly became popular, and by 1843 the area increased to 22,331 acres. This was only the beginning, and the cultivation became more and more extensive reaching 178,682 acres by 1861, in the districts

* The investigations recorded in the present bulletin were done partially under subsidy from the Indian Central Cotton Committee.

† An account of the early history of American cotton in Dharwar will be found in the Bombay Gazetteer, Vol. XXII (Dharwar), 1884.

of the Bombay Presidency alone In that year, a Lanchashire report stated that the Dharwar American cotton was of good staple and colour, clean and with the staple not seriously damaged by the ginning. It was valued $6\frac{1}{2}d.$ per pound in Liverpool when the best Surat cotton was selling at $5\frac{3}{4}d.$ per pound, and American qualities from middling to fair were selling at $4\frac{1}{4}d.$ per pound. In spinning tests it lost 15 per cent. in the blow room, when ordinary New Orleans (American) lost $17\frac{1}{2}$ per cent.

As early in 1850, the cotton had so far made its reputation that an agency of Manchester users of this cotton was established in the Dharwar District for saw-ginning and purchasing this cotton. The quality of the cotton grown from the acclimatized New Orleans seed was maintained, as was chosen by Mr. Forbes in 1861 but the complaints of mixing were rife, and were one of the causes for the passing of the Cotton Frauds Act of 1863. The Act was, however, a failure, and mixing of the cotton continues almost unabated to the present day. The area, in the two districts of the Bombay Presidency which grow this cotton, has increased in 1925-26 to 332,147 acres and much is grown in the adjoining tracts of which records are not available.

Such is a very short outline of the history of this very successful introduction of American cotton. The seed used, though of American origin, is now fully acclimatized and as fresh introductions do as well as that locally produced. It is known on the market usually as "Saw-ginned Dharwar" and locally is termed *Dodda-Hatti* or big-seeded cotton, *Vilayati-Hatti* or *Farangi-Hatti* (foreign cotton).

So far as the Bombay Presidency is concerned, it is now grown in almost every taluka of the Dharwar and Bijapur Districts, and in the Indian States and in the borders of these districts. So far as the British districts are concerned, the following figures show the distribution by talukas in 1925-26, and the relative area of this and of the local *Kumpta* cotton in each case :—

Taluka	Area in acres	
	Kumpta cotton	Dharwar-American cotton
Dharwar District.	Acres	Acres
1. Dharwar	29,261	824
2. Hubli	53,014	9,987

Taluka	Area in acres	
	Kumpta cotton	Dharwar-American cotton
Dharwar District—contd.	Acres.	Acres.
3. Kalghatgi	6,194	66
4. Bankapur	16,776	30,242
5. Haveri	52,140	32,041
6. Hangal	6,237	4,037
7. Hirekerur	10,000	10,280
8. Ranebennur	22,847	38,043
9. Gadag	60,240	74,030
10. Ron	43,980	83,970
11. Navalgund	104,946	9,605
TOTAL	405,635	263,525
Bijapur District.		
1. Bijapur	92,223	629
2. Indi	90,124	16,825
3. Sindgi	107,390	3,601
4. Bagewadi	76,280	9,220
5. Muddebihal	7,400	4,361
6. Bagalkot	89,488	..
7. Badami	37,702	..
8. Hungund	67,986	33,983
TOTAL	568,370	68,622

Perhaps the most typical centre of its cultivation is near the town of Gadag, and the climatic conditions which prevail there, in the matter of rainfall, mean maximum temperature and the mean minimum temperature, from the records of forty-three years are taken in the following tables for each month in the year :—

	Average rainfall inches.	Mean maximum temperature F.	Mean minimum temperature F.
January	..	87	61
February	..	93	66
March	..	100	70
April	1·0	102	74
May	2·0	100	74
June	2·5	97	73
July	2·5	93	72
August	1·0	91	71
September	5·0	90	72
October	3·0	90	70
November	0·5	88	63
December	..	86	61

The usual course of the season is usually something as follows. After a few ante-monsoon showers in April and May which may be heavy but cannot be relied upon, the land becomes fit for cultivation, and is usually ploughed (the previous crop having usually been *jowar*) with a light plough and then harrowed two or three times at intervals. No manure is usually given first to the crop, though the previous crop of *jowar* has usually been treated with two or three cartloads per acre of farm-yard manure. The seed is sown in September or the beginning of October, seven pounds of seed being used per acre. The practice is to sow in rows 21 inches apart, with 12 inches between the plants in the row. Three to four hoeings are given to the growing crop. Flowering commences in November and the plants are in full flower at the end of December or the beginning of January. Boll formation is most perfect in the second part of January and in February. The seed cotton is picked in two or three pickings and the harvest is over by the end of April. The cotton can usually be picked much cleaner than the local *Kumpta* cotton, as the leaves and bracts do not dry up as with the latter cotton.

The yield usually obtained varies from 200 to 600 pounds of seed cotton per acre—and the produce is usually sold without ginning as "Kapas." The total cost of production is about Rs. 30 per acre while the value of the produce is usually about Rs. 60 per acre, taking Rs. 250 per *Naga* (1,344 lb.) of seed cotton as a normal price.

The cultivation is generally carried out in medium black cotton soil, well-drained. Excess of rain or of water in the soil is injurious to the crop, and the crop disappears, in favour of *Kumpta* cotton.

The crop, though it is immune from the wilt disease which makes such havoc with the *Kumpta* cotton crop, is affected seriously by the cotton leaf-hopper or *Jassid*, by the cotton aphis, and particularly by the so-called "red leaf blight." The aphids appear specially when cloudy weather continues for long periods, and if they are abundant during the time the plants are in flower there is a large shedding of both flower buds and bolls. The *Jassids* by sucking the leaves, cause these latter to appear wrinkled and crumpled, and sap the vigour of the plants. Glabrous plants are more susceptible to attack by *Jassids* than hairy types. "Red leaf blight" appears during the later life of the plants, when dry east winds prevail, that is to say from the end of October until January. As the name implies, the leaves turn red and then curl and fall. If the attack is very severe the reddening extends to the bolls, and the plants either die or cease to flower. The glabrous types are more liable to it than the hairy ones. It has, so far, not been found to be associated with any parasite.

II. Improvement of Dharwar American Cotton by Selection.

Attempts at the improvement of cotton in the Dharwar American area either by the importation of exotic type from America or Egypt, or by selection from the type already acclimatized in the country have been in progress for many years. This has been particularly the case since 1901 when an experimental station was established at Dharwar, and supplemented in 1908 by another station at Gadag. It may at once be said, that, despite the greater care, all direct importations, whether from the United States or from Egypt, have failed,—largely as a result of the extreme development of red leaf blight. One outside cotton was at first a success,—the so-called Madras Cambodia cotton, which is an American and has reached India by way of Cambodia. It at first yielded equally well with the local Dharwar American cotton, and had a higher ginning percentage. Its success, in the area, was however, purely temporary and when tried, on a large scale under cultivator's conditions, it failed giving a poor crop in years of slightly heavier rain than ordinary with a weak staple which tended to deteriorate. It had, therefore, to be abandoned.

In view of this general failure with cottons from other centres, attention was concentrated on the selection of superior types from the mixture of various cottons known as "Dharwar American." That this was a mixture of various types had long been known,—and the Dharwar American cotton of to-day presents a mixed mass of heterogeneous material, hardly any two plants agreeing in all characters. Some plants have a more open habit of growth than others; some are sparingly hairy, some very hairy, while few are glabrous; many plants have pale yellow flowers, some flowers are a bright yellow while a few are white; the majority of the flowers have no "eye" at the base of the petals, but a few have a faint or bright red "eye" indicating presence of Sea-Island or Egyptian influence; the seed of some plants is white, and of some is green, while a very small percentage has either fully or partially naked seeds. The amount and quality of lint also varies widely from plant to plant. The whole of these types were minutely studied and separated by Mr. Kottur in the years previous to 1913.* In that year he showed that in the mixture of types, the hairy ones were far more immune to red leaf blight than the others, while they were less attacked by *jassids*. Finally several strains, breeding true, were isolated, which not only grew healthily in the Dharwar American area, but which yielded highly, had the full staple expected in this type of cotton and gave much higher ginning percentage than the cotton usually grown.

One of these now known as "Gadag No. 1" proved so successful that it has become the standard type all over the area, and the only trouble is now to produce enough seed to meet the demand. To show how far this selection is an improvement on the ordinary growth the average of five years' trial may be given. The Gadag No. 1 seed gave an average yield of *Kapas* of 466 lb. per acre with a ginning outturn of 34·0 per cent.; the ordinary Dharwar American seed gave, under the same conditions, a yield of *Kapas* of 390 lb. per acre with a ginning outturn of 29·3 per cent. This selection is of the Upland Georgian type, and is now locally known as "Upland-hatti" or Upland cotton. It has a staple of a clear seven-eighths of an inch, and represents the best that it has been possible to obtain by selection from the existing Dharwar American cotton. The following report on the lint of this Gadag No. 1 cotton, from the crops of 1923-24, 1924-25 and 1925-26, made by the Technological Laboratory of the Indian Central Cotton Committee, shows the general characters of this cotton.

* Kottur, G. L.—Dharwar American Cotton, *Bombay Dept. Agri. Bull.* 106, 1920.

GADAG NO. 1 (DHARWAR AMERICAN).

I. Size of crop. About 20,000 bales.

II. Grader's report.

—	Season 1923-24	Season 1924-25	Season 1925-26
Class	Fine western .	F. G to F western	Fine western.
Colour . . .	..	..	White.
Staple length . .	13/16 to 15/16 inch.	$\frac{5}{8}$ to $\frac{3}{4}$ inch . .	$\frac{5}{8}$ to $\frac{7}{8}$ inch.
Regularity . . .	Not as regular as Dharwar No. 1.	Inferior to 1923-24 sample and not a fair sample of Gadag cotton.	Irregular.

III. Fibre particulars.

1. FIBRE LENGTH DISTRIBUTION (BALLS SORTER)

Mean group length in eighths of an inch	PERCENTAGE		
	Season 1923-24	Season 1924-25	Season 1925-26
2	0·2	0·2	1·1
3	1·8	2·0	2·3
4	3·4	4·4	4·4
5	6·4	11·6	9·7
6	13·8	25·1	20·9
7	29·4	35·5	35·2
8	31·2	16·5	20·8
9	11·4	4·5	5·5
10	2·1	0·2	..
11	0·3	..	..
2*a*. Mean fibre length by Balls Sorter	0·90	0·82	0·83
2*b* Mean fibre length by Baer Sorter	0·90	0·81	0·84
3. Mean ribbon width inch . .	0·00070	0·00067	0·00071
4. Mean convolutions per inch .	130	132	134

IV. Spinning Tests.

Spinning master's report. 1923-24 cotton a trifle seedy; 1924-25 cotton contains too much leaf and husk, is creamy in colour; 1925-26 cotton white, leafy and neppy.

V. Remarks.

The 1924-25 season was bad compared with 1923-24 and this no doubt accounts for the lowered grade and increased dirtiness of the cotton in the former season as well as for the diminished length and strength of staple. In consequence while the 1923-24 sample is suitable for standard warp yarn for counts up to 38'*s* the 1924-25 cotton gives poor results even for 20'*s*. In the 1925-26 season this cotton while better than in 1924-25 is still not up to the standard of 1923-24 and is suitable for standard warp yarn up to 30'*s*. The staple is slightly better than in 1924-25 but still much shorter than in 1923-24. The 1925-26 cotton is again dirty and even more serious in its much increased neppiness.

III. Attempts to Produce Improved Cotton for the American Tract by Hybridization.

It is clear that the improvement in Dharwar American cotton represented by the Gadag No. 1 type, while considerable only leaves us with a moderate cotton and it is natural to aim at a further improvement, which can only, so far as we know, be achieved by hybridization. Before indicating what has been done in this direction it will be well to describe the characters which must be contained in a really suitable type for cultivation in the area under consideration.

In general terms, the best cotton for this tract has already been described by Kottur[1] as follows:—"The type which is perfectly sympodial growing tall with internodes sufficiently long to promote the healthy growth of fruiting branches, flowering early so as to produce all its flowers in the month of December, and bearing big bolls, is the one which is ideal for the Dharwar American tract." On these considerations the type known as Gadag No. 1 was selected, but it will be noticed that this ignores the question of staple. But in addition to the characters specified by Kottur, there is always the advantage to be secured by getting a vigorous hardy type which also has a staple of at least over one inch, and if possible up to 1⅛ inch. If this area is to

[1] Kottur, G. L.—Dharwar American Cotton; its History, Cultivation and Improvement. *Bombay Dept. Agri. Bull.* 106, 1920.

compete with many of the long-staple Upland American varieties such as, for instance, *Durango*—a type with such a staple must be considered as an essential part of the ideal cotton type.

Now in Gadag No. 1 itself there are always a few plants which give lint with a staple of over one inch, but this is not hereditary, and further selection in this manner has been a failure. It was clear therefore that the only resource for obtaining a cotton which retained all the desirable qualities of Gadag No. 1 but had a better staple, more nearly equal to the better American Upland varieties was only likely to be obtained by crossing with suitable American or Egyptian long staple types capable of growing at Dharwar or Gadag.

Now similar crosses had been previously attempted between Dharwar American cotton and many such long staple types in the years from 1901-07, with no satisfactory results and the resulting material had ultimately to be abandoned. Further attempts demanded the previous provision of pure line types of the material used for crossing with Gadag No. 1 cotton and for this reason the following supposed pure varieties were obtained for the selection of the best long-staple plant. *Upland American:*—Durango, Columbia, Snowflake, Improved-Cook, Black-seed, Meade, Truitt, Lonestar, Dixie, Ideal, Webb.

Egyptian. Afifi, Abassi, Pima.

Sea-Island. Two unnamed strains.

The seed supplied of each of these varieties proved to be mixed, and three to four seasons were needed to obtain pure types from them. When this had been done, the resulting pure material did not, in the case of the Upland types, show sufficient advantage in the point of staple to make crossing worth while. The Egyptians grew very unhealthily being attacked with *Macrosporium* at an early stage, and owing to the lateness in flowering, they were very difficult to use for crossing with the Gadag No. 1 type. On the other hand, the Sea-Island cotton grew quite well in the earlier part of the season and produced a large number of flowers. Though they were badly attacked, later on, by the red leaf blight, they did actually ripen a certain number of bolls, and no difficulty was found in using these types for crossing purposes. The original Sea-Island cotton types were obtained in 1915, but the material was not completely developed as a pure line until 1920 when the cross with Gadag No. 1, an account of which forms the subject of the present bulletin, was first made by Kottur. He also grew the first and second generation of the cross in 1921 and 1922, but the whole of the material was handed over to the present authors in 1923. Since then the study of the various generations of the cross has been conducted by them at the Experimental Station at Dharwar.

IV. The Parents of the Cross.

The parents of the proposed cross may first be described. The Gadag No. 1 strain of *Gossypium hirsutum* was, as already indicated, isolated by Kottur[1] in 1914, from the mixed material contained in Dharwar American cotton grown at Gadag. The other parent was a pure strain of Sea-Island cotton (*Gossypium barbadense*). The principal special characteristics of each of these parents may be now described and compared. A picture of a typical plant of each of the parents is shown in Plate I.

1. Hairiness of plants.

The stem and petiole of Gadag No. 1 are studded with simple long hairs and a few stellate hairs. The leaves, especially on the lower surface, are also hairy, but in this case short stellate hairs predominate, with a few simple hairs. In the strain of Sea-Island cotton used, the stem, petiole and leaf are completely glabrous, and thus differ completely from the other parent.

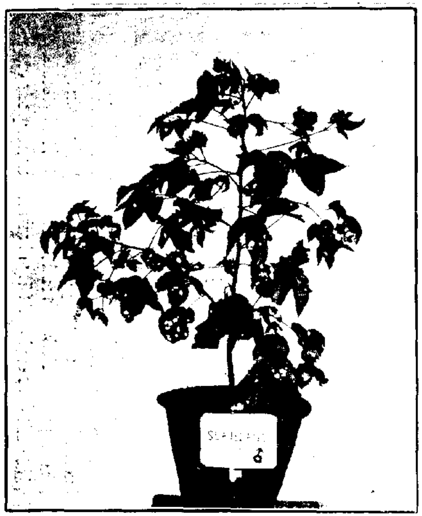
2. The number of monopodia.

The number of monopodia on each plant in the case of Gadag No. 1 varies from none to five, the most frequent number being two. About 70 per cent. of the whole of the plants examined have either two or three monopodia per plant. The number of monopodia on a number of plants taken at random in three successive years is represented by the following frequency figures :—

Number of monopodia (Gadag No. 1)	Frequency		
	1924-25	1925-26	1926-27
0	9	..	2
1	51	22	39
2	100	71	100
3	33	54	54
4	6	40	5
5	1	7	..
6	..	6	..
Total .	200	200	200

[1] Kottur, G. L.—Dharwar American Cotton : its History, Cultivation and Improvement. *Bombay Dept. Agri. Bull.* 106, 1920.

PLATE I.



Parental plants of the cross.

In the case of the strain of Sea-Island cotton used, the number of monopodia per plant was similar, varying from none to 3, the frequency of occurrence of different numbers being shown in the following table for three successive years :—

Number of monopodia (Sea-Island cotton)	Frequency		
	1924-25	1925-26	1926-27
0	39	13	38
1	*113*	41	*96*
2	42	*65*	58
3	6	57	8
4	..	23	..
5	..	1	..
Total .	200	200	200

Both parents are, therefore, highly sympodial cottons, the Sea-Island type being a little more markedly sympodial than the American type used.

3. Position of first fruiting branch.

The position at which first fruiting branch arises varies, in the case of Gadag No. 1, from the third to the seventh node on the main stem, the most frequent position being the fourth or fifth node. The exact position on a number of plants taken at random in three successive years is represented by the following frequency figure :—

Position of first fruiting branch (Gadag No. 1)	Frequency		
	1924-25	1925-26	1926-27
3rd node	7	55	2
4th ,, ...	10	*100*	29
5th ,, ...	*111*	35	*120*
6th ,, ...	71	8	49
7th ,, ...	1	2	..
Total .	200	200	200

In the case of the Sea-Island cotton used, the position of the first fruiting branch varies from the fourth to the ninth node, with the greatest frequency at the sixth node, or a little higher than with the American parent. The occurrence of different positions is shown in the following table for three successive years :—

Position of first fruiting branch (Sea-Island cotton)	Frequency		
	1924-25	1925-26	1926-27
4th node	..	11	1
5th „	8	43	16
6th „	*106*	*105*	*105*
7th „	70	33	62
8th „	10	7	15
9th „	5	1	1
10th „	1	..	..
Total .	200	200	200

4. Colour of the petiole.

In the case of Gadag No. 1, the red colour of the petiole at the point where it divides to form the leaf veins is very prominent and characteristic. In the Sea-Island cotton the colour at this point is fainter and pink rather than red. The difference is very characteristic, and can be seen even in the seedlings.

