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Studies on races of cotton species *Gossypium arboreum* L : Fibre quality

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ABSTRACT : The inherent hardiness of the species *Gossypium arboreum* has always been a cause of interest and often attracts the attention of agricultural scientists. The present study was intended to strengthen the case of this forgotten indigenous hardy species of cotton. In this paper attempt has been made to analyse the qualitative status of races of species *Gossypium arboreum* from the view point of fibre technologist and generate awareness towards protecting and popularising this important, invaluable indigenous genetic resource.

Key words : *Arboreum*, gining, *Gosspium*, perennial, potential, races

Cotton the major fibre crop of the world belongs to the genus *Gossypium*; named by Linnaeus in the middle of 18th century. The genus *Gossypium* is a very large genus that includes several wild and cultivated species, showing wide range of variations in plant morphological, structural, seed and fibre characteristics and distinct genotype differences (Santhanam, 1976 and ICCC, Cotton in India, A Monograph, 1960). There are more than 50 species of cotton identified so far and studied but only four of them have successfully been domesticated. The commercial cotton fibre is obtained from these four domesticated species of the genus *Gossypium* which provide most of the world's textile fibre and is important source of oil and cottonseed meal (Pillay and Myers, 1999). The domesticated species, categorised under the heads old world [diploid species *Gossypium arboreum* and *Gossypium herbaceum*] and new world (tetraploid species *Gossypium hirs*utum and *Gossypium barbadense*) cottons, have further been classified in to different geographical races (Table 1) depending upon the location of their dominance and are considered to be of major commercial importance (Santhanam, 1976, ICCC, Cotton in India, A Monograph, 1960 and Iqbal *et al.,* 2001).

Cotton species *of Gossypium arboreum* : The species *Gossypium arboreum* is described as perennial, much branched shrubs or annual sub-shrubs with few or no vegetative branches, 1.5 to 2 meters tall; vegetative branches when present are ascending thin and flexible, twigs and young leaves pubescent, cannescent or hairy, fruiting branches two jointed, leaves often with small accessory lobes in the sinuses cut in to five to seven lobes, ovate, oblong or falcate, caducous bracteoles closely investing the bud and flower, entire or with three or four coarse teeth, staminal column long and antheriferous;

Table 1. Cultivated species of cotton and their races

Old world cotton		New world cotton	
G. arboreum. L	*G. herbaceum.* L	*G. hirsutum.* L	*G. barbadense.* L
Indicum	*Persicum*	*Morrilli*	*Brasiliense*
Cernuum	*Kuljianum*	*Richmondii*	*Darwinii*
Bengalense	*Acrifolium*	*Palmeri*	——
Sinense	*Wightianum*	*Punctat)um*	——
Burmanicum	*Africanun*	*Vucatenense*	——
Soudanense	——	*Mariegalante*	——
——	——	*Latifolium*	——

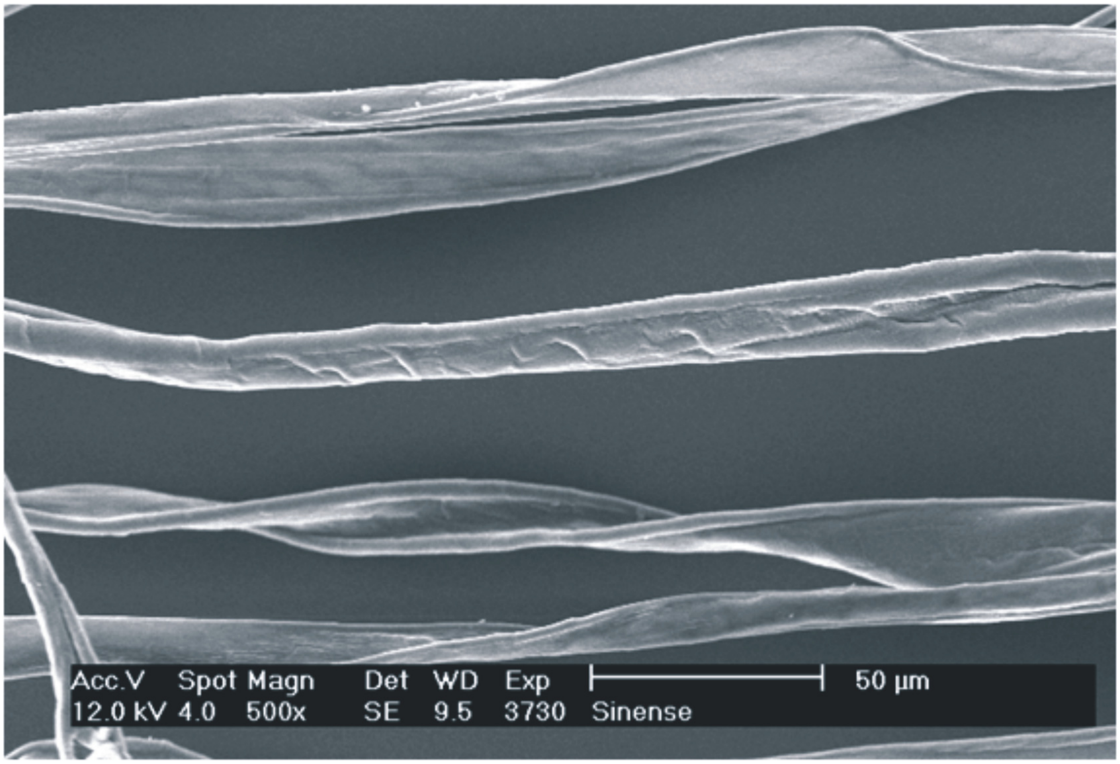
short anther filaments short style, united stigmas, which are rarely divided at the tip-capsules tapering and profusely pitted with prominent oil glands three to four locular, six to seventeen seeds per locule, seed usually with short fuzzy hairs and long lint hairs.

