THE GENETICS OF COTTON.

PART XV. THE INHERITANCE OF FUZZ AND LINTLESSNESS AND ASSOCIATED CHARACTERS IN ASIATIC COTTONS.

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CONTENTS.

INTRODUCTION.

THE experiments here reported constituted part of a programme of investigation into inheritance in Asiatic cottons. In two important respects—the inheritance of *G. herbaceum* var. *Wightiana* naked and the behaviour of *arboreum* tuft and lintless in interspecific hybrids—the study of fuzz characters is incomplete. The results here reported are, however, complete for the species *G. arboreum*.[1]

Previous work has been summarised by Harland (1932) and will not be further discussed here.

MATERIAL.

The strains used in these experiments were from the collection of types of Asiatic cotton grown at the Cotton Research Station, Trinidad.

Most Asiatic cottons have two coats of hairs on the seed, long hairs forming the lint of commerce, and short hairs, or fuzz, which form an inner coat which is mechanically difficult to remove from the seed. Two main types of fuzz can be distinguished, a thin fuzz made up of very short hairs, through which the seed coat is visible, giving the seed an ashy grey appearance, and a thick fuzz made up of relatively long hairs, through which the seed coat is not visible. The fuzz may be brown, green, or white, and on thick-fuzzed types the colour is quite charac-

[1] Specific and varietal names are according to the classification included in Harland's (1932) "Genetics of *Gossypium*".

teristic. With thin-fuzzed types the black seed coat showing through usually effectively masks the fuzz colour.

In *G. arboreum* both types of fuzz occur. Of the Indian arboreums, the majority have thin fuzz. Of the strains examined from Burma, some have thick fuzz and some have thin fuzz. All the fuzzy Chinese strains examined have more or less thick fuzz.

The following fuzzy types were used as parents:

Type	Reference	Species	Origin
Sanguineum	G.S. 2	*G. arboreum*	India
Cawnpore White	C.W.	*G. arboreum*	U.P., India
Yenching "Million Dollar"	N 11–2	*G. arboreum* var. *Nanking*	Yenching, China
"Million Dollar"	N 1	*G. arboreum* var. *Nanking*	Nanking, China
	N 6	*G. arboreum* var. *Nanking*	Extracted multiple recessive

Two types of fuzz reduction occurred among the *G. arboreum* strains, tufted, in which the fuzz is reduced to a small tuft of short hairs at each end of the seed, and semi-tufted, in which fuzz is absent from a patch on the dorsal surface of the seed, while the rest of the seed is covered with thick fuzz.

The following tufted and semi-tufted types were used as parents:

	Type	Reference	Species	Origin
Chinese Tufted Seeded	Tufted	C.T.S.	*G. arboreum* var. *Nanking*	China
Chickenfoot	Tufted	A 16	*G. arboreum*	Kiangyin, China
Semi-tufted "Million Dollar"	Semi-tufted	N 3	*G. arboreum* var. *Nanking*	Nanking, China

All typical specimens of *G. herbaceum* examined are fuzzy. Some have thick fuzz, and some thin fuzz. In *G. herbaceum* var. *Wightiana*, all the strains examined from India have thin fuzz. A strain obtained from Gambia, West Africa, has thick fuzz.

A variety of *G. herbaceum* var. *Wightiana* numbered 231 obtained from the Geneticist in Charge, the Transcaucasian Cotton Research Institute, Ganja, U.S.S.R. has an entirely naked seed, except for a small, sharply demarcated, tuft at the base. The lint is much reduced in quantity, and is restricted to the basal half of the seed. The genetics of this type have not yet been investigated. It appears to be that described by Gammie (1907) as *G. herbaceum* var. *melanosperma*.

The three strains of *G. herbaceum* var. *africana* under cultivation at the Cotton Research Station all have thin fuzz.

EXPERIMENTS.

(1) *Tufted crosses.*

Chinese Tufted Seeded × *Sanguineum* 2.

The sanguineum parent had thin fuzz. In F_2 segregation occurred into tufted, intermediate, and fuzzy. Six grades were selected representative of the range of tufted and intermediate types, and numbered 1–6 in order of increasing amount of fuzz. Fuzzy formed a distinct class. In Table I are given frequency arrays of fuzz grade for parents, F_1, F_2 and a back-cross to sanguineum 2.

TABLE I.

Frequency arrays of fuzz grade for parents, F_1, F_2 and F_1 × G.S. 2 of Chinese Tufted Seeded × *Sanguineum* 2.

Type	Fuzz grade 1	2	3	4	5	6	F.	Total
G.S. 2	.	.	.	.	.	.	All	All
C.T.S.	.	.	2	14	.	.	.	16
C.T.S. × G.S. 2 F_1	.	.	1	1	.	.	.	2
C.T.S. × G.S. 2 F_2	21	72	81	121	102	52	158	607
(C.T.S. × G.S. 2) × G.S. 2	.	.	3	44	63	10	127	247

There were in all 449 tufted : 158 fuzzy in F_2, and 120 tufted : 127 fuzzy in the back-cross, or approximately 3 : 1 and 1 : 1 respectively. The F_1 was similar to the tufted parent. In F_2 intensification of the tufted character occurred, and in the back-cross tufted was recovered as low in grade as the lower parent. Genes further reducing the amount of fuzz must have been brought in by the fuzzy parent. There was no evidence of dominance, comparison of the F_2 and back-cross results showing clearly that heterozygotes were high-grade tufted. In this cross, no notes were made on the type of fuzz carried by the fuzzy segregates.

Cawnpore White × *Chickenfoot.*

The Cawnpore White parent had thin fuzz.

The F_1 again resembled the tufted parent. In F_2 there was again intensification of the tufted character, but it was not so pronounced as

TABLE II.

Frequency arrays of fuzz grade for parents, F_1, F_2 and F_1 × C.W. of Cawnpore White × *Chickenfoot.*

Type	Fuzz grade 1	2	3	4	5	6	F.	Total
Cawnpore White	.	.	.	.	.	.	All	All
Chickenfoot	.	.	4	9	.	.	.	13
C.W. × A 16 F_1	.	.	1	1	.	.	.	2
C.W. × A 16 F_2	.	2	16	32	3	.	16	69
(C.W. × A 16) × C.W.	.	.	5	14	.	.	28	47

in the previous cross. Comparison of the tufted classes from F_2 and back-cross again showed that the heterozygote was intermediate. Clear segregation again occurred into 3 tufted : 1 fuzzy in F_2. In the back-cross there were 19 tufted : 28 fuzzy. Frequency arrays are given in Table II.

