A Study of the Effect of Pollen Upon The Length of Cotton Fibers

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A STUDY OF THE EFFECT OF POLLEN UPON THE LENGTH OF COTTON FIBERS

By E. H. Pressley

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‡In co-operation with United States Department of Agriculture, Bureau of Agricultural Engineering.

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INTRODUCTION

It is possible that at the present time many of our most widely grown varieties of cotton are capable of producing yields as high as the fertility of the soil and general environmental conditions will permit. In other words, the limiting factor in yield per acre may often be the conditions under which the cotton is grown, and not the variety used. In all probability the time will come when the maximum possible yield, from the standpoint of the breeder, will be reached. Much yet remains to be done along the line of increasing the best strains and distributing the seed to the growers. When the highest possible yields per acre have been achieved, constant effort will be necessary to maintain these high standards. Probably as much effort is required to maintain a variety at its highest possible yielding point as is necessary in the initial achievement.

One field for cotton improvement which the writer believes will increase in importance as the limit in possible yield is approached is that of the uniformity of the lint produced. A large part of this problem of uniformity, or lack of uniformity, is physiological in its nature and must be approached from the standpoint of the agronomist. Better growing conditions will eliminate a part of the variation from plant to plant and from field to field. More uniform growing conditions throughout the season will eliminate a part of the variation from boll to boll on the individual plant. The production of seed giving the most uniform lint possible under ideal growing conditions is the work of the cotton breeder.

Since the individual plant is the unit with which the breeder must work, and since the uniformity of the lint of the plant depends quite largely on the uniformity of the fibers of the individual seed, the study of the length and distribution of the fibers of the individual seed is quite likely to become of increasing importance as time passes. This uniformity from the standpoint of length is determined by the proportion of the fibers in the various length-classes. Variation between varieties as well as between plants of the same variety has been for a long time a matter of common knowledge. However, no satisfactory method of making definite determinations in regard to these plant differences was available until the invention of the cotton sorter. With the development of various types of this machine it will be possible in the future to more easily determine the amount of lint of various lengths in

plant samples and to take advantage of the differences observed. Many of the differences noted will no doubt be due to the natural variation found in all plants. A part of them, however, may be found to be heritable, and this should make possible the production of more uniform lint. There is little doubt that selection based upon uniformity in the plant will in time improve considerably the character of the lint produced.

Due to the fact that the cotton plant readily crosses with others of the same or different species and to the fact that the production of strictly selfed seed in any appreciable quantity is impractical, the cotton breeder is continually forced to make selections of plants which may be highly heterozygous and open-pollinated. It is often desirable to bring into the breeding plots seeds of plants obtained from the increase plot or general fields as well as other outside sources. When several varieties, as well as strains of the same variety, are grown without proper isolation considerable crossing may be expected. When this crossing is between plants of the same strain, no harmful effects may be noticed in the succeeding generations. However, when the crossing takes place between plants of different types, and especially between plants varying considerably in length of lint, the effect is likely to be very noticeable as well as detrimental. The greater the difference between the types concerned in the cross, the greater will be the variation in the progeny and in the uniformity of the lint produced.

In 1931 Harrison (3) published data resulting from three years of experimental work which indicated that pollen has an immediate effect upon the length of lint in crosses between varieties or species of cotton varying considerably in the length of lint normally produced. Since cotton fibers are single-celled elongations from the outer seed coat, and since this is a part of the tissues of the mother plant, none of the variations in the length of lint that are commonly found among seeds of the same boll had been attributed to the direct effect of pollen until Harrison's work was published. Experimental evidence of the direct effect of pollen on the tissues of the mother plant outside the embryo and endosperm was first reported by Nixon (9) and Swingle (11) in the case of the date palm. Swingle termed this effect "metaxenia," and advanced the theory that hormonelike substances secreted from the embryo or endosperm might be responsible.

Harrison found that bolls of Pima plants (*Gossypium barbedense* L) when fertilized with pollen from the Acala variety (*G. hirsutum* L) produced lint that was approximately 3/32 inch shorter than that from bolls of the same plants that were fertilized with self pollen. Bolls of Acala when fertilized with pollen from Pima plants produced lint approximately 1/16 inch longer than that of bolls from the same plants that had been fertilized with self pollen. Effects were also noted on the length of the maturation period of the bolls and upon the amount of fuzz on the seeds.

Harrison's results showed that not only was the staple length of the fibers influenced by unlike pollen, but that the amount of lint which might be considered substaple was also influenced. Seeds

of a Durango mother plant (*Gossypium hirsutum* L) that were fertilized with Pima pollen produced lint of which approximately 13 per cent was less than an inch in length. Seeds from another boll of the same mother plant that were fertilized with Hopi pollen (*G. hopi* Lewton) produced lint of which approximately 35 per cent was less than an inch in length. Thus there was a difference of about 22 per cent by weight in the amount of lint in the two samples that might be considered substaple. A third boll whose seeds were fertilized with like pollen produced lint of which approximately 25 per cent was less than an inch in length.

If plant selections are to be made on the basis of the uniformity of the lint, and if crossing with other types of cotton will influence directly the percentage of lint in the shorter classes as indicated by Harrison's results, the practice of selecting plants that have been open-pollinated may lead the cotton breeder into considerable difficulty. Roguing will remove the plants that do not conform to the desired type, and selections may be made only from plants that show no signs of hybridization, but there is no way for the breeder to know whether or not one or more of the seeds from which he obtained his sample of lint was fertilized with pollen from a plant differing considerably in length of lint. If an open-pollinated plant is found with a very small percentage of its lint in the shorter classes, can it be assumed that this is a chance variation, a heritable variation, or simply the result of including in the sample seeds that were fertilized with pollen from a longer linted variety? Of course the final answer to these questions can only be obtained by growing progenies and studying the lint produced by them. If, in selecting for uniformity of lint, or for a low percentage of the lint in the shorter lengths, plants are chosen whose uniformity is due solely to the fact that hybrid seeds were included in the sample, there is little hope of making any progress with open-pollinated plants. This is especially true where the work is being done with the shorter stapled varieties in sections where longer stapled varieties are grown. If in addition to the fluctuations caused by chance, heredity, and environmental conditions, we have another which may be called "pollination variation," and if the latter is of such a nature as to overshadow all others, the chances of making the best possible selections from a lot of material are greatly reduced.

Harrison's determinations of length were made by measuring the lint on one seed from each of approximately 100 bolls of each population. His determinations of the amount of lint of different lengths in samples resulting from different pollinations were made from the lint of a single boll in each case. The variation in the amount of lint in the shorter classes was so great as to lead to the belief that more work should be done along this line in view of the fact that selections are being made from open-pollinated plants on the basis of a small amount of lint in the shorter classes.

While rotation of the pollens used in fertilizing the bolls and the use of sufficient numbers of bolls should compensate for the effect on the length of lint of different dates of flowering and different

growing conditions (1-4-8), it was thought that perhaps a better method would be to grow the selfed and hybrid seeds in the same bolls. This should overcome as completely as possible any difference in the conditions under which the selfed and hybrid seeds were produced. Conditions more nearly comparable to those ordinarily found would be provided since there is very little chance of all the seeds in any boll being cross-fertilized by insects in the field.

RECIPROCAL CROSSES BETWEEN RED ACALA AND DELFOS

Material was available which was in some respects ideal for the purpose in mind. Seeds from a red colored plant found growing in a field of Acala in the Salt River Valley produced plants which were pure for the red color. Pure red plants from a progeny row of this strain, which will be called Red Acala for purposes of identification, were used as one of the parents in the cross. Hybrids resulting from a cross between a pure red colored plant and a normal green plant are intermediate in color (12). Individuals from a progeny row of typical Delfos plants were selected for use as the green parents in the cross. The difference in the length of lint normally produced by the two strains was approximately 3/32 inch. A greater difference in length would have been preferable, but no other plants were available at the time with lint longer than that of Delfos.

The criticism may be offered that the lint studied was produced by plants of strains that had not been self-fertilized for several generations, and that consequently the plants were in a highly heterozygous condition. This is perhaps a legitimate criticism in some respects. If there is any difference, however, in the effect of pollen from heterozygous and homozygous plants upon the length of lint of heterozygous and homozygous mother plants respectively, the results obtained from inbred strains cannot be applied to lint produced commercially, because the seed producing the plants grown commercially are open-pollinated on plants that are extremely heterozygous. They can only be applied in the case of lint from a small number of plants grown experimentally. Then, too, in cotton breeding work a great many selections must necessarily be made from time to time of heterozygous plants that have been open-pollinated. The strains from which the lots of mother plants were selected were much less mixed with other varieties and strains than are the plants in the average commercial field. Since no seeds were saved from other than true breeding red plants each year, crossing in this strain could only have taken place with other red plants of the same family. In the case of the Delfos plants, crossing with other normal colored varieties may have taken place, as there was no sure method of determining hybrids between Delfos and these other upland varieties.

In making the crosses in 1931 the following procedure was carried out: As soon as anthesis had taken place in the morning, pollen from the red plants was placed upon the stigmas of the open flowers of the green plants. On the next day reciprocal

crosses would be made by placing pollen from the green plants upon the stigmas of the open flowers of the red plants. The flowers upon which the crosses were made were not emasculated so that pollen from both red and green plants was available for fertilization soon after anthesis occurred. The flowers were then tied up to prevent visits from pollen-laden insects. Nine plants of each strain were used as mother plants and also as sources of pollen for making the crosses. The attempt was made to secure hybrid seeds from each mother plant by the use of pollen from each plant of the other variety. The flowers were marked with tags bearing the number of the mother plant as well as the number of the plant which furnished the unlike pollen.

It was hoped that, by growing the selfed and hybrid seeds side by side in the same bolls in this manner, all influence upon the length of lint of varying seasonal conditions would be eliminated as well as all variations due to the position of the bolls upon the plants. Of course this could only be accomplished by using an equal number of selfed and hybrid seeds from each boll in making comparisons. Another source of possible error, that of the personal factor, would also be eliminated in view of the fact that all measurements on the lint would have to be made before the seeds were planted and thus without any knowledge of which were selfed and which were hybrid.

The lint on each mature seed in each boll was carefully divided into two parts and combed out on the seed. The distance was then measured to the nearest 1/16 inch from the unattached end of the fibers on one side of the seed to the unattached end of the fibers on the other. The results of these measurements were recorded in terms of thirty-seconds of an inch, this being the average distance from the center of the seed to the ends of the fibers. It was realized that this method would give results differing considerably from those that would have been obtained had the lint been stapled by hand. It was realized also that varying numbers of long fibers on different seeds would make the measurements somewhat irregular. However, in making a large number of measurements this error should be compensating, especially so in view of the fact that both selfed and hybrid seeds were being measured without any knowledge of their identity and more or less alternately. The lengths obtained were comparable from seed to seed and should have revealed any difference in length between the lint of the two classes of seeds.

After the measurements were made the lint of each seed was filed away. The intention at the time was to determine which seeds were selfed and which hybrid, and then to take the lint of the selfed seeds, mix it thoroughly, and determine the proportions of the various lengths by sorting samples on the Johannsen sorter. The same determinations would then be made on the lint from the hybrid seeds. Before this could be accomplished, however, the writer made a sorter with which these determinations can be made from the combed seeds (10). This, and the fact that there was practically no difference found in the length of the lint from the

selfed and hybrid seeds, led to a decision to prepare material in 1933 from varieties differing to a greater extent in the length of lint normally produced.