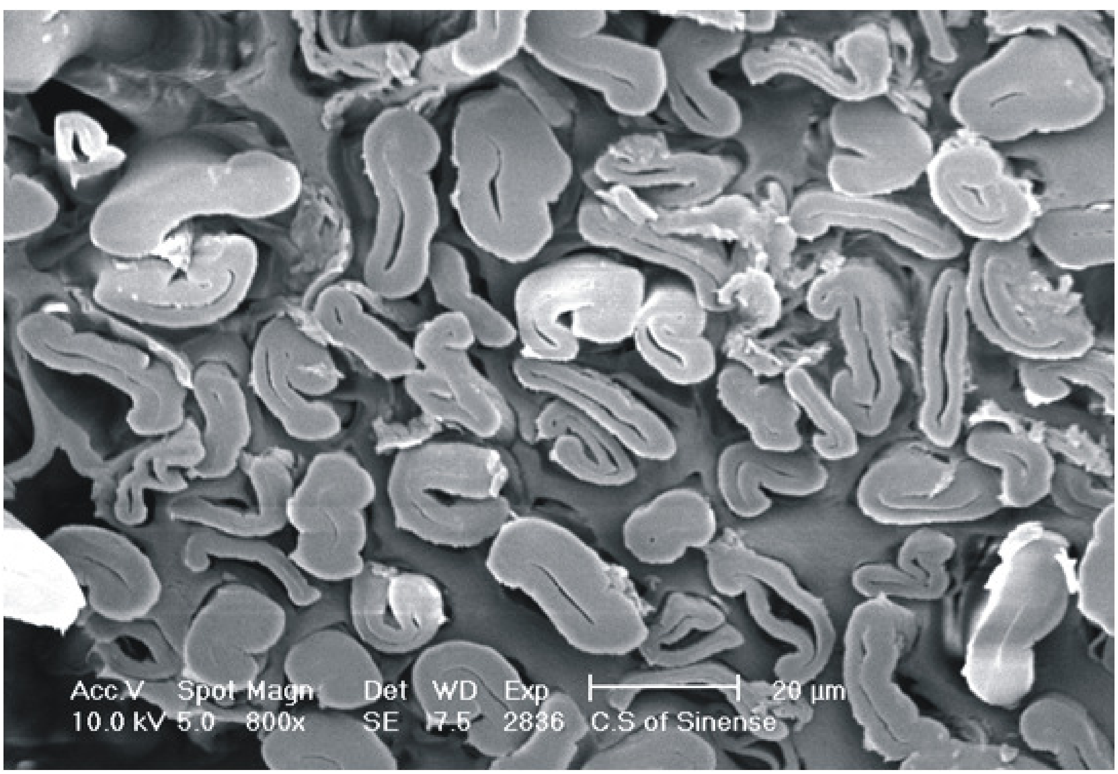
Hutchinson (1954) reported that the *Gossypium herbaceum* race *africanuum*, which is found in South Africa, is truly wild and represents the closest modern relative to the progenitor of the diploid species. This race gave rise to the primitive cultivated race *acerifolium,* which spread northward following development of an annual habit and led to the races *persicum* in Arabia and the very early race *kuljianum*, which was adapted to the hot summers of Central Asia. Primitive perennial *Gossypium herbaceum* spread to India and gave rise to the earliest forms of *Gossypium arboreum*.

This moved in to the alluvial areas of what is now Bangladesh where the perennial northern form of *Gossypium arboreum* developed. These forms spread throughout the area of the old world, which was suitable for the production of perennial cotton. However, the success of cotton as textile material necessitated the production in areas where perennial growth was not possible. The need was first filled by, *Gossypium herbaceum*, giving rise to the evolution of the race *wightianum*. This was followed by the development of annual *Gossypium arboreum*, which spread throughout the cotton producing areas, relegating the perennial forms to relic status (Hutchinson, 1959). The spread of domesticated cottons was closely connected to commerce and industry.