Chickenfoot × Yenching "Million Dollar".

The "Million Dollar" parent had thick fuzz.

The F_1 was grade 5, more fuzzy than the previous F_1's. In F_2 the distinction between fuzzy and tufted was not so clear as in the two previous crosses. In the fuzzy class there were grades of fuzz thickness from nearly as thin as in Cawnpore White to thick, as in the "Million Dollar" parent. A back-cross was made to Cawnpore White and gave thin fuzzies and grade 4 tufted only. Frequency arrays of fuzz grade are given in Table III.

TABLE III.

Frequency arrays of fuzz grade for parents, F_1, F_2 and $F_1 \times C.W.$ of Chickenfoot × Yenching "Million Dollar".

	Fuzz grade							
Type	1	2	3	4	5	6	F.	Total
Yenching "Million Dollar"	.	.	.	.	.	.	All	All
Chickenfoot	.	.	4	9	.	.	.	13
A 16 × N 11–2 F_1	.	.	.	.	2	.	.	2
A 16 × N 11–2 F_2	.	.	11	27	54	12	27	131
(A 16 × N 11–2) × C.W.	.	.	.	13	.	.	19	32

No intensification of tufted occurred in this cross, but a comparison of the F_2 tufted frequency array with the F_1 value shows that the heterozygote was again intermediate. Since Cawnpore White (a thin-fuzz type) has been shown to carry genes intensifying the effect of the tufted gene, the absence of grades 5 and 6 from the back-cross was to be expected.

There were in all 104 tufted : 27 fuzzy in F_2, and 13 tufted : 19 fuzzy in the back-cross, a fair fit in each case to the expected 3 : 1 and 1 : 1 ratios.

(2) *Semi-tufted crosses.*

Grades 5 and 6 in the above crosses were similar in fuzz distribution to the semi-tufted type. The standard semi-tufted was a selection from the "Million Dollar" strain, which is a woolly fuzzy type. The semi-tufted strain was, therefore, crossed with Chickenfoot and with its parent "Million Dollar" strain to determine whether semi-tufted is due to the action of the same gene as tufted, and if so, whether the genes responsible for the difference between tufted and semi-tufted are the same as those responsible for the difference between thin and thick fuzz.

Chickenfoot × "Million Dollar" Semi-tufted.

F_1 was tufted grade 3. An F_2 was grown, and a back-cross to Cawnpore White. Only tufted plants were obtained. In F_2 the grade of tuft varied from 3 to 6, and in the back-cross to Cawnpore White all plants but two were grade 4. Frequency arrays are given below.

TABLE IV.

Frequency arrays of fuzz grade of parents, F_1, F_2 and $F_1 \times C.W.$ of Chickenfoot × Semi-tufted.

	Fuzz grade				
Type	3	4	5	6	Total
Chickenfoot	4	9	.	.	13
Semi-tufted	.	.	5	.	5
A 16 × N 3 F_1	3	.	.	.	3
A 16 × N 3 F_2	10	26	6	2	44
(A 16 × N 3) × C.W.	1	38	1	.	40

Evidently, semi-tufted and tufted result from the action of a single main gene, and the intensity of expression of the gene is greatly modified by other minor genes. These intensifiers of tuft appear to be dominant, since the F_1 of tufted × semi-tufted was fully tufted.

"Million Dollar" Semi-tufted × "Million Dollar".

Two semi-tufted strains were used. One was derived from a strain of "Million Dollar" received from Nanking, its place of origin. This strain was grown under the number N 3. The other was selected from a sample of seed from Lingnan University, said to have been grown from Nanking seed, and, therefore, probably of "Million Dollar" ancestry. This strain was grown under the number N 13–12.

N 3 was grade 5 tufted, with thick fuzz on the fuzzy parts of the seed. N 13–12 had similar fuzz on the fuzzy parts, but had a rather larger naked area, being nearer to grade 4. It differed from grade 4 Chickenfoot types in having much longer fuzz hairs on the fuzzy parts of the seed.

The difference in fuzz grade between the semi-tufted parents was reflected in the F_1's. In both F_1's fuzzy seeded plants appeared. In N 3 × "Million Dollar" F_1 there were two plants grade 6 tufted, and five fuzzy. In N 13–12 × "Million Dollar" there were three plants grade 5, eight plants grade 6, and two plants fuzzy. The F_1 used as parent of the F_2 was a fuzzy seeded plant from N 3 × "Million Dollar". Six F_3 families were also raised from a small group of F_2 plants grown in the greenhouse. Frequency arrays of fuzz grade are given in Table V.

There was evidently segregation for modifying genes even though the two parental strains were closely related. The two homozygous semi-tufted F_3 families differed considerably, plant 3 which was grade 4 having nearly 75 per cent. of grade 4 progeny, whereas only slightly over 50 per cent. of the progeny of F_2 plant 6, which was grade 5, were grade 4. Genes increasing the amount of fuzz were present to such an extent, however, that the difference between fuzzy and tufted was masked. A fuzzy F_1 proved to be a heterozygote, and 41 per cent. of the F_2 were fuzzy. Unfortunately, owing to an attack of seedling wilt in the greenhouse, seed of only seven F_2 plants was available for growing F_3 families. Of these seven plants, only one grade 6 plant proved to be heterozygous. It gave an F_3 family of eighteen plants, of which thirteen were clearly

TABLE V.

Frequency arrays of fuzz grade of parents, F_1, F_2 and F_3 of "Million Dollar" Semi-tufted × "Million Dollar".