5. Measurement of the leaves.

All the measurements of the leaves were made on the primary leaves borne at the tenth, eleventh and twelveth nodes on the main stem which proved to be the most constant on the plants. Taking these as the standard, a comparison was made of the size of different parts of the leaf in 1924-25 as follows :—

(*a*) *Length of leaves.* The leaf length was measured from the base of the blade to the apex of the terminal lobe, and the frequency in each of the two parents was as follows :—

Leaf length	Frequency	
	Gadag No. 1	Sea-Island
71—80 mm.	23	12
81—90 mm.	53	25
91—100 mm.	77	57
101—110 mm.	36	45
111—120 mm.	11	35
121—130 mm.	..	20
131—140 mm.	..	6
Total .	200	200

Though the mean length of the Sea-Island cotton leaf is greater than that of the American type, yet the characters overlap very completely, and there is no very clear distinction in this matter between the two parents.

(*b*) *Length of middle lobe of leaf.* The frequency of occurrence of various lengths of the middle lobe of the leaf in the two parental types is shown below :—

Middle lobe length	Frequency	
	Gadag No. 1	Sea-Island
38—43 mm.	27	..
44—49 mm.	47	6
50—55 mm.	76	16
56—61 mm.	33	25
62—67 mm.	17	41
68—73 mm.	..	39
74—79 mm.	..	26
80—85 mm.	..	26
86—91 mm.	..	9
92—97 mm.	..	12
Total .	200	200

The lobe length of the Sea-Island cotton is on the whole greater, but it is also far more variable. But the character completely overlaps in the two parental types.

(c) *Breadth of middle lobe of leaf.* The frequency of occurrence of various breadths of the middle lobe of the leaf of the two parents is as follows :—

Middle lobe breadth	Frequency	
	Gadag No. 1	Sea-Island
27—32 mm.	3	..
33—38 mm.	25	1
39—44 mm.	83	9
45—50 mm.	67	33
51—56 mm.	19	69
57—62 mm.	3	45
63—68 mm.	..	36
69—74 mm.	..	7
Total	200	200

In this case, as with the middle lobe length the size of the leaf of the Sea-Island cotton is on the whole greater, but it is much more variable, while the character completely overlaps in the two parental types.

(d) *The leaf factor.* This figure suggested by Leake [1] is substantially represented by the length of the middle lobe of the leaf divided by its breadth. Taking this figure for each of the two parents, the character in 1924-25 is shown by the following frequency table.

Leaf factor	Frequency	
	Gadag No. 1	Sea-Island
0·9	16	10
1·0	31	17
1·1	40	29
1·2	74	58
1·3	31	49
1·4	8	30
1·5	..	7
Total	200	200

Under Leake's classification, the leaves of both parents would be marked as broad-lobed, as they have a leaf factor less than 2. There

[1] Leake, H. M. and Ram Prasad. Studies in Indian Cottons, Part I. *Mem. Dept. Agri. India Bot. Ser.*, Vol. VI, No. 4, 1914.

is little difference between the two, but on the whole the lobe of the leaf of Sea-Island cotton is a little more elongated.

(*e*) *The leaf vein angle.* Another leaf character which has some interest in the present case is the angle between the two chief lateral veins of the leaf, which in some measure denotes the width of the leaf. The character in 1924-25 in the two parents of the cross is shown in the following frequency table.

Leaf vein angle degrees	Frequency	
	Gadag No. 1	Sea-Island
69–74	4	..
75–80	22	..
81–86	42	1
87–92	91	4
93–98	21	12
99–104	18	53
105–110	2	91
111–116	..	18
117–122	..	19
123–128	..	1
129–134	..	1
Total .	200	200

It will at once be noticed that the angle is on the whole very much greater in Sea-Island cotton than in the American parent. There is, however, a good deal of overlapping which must prevent its being used as a diagnostic character.

(*f*) *Length of petiole.* The Sea-Island cotton parent has, on the whole, a longer petiole than in the American parent, but again there is so much overlapping as to prevent the character being useful in diagnosis. The following frequency figures, from the 1924-25 crop, show this clearly.

Length of petiole	Frequency	
	Gadag No. 1	Sea-Island
Below 55 mm.	3	..
56—65 mm.	48	..
66—75 mm.	98	22
76—85 mm.	46	20
86—95 mm.	5	32
96—105 mm.	..	50
106—115 mm.	..	39
116—125 mm.	..	33
Over 126 mm.	..	4
TOTAL	200	200

6. Measurements of the bracts.

The bracts show very characteristic differences in the two parents used in the cross under discussion. In order to ensure the measurements being comparable, the bracts of newly opened flowers on the first or second node of the tenth primary fruiting branch were always taken for comparison. All the following comparisons were done on the 1924-25 crops grown side by side at Dharwar.

(*a*) *Length of bracts.* The length of the bracts was very different in the two parents as the following frequency table shows.

Bract length.	Frequency	
	Gadag No. 1	Sea-Island
17—19 mm.	5	..
20—22 mm.	8	2
23—25 mm.	53	2
26—28 mm.	63	9
29—31 mm.	37	24
32—34 mm.	32	47
35—37 mm.	2	65
38—40 mm.	..	38
41—43 mm.	..	9
44—46 mm.	..	4
TOTAL	200	200

Though the difference is most striking in the field there is so much overlapping in this character that it seems to be of little use as a diagnostic character.

(*b*) ***Width of bracts.*** The bracts in the Sea-Island type are, on the average, distinctly larger in every way than in the American parent (Gadag No. 1) but the sizes overlap a good deal, as the following frequency figures indicate.

Bract width	Frequency	
	Gadag No. 1	Sea-Island
9—11 mm.	3	..
12—14 mm.	30	..
15—17 mm.	97	..
18—20 mm.	57	17
21—23 mm.	10	20
24—26 mm.	3	74
27—29 mm.	..	58
30—32 mm.	..	25
33—35 mm.	..	5
TOTAL	200	200

(*c*) *Number of teeth per bract.* In this character also the average figure is higher with the Sea-Island parent, but again there is considerable overlapping, which prevents the use of the character for diagnostic purposes.

Teeth per bract	Frequency	
	Gadag No. 1	Sea-Island
5	34	..
6	58	..
7	70	..
8	31	14
9	5	51
10	2	66
11	..	56
12	..	10
13	..	3
TOTAL	200	200

7. Flower characters.

The differences in respect to several flower characters are distinct and uniform. Thus the colour of the petals of the freshly opened flowers in the Gadag No. 1 (American) type is always white, while that of the Sea-Island parent is bright yellow. With regard to the petal spot or eye, so characteristic of the flower of certain cotton varieties, this is always entirely absent in the Gadag No. 1 parent, while in the Sea-Island type there is always an extensive bright red eye.

In the matter of the size of the petal, the average length is very much greater with the Sea-Island parent, but in this character, as in so many others, the figures obtained from different plants overlap. The following frequency figures show the results obtained with the 1924-25 crop, taking the same flowers as standards as were used in the bract measurements.

Petal length	Frequency	
	Gadag No. 1	Sea-Island
19—24 mm.	21	..
25—30 mm.	85	..
31—36 mm.	*88*	37
37—42 mm.	6	*94*
43—48 mm.	..	64
Over 48 mm.	..	5
Total	200	200

8. Boll characters.

One of the striking differences between the parental types is the colour of the bolls, which forms an easy diagnostic character in the field. In the Gadag No. 1 parent the colour is light green, easily distinguishable from the bright green and shiny appearance of the Sea-Island cotton. The surface of the bolls in Gadag No. 1 is smooth, and glands appear simply as specks here and there and are hardly visible. On the other hand the surface of the Sea-Island bolls is rough as the glands are situated thickly and appear very prominently, forming a very marked distinction between the types.

As regards the number of loculi in the bolls, the mean number was determined for a large number of plants of both types, all the bolls on each plant early in February being used for the determinations. The results are shown in the following frequency table.

Mean number of loculi per boll	Frequency	
	Gadag No. 1	Sea-Island
3·0—3·1	..	179
3·2—3·3	..	21
3·4—3·5	..	..
3·6—3·7	9	..
3·8—3·9	26	..
4·0—4·1	132	..
4·2—4·3	28	..
4·4	5	..
Total	200	200

We have here, in the number of locks per boll, a matter in which the types are quite distinct, the Sea-Island cotton being almost exclusively a three lock type, with *very* few bolls with four locks. On the other hand the Gadag No. 1 is chiefly a four lock type with relatively few bolls with three locks and a few with five locks.

(*a*) *Length of boll.* The basis of measurement was the average of the bolls per plant in 1924-25 obtained by measuring, by means of callipers, five well developed bolls per plant from the nectary at the base to the tip of the bolls. The results show that while the Sea-Island type has a slightly larger boll than Gadag No. 1, there is no really recognizable distinction on this account. The following frequency figures illustrate this.

Length of boll	Frequency	
	Gadag No. 1	Sea-Island
26—28 mm.	13	..
29—31 mm.	47	33
32—34 mm.	*86*	33
35—37 mm.	52	*57*
38—40 mm.	2	56
41—43 mm.	..	18
44—46 mm.	..	3
Total	200	200

(*b*) *Diameter of boll.* The method of obtaining standard figures for a large number of plants of each parental type with regard to this character was the same as that adopted in determining the length of the bolls. The following frequency table shows that there is little difference in the two types examined :—

Diameter of boll	Frequency	
	Gadag No. 1	Sea-Island
20—22 mm.	34	*132*
23—25 mm.	*112*	57
26—28 mm.	52	11
29—31 mm.	2	..
Total	200	200

9. Staple of lint.

As the main purpose of making the cross described in the present bulletin was to increase the length of staple in Gadag No. 1, considered as a type of Dharwar American cotton, the study of the staple of the parental types has special interest. The method adopted in determining the length was by combing out the lint *on the seed*, and measuring those that start from the middle of the seed. Five bolls per plant were taken and the mean of these five measurements was taken as representing that plant.

The results of such staple measurements in Gadag No. 1 in four successive seasons are shown below :—

Length of staple (Gadag No. 1)	Frequency			
	1923-24	1924-25	1925-26	1926-27
13—15 mm.	..	..	..	1
16—18 mm.	6	5	5	10
19—21 mm.	*59*	27	25	*54*
22—24 mm.	34	*58*	*57*	33
25—27 mm.	1	10	13	3
Total .	100	100	100	100

The lint from most of the plants has a staple, determined as above described, of between 19 and 24 millimeters.

We may compare with this the lint from the proposed Sea-Island parent which came as follows :—

Length of staple (Sea-Island cotton)	Frequency			
	1923-24*	1924-25	1925-26	1926-27
28—30 mm.	..	..	10	5
31—33 mm.	..	..	10	3
34—36 mm.	4	7	*42*	20
37—39 mm.	24	13	25	*48*
40—42 mm.	24	*43*	13	18
43—45 mm.	*28*	33	..	6
46—48 mm.	12	3	..	..
49—51 mm.	8	1	..	..
Total .	100	100	100	100

* The actual determinations of staple in 1923-24 were only done with seeds from 25 plants, but they have been calculated to 100 plants so as to compare readily with the others.

The opening of the bolls in the Sea-Island cotton in 1925-26 and 1926-27 was very bad, and hence the reduction in staple. But without even allowing for this, it will be seen that *all* the plants used have a higher staple than any of those of Gadag No. 1. The lint from most of the plants has a staple, determined as above described, of between 34 and 45 millimeters.

10. Ginning percentage.

The produce of a number of plants was ginned on a roller gin and the proportion of lint to the whole weight of seed cotton determined for a number of plants. The results of such determinations in Gadag No. 1, in four successive seasons are shown below :—

Ginning percentage (Gadag No. 1)	Frequency			
	1923-24	1924-25	1925-26	1926-27
25—26 per cent.	..	5	..	..
27—28 ,,	2	10	1	1
29—30 ,,	8	21	7	14
31—32 ,,	35	*34*	38	*45*
33—34 ,,	*40*	20	*43*	32
35—36 ,,	13	8	7	7
37—38 ,,	2	1	3	1
39 ,,	..	1	1	..
Total	100	100	100	100

The most frequent ginning percentage varies from 31 to 34 per cent.

We may compare with this the ginning outturn from the proposed Sea-Island parent which came as follows :

Ginning percentage (Sea-Island cotton)	Frequency			
	1923-24*	1924-25	1925-26	1926-27
10—11 per cent.	..	..	7	..
12—13 „	..	..	9	..
14—15 „	8	1	15	4
16—17 „	..	1	12	4
18—19 „	8	7	15	12
20—21 „	..	12	12	19
22—23 „	20	31	11	29
24—25 „	32	21	13	18
26—27 „	20	19	5	6
28—29 „	12	8	1	6
30 „	..	..	..	1
Total .	100	100	100	100

Of course, the ginning is far lower than with the American parent, and is far more variable especially when the crop grows badly as in the last two years recorded. But there is a certain amount of overlapping in this character, which prevents it being used as a diagnostic character.

11. Lint index.

The lint index is the weight of lint per one hundred seeds, and, therefore, indicates the amount of lint obtainable irrespective of the size of the seeds themselves. Where the seed weight is the same in two types of cotton, the lint index and the ginning percentage give similar relationships. This is the case in the present instance and hence there is no special need for dealing with the lint index separately.

* From 25 plants only.

The seed weight as determined in the two cases in three successive years may be recorded. The results with Gadag No. 1 are as follows :—

Seed weight (Gadag No. 1)	Frequency		
	1924-25	1925-26	1926-27
5—6 grm.	..	1	..
7—8 „	15	36	20
9—10 „	62	61	73
11—12 „	21	1	7
13—14 „	2	1	..
Total .	100	100	100

Corresponding figures for the Sea-Island parent are as follows :—

Seed weight (Sea-Island)	Frequency		
	1924-25	1925-26	1926-27
5—6 grm.	..	10	..
7—8 „	11	41	23
9—10 „	43	41	53
11—12 „	41	8	23
13—14 „	5	..	1
Total .	100	100	100

In both cases the mode is, in every year, between 9 and 10 grams per 100 seeds.

12. Characters of the seed.

The seeds of the Gadag No. 1 parent are entirely fuzzy, the fuzz being greenish white in colour, while those of the Sea-Island strain are naked with little fuzz at the tip and on the raphe. In this case, the fuzz is green fading to brown in some cases, differing thus markedly from the light greenish white fuzz of Gadag No. 1.

Considering the whole of the characters of the parents of the proposed cross, it may be stated that we have two strains of cotton very similar as to the general growth of the plants, both being sympodial types, and as to the seed weight. They are not widely different in all the leaf characters, except the colour of the petiole at the base of the leaf. They differ to some extent as regards the number of teeth in the bracts, and the ginning percentage of the seed cotton, but the differences do not separate the types completely. They are, on the other hand, contrasted with one another in their characters as shown in the following list :—

	Gadag No. 1	Sea-Island
1. Hairiness of stem, petiole, and leaf .	Fully hairy . .	Glabrous.
2. Colour of pulvinus spot . . .	Red . . .	Pink.
3. Colour of flower petals . . .	White . . .	Bright yellow.
4. Coloured eye in flower . . .	Absent . . .	Present bright red.
5. Petal length	19 to 39 mm. .	31 to 54 mm.
6. Colour of boll	Light green and dull	Deep green and shining.
7. Surface of boll	Smooth . .	Rough.
8. Mean number of loculi in boll . .	3·7 to 4·4 . .	3·0 to 3·2.
9. Length of staple	16 to 27 mm. .	28 to 48 mm.
10. Fuzz on seed	Seed fuzzy . .	Seed naked except for little fuzz at tips.
11. Colour of seed fuzz . . .	Greenish . .	Green, fading to brown.

We shall now see how these contrasted characters, and a few of the others already named, behave on crossing the parental types described.

V. The Method of Selfing and Making the Cross.

The fact of natural crossing among cottons grown near one another is now generally recognized, though the amount of such cross fertilization varies much with different types of cotton. Balls[1] has shown that about 5 per cent. of crossing takes place with the Egyptian crop, and Leake[2] has reached a similar figure for the north Indian cottons. Kottur[3] working with *Kumpta* cotton and Patel[4] with Gujarat cottons (both being types of *Gossypium herbaceum*) state that about 2 per cent. of crossing is normal. It is probably largely brought about by insects and especially by bees.

The amount of cross fertilization which would normally take place between Gadag No. 1 and Sea-Island cotton at Dharwar was determined by growing these in adjacent lines, two feet apart. No other American cottons were grown anywhere near. The seed obtained from each row was grown separately. The result showed that out of 375 plants from Gadag No. 1, not a single one was found to be off the type, but out of 178 plants from Sea-Island cotton, eight plants were not true to the Sea-Island type, and resembled exactly the first generation of the cross between these cottons. These figures indicate that cross fertilization does take place, but that it is more active when Sea-Island is the female parent, possibly because the flowers of this type are more attractive to insects. These figures indicate 4·5 per cent. of crossing in this particular case under the conditions described.

As crossing *does* take place it is necessary to protect the flowers in all cultures from such natural crossing and the method used for doing so was by ringing the flowers in the manner described by Kottur[3].

The crosses were made by emasculating the flowers of what it was intended to make the female parent early in the morning before 8.0 A.M., using flowers which would open the same day at noon. The flowers thus operated upon were then protected by small paper bags. The pollen from the male parent is then applied at about 2-0 P.M. on the same day. One pollination was found to be sufficient, and over 50 per cent. of success in ripe bolls was always obtained during five years of work. In all the crosses made and recorded in the present bulletin, the American cotton, Gadag No. 1, was the female parent, and the Sea-Island cotton was the male parent.

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[1] Balls, W. L. Cotton Plant in Egypt, London (1919).

[2] Leake, H. M. and Ram Prasad. Studies in Indian Cottons, Part I. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. VI, No. 4, 1914.

[3] Kottur, G. L. Studies in Inheritance in Cotton I. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. XII, No. 3, 1923.

[4] Patel, M. L. and Patel, S. J. Studies in Gujarat Cottons, Part IV : Hybrids between *Broach-Deshi* and *Goghari* Varieties of *Gossypium herbaceum*. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. XIV, No. 4, 1927.

VI. The Characters of the Hybrid Plants.

The cross between a pure strain of *Gossypium hirsutum* (Gadag No.1) and one of *Gossypium barbadense* (Sea-Island cotton) already described was first made by Kottur in 1920. The F_1 generation of the cross was grown at Gadag in 1921, and the F_2 generation from self fertilized flowers in 1922. Unfortunately the rains failed that year and the whole crop was lost. The F_1 and F_2 generations were again grown from reserve seed at Dharwar in 1923, when the work was transferred to the present authors. Since then the F_1 and F_2 generations have been thoroughly studied, the F_3 generation grown in 1924, and the F_4 generation in 1925. In the present chapter of this bulletin, the authors wish to follow, through those four generations of the cross, the behaviour of the characters already indicated.