Races of species Gossypium arboreum : There are six forms or races of *Gossypium arboreum*, which are adapted to different environments. In India only three races *viz., bengalense, indicum* and *cernum* are grown. The race *bengalense* is the predominant race and covers vast area in north and central cotton growing zones. The race *indicum* comes next and is mainly grown in peninsular India. The race *cernum* is mainly grown in north eastern hill region, especially in Assam, Nagaland, Tripura and Meghalaya (Singh and Narayanan, 1991). The major features and general importance of each race are briefly described.

Bengalense : This race is predominantly found and cultivated in northern irrigated and central rain-fed cotton belt of India. It has high bolling potential, high yield, low boll weight (1.2-





Micrograph-1.*G. arboreum* race: *sinense* [Longitudinal and cross sectional view]

1.5 g) short to medium staple length (14-24 mm), medium to high ginning outturn (25 -42%) and late maturity [Singh and Raut, 1983]. The *sanguineum* types of *bengalense* have red plant body, early maturity, short and coarser fibre and small boll size.

Burmanicum : This race was first traced in Burma, now it is found in parts of Bangladesh, Assam, Indonesia and Malaysia. This race is an annual form (Singh and Narayanan, 1991).

Cernuum : This race comprises of annual long boll types of Garo Hills of Assam. This race is found in the hilly regions of Bangladesh also and includes comila cottons. The race is shy bearer, low yielder and produces coarser fibres. It is a good source of high ginning outturn (upto 50%), big boll size (upto 6.5 g) more seeds/boll (upto 51) and has erect plant stature (Singh and Raut, 1983, Singh and Nandeshwar, 1983). The race also possesses locule retentivity, high absorbency and tolerance to bollworm.

Indicum : This race comprises of Rosi cottons of western India and perennial *arboreum* of Madagaskar and coastal Tanzania and the annual commercial cottons of peninsular India. The race *Indicum* is closely related to *Gossypium herbaceum*. It has broad leaf lobe, long and fine fibre (upto 30mm) but is a low yielder, low in ginning out turn (26-32%), small in boll size and weight (1.2-1.5g) and is susceptible to bollworm (Singh and Raut, 1983).

Sinense : This race was traced in China, Manchuria, Korea, Japan and Formosa. It has earliness, red plant body, spotless yellow flower that can be used as marker. The race produces fibre with medium fibre length and smaller boll size (Singh and Narayanan, 1991).

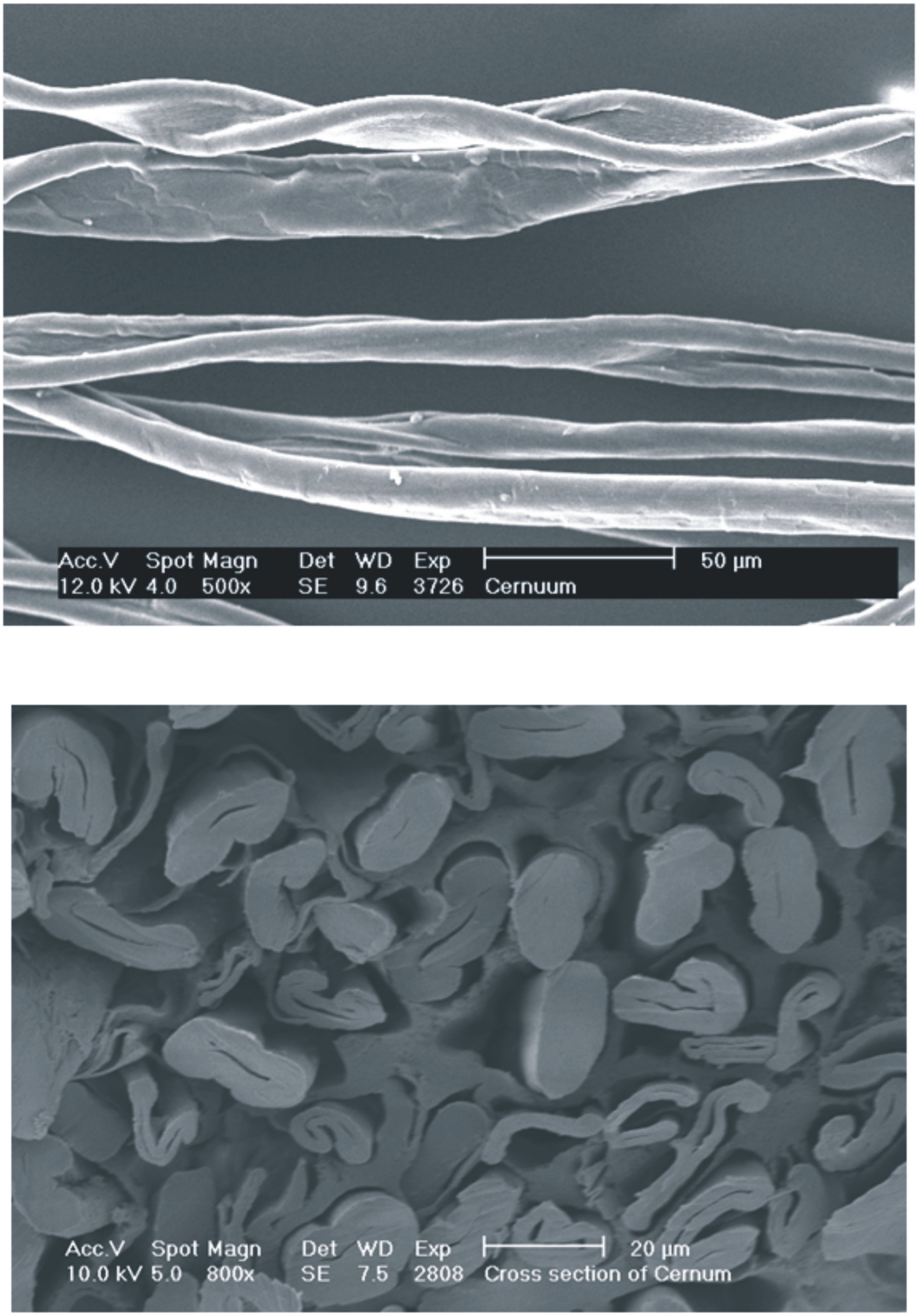
Soudanense : This is an African form, which is grown there from ancient time. The race has wider adaptability and drought hardiness (Singh and Narayanan, 1991).