Approximately 5,500 seeds were obtained from the bolls involved in each of the crosses, Red Acala x Delfos and Delfos x Red Acala. The seeds in each lock were numbered consecutively beginning with the first seed at the base of the lock. The locks and bolls were also numbered so that each seed could be positively identified as well as the lint which it produced. The seeds from the Delfos mother plants were planted in the spring of 1932, and the male parentage determined for all the seedlings produced. The difference in color between the pure Delfos plants and the Delfos x Red Acala hybrids was sufficient to make this determination certain within a few days after the plants emerged from the ground. The seeds from the Red Acala mother plants were planted in the spring of 1933. Here again the male parentage of each plant was easily determined due to the difference between the pure red color and the intermediate color of the hybrids.

In both 1932 and 1933 very poor stands were obtained from the seeds planted. In addition to this the proportion of selfed to hybrid seeds in the bolls varied to such an extent that measurements of the lint of many of the seeds that did produce seedlings could not be used. In some cases all of the seeds in a boll were selfed while in other cases the opposite was true. A selfed seed from a given position in a lock was at all times compared with a hybrid seed from approximately the same position in that lock or with one from the same position in another lock of the same boll. In every case an equal number of selfed and hybrid seeds were selected from each boll for comparison. Due to the poor stand, as well as to the proportion of selfed to hybrid seeds in the bolls, only about 20 per cent of the measurements secured could be used. The actual numbers were 553 comparable pairs from the Delfos mother plants and 564 comparable pairs from the Red Acala mother plants.

No attempt was made to determine the effect of pollen upon any lint character except that of length. The results are shown in tables 1 and 2. All lint lengths and length differences are expressed in 128ths of an inch. The lengths when measured were recorded in thirty-seconds of an inch. After the male parentage of each seed had been determined the lengths were added for the lint of all seeds of a given cross, and the average then determined to the nearest 1/128 inch. The reason for using such a small unit of measurement is that the difference in length was in many cases too small to be indicated by a larger unit. In a great number of cases even this small unit failed to indicate a difference as is shown by the zero in many of the squares.

Throughout the following discussion the terms "self lint" and "hybrid lint" will be used to designate the lint obtained from selfed and hybrid seeds respectively. The various Delfos plants will be referred to as D1, D2, etc., and in like manner the Red Acala plants will be referred to as R1, R2, etc.

Table 1 shows the difference in length between the self and hybrid lint for each Delfos mother plant as a whole, as well as the difference between the self and hybrid lint for each Delfos mother plant when different Red Acala plants were used as the source of pollen. It also shows the results of the use as a source of pollen of each Red Acala plant upon each Delfos mother plant where crosses were secured, and the result of the use as a source of pollen of each Red Acala plant upon the group of Delfos mother plants as a whole.

TABLE 1.—DIFFERENCES IN THE LENGTH OF SELF AND HYBRID LINT IN 128THS OF AN INCH. NEGATIVE SIGNS INDICATE DIFFERENCES IN THE DIRECTION OPPOSITE TO THAT EXPECTED.

			DELFOS ♀ Plant number									Lint length of selfed & crossed seeds		Difference	No. of pairs of seeds measured
	Length of lint of selfed seeds		1	2	3	4	5	6	7	8	9				
			140	154	150	143	152	152	155	153	152	S	X		
RED ACALA ♂ Plant number	1	139	1	3	0	1	—2	2	1	—1	0	150	150	0	73
	2	139	—2	—1			—3	7	3			149	150	—1	37
	3	137	—2	0	—1	1	—2	8	7	1		146	145	1	79
	4	139	—1	5	5	3	—2	2			2	146	145	1	44
	5	140	1	2	—2	0	2	3		—3		145	145	0	47
	6	138	0	2		3	3	3		—3	—4	151	150	1	35
	7	136	0	2	4	—6	—2	1	1	3	3	153	151	2	104
	8	139	—1	—1	—1	1	3		4	—8		147	147	0	38
	9	138		1	1	0	3	—1	3	0	0	152	151	1	96
Lint length of selfed & crossed seeds		S	140	154	150	143	152	152	155	153	152	149			
		X	140	153	150	142	152	151	153	153	152		149		
Difference			0	1	0	1	0	1	2	0	0			0	
No. of pairs of seeds measured			73	73	44	103	80	57	30	48	40				553

The figures in the small squares in that part of the table enclosed within the double lines give the difference in length between the self lint of the mother plant indicated above and that of the hybrid lint resulting from the cross on this mother plant of pollen from the male parent shown in the same row at the left. Thus "1" in the first square represents a difference of 1/128 inch

between the length of self lint of D1 and the hybrid lint resulting from the cross D1 x R1. In this case the self lint was 1/128 inch longer than the hybrid lint. If the pollen has any effect upon the length of lint, hybrid seeds of a Delfos plant should have shorter lint than selfed seeds from the same plant when Red Acala is used as the male parent in the cross.

In the second square of the same row a "3" shows a difference of 3/128 inch between the length of self lint of D2 and that of the hybrid lint resulting from the cross D2 x R1. The third square shows no difference, the fourth a difference of 1/128, while the negative "2" in the fifth square shows a difference of 2/128 inch. Here, however, the hybrid lint was 2/128 inch longer than the self lint. In all cases in this table where the lint of hybrid seeds was longer than that of comparable selfed seeds, a negative sign is used before the figure indicating the difference. The first square outside the central part of the table in the same row contains the figures for the average length of lint of all the selfed seeds of the nine Delfos mother plants which were compared with the hybrid seeds whose male parent was R1. In this case the average was 150/128 inches. The next square to the right gives the average length of lint of those seeds whose male parent was R1. The difference in length between the self and hybrid lint and the number of pairs of seeds from which the averages were obtained are given in the next two squares.

Beginning in the first square of row 1 in the central part of the table and proceeding downward, the differences are given between the length of self lint of D1 and that of the comparable hybrid lint resulting from the crosses of D1 on the several Red Acala plants. The self lint from D1 was, as previously stated, 1/128 inch longer than the hybrid lint from the cross D1 x R1. The negative sign before the figures in the second, third, fourth, and eighth squares of column 1 indicates that the hybrid lint from the respective crosses was longer than the comparable self lint. There was no difference between the self and hybrid lint in the case of the crosses D1 x R6 and D1 x R7 as is indicated in the proper squares. No seeds were obtained from the cross D1 x R9. The first square in this column below the double line shows the average length of lint of all the selfed seeds of D1 that were measured. This length was 140/128 inches, while that for the lint of comparable hybrid seeds shown directly below was the same. The difference between the two is given next, and at the bottom is shown the number of pairs of comparable seeds from which the measurements were obtained.

The difference in length between the self lint and that of comparable hybrid lint may be seen at a glance for each mother plant as a whole, or for each mother plant in any particular cross by observing the figures in the proper square. Where the last four columns and rows cross in the lower right hand corner of the table, the averages are given for all lint measured, both self and hybrid, and also the difference in length and the number of pairs of seeds involved.

TABLE 2.—DIFFERENCES IN THE LENGTH OF SELF AND HYBRID LINT IN 128THS OF AN INCH.

			RED ACALA ♀ Plant number									Lint length of selfed & crossed seeds		Difference	No. of pairs of seeds measured
	Length of lint of selfed seeds		1	2	3	4	5	6	7	8	9				
			139	139	137	139	140	138	136	139	138	S	X		
DELFOS ♂ Plant number	1	140	−2		1	1		−1	6	4	0	137	138	1	52
	2	154		1	0		1	14	−4	3		136	136	1	47
	3	150	−6	0	2	−2	0		1	−4		140	140	0	78
	4	143	0	−4	0	2	2	3	1		2	139	140	1	61
	5	152		0	1	0	1	1	3		2	137	138	1	81
	6	152		−1	0	1	3		0			138	139	1	58
	7	155		0								132	132	0	1
	8	153		−2	−3	0	2	0	2	−2	0	140	140	0	91
	9	152	2		2	3	1	2	0	−2	2	137	138	1	95
Lint length of selfed & crossed seeds		S	139	139	137	139	140	138	136	139	138	138			
		X	139	139	137	140	140	141	137	138	140		139		
Difference			0	0	0	1	0	3	1	−1	2			1	
No. of pairs of seeds measured			19	66	116	78	72	21	111	25	56				564

Table 2 gives the same details for the self and hybrid lint of the Red Acala mother plants as are given for the Delfos mother plants in Table 1. The only difference to be kept in mind is that the negative sign in Table 2 means that the self lint was longer than the hybrid lint instead of shorter as was the case in Table 1. In both tables the negative sign means that the difference in length between self and hybrid lint was in the direction opposite to that to be expected if the pollen responsible for fertilization has any effect upon the length of lint.

A close inspection of the figures in the squares in Table 1 will show that in only two out of the sixty-seven crosses obtained was the difference in length between the self and hybrid lint as much as 1/16 inch. In one of these cases the self lint was longer than the hybrid lint, while in the other the opposite was true. In Table 2 a difference of 14/128 inch is shown between the length of hybrid lint from the cross R6 x D2 and the self lint from R6. The averages

in the latter case were obtained from only two pairs of comparable seeds. In no other instance in Table 2 was the difference as much as 1/16 inch, while that for the average of all seeds measured was only 1/128 inch.

The statistical constants shown in Table 3 indicate a slightly significant difference in length between the lint from the selfed seeds of the Red Acala mother plants and that from the hybrid seeds resulting from the cross Red Acala on Delfos. The difference in length between the self lint from Delfos and that from the hybrid seeds resulting from the cross Delfos on Red Acala was not significant. In both cases the difference was in the direction to be expected if the pollen influences directly the length of lint. However, these differences which amounted to 1/188 and 1/215 inch respectively were much too small to be detected in classing and could have no effect whatever upon the spinning of the lint. In the case of the Delfos mother plants the coefficient of variability was slightly greater for the hybrid lint than for the self lint, while in the case of the Red Acala mother plants the opposite was true.

TABLE 3.—MEAN, STANDARD DEVIATION, AND COEFFICIENT OF VARIABILITY FOR THE FOUR CLASSES OF LINT IN THE CROSSES.

Parentage of seeds	Mean length (inches)	Standard deviation (inches)	Coefficient of variability (per cent)	Difference / Error of difference
D♀ x D♂	1.167	0.066	5.651	2.81
D♀ x R♂	1.161	0.066	5.666	
R♀ x R♂	1.080	0.046	4.275	3.68
R♀ x D♂	1.084	0.043	3.948	

Table 4 gives the statistical constants for the weight of seed in the two crosses and for the weight of lint per seed in the cross Delfos x Red Acala. The weights of the lint per seed of the cross Red Acala x Delfos are not available. In only one case, that of the weight of seeds from the Red Acala mother plants was the difference significant. The coefficient of variability was larger for the weight of selfed seeds in one cross and for that of the hybrid seeds in the other. By comparing tables 3 and 4 it will be noted that while the self lint from the Delfos mother plants is less variable in length than the hybrid lint, the selfed seeds are more variable in weight than the hybrid seeds. On the other hand, while the self lint from the Red Acala mother plants was more variable in length than the hybrid lint, the selfed seeds were less variable in weight than the hybrid seeds. The self lint from the Delfos mother plants was less variable, both in length and weight, than was the hybrid lint. A more detailed discussion of differences in length of lint from seeds of different weights will be given below.

TABLE 4.—MEAN, STANDARD DEVIATION, AND COEFFICIENT OF VARIABILITY FOR SEED AND LINT WEIGHT.

