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Crystallite Orientation in Some Cotton Varieties of *Gossypium herbaceum*

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The bundle tenacity and crystallite orientation of cotton fibres of 25 varieties of *Gossypium herbaceum* species grown at the Surat farm of the Gujarat Agricultural University in 1983 crop year were determined. The crystallite orientation was expressed in terms of 40, 50 and 75% X-ray angles and the Hermans crystallite orientation factor, and the average orientation angle α_m was computed from the latter. The bundle tenacity and the orientation parameters were correlated.

The varieties should be characterized for strength on the basis of the Hermans factor and not on the basis of the X-ray angles conventionally used.

Keywords: Crystallite orientation, Cotton fibre, Fibre bundle strength, *Gossypium herbaceum*, Hermans crystallite orientation factor

1 Introduction

The relationship between strength and crystallite orientation in native cotton fibres has been studied extensively[1-12]. Most of these reports were based on studies conducted on native cotton fibres without paying much attention to the species, season, location of growth and the agroclimatic conditions under which the cotton was grown. Climatic conditions have been known to affect considerably the degree of polymerization of cellulose, physical and technological behaviour of fibres and their structure[13-20]. Therefore, much controversy exists about the choice of the parameter for characterizing the variety of fibres for strength required in industry and for selecting the basic germ-plasm in quality breeding programmes[3,5,6,8,10,11].

Sundaram *et al.*[18-20] underscored the importance of studying native cotton fibres grown at the same location and in the same crop season. Their studies[18-20], confined to only a very few varieties, correlated the bundle tenacity and the X-ray angles. We have shown recently that characterization of cotton fibres for strength based on 40 and 50 % X-ray angles can be misleading[21-25]. Because of these contradictions it was necessary that, for arriving at conclusions of practical value, a large number of varieties should be grown species-wise at the same location and in the same crop year, so that the fibre properties could be compared so as to enable proper selection.

X-ray diffraction studies were therefore conducted on cotton varieties belonging to *Gossypium hirsutum*, *Gossypium arboreum* and *Gossypium barbadense*[21-26]. Twenty-five varieties of each species were grown species-wise at New Delhi, Sirsa and Coimbatore respectively. The studies[22-26] show clearly that within a species, the Hermans crystallite orientation factor consistently gave higher correlations with the bundle tenacity of fibres than the 40, 50 and 75 % X-ray angles conventionally used[3-6,8,10,11,19]. Even on introduction of variability with regard to species (*G. hirsutum* and *G. arboreum*), year and location of growth, the Hermans crystallite orientation factor was superior to X-ray angles as an index for varietal characterization of fibres for strength[24].

In this paper, data on the relationship between strength and crystallite orientation for 25 cotton varieties of *G. herbaceum* species are given.

2 Experimental Procedure

2.1 Samples

The varieties (25) of the *G. herbaceum* species chosen were grown at the Surat farm of the Gujarat Agricultural University in the crop year 1983.

2.2 Purification

The fibre samples were dewaxed and purified to remove pectic substances and fats by extraction for 6 h each with carbon tetrachloride and methanol and by boiling for 3 h in 2 % sodium hydroxide under pressure. These fibres were neutralized with 0.1 *N* hydrochloric acid for 1 h and finally washed thoroughly in distilled water and dried at room temperature. The details of purification procedure and characterization are described elsewhere[21-23].

2.3 Characterization

The mean fibre length was measured with the help of a Ball's sledge sorter. Fibre fineness and maturity coefficients were determined by using a micronaire apparatus and the bundle tenacity, by a Pressley strength tester using nominal zero gauge length. Flat-plate X-ray diffractograms from bundles of well-parallelized fibres were recorded on a Philips X-ray diffractometer. A Joyce Loeble microdensitometer was used for mapping the azimuthal intensity curves for the 002 and the 101, 101 equatorial reflections, by computing the radial distribution of intensity along the diffraction arcs at every 5° angle, according to the graphical integration procedure described by Hermans[1].

The intensity scans of the 002 reflections were normalized to equal peak intensity and the 40, 50 and 75 % X-ray angles were measured from the normalized curves.

The Hermans crystallite orientation factor (f) was determined by using the relationship :

$$f = 1 - \frac{3}{2} < \sin^2\alpha > \quad \ldots (1)$$

where α is the angle made by the molecular chain in the crystallite with the fibre axis, and $< \sin^2\alpha >$ is the average value of $\sin^2\alpha$. The details of the method for evaluating $< \sin^2\alpha >$ are given in our earlier publications[21-24,26]. From the average value of $\sin^2\alpha$, the average angle α, designated as α_m, was calculated.

3 Results and Discussion

The experimental data for the various varieties of *G. herbaceum* species are given in Table 1. The table shows that the mean fibre length varies from 1.8 cm to 2.41 cm within the varieties of this species grown under identical agroclimatic conditions. The fineness varies from 159 to 223 mtex.