From the viewpoint of a plant physiologist all the four cultivated species have been widely studied as far as their genetics is concerned. The races of cotton species *Gossypium arboreum* are scantily studied even for fundamental fibre quality attributes; no data, what so ever, is available with regards to their morphological, structural and other related quality parameters. The present study evaluates, various fibre characteristics i.e. physical, morphological and structural and available variability amongst the races of the species.

MATERIALS AND METHODS

The lint samples of six races of the species *Gossypium arboreum* were collected from Cotton Research Farm, University of Agriculture Sciences (UAS) Dharwad, Karnataka, planted under green house conditions.

Physical quality parameters : The lint samples were evaluated by using the commercially available High Volume Instrument (HVI) and Advanced Fibre Information System (AFIS) as per the standard test methods and replicated five times for both HVI and AFIS. In the present study, some of the parameters *viz.,* bundle strength (0 and 3.2mm gauge length) and Tex (linear density) values were also estimated by using other standard



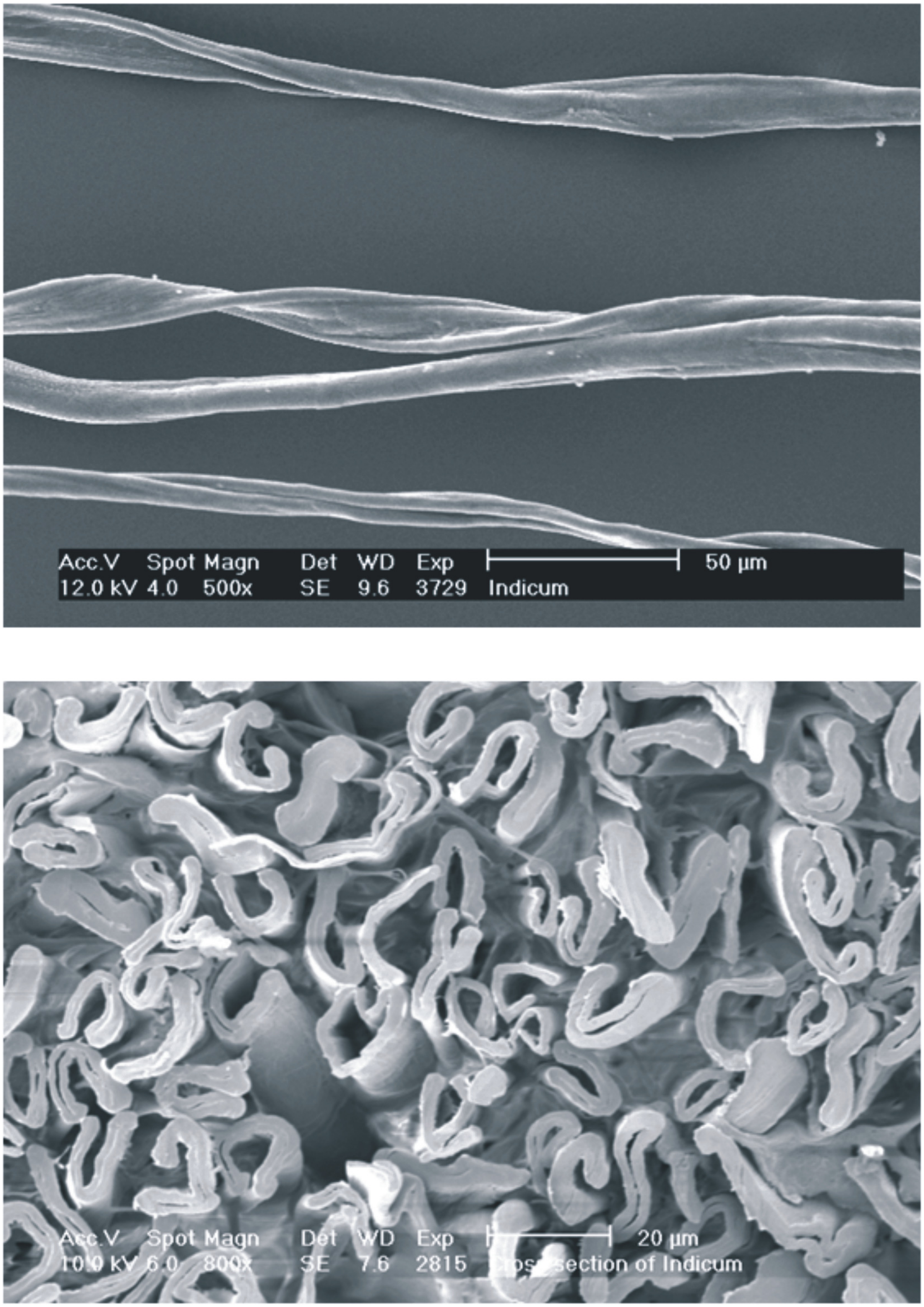
Micrograph-2.*G. arboreum* race: *cernum* [Longitudinal and cross sectional view] methods (stelometer, cut and weigh). The tensile parameters, namely, strength uniformity ratio (SUR), toughness and stiffness were also derived /evaluated [for fibre bundle]. A slippage factor of 0.8 was applied for the calculation of elongation.