Parentage	Mean weight (mgm.)	Standard deviation (mgm.)	Coefficient of variability (per cent)	Difference / Error of difference
Seed				
D♀ x D♂	119.712	11.127	9.295	0.25
D♀ x R♂	119.800	10.598	8.846	
R♀ x R♂	142.200	12.212	8.588	4.13
R♀ x D♂	144.657	12.780	8.835	
Lint				
D♀ x D♂	67.224	12.637	18.799	0.98
D♀ x R♂	66.856	13.661	20.433	

RED ACALA X PIMA

While no Pima plants were available for use as mother plants when the crosses were made in 1931, a small amount of Pima pollen was used in crosses on both the Red Acala and Delfos mother plants. No comparable selfed and hybrid seeds were secured from the cross Delfos on Pima. Due to a poor stand and to the proportion of selfed to hybrid seeds, only twenty-four pairs of comparable seeds were secured from the cross Red Acala x Pima. The statistical constants obtained from the measurement of the lint of these seeds are given in Table 5. The difference in length between the selfed and hybrid lint was only 0.00911 or about 1/110 inch. The difference is only 1.39 times the error of the difference and is not significant. The weights of the seeds and their lint were not obtained.

TABLE 5.—MEAN, STANDARD DEVIATION, AND COEFFICIENT OF VARIABILITY FOR THE LENGTH OF LINT FROM THE CROSS RED ACALA X PIMA.

Parentage of seeds	Mean length (inches)	Standard deviation (inches)	Coefficient of variability (per cent)	Difference / Error of difference
R♀ x R♂	1.048	0.039	3.749	1.39
R♀ x P♂	1.057	0.039	3.686	

RESULTS OBTAINED FROM RECIPROCAL CROSSES BETWEEN RED ACALA AND PIMA

Due to the fact that both strains used in the first crosses were upland strains, and that the difference in length of lint was much

less than that between upland and Pima, the latter variety was substituted for the Delfos strain in the crosses made in 1933. A white flowered plant was found growing in a field of Pima in the Salt River Valley in 1931. The seeds from this plant, which were open-pollinated, were planted at the university in 1932. Selfed seeds were secured from the plants grown in 1932, and planted in progeny rows at the university in 1933. Plants from one of these progeny rows were used as the Pima parents of the crosses made They were typical Pima plants in every respect with the exception of color of flower. All were true breeding whites.

The Red Acala parents came from the seeds that were planted in 1933 to determine their male parentage. A number of pure red plants were allowed to grow, and fourteen of these were used as parents for the 1933 crosses. Thus they were self-fertilized for only one generation, but the progeny row from which the seed came was pure as far as the red color is concerned.

In order to assure a more uniform distribution between selfed and hybrid seeds, a different method was followed in making the crosses in 1933 than was used in 1931. The plants were carefully gone over each afternoon and inspected for young bolls ready to flower the next day. The first of these found on each plant was bagged to prevent mixture of pollen by insects and was saved as a source of pollen for use in selfing other flowers of that particular plant and for the cross-pollination of flowers of plants of the other variety on the succeeding day. In some cases where a large number of young bolls were found ready to flower the following day, two or more would be bagged as a source of pollen. All other flowers found in this stage were emasculated and bagged to prevent insect pollination.

On the morning of the following day the blossoms saved for pollen were gathered and the crosses made. The system followed throughout was to gather the bagged flowers from the Red Acala plants first and then make the crosses on the Pima plants. While this was being done, the bagged flowers were gathered from the Pima plants, and used later in making the crosses on the Red Acala. This resulted in a somewhat earlier pollination of the emasculated flowers on the Pima plants than on the Red Acala plants each day.

When crosses were to be made on P1 with pollen from R1, the following technique was used: The bagged but unemasculated flower or flowers of R1 were removed from the plant and taken to P1. The flower on the Pima plant that was saved for pollen was also removed. Pollen from the Pima blossom as well as from the Red Acala blossom was then shaken into a small vial and mixed as thoroughly as possible with the end of a camel's hair brush. The attempt was made in every case to add to this mixture more of the foreign pollen than of the self in order to overcome in so far as possible the plant's natural antagonism to the foreign pollen (7). The amounts from the two plants were never accurately measured but, as estimated roughly, twice as much foreign pollen was used as self. After the two pollens were mixed thoroughly,

as much of the mixture as would adhere was applied to the stigma of the emasculated flowers. The flowers were then bagged again to prevent visits from pollen-laden insects.

When, as frequently happened, there were several emasculated flowers on a plant at one time, they were all pollinated with the same mixture. The vial in which these pollens were mixed was not used again until next day, and the brush was thoroughly cleaned before being used on another plant. After pollination each flower was tagged with a label bearing the number and variety of the mother plant and the number and variety of the plant from which the foreign pollen was obtained.

Fourteen plants of each variety were used as parents. The attempt was made to secure hybrid seeds on each plant by using pollen of each plant of the other variety. It was soon evident that this would require more flowers than some of the plants were likely to bear. The plants were then divided into two groups in each variety consisting of seven plants in each group. With perhaps a few exceptions hybrid seeds were obtained on each Red Acala plant in group 1 by using pollen from each Pima plant in group 1. Reciprocal crosses gave seeds on each Pima plant in the first group with pollen from each of the Red Acala plants in this group. The same method was followed with the plants of each variety in the other group.

When the bolls were mature and harvested it was evident that, in the time that could be devoted to this work, it would be impossible to sort individually the lint of all of the seeds of each boll because of the large number produced. Since so much time was required to sort the lint of each seed separately, only four from each lock were used. These were taken from as near the center of the lock as possible. Poorly developed locks were discarded as were some entire bolls. In so far as could be determined only strong and vigorous seeds were used. The bolls obtained from the seven Red Acala plants were numbered consecutively from 1 to 142, while those from the seven Pima plants were numbered consecutively from 150 to 268. On account of the abundance of material obtained from the plants of the first group, no effort has been made to study that obtained from the second.

Plate I illustrates the system used in numbering the four seeds taken from each lock. One and 2 represent in each case a pair of seeds which grew approximately opposite each other, one being slightly nearer the base end when the lock was extended. Three and 4 represent in each case the next pair of seeds toward the tip of the lock and located opposite each other. At all times *1* and *3* were located on one side of the lock while *2* and *4* were located on the other. All four grew as closely together near the center as was possible. It was hoped that by taking seed from this general position most of the effect upon the length of lint caused by the position of the seed in the lock would be eliminated (1). After being removed from the lock each seed was placed in a separate coin envelope which was labeled with the number of the boll, the number of the lock, and that of the seed.

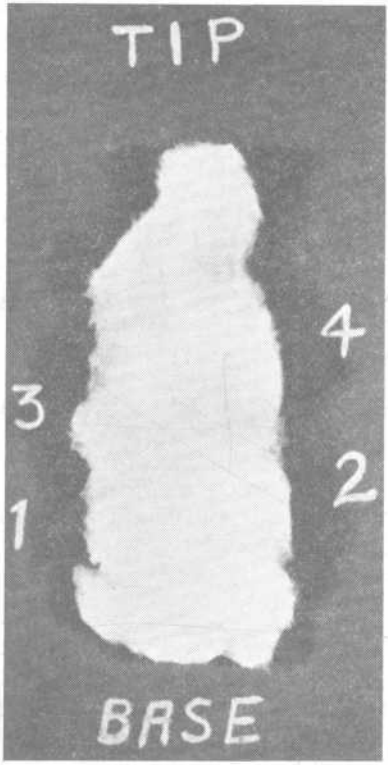

Plate I.—Photograph of lock showing method used in numbering seeds selected for sorting.

The lint on each seed was divided into two equal parts with a dissecting needle, and very carefully combed out and straightened as thoroughly as possible. Due to the ease with which Pima fibers are removed from the seed, the loss in combing this variety was greater than that in combing the Red Acala. From 187 selfed Pima seeds this loss was 13.4 per cent, while from the same number of hybrid Pima seeds the loss was 13.0 per cent. The loss from the 405 pairs of Red Acala seeds was 9.7 per cent for the hybrid and 9.9 per cent for the selfed.

After combing, each seed was placed in the Pressley sorter (10), and the lint separated into the different 1/8-inch class lengths. The classes from each seed were kept separate and filed away to be weighed after the male parentage of the seed should be determined. Each seed was then replaced in the envelope from which it was taken.

Before being planted each seed was weighed on a Roller-Smith Milligram Balance having a capacity of from 1 to 1,500 mgm. The weight of each seed was determined to the nearest tenth of a milligram. No effort was made to estimate the amount of fuzz on either the Pima or Red Acala seeds.

After all danger of frost had passed, the seeds were planted for the purpose of determining the male parentage of each. Plate II gives a general view of the plants about one week after they had emerged from the ground. A piece of 16-gauge galvanized iron, through which four rows of half-inch holes had been drilled 4 inches apart each way, was used as a planting board to assure the planting of each seed in exactly the right place, and to keep the rows perfectly straight and in line. Holes 1 inch deep were punched in the ground through the holes in this iron, and the seeds planted in these. As indicated by Plate II, the seeds were planted in beds 12 inches wide and approximately 14 feet long. The rows run across the beds. Each contains the seeds from a single lock. The four seeds from lock 1 of boll 1 were planted in row 1 of bed 1. Those from lock 2 of boll 1 were planted in row 2 of bed 1. This system was followed throughout. A large stake

placed by the first row of each plant was labeled with the plant number. A smaller stake was placed opposite the first row of each boll. In this way it was possible to identify definitely each seedling produced.

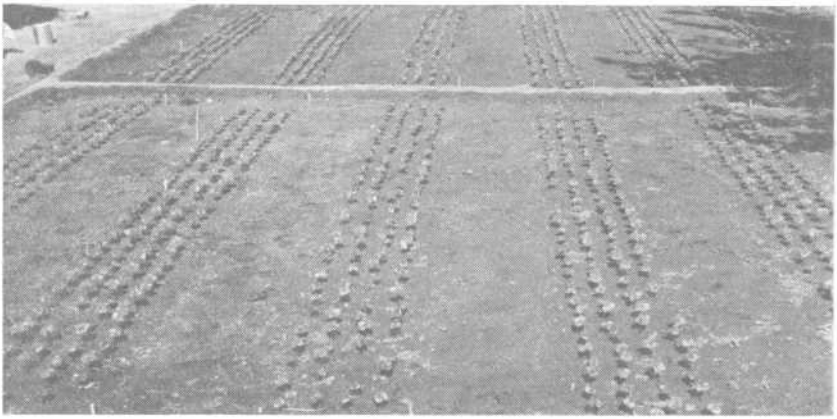

Plate II.—Appearance of plants at the time the male parentage was determined.

The beds were covered with burlap bags to prevent too rapid drying out of the soil and the formation of a crust on top. These bags were sprinkled with water from time to time as the condition of the moisture in the soil demanded, and were removed altogether when the plants began breaking through the ground.

As soon as the plants were large enough they were thoroughly inspected in order to determine the male parentage of each. All hybrids were marked with an "X" on the planting list while all selfed plants were marked with an "S." The difference between the pure plants and hybrids was striking. The hybrids from the Red Acala mother plants were intermediate in color between the pure red of the female parent and the green of the male (12). This difference could be easily distinguished as soon as the seedlings were two or three days old. The difference between the pure and hybrid seedlings coming from the Pima mother plants was even more noticeable. In addition to the intermediate color of the leaves, the leaf callus was red in the hybrid plants and green in that of the selfed (5).

Table 6 was made up from the planting list after the parentage of each seedling had been determined and from the list containing the weight of each seed. Boll No. 2, for instance, had twenty seeds coming from five locks. The male parent used in making the crosses on this boll was P2. The first seed of boll 2, lock 1 was selfed, the second hybrid, the third selfed, and the fourth hybrid. In lock No. 2, seed 1 was selfed, 2 selfed, 3 hybrid, and 4 selfed. Lock 3 had three selfed and one hybrid, while locks 4 and 5 had two of each.