The variations in the values of 40, 50 and 75 % X-ray angles and α_m are 13.5°, 12.5°, 11.0° and 6.25°

Table 1—Experimental Data for Different Varieties of *Gossypium herbaceum*

Sl No	Cotton variety	Mean fibre length cm	Fineness mtex	Maturity coefficient	Bundle tenacity N/tex	X-ray angle, deg			α_m	f
						40 %	50 %	75 %		
1	Kalyan	1.80	163	0.79	0.378	33.0	30.0	22.0	31.25	0.5961
2	V-797	2.03	172	0.77	0.399	37.5	32.5	21.0	31.03	0.6013
3	1027 A L F	2.16	197	0.79	0.409	35.0	32.0	24.0	31.93	0.5801
4	Suyog	2.21	223	0.77	0.462	24.0	20.0	13.0	29.23	0.6429
5	Vijalpa	2.00	179	0.78	0.441	32.0	27.5	17.0	28.71	0.6537
6	BD-8	1.80	203	0.79	0.380	36.0	32.0	22.0	32.85	0.5585
7	Vijay	2.08	181	0.78	0.451	31.0	27.0	19.0	30.23	0.6195
8	Digvijay	2.08	159	0.77	0.499	30.0	27.0	20.0	28.21	0.6646
9	G Cot 13 (53-3-1)	2.00	166	0.77	0.399	33.0	29.0	21.5	29.78	0.6300
10	G Cot 10 (1440)	2.06	192	0.78	0.446	31.0	27.0	17.0	28.17	0.6654
11	5497	2.21	210	0.77	0.425	30.0	25.5	17.0	31.18	0.5979
12	4042	2.23	207	0.78	0.467	30.5	28.0	20.0	29.03	0.6468
13	5510	2.18	190	0.78	0.415	33.0	29.0	21.0	31.66	0.5867
14	5495	2.41	195	0.77	0.478	29.0	26.0	17.5	29.81	0.6292
15	3604	2.08	198	0.78	0.487	29.0	26.0	17.0	27.81	0.6736
16	10941	2.06	191	0.78	0.460	31.0	27.0	18.0	27.06	0.6895
17	4011	2.16	179	0.78	0.399	33.0	30.0	22.0	29.65	0.6328
18	10746	2.03	208	0.77	0.451	34.0	29.0	18.0	29.51	0.6358
19	3518	2.36	219	0.77	0.446	29.0	25.0	15.5	28.11	0.6667
20	4208/838	2.08	175	0.77	0.488	31.0	26.5	15.0	29.86	0.6280
21	7502	2.41	189	0.78	0.457	29.0	26.0	17.0	28.23	0.6641
22	5504	2.18	183	0.77	0.492	27.0	23.0	15.5	26.60	0.6992
23	6455	2.11	200	0.78	0.493	27.0	24.0	15.0	26.75	0.6960
24	4283	2.13	201	0.78	0.483	27.0	23.5	15.0	28.00	0.6694
25	6437	2.16	171	0.78	0.525	25.0	22.0	14.0	27.16	0.6874

Table 2 — Correlation Coefficients and Probability Levels

	X - ray angle			α_m	Hermans factor
	40 %	50 %	75 %		f
Bundle tenacity	$r = -0.778$ $P > 0.001$	$r = -0.763$ $P > 0.001$	$r = -0.754$ $P > 0.001$	$r = -0.778$ $P > 0.001$	$r = 0.764$ $P > 0.001$

respectively. The bundle tenacity varies from 0.378 N/tex for Kalyan to 0.525 N/tex for the variety 6437. The results show that α_m offers the minimum angular spread as compared to 40, 50 and 75% X-ray angles for a corresponding dispersion in bundle tenacity. This small dispersion of α_m may indicate the species characteristics of *G. herbaceum*, in which the genetic variability in terms of α_m and, therefore, in mean fibre length, fineness and strength is very narrow.

3.1 Correlations

The correlation coefficients and probability levels obtained for bundle tenacity with respect to various orientation parameters are given in Table 2. The bundle tenacity shows significantly high correlations with 40, 50 and 75 % X-ray angles. In fact, 40 % X-ray angle and α_m have almost the same correlations with bundle tenacity. Hence, this seems to be because of the narrow variation in the values of 40, 50 and 75 % X-ray angles. Here again, the 40 % X-ray angles with higher dispersions show an identical correlation with α_m, where the dispersion is least. This behaviour is very strange. It had been seen earlier[24,26] in *G. arboreum* species also that both the 40 % X-ray angle and α_m show almost the same correlations with bundle tenacity. On the other hand, the varieties of the *G. hirsutum* and *G. barbadense* species showed higher correlation coefficients with α_m than with 40 and 50 % X-ray angles[22,25]. Both the *G. hirsutum* and *G. barbadense* cotton varieties belong to the New-World cotton species with 26 pairs of chromosomes, whereas the *G. arboreum* and *G. herbaceum* species of cotton varieties belong to the Old-World species with only 13 pairs of chromosomes. From the correlation coefficients species-wise[22,24,25] it is evident that the bundle tenacity of the varieties belonging to *G. arboreum*[24,26] and *G. herbaceum* species is not very sensitive to the 40 and 50 % X-ray angles, whereas the bundle tenacity of the varieties belonging to the *G. hirsutum*[22–24] and *G. barbadense*[25] species shows a high degree of sensitivity. Moreover, Table 1 shows that the smaller values of 40 % X-ray angles do not ncessarily correspond to the increased fibre strength. This is evident from Table 1, where in spite of the least value of 40 % X-ray angle for the variety Suyog the tensile strength is not the maximum for this variety. On the other hand, the higher values of the Hermans crystallite orientation factor correspond with the increased strength of fibres, e.g. for variety 6437 (Table 1). This suggests that though 40 % and 50 % X-ray angles provide high correlations with bundle tenacity in the Old-World cotton species, the actual characterization for strength must necessarily be done on the basis of their Hermans crystallite orientation factors, since it has been shown earlier[24,25] that the characterization of cotton fibres on the basis of the X-ray angles can at times be misleading. The marginal variation in the correlations of f and α_m with bundle tenacity (Table 2) arise as a result of the choice of the number of significant figures used in the evaluation of $\sin^2\alpha$ and $\sin\alpha$ values in further evaluating α_m, using standard tables for sine functions.

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