Type		Parental grade	Fuzz grade 3	4	5	6	F.	Total
Million Dollar"		F.	.	.	.	.	All	All
Semi-tufted N 3		5	.	.	5	.	.	5
Semi-tufted N 13–12		4	1	15	.	.	.	16
N 3 × MD	F_1	.	.	.	.	2	5	7
N 13–12 × MD	F_1	.	.	.	3	8	2	13
N 3 × MD–843	F_2	F.	.	20	11	8	27	66
N 3 × MD–843–1	F_3	F.	.	.	.	.	70	70
N 3 × MD–843–2	F_3	F.	.	.	.	.	44	44
N 3 × MD–843–4	F_3	F.	.	.	.	.	29	29
N 3 × MD–843–7	F_3	6	.	3	5	5	5	18
N 3 × MD–843–6	F_3	5	.	29	20	5	.	54
N 3 × MD–843–3	F_3	4	.	30	9	2	.	41

tufted of grades 4–6, and five were clearly fuzzy. Tufted and fuzzy were quite distinct. In the F_2, on the other hand, most of which was grown in neighbouring rows at the same time, there were a number of plants for which it was very difficult to decide between grade 6 and fuzzy.

When it was found that fuzzy seeded F_1's could be obtained in crosses between semi-tufted and thick fuzzy types, the F_1 of Chickenfoot × N 3 was back-crossed to "Million Dollar". Out of eleven plants five were fuzzy, five were grade 6, and one was grade 5, and grade 6 and fuzzy were not sharply distinguishable.

The behaviour of semi-tufted in crosses with heavy fuzz types provides an interesting example of the way in which a group of factors of small individual effect can reduce the effect of what is normally a major factor almost to vanishing point.

The evidence of all crosses so far discussed goes to show that the factors responsible for the increase in amount of fuzz on tufted types are those responsible for the development of thick fuzz on fuzzy types.

Results from one other cross involving tufted are available. In an investigation of linkage, a complex hybrid was crossed with Chickenfoot in order to obtain plants heterozygous for a large number of genes. Two such plants, 31–5–1 and 31–5–2, were back-crossed to the multiple re-

TABLE VI.

Frequency arrays of fuzz grade and fuzz thickness in laciniated and Arboreum *leaf-shape classes in progeny of* 31–5 × *N* 6.

Leaf shape	Tufted Fuzz grade 3	4	5	6	Total	Fuzzy Fuzz thickness 1	2	3	4	5	6	Total
L^L	.	12	30	28	70	1	20	20	17	14	3	75
L	4	15	27	16	62	13	17	25	18	7	.	80

Tufted		Fuzzy	
M (L^L)	5·23	M (L^L)	3·43
M (L)	4·89	M (L)	2·86
d	0·34	d	0·57
$\sigma(d)$	0·148	$\sigma(d)$	0·195
d/σ	2·3	d/σ	2·9
P	0·02	P	Very small

TABLE VII.

Correlation table of fuzz grade and fuzz thickness with lint colour in progeny of 31–5 × *N* 6.

Lint colour	Tufted Fuzz grade 3	4	5	6	Total	Fuzzy Fuzz thickness 1	2	3	4	5	6	Total
4	.	1	1	13	15	.	.	1	2	2	.	5
3	.	4	23	14	41	.	3	22	17	16	3	61
2	.	3	14	7	24	.	10	10	8	3	.	31
1	1	11	16	9	37	8	12	13	8	.	.	41
0	3	8	3	1	15	6	11	.	.	.	.	17
Total	4	27	57	44	132	14	36	46	35	21	3	155

Tufted		Fuzzy	
r	+0·49	r	+0·63
z	0·54	z	0·75
$\sigma(z)$	0·0880	$\sigma(z)$	0·0811
P	Very small	P	Very small

cessive type N 6. Segregation occurred, among other characters, for leaf shape, lint colour, and fuzz. Segregation for lint colour occurred in three factors, there being 7 coloured : 1 white, and among the coloured class a graded series of colours from grey to full brown. These were classified into four grades. One of the three factors involved in the lint colour segregation has been shown to be linked with the leaf-shape factor (Hutchinson, 1934). A fuzz modifying factor proved to be linked with both lint colour and leaf shape. In the fuzzy class the thickness of the coating of fuzz was graded into six classes, and in the tufted class the amount of fuzz was graded as in the crosses discussed above. Below are given frequency arrays of fuzz grade and fuzz thickness for the two leaf-shape classes (Table VI) and correlation tables of fuzz grade and fuzz thickness with lint colour (Table VII).

The mean fuzz grade and the mean fuzz thickness were both significantly higher in the laciniated class than in the *arboreum* class, and both were highly correlated with lint colour. There must, therefore, be a factor in the same chromosome as the **L** series of allelomorphs and the **K** factor for brown lint which affects the amount of fuzz on tufted seeds, and the thickness of fuzz on fuzzy seeds.

Some information concerning the distribution of this factor is available for the crosses Chickenfoot × Yenching "Million Dollar" and Chickenfoot × "Million Dollar" semi-tufted. Both crosses segregated for leaf shape. Frequency arrays are given below of fuzz grade and fuzz thickness for narrow (**L**) and broad (**l**) classes separately.

		Fuzz grade				Fuzz thickness			
Cross	Class	3	4	5	6	2	3	4	Total
A 16 × N 11–2	**L**	10	24	39	6	11	11	.	101
	l	.	2	11	6	3	1	1	24
A 16 × N 3	**L**	9	18	5	1	.	.	.	33
	l	1	8	1	1	.	.	.	11

Only A 16 × N 11–2 segregated for the main fuzz factor, and the fuzzy broad-leaved class was too small to give satisfactory evidence of the distribution of fuzz thickness. Comparing the distributions of fuzz grade in the tufted class, there is clear evidence that in A 16 × N 11–2 the broad-leaved class had on the whole higher fuzz grade than the narrow-leaved class. In A 16 × N 3, on the other hand, there is practically no difference between the distributions of the narrow and broad classes. It may be concluded, therefore, that N 11–2 carried the gene linked with **l** which increases the amount of fuzz on the seed, and N 3 did not.

(3) *Linkage relations of the tufted-fuzzy factor.*

Progeny of 31–5 gave information on the relation between the main fuzz factor, which may be given the symbol **T** (tufted)–**t** (fuzzy), and the leaf shape series ($\mathbf{L^L}$–**L**), the anthocyanin series ($\mathbf{R^S}$–$\mathbf{r^g}$), corolla colour (**Y**–**y**), lint colour (3 factors, **K**–**k**, $\mathbf{D_1}$–$\mathbf{d_1}$ and $\mathbf{D_2}$–$\mathbf{d_2}$) (for accounts of these factors see Hutchinson, 1931, 1932, and 1934), and leaf nectaries (**N**–**n**) (see Leake, 1914). Independent inheritance was found in all cases. Details are given below (Table VIII).