TABLE 6.—A REPRODUCTION OF ONE SECTION OF THE PLANTING LIST SHOWING NUMBER OF BOLL AND LOCK, MALE PARENTAGE OF HYBRID SEEDS, SELFED AND HYBRID SEEDS, AND WEIGHT OF EACH SEED IN MILLIGRAMS.

Plant R 1 ♀						
Boll no.	Lock no.	♂	Seed no. 1	Seed no. 2	Seed no. 3	Seed no. 4
1	1	P 2	S 134.3	X 175.4	X 169 3	S 156.3
	2		X 170.0	X 174.5	S 167.9	S 169.6
	3		H X 174.3	L X 165.9	X 173.6	S 160.8
2	1	P 2	S 131.4	X 151.6	S 134.4	X 139.0
	2		H S 146.8	L S 139.4	X 145.9	S 139.8
	3		S 138.3	S 138.3	S 137.7	X 153.4
	4		X 144.8	X 151.7	S 132.0	S 134.2
	5		S 137.4	X 137.5	X 148.1	S 132.3
3	1	P 2	S 158.2	S 152.6	H X 160.6	L X 153.9
	2		S 164.2	X 169.0	L X 158.8	H X 164.1
	3		X 178.0	X 169.4	H X 164.0	L X 161.0
4	1	P 4	L S 129.2	H S 131.2	L S 121.5	H S 126.3
	2		S 137.4	S 128.3	X 137.6	S 134.0
	3		X 134.1	X 151 2	L S 135 8	H S 140.0
5	1	P 4	S 149.3	X 157.0	X 149.4	S 149.5
	2		S 144.8	X 156.8	S 152.7	X 158.4
	3		S 153.0	X 163.3	145.6	44.8
6	1	P 4	X 132.6	S 142.8	S 145.8	X 152.1
	2		S 140.3	X 155.9	H S 152.1	L S 147.9
	3		L S 146.0	H S 150.2	H S 148.0	L S 140.1

The underlined letters designate those seeds which were used in making a comparison of the length of lint between selfed and hybrid seeds. Thus from boll No. 2 of R1, two pairs of selfed and hybrid seeds were obtained from lock 1, while one pair was obtained from each of locks 2 and 3, and two pairs from each of locks 4 and 5. From this one boll eight selfed and eight hybrid seeds were used for comparison. These eight pairs, consisting of an equal number of selfed and hybrid seeds, grew under conditions as nearly uniform as it is possible to secure under any circumstances.

The selection of well developed seeds for sorting and the method used in planting resulted in the production of 1,880 seedlings from the 2,012 seeds sorted. Thirteen hundred seeds from the Red Acala mother plants gave 1,215 seedlings of which 53.8 per cent were selfed and 46.2 per cent hybrid. Seven hundred twelve seeds from the Pima mother plants gave 665 seedlings of which 55.6 per cent were selfed and 44.4 per cent hybrid. Of the entire number of seedlings produced, 54.5 per cent were selfed while 45.5 per cent were hybrid.

As previously stated, the four seeds from each lock consisted of two pairs growing approximately opposite each other. The seeds of the first pair were numbered 1 and 2, while those of the second pair were numbered 3 and 4 (Plate I). In selecting pairs of seeds for comparison, a selfed seed of the first pair was matched with a hybrid seed of the first pair, and a selfed seed of the second pair was matched with a hybrid seed of the second pair. The above method was followed wherever possible, but in order to increase the number of pairs of seeds, a selfed seed of the first pair was sometimes matched with a hybrid seed of the second pair, or vice versa. Very rarely a seed of one pair in one lock was matched with another of the same pair in another lock. Still more rarely, a seed of the first pair in one lock was matched with a seed of the second pair in another lock. Thus the effort was made at all times to balance a selfed seed of one pair of a given lock with a hybrid seed of the same pair and lock. In no case was a selfed seed of one boll compared with a hybrid seed of another.

Before weighing the lint in the different ⅛-inch classes, the corresponding class lengths of each seed coming from bolls of a mother plant upon which the same mixture of pollen was used, were combined and weighed as one series of classes. Table 6 shows that bolls 1, 2, and 3 were pollinated with a mixture of pollen from R1 and P2; while bolls 4, 5, and 6 were pollinated with a mixture of pollen from R1 and P4. The corresponding class lengths of all of the underlined selfed seeds of bolls 1, 2, and 3 were combined for weighing. The same method was used for bolls 4, 5, and 6 and for the bolls of all the other plants involved. In this way the amount of time necessary in making the weighings and calculations was greatly reduced. At the same time the lint of the hybrid seeds of each mother plant was kept separate for each plant of the other variety involved together with its corresponding self lint. This allowed for the determination of the effect of each plant when used as a source of pollen upon each plant with which it was crossed.

Table 7 shows the difference in length to the nearest 1/128 inch between all the self and hybrid lint for each Pima mother plant as well as the difference between the self and hybrid lint for each Pima mother plant when different Red Acala plants were used as the source of pollen. It also shows the result of the use as a source of pollen of each Red Acala plant upon each Pima mother plant where crosses were secured, and the result of the use as a source of pollen of each Red Acala plant upon the group of Pima mother plants as a whole.

Table 8 gives the same information concerning the self and hybrid lint produced by the Red Acala mother plants as is given in Table 7 for the self and hybrid lint of the Pima mother plants. The figures in the squares in the central part of the tables give the difference in length between the self and hybrid lint for each cross secured in the same manner as previously discussed for tables 1 and 2. In each case the negative sign indicates a difference in the direction opposite to that expected.

TABLE 7.—DIFFERENCES IN THE LENGTH OF SELF AND HYBRID LINT IN 128THS OF AN INCH. NEGATIVE SIGNS INDICATE DIFFERENCES IN THE DIRECTION OPPOSITE TO THAT EXPECTED

			PIMA ♀ Plant number							Lint length of selfed & crossed seeds		Difference	No. of pairs of seeds sorted
	Length of lint of selfed seeds		1	2	4	7	8	9	11				
			133	130	133	139	132	134	137	S	X		
RED ACALA ♂ Plant number	1	127	1	—1	1	—4	—4	—4	—4	139	132	—3	25
	2	131	—1	4			3		1	131	129	2	27
	3	133		5	4		2	—2	—5	132	130	2	18
	4	127		3	—15	—2	—1	—3	—4	127	130	—3	20
	5	135	4	5	0	—3	0	—4	1	137	136	1	37
	6	131		—3		2	2	3	0	138	138	0	18
	7	129	—1	0	—2	—3	1	—1	—2	135	136	—1	42
Lint length of selfed & crossed seeds		S	133	130	133	139	132	134	137	136			
		X	135	128	133	134	131	136	138		135		
Difference			—2	2	0	—5	1	—2	—1			0	
No. of pairs of seeds sorted			13	32	24	16	33	18	51				187

The length of the self and hybrid lint shown in tables 7 and 8, however, was not determined by measuring, but was determined from the sorting data by a method previously described (10). Arrays or curves were constructed from the sorting data based upon the percentage of lint in each ⅛-inch class. These arrays were constructed on a scale of 8 to 1, and were thus enlarged to the point where a difference of 1/128 inch could be detected. The reason for using so small a unit of measurement is that in most cases the lots of lint compared were so uniform that a larger unit would have shown no difference between them. Even this extremely small unit frequently failed to show a difference in comparable lots of lint.

A close study of these two tables will show that there was no consistent effect of the foreign pollen upon the length of lint of any mother plant, nor was the pollen from any plant of either

TABLE 8.—DIFFERENCES IN THE LENGTH OF SELF AND HYBRID LINT IN 128THS OF AN INCH. NEGATIVE SIGNS INDICATE DIFFERENCES IN THE DIRECTION OPPOSITE TO THAT EXPECTED.

			RED ACALA ♀ Plant number							Lint length of selfed & crossed seeds		Difference	No of pairs of seeds sorted
	Length of lint of selfed seeds		1	2	3	4	5	6	7				
			127	131	133	127	135	131	129	S	X		
PIMA ♂ Plant number	1	133		0	6	1	1	2	5	128	130	2	61
	2	130	4	5	2	0	—2	5	—1	127	129	2	82
	4	138	—1	1	2	—1	—1	4	1	131	132	1	60
	7	139		—2	—2	3	1	1	1	133	133	0	63
	8	132		5	12	2	0	0	0	134	135	1	49
	9	134		—2	0	1	2	3	4	130	132	2	51
	11	137		—3	—1	—3	0	0	5	132	132	0	39
Lint length of selfed & crossed seeds		S	127	131	133	127	135	131	129	131			
		X	130	131	133	129	135	132	131		132		
Difference			3	0	0	1	0	1	2			1	
No of pairs of seeds sorted			27	79	52	48	69	83	47				405

group consistent in its effect upon the length of lint of the mother plants upon which it was used. In Table 7 each column contains both positive and negative figures showing that in some instances the self lint was longer than the hybrid lint, while in other instances the opposite was true. In many cases there was no difference at all as is indicated by the zero in some of the squares. A study of the figures in each row will show the same difference in the effect of the pollen of any particular plant upon the length of lint of the different mother plants.

In Table 8 the figures in the squares of the first row show that in five out of six crosses the differences were all positive, which means that in each of the five cases the length of the lint from the hybrid seeds was greater than that from the selfed seeds. In the sixth cross there was no difference at all. The figures in the squares of row 5 are also all positive, but in three out of the six

crosses there was no difference in the length of lint. The figures in the squares of column 6 are all positive, but in two of the seven crosses the length of the lint was the same. In the second square of this column a difference of 5/128 or about 1/32 inch is shown between the length of the self lint of R6 and that of the hybrid lint from the cross R6 x P2. In the fourth square of the same column a difference of 1/128 inch is shown between the length of the self lint from R6 and that of the hybrid lint from the cross R6 x P7. While the difference in length between the self and hybrid lint is five times as great in the first cross as in the second, the self lint of the male parent used in the second cross was 1/16 inch longer than that of the male parent used in the first cross.

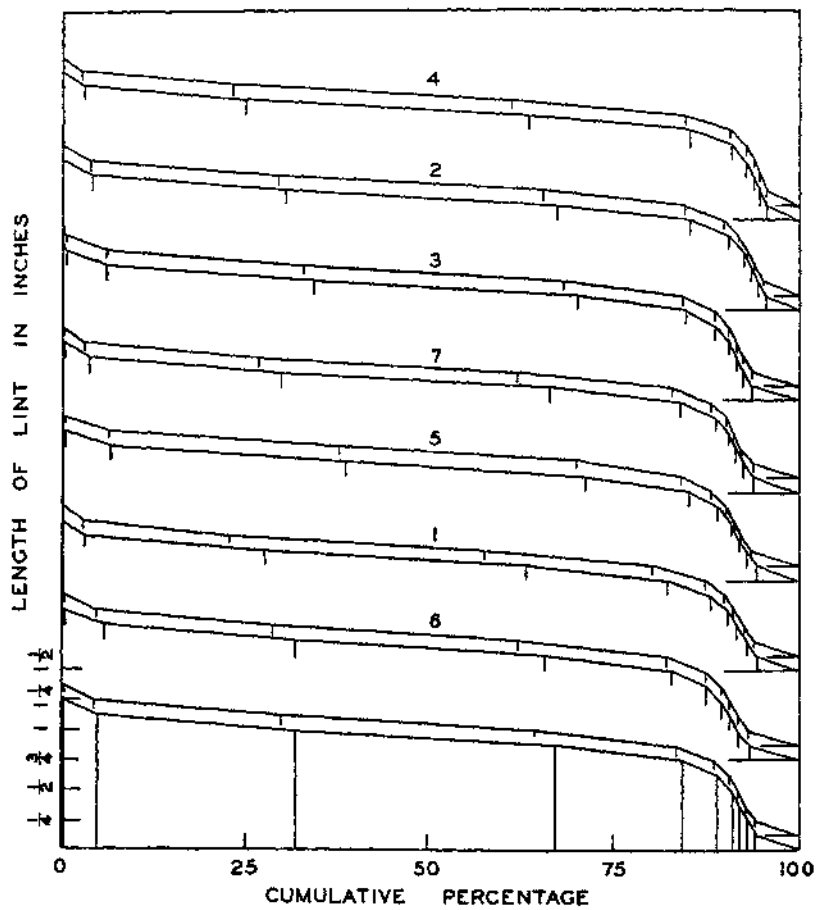

Figure 1.—Sorter arrays showing the percentage of self and hybrid lint in each ⅛-inch class of each of the Red Acala mother plants, and for all Red Acala mother plants combined.