(A) Hairiness of the plants.

On account of the supposed relationship between hairiness and resistance to red leaf blight, there was special importance attached to the study of this character. Starting with the fully hairy Gadag No. 1 type and the totally glabrous plants of Sea-Island cotton, it was found that the F_1 generation of the cross gave plants the stalk and petiole of which were quite glabrous (except for a few hairs at the point where the petiole joins the blade) and the leaf on both surfaces, was sparingly hairy. This behaviour suggests that the hairiness on the stem and petiole is a recessive character, and that on the leaf is incompletely dominent.

In the F_2 generation there was a splitting of types giving plants as follows :—

Total number of plants examined	774
Very hairy plants like Gadag No. 1 (H)	31
Stem, petiole and leaves sparingly hairy (Sp. H)	75
Leaves only hairy as in F_1 generation (L. Sp. H)	388
Glabrous plants like Sea-Island (G)	280

Taking the first two types (H and Sp. H) together, the proportion between the three kinds of hairiness was as follows :—

Hairy types	Leaf only hairy types	Glabrous types
1	3·66	2·64

It was noticed that 66 per cent. of the hairy plants escaped red leaf blight altogether, while most of the glabrous types were very badly attacked. The close connection of hairiness with immunity from this disease seems clear.

The seed of a number of plants of each of the above four types were grown in the F_3 generation with results as now described.

1. Four plants which were fully hairy, like Gadag No. 1 in the F_2 generation yielded progeny in the F_3 generation as follows :—

Plant No.	Total number of progeny	Hairiness			
		H	Sp. H	L. Sp. H	G
1	72	39	32	1	0
2	80	38	41	1	0
3	34	23	8	3	0
4	26	18	8	0	0

As the difference between the " H " and " Sp. H " is merely one of degree we may say that 207 out of 212 plants had the hairy character more or less developed of their parent in the F_2 generation.

2. Eight plants which were sparingly hairy (Sp. H) all over in the F_2 generation yielded progeny in the F_3 generation as follows :—

Plant No.	Total number of progeny	Hairiness				Proportion of classes		
		H	Sp. H	L. Sp. H	G	H and Sp. H	L. Sp. H	G
1	64 . .	0	23	41	0	1	1·8	0
2	46 . .	5	8	33	0	1	2·5	0
3	92 .	3	21	66	2	1	2·75	0·1
4	72 . .	0	61	9	2	7·1	1	0·25
5	60 . .	16	32	12	0	4·0	1	0·
6	96 . .	20	50	24	2	2·9	1	0·1
7	81 . .	46	24	11	0	6·4	1	0·
8	97 . .	29	50	18	10	4·4	1	0·6

The results are of three classes. The first three give large proportion of progeny without the hairy character of the stem and petiole but retaining that of the leaves. The number of such plants is from 1·8 to 2·75 times that of those retaining the hairy character throughout. The second class (plants 4 to 7) retain the generally hairy character in the greater part of the progeny, the number of such plants being from 2·9 to 7·1 times greater than those with hairs only on the leaves. The eighth plant has a substantial proportion of glabrous plants, but otherwise it gives results similar to the second class.

It seems clear that whatever influence has caused the reduction in the hairiness in the F_2 generation has continued its activity in certain cases in the F_3 progeny.

3. Twenty-three plants in which the leaf only was sparingly covered with hairs (L. Sp. H) in the F_2 generation yielded progeny in the F_3 generation as follows :—

Plant No.	Total number of progeny	Hairiness				Proportion of classes		
		H	Sp. H	L. Sp. H	G	H and Sp H	L. Sp. H	G
1–4	234 . .	0	0	234	0	0	1	0
5	88 . .	2	11	75	0	1	5·8	0
6	88 . .	1	13	74	0	1	5·3	0
7	57 . .	1	9	47	0	1	4·7	0
8	57 . .	3	12	42	0	1	2·8	0
9	41 . .	0	0	22	19	0	1·2	1
10	36 . .	0	0	30	6	0	5·0	1
11	39 . .	0	0	15	24	0	0·6	1
12	31 . .	1	0	14	16	0·06	0·9	1
13	30 . .	0	0	14	16	0	0·9	1
14	75 . .	1	0	7	67	0·01	0·15	1
15	40 . .	0	0	27	13	0	2·0	1
16	76 .	0	0	34	42	0	0·8	1
17	78 . .	0	1	36	31	0·03	1·2	1
18	74 . .	0	4	35	35	0	1·0	1
19	76 . .	0	3	70	3	1	23·0	1
20	95 . .	1	3	67	24	0·1	2·8	1
21	81 . .	2	4	66	9	0·7	7·3	1
22	88 . .	3	8	74	3	3·7	24·7	1
23	73 . .	6	11	37	19	1·0	2·0	1

In this case it is evident that we are in face of a very complicated problem in inheritance. Certain plants (1 to 4) have bred true to the character in the parent. Others (5 to 8) have given no glabrous progeny, but a variable proportion of plants hairy all over and only on the leaves; a third group (9 to 20) with a very varying proportion of glabrous plants, but substantially as completely hairy ones; and a fourth lot which gives a considerable proportion of all degrees of hairiness. The F_4 generation may enable this confusion to be cleared up.

4. Thirteen plants which were glabrous in the F_2 generation yielded progeny in the F_3 generation as follows:—

Plant No.	Total number of progeny	Hairiness			
		H	Sp. H	L. Sp. H	G
1	14	0	0	0	14
2	38	0	1	1	36
3	28	0	0	2	26
4	30	0	0	2	28
5	99	0	0	3	96
6	27	0	1	1	25
7	73	0	0	1	72
8	32	0	0	2	30
9	48	0	0	4	44
10	32	0	0	0	32
11	62	0	1	2	59
12	50	0	0	2	48
13	25	0	0	3	22

Here we have glabrous plants giving *almost* entirely glabrous progeny, but out of a total of 558 plants 3 are generally though sparingly hairy, and 23 are sparingly hairy on the leaves only. Though, therefore, the glabrous character breeds almost true, yet this is not entirely the case, and the matter demands further investigation.

To elucidate the inheritance of hairiness further seeds derived from a number of plants of known character in the F_2 and F_3 generations were grown and the results in the F_4 generation noted.

(*a*) *All the plants with one exception which were fully hairy (H) or completely but sparingly hairy (Sp. H) in the F_2 and F_3 generations bred true to the hairy character in the F_4 generation* : though the extent of the hairiness varied much. The records for the progeny of thirty F_3 plants of this kind are given :—

Plant No.	Hairiness in F_3	Total No. of progeny	Hairiness in F_4			
			H	Sp. H	L. Sp. H	G
1	Sp. H . .	10	3	7	..	..
2	H . .	45	43	2	..	..
3	H . .	58	58	..	..	..
4	H . .	9	9	..	..	..
5	H . .	40	8	32	..	..
6	H . .	57	13	44	..	..
7	H . .	57	10	47	..	..
8	H . .	31	8	23	..	..
9	Sp. H . .	18	2	16	..	..
10	H . .	40	39	1	..	..
11	Sp. H . .	47	25	22	..	..
12	H . .	42	22	20	..	..
13	H . .	60	59	1	..	..
14	H . .	51	51	..	..	..
15	H . .	45	26	19	..	..
16	H . .	57	13	44	..	..
17	H . .	44	15	29	..	..
18	H . .	6	6	..	..	..
19	H . .	7	7	..	..	..
20	Sp. H . .	33	..	33	..	..
21	Sp. H . .	27	..	27	..	..
22	H . .	18	12	6	..	..
23	Sp. H . .	49	18	7	24	..

Plant No.	Hairiness in F_3	Total No. of progeny	Hairiness in F_4			
			H	Sp. H	L. Sp. H	G
24	Sp. H . .	12	7	5	..	..
25	Sp. H . .	14	14	..	..	..
26	Sp. H . .	9	7	2	..	..
27	H . .	70	36	34	..	..
28	H . .	9	..	9	..	..
29	Sp. H . .	30	8	22	..	..
30	Sp. H . .	43	12	31	..	..

The fully hairy plants (H) in both the F_2 and F_3 generations have given a larger proportion of very hairy plants in the F_4 generation, but apart from this there does not seem to be much relationship between the extent of hairiness in the different generations of the cross. The position is shown in the following figures :—

Hairiness in F_2	Hairiness in F_3	Proportion of hairiness in F_4	
		H	Sp. H
1 H . . .	H . . .	1·48	1·0
2 H . .	Sp. H . . .	0·67	1·0
3 Sp. H . . .	H . . .	0·98	1·0
4 Sp. H . . .	Sp. H . . .	0·80	1·0

The one example (No. 23 in the table given above) where a plant derived from hairy parents in F_2 and F_3 generation apparently gives progeny with glabrous stems and petiole remains at present unexplained.

(*b*) All the plants which were fully hairy (H) in the F_2 and F_3 generations have given hairy progeny (fully or sparingly) in the F_4 generation. There is no exception to this.

(*c*) The progeny of plants, which were sparingly hairy (Sp. H) in the F_2 generation, but seed from which gave hairs only on the leaves (L. Sp. H) in the F_3 generation, gave varying results in the F_4 generation, as would be expected; the results for the progeny of 6 F_3 plants are as follows :—

Plant No.	Hairiness in F_2	Hairiness in F_3	Total No. of plants	Hairiness in F_4			
				H	Sp. H	L. Sp. H	G
1	Sp. H .	L. Sp. H .	46	3	25	18	..
2	Sp. H .	L. Sp. H .	26	1	6	19	..
3	Sp. H .	L. Sp. H .	34	..	...	34	..
4	Sp. H .	L. Sp. H .	58	..	..	58	..
5	Sp. H .	L. Sp. H .	24	1	23	..	..
6	Sp. H .	L. Sp. H .	15	1	5	9	..

In this case it is obvious that we have a condition in which seeds may be obtained either (1) breeding true to hairiness (plant No. 5), (2) breeding true to hairiness on the leaves only (plants 3 and 4) and (3) splitting into hairy plants and those with hairiness only on the leaves (plants 1, 2 and 6). No completely glabrous plant appeared.

(*d*) *The progeny of plants, which had hairs only on the leaves (L. Sp. H) in the F_2 generation,* behaved in a variable manner according to the character in the F_3 generation. The results may be seen in the following figures :—

Plant No.	Hairiness in F_3	Total No. of plants	Hairiness in F_4			
			H	Sp. H	L. Sp. H	G
1	H . .	22	8	14	..	..
2	H . .	48	17	31	..	..
3	H . .	80	31	48	..	1
4	H . .	59	48	11	..	..
5	Sp. H . .	64	11	52	1	..
6	Sp. H . .	56	1	55	..	..
7	Sp. H . .	22	0	22	..	..
8	L. Sp. H . .	18	0	1	17	..

Plant No.	Hairiness in F_3	Total No. of plants	Hairiness in F_4			
			H	Sp. H	L. Sp. H	G
9	L. Sp. H . .	35	0	1	34	..
10	L. Sp. H . .	71	12	16	43	..
11	L. Sp. H . .	60	0	1	59	..
12	L. Sp. H . .	50	0	0	50	..
13	L. Sp. H . .	41	0	0	41	..
14	L. Sp. H . .	37	0	0	37	..
15	L. Sp. H . .	51	0	0	51	..
16	L. Sp. H . .	54	1	30	9	14
17	L. Sp. H . .	40	0	0	40	..
18	L. Sp. H . .	42	0	2	40	..
19	L. Sp. H . .	33	0	0	33	..
20	L. Sp. H . .	27	0	0	27	..
21	L. Sp. H . .	69	1	58	3	5
22	L. Sp. H . .	18	2	10	6	..

In summary these results may be stated as follows :—

(1) If the F_2 parent has only the leaves hairy and *the F_3 plant is fully hairy* all the plants in F_4 generation will be hairy throughout—either fully or sparingly. This is the case in 208 out of 209 plants. The glabrousness of one plant is as yet unexplained.

(2) If the F_2 parent has only the leaves hairy (L. Sp. H) and *the F_3 plant is* wholly but *sparingly hairy* (Sp. H) all the plants in the F_4 generation will be hairy throughout either fully or sparingly. This is the case in 141 plants out of 142. The fact that one plant has only the leaves hairy is as yet unexplained.

(3) If the F_2 parent has only the leaves hairy (L. Sp. H) *and the F_3 plant is similar to the F_2 parent* (L. Sp. H), the result varies out of fifteen progenies in the F_4 generation.

(a^1) 11 progenies are almost exclusively of the same character as the F_3 parent. This is the case in 424 plants out of 429 in the progenies.

(b^1) 1 progeny gives plants hairy throughout (H and Sp. H) and plants with only the leaf hairy (L. Sp. H) in the proportion of 28 to 43 (1 to 1·54).

(c^1) 3 progenies give plants hairy throughout (H and Sp. H), plants with only the leaves hairy (L. Sp. H) and the glabrous plants (G) in the proportion of 92 : 22 : 25. This is equivalent to 4·2 : 1 : 1·1.

It is clear that in this case we have a mixture of plants breeding true to the L. Sp. H character, of plants containing both the factor developing leaf-hairiness and general hairiness of the plants, and of plants which contain all the elements controlling hairiness. The proportion between the numbers of each class does not enable us to decide the nature of the heredity in this case, but they certainly suggest a complex nature for the character of hairiness.

(e) All the plants (with two exceptions) which were glabrous (G) in the F_2 and F_3 generations bred true to the glabrous character in the F_4 generation. The two exceptions were slightly hairy on the leaves only. The records for the progeny of four F_3 plants of this kind are given.

Plant No.	Hairiness in F_3	No. of plants	Hairiness in F_4			
			H	Sp. H	L. Sp. H	G
1	G . .	25	0	0	1	25
2	G . .	22	0	0	1	21
3	G . .	7	0	0	0	7
4	G . .	9	0	0	0	9

From this study of the inheritance of hairiness in cotton in connection with the first four generations of the cross between Gadag No. 1 and Sea-Island cotton, we may conclude that it is quite possible to obtain strains which are hairy all over and breed true to this character (though the amount of hairiness will vary) and also strains which are glabrous and breed true to this character. The relationship between the number of each class in any progeny are not such as to indicate that the character is a simple one.

All the glabrous plants substantially breed true throughout indicating that the absence of hairs is a recessive character. The plants which are only hairy on the leaves may breed true to this character, or may give progeny with every type of hairiness, including its absence.

(B) Colour of the spot on the pulvinus.

At the base of the leaf, as has already been described, the petiole is coloured bright red in the case of Gadag No. 1 parent, while this spot is smaller, and pink rather than crimson in the case of the Sea-Island parent. The authors are not aware that the inheritance of this character has been previously studied, and, except as a means of identifying the types, its study has only an academic interest.

The plants of the F_1 generation of the cross bear a spot of intermediate character at this point, being pale red in colour and of intermediate size.

In the F_2 generation, a very minute naked-eye examination of a large number of plants in the seedling stage gave the following results :

Total number of plants examined	585
Leaf spot, large and crimson, like Gadag No. 1	167
Leaf spot, intermediate, like the F_1 plants	267
Leaf spot, pink, like Sea-Island	151

This gives a proportion between the different types of leaf spot as follows :—

Crimson leaf spot	Intermediate leaf spot	Pink leaf spot
1·0	1·60	0·90

The seed of a number of plants of each of the above three types were grown in the F_3 generation, with results now described.

1. Twelve plants with the full crimson leaf spot (like Gadag No. 1 in the F_2 generation, yielded progeny in the F_3 generation as follows :—

Plant No.	Total No. of plants	Number of plants			Proportion		
		Red spot	Inter-mediate spot	Pink spot	Red spot	Inter-mediate spot	Pink spot
1	77 .	76	0	1	1	0	0·01
2	33 .	33	0	0	1	0	0
3	51 .	51	0	0	1	0	0
4	76 .	75	0	1	1	0	0·01
5	39 .	37	1	1	1	0·02	0·02
6	24 .	24	0	0	1	0	0

Plant No.	Total No. of plants	Number of plants			Proportion		
		Red spot	Inter-mediate spot	Pink spot	Red spot	Inter-mediate spot	Pink spot
[illegible]	55 .	54	1	0	1	0·02	0
[illegible]	46 .	45	0	1	1	0	0·02
9	69 .	67	1	1	1	0·01	0·01
10	79 .	76	2	1	1	0·02	0·01
11	26 .	26	0	0	1	0	0
12	20 .	19	1	0	1	0·05	0

The plants breed substantially true to the character of a large red pulvinus leaf spot.

2. Thirteen plants with a leaf spot of intermediate character (like the F_1) in the F_2 generation, yielded progeny in the F_3 generation as follows :—

Plant No.	Total No. of plants	Number of plants			Proportion		
		Red spot	Inter-mediate spot	Pink spot	Red spot	Inter-mediate spot	Pink spot
1	15 .	4	7	4	1	1·7	1·0
2	46 .	12	23	11	1	1·9	1·0
3	48 .	12	23	13	1	1·9	1·0
4	69 .	16	37	16	1	2·3	1·0
5	64 .	15	32	17	1	2·1	1·1
6	109 .	29	55	25	1	1·9	0·9
7	26 .	7	13	6	1	1·9	1·1
8	44 .	10	24	10	1	2·4	1·0
9	62 .	16	31	15	1	1·9	1·0
10	31 .	9	14	8	1	1·6	0·9
11	73 .	18	36	19	1	2·0	1·1
12	65 .	17	29	19	1	1·7	1·1
13	33 .	9	17	7	1	1·9	0·8

If all these are taken together, the proportion between the three kinds of leaf spot is as follows :—

Red spot	Intermediate spot	Pink spot
1	1·96	0·98

This corresponds very closely to the original figures for the F_2 generation (see above).

3. Eight plants with the pink leaf spot (like Sea-Island) in the F_2 generation, yielded progeny in the F_3 generation as follows :—

Plant No.	Total No. of progeny	Number of plants			Proportion		
		Red spot	Inter-mediate spot	Pink spot	Red spot	Inter-mediate spot	Pink spot
1	36	0	1	35	0	0·02	1·0
2	37	1	1	35	0·02	0·02	1·0
3	89	0	2	87	0	0·01	1·0
4	74	0	2	72	0	0·02	1·0
5	62	0	1	61	0	0·01	1·0
6	70	0	3	67	0	0·03	1·0
7	30	0	1	29	0	0·03	1·0
8	53	0	1	52	0	0·02	1·0

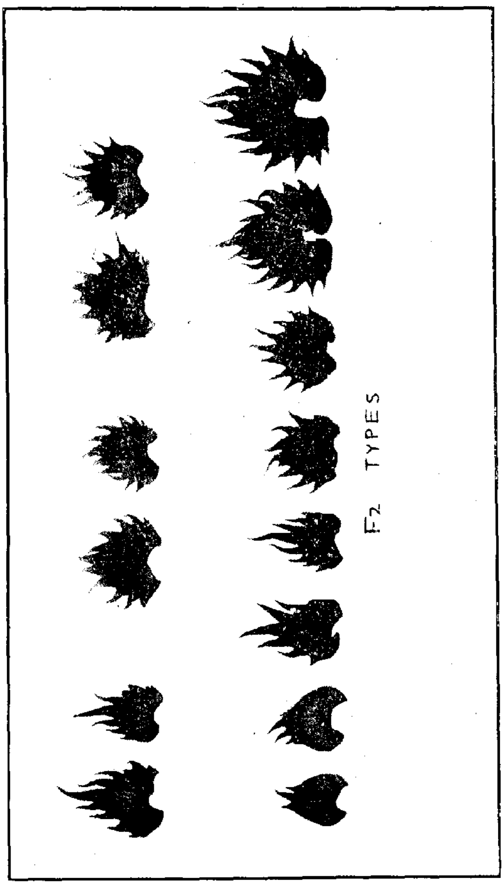
The plants breed substantially true to the character of a pink pulvinus spot.