(4) *The inheritance of lintlessness.*

The behaviour in simple crosses of the lintless factor H^G–h^G discovered by Kottur (1927) has already been reported (Afzal and Hutchinson, 1934). Lintlessness of this type behaves as a simple recessive causing complete absence of hair throughout the plant body.

A plant of Kottur's lintless strain known as N 19–6 was crossed with Chickenfoot to investigate the relation between lintlessness and tuft. F_1 was tufted. The grade of tuft was not recorded. F_2's were grown and

TABLE VIII.

Two-factor ratios involving fuzz in progeny of 31–5 × *N* 6.

Parental constitution		**XT**	**Xt**	**xT**	**xt**	Total
R^{st} t × r^{g} T	Obs.	66	75	66	83	290
	Exp.	72·5	72·5	72·5	72·5	290·0
yt × YT	Obs.	63	66	65	89	283
	Exp.	70·75	70·75	70·75	70·75	283·00
L^{L}t × LT	Obs.	70	75	62	80	287
	Exp.	71·75	71·75	71·75	71·75	287·00
nt × NT	Obs.	65	78	67	80	290
	Exp.	72·5	72·5	72·5	72·5	290·00
Brown t × White T	Obs.	116	138	16	17	287
	Exp.	125·56	125·56	17·94	17·94	287·00

TABLE IX.

Segregation of tufted and lintless in F_2's and back-crosses of A 16 × *lintless.*

			Linted		Lintless		
Family			Tufted	Fuzzy	Tufted	Fuzzy	Total
(A 16 × N 19) 1	F_2	Obs.	80	37	21	15	153
		Exp.	86·0	28·7	28·7	9·6	153·0
(A 16 × N 19) 2 and 3	F_2	Obs.	110	34	33	14	191
		Exp.	107·5	35·8	35·8	11·9	191·0
F_1 2 and 3 × N 19	Back-cross	Obs.	15	14	11	11	51
		Exp.	12·75	12·75	12·75	12·75	51·00
F_1 1 × N 6	Back-cross	Obs.	66	56	.	.	122
		Exp.	61	61	.	.	122·0
F_1 3 × N 6	Back-cross	Obs.	73	64	.	.	137
		Exp.	68·5	68·5	.	.	137·0

back-crosses to N 19 (lintless) and N 6 (fuzzy). In F_2 and back-crosses to N 19, two-factor segregation was obtained, giving approximately 9 tufted : 3 fuzzy : 4 lintless and 1 tufted : 1 fuzzy : 2 lintless respectively. Careful inspection showed that the rudiments of fuzz hairs existed on the seed of lintless plants, and it was possible to classify them with some confidence into tufted and fuzzy. In back-crosses to N 6, single-factor segregation into equal numbers of tufted and fuzzy was obtained. Details are given in Table IX.

Expectation is closely realised in all cases except the F_2 grown from F_1 plant 1, in which a large and significant deviation unexpectedly occurred in the tufted-fuzzy segregation. Instead of the expected ratio of 3 tufted : 1 fuzzy, there were almost exactly 2 tufted : 1 fuzzy. Free assortment occurred between the two factors concerned.

In spite of the fact that $\mathbf{h^G}$ plants are in all cases entirely devoid of hair throughout the plant body, and that the original lintless parent was devoid of hair on the seed except for a very few fuzz hairs, a considerable number of $\mathbf{h^G}$ segregates in the F_2 of Chickenfoot × N 19 and in the back-cross to N 19 carried a thin coat of lint on the seed. It was not possible to obtain lint weights, but a rough classification was made into $\mathbf{h^G}$ plants with and without lint. Details are given in Table X.

TABLE X.

Classification into linted and lintless of $\mathbf{h^G}$ *plants from A 16 × N 19* F_2, *and (A 16 × N 19) × N 19.*

Type	Linted	Lintless	Total
F_2	51	14	65
F_1 × N 19	12	8	20

The results suggest a single-factor relationship, with lint dominant over its absence, but, in view of the uncertainty of classification in some cases, further information is required. In crosses of N 19 by Cawnpore White (A 1), and N 14, two varieties of *G. arboreum* from India, no linted segregates were obtained in the $\mathbf{h^G}$ class.

The relation between the lintless factor pair $\mathbf{H^G}$–$\mathbf{h^G}$ and other factors, the inheritance of which is known, was studied in three crosses, Chickenfoot × N 19 already referred to, N 19 × Cawnpore White (C.W.) and N 19 × N 14. N 14 is an Indian variety of *G. arboreum.*

Two-factor ratios are available for lintless with the following factor pairs:

Tufted-fuzzy (discussed above)	A 16 × N 19
Anthocyanin pigment $\mathbf{R^s}$–$\mathbf{r^g}$	A 16 × N 19
Leaf shape **L**–**l**	N 19 × C.W.
Corolla colour **Y**–**y**	N 19 × N 14 and N 19 × C.W.
Leaf nectaries **N**–**n**	N 19 × N 14 and N 19 × C.W.

Details are given in Table XI.

In all three crosses the proportion of lintless plants was reasonably close to expectation on the basis of single-factor segregation. Of the four other factors involved, however, three gave definitely abnormal ratios in one or more families. Two of three F_1's tested gave approximately 3 $\mathbf{R^s}$: 1 $\mathbf{r^g}$ in F_2. In the third F_2 there were obtained 115 $\mathbf{R^s}$: 21 $\mathbf{r^g}$, $\chi^2\,(3:1) = 6{\cdot}63$, and $P = 0{\cdot}01$, a significant defect of $\mathbf{r^g}$. F_2's were grown from two F_1 plants of N 19 × C.W. Both gave similar ratios for leaf shape, in all 218 **L** : 101 **l**, or approximately 2 : 1. χ^2 (3 : 1) = 7·54 and $P = 0·01$. In back-crosses to N 19, the ratio of **L** : **l** was approximately 1 : 1, as expected. The same two F_1's gave approximately 3 **Y** : 1 **y**, but two F_1's of N 19 × N 14 gave 208 **Y** : 48 **y**, for which χ^2 (3 : 1) = 16·0, and $P = 0·01$. Ratios differing considerably from the expected 3 : 1 proportions will, of course, occur occasionally by chance alone, but the occurrence of so many large deviations in the progeny of three crosses involving lintless cannot be regarded as merely fortuitous. The cause of the deviations is under investigation.