The larger figures in some of the squares of both tables resulted from a comparison of small numbers of pairs of seeds. Whenever sufficient numbers were secured to give representative samples, these differences became very small and in some cases disappeared entirely. While in no case was all the lint from the selfed seeds of the Red Acala mother plants longer than that of the crossed seeds, in three out of seven cases the length was the same to the nearest 1/128 inch. The difference was 1/128 inch in two cases, 2/128 inch in one, and 3/128 inch in the other. In the latter case the number of pairs of comparable seeds, twenty-seven, was the smallest obtained from any of the Red Acala mother plants.

Figure 1 shows the sorter arrays for the self and hybrid lint of each of the seven Red Acala mother plants, and at the bottom the arrays representing respectively the self and hybrid lint of all of the Red Acala mother plants combined. In each case the array representing the self lint is placed above that for the hybrid lint. The number of each plant is shown above. The arrays for the different plants are not placed in numerical order, but in the order of amount of lint in the shortest class shown at the right.

From these arrays it may be seen that, while varying from plant to plant, the percentage of lint in the longest four or five classes is somewhat greater for the hybrid lint than for the self. This is also necessarily true for the respective arrays of the self and hybrid lint of all plants combined, and is the result to be expected if the pollen responsible for fertilization has any immediate effect upon the length of lint produced by the seed. However, when the staple length is considered the difference between the self and hybrid lint is too small to be measured in any ordinary manner. No matter how the respective lengths are determined, the difference amounts to less than 1/64 inch.

TABLE 9.—PERCENTAGE OF LINT IN EACH ⅛-INCH CLASS FROM SELFED AND HYBRID SEEDS OF RED ACALA MOTHER PLANTS.

Class lengths in inches	Parents					
	R♀ xR♂	R♀ xP♂	R♀ xR♂ Heavy	R♀ xR♂ Light	R♀ xP♂ Heavy	R♀ xP♂ Light
1¼-1⅜	.27	.27	.44	.24	.14	.13
1⅛-1¼	4.25	4.62	5.19	4.38	3.73	3.71
1 -1⅛	25.32	27.04	26.09	22.45	26.22	23.53
⅞-1	34.70	35.32	34.54	34.15	37.14	37.26
¾- ⅞	18.72	16.89	18.05	21.09	16.60	18.02
⅝- ¾	5.20	4.72	4.83	6.19	4.42	4.87
½- ⅝	2.10	1.99	2.01	2.31	2.01	2.11
⅜- ½	1.10	1.08	1.01	1.20	1.09	1.11
¼- ⅜	1.05	1.01	.94	1.05	1.12	1.21
⅛- ¼	1.34	1.33	1.23	1.23	1.51	1.56
0 - ⅛	5.94	5.72	5.67	5.60	6.03	6.91
	99.99	99.99	100.00	99.99	100.01	100.02
Average weight of seed	151.7	160.4	156.8	147.6	167.9	156.6

TABLE 10.--PERCENTAGE OF LINT IN EACH ⅛-INCH CLASS FROM SELFED AND HYBRID SEEDS OF PIMA MOTHER PLANTS.

Class lengths in inches	Parents					
	P♀ x P♂	P♀ x R♂	P♀ x P♂ Heavy	P♀ x P♂ Light	P♀ x R♂ Heavy	P♀ x R♂ Light
1⅝-1¾	2.81	3.08	2.18	2.02	4.20	2.95
1½-1⅝	12.07	12.39	12.00	10.48	14.65	12.39
1⅜-1½	23.19	23.21	24.61	24.11	24.75	24.08
1¼-1⅜	24.50	24.36	25.42	25.70	23.78	24.55
1⅛-1¼	14.15	13.79	13.66	14.01	12.18	13.20
1 -1⅛	9.19	9.13	8.65	9.24	7.75	8.78
⅞-1	4.94	4.90	4.66	5.27	4.22	4.87
¾- ⅞	3.15	3.19	3.06	3.23	2.90	3.27
⅝- ¾	1.71	1.71	1.68	1.78	1.51	1.66
½- ⅝	1.23	1.24	1.20	1.23	1.09	1.16
⅜- ½	.82	.82	.81	.79	.79	.82
¼- ⅜	.76	.74	.71	.71	.74	.73
⅛- ¼	.64	.64	.62	.65	.62	.65
0 - ⅛	.83	.80	.72	.78	.81	.88
	99.99	100.00	99.98	100.00	99.99	99.99
Average weight of seed	144.8	144.5	145.3	138.12	148.5	138.4

Tables 9 and 10 show the percentage of lint in each length-class, while Table 11 shows the length to the nearest 1/128 inch when various percentages of the longest fibers were discarded as is done in classing. The arrays from which these lengths were determined were constructed from the sorting data shown in tables 9 and 10. A scale of 8 inches on paper to 1 inch in the length of the lint was used in order to make very small differences noticeable. Percentages and lengths are also given in the tables for the lint of comparable heavy and light selfed and hybrid seeds for each set of mother plants. These will be discussed later.

Figure 2 shows the arrays for the self and hybrid lint of each of the seven Pima mother plants. The arrangement used here is the same as that for the Red Acala mother plants with the arrays for the self lint above those for the hybrid lint. The array at the bottom represents the combined hybrid lint of all seven Pima plants, while that above represents the combined self lint. A study of the arrays shown in figures 1 and 2 shows one significant difference. All the arrays in Figure 1 show a greater weight in the longest classes of the hybrid lint than in those of the self. This difference, while occurring in each case, varies from plant to plant, and is very slight for the average. The arrays for the Pima mother plants do not all show a variation in the same direction. Those for plants 1, 4, 7, 9, and 11 show a greater weight in the longest classes of the hybrid lint than in those of the self lint. The arrays for plants 2 and 8 show a variation in the opposite direction. The averages, represented by the arrays at the bottom of

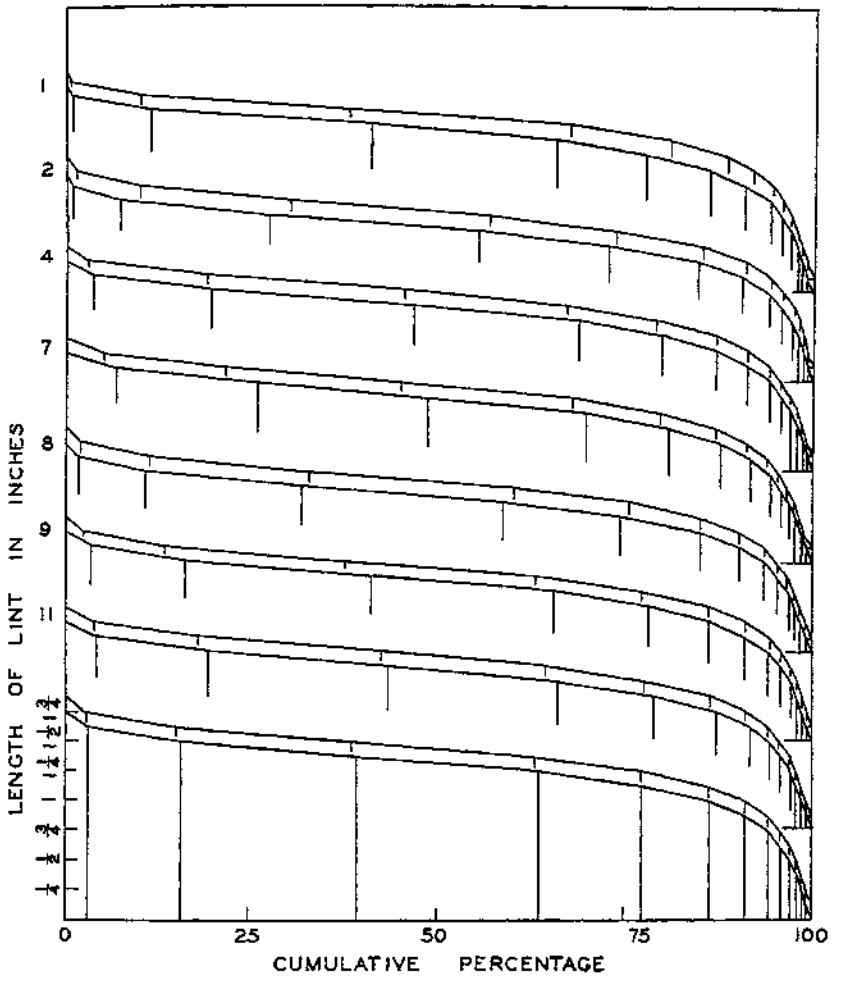

Figure 2.—Sorter arrays showing the percentage of self and hybrid lint in each ⅛-inch class for the Pima mother plants individually, and for all Pima mother plants combined.

Figure 2, show a greater weight in the longest classes of the hybrid lint than in those of the self lint. This is contrary to the expected results.

Here again the difference in length caused by the slightly larger weight in the longest classes of the hybrid lint is too slight to be measured in the ordinary manner. A study of the first two lines in the lower half of Table 11 will show that the difference is no more than 1/128 inch when measured by means of large-scale arrays. This is too slight a difference to be detected in classing. The only remarkable feature about the arrays and the length, as

shown in Table 11, is their very close similarity. This is emphasized by the percentages of lint in the various corresponding length-classes as shown in the first two columns of Table 10. The greatest difference in percentage of lint in any two corresponding length-classes is that of 0.36 per cent in the class ranging in length from 1⅛ to 1¼ inches. Of the lint from selfed seeds, 85.91 per cent was 1 inch or more in length; while of that from hybrid seeds, 85.96 per cent was 1 inch or more in length. In the cumulative percentage the greatest difference was one of 0.61 per cent in the amount of lint 1⅜ inches or longer.

TABLE 11.—LENGTH OF LINT AFTER DISCARDING VARIOUS PERCENTAGES BY WEIGHT OF THE LONGEST FIBERS.

Parentage of seeds	Length of lint after various percentages of the longest fibers were removed. Length to the nearest 1/128 inch							No. of seeds	Comparative weight of seeds
	0	10	20	25	30	40	50		
R♀ x R♂	176	141	134	131	128	123	119	405	
R♀ x P♂	176	141	135	132	129	124	120	405	
R♀ x R♂	176	159	152	149	145	140	136	107	heavy
R♀ x R♂	176	156	149	146	143	138	133	107	light
R♀ x P♂	176	157	150	147	144	140	136	63	heavy
R♀ x P♂	176	156	149	146	143	139	134	63	light
P♀ x P♂	224	199	189	185	182	175	169	187	
P♀ x R♂	224	199	189	186	182	176	169	187	
P♀ x P♂	224	198	188	185	182	175	169	73	heavy
P♀ x P♂	224	196	187	184	181	174	168	73	light
P♀ x R♂	224	202	191	188	185	178	172	46	heavy
P♀ x R♂	224	199	189	186	182	176	169	46	light

Figure 3 shows somewhat more clearly the very close similarity in the distribution by weight in the corresponding length-classes of the lint from selfed and hybrid seeds. The self lint is in each case represented by the solid lines and the hybrid lint by dotted lines. The percentages in the longest classes of the lint from the Red Acala mother plants are somewhat larger for the hybrid lint than for the self. In the case of the lint from the Pima mother plants the percentages in the shorter corresponding length-classes are so nearly the same that the lines fall one upon the other. This is also true for the shorter lengths of the lint from the Red Acala plants with the exception of the last class.