In the case of this character there is hardly any need to pursue the study further. The pulvinus leaf spot behaves as a simple mendelian character, with intermediate dominance. A few progenies in the F_4 generation were, however, examined in 1925-26, which confirmed this conclusion. It is clear that the character in question may prove a most valuable diagnostic character in maintaining the purity of a selected type as it can be examined in the seedling stage of the plant.

(C) Number of teeth in the bracts.

Cotton varieties vary very much in the number of incisions or teeth of the flower bracteoles. They also vary in the manners in which the

PLATE II.



Number of teeth in the bract of the parents and F_1 types together with those occurring in F_2 types.

teeth are cut; some are very deep and some very shallow. Harland[1] has found that in the crosses of strains having quite a distinct number of teeth in the bract, the larger number of teeth was dominant in the F_1 generation over the smaller number.

In the present case the incisions in both the parents of the cross were more or less similar, but the number was found to differ (see page 26). The following table shows the frequency distribution of the parents, and the F_1 and F_2 generation of the cross as grown side by side in 1923-24. All are calculated to an even 200 plants. Plate II shows a picture of the bract types of the parents, the F_1 and the F_2 generations.

No. of teeth	Gadag No. 1	Sea-Island	F_1	F_2
3 . .	..	..	..	1
4 . .	..	..	..	2
5 . .	7	..	..	9
6 . .	27	..	..	17
7 . .	65	23	..	46
8 . .	55	31	14	38
9 . .	34	85	64	40
10 . .	12	46	83	25
11 . .	..	15	36	14
12 . .	..	..	3	5
13 . .	..	..	..	2
14 . .	..	..	..	1
TOTAL .	200	200	200	200

These figures show that the mean and the mode in the F_1 generation follow closely the Sea-Island parent, and in fact, go a little beyond it.

---	Gadag No. 1	Sea Island	F_1
Mean . . .	7·6 teeth . .	9·0 teeth . .	9·7 teeth.
Mode . . .	7 teeth . .	9 teeth . .	10 teeth.

[1] Harland, S. C. Studies in Inheritance in Cotton. *West Indian Bull.*, Vol. XVIII, 1920.

It is interesting to see how the number of teeth in the F_2 generation may be both lower and higher than is found in either parent, and an important consideration in the study of this character is to find whether these extra-parental variations can be maintained and will breed true.

To clear this point seed derived from plants with 3, 4, 12 and 13 teeth respectively in the F_2 generation was grown in the F_3 generation with the following results :--

—	Frequency of bract teeth in the F_3 generation					
	3 Teeth in F_2	4 Teeth in F_2	12 Teeth in F_2 (1)	12 Teeth in F_2 (2)	13 Teeth in F_2 (1)	13 Teeth in F_2 (2)
No. of plants in F_3 generation.	44	95	30	46	69	61
Frequency distribution—						
3 . .	*19*	9	..	..	..	..
4 . .	7	20	..	..	..	..
5 . .	6	*35*	..	..	..	..
6 . .	6	14	..	..	..	..
7 . .	6	17	..	..	..	..
8 . .	..	..	4	..	7	8
9 . .	..	..	5	1	8	11
10 . .	..	..	5	5	12	11
11 . .	..	..	5	*15*	*18*	11
12 . .	..	..	*6*	12	10	*14*
13 . .	..	..	3	6	5	3
14 . .	..	..	2	6	6	2
15 . .	..	..	..	1	3	1
Mode . .	3	5	12	11	11	12
Mean . .	4·3	5·1	10·7	11·8	11·0	11·8

These figures show clearly that the progeny of the plants with an exceptionally small number of bract teeth (3 and 4) also have a number of teeth only slightly higher, and the range of variation is almost the same as in either of the original parents. The same is true with those having an extra large number of teeth, except that in this case the range is a little greater. The matter can be carried a little further by a study of the fourth generation (F_4) of the cross.

1. Plants *with 3 teeth per bract* in F_3 generation.

—	Frequency of bract teeth in F_4 generation			
	3 teeth in F_3	5 teeth in F_3	7 teeth in F_3	Total
No. of plants in F_4 generation	28	37	31	96
Frequency distribution—				
3 teeth	*12*	7	1	20
4 „	5	10	12	27
5 „	5	*12*	14	31
6 „	3	6	2	11
7 „	2	2	1	5
8 „	1	..	1	2
Mode	3	5	5	5
Mean	4·3	4·6	4·7	4·6

Taking all together we may compare the mode, mean and range of all these plants derived from plants with three bract teeth in the F_2 generation, in the F_3 and F_4 generations.

—	F_3 generation	F_4 generation
Mode	3 teeth	5 teeth.
Mean	4·3 teeth	4·6 teeth.
Range	3 to 7 (4) teeth	3 to 8 (5) teeth.

There is slight regression, but it is only by the study of one or two more generations that its real meaning can be made out.

2. Plants *with 4 teeth per bract* in F_2 generation.

—	Frequency of bract teeth in F_4 generation			
	4 teeth in F_3	5 teeth in F_3	7 teeth in F_3	Total
No. of plants in F_4 generation . .	86	78	40	204
Frequency distribution—				
3 teeth	14	5	1	20
4 „	18	13	3	34
5 „	*33*	*30*	*16*	79
6 „	15	17	15	47
7 „	6	11	5	22
8 „	0	2	0	2
Mode	5	5	5	5
Mean	4·7	5·2	5·5	5·1

Taking all these together as in the last case, we find as follows :—

—	F_3 generation	F_4 generation
Mode	5 teeth	5 teeth.
Mean	5·1 teeth	5·1 teeth.
Range	4 teeth	5 teeth.

In this case the regression is not detectable from the figures, but there is a slight increase in the F_4 generation, in the range of variation.

3. Plants *with 12 teeth per bract* in F $_2$ generation.

——	Frequency of bract teeth in F_4 generation.						
	9 teeth in F_3	10 teeth in F_3	11 teeth in F_3	12 teeth in F_3	13 teeth in F_3	14 teeth in F_3	Total
No. of plants in F_4 generation.	40	32	35	92	52	35	286
Frequency distribution —							
7 teeth .	1	..	..	2	1	..	4
8 „ .	..	..	1	4	..	..	5
9 „ .	5	5	5	10	4	3	32
10 „ .	5	*13*	3	10	3	5	39
11 „ .	*14*	4	4	*28*	7	5	*62*
12 „ .	10	6	*9*	10	*17*	6	58
13 „ .	3	2	*9*	14	11	8	47
14 „ .	1	1	3	10	4	6	25
15 „ .	1	1	1	4	5	2	14
Mode . . .	11	10	12 & 13.	11	12	13	11
Mean . . .	11·1	10·8	11·7	11·3	12·1	12·00	11·5

Taking all these together as in the last case, we find as follows :—

——	F_3 generation	F_4 generation
Mode	11 teeth	11 teeth.
Mean	11·4 teeth	11·5 teeth.
Range	8 to 15 (7) teeth	7 to 15 (8) teeth.

In this case also, regression is not detectable from the figures, but there is a slight increase in the range in the F_4 generation.

The evidence is, therefore, very strong that the extra-parental variations in the number of teeth in the bract can be bred true and fixed in a *new* type if this is thought desirable.

(D) Colour of the flower petals.

The inheritance of flower colour in the American group of cottons has been studied by a number of workers. Balls [1] found that the inheritance of colour of flower is complex, but he was not able to elucidate its character completely. McLendon [2] in Georgia and Harland [3] in the West Indies have handled crosses between Sea-Island and American cottons, and, therefore, this work is of special importance in the present connection. McLendon found that the petal colour in the cross was intermediate between the parents in the F_1 generation, and in F_2 generation a much greater number of individuals had a pale yellow colour than the characteristic white or full yellow of the parents. Harland also found intermediate dominance in the F_1 generation while in the second generation of the cross the parental types and many intermediate colours appeared. It is obvious that the inheritance of petal colour is of an extremely complex character.

The present cross is between a creamy-white flowered type (Gadag No. 1) and a bright full-yellow flowered type (Sea-Island), and the examination of the first four generations of this cross in respect of flower colour may now be described.

In the F_1 generation, the whole of the plants obtained gave pale yellow flowers if examined soon after the opening of the flowers. In the F_2 generation, out of a total of 719 plants, the colours were as follows :—

—	Number of plants	Proportion
Bright yellow	198	1·2
Pale yellow	377	2·6
White	144	1·0

All examinations of these colours were made in the morning between 10 and 11 A.M. soon after the opening of the petals, by matching with the parental and the F_1 types as fading took place by the afternoon. It was found very difficult to match the intermediate types, as there were many plants which had much paler yellow flowers than the F_1

[1] Balls, W. L. Mendelian Studies of Egyptian Cottons. *Jour. Agri. Science*, Vol. II. 1908.

[2] McLendon, C. A. Mendelian Inheritance in Cotton Hybrids. *Georgia Agri. Expt. Sta. Bull.* 99, 1912.

[3] Harland, S. C. Studies in Inheritance in Cotton. *West Indian Bull.*, Vol. XVIII. 1920.

intermediate, so pale, in certain cases, as to be little distinguishable from white. All such cases have, however, been classed as "pale yellow."

In the F_3 generation, all the plants, which had white coloured flowers in the F_2 generation, yielded white flowers. Or in other words, the white flowered plants bred true to this character. This is exactly what has been found by Kottur [1] with Asiatic cottons.

On the other hand, the plants, which had *bright full yellow* flowers in the F_2 generation, gave flowers of varying colour in the F_3 generation.

Plant No.	Total number of plants	Bright yellow	Pale yellow	White	PROPORTION		
					Bright yellow	Pale yellow	White
1	27 . . .	27	0	0	1	0	0
2	59 . . .	58	1	0	1	0·01	0
3	8 . . .	7	1	0	1	0·1	0
4	42 . . .	1	41	0	0·02	1	0
5	14 . . .	1	13	0	1·1	1	0
6	27 . . .	0	26	1	0	1	0·03
7	19 . . .	1	18	0	0·05	1	0
8	28 . . .	6	14	8	1·0	2·3	1·3
9	35 . . .	20	13	2	1·0	0·65	0·1
10	52 . . .	4	37	11	1·0	9·2	2·7
11	45 . . .	11	31	3	1·0	2·8	0·3
12	34 . . .	4	26	1	1·0	6·5	1·0

[1] Kottur, G. L. Studies in Inheritance in Cotton, I, *Mem. Dept. Agri. India, Bot. Ser.*, Vol. XII, No. 3, 1923.

We have thus, among the bright yellow flowered plants of the F_2 generation, some which breed true to the bright yellow flowered character, others which give substantially only pale yellow flowered plants, and, finally, others which give bright yellow, pale yellow and white plants in very varying proportions.

When the seed from *pale yellow* flowered plants in the F_2 generation is grown in the F_3 generation the following results were obtained:—

Plant No.	Total number of plants	Bright yellow.	Pale yellow.	White	Proportion		
					Bright yellow	Pale yellow	White
1	15	0	15	0	0	1·0	0
2	19	0	19	0	0	1·0	0
3	68	1	67	0	0·01	1·0	0
4	59	1	58	0	0·01	1·0	0
5	47	0	46	1	0	1·0	0·02
6	10	0	10	0	0	1·0	0
7	39	0	38	1	0	1·0	0·03
8	51	6	39	6	1·0	6·5	1·0
9	30	3	20	7	1·0	7·7	2·3
10	37	9	23	5	1·0	2·6	0·6
11	61	4	35	22	1·0	8·7	5·5
12	61	19	27	15	1·0	1·4	0·8
13	56	9	34	13	1·0	3·7	1·4
14	20	9	5	6	1·0	0·6	0·7

We have, therefore, among the pale yellow flowered plants of the F_2 generation, some which breed true to the pale yellow flower character. The remainder gave bright yellow, pale yellow and white petalled plants in varying proportion.

In the F_4 generation, seed from 32 plants of the F_3 generation (themselves derived from 11 plants of the F_2 generation) was taken. No plants which had given white flowers were used, as this colour has proved to be a pure recessive. The results may now be noted and the table which follows, shows what has happened to a number of plants whose heredity, in this respect, in the F_2 and F_3 generations, is known.

I. Progeny of plants with bright yellow flowers in the F_2 generation.

Plant in F_3	Flower colour in F_3	Total No. of plants in F_4	Flower Colour in F_4			Proportion		
			Bright yellow	Pale yellow	White	Bright yellow	Pale yellow	Whiee
		A. All progeny bright yellow in F_3						
1	1 Bright yellow.	19	19	0	0	1	0	0
	2 Do.	29	29	0	0	1	0	0
	3 Do.	21	0	0	0	1	0	0
	4 Do.	15	14	1	0	1	0·07	0
	5 Do.	7	7	0	0	1	0	0
		B. All progeny pale yellow in F_3.						
2	1 Pale Y	20	0	20	0	0	1	0
	2 Do.	19	0	18	1	0	1	0·05
3	1 Do.	6	1	5	0	0·2	1	0
	2 Do.	7	0	7	0	0	1	0
		C. Progeny variable in F_3.						
1	1 White	27	0	0	27	0	0	1
	2 Pale Y	22	0	10	12	0	1	1·2
	3 Do.	20	0	11	9	0	1	0·8
	4 Do.	25	0	24	1	0	1	0·04
2	Bright yellow	11	6	5	0	1·2	1	0
	Pale Y	13	3	7	3	1	2·3	1

We find, therefore, that the plants which have bright yellow flowers in the F_2 generation may be divided into three types. Those yield only *bright* yellow flowers in the F_3 generation also yield only bright yellow flowers in the F_4 generation. In other words they breed true to flower colour. Those which yield *pale* yellow flowers in the F_3 generation also yield only pale yellow flowers in the F_4 generation. These also, therefore, breed true. Where, however, the progeny of an F_2 plant are variable in colour in the F_3 generation, then the plants of the F_4 generation are also variable, the white flowers breeding true, some pale yellow flowers, breeding true and the rest giving pale yellow and white, pale yellow and bright yellow or all three colours. Where splitting into two colours occurs, the proportion approaches 1 : 1 for the two colours concerned. Where splitting into three colours takes place the proportion approaches 1 : 2 : 1. This last figure is one, however, on which little reliance can be placed, as it depends on one instance and on very few plants.

D 2

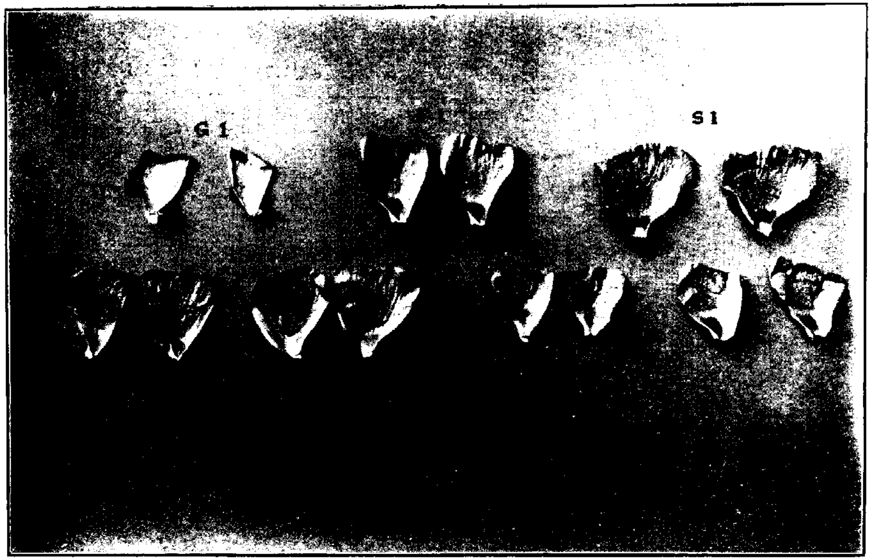
II. Progeny of plants with pale yellow flowers in the F_2 generation.

Plant in F_2	Flower colour in F_3	Total No. of plants in F_4	Flower Colour in F_4			Proportion		
			Bright yellow	Pale yellow	White	Bright yellow	Pale yellow	[illegible]
			A. All progeny pale yellow in F_4.					
1	1 Pale Y.	14	0	14	0	0	1	[illegible]
	2 Do.	17	1	16	0	0·06	1	[illegible]
	3 Do.	15	0	15	0	0	1	[illegible]
2	1 Do.	33	1	32	0	0·03	1	[illegible]
	2 Very Pale Y.	22	0	21	1	0	1	[illegible]
3	1 Pale Y.	20	1	19	0	0·05	1	[illegible]
	2 Do.	20	0	20	0	0	1	[illegible]
			B. Progeny variable in F_4.					
1	1 Pale Y.	16	0	9	7	0	1	[illegible]
	2 Do.	25	6	16	3	2·0	5·3	[illegible]
	3 White	28	0	2	26	0	0·07	[illegible]
	4 Do.	18	0	1	17	0	0·05	[illegible]
2	1 Pale Y.	21	3	18	0	0·1	1·0	[illegible]
	2 Do.	40	0	28	12	0	2·3	[illegible]
	3 White	27	0	1	26	0	0·03	[illegible]
3	1 Bright yellow.	65	63	2	0	1	0·03	[illegible]
	2 Pale Y.	15	2	12	1	0·2	1·0	[illegible]
	3 White	28	0	1	27	0	0·03	[illegible]

In the case of the plants which have pale yellow flowers in the F_2 generation, they may be divided into two types. Those which yield only pale yellow flowers in the F_3 generation also yield only pale yellow flowers in the F_4 generation. They, therefore, breed true; where, however, the progeny of an F_2 plant is variable in colour in the F_3 generation, then the plants of the F_4 generation are also variable, the white flowers breeding true and the rest giving pale yellow and white or all three colours. Where splitting into two colours occurs the proportion approaches either 1 : 1 or 2 : 1 for pale yellow to white. When splitting into three colours takes place, the proportion is variable.