In the same crosses considerable departures from free assortment occurred.

TABLE XI.

Two-factor ratios involving lintless.

Cross	Parental constitution			H^GX	H^Gx	h^GX	h^Gx	Total	χ^2
(A 16 × N 19)	$H^Gr^g \times h^GR^s$	F_2	Obs.	101	41	39	6	187	
I and 2			Exp.	105·3	35·0	35·0	11·7	187·0	3·87
(A 16 × N 19)3	$H^Gr^G \times h^GR^s$	F_2	Obs.	86	16	29	5	136	
			Exp.	76·5	25·5	25·5	8·5	136·0	6·64
N 19 × C.W.	$H^GL \times h^Gl$	F_2	Obs.	178	73	40	28	319	
			Exp.	179·4	59·8	59·8	19·9	318·9	12·77
(N 19 × C.W.)	$(H^GL \times h^G)$	Back-	Obs.	55	68	59	56	238	
× N 19	$\times h^Gl$	cross	Exp.	59·5	59·5	59·5	59·5	238·0	1·76
N 19 × C.W.	$H^Gy \times h^GY$	F_2	Obs.	180	76	60	9	325	
			Exp.	182·9	60·9	60·9	20·3	325·0	10·5
N 19 × N 14	$H^Gy \times h^GY$	F_2	Obs.	156	34	52	14	256	
			Exp.	144·0	48·0	48·0	16·0	256·0	5·66
N 19 × C.W.	$H^Gn \times h^GN$	F_2	Obs.	185	72	58	13	328	
			Exp.	184·5	61·5	61·5	20·5	328·0	4·74
N 19 × N 14	$H^Gn \times h^GN$	F_2	Obs.	167	48	57	19	291	
			Exp.	163·6	54·6	54·6	18·2	291·0	1·12

In the two F_2's of A 16 × N 19 in which the ratio of $\mathbf{R^s : r^g}$ was normal, there was an excess of the non-cross-over classes, $\mathbf{H^Gr^g}$ and $\mathbf{h^GR^S}$. χ'^2 (see Yates, 1934) for the linkage degree of freedom is 3·5, for which $P > 0·05$, so that by the generally accepted standards, the deviation should not be regarded as significant. In the F_2's of N 19 × C.W. there were excesses of non-cross-over classes both in lintless-leaf shape, and in lintless-corolla colour ratios. In the former case χ'^2 for the linkage degree of freedom is 2·64, for which $P > 0·1$, and the deviation cannot be judged significant. Between lintless and corolla colour, however, χ'^2 for the linkage degree of freedom is 6·88, for which P is about 0·01, and the deviation must, therefore, be regarded as significant. In the back-cross to lintless there was an insignificant excess of the non-cross-over classes between lintless and leaf shape. Since there was a significant excess of non-cross-overs between lintless and corolla colour, and a suggestive excess of non-cross-overs between lintless and leaf shape, the two-factor ratio for corolla colour and leaf shape was calculated. There were in the two F_2's:

Obs.	153 **YL**	: 78 **Yl**	: 65 **yL**	: 20 **yl**	316
Exp. (6 : 3 : 2 : 1)	158	: 79	: 52·7	: 26·3	315·0

χ^2 for the linkage degree of freedom is 3·21, for which $P=0{\cdot}07$, a suggestive deviation, but not conclusive.

In N 19 × N 14 the excess of non-cross-over classes between lintless and corolla colour was entirely insignificant.

In both N 19 × C.W. and N 19 × N 14 free assortment occurred between lintless and leaf nectaries.

Summing up, leaf nectaries behaved normally and segregated independently in both crosses. Anthocyanin pigment and corolla colour gave evidence of linkage with lintless in some F_2's, and gave significantly less than 25 per cent. of recessives in those F_2's which showed no evidence of linkage. In leaf shape there were obtained approximately 2 **L** : 1 **l** instead of the expected 3 : 1, and there was a considerable, but not a significant, excess of non-cross-over classes between leaf shape and lintless. The two-factor ratio between leaf shape and corolla colour suggests linkage between them, whereas previous work has shown that they normally assort freely (Hutchinson, 1934). Lintless and tufted assorted freely. In one F_2 family out of three, there were approximately 2 tufted : 1 fuzzy instead of the expected 3 : 1.

(5) *The relation between fuzz distribution and hairiness of the plant body.*

All the tufted types grown in the variety plots during the course of this investigation had only sparsely scattered hairs on the plant body. The semi-tufted types appeared to be in general rather more hairy. Among fuzzy types, great variations in hairiness occurred, from types with sparsely scattered hairs to types with a dense coating of hairs all over the plant. The Chinese cottons, to which group the tufted and semi-tufted strains used belong, are characteristically less hairy than the Indian types.

An attempt was made to determine whether either the main fuzz gene or fuzz modifiers had any effect on general hairiness. General hairiness is, however, difficult to estimate.

On the progeny of the cross Chinese tufted seeded × sanguineum the pedicels were graded against an arbitrary series of Indian ink line drawings. Means of five estimates per plant were taken. In Tables XII and XIII are given correlation tables of grade of pedicel hairiness with fuzz grade.

TABLE XII.

Correlation table of pedicel hairiness with fuzz grade in F_2 of C.T.S. × G.S. 2.

Pedicel hairiness	Fuzz grade 1	2	3	4	5	6	F.	Total
8	.	2	2	4	6	5	10	29
7	1	16	17	41	21	12	40	148
6	6	16	24	26	34	13	39	158
5	5	20	24	27	21	8	22	127
4	2	8	8	7	2	2	15	44
3	1	.	1	2	1	1	1	7
2	.	2	.	.	.	.	1	3
Total	15	64	76	107	85	41	128	516

TABLE XIII.

Correlation table of pedicel hairiness with fuzz grade in the back-cross of (C.T.S. × G.S. 2) × G.S. 2.