LENGTH OF LINT FROM SEEDS OF DIFFERENT WEIGHTS

After the length of lint had been determined for the selfed and hybrid seeds of all mother plants, the average seed weight was

calculated for the selfed and hybrid seeds of each plant that was used in the above determinations. The average for each set of mother plants, together with the length of lint, is shown in the first two lines of the upper and lower sections of Table 12. There was practically no difference in the average weight of the selfed and hybrid seeds of the Pima mother plants. The selfed seeds averaged 0.36 mgm. heavier than the hybrid seeds, while the length of lint was the same to the nearest 1/128 inch. In the case of the seeds from the Red Acala mother plants, however, the hybrid seeds averaged 8.73 mgm. heavier than the selfed seeds, while the lint averaged 1/128 inch longer.

TABLE 12.—A COMPARISON OF THE WEIGHT AND THE LENGTH OF LINT OF SELFED AND HYBRID SEEDS, AND OF RELATIVELY HEAVY AND LIGHT SELFED AND HYBRID SEEDS FROM RED ACALA AND PIMA MOTHER PLANTS.

Parentage of seeds	No. of seeds sorted	Average wgt. of seeds	Length of lint (128ths inch)	Difference in average wgt. of seed	Difference in length of lint
P♀ x P♂	187	144.84	185	0.36 mgm.	0
P♀ x R♂	187	144.48	185		
P♀ x P♂	73	145.30	185	7.18 mgm.	1/128
P♀ x P♂	73	138.12	184		
P♀ x R♂	46	148.54	188	10.11 mgm.	3/128
P♀ x R♂	46	138.43	185		
R♀ x R♂	405	151.71	131	8.73 mgm.	1/128
R♀ x P♂	405	160.44	132		
R♀ x R♂	107	156.76	132	9.20 mgm.	3/128
R♀ x R♂	107	147.56	129		
R♀ x P♂	63	167.89	131	11.33 mgm.	2/128
R♀ x P♂	63	156.56	129		

Since so many of the sorted seeds could not be used in making the above comparisons of length of lint due to the fact that selfed and hybrid seeds were not always obtained in the same proportion in the bolls, it was decided to determine the length of lint for the unused selfed and hybrid seeds of different weights. Table 6 shows the selfed and hybrid seeds of Red Acala mother plant 1, and the weight of each seed. It will be noted that several seeds of each kind have either the letter "H" or "L" before the one designating the male parentage. These letters indicate the comparative weights of a pair of seeds. The same procedure in securing seeds

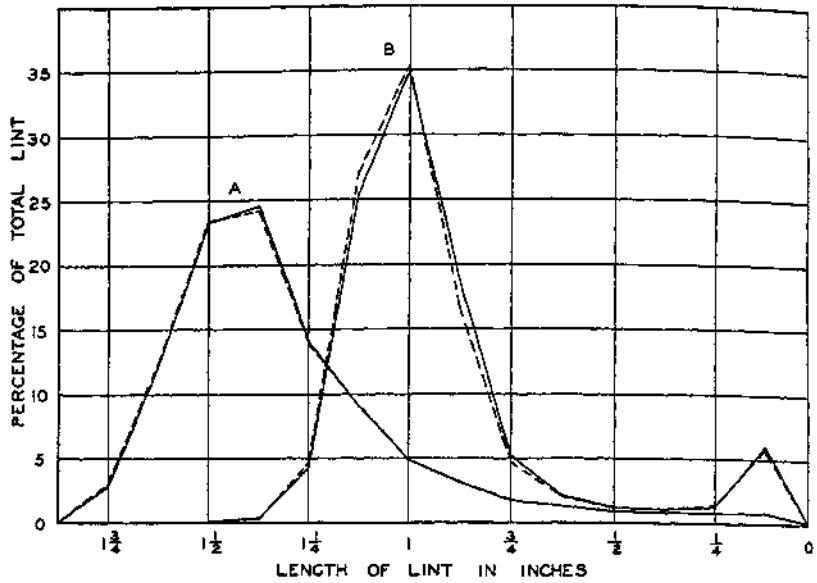

Figure 3.—Percentage of lint in each ⅛-inch class. *A*, solid line, self Pima lint; dotted line, hybrid Pima lint. *B*, solid line, self Red Acala lint; dotted line, hybrid Red Acala lint.

from the same pair, lock, and boll was used in selecting the heavy and light seeds for comparison as was used in matching the selfed and hybrid seeds. Whenever there was any difference at all in the weights of the two seeds making up a pair, each was placed in its respective weight class, heavy or light. The corresponding length-classes of the lint of these comparable pairs of seeds were then combined for each mother plant, the weight of each class determined, and the percentages calculated.

Because of the fact that all the selfed and hybrid seeds growing in comparable positions in each boll had already been used, heavy selfed seeds are here compared with light selfed seeds, and heavy hybrid seeds with light hybrid seeds. These selfed and hybrid seeds cannot be compared with each other for the reason that different bolls are represented. The number of seeds compared, their weight and length of lint, and the difference in each are shown in the second and third pairs of lines in the upper and lower sections of Table 12. The comparative length of lint at different points in the cumulative percentage is shown in Table 11. The lint coming from the heavier seeds was longer than that from the lighter seeds growing side by side with them. In each case, with the exception of the selfed seeds from the Pima mother plants, the difference amounted to 1/64 inch or more. Thus there was, on the average, a greater difference in the length of lint of heavy and light selfed seeds growing side by side than there was in the length of lint of selfed and hybrid seeds growing in the

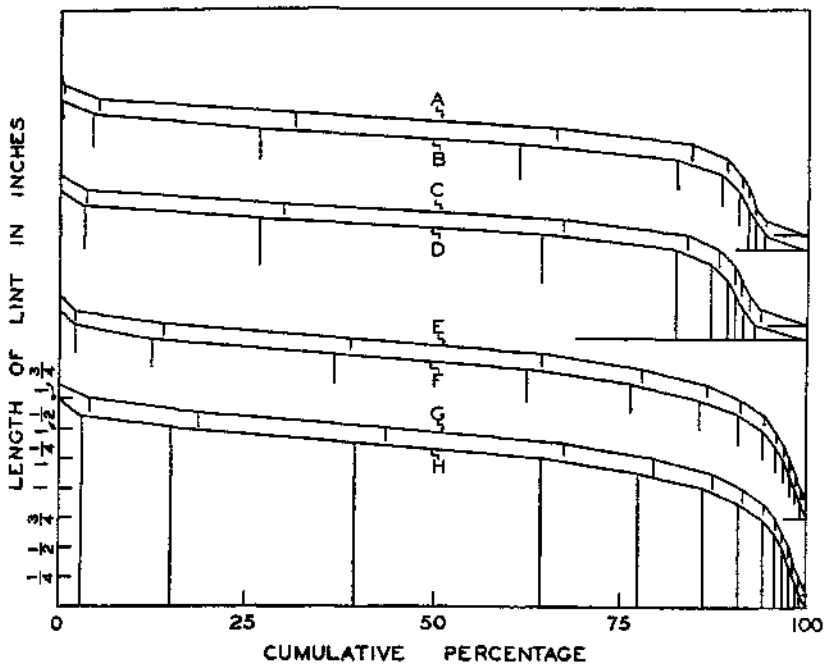

Figure 4.—Sorter arrays showing the percentage of lint in each ⅛-inch class from relatively heavy and light selfed seeds and relatively heavy and light hybrid seeds for the Red Acala and Pima mother plants.

same relative positions. This also held true for heavy and light hybrid seeds.

Figure 4 shows the arrays for the lint of the heavy and light seeds, both selfed and hybrid, of the Red Acala mother plants, as well as the corresponding arrays for the lint of the seeds of the Pima mother plants. *A* and *B* represent the arrays of the lint from the heavy and light selfed Red Acala seeds respectively; *C* and *D*, those of the lint from the heavy and light hybrid Red Acala seeds; *E* and *F*, those of the lint from the heavy and light selfed Pima seeds; and *G* and *H*, those of the lint from the heavy and light hybrid Pima seeds. In every case the array representing the lint from the heavy seeds shows a greater percentage in the longest length-classes than does that for the lint of the light seeds.

The curves in Figure 5 show the percentage of the total amount of lint in each ⅛-inch class in a more noticeable manner than do the arrays in Figure 4. The solid line at *A* represents the percentage in each ⅛-inch class for the lint of the heavy selfed seeds of the Red Acala mother plants. The dotted line at *A* shows the same thing for the light selfed seeds growing in comparable positions. The percentages of lint in each ⅛-inch class are shown at

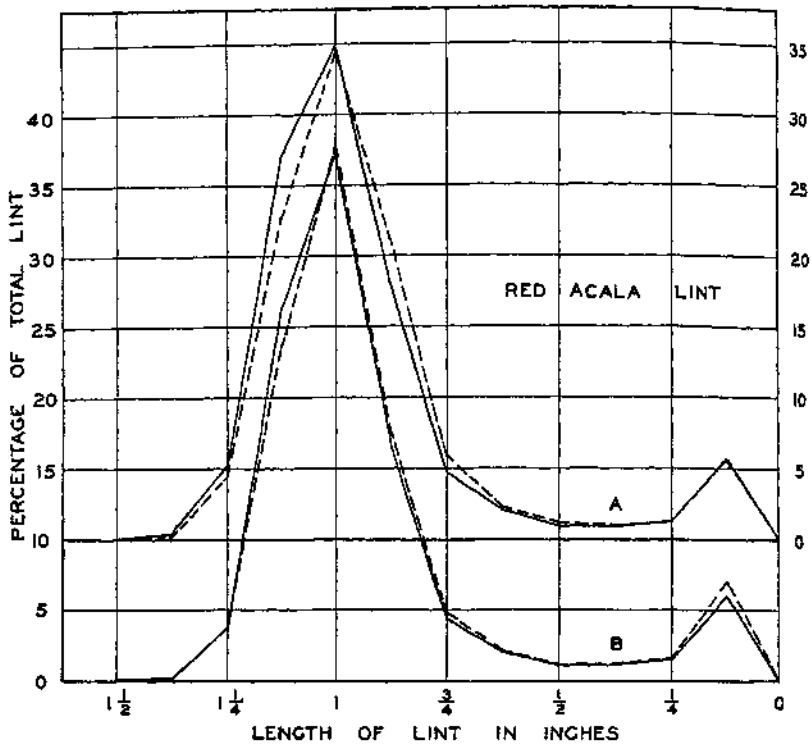

Figure 5.—Heavy and light self and heavy and light hybrid lint. *A*, solid line, heavy self lint; dotted line, light self lint. *B*, solid line, heavy hybrid lint; dotted line, light hybrid lint.

B for the heavy and light hybrid seeds of the Red Acala mother plants by the solid and dotted lines respectively.

In the same manner the percentage of the total amount of lint in each ⅛-inch class is shown for the Pima mother plants in Figure 6. A comparison of the curves in Figure 3 with those in figures 5 and 6 shows very plainly that there was a greater difference in the amount of lint in the longest ⅛-inch classes between the heavy and light seeds of both groups of mother plants than there was between that of the selfed and hybrid seeds.