This study of the inheritance of flower colour in the cross under study confirms previous conclusions that a white colour is a pure recessive and makes it also probable that the various colours involved are inherited

PLATE III.



Petals in parents, F_1 and F_2 generations showing the presence or absence of the "Eye," independently. On the other hand, it seems clear that the yellow colour is a complex mixture of several colour factors, but the nature of this complex mixture has not yet been elucidated.

(E). Presence of petal spot or "eye."

One of the most striking differences between the parents of the cross under discussion is the presence of a bright red eye to the flower in the Sea-Island cotton and its complete absence in the American parent. In crossing parents similar in this respect (Upland and Egyptian) Balls [1] found intermediate dominance of the character, the F_1 generation showing a smaller and paler spot than the Egyptian parent. In the F_2 generation, the proportion of plants having any sort of an eye to those where it was entirely absent was about 2 : 1 and in succeeding generations the spotless plants bred true. McLendon [2] in an Upland Sea-Island cross found a smaller and paler spot in the F_1 generation and a proportion of spotted to spotless plants in the F_2 generation less than 3 : 1. Kearney[3], in an Upland Egyptian cross, found again a smaller and paler spot in the F_1 generation, but, unlike others, he found a 3 to 1 ratio of spotted and spotless plants in the F_2 generation. Working with Asiatic cottons—a Chinese spotless cotton and Indian spotted cotton—Leake [4] found complete dominance of the spot in the F_1 generation.

In the authors' cross, the F_1 generation had in all cases only a pale red eye, smaller than that in the Sea-Island parent. The F_2 generation showed the following behaviour :—

Total number of plants examined	719
Plants with no petal spot (eye)	333
Plants with pale red spot (*i.e.*). intermediate in size and colour) .	242
Plants with deep red spot (like the Sea-Island parent) . . .	144

The flowers were examined in each case between 10 and 11 A.M. soon after the opening of the petals. The size of the "eye" varied very much in these plants of the F_2 generation ; some of them had so faint and minute a petal spot that it might easily be overlooked. The Plate III shows types of spot found in this generation along with those in the parents and the first generation of the cross. It will be seen from the above figures that the proportion between the number of plants with

[1] Balls, W. L. Mendelian Studies of Egyptian Cotton. *Jour. Agri. Science*, Vol. II. 1908.

[2] McLendon, C. A. Mendelian Inheritance in Cotton Hybrids. *Georgia Agri. Expt. Sta. Bull.* 99, 1912.

[3] Kearney, T. H. Segregation of Characters in an Upland Egyptian Hybrid. *U. S. Dept. Agri. Bull.* 1164, 1923.

[4] Leake, H. M. and Ram Prasad. Studies in Indian Cottons, Part I. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. VI, No. 4, 1914.

no petal spot whatever and those with some sort of spot is 2·31 to 2·6. This corresponds with no simple form of inheritance, but the F_3 generation throws some further light on the subject.

In the F_3 generation, all but one of the plants which had *no* petal spot (eye) in the F_2 generation, yielded spotless plants. Or in other words, with the one exception noted, all the non-spotted plants bred true to this character. This recessive character in the non-spotted plants has been noted by previous workers. In the one exceptional case, 32 seeds from one spotless F_2 plant gave nine plants with faint red flower spots, while the rest of them gave flowers free from spots. This progeny must remain unexplained at present, but apart from this one case, the non-spotted character behaves as a complete recessive.

On the other hand, plants which were spotted in the F_2 generation gave progeny of several different kinds. The behaviour of the progeny of plants with deep red spots and faint red spots in the F_2 generation is not widely different, so they are taken together.

Plant No.	Spot character in F_2	Total plants in F_3	Spot character in F_3			Proportion	
			Deep red spot	Faint spot	No spot	Spotted	Non-spotted
1	Dark red . .	68	9	58	1	1·0	0·01
2	Do. . .	26	4	21	1	1·0	0·04
3	Do. . .	47	30	16	1	1·0	0·02
4	Faint red . .	80	11	68	1	1·0	0·01
5	Dark red . .	33	18	9	6	4·5	1·0
6	Do. . . .	44	9	25	10	3·4	1·0
7	Do. . .	60	8	38	14	3·3	1·0
8	Faint red . .	49	5	29	15	2·3	1·0
9	Do. . .	45	4	30	11	3·0	1·0
10	Do. . .	74	0	52	22	2·4	1·0
11	Dark red . .	59	4	30	25	1·4	1·0
12	Do. . .	34	8	14	12	1·8	1·0
13	Do. . .	39	0	20	19	1·0	1·0
14	Faint red . .	34	4	14	16	1·1	1·0
15	Do. . .	57	4	27	26	1·2	1·0
16	Do. . .	26	1	16	9	1·9	1·0
17	Dark red . .	66	16	11	39	0·7	1·0
18	Do. . .	34	0	14	20	0·7	1·0
19	Do. . .	39	0	11	28	0·4	1·0
20	Faint red . .	30	0	12	18	0·7	1·0
21	Do. . .	53	0	23	30	0·8	1·0
22	Do. . .	58	0	21	37	0·6	1·0

We have thus a certain number of progenies (Nos. 1—4 above) which breed true to the spotted character, though the intensity varies much. On the other hand, we have a series of progenies where the relation of spotted to the non-spotted plants varies in an almost unbroken series from 4·5 to 1 down to 0·4 to 1. There seems perhaps a tendency for ratios approaching 3 to 1, 2 to 1, 1 to 1, and 0·7 to 1. But it is hardly more than a tendency.

A study of the F_4 generation throws a little more light on the inheritance of this character. In this case the similar conclusion reached as to the recessiveness of the non-spotted character is confirmed for all the progenies of plants giving non-spotted flowers in the F_3 generation breed true to this character in the F_4 generation. For the study of the plants, bearing spots, seeds from 29 plants of the F_3 generation (themselves derived from 10 plants of the F_2 generation) were taken. The results may now be noted, and the table which follows shows what has happened to a number of plants whose character, in this respect, in the F_2 and F_3 generations is known.

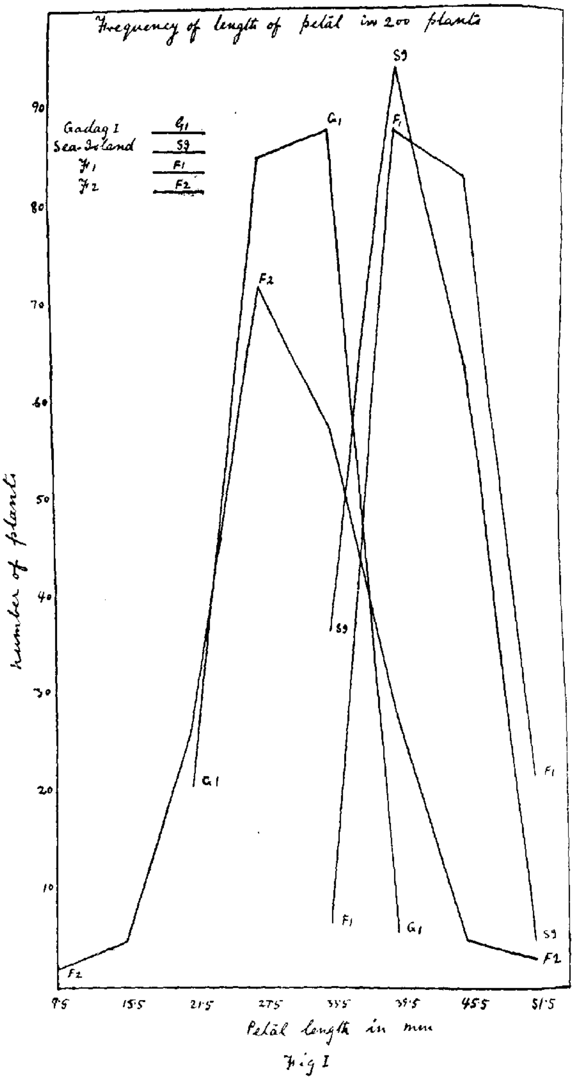
Plant in F_2	Spot character in F_3	Total plants in F_4	Spot character in F_4			Proportion	
			Deep red spot	Faint red spot	No spot	Spotted	Non-spotted
A. Progeny of plants with deep red spot in F_2 generation.							
1.1	Faint red . .	14	1	10	3	3·7	1
1.2	Do. . .	17	3	10	4	3·2	1
1.3	Do. . .	15	0	11	4	2·7	1
1.4	Do. . .	11	2	8	1	0·0	1
2.1	Deep red . .	10	1	8	1	9·0	1
2.2	Faint red . .	13	1	5	7	0·9	1
3.1	Deep red . .	42	7	26	9	3·7	1
3.2	Faint red . .	60	1	30	29	1·1	1
3.3	No spot . .	30	0	0	30	0	1
4.1	Deep red . .	7	0	1	6	0·2	1
4.2	Do. . .	11	0	9	2	4·5	1
4.3	Faint red . .	36	1	11	24	0·5	1
4.4	Do. . .	35	1	20	14	1·5	1
4.5	Do. . .	38	0	15	23	0·7	1
5.1	Faint red . .	20	1	12	7	1·9	1
5.2	No spot . .	18	0	0	18	0	1
5.3	Do. . .	3	0	0	3	0	1

Plant in F_2	Spot character in F_3	Total plants in F_4	Spot character in F_4			Proportion	
			Deep red spot	Faint red spot	No spot	Spotted	Non-spotted
B. Progeny of plants with faint red spot in the F_2 generation.							
6 { 1	Faint red . .	10	0	7	3	2·3	1
6 { 2	No spot . .	11	0	0	11	0	1
7 { 1	Faint red . .	26	2	14	10	1·6	1
7 { 2	Do. . .	36	0	10	26	0·4	1
8 { 1	Faint red . .	31	0	28	3	9·3	1
8 { 2	Do. . .	45	1	15	29	0·6	1
8 { 3	No spot . .	21	0	1	20	0·05	1
8 { 4	Do. . .	22	0	0	22	0	1
9 { 1	Faint red . .	28	0	8	20	0·4	1
9 { 2	Do. . .	45	0	9	36	0·25	1
10 { 1	No spot . .	18	0	0	18	0	1
10 { 2	Do. . .	42	0	0	42	0	1

The results thus shown confirm the conclusion that non-spotted flowers give seeds breeding true in this respect. So far as the plants which have given spotted flowers through the F_2 and F_3 generations, the inheritance is evidently a very complex one, and the data available do not enable us to elucidate it. Even if attention is limited to those cases where over 25 plants in the F_4 generation are obtained from one plant in the F_3 generation the proportion of those giving spotted and unspotted plants varies from 9·3 to 1 to 0·25 to 1. It will obviously need a good deal more study than the authors have been able to make, before the very complicated inheritance of the "eye" of the cotton flower can be clearly made out.

(F). Length of the flower petal.

In the cross under discussion, it has already been noted that the Gadag No. 1 has relatively short petals, these varying from 19 to 39 mm. in length, while those of Sea-Island strain used varied from 31 to 37 mm.



Graph showing the distribution of the length of petal in the parents F_1 and F_2 generations.

in length. The behaviour on crossing, in the first two generations, is shown in following frequency table :—

Petal length	Gadag No. 1	Sea-Island	F_1	F_2
Below 12 mm.	..	..	..	2
13—18 mm.	..	..	..	5
19—24 mm.	21	..	..	27
25—30 mm.	85	..	..	72
31—36 mm.	88	37	7	58
37—42 mm.	6	94	88	28
43—48 mm.	..	64	83	5
49—54 mm.	..	5	22	3
TOTAL	200	200	200	200

In Figure I is shown the graphic representation of this character.

From these figures it will be seen that in the parents of the cross, 97 per cent. of the plants of Gadag No. 1 have a flower petal less than 36 mm. long, and 80 per cent. of the Sea-Island plants have a flower petal more than 36 mm. long. The F_1 generation of the cross gives petals of which 96½ per cent. have a flower petal larger than 36 mm. There is thus evidence that the long petal is a dominant character. The results obtained in the F_2 generation do not however, accord with this simple explanation, for 82 per cent. of the plants obtained have flower petals below 36 mm. in length. The proportion of short petals to long petals in this generation is, in fact, 4·5 to 1.

This unexpected behaviour seems to be at least partially explainable by the very high degree of linkage which seems to exist between short petals and a white colour of the cotton flower. If the F_2 plants are divided according to the colour of the flowers, the result with 718 plants are shown in the following frequency table :—

Length of petals	White petalled F_2 plants	Yellow petalled F_2 plants
Below 12 mm.	..	6
13—18 mm.	2	17
19—24 mm.	25	71
25—30 mm.	59	199
31—36 mm.	40	169
37—42 mm.	11	89
43—48 mm.	3	15
49—54 mm.	1	10
55—60 mm.	..	1
TOTAL	141	577

Thus there are 89·4 per cent. of white petalled plants giving flowers with short petals (below 36 mm.), as against 80 per cent. of those with yellow petals. The close linkage thus indicated is confirmed by the behaviour of the progeny from white flowered plants (which, of course, breed true to colour of flower) in the F_3 and F_4 generations, when the following behaviour was seen.

F_3 generation . . 387 plants from white flowered parents gave 372 plants with petals less than 36 mm. long or 96·1 per cent.

F_4 generation . . 250 plants from white flowered parents (whether the petals were short or long) gave 244 plants with petals less than 36 mm. long or 97·6 per cent.

The linkage between white flowers and short petals seems therefore nearly complete, and in any investigation of the inheritance of long petals, these flowers must be excluded. But even if these be excluded, the contrast between the F_1 generation with its dominance of long petals, and the 80 per cent. of short petalled flowers which are also yellow, is nearly as great.

If we follow up the inheritance of petal length in the F_3 and F_4 generations, with *yellow flowers* only, the following results are obtained, though unfortunately, it almost entirely deals the progeny of plants with short petalled flowers :—

F_3 generation.

Plant No.	Petal in F_2	Total number of plants	Petal-character		Proportion	
			Long petal	Short petal	Long petal	Short petal
	A. Bright yellow flower in F_2, breeding true to bright yellow in F_3.					
1	Short . . .	26	3	23	0·08	1
2	Do. . . .	45	3	42		
3	Do. . . .	8	0	8		
	B. Pale yellow flower in F_2, breeding true to pale yellow in F_3.					
1	Short . . .	15	1	14	0·1	1
2	Do. . . .	18	1	17		
3	Do. . . .	56	7	49	0·14	1
4	Do. . . .	58	7	51		
5	Do. . . .	29	1	28	0·03	1
6	Do. . . .	7	0	7		
7	Long . . .	35	10	25	1	2·5

F_4 generation.

Plant in F_2		Petal in F_3	Total number of plants	Petal-character		Proportion	
				Long petal	Short petal	Long petal	Short petal
		A. Bright yellow flower in F_2, breeding true to bright yellow in F_3.					
1	1	Short . . .	11	0	11	0	1
	2	Do. . . .	23	0	23		
	3	Do. . . .	11	0	11		
	4	Long . . .	15	0	15		
	5	Short . . .	7	0	7		

Plant in F_2	Petal in F_3	Total number of plants	Petal-character		Proportion	
			Long petal	Short petal	Long petal	Short petal
B. Pale yellow flower in F_2, breeding true to pale yellow in F_3.						
2 { 1	Short	12	0	12	0	1
2	Do.	15	0	15		
3	Do.	14	0	14		
3 { 1	Do.	20	5	15	0·32	1
2	Do.	17	4	13		
4 { 1	Long	20	5	15	0·33	1
2	Short	16	1	15	0·07	1

There are, among the short-petalled yellow flowered individuals, clearly two types of plants,—those which breed true or give a very large majority of short petals, and the other which give about one-third of the progeny with long petals. This latter type is illustrated by the progeny of F_2 plant 3 in the F_4 generation in the above table. Exactly what the meaning of this behaviour is, is not clear from the data available.

(G). Colour of bolls.

No study has been hitherto published as to the inheritance of the colour of the bolls, but the difference in the present case was so striking between the parents, that it seemed useful to follow the behaviour in the cross. The Gadag No. 1 parent has a *dull*, light green boll; the Sea-Island parent has a *shiny* bright green boll. All the F_1 generation plants had an intermediate green colour and all were rather dull.

The plants in the F_2 generation were easily grouped into three lots,—those similar to the Gadag No. 1 parent, those like the Sea-Island parent, and those like the F_1 generation of the cross. Classed in this way, the produce of 608 plants was as follows :—

——	No. of plants	Proportion
Light green (like Gadag No. 1)	159	1·07
Medium green (F_1 generation)	301	2·03
Deep bright green (like Sea-Island)	148	1·00

The proportion almost exactly tallies with what would be expected if the character was a simple mendelian one, the intermediate form being dominant.

This conclusion is confirmed by the examination of the F_3 generation. In this case 206 plants derived from eight light green plants of the F_2 generation gave light green bolls in 200 cases, and medium green bolls in six cases, thus substantially breeding true to the light green character of the bolls. Likewise 94 plants, derived from seven deep bright green plants of the F_2 generation, gave deep green bolls in 92 cases and medium green bolls in two cases, thus substantially breeding true to the deep green character.

As regards the progeny of F_2 plants with medium green bolls, eleven F_2 plants gave 230 plants in the F_3 generation, with bolls distributed as follows :—

	No. of plants	Proportion
Light green	57	1·03
Medium green	118	2·1
Deep green	55	1·0
TOTAL	230	..

The produce of all the plants shows itself of a splitting nature in respect to boll colour, and the proportion remains of the kind that would be expected if the character was a simple mendelian one, and if this intermediate form were dominant.

In the F_4 generation, the progeny of the "light green" and "deep green" bolled plants continue to breed true to these characters respectively. Plants with "medium green" bolls in the F_3 generation, however derived, gave a similar result recorded above. Six F_3 plants of this character yielded 143 plants in the F_4 generation with the following results :—

	No. of plants	Proportion
Light green	34	1·0
Medium green	72	2·1
Deep green	37	1·1
TOTAL	143	..

The boll colour making the very striking difference between the Gadag No. 1 and the Sea-Island cotton, therefore behaves as a simple mendelian character, with intermediate dominance.

(H). Surface and glandulation of bolls.

The whole of the surface of the cotton plant, above the ground, bears small black resin glands of the size of a pin's head. The density of these glands on the boll surface varies much in different types of cotton. In the case of types belonging to *Gossypium hirsutum* and *Gossypium herbaceum* the boll surface is smooth and the glands are visible only as small specks here and there; in the case of types, on the other hand, belonging to *Gossypium barbadense* or *Gossipium neglectum* the boll surface is rough, for the glands appear prominently as small pits packed somewhat closely together. The inheritance of the gland character has been studied by Balls [1], Kearney [2] and McLendon [3] and the general conclusion is that in crosses an intermediate condition is dominant, but that the inheritance is not of a simple mendelian character.

