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Inheritance of Fineness of Lint in Upland Cotton[1]

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FINENESS of cotton lint is a factor in the spinning of fine yarns. This relation may be noted in Baines' (1) and in Scherer's (5) descriptions of hand manufacture of cotton in ancient India. Fineness, or silkiness, of cotton lint, along with great length, as found in Sea Island, Egyptian, or extra-long-staple Upland has been the basis of the fine-cotton spinning industry since the advent of the factory system. Supply of these long and fine cottons and their factory utilization in fine spinning were discussed at some length in a paper given at a meeting of the New England Cotton Manufacturers' Association by Kittredge (4) about 60 years ago. In short cottons, particularly in short-staple and medium-staple Upland, fineness was not given much consideration as a factor in facilitating finer spinning until about 25 years ago.

In 1936 Webb[3] demonstrated that Sea Island lint cut to the length of ordinary Upland cotton produced yarn that still possessed strength to about the same degree as derived from the long fine cottons prior to being cut. Strength of yarn, therefore, appeared to be more a result of fineness of lint than of length of lint. Webb also tested naturally short and fine-lint cotton from a primitive Arizona or Hopi Indian cotton, and from its F_1 population derived from a cross with Acala, an Upland variety. He found that remarkably fine and strong yarns could be spun from such naturally short and fine cottons. Modern spinners, however, generally prefer fineness of lint in an intermediate range rather than extremely fine or extremely coarse. Yarns from extremely fine lint are apt to contain more neps and, therefore, be rougher; and yarns from extremely coarse lint are likely to have less strength.

The identification and separation of the function of fineness of lint from that of length of lint in machine spinning was delayed because of time required to characterize fineness. Prior to 1940 fineness of lint was determined by measuring the lint-hair diameter, by taking the weight of the lint hair, or by cutting and weighing a unit of length of the lint hair and expressing in micrograms per inch. Such methods have been relatively accurate, but extremely tedious and slow. The first fast and reasonably accurate method was provided by the arealometer, an air-flow device designed and described by Sullivan and Hertel (7) in 1940. Fine cotton, compressed in an air chamber such as provided by the air-flow device, offers more resistance to a current of air flowing through the fibers than coarse cotton placed under the same condition. Several other air-flow instruments have been fashioned and built since 1940. The one of this group used most in commercial work is the micronaire (6). The arealometer was modified to measure immaturity of lint as well as fineness of lint by Hertel and Craven (3) in 1951. The basis of measuring fineness itself also was revised and the numerical expressions changed to be read in whole numbers.

After Webb's announcement of the importance of fineness in short cotton much emphasis was placed on breeding this characteristic into such cottons. More crossing of Hopi and Upland varieties was done and several combinations of interspecies hybrids were exploited. Breeding for finer lint was accelerated with the establishment of a national cotton fiber testing service by the U. S. Department of Agriculture in cooperation with the University of Tennessee at Knoxville. The newly developed arealometer was installed in that laboratory along with other instruments for rapid measurement of some of the other lint properties. The testing service was utilized by most of the federal and state cotton breeders of the Cotton Belt of the United States, especially for the fineness determination.

Among some segregates involving hybridization of 4 Upland varieties (Farm Relief, Coker Cleveland 5–7, Stoneville 5, and Dixie Triumph 12) sent to the Knoxville laboratory in 1943 by P. H. Kime of the North Carolina Agricultural Experiment Station considerable plant variation in fineness was noted. Although breeders were considering shifts in lint fineness as breeding objectives, there was little evidence especially in Upland cotton that this property was under gene control. In this respect the Kime variants attracted interest.

MATERIALS AND METHODS

Seeds of 6 of the plants (sixth generation from the four-way cross) showing maximum arealometer fineness were obtained from P. H. Kime and planted in plant-to-row isolation at the Pee Dee Experiment Station, Florence, S. C. (branch of the South Carolina Agricultural Experiment Station, Clemson) in 1944. In this growth, 4 of the six 1943 plants were found not to produce any coarse-lint segregates. Also further growth of subsequent generations at the Pee Dee Experiment Station demonstrated that the lint of the four fine stocks continued to be fine and the lines relatively stable. Thus identified, these fine lines were collectively designated as "Kime's Fine." While the fine lines were being developed, contrastingly coarse-lint lines also were isolated out of other Upland varieties. Half and Half and Florida Green Seed already having relatively coarse lints, it was not difficult to further raise their lint-coarseness levels by special plant selection. The coarse lines, however, were shorter in length of lint. The Kime's Fine lines had lint length of approximately 1$\frac{1}{16}$ inches; the Half and Half lines, about ¾ inch; and the Florida Green Seed lines, about ⅝ inch. Half and Half was an old commercial variety always having very short lint and very high lint percentage (2). Florida Green Seed had strong-short lint and seed of a bright pea-green color (8).