Morphological and structural parameters

Convolution frequency, angle and structural reversals : The number of convolutions/unit length of the fibre was determined by using the method adopted by Betrabet *et al.,* (1960), examining the central 10 mm length of the fibre. The number of convolutions over the central 10 mm length of the mounted fibres was counted and the average number of convolutions/unit length calculated. This average figure is expressed as the number of convolutions/cm of the fibre. The convolution angle was calculated using Meredith's expression (Meredith, 1953), Tan è = ð/2(D/C), where 'D' is the ribbon width and 'C' is the pitch. The fibre specimen scanned for the determination of convolution frequency was also used for the measurement of wall thickness and ribbon width (Meredith, 1953 and Sundaram *et al.,* 2002). The identification and measurement of structural reversals were carried out as per the methodology (Betrabet *et al.,* 1963) developed at CIRCOT. The specimens used for determining reversal frequency were the same fibres used for determination of convolutions and other fiber dimensions discussed above. The mean value and CV(%) for a specimen (race) were calculated from the data recorded on 100 fibres.

Cross sectional perimeter, area and circularity : With Scanning Electron Microscope (SEM) both the longitudinal and cross sectional profiles of fibre were obtained. From the cross sectional view, three parameters, the perimeter of the fibre 'P', area enclosed by outer profile 'A', and area of lumen 'A^1' were estimated by using a super planix –á which is a combined map measurer cum planimeter. The circularity or shape factor (å) of the fibre cross section was calculated using the formula "å = 4ð A /P^2". The degree of thickening was also evaluated by using the formula "q = 4ð (A-A^1)/P^2". The average and CV% for the 100 fibres for each specimen (race) were calculated and reported.

Crystallinity, crystallite size and orientation by X-ray analysis : Crystallinity was determined as per the standard test method (Sundaram *et al.,* 2002) by using Nickel filtered CuKá X-ray radiation emerging from a stabilized Philips X-ray generator. The intensity profile recorded was corrected for air scattering that was obtained by matching a run without the sample under identical conditions (Sreenivasan *et al.,* 1988). Crystallinity was calculated by the method reported by Segal *et al.,* (1959) using the indices established by Chidambareswaran *et al.,* (1987). Crystallite size was determined from the strongest peak using Scherrer equation (Klug and Alexander 1974) D_{hkl} = kl / b Cosq . Where, D_{hkl} is the dimension of the crystal perpendicular to the (hkl) plane from which reflection arises, l is the wavelength of the X-rays, and q the Bragg angle reflection, b the angular broadening (in radians) of the reflection and k, a constant having a value of about 0.9. Herman's X-ray orientation factor and 50(%) X-ray angle, two commonly used indices for characterizing the fibrillar orientation, were estimated from X- ray



Micrograph-3.*G. arboreum* race: *indicum* [Longitudinal and cross sectional view] diffractograms obtained from bundle of well parallelized fibres recorded on a Philips X-ray diffractometer. Herman's orientation factor (f_x) was computed from the intensity profile by using the standard procedure (Herman's, 1946).

All the samples were evaluated at standard atmospheric conditions of 65 ± 2% RH and 27± 2°C Temperature.

Statistical Analysis : The data obtained were statistically analysed using Completely Randomized Design (CRD). Duncan's Multiple Range Test was applied for individual comparison of mean values among various quality parameters using SPSS 15.0 statistical software programme.