A COMPARISON OF THE LENGTH OF LINT FROM SELFED SEEDS WITH THAT OF A MIXTURE FROM SELFED AND HYBRID SEEDS

Kearney (6) found the average amount of crossing between Pima and upland cotton to be 12 per cent on the Pima plants and 28 per cent on Acala plants when the plants were scattered throughout a field of the other type. We may consider this an ideal condition for cross-fertilization, and may safely assume that

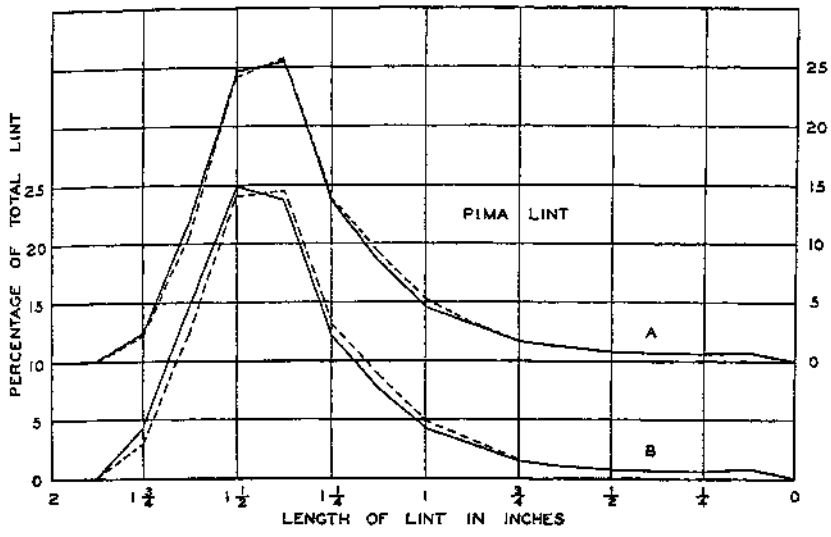

Figure 6.—Heavy and light self and heavy and light hybrid lint. *A*, solid line, heavy self lint; dotted line, light self lint. *B*, solid line, heavy hybrid lint; dotted line, light hybrid lint.

under conditions where the two types are grown in different fields the percentage of cross-fertilization will be considerably less. The percentages given above are used in the construction of the curves shown in Figure 7. The solid lines of the curves represent the percentage of lint from selfed seeds in each ⅛-inch class. The dotted line at *A* represents the percentage of lint in each ⅛-inch class obtained from a mixture consisting of 88 per cent self lint and 12 per cent hybrid lint from Pima mother plants, while that at *B* represents the percentage of lint in each ⅛-inch class of a mixture consisting of 72 per cent self lint and 28 per cent hybrid lint from the Red Acala mother plants. These percentages are probably much higher than would obtain under ordinary growing conditions since they were secured from plants that were entirely surrounded by plants of the other type. The concensus of opinion of a number of writers (2) is that the amount of natural crossing between plants of adjacent fields is less than 10 per cent. The curves show that there is no difference that can be detected in any ordinary manner between the lint of selfed seeds and that of a mixture of lint from selfed and hybrid seeds in the proportions which are likely to be found under ordinary growing conditions.

The percentages in the corresponding length-classes of the lint from the Pima mother plants are so nearly the same in both cases that the solid line representing the selfed lint falls upon the dotted line representing the mixed lint so completely that the two cannot be distinguished. In the case of the lines representing the two

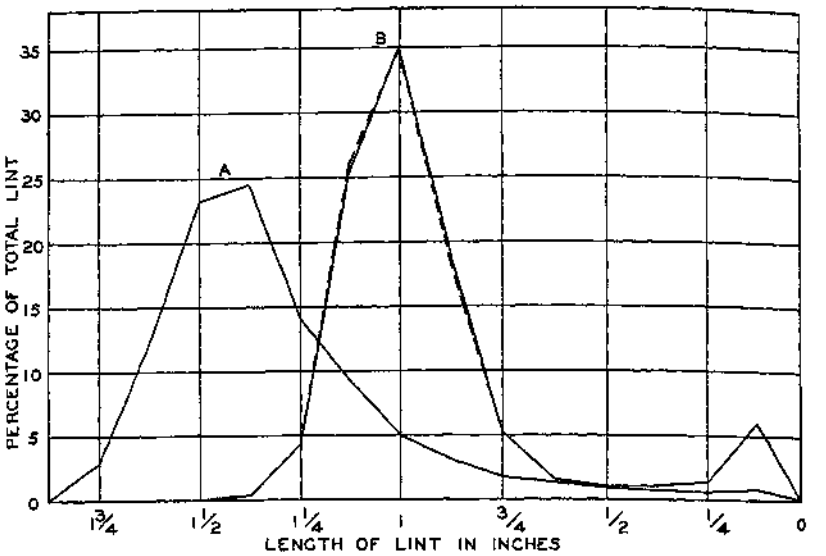

Figure 7.—Self lint and self and hybrid lint mixed. *A*, Pima lint, *B*, Red Acala lint. Solid line, self lint; dotted line, mixed self and hybrid lint.

lots of lint from the Red Acala mother plants, the difference in the percentage in the corresponding classes is great enough that the lines may be distinguished one from the other in that part of the curve representing the longer lengths. Table 13 gives the percentage in each ⅛-inch class for each of the four lots of lint.

TABLE 13.—PERCENTAGE OF LINT IN EACH ⅛-INCH CLASS FOR LOTS OF SELF AND MIXED SELF AND HYBRID LINT.

Class lengths in inches	Parents			
	P♀ x P♂	P♀ x P♂ 88% P♀ x R♂ 12%	R♀ x R♂	R♀ x R♂ 72% R♀ x P♂ 28%
1⅝-1¾	2.81	2.84		
1½-1⅝	12.07	12.11		
1⅜-1½	23.19	23.20		
1¼-1⅜	24.50	24.48	.27	.27
1⅛-1¼	14.15	14.10	4.25	4.35
1 -1⅛	9.19	9.19	25.32	25.80
⅞-1	4.94	4.94	34.70	34.87
¾- ⅞	3.15	3.15	18.72	18.21
⅝- ¾	1.71	1.71	5.20	5.06
½- ⅝	1.23	1.23	2.10	2.07
⅜- ½	.82	.82	1.10	1.09
¼- ⅜	.76	.76	1.05	1.04
⅛- ¼	.64	.64	1.34	1.33
0 - ⅛	.83	.83	5.94	5.88
	99.99	100.01	99.99	99.97

VARIATION IN LENGTH OF LINT BETWEEN PLANTS AND BETWEEN BOLLS OF THE SAME PLANT

Figures 8 and 9 are included for the purpose of showing the great variation in lint length from plant to plant in a fairly pure strain as well as that between bolls from the same plant. The solid line at *A* in Figure 8 shows the percentage in the various ⅛-inch classes of the lint of sixteen selfed seeds from Pima mother plant 7, while the dotted line shows the same thing for the lint of thirty-two selfed seeds from Pima mother plant 2. These plants had respectively the longest and shortest lint from selfed seeds in the lot of seven Pima plants used. There was a difference of 1/16 inch in the length of the self lint between the two plants. A much larger proportion of the total lint was found in the three longest classes of plant 7 than was found in the corresponding classes of plant 2.

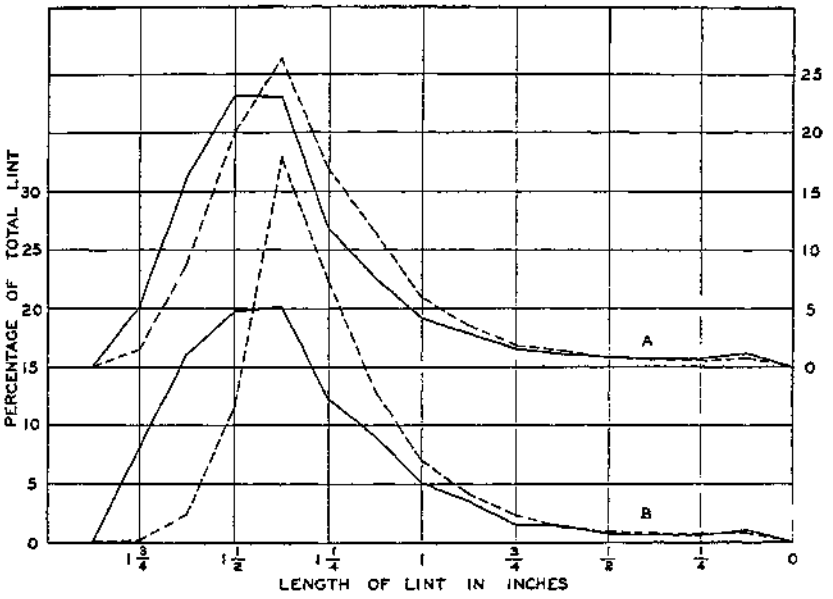

Figure 8.—Self lint from P2 and P7. Longest and shortest lint from P8. *A*, solid line, self lint from P7; dotted line, self lint from P2. *B*, solid line, longest self lint from P8; dotted line, shortest self lint from P8

The solid line at *B* in Figure 8 shows the percentage in the various ⅛-inch classes of the self lint from one group of bolls, and the dotted line those for the self lint from another group of bolls produced on the same plant. The difference in length between the lint of the two groups of bolls was 5/32 inch. The bolls were originally grouped and the lint combined according to the number of the Red Acala plant which produced the pollen that was used in making the crosses, and not according to the length of lint of

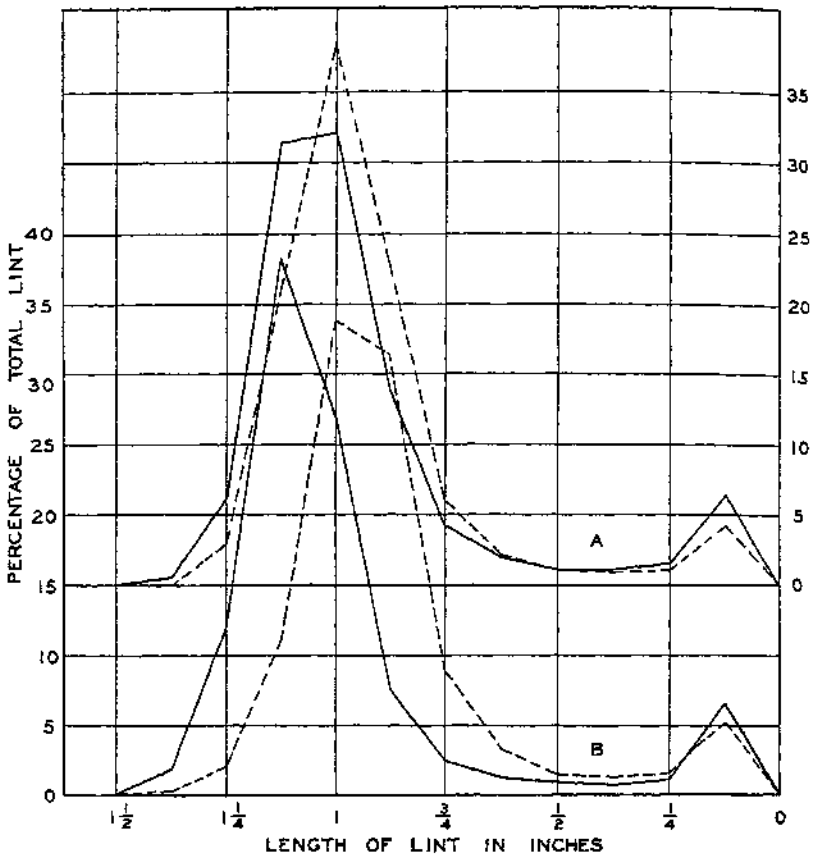

Figure 9.—Self lint from R5 and R4. Longest and shortest lint from R6. *A*, solid line, self lint from R5; dotted line, self lint from R4. *B*, solid line, longest self lint from R6; dotted line, shortest self lint from R6.

the individual bolls. Had the latter method been used it is possible that an even greater difference would have been found than that shown at *B* in Figure 8.