During the flowering season of 1944, crossing was carried out at the Pee Dee Experiment Station between plants of the Kime's Fine lines and plants of the Half and Half lines, and between the same or similar plants of the Kime's Fine lines and plants of the Florida Green Seed lines. The plants used as parents of the crosses also were self-pollinated in order to grow pure parent lines parallel with the F_1 hybrids the following year.

In 1945, F_1 hybrids of plants having satisfactory contrast of fineness and coarseness and lines from the parent plants thus involved were grown. The respective F_1 hybrids also were backcrossed to both of their parent lines. All plants used in the F_1's and parent lines for backcrossing were self-pollinated. Self-pollination was

[1] Contribution from Crops Research Division, ARS, USDA, in cooperation with the Clemson College Department of Agronomy and Arkansas Agricultural Experiment Station. Received Sept. 17, 1962.

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[3] Webb, R. W. New facts on strength of cotton start breeding for fine short staple. USDA Off. of Inf. Press Serv., June 1 release (Processed). 1936.

Table 1—Fineness data for crosses and backcrosses between a fine Upland cotton, Kime's Fine, and two course Upland cottons, Half and Half and Florida Green Seed.

Year	Parent line, crosses and backcrosses*	No. of plants within the designated arealometer measurement classes									Total plants	Mean	Standard deviation
		< 281	281-300	301-330	331-370	371-420	421-480	481-550	551-630	> 630			
1944	Kime's Fine						3	22	22	7	54	559	59
	Half and Half		6	57	52	10					125	330	20
	Florida Green Seed	16	32	8							56	287	14
1945	Kime's Fine						2	15	9	2	28	537	43
	Half and Half		3	21	30	2					56	331	20
	Florida Green Seed	10	9	3							22	281	19
	F_1, Kime's Fine x Half and Half				1	11	6				18	411	30
	F_1, Kime's Fine x Florida Green Seed					20	15	2			37	416	32
1946	Kime's Fine				1	2	29	97	21	4	154	509	37
	Half and Half		5	9	3						17	310	20
	Florida Green Seed	52	7	2							61	< 281	unk.
	F_2, Kime's Fine x Half and Half			13	64	101	18	1	2		199	380	32
	F_2, Kime's Fine x Florida Green Seed		3	16	68	90	38	5	1		221	383	43
	BC of F_1 (KF x H & H) on KF				1	25	53	3	3		85	432	34
	BC of F_1 (KF x H & H) on H & H		1	3	1	1					6	325	32
	BC of F_1 (KF x FGS) on KF				2	7	26	7	1		43	447	34
	BC of F_1 (KF x FGS) on FGS		8	15	7	1					31	319	25
	F_1, Kime's Fine x Florida Green Seed				17	26	1				44	375	24
1947	Kime's Fine				1	1	18	26			46	493	32
	Half and Half		2	8	2	2					14	322	30
	Florida Green Seed	63	9	1							73	< 281	unk.
	2 BC, 1st BC of F_1 (KF x H & H on KF) repeated on KF					4	30	12	1		47	474	40
	2 BC, 1st BC of F_1 (KF x FGS on KF) repeated on KF					1	9	8	1		19	458	32
	2 BC, 1st BC of F_1 (KF x FGS on FGS) repeated on FGS	41	37	13	1						92	283	17
	$(BC)_2$, progeny of 1st BC of KF x H & H on KF				2	15	69	36	2		124	449	62
	$(BC)_2$, progeny of 1st BC of KF x FGS on KF				1	4	14	5	2	2	28	465	47
	$(BC)_2$, progeny of 1st BC of KF x FGS on FGS	15	17	15	26	16	2				91	323	47

* *Abbreviations used: BC for the first backcross; 2 BC for the second backcross; $(BC)_2$ for the progenies of the first backcross; KF for Kime's Fine; H & H for Half and Half; FGS for Florida Green Seed.*

emphasized additionally in the F_1's to have large numbers of plants in the F_2's. Simultaneously, crosses were made again between plants of Kime's Fine and plants of Florida Green Seed lines.

In 1946, the F_2 generation, the backcross progenies (BC), and the parent lines of both cross groups were grown. Also the new F_1 from the 1945 crosses of Kime's Fine and Florida Green Seed was grown. During the flowering season, the backcross progenies were self-pollinated and again backcrossed to their respective parent lines. Self-pollination in parent lines also was continued.

In 1947, the last field-year of the experiment, second-backcross progenies, 2 BC, a second generation of backcross progenies, $(BC)_2$, and the parent lines were grown. However, in the Kime's Fine $\times$ Half and Half cross group, the 2 BC and $(BC)_2$ to Half and Half were omitted.

Since Kime's Fine was a parent to the 2 cross groups, pure lines of 3 parents only needed to be maintained. Populations of these parent lines as well as the several populations of hybrid combinations of both cross groups, therefore, are set up in frequency distributions for comparison in a common table, Table 1.