In the present study the smooth bolled Gadag No. 1 was crossed with the rough bolled Sea-Island cotton. In the F_1 generation, the boll surface, though resembling in general appearance the Sea-Island parent more than the other, was only sparingly dotted with glands, and was considerably less rough than the Sea-Island bolls. It was, in fact, intermediate in character. In the F_2 generation, the number of plants of each different character out of a total of 608 was as follows :—

	No. of plants	Proportion
Smooth boll surface	17	1
Intermediate boll surface	238	14
Rough boll surface	353	21
Total	608	..

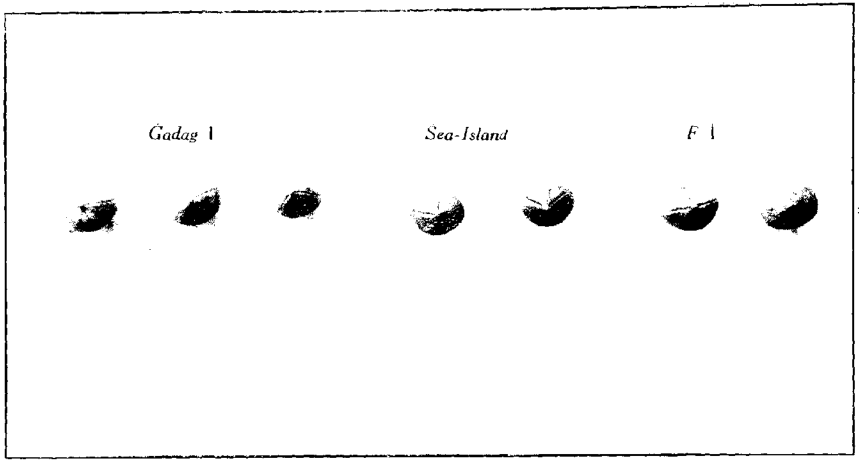
These figures indicate that the standard for differentiating the kinds of surface is not clearly enough defined to form any conclusion. The fact that the F_3 families derived from smooth bolled F_2 plants were entirely smooth bolled, suggests that this forms a recessive character. Further than this, it is impossible at present to go.

[1] Balls, W. L. Mendelian Studies of Egyptian Cotton. *Jour. Agri. Science*, Vol. II, 1908.

[2] Kearney, T. H. Segregation of Characters in an Upland Egyptian Hybrid. *U. S. Dept. Agri. Bull.* 1164, 1923.

[3] McLendon, C. A. Mendelian Inheritance in Cotton Hybrids. *Georgia Agri. Expt. Sta. Bull.* 99, 1912.

PLATE IV.



Bolls of the parents and F_1 showing the locks

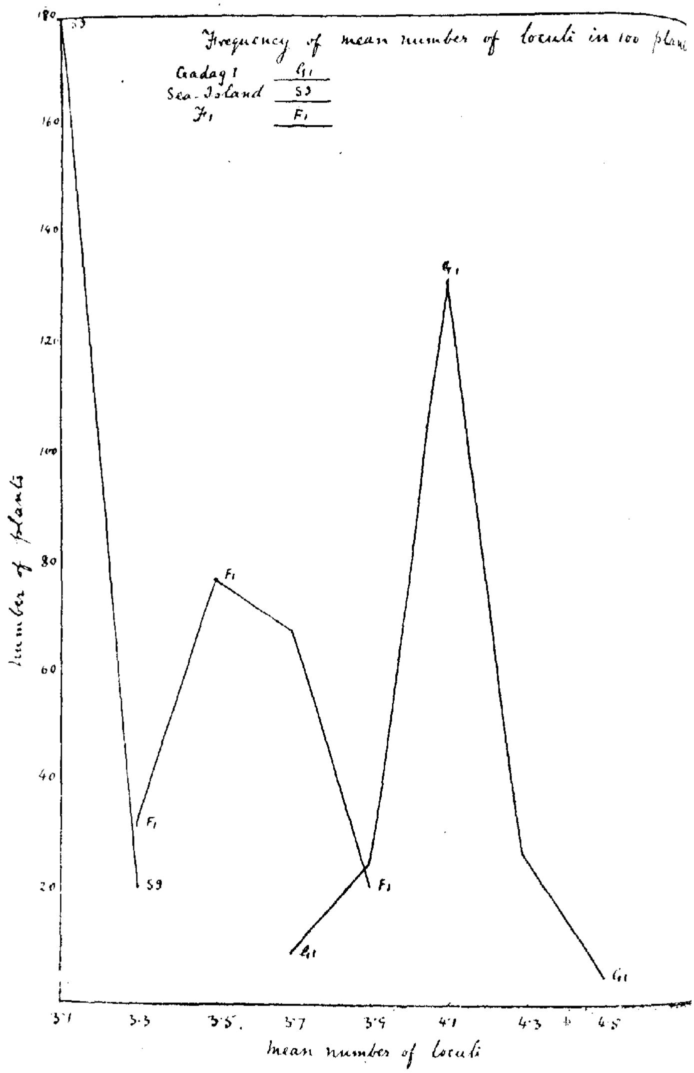


Fig 2.

Graph showing the frequency of the mean number of loculi in parents, and F_2.

(I). NUMBER OF LOCULI IN THE BOLLS.*

In a previous section of the present bulletin it has been shown that the mean number of loculi in the bolls from plants of Gadag No. 1 cotton varies from 3·7 to 4·1 per boll, and the numbers of 3, 4, and 5 locked bolls are commonly found. On the other hand, in Sea-Island cotton, the mean number of loculi in the bolls varies in different plants from 3·0 to 3·2 while 3 and 4 locked bolls (with an occasional 2 locked boll) only are found.

In the first and second generations of the cross the following frequency figures were obtained :—

Mean number of loculi per boll	Gadag No. 1	Sea-Island	F_1	F_2
3·0–3·1 . . .	..	*179*	..	*111*
3·2–3·3 . . .	..	21	32	98
3·4–3·5 . . .	..	..	78	89
3·6–3·7 . . .	9	..	68	64
3·8–3·9 . . .	26	..	22	17
4·0–4·1 . . .	*132*	..	..	52
4·2–4·3 . . .	28	..	..	7
4·4–4·5 . . .	5	..	..	2
TOTAL .	200	200	200	500

In Figure 2 is shown the graphic representation of this character in the parents and F_1 generation, and Plate IV shows the locks of the bolls.

The F_1 generation, therefore, is seen to have a mean number of boll locks intermediate between the two parents, but the distribution of the plants in the F_2 generation is not in accordance with any simple inheritance of the boll lock character. As the matter is an important one,—this character being one of those which govern the yield,—it was studied in the F_3 and F_4 generations.

* The inheritance of loculi in the bolls has been treated more in detail by one of the authors (R. K. Kulkarni) in the Agricultural Journal of India, Vol. XXII, Part 3, (May 1927).

Seventy-six plants of the F_2 generation were taken including representations of every value for the mean numbers of boll-locks, and the value similar for the progeny of each of them in the F_3 generation determined. The attached table shows the correlation between the mean number of boll-locks in the parent and families derived from it.

Mean boll-locks in F_2 parental plant	Total number of F_3 families	Number of F_3 families with various means of the mean boll-loculi					
		3·0 to 3·1	3·2 to 3·3	3·4 to 3·5	3·6 to 3·7	3·8 to 3·9	4·0 to 4·1
3·0 . . .	7	3	4	..	..	..	..
3·1 . . .	9	4	5	..	..	..	..
3·2 . . .	7	1	5	1	..	..	..
3·3 . . .	8	2	5	1	..	..	..
3·4 . . .	10	..	5	4	1	..	..
3·5 . . .	9	..	5	4	..	..	..
3·6 . . .	6	..	1	2	3	..	..
3·7 . . .	2	..	..	..	2	..	..
3·8 . . .	4	..	..	..	3	1	..
3·9 . . .	5	..	..	..	3	2	..
4·0 . . .	3	..	..	..	..	2	1
4·1 . . .	3	..	..	..	..	2	1
4·2 . . .	3	..	..	..	..	..	3
Total .	76	10	30	12	12	7	5

These figures clearly indicate a very high positive correlation between the number of boll-locks in the parent and in the progeny in the F_3 generation, the co-efficient of correlation being $+0{\cdot}93 \pm 0{\cdot}15$. A similar result was obtained by the study of numerous progenies in the F_4 generation, and it seems clear that forms giving a high boll-lock value can be extracted and will breed true. It has proved, in fact, quite possible to obtain, by selection, strains from the cross which have as high a value as the Gadag No. 1 parent, with a much improved lint staple.

(J). Length of staple of lint.

As has been already explained, the principal purpose of the work now under discussion was to obtain a cotton equally suitable for cultivation in the Dharwar American cotton area, as Gadag No. 1, and possessing its high yield and high ginning percentage, but also giving a much longer staple. Hence the inheritance of this character has a peculiar importance. Previous investigations seem to have shown that the long-staple character is usually dominant over short staple, and between types of cotton of distinctly different staple, Balls [1] and also Kottur [2] have found that this character segregated as a mono-hybrid ratio, though other workers have not confirmed this finding.

The staple of the parents and of the first generation (F_1) of the cross now under discussion, in three successive years, is shown in the following frequency table :

Staple length	Frequency								
	1923-24		F_1	1924-25		F_1	1925-26		F_1
	Gadag No. 1	Sea-Island		Gadag No. 1	Sea-Island		Gadag No. 1	Sea-Island	
16 - 18 mm. .	6	..	..	5	..	..	5	..	..
19 - 21 mm. .	59	..	..	27	..	..	25	..	..
22 - 24 mm. .	34	..	..	58	..	..	57	..	..
25 - 27 mm. .	1	..	..	10	..	..	13	..	..
28 - 30 mm. .	..	..	..	..	..	..	..	10	16
31 - 33 mm. .	..	..	..	..	..	9	..	10	25
34 - 36 mm. .	..	4	5	..	7	32	..	42	33
37 - 39 mm. .	..	21	21	..	13	33	..	25	16
40 - 42 mm. .	..	25	21	..	43	24	..	13	9
43 - 45 mm. .	..	28	24	..	33	2	..	..	1
46 - 48 mm. .	..	12	16	..	3	..	..	..	..
49 - 51 mm. .	..	8	12	..	1	..	..	..	..
52 - 54 mm. .	..	..	1	..	..	..	..	..	..
Total .	100	100	100	100	100	100	100	100	100
Mode mm. .	19-21	43-45	43-45	22-24	40-42	37-39	22-24	34-36	34-36
Mean mm. .	20·9	42·3	43·0	22·2	41·5	34·6	21·2	35·6	34·5

[1] Balls, W. L. Mendelian Studies of Egyptian Cotton. *Journ. Agri. Science*, Vol. II. 1908.

[2] Kottur, G. L. Studies in Inheritance in Cotton, I. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. XII, No. 3, 1923.

In Plate V is shown the pictures of staple of lint spread on seed of the parents, the F_1 and all the types occurring in the F_2 generation. Figure$_3$ shows the graphic representation of this character so far as the parents and the F_1 generation plants behave in the year 1923-24.

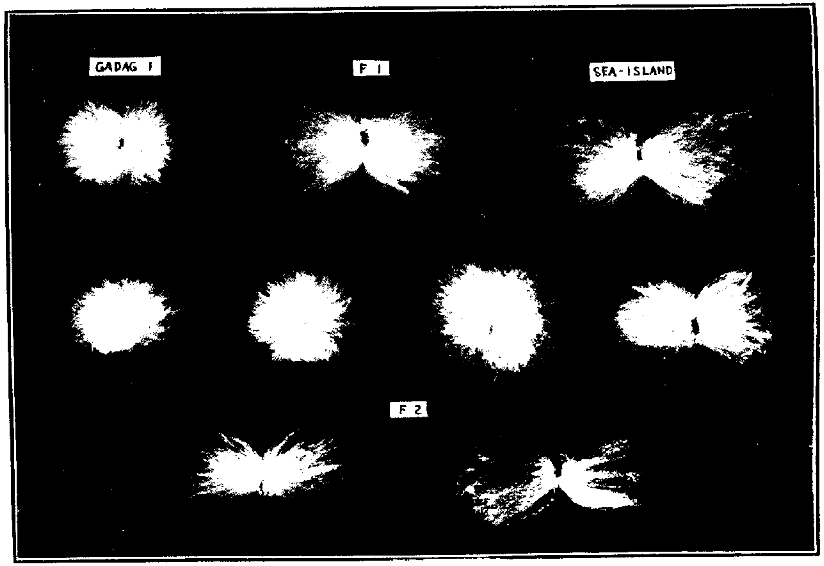
While these figures show that the year 1925-26 was not favourable to the Sea-Island type of cotton, yet it is quite clear in each of the three years that the first generation of the cross has a staple very close to that of the Sea-Island parent in the same year. The F_2 generation, grown side by side with the parents in the same year, showed the following results :—

Staple length	Frequency in F_2 generation.		
	1923-24	1924-25	1925-26
16—18 mm.	2	1	0
19—21 mm.	5	0	0
22—24 mm.	19	19	11
25—27 mm.	28	36	38
28—30 mm.	95	64	49
31—33 mm.	84	52	50
34—36 mm.	137	44	29
37—39 mm.	95	4	8
40—42 mm	72	1	3
43—45 mm.	44	0	0
46—48 mm.	3	..	0
Total	574	221	188

Figure 4 gives the graphic representation of the F_2 generation as grown in 1923-24.

If we take the actual number and proportion of plants the staple of whose cotton is 27 mm. and below (like the Gadag No. 1 cotton) on the

PLATE V.



Staple of lint spread on seed of the parents and F_1 generation and of the types occurring in F_2.

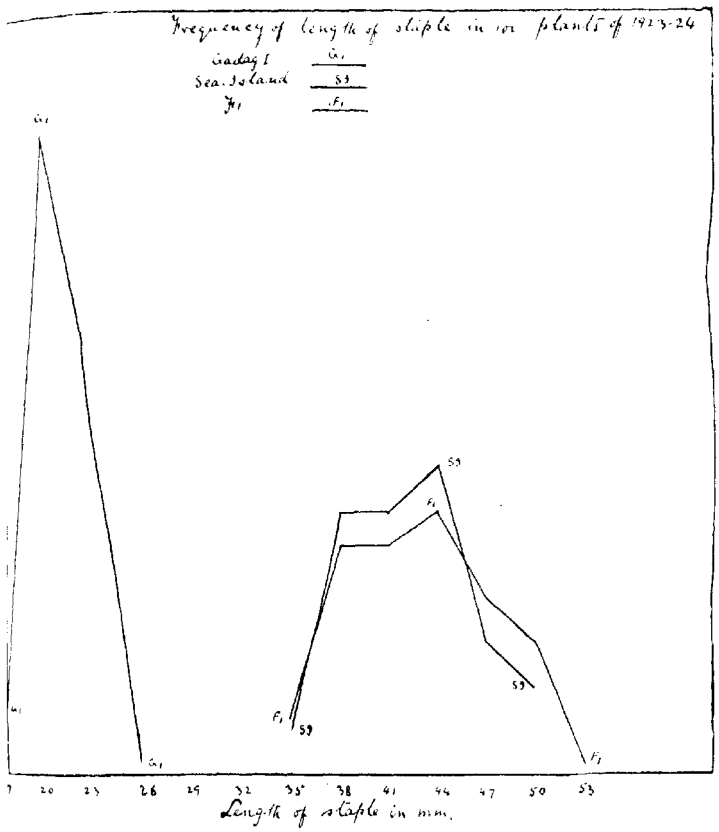


Fig 3

Graph showing the variation in the length of staple in the parents and F_1 generation.

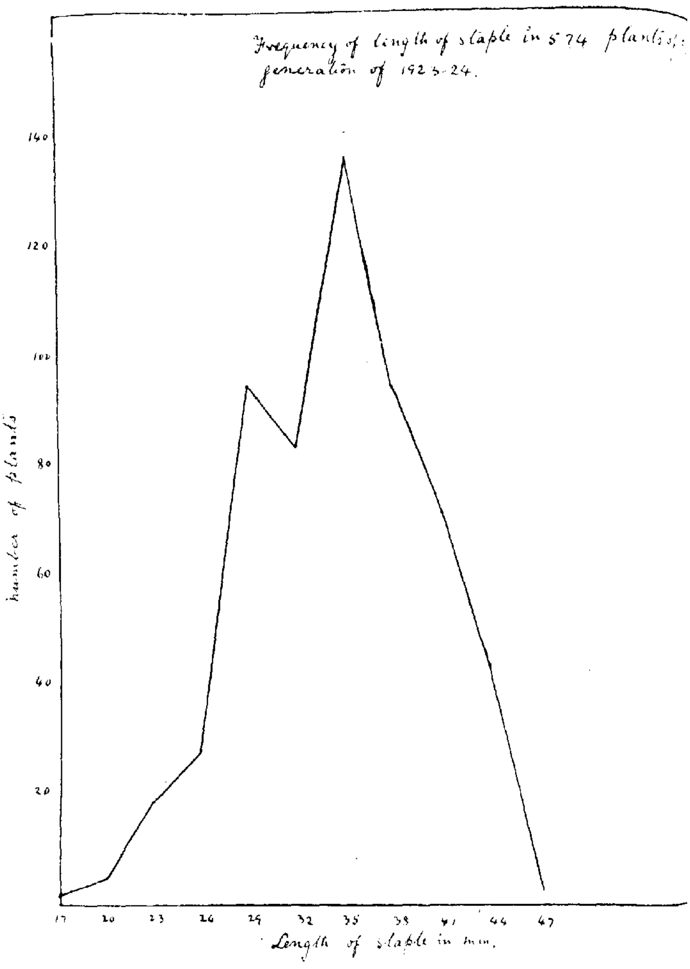


Fig 4

Graph showing the variation in the length of staple in the F_2 generation.

one side, and those with a longer staple than this (like the Sea-Island cotton) on the other the following figures are obtained :

Year	Number of plants		Proportion	
	With staple over 27 mm.	With staple under 27 mm.	With staple over 27 mm.	With staple under 27 mm.
1923-24	425	149	2·85	1
1924-25	165	56	2·90	1
1925-26	139	49	2·80	1
Total .	729	254	2·87	1

These proportions are a close approximation to what would be expected if the 'long' and 'short' staples are considered as simple mendelian characters, the 'long' staple of the Sea-Island parent being dominant over the "short" staple of Gadag No. 1. It seemed as important to determine whether this conclusion was justified that in 1923-24, a back cross was made between F_1 generation and the Gadag No. 1 parent and the resultant seed was grown along with the parents in 1924-25, with the results recorded in the following table. The numbers are calculated as per 100 plants in each case.