Pedicel hairiness	Fuzz grade 3	4	5	6	F.	Total
8	.	1	2	.	1	4
7	.	5	14	2	30	51
6	1	12	14	2	38	67
5	2	3	13	5	30	53
4	.	18	14	1	29	62
3	.	2	6	.	2	10
Total	3	41	63	10	130	247

Correlations were calculated from each table both including and excluding the fuzzy class. Correlation coefficients, corresponding values of z, and their significances are given below:

Data	r	z	$\sigma(z)$	P
F_2 including fuzzy	+0·127	+0·13	0·043	Very small
F_2 excluding fuzzy	+0·207	+0·21	0·051	Very small
Difference		0·08	0·067	0·23
Back-cross including fuzzy	+0·117	+0·12	0·063	0·05
Back-cross excluding fuzzy	+0·097	+0·10	0·094	0·29
Difference		0·02	0·118	Very large

In F_2 small but significant positive correlations were obtained both by including and by excluding the fuzzy class. The correlation was slightly but not significantly greater when the fuzzy class was excluded. In the back-cross, a small but probably significant positive correlation was obtained when the fuzzy class was included. When the fuzzy class was excluded the correlation was slightly less, and not significant.

A small proportion of the variation in hairiness, therefore, was in this cross associated with factors affecting the distribution of fuzz.

The sanguineum strain used in the cross was very hairy, and entirely unrelated to Chinese tufted seeded. It was considered that better evidence was likely to be obtained in a cross in which the differences in hairiness between the parents was less. Observations were, therefore, made on the F_2 of "Million Dollar" × "Million Dollar" semi-tufted. By choosing the hairiness of the margin of the bracteole as an estimate of general hairiness, it was possible to obtain a considerable number of estimates from every plant, all on the same day. A correlation table of fuzz grade and bracteole hairiness is given in Table XIV.

TABLE XIV.

Correlation table of fuzz grade and bracteole hairiness in F_2 of (M.D. × N 3) 843.

Bracteole margin hairiness	Fuzz grade 4	5	6	F.	Total
6	1	5	3	18	27
5	5	2	1	3	11
4	11	1	1	.	13
Total	17	8	5	21	51

The correlation in this case is strong and again positive. The coefficients with their significances are given below, for totals and for tufted classes only.

Data	r	z	$\sigma(z)$	P
F_2 including fuzzy	+0·41	0·44	0·144	Very small
F_2 excluding fuzzy	+0·84	1·22	0·192	Very small
Difference		0·78	0·24	Very small

The correlation is largely and significantly increased by omitting the fuzzy class, and it may, therefore, be concluded that most or all of the association between fuzz grade and bracteole margin hairiness is due to minor factors affecting fuzz grade, and not to the main gene.

(6) *The relation between lint characters and fuzz.*

(*a*) *Lint length.*

Data are available from Chinese Tufted Seeded × Sanguineum, Cawnpore White × Chickenfoot, Chickenfoot × Yenching "Million Dollar", and Chickenfoot × "Million Dollar" Semi-tufted. Data are condensed to frequency arrays of lint length for tufted and fuzzy classes only (see Table XV).

In Table XVI are given mean lint lengths and differences of fuzzy and tufted classes and P, the chance of obtaining such differences on random sampling. Where numbers were large P was determined from the relation of the difference to its standard error. Where numbers were small, t was calculated, and P determined from the table given by Fisher (1934).

In C.T.S. × G.S. 2 F_2 and in (C.W. × A 16) × C.W., the tufted class had significantly longer lint than the fuzzy. In the F_2 of C.W. × A 16 a similar difference occurred. In progeny of A 16 × N 11–2 no differences were obtained. In only one case was there a significant correlation between fuzz grade (including full fuzzy) and lint length. In the F_2 of C.W. × A 16 there was a correlation of $r = -0{\cdot}25$, for which $P = 0{\cdot}04$. Hence the Chinese strains used (C.T.S., A 16, and N 11–2) all carried a gene for long lint not carried by either Sanguineum 2 or Cawnpore White, and linked with **T**, the gene for tufted.

TABLE XV.

Frequency arrays of lint length of fuzzy and tufted classes in F_2's and back-crosses.

Cross		Class	Lint length (mm.) 20	21	22	23	24	25	26	27	28	29	30	31	32	Total
C.T.S. × G.S. 2	F_2	Tufted	1	2	2	12	19	35	20	8	3	.	.	.	.	102
		Fuzzy	.	1	3	11	9	6	5	.	1	.	.	.	.	36
C.W. × A 16	F_2	Tufted	.	.	.	1	2	12	16	10	8	2	.	.	.	51
		Fuzzy	.	.	1	2	1	3	4	2	3	.	.	.	.	16
(C.W. × A 16) × C.W.	Back-cross	Tufted	.	.	.	1	4	.	3	9	1	.	.	.	.	18
		Fuzzy	.	.	.	4	3	10	8	1	1	.	.	.	.	27
A 16 × N 11–2	F_2	Tufted	.	.	.	.	.	.	.	3	30	39	24	4	3	103
		Fuzzy	.	.	.	.	.	.	.	1	10	8	3	6	.	28
(A 16 × N 11–2) × C.W.	Back-cross	Tufted	.	.	.	.	.	.	2	9	1	1	.	.	.	13
		Fuzzy	.	.	.	.	.	.	5	10	4	.	.	.	.	19

TABLE XVI.

Comparison of lint lengths of fuzzy and tufted classes in segregating families.

Cross		Mean tufted	Mean fuzzy	d	P
C.T.S. × G.S. 2	F_2	24·83	24·00	+0·83	Very small
C.W. × A 16	F_2	26·26	25·59	+0·67	0·1
(C.W. × A 16) × C.W.	Back-cross	26·00	25·07	+0·93	0·05
A 16 × N 11–2	F_2	30·03	30·11	−0·08	Large
(A 16 × N 11–2) × C.W.	Back-cross	28·08	27·95	+0·13	Large

(*b*) *Seed weight, lint index, and lint percentage.*

These three characters will be considered together, for convenience of interpretation of the results.

Seed weight is expressed as weight (in gm.) of 100 seeds, lint index as weight (in gm.) of lint on 100 seeds, and lint percentage as weight (in gm.) of lint on 100 gm. of seed.

Data are available from Cawnpore White × Chickenfoot, and Chickenfoot × Yenching "Million Dollar" only. Frequency arrays for tufted and fuzzy classes separately are given in Tables XVII, XVIII and XIX.

In Table XX are given means and differences of tufted and fuzzy classes and the probabilities of obtaining such differences by random sampling, for the three characters under consideration.