The original or Sullivan and Hertel (7) model of the arealometer was utilized to measure the fineness of the plants. In using the old model, units of surface area of fiber were divided by units of weight of the sample, specifically, square centimeters by milligrams, $cm.^2/mg$. With the new model (3), which was substituted for the old model at the Knoxville laboratory September 20, 1949, units of surface area of fiber are in square millimeters and divided by cubic millimeter values, $mm.^2/mm.^3$.

The calibration chart set up for recording fineness data from the old arealometer extended from the ratio of 1.73 for coarsest lint to the ratio of 4.12 for finest lint. This range of ratios in terms of values of the new arealometer scale extends from 272 to 647 and can be obtained by a conversion factor of 157.[4]

In the fineness experiment, only a few plants had lint too fine to measure, but a relatively large number of contrasting plants had lint too coarse to measure. Also the coarseness was greater in the Florida Green Seed and the cross group in which this parent was used than in Half and Half and its cross group.

EXPERIMENTAL RESULTS

Table 1 is set up according to a special format[5] to accommodate the fineness data after conversion to the new arealometer scale and to provide extra arealometer classes for adjusted evaluation of the unmeasured plants. Spaces for nine class columns are laid out to take care of possible frequency spread of all population whether the particular array includes converted arealometer data alone or both the converted and those formerly out of range. Besides the nine arealometer class columns and the stub showing the year of growth and kind of population, the table also includes the total of plants for each population and the mean and standard deviation for each population.

Detailed examination of the individual arealometer values which could be recorded by instrument in each population showed these observations, in every case, to have excellent conformity to the assumption that they had come from a normal distribution. With this assumption, the values reported as less than 281 or greater than 630 could be used in estimating their appropriate contribution to the cumulative normal distributions. After these cumulative distributions had been determined, the estimates of the means and standard deviations for each population were readily provided. This methodology made it possible to use almost all the available data in arriving at the means and standard deviations as reported.

The special format mentioned previously as allowing for nine class columns, and therefore, accommodating the whole range of the data, gives the reader a better opportunity to observe the general nature of the distribution of the population sets of observations as separated into these specified classes. The width of the classes of definite range was made variable (each differing in width by 10 units from the one next to it) so that comparable definition of both fine and coarse varieties could be exhibited in the same table.

SUMMARY OF EXPERIMENT

By use of the arealometer, fine and coarse lines of Upland cotton were identified and isolated. Kime's Fine is the fine-lint line, and Half and Half and Florida Green Seed are the coarse-lint lines. The second coarse-lint line is very coarse. Kime's Fine was crossed with both Half and

[4] "Change in Reporting Arealometer Results," The University of Tennessee Fiber Research Laboratory, Knoxville, Tenn., September 21, 1949; and a table of "Arealometer Conversions" issued soon thereafter from the Cotton and Cordage Fibers Research Branch, Crops Research Division, ARS, USDA, Beltsville, Md.

[5] Constructed by Edwin L. Cox, Biometrician in Charge, Biometrical Services, ARS, USDA, Plant Industry Station, Beltsville, Md.

Half and Florida Green Seed. Parent lines, F_1's, F_2's, and three stages of backcrosses were grown. The growth phase of the experiment extended over a period of 4 years, 1944 to 1947, inclusive. The parent lines as set up and grown the first year were repeated each of the three following years for possible further use in crossing, in backcrossing, and as standards of comparison for the data of the hybrid phases.

The ranges from finest to coarsest lint among the arrays of populations in Table 1 display the extremes of the fineness-coarseness property generally seen in short-staple to medium-staple American Upland cotton, and demonstrate that such extremes can be isolated and genetically established in cotton breeding stocks.

The frequency arrays and mean levels of the F_1 populations indicate intermediate inheritance, but in the several comparisons, a particular F_1 mean is somewhat more often slightly on the coarse side than likewise on the fine side of the mid-value of the parent lines. Comparison of the average of the 3 F_1 means with the average of the possible 8 mid-parental mean values shows the former average at a level only a shade coarser. On carrying out this procedure of computation, the F_1 average mean value would be at the level of 401 arealometer units and the mid-parental average mean value at the level of 414 arealometer units.

The plant frequency arrays of the F_2 of both cross groups are monomodal and follow about the same pattern of distribution, but they are considerably more widespread than any of the F_1 arrays. The means of the two F_2 populations also are much alike. They are at about the same level. As in the F_1's, the positions of the F_2 distributions and their means tend to show more influence of the coarser parent than of the finer parent.

The phases of backcrossing also tend to show some dominance of the coarse parent, but the influence is not great enough to prevent shifting toward the finer parent when it is involved as the recurrent parent. The second backcrosses, in either direction, show more stability than the first backcrosses or the progenies of these first backcrosses. The populations of the second backcrosses are about as stable as corresponding recurrent parent lines, but their oppositely moved means approach parent fineness somewhat less than parent coarseness. However, the plant distributions of the second backcross populations overlap respective recurrent parent ranges enough to suggest the beginning of selection of plant breeding stocks in whichever recurrent hybrid that carries the recovered character desired.

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