Staple length	Frequency		
	A Gadag No. 1	B Gadag No. 1 Sea-Island F_1	C Back Cross A × B
16—18 mm.	6	..	1
19—21 mm.	59	..	8
22—24 mm.	34	..	26
25—27 mm.	1	..	22
28—30 mm.	..	..	27
31—33 mm.	..	..	12
34—36 mm.	..	5	3
37—39 mm.	..	21	1
40—42 mm.	..	21	..
43—45 mm.	..	24	..
46—48 mm.	..	16	..
49—51 mm.	..	12	.
52—54 mm	..	1	..
Total .	100	100	100

Out of the plants obtained from the back cross described, 57 per cent. are short stapled according to the standard adopted and 43 per cent. are long stapled. If the "long" and "short" staple behaved in this case as simple mendelian character, then the number should be equal. This is not quite the case, but is sufficiently close for it to be probable that a simple mendelian factor is chiefly involved, modified by minor linkages of which at present we know nothing.

Seeds from 32 plants giving long staple and of 12 plants giving short staple in the F_2 generation of the original cross were now grown. The results showed that—

(1) All seeds derived from *short stapled* plants in the F_2 generation bred substantially true to the short staple character.

(2) Seed derived from *long stapled* plants in the F_2 generation gave results of two kinds. 12 out of 22 plants bred substantially true to the long stapled character, though four of them are only just a mean staple length of 27 mm.; the remainder (10 plants) gave a proportion of substantially 3 to 1 of long to short stapled plants. The actual proportion varied from 2·5 to 1 and 4·0 to 1 in individual cases.

The actual results for each class of plants was as follows :—

Plant No.	Total number of plants in F_3	Long staple over 27 mm.	Short staple under 27 mm.	Proportion	
				Long staple	Short staple
	1. Long stapled parents in F_2				
1—12	178 . . .	172	6	1	0·03
13—22	191 . . .	144	47	3·06	1
	2. Short stapled parents in F_2				
1—12	217 . . .	3	214	0·01	1

These results accord with what would be expected if long staple behaved as a simple mendelian dominant, all the long stapled plants have not given similar staple length, nor were they combined with yield qualities and ginning outturn which would make them desirable for multiplication. Only three (Nos. 1, 2 and 4) of those which bred true for long staple, seemed likely to be of real value and these three gave lint whose staple is more exactly shown in the following table (compared with Gadag No. 1) :—

Staple length	Frequency of staple length (F_2 1924-25)			
	Plant No. 1	Plant No. 2	Plant No. 4	Gadag No. 1
16—18 mm. . .	..	..	..	5
19—21 mm. . .	..	..	..	28
22—24 mm. . .	..	..	..	60
25—27 mm. . .	1	1	1	11
28—30 mm. . .	8	6	13	..
31—33 mm. . .	8	3	3	..
34—36 mm. . .	3	1	2	..
37—39 mm. . .	1	0	1	..
Total .	21	11	20	104
Mode (mm.) . .	28-33	28-30	28-30	22-24
Mean (mm.) . .	31	30	30	22·2
Co-efficient of variability.	8·8 per cent.	7·7 per cent.	10·1 per cent.	9·4 per cent.

Thus the three progenies possessing all the necessary characters for an agriculturally valuable plant have given plants whose length of staple varies from 27 to 39 mm. with a mean of 30 mm., and as such, are much superior to Gadag No. 1. To this value and behaviour further, along with that of a few others, the F_4 generation was followed in each case in row culture, side by side with the parents and the F_1 generation, in 1925-26. As already noted, the season of 1925-26 was not favourable for the production of long staple cotton of this type, whether from the Sea-Island parent or from the cross,—and hence in this year a limit of 25 mm. was taken for the boundary between "long" and "short" staple.

The results, derived from eight out of the twelve plants of the F_2 generation which *bred true to the long staple character*, are shown below, and indicate that in the F_4 generation all again *bred true to long staple.*

Plant in F_2	Plants of F_3 used	Plants in F_4	Long staple plants in F_4	Short staple plants in F_4	PROPORTION	
					Long staple	Short staple
1	8 plants	72	70	2	1	0·03
2	3 ,, ...	54	54	0	1	0
3	2 ,, . . .	48	47	1	1	0·02
4	14 ,, ...	240	233	7	1	0·03
5	1 plant	13	13	0	1	0
6	1 ,, ...	56	53	3	1	0·05
7	1 ,, ...	9	9	0	1	0
8	6 plants	112	109	3	1	0·03
	TOTAL 36 plants . .	604	588	16	1	0·03

From the plants which gave progeny in the F_3 generation of which part were long and part were short-stapled, seed from twenty-three were taken, and the progeny can again be divided into two classes. Seven of them bred substantially true for the long staple character; sixteen gave a proportion of substantially 3 to 1 of long to short stapled plants. The actual results for each class of plants was as follows :—

Plant Numbers	Total number of plants in F_4	Long staple (over 25 mm.)	Short staple (under 25 mm.)	PROPORTION	
				Long staple	Short staple
1—7	144 . .	141	3	1	0·02
8—23	429 . .	316	113	2·8	1

The progeny of the plants with short staple in the F_2 and F_3 generations all gave short staple plants in the F_4 generation as would be expected.

These results amply confirm the conclusion reached from a study of the F_3 generation of the cross that the staple in this case is controlled as a simple mendelian factor (with possible minor linkages) and that long staple is fully dominant over short staple of the lint.

If now we take the three F_2 plants (Nos. 1, 2 and 4) which have been selected (see above) as possessing other desirable characters combined with high staple, it is important to see how the staple character is retained in the year following the original selection. The table now given shows this, and indicates that there is little sign of regression from the standard when the selections were made.

Staple length	FREQUENCY OF STAPLE LENGTH (F_4 1925-26)			
	Plant No. 1	Plant No. 2	Plant No. 4	Gadag No. 1
16—18 mm. . .	..	..	..	7
19—21 mm. . .	..	..	..	37
22—24 mm. . .	2	..	7	85
25—27 mm. . .	14	7	34	20
28—30 mm. . .	*51*	*33*	*109*	..
31—33 mm. . .	24	8	55	..
34—36 mm. . .	9	5	32	..
37—39 mm. . .	0	1	3	..
TOTAL .	103	54	240	149
Mode . . .	28/30 mm.	28/30 mm.	28/30 mm.	22/24 mm.
Mean . . .	29·7 mm.	29·8 mm.	30·0 mm.	21·2 mm.
Co-efficient of variation.	9·8 per cent.	8·6 per cent.	10·4 per cent.	7·4 per cent.

(K). GINNING PERCENTAGE AND LINT INDEX.

Along with the yield of *Kapas* (seed cotton) per plant and the staple of lint,—the quantity of lint that the seed cotton gives on ginning, determines the value of a type of cotton. Hence the importance of the ginning percentage, and in the present case it is essential to retain, in any cross, the relatively high ginning percentage of the Gadag No. 1 parent. The inheritance of this character is, therefore, of much importance. In the present instance, the lint index will give practically the same results as the ginning percentage, as the seed weight in both parents is practically the same.

On this point we have the previous work of Kottur [1] in connection with his cross between strains of *Gossypium herbaceum* and *Gossypium neglectum* which indicated that in this cross, the proportion of lint to seed is a simple mendelian character varying independently of the length of staple. McLendon [2] with a cross of American Upland and Sea-Island cotton, found that a low percentage of lint was dominant to high percentage in the F_1 generation and that in the F_2 generation the original percentages reappear with variations extending beyond the extremes of the parental percentages. More recent work by Thadani [3] on varietal crosses of American Upland cottons in Sind, indicated, on the other hand, that while the amount of lint varied as if it were controlled as a single mendelian pair of characters, high percentage of lint was dominant to low percentage.

The position with regard to the ginning percentage in the parents and in the first two generations of the cross now under consideration in 1923-24 are shown in the following frequency table :—

Ginning percentage	Gadag No. 1	Sea-Island	Frequency in 1923-24.	
			F_1	F_2
10—11 per cent.	..	..	..	2
12—13 ,,	..	..	..	2
14—15 ,,	..	8	..	2
16—17 ,,	..	0	..	10
18—19 ,,	..	8	..	19
20—21 ,,	..	0	..	34
22—23 ,,	..	20	..	52
24—25 ,,	..	32	1	78
26—27 ,,	1	20	6	84
28—29 ,,	4	12	12	115
30—31 ,,	19	..	30	74
32—33 ,,	45	..	30	55
34—35 ,,	24	..	3	27
36—37 ,,	2	..	..	11
38—39 ,,	1	..	..	5
40—41 ,,	..	..	..	3
42 ,,	..	..	..	1
Total	96	100	82	574
Mode	33 per cent.	26 per cent.	32 per cent.	..
Mean	32·4 per cent.	23·8 per cent.	30·7 per cent.	..

[1] Kottur, G. L. Studies in Inheritance in Cotton, I. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. XII, No. 3, 1923.

[2] McLendon, C. A. Mendelian Inheritance in Cotton Hybrids. *Georgia Agri. Expt. Sta. Bull.* 99, 1912.

[3] Thadani, K. I. Inheritance of certain Characters, in *Gossypium*. *Agri. Jour. India*, Vol. XX, Part I, 1925.

These figures closely agree with those of Kottur who found that high percentage of lint while not completely dominant, yet showed the greater effect in the F_1 generation. The cross in the F_2 generation spread beyond the limits of the two parents, and gave plants with seeds with as low as 10 per cent. of lint and others with over 40 per cent. As there is a good deal of overlapping in the ginning percentage of the two parents it is impossible to divide the plants of F_2 generation into two groups, representative respectively of Gadag No. 1 and of Sea-Island cotton.

In the actual work done, however, only the progeny of plants which ginned over 30 per cent. was grown in the F_3 generation, and we may restrict our consideration to three plants Nos. 1, 2 and 4, which had high staple and which also had a ginning percentage which made them desirable for multiplication. The seeds from each of the plants named were few, but when grown in 1924-25 these yielded produce with ginning percenatge as shown in the following frequency table the figures for Gadag No. 1 being also quoted for comparison :—

Ginning percentage	Frequency in F_3 generation (1924-25)			
	Plant No. 1.	Plant No. 2.	Plant No. 4.	Gadag No. 1.
24-25 per cent. .	2	..	..	4
26-27 ,, .	6	..	3	4
28-29 ,, .	1	3	2	12
30-31 ,, .	5	2	2	34
32-33 ,, .	3	0	4	31
34-35 ,, .	1	6	6	15
36-37 ,, .	1	..	0	3
38-39 ,, .	..	..	3	1
TOTAL .	19	11	20	104
Mode	30 per cent.	34 per cent.	35 per cent.	32 per cent.
Mean	27·9 per cent.	32·4 per cent.	32·5 per cent.	30·7 per cent.
Co-efficient of variation.	12·9 per cent.	7·7 per cent.	11·3 per cent.	8·4 per cent.

The number of progeny in these three cases is not large enough to make conclusions certain, but as far as they are reliable, they indicate that the progeny of plants 2 and 4 have a ginning percentage at least as high as Gadag No. 1 with a co-efficient of variation little greater than with the latter.

A larger number of individuals from the progeny of these three plants in the F_4 generation, gave more reliable results, and the following frequency table indicates the results obtained :—

Ginning percentage	Frequency in F_4 generation (1925-26)			
	Plant No. 1	Plant No. 2	Plant No. 4	Gadag No. 1
22—23 per cent.	1	1	8	..
24—25 „	5	2	18	..
26—27 „	15	2	26	..
28—29 „	23	10	34	4
30—31 „	22	10	37	26
32—33 „	20	15	38	70
34—35 „	7	9	24	37
36—37 „	3	5	13	5
38—39 „	2	1	8	3
40—41 „	..	..	4	..
Total	98	55	210	145
Mode	29 per cent.	32 per cent.	30 per cent.	32 per cent.
Mean	30·1 per cent.	31·5 per cent.	30·3 per cent.	32·7 per cent.
Co-efficient of variation.	12·3 per cent.	10·8 per cent.	13·4 per cent.	5·4 per cent.

These figures indicate that these progenies in the F_4 generation retain the ginning percentage which they had in the F_3 generation, with little increase in the variability.

A similar study for the lint index has led to the same result, as would naturally be expected when one of the factors in the ginning percentage (the seed weight) is similar in the two parents.

It seems clear that it has been possible to combine in at least three strains of the cross between Gadag No. 1 and the strain of Sea-Island cotton used, the high ginning character of the Gadag No. 1 parent and the staple qualities of the Sea-Island parent, though the staple qualities have not been retained in these strains of the cross to the fullest extent.

(L). AMOUNT OF FUZZ ON THE SEED.

The quantity and distribution of the fuzz on the cotton seed vary very much with different cotton varieties and even with different strains of the same variety. Thus in cottons grown at Dharwar, it has been found that some of the American Upland types, a few strains of Sea-Island cotton, and a strain of *Gossypium herbaceum* called "*Sannahatti*" have seed with no fuzz whatever, that is to say, they were naked. All the Egyptian strains grown at Dharwar and some Sea-Island types have semi-naked seeds; in these a portion of the seed is naked and the remainder fuzzy. The Sea-Island strains of this kind have almost naked seeds with small tufts of fuzz at both ends. *Most* of the American Upland types (including Gadag No. 1) and almost all the Indian cottons have entirely fuzzy seeds, the fuzz being distributed over the whole surface.

Previous study of the inheritance of the character of bearing fuzz on the seed have been numerous, by Balls [1] in Egypt, by Fletcher [2], Fyson [3], and more recently by Thadani [4] in India, and by McLendon [5], Kearney [6] in America. All these workers have found that the fuzzy character is dominant over the naked seed character.

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[1] Balls, W. L. Mendelian Studies of Egyptian Cotton. *Jour. Agri. Science*, Vol. II, 1908.

[2] Fletcher, F. Mendelian Heredity in Cotton. *Jour. Agri. Science*, Vol. II, 1907.

[3] Fyson, P. F. Some Experiments in the Hybridizing of Indian Cottons. *Mem. Agri. Dept. India, Bot. Ser.*, Vol. II, No. 6, 1908.

[4] Thadani, K. I. Inheritance of certain Characters in *Gossypium*. *Agri. Jour. India*, Vol. XX, Part I, 1925.

[5] McLendon, C. A. Mendelian Inheritance in Cotton Hybrids. *Georgia Agri. Expt. Sta. Bull.* 99, 1912.

[6] Kearney, T. H. Segregation of Characters in an Upland Egyptian Hybrid. *U. S. Dept. Agri. Bull.* 1164, 1923.

The cross between Gadag No. 1 and Sea-Island cotton was one between an entirely fuzzy seed and a semi-naked seed (Sea-Island). The latter had small tufts of fuzz at the two ends of the seed and along the *raphe*. In the F_1 generation, all the plants gave seeds entirely fuzzy, showing the dominance of the fuzzy condition. In the F_2 generation counts were made on a population of 574 plants, all plants giving seeds entirely or partially fuzzy being taken as fuzzy. Plate VI shows a picture of different grades of fuzzy and naked seeds occurring in the F_2 generation together with the parental and F_1 types.

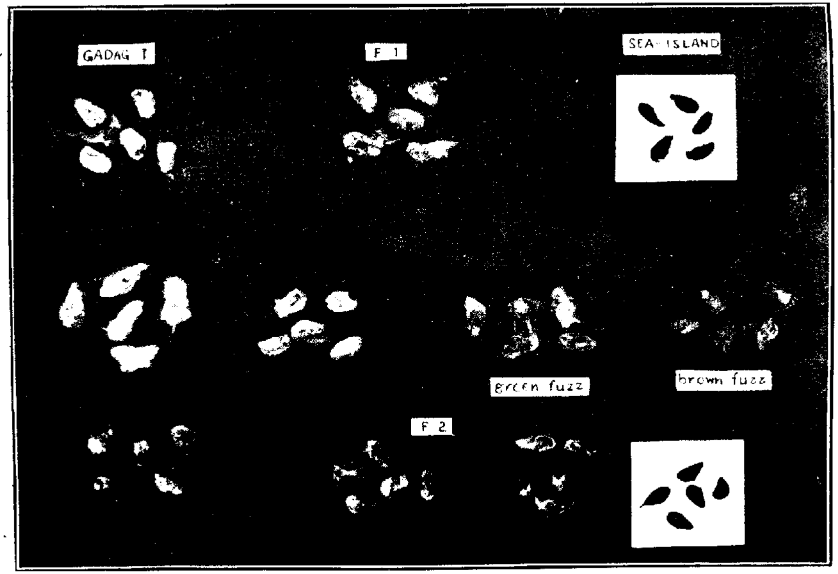
The results of the counts were as follows :—

	No. of plants	Proportion
Plants giving fuzzy seeds	539	15·4
Plants giving naked or semi naked seeds . . .	35	1·0
TOTAL .	574	..

In the third generation of the cross (F_3) the progeny of both the naked seeded and the fuzzy seeded plants of the F_2 generation can be divided into two sections. The results for seven plants of the former and eight plants of the latter may be summarized as follows :—

Plant Number	Total Number of plants in F_3	Plants with fuzzy seeds	Plants with naked seeds	PROPORTION Fuzzy	PROPORTION Naked
	I. Naked seeded plants in F_2				
1—2	12	0	12	0	1
3—7	74	57	18	3·2	1
	II. Fuzzy seeded plants in F_2				
1—4	56	42	14	3·0	1
5—8	51	47	4	11·7	1

PLATE VI.



Amount of fuzz on seed of the parents F_1 and F_2 generations.

These results are unexpected. Of the progeny of the seven naked seeded plants, that of two has bred true to this character, while that of the remaining five has given a proportion of three fuzzy seeded plants to one naked seeded plant. *All* would have been expected to breed true to the naked seeded character, and the actual results obtained does not seem to be explainable on any current hypothesis.

Out of the progeny of the eight fuzzy seeded plants, that of four have given a proportion of three fuzzy seeded to one naked seeded plant; the other four have given a *very* large excess of fuzzy seeded plants in the progeny.

The F_4 generation was followed in connection with the progeny of six of the above F_3 plants.

1. Plants giving naked seeds in F_2, and breeding true to this character in the F_3 generation, have also bred true in the F_4 generation, and have given naked seeds only.

2. Plants giving naked seeds in F_2, whose progeny give both fuzzy and naked seeds in the F_3 generation, have behaved as follows :—

Plant No. in F_2	Seed condition in F_3	Total number of plants in F_4	Plants with fuzzy seeds	Plants with naked seeds	Proportion	
					Fuzzy	Naked
34	1 Fuzzy	36	36	..	1	0
	2 Naked	7	7	7	0	4
	3 Fuzzy	7	5	2	2·5	1
4[illegible]	1 Fuzzy	20	20	0	1	0
	2 Do.	41	41	0		
5[illegible]	1 Naked	23	0	23	0	1
	2 Do.	25	0	25		
[illegible]	1 Fuzzy	41	41	0	1	0

Thus all the naked seeded plants have bred true to this character in the F_4 generation. It may be noted that all the seeds in these progenies were fully naked, they had not even the little tufts of fuzz found on the Sea-Island parent. The fuzzy seeded plants have either bred true to the fuzzy character (4 plants) or given fuzzy and naked seeded plants in the proportion of 2·5 to 1. The number of plants in this last case is, however, so small that no definite conclusion can be reached as to the exact proportion.