RESULTS AND DISCUSSION

Gross fibre parameters (HVI and AFIS) : In a successful varietal improvement programme, the availability of adequate variability in basic genetic stock and their proper utilization through breeding for developing improved strains is very important. The six, domesticated races of *Gossypium arboreum* cotton were evaluated for physical quality parameters with the help of HVI and AFIS.

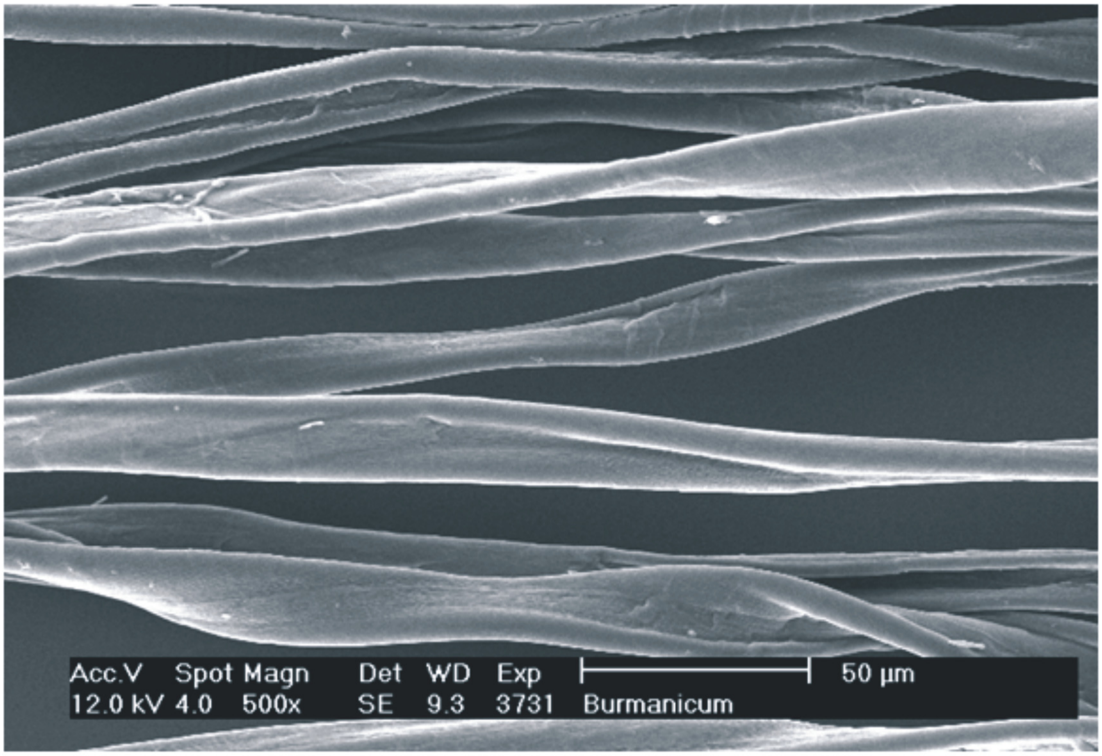
HVI fibre properties : All the six races of species *Gossypium arboreum*, evaluated under the present study on HVI system in ICC mode, in general fell in the category of medium long staple length and excellent length uniformity. The close scrutiny of the data (Table 2) reveals that all the six domesticated races of the species possess quality traits which can easily be identified for medium staple cotton, especially with respect to fibre length (23.3–26.1mm) length uniformity (47–51). The race *bengalense* recorded highest span length (26.1mm). As regards the presence of short fibres is concerned the short fibre index values recorded were found to be in the range of 11.7 - 20.7. The values recorded for UR are exceptionally high, Higher values of UR are indicative of the fact that the yarn spun from such fibres will be uniform in size and strength and there will be less fibre wastage. High length uniformity and low short fibre content are desired characteristics from the viewpoint of textile industry, as these traits are associated with reduced manufacturing waste, neps, and ends down during the yarn production, along with improved yarn appearance (Behrey, 1993). A majority of the present day popular *Gossypium arboreum* cottons, under cultivation, predominantly belong to the race *bengalense* and measures up to about 16-18mm only. Keeping in view the popularity, adaptability of the cultivars belonging to the race, sincere efforts needs to be initiated to attain desired level of fibre length since sufficient variability is available with regards to this parameter.