In Chickenfoot × Yenching "Million Dollar", fuzzy seeds were heavier than tufted seeds by about 0·5 gm. per 100 seeds, in both F_2 and back-cross to Cawnpore White. The lint index also was nearly 0·5 gm. higher on fuzzy than on tufted seeds. The differences are in all cases significant. Lint percentage in this cross was practically the same in the tufted and fuzzy classes. Since lint percentage was unaffected, and lint index followed seed weight, it may be concluded that the density of the lint on the seed is unaffected by the tufted gene. There was a clear association between fuzzy seed and higher seed weight, and this was reflected in the higher lint index.

Results from the F_2 of Cawnpore White × Chickenfoot are of very little value, since records are available from only seven fuzzy plants. In the back-cross to Cawnpore White, however, the tufted class gave a significantly higher seed weight and lint index than the fuzzy class. Again, there was no difference in lint percentage between the tufted and fuzzy classes, and the higher lint index of the tufted class may be taken as a reflection of its higher seed weight.

Since the tufted parent (Chickenfoot) was common to both crosses, the results suggest the existence of three allelomorphs of a single factor affecting seed weight in the same chromosome as the tufted-fuzzy factor.

Discussion.

The gene for tufted appears to be much more common in China than in India or Burma.

All tufted and semi-tufted types used in the experiments here reported were obtained from China. Samples of cotton seed were obtained from China on four occasions. In every sample of local unselected types, semi-tufted seeds were found, and two samples were received of almost pure tufted seed. Two selected strains were obtained from China. Both appeared to be pure fuzzy when obtained, but from one of them ("Million Dollar"), semi-tufted was isolated in the third season of its growth in Trinidad.

In a sample of seed cotton from Burma, containing locks from a large number of different types, no tufted or semi-tufted seeds were found.

TABLE XVII.

Frequency arrays of seed weight of fuzzy and tufted classes in F_2's and back-crosses.

Cross		Class	4·0	4·2	4·4	4·6	4·8	5·0	5·2	5·4	5·6	5·8	6·0	6·2	6·4	6·6	6·8	7·0	7·2	7·4	7·6	7·8	8·0	8·2	8·4	8·6	8·8	9·0	9·2	Total
			Seed weight																											
C.W. × A 16	F_2	T.	.	.	1	.	1	.	.	2	1	1	1	2	2	1	6	1	2	1	.	1	.	1	.	.	.	.	.	24
		F.	.	.	.	.	.	.	.	.	.	2	2	.	.	1	1	.	.	.	.	.	.	1	.	.	.	.	.	7
(C.W. × A 16) × C.W.	Back-cross	T.	.	.	.	.	.	.	.	.	1	.	.	.	2	.	.	.	3	2	1	1	3	.	2	.	1	.	.	16
		F.	.	.	.	.	.	.	.	.	1	2	2	2	2	2	1	2	1	3	1	1	.	1	1	.	.	.	.	22
A 16 × N 11–2	F_2	T.	.	.	.	.	.	.	.	.	2	3	1	5	7	5	2	5	4	7	5	2	5	3	4	1	1	2	1	65
		F.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	1	.	1	1	3	1	3	3	2	2	1	.	.	20
(A 16 × N 11–2) × C.W.	Back-cross	T.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	1	1	4	1	.	2	1	1	.	.	13
		F.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	1	.	4	.	3	5	1	1	17

TABLE XVIII.

Frequency arrays of lint index of fuzzy and tufted classes in F_2's and back-crosses.

Cross		Class	2·5	2·6	2·7	2·8	2·9	3·0	3·1	3·2	3·3	3·4	3·5	3·6	3·7	3·8	3·9	4·0	4·1	4·2	4·3	4·4	4·5	4·6	4·7	4·8	4·9	5·0	5·1	5·2	5·3	5·4	5·5	5·6	5·7	5·8	5·9	6·0	6·1	6·2	6·3	6·4	6·5	Total
			Lint index																																							
C.W. × A 16	F_2	T.	.	.	.	1	.	.	.	.	.	1	.	.	1	1	1	1	.	.	1	3	2	1	.	2	1	2	1	2	1	.	.	.	.	1	.	.	.	.	1	.	.	24
		F.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	2	.	.	.	.	1	.	.	.	.	.	.	1	.	.	.	.	.	.	.	1	.	.	.	.	.	7
(C.W. × A 16) × C.W.	Back-cross	T.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	1	.	1	1	.	.	.	.	1	1	1	.	1	1	.	.	.	3	.	2	.	.	.	1	.	.	.	16
		F.	.	.	.	.	.	.	.	.	.	1	1	3	.	1	1	1	1	1	2	1	.	1	2	1	.	.	1	1	.	1	.	1	.	1	.	.	.	.	.	.	.	22
A 16 × N 11–2	F_2	T.	.	1	1	.	.	1	.	.	2	.	1	1	1	.	2	4	.	6	2	7	1	2	1	4	1	3	4	5	3	2	4	2	.	.	.	.	1	1	.	.	2	65
		F.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	1	1	1	.	2	2	1	1	2	2	.	2	.	.	.	.	3	.	.	.	.	.	20
(A 16 × N 11–2) × C.W.	Back-cross	T.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	1	.	.	.	.	.	1	.	1	.	.	.	1	1	.	1	2	.	1	.	2	.	.	.	.	.	13
		F.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	1	.	2	1	1	1	3	.	4	1	.	1	1	.	.	.	17

TABLE XIX.

Frequency arrays of lint percentage of fuzzy and tufted classes in F_2's and back-crosses.

Cross		Class	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	Total
			Lint percentage																										
C.W. × A 16	F_2	T.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	2	5	4	4	2	1	.	1	1	24
		F.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	1	.	.	1	.	1	1	.	1	.	.	7
(C.W. × A 16) × C.W.	Back-cross	T.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	1	1	1	.	2	3	3	.	2	1	.	.	.	.	16
		F.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	2	5	1	4	3	3	2	1	.	.	.	.	.	22
A 16 × N 11–2	F_2	T.	.	.	1	.	.	.	.	1	.	2	.	1	.	2	3	4	6	8	8	5	7	6	4	4	1	.	2	.	65
		F.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	2	3	3	4	2	1	2	1	1	.	.	.	.	20
(A 16 × N 11–2) × C.W	Back-cross	T.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	1	1	1	2	2	1	2	2	.	.	.	.	.	13
		F.		.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	4	2	5	2	1	1	.	.	.	.	.	17

No tufted or semi-tufted seeds were found in a large number of samples of seed obtained from all the important cotton-growing tracts of India. Tufted seed has, however, been recorded occasionally from Indian strains of *G. arboreum*.