3. One plant giving fuzzy seeds in F_2, whose progeny give both fuzzy and naked seeds in the F_3 generation in the proportion of 3 to 1 has behaved as follows:—

Plant No. in F_2	Seed condition in F_3	Total number of plants in F_4	Plants with fuzzy seeds	Plants with naked seeds	PROPORTION	
					Fuzzy	Naked
28	1 Naked	4	0	4	0	[illegible]
	2 Fuzzy	23	21	2	10·5	[illegible]
	3 Do.	9	9	0	1	
	4 Do.	14	11	3	3	[illegible]
	5 Do.	14	10	4		
	6 Do.	23	21	2	10·5	[illegible]

Again the naked seeded plant of the F_2 generation has bred true to this character. The fuzzy seeded plant of the F_3 generation has yielded progeny apparently of three types. Some have bred true to the fuzzy character: others (4 and 5) have split in the proportion of 3 fuzzy to 1 naked seeded plant; the remainder (2 and 6) have split in the proportion of 10·5 fuzzy to one naked seeded plants. The meaning of this last named group remains unexplained.

4. Plants giving fuzzy seeds in F_2, and breeding true to this character in the F_3 generation, have also bred true in the F_4 generation, and have given fuzzy seeds only.

Generally, this study indicates the complete dominance of the fuzzy seeded character. There is no difficulty in obtaining types with naked, and also with fuzzy seeds which breed true. Where impure fuzzy types are grown, the progeny either split into fuzzy and naked seeded plants in the proportion of approximately 3 to 1, or in a much larger proportion, varying from 9 to 1 to 13 to 1, but most usually about 10·5 to 1. The explanation of this latter form of splitting has not yet been made out.

(M) COLOUR OF THE SEED FUZZ.

Attention was drawn by Mr. B. C. Burt in 1924 to the fact that cotton varieties with green fuzz have a tendency to leave specks in the cotton, and are not liked by spinners on this account. This has led the authors to devote some consideration to the subject of the fuzz colour.

The colour of the seed fuzz in the Gadag No. 1 parent is greenish-white while that of the small amount of fuzz on the Sea-Island parent is quite green, tending to a brown colour. In the F_1 generation, all plants had green fuzz, fading in some plants to brown, thus showing the dominance of the more highly coloured type. In the F_2 generation, in addition to the plants with greenish-white and green fuzz, some plants were found with entirely brown fuzz. The actual number of each kind in a population of 208 plants was as follows :

—	No. of plants	Proportions
Plants with greenish-white fuzz (like Gadag No. 1)	58	1·1
Plants with green fuzz	97	1·8
Plants with brown fuzz	53	1·1

These figures indicate that the coloured fuzz of the Sea-Island cotton seed contains two elements, and that the brown coloured plants when segregated in the F_2 generation form a proportion of 1 to 2·9 compared with those whose fuzz has a tinge of green.

In the F_3 generation, the plants whose F_2 parent had brown fuzz bred substantially true to this character, for out of 115 plants, 111 plants had brown fuzz (96·5 per cent.). As to the plants with greenish-white and with green fuzz, there was such a gradual passage from fully green to light greenish-white colour that it was found impossible to classify them, and the inheritance of the green fuzz could not be followed.

In the F_4 generation, all the plants whose F_3 parent had brown fuzz, bred substantially true to this character, for out of 155 plants, 152 plants had brown fuzz (98 per cent.).

Thus it seems clear that the brown tinge found in the green fuzz of Sea-Island cotton completely segregates in the F_2 generation and breeds true in the succeeding generations. As regards the greenish-white and green types of fuzz, it was found easy to segregate the types with definitely greenish-white fuzz in the F_3 generation, but that this was very difficult for the types with decidedly green fuzz. All selections for multiplication have been made among types with either brown or greenish-white fuzz and the difficulty of the association of green fuzz with specks in the cotton has been eliminated.

VII. Correlation Studies.

(A) Correlation between length of stigma and staple

Some workers on cotton, and especially Ram Prasad [1] working in the United Provinces (India), have found a strong relationship between

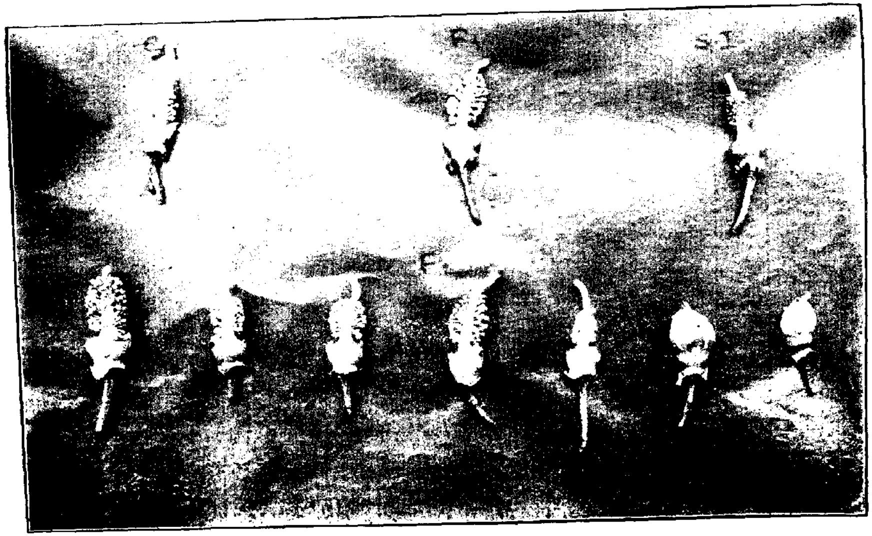
[1] Ram Prasad. Note on the Probability of an Inter-relation between the length of the Stigma and that of the Fibre in some forms of the Genus *Gossypium*. *Agri. Res. Inst. Pusa Bull.* 137 1923.

the length of stigma in cotton flowers and the length of staple of the cotton fibre produced from these flowers. If such a relationship were proved to exist, it would be of great use in selection and roguing work in cotton. Ram Prasad has determined the probability of such a relationship in many Indian and American varieties, but recognizes that the only way to determine whether the correlation is a real one is to cross forms with different lengths of stigma, and ascertain whether the fibre length and the stigma length are inherited together. The cross under consideration in the present bulletin gave an opportunity to do so as the stigma in the Gadag No. 1 parent is decidedly shorter than that in the Sea-Island strain used to cross with it.

The length of stigma in flower at different positions on the cotton plant varies very considerably, and in order to avoid errors on this account, all measurements were taken on flowers at the first or second joint on a primary fruiting branch arising at the tenth or eleventh node on the main stem. The stigma was measured, in millimeters, from the upper end of the staminal column, and not from the point reached by the uppermost anther, as the latter is very indefinite. The latter is, however, the method used by Ram Prasad, and he notes that the relation to which he has called attention is specially close if his method is used.

The following frequency table shows the distribution of stigmas of various lengths in the original parents and in the first two generations of the cross, calculated for 100 plants in all except the F_2 generation, in which it is given for 700 plants. Plate VII shows the picture of the stigma of the parental and F_1 types, together with all the types occurring in the F_2 generation.

Length of stigma	Frequency distribution			
	Gadag No. 1	Sea-Island	F_1	F_2
3—4 mm.	1	..	..	31
5—6 mm.	19	9	5	144
7—8 mm.	41	13	17	191
9—10 mm.	27	52	36	168
11—12 mm.	12	22	33	101
13—14 mm.	..	4	6	27
15—16 mm.	..	..	3	21
17—18 mm.	..	..	..	8
19—20 mm.	..	..	..	4
21—22 mm.	..	..	..	5
Total	100	100	100	700
Mode	7 mm.	10 mm.	11 mm.	..
Mean	8·05 mm.	9·52 mm.	10·1 mm.	..



Length of stigma in parents. F_1 and F_2 generations.

Though the stigma lengths of the parents overlap a good deal, the mean length of the stigma in the F_1 generation is rather greater than in the higher parent. As the long staple of the Sea-Island parent has been shown to be fully dominant over the shorter staple of Gadag No. 1, it will be seen that the tendency of both characters is to vary in the same direction. Splitting takes place in the F_2 generation, with examples of stigmas far longer than in either parent.

The correlation between the two characters can be made out in each generation, and correlation tables indicating the results are shown in appendix No. 1. They show, however, very slight correlation in any generation between the length of stigma and the length of staple within the parents, or within each generation of the cross. The co-efficient of correlation in each of these is as follows :—

Co-efficient of correlation.

	Stigma length and staple of lint.
Gadag No. 1	$-0·004 \pm 0·08$
Sea-Island	$+0·006 \pm 0·15$
F_1 generation	$+0·3 \pm 0·08$
F_2 generation	$+0·11 \pm 0·03$

There is, therefore, no correlation whatever in either of the two parents; apparently a slight correlation can be made out in the plants of the F_1 generation, but it no longer exists in the F_2 generation. It seems clear that the supposed relationship is, at most, a very slight one, and will be of no practical service in the selection or roguing of cotton for good staple types.

(B). Correlation between ginning percentage and staple of lint.

It has been usually assumed by practical men working with cotton that there is a definite correlation between a high ginning type of cotton and a low staple and *vice versâ*, or in other words that it is difficult if not impossible to obtain a long staple cotton which has also a high ginning percentage. Doubt has been thrown on this position in recent years by Kottur[1] who showed that in a cross between strains of *Gossypium herbaceum* and *Gossypium neglectum* the two characters were almost if not entirely independent and by Stroman[2] in a biometrical study of

[1] Kottur, G. L. Studies in Inheritance in Cotton, I, *Mem. Dept. Agri. India, Bot. Ser.*, Vol. XII, No. 3, 1923.

[2] Stroman, G. N. Biometrical Studies of Lint and Seed Characters in Cotton. *Texas Agri. Expt. Sta. Bull.* 332, 1925.

sixteen varieties of Texas cotton, who found the correlation between these characters to be very small. The latest work on the subject is that of Patel and Patel[1] who in a study of inter-varietal crosses of *Gossypium herbaceum* came to the conclusion that in certain cottons only, there is reason to suspect some coherence between these characters.

The characters of the cross now under study seemed to be able to throw light on this question and hence the correlation tables given in appendix No. 2, have been prepared, showing the relationships of the length of the staple of the lint, and the ginning percentage in the parents and in the first two generations of the cross. The co-efficient of correlation in each of these is as follows :—

Co-efficient of correlation.

	Staple of lint and ginning percentage.
Gadag No. 1	$-0·30 \pm 0·06$
Sea-Island	$+0·32 \pm 0·12$
F_1 generation	$+0·26 \pm 0·08$
F_2 generation	$-0·10 \pm 0·03$

These figures show no evidence of any certain correlation between the two characters in either parent or in either generation of the cross. In the present case, therefore, there is no certain genetic correlation, and they may be considered as varying in substantial independence.

[1] Patel, M. L. and Patel, S. J. Studies in Gujarat Cottons, Part IV, Hybrids between *Broach-Deshi* and *Goghari* Varieties of *Gossypium herbaceum* *Mem. Dept. Agri. India, Bot. Ser.*, Vol. XIV, No. 4, 1927.

APPENDIX No. 1.

CORRELATION TABLES BETWEEN THE LENGTH OF STIGMA AND THAT OF THE FIBRE.

Gadag No. 1.

Length of staple mm.	STIGMATIC LENGTH MM									
	4	5	6	7	8	9	10	11	12	F
16—18	..	1	1	2	..	..	..	1	..	5
19—21	..	1	3	8	7	6	4	5	2	36
22—24	1	3	2	3	5	4	4	1	..	23
25—27	..	..	..	..	..	..	1	..	..	1
F .	1	5	6	13	12	10	9	7	2	65

Co-efficient of correlation = —·004 ± 0·08

Sea-Island.

Length of staple mm.	LENGTH OF STIGMA IN MM.								
	6	7	8	9	10	11	12	13	F
37—39	..	..	..	1	3	..	1	..	5
40—42	..	1	1	1	..	1	..	..	4
43—45	1	..	1	2	1	1	1	..	7
46—48	..	..	..	..	1	1	..	1	3
49—51	..	..	..	1	1	..	..	..	2
F .	1	1	2	5	6	3	2	1	21

Co-efficient of correlation = +0·006 ± 0·15

Gadag No. 1 × *Sea-Island* F_1.

Length of staple mm.	LENGTH OF STIGMA IN MM.										
	6	7	8	9	10	11	12	13	14	15	F
34—36 . . .	..	..	..	..	1	1	..	..	..	..	2
37—39 . . .	..	2	4	2	1	..	2	..	..	..	11
40—42 . . .	..	1	2	2	3	3	1	..	1	..	13
43—45 . . .	2	1	1	3	6	3	1	..	..	..	17
46—48 . . .	..	..	..	2	1	5	1	..	..	2	11
49—51 . . .	1	..	..	1	..	3	1	3	..	..	9
F .	3	4	7	10	12	15	6	3	1	2	63

Co-efficient of correlation = +0·3 ± 0·08

Gadag No. I × Sea-Island F_2.

Length of staple mm.	Length of stigma in mm.																				
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	F
16—18 . .	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	1
19—21 . .	..	..	..	1	1	1	2	..	..	..	..	..	..	..	..	..	..	..	..	..	5
22—24 . .	..	..	1	5	3	3	2	1	1	1	1	..	..	..	..	1	..	..	..	..	19
25—27 . .	2	..	2	4	9	3	1	1	3	0	1	..	..	..	..	..	..	..	..	..	26
28—30 . .	1	8	8	10	11	12	12	8	5	2	2	1	..	1	1	1	..	..	..	..	83
31—33 . .	..	1	11	10	16	15	7	11	5	6	2	2	1	..	..	..	..	..	1	..	88
34—36 . .	1	2	10	18	16	14	21	20	15	5	3	0	3	..	..	..	..	..	1	2	131
37—39 . .	2	1	5	14	13	13	14	7	4	8	3	0	3	1	1	1	..	..	1	..	91
40—42 . .	1	1	5	9	11	10	8	12	6	2	1	..	1	1	..	..	..	..	..	..	68
43—45 . .	..	1	..	2	6	2	6	2	5	3	1	2	1	..	..	..	..	..	..	..	31
46—48 . .	..	..	..	..	1	..	1	..	..	..	..	1	..	..	..	..	..	..	..	..	3
F .	7	14	42	73	87	73	74	63	44	27	14	6	9	3	2	3	..	..	3	2	546

Co-efficient of correlation = $+0{\cdot}11 \pm 0{\cdot}03$

APPENDIX No. 2.

CORRELATION TABLES BETWEEN GINNING PERCENTAGE AND LENGTH OF STAPLE.

Gadag No. I.

Length of staple mm.	Ginning percentage												
	27	28	29	30	31	32	33	34	35	36	37	38	F
16—18	..	..	..	1	2	2	1	..	..	..	..	..	6
19—21	..	..	..	2	8	8	15	10	10	..	1	..	54
22—24	1	1	3	2	4	7	10	3	1	..	..	1	33
25—27	..	..	..	..	..	..	..	..	..	1	..	..	1
F .	1	1	3	5	14	17	26	13	11	1	1	1	94

Co-efficient of correlation = $-0 \cdot 3 \pm 0 \cdot 06$

Sea-Island.

Length of staple mm.	Ginning percentage																
	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	F
34—36 .	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1
37—39 .	1	..	..	..	..	1	..	..	..	2	..	..	..	1	..	1	6
40—42 .	..	..	..	..	..	..	..	..	..	2	1	1	1	..	1	..	6
43—45 .	..	..	..	..	..	..	..	..	..	2	1	2	..	1	1	..	7
46—48 .	..	..	..	..	..	1	..	..	..	..	..	1	1	..	..	..	3
49—51 .	..	..	..	..	..	..	..	..	..	..	1	..	..	1	..	..	2
F .	1	1	..	..	..	2	..	..	..	6	3	4	2	3	2	1	25

Co-efficient of correlation = $+0 \cdot 32 \pm 0 \cdot 12$

Gadag No. 1 × Sea-Island F_1.

Length of staple mm.	Ginning percentage												
	24	25	26	27	28	29	30	31	32	33	34	35	F
34—36	..	..	1	2	..	1	..	..	..	..	..	..	4
37—39	1	..	..	2	..	1	2	4	3	1	..	1	15
40—42	..	..	..	..	..	2	1	2	4	4	..	..	13
43—45	..	..	..	..	2	..	5	..	3	2	..	1	13
46—48	..	..	..	..	..	..	1	2	3	..	..	..	6
49—51	..	..	..	..	..	1	1	..	2	..	..	..	4
F .	1	..	1	4	2	5	10	8	15	7	..	2	55

Co-efficient of correlation = $-0 \cdot 26 \pm 0 \cdot 08$

Gadag No. 1 × Sea-Island F_2.

Length of staple mm.	Ginning percentage 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	F
16—18 . .	..	..	1	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2
19—21 . .	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	2	..	..	..	..	1	..	..	1	..	..	..	..	..	..	5
22—24 . .	..	..	..	..	..	..	..	..	..	..	2	1	..	..	..	1	3	2	1	1	1	1	3	..	1	..	..	1	..	..	..	..	1	19
25—27 . .	..	..	..	..	..	..	..	..	..	..	1	..	2	..	3	1	1	2	4	3	2	3	3	1	..	..	1	1	..	..	..	..	..	28
28—30 . .	..	..	..	..	..	..	1	..	..	2	4	1	3	7	7	9	6	6	10	12	5	5	4	6	2	1	1	1	..	..	2	..	..	95
31—33 . .	1	..	..	..	..	..	..	..	1	2	3	2	2	4	2	8	4	4	8	7	4	6	8	7	5	3	..	..	2	1	..	..	..	84
34—36 . .	..	..	..	..	..	..	4	..	5	4	5	2	5	8	3	12	12	8	8	22	12	5	7	1	4	4	2	1	2	..	..	1	..	137
37—39 . .	..	..	..	1	..	1	..	1	..	5	1	2	4	4	3	12	8	4	12	10	7	11	3	3	..	3	..	..	..	..	..	..	..	95
40—42 . .	1	..	..	..	..	1	1	1	..	..	2	3	3	4	2	11	9	7	7	4	5	3	2	..	4	..	..	2	..	..	..	..	..	72
43—45 . .	..	..	..	..	..	..	..	1	..	..	1	3	3	3	3	1	5	2	3	..	1	2	3	3	..	..	..	..	..	..	..	..	..	34
46—48 . .	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..	3
F .	2	..	1	1	..	2	6	4	6	13	20	14	22	30	23	55	48	36	55	60	38	36	33	22	16	11	5	6	4	1	2	1	1	574

Co-efficient of correlation = —0·10 ± 0·03

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