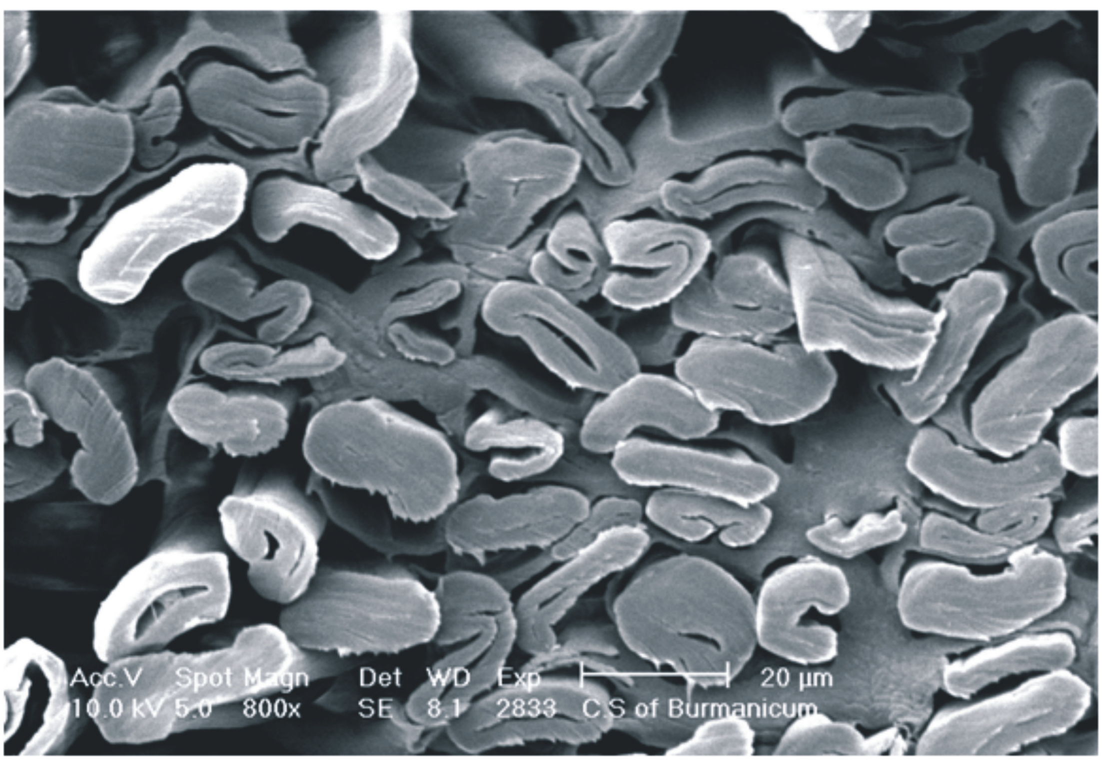
The micronaire values recorded were found to range from 4.0 to 5.7. The race *indicum* recorded the lowest value (4.0) whereas the race *bengalense* recorded highest vale (5.7). With respect to the fibre maturity, as expected, all the races reflect the inherent trait of the species of producing mature fibres. Fibre maturity (coefficient) recorded (Table 2) fall in the category of good to excellent with the range of 0.73 to 0.79. The highest value (0.79) was recorded for the races *indicum* and *bengalense*. The race *indicum* with micronaire value reading at 4.0 and maturity level 0.79 demonstrate the potential of the race to produce fine and mature fibre. In light of the fact, that the fibre maturity and fineness account nearly for 90 per cent of variations in micronaire reading (Meredith. Jr, 1994), the *Gossypium arboreum* races with exceptionally higher fibre maturity levels, provides a readily available, viable and potent genetic resource to formulate future breeding strategies. While breeding for finer cotton, enough impetus needs to be given to the maturity of the fibre as well. Fineness and maturity of cotton fibre together determine to a great extent the dyeability of a fabric.

Fibre bundle strength is perhaps the most important fibre property next to length that contributes to the utilization of cotton as a textile fibre. The bundle strength (tenacity) of all the *arboreum* races, measured on the HVI system in ICC mode, varied from low to good category (17.2 to 22.3 g/tex).The race *indicum* recorded the highest value (22.3 g/tex) followed by the race *soudanese* (22.0 g/tex). The values obtained for fibre (bundle) elongation were in the range of 4.6 to 6.4 percent. The highest value was recorded by the race *sinease* (6.4%) followed by the races *cernum* (6.3 %) and *soudanese* (6.1%). The improvement of fibre strength and elongation should be a relatively straightforward goal for cotton breeders. The contribution of fibre elongation to the spinning and textile performance is associated with improved yarn quality particularly that of open end spun yarn and ability to withstand the demands of weaving (Backe, 1996). Race *indicum* is blessed with excellent fibre quality traits and needs to be given due recognition in future *arboreum* cotton breeding programmes.

AFIS fibre properties : The scrutiny of test results (Table 2) reveals that the all the six races recorded markedly higher values for fineness and length related parameters. The race *bengalense* recorded highest values for L (w), UQL (w), L (n), 2.5 and 5.0 per cent whereas lowest values for these parameters were recorded for the race *soudanese,* at the same time it can be noted (Table 2) that there exist sufficient variability for these parameters amongst different races. With regards to IFC (immature fibre content), the values recorded lie in the range of 3.2 -10.4, with the race *bengalense* recording lowest value (3.2). The maturity ratio values recorded a wide range (0.82–0.97) with the race *indicum* and *bengalense* recording lowest (0.82) and highest (0.97) values respectively. The maturity ratio is supposedly closely related to the circularity or degree of thickness (1/q), the comparatively varied (the races are having significantly different values) and higher values of maturity ratio reaffirm (confirm) the potential of the race species as well as the availability of sufficient genetic variability within the species for furthering the fibre quality improvement programme.