The Chinese fuzzy types are of the thick fuzz type which is partially dominant over tufted, giving a considerable proportion of fuzzy seeded plants among the heterozygotes. Most of the Indian fuzzy types, on the other hand, and some of the Burmese, have the thin fuzz which gives an intermediate tufted heterozygote and in some cases intensifies the tufted condition of the homozygote. Since in India a thick coat of fuzz is considered undesirable when feeding cotton seed to cattle, there has been

TABLE XX.

Comparison of seed weights, lint indices and lint percentages of tufted and fuzzy classes in segregating families.

Cross		Mean tufted	Mean fuzzy	Difference	P
	Seed weight.				
C.W. × A 16	F_2	6·40	6·39	+0·01	Large
(C.W. × A 16) × C.W.	Back-cross	7·44	6·75	+0·69	0·01
A 16 × N 11–2	F_2	7·17	7·73	−0·56	0·01
(A 16 × N 11–2) × C.W.	Back-cross	7·75	8·36	−0·61	0·01
	Lint index.				
C.W. × A 16	F_2	4·59	4·39	+0·20	0·5
(C.W. × A 16) × C.W.	Back-cross	4·89	4·39	+0·50	0·06
A 16 × N 11–2	F_2	4·67	5·05	−0·38	0·03
(A 16 × N 11–2) × C.W.	Back-cross	5·02	5·53	−0·51	0·05
	Lint percentage.				
C.W. × A 16	F_2	71·5	68·4	+3·1	0·25
(C.W. × A 16) × C.W.	Back-cross	65·5	65·2	+0·3	Large
A 16 × N 11–2	F_2	65·2	65·4	−0·2	Large
(A 16 × N 11–2) × C.W.	Back-cross	65·6	66·3	−0·7	0·7

human selection in favour of thin fuzz. This preference for thin fuzz is sufficiently strong to prove a serious obstacle in the way of the spread of improved types of Punjab American cotton with fuzzy seeds. Selection for thin fuzz is therefore proceeding independently of the tufted gene, but when tufted occurs its expression is greatly modified by the constitution of the genotype in regard to fuzz modifiers. Of these fuzz modifiers, one has been located in the leaf shape—brown lint linkage group.

The lintless factor, the inheritance of which was investigated by Afzal and Hutchinson (1934), was inherited independently of the tufted factor. No satisfactory evidence was gained of linkage between lintless and any of the five factors investigated, but a series of deviations in single-factor ratios in progenies of some F_1 plants, and of deviations from free assortment in progenies of other F_1's was obtained, for which no satisfactory explanation can be offered.

The lintless gene causes complete failure of development of all plant hairs. There was no evidence that the tufted gene had any effect on plant hairiness. Minor factors affecting distribution and amount of fuzz do appear to affect slightly the amount of hair on the plant body.

An investigation of lint length in families segregating for tufted showed that the tufted and semi-tufted strains used carried a gene for long lint linked with **T** which was absent from Sanguineum 2 and Cawnpore White.

Evidence was obtained that there exists, in the same chromosome as tufted, an allelomorph series of three members affecting seed weight. Lint index, as would be expected, varied with seed weight, but no association existed between tufted and lint percentage. There was no evidence for association between seed weight, lint index, or lint percentage, and minor factors affecting fuzz.

The experiments here recorded provide no support for the belief current in some parts of India, that nakedness of seed is associated with reduction in ginning percentage.

SUMMARY.

1. Tufted seed (**T**) is shown to differ in a single gene from fuzzy (**t**), giving an intermediate heterozygote.

2. The identity of the gene for tufted with that for semi-tufted is established.

3. The modifying factors responsible for the difference between tufted and semi-tufted cause the heterozygote to be almost or completely indistinguishable from fuzzy, and are the same as those responsible for the difference between thick and thin fuzz on fuzzy seeds. One of these modifiers is located in the brown lint—leaf shape linkage group.

4. Fuzz modifiers, but not the main tuft factor, affect slightly the hairiness of the plant body.

5. A long lint factor and a seed weight multiple allelomorph series are located in the same chromosome as the tufted factor. There were no other associations between lint characters and fuzz characters.

6. The tufted factor and the lintless factor are independent.

7. Tufted assorts freely with: leaf shape, anthocyanin pigment, corolla colour, lint colour (3 factors), leaf nectaries.

8. No satisfactory evidence of linkage was obtained between the

lintless factor and leaf shape, anthocyanin pigment, corolla colour, leaf nectaries.

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REFERENCES.

AFZAL, M. and HUTCHINSON, J. B. (1934). "The inheritance of 'lintless' in Asiatic cottons." *Indian J. agric. Sci.* **3**, 1124.

FISHER, R. A. (1934). *Statistical Methods for Research Workers.* 5th Edition. Oliver and Boyd.

GAMMIE, G. A. (1907). "The Indian Cottons." *Mem. Dep. Agric. Ind.* Bot. Ser, **2**, No. 2.

HARLAND, S. C. (1932). "The genetics of *Gossypium*." *Bibliogr. genet.* **9**.

HUTCHINSON, J. B. (1931). "The genetics of cotton. Part IV. The inheritance of corolla colour and petal size in Asiatic cottons." *J. Genet.* **24**, 325.

—— (1932). "The genetics of cotton. Part VIII. The inheritance of anthocyanin pigmentation in Asiatic cottons." *Ibid.* **26**, 317.

—— (1934). "The genetics of cotton. Part X. The inheritance of leaf shape in Asiatic *Gossypiums*." *Ibid.* **28**, 437.

KOTTUR, G. L. (1927). *Nature*, Lond., **119**, 747.

LEAKE, H. M. (1914). "Studies in Indian Cottons. Part I." *Mem. Dep. Agric. Ind.* Bot. Ser. **6**, No. 4.

YATES, F. (1934). "Contingency tables involving small numbers and the χ^2 test." *J. Roy. Statist. Soc.* Suppl. **1**, 217.