The solid and dotted lines at *A* and *B* in Figure 9 show the same things for the Red Acala plants that are shown in Figure 8 for the Pima plants. The lint of sixty-nine selfed seeds was used in calculating the percentages indicated by the solid line at *A*, while that of forty-eight was used in determining those indicated by the dotted line. The difference in the length of the self lint of these two plants was 1/16 inch. A difference of ⅛-inch was found between the lengths of lint of the two groups of bolls shown at *B*. The lint of eight selfed seeds was used in each case in determining the length of lint of the two groups of bolls. Here again the difference would probably have been greater if the bolls had been grouped on a different basis.

AMOUNT OF LINT PER SEED

The variation in the average weight of lint per seed followed very closely that of the average weight of the seeds themselves. The average weight of the lint from the selfed Pima seeds was slightly greater than that from the hybrid seeds. The difference, however, was only 0.42 mgm., and was not significant. The lint from the heavy selfed Pima seeds averaged 1.16 mgm. more than that from the light selfed seeds, while the lint from the heavy hybrid seeds averaged 1.26 mgm. more than that from the light hybrid seeds.

TABLE 14.—AVERAGE WEIGHT AND LENGTH OF LINT AND THE AVERAGE DIFFERENCE IN WEIGHT AND LENGTH OF LINT FROM SELFED AND HYBRID SEEDS, AND FROM RELATIVELY HEAVY AND LIGHT SELFED AND HYBRID SEEDS FOR PIMA AND RED ACALA MOTHER PLANTS.

Parentage of seeds	No. of seeds sorted	Average wgt. of lint	Length of lint (128ths inch)	Difference in average wgt.	Difference in length
P♀ x P♂	187	56.38	185	0.42	0
P♀ x R♂	187	55.96	185		
P♀ x P♂	73	57.49	185	1.16	1/128
P♀ x P♂	73	56.33	184		
P♀ x R♂	46	55.42	188	1.26	3/128
P♀ x R♂	46	54.16	185		
R♀ x R♂	405	73.62	131	1.39	1/128
R♀ x P♂	405	75.01	132		
R♀ x R♂	107	74.62	132	3.68	3/128
R♀ x R♂	107	70.94	129		
R♀ x P♂	63	77.47	131	3.44	2/128
R♀ x P♂	63	74.03	129		

Table 14 shows the parentage of the seeds, the number sorted, the average weight of lint per seed, the length of lint to the nearest 1/128 inch, the difference in the average weight of lint, and the difference in the average length for each lot of lint studied. It will be noted that the average weight of lint per seed is 1.39 mgm. greater for the lint of the hybrid seeds than for the selfed seeds in the case of those coming from the Red Acala mother plants. On the whole the variation in the average weight of lint per seed is greater for the lint of the Red Acala mother plants than for the Pima mother plants. This was also true in respect to the length of lint of the two lots.

SIGNIFICANCE OF DIFFERENCES

Table 15 shows the significance of the difference in the average weights of comparable seeds for each of the six lots studied. It will be noted that the difference is in each case significant with the exception of that between the selfed and hybrid seeds of the Pima mother plants. In this case the difference in weight was only 0.61 as large as the error of the difference. In the other lots the difference varied from 6.65 to 19.06 times the error.

TABLE 15.—THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN THE MEAN WEIGHTS OF THE SIX LOTS OF SEEDS STUDIED.

Parentage of seeds	No. of seeds sorted	Mean weight of seeds	Difference in mgm.	Difference / error
P♀ x P♂	187	144.96	0.44	0.61
P♀ x R♂	187	144.52		
P♀ x P♂	73	145.65	7.38	7.27
P♀ x P♂	73	138.27		
P♀ x R♂	46	148.52	9.93	6.65
P♀ x R♂	46	138.59		
R♀ x R♂	405	153.02	7.30	12.48
R♀ x P♂	405	160.32		
R♀ x R♂	107	156.78	9.17	13.17
R♀ x R♂	107	147.61		
R♀ x P♂	63	167.59	10.86	19.06
R♀ x P♂	63	156.73		

The signicance of the differences in the length of lint could not be calculated because of the fact that the length of lint of each seed was not determined separately. As previously stated the corresponding length-classes of the lint from all seeds from each mother plant with a common male parent were combined for weighing. From these figures the average length was obtained for the lint of the seeds involved. While the true average to the nearest 1/128 inch was thus obtained for each seed sorted, the length distribution cannot be determined from the data. Even though the statistical significance cannot be calculated, very few, if any, of the differences are of any importance from the practical standpoint. It is certain that a difference of 1/128 inch cannot be detected by the cotton classer. It is almost as certain that a difference of 1/64 inch cannot be detected, while one as great as 1/32 inch may not always be noted. In neither case was the difference in length between the selfed and hybrid lint as much as 1/64 inch.

We may safely say then that regardless of the statistical significance, the lengths are the same from the standpoint of both the cotton classer and the spinner.

EFFECT OF CROSSING ON THE AVERAGE WEIGHT OF SEEDS AND THE AVERAGE WEIGHT OF LINT PER SEED

In the crosses made in 1931 there was no significant difference between the weight of the selfed Delfos seeds and those resulting from the cross Delfos on Red Acala. In the case of the cross Red Acala on Delfos, however, the hybrid seeds were significantly heavier than the selfed seeds, the difference being 4.13 times the error of the difference. It should be remembered that the difference in length between the self and hybrid lint of the Delfos mother plants was not significant while that between the self and hybrid lint from the Red Acala mother plants was significant.

In the crosses made in 1933 the results were practically the same in that the hybrid seeds on the Pima mother plants resulting from the cross Pima on Red Acala were very nearly the same in average weight as were the comparable selfed seeds; while in the reciprocal cross, Red Acala on Pima, the hybrid seeds were significantly heavier than the selfed seeds. Here again the difference in length between the self and hybrid lint was greater in the cross Red Acala on Pima than in the cross Pima on Red Acala. As previously stated the significance of this difference cannot be calculated from the data.

Reference to tables 14 and 15 will show that in each case where there was a significant difference in the weight of seeds, there was also a difference in the length of lint, and that in each case the heavier seeds produced the longer lint. Reference to Table 12 will show that the difference in length of lint was to a great extent in proportion to the difference in the average weight of the seeds.

The lint index, which is found by dividing the total weight of lint by the number of seeds and multiplying the quotient by 100, varied in the same way as did the length of lint. In each case the heavier seeds produced the greater average weight of lint.

These data seem to indicate that the small amount of difference in length between the self and hybrid lint was due to better nutrition afforded the fibers by the heavier seeds, and not to any direct effect of the pollen on the lint. This is especially true in view of the fact that comparable pairs of both selfed and hybrid seeds from each group of mother plants produced lint varying in length as the seeds varied in weight. It should be remembered that these selections were based solely upon the relative weights of the seeds. In each case the variation in both seed weight and lint length was greater than in the case of the comparable selfed and hybrid seeds.

SUMMARY

Reciprocal crosses made in 1931 between strains of Delfos and Red Acala produced seeds whose lint varied very little in length from that of selfed seeds which grew in comparable positions in the same bolls. Hybrid lint from the cross Delfos on Red Acala was the same in length to the nearest 1/128 inch as comparable self lint from the same mother plants. The selfed and hybrid seeds on which the lint grew were not significantly different in weight. Hybrid lint from the cross Red Acala on Delfos was 1/128 inch longer than comparable self lint from the same mother plants. The hybrid seeds were significantly heavier than the selfed seeds.

Reciprocal crosses made in 1933 between strains of Pima and Red Acala produced seeds whose lint varied only slightly in length from that of comparable selfed seeds. Hybrid lint from the cross Pima on Red Acala was the same in length to the nearest 1/128 inch as that of comparable self lint, while hybrid lint of the cross Red Acala on Pima was 1/128 inch longer than comparable self lint when measured by means of large-scale arrays based on sorting data. This difference, while statistically significant in 1931 and possibly so in 1933, was too small to be detected in classing and could have no noticeable effect upon the spinning qualities of the lint. In 1933, as in 1931, hybrid seeds produced by the use of pollen from the Red Acala plants were not significantly heavier than comparable selfed seeds, while hybrid seeds produced on the Red Acala mother plants by the use of unlike pollen were significantly heavier than the comparable selfed seeds.

Lint from a group of relatively heavy selfed seeds from each set of mother plants was longer than that from another comparable group of relatively light selfed seeds from the same mother plants. Selections for these two groups were made solely on the basis of the relative weights of the two seeds making up a comparable pair, the heavier seed being placed in one group in each instance and the lighter in the other. The lint from two groups of hybrid seeds from each set of mother plants showed the same results. In each case, with the exception of that of the lint from the heavy and light selfed Pima seeds, the difference was greater than any difference in the length of lint from the comparable selfed and hybrid seeds.

The greatest difference in the percentage of lint in corresponding ⅛-inch classes between a lot of lint from selfed Pima seeds and another composed of 88 per cent self Pima lint and 12 per cent hybrid lint was only 0.05 per cent in the class ranging in length from 1⅛ to 1¼ inches. In the nine shorter corresponding length-classes the percentages were the same to the nearest 0.01 per cent.

In the case of the lint from the Red Acala mother plants, the greatest difference in percentage between corresponding length-classes of lint from selfed seeds and that of a mixture of 72 per cent self lint and 28 per cent hybrid lint was 0.61 per cent in the class ranging in length from ¾ to ⅞ inch.

The figures used in making up the mixtures were those found

by Kearney to be the average percentage of crossing on plants entirely surrounded by plants of the other type, and are probably much higher than would actually take place between plants growing in separate fields.

The lint produced by the selfed seeds of Pima plant 7 was 1/16 inch longer than that produced by the selfed seeds of Pima plant 2. The difference in length between the self lint of two groups of bolls grown on the same Pima plant was 5/32 inch. The lint produced by the selfed seeds of Red Acala 5 was 1/16 inch longer than that produced by the selfed seeds of Red Acala 4, while the difference between the length of self lint from two groups of bolls grown on the same Red Acala plant was ⅛ inch. When measured to the nearest 1/128 inch, no difference was found between the length of self and hybrid lint from Pima mother plants, while a difference of only 1/128 inch was found between the self and hybrid lint of the Red Acala mother plants. In the latter case the difference was only one-eighth as great as that between plants, and only one-sixteenth as great as that between two groups of bolls on the same plant.

A study of the results obtained from the four comparable lots of lint during the two years shows that in all cases where both weight and length of lint were determined, both the longer and heavier lint were produced on the same seeds. With one exception the longer and heavier lint was produced on the heavier seeds. In the case of this exception the difference in seed weight was not significant.

The data show no reason for the difference in the effect upon the weight of seeds of the different pollens used. Neither in 1931 when the Red Acala pollen was used in crosses with Delfos nor in 1933 when it was again used in crosses with Pima were the hybrid seeds significantly heavier than the selfed seeds. In 1931 the hybrid seeds were slightly heavier than the comparable selfed seeds, while in 1933 the opposite was true. In both years, however, in the crosses Red Acala on Delfos and Red Acala on Pima, the hybrid seeds were significantly heavier than the selfed seeds. These averages were obtained from 564 pairs of seeds in 1931 and from 405 pairs in 1933. In each case the two seeds making up a pair grew in comparable positions in the same boll.

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