The SFC (w) (percentage of fibres by weight) values recorded were in the range of 8.8 to 13.2 per cent and the race *bengalense* recorded the lowest value (8.8%). With respect to SFC (n) (percentage of fibres by number), the values recorded were found to be in the range of 22.7–28.1 per cent, the race *cernum* recorded the lowest value (22.7%). The measurements for neps size (μm) were found to be in a narrow range (654 - 745 μm) where as the values recorded for number of neps (cnt/gm) indicated that a marked difference existed amongst the races with a





Micrograph-4.*G. arboreum* race: *burmanicum* [Longitudinal and cross sectional view]

Table 2 . Gross fibre properties

Parameter	*Indicum*	*Cernuum*	*Bengalense*	*Sinease*	*Burmanicum*	*Soudanese*
HVI fibre properties						
2.5 per cent span length, (mm)	24.5^{c}	24.1^{b}	26.1^{d}	24.1^{b}	24.5^{c}	23.3^{a}
Uniformity ratio, (%)	50^{bc}	51^{c}	48^{ab}	47^{a}	48^{a}	51^{c}
Micronaire value	4.0^{a}	4.3^{b}	5.7^{e}	5.4^{d}	4.5^{c}	4.2^{b}
Tenacity, (g/tex)	22.3^{e}	20.0^{c}	18.4^{b}	17.2^{a}	21.1^{d}	22.0^{e}
Elongation, (%)	5.1^{a}	6.3^{c}	4.6^{a}	6.4^{c}	5.8^{b}	6.1^{bc}
Short fibre index	17.1^{b}	18.1^{b}	11.7^{a}	18.4^{b}	17.6^{b}	20.7^{c}
Fibre maturity						
Maturity coefficient	0.79^{b}	0.77^{b}	0.79^{b}	0.77^{b}	0.73^{a}	0.77^{b}
Mature fibre (%)	75^{a}	83^{b}	86^{b}	79^{ab}	83^{b}	81^{ab}
AFIS fibre properties						
Length (w), (mm)	21.0^{b}	20.9^{b}	23.6^{c}	21.7^{b}	21.4^{b}	19.7^{a}
Upper quartile length (w), (mm)	24.9^{bc}	24.7 ^{b}	28.3^{e}	25.6^{d}	25.4^{cd}	23.2^{a}
Short fibre content (w) <12.7mm, (%)	12.9^{c}	9.9^{ab}	8.8^{a}	11.2^{b}	10.9^{b}	13.2^{c}
Length (n), mm	17.3^{ab}	18.1^{b}	19.5^{c}	18.2^{b}	17.9^{b}	16.6^{a}
Short fibre content (n), (%) <12.7,mm	28.1^{c}	22.7^{a}	24.4^{ab}	25.6^{b}	25.5^{b}	27.9^{c}
5.0 per cent span length, mm	26.9^{b}	26.5^{b}	32.5^{d}	28.6^{c}	29.4^{c}	25.1^{a}
2.5 per cent span length, mm	28.3^{a}	28.7^{a}	34.7^{c}	31.0^{b}	31.6^{b}	27.4^{a}
Immature fibre content, (%)	10.4^{e}	4.4^{b}	3.2^{a}	7.8^{d}	4.7^{b}	5.6^{c}
Fineness, mtex	141^{a}	179^{cd}	193^{d}	156^{ab}	176^{c}	164^{bc}
Mat ratio	0.82^{a}	0.93^{cd}	0.97^{d}	0.87^{b}	0.94^{cd}	0.91^{c}
Nep, mm	654^{a}	745^{b}	735^{ab}	714^{ab}	730^{ab}	710^{ab}
Nep, cnt/g	261^{e}	129^{a}	124^{a}	170^{b}	192^{c}	220^{d}
Seed coat neps,mm	1014^{a}	1353^{bc}	1255^{b}	974^{a}	1370^{c}	995^{a}
Seed coat neps, cnt/g	11^{ab}	10^{a}	10^{a}	15^{b}	14^{ab}	13^{ab}

Any two mean values not sharing a letter (a, b, c, d or e) in common, differ significantly at 0.05 level of probability (Duncan's multiple range test)

range of (124-261cnt/g), the race *bengalense* recorded lowest value(124cnt/g).The seed coat neps [SCN (µm) and SCN (cnt/g)] values recorded were found to be in a narrow range particularly the number of seed coat neps (10-15 cnt/g). In view of the fact that in textile industry, globally, the presence of seed coat trash is considered as a major drawback and leads to about 50 per cent of yarn imperfections (Pearson, 1933), this invaluable genetic resource needs to be exploited efficiently in breeding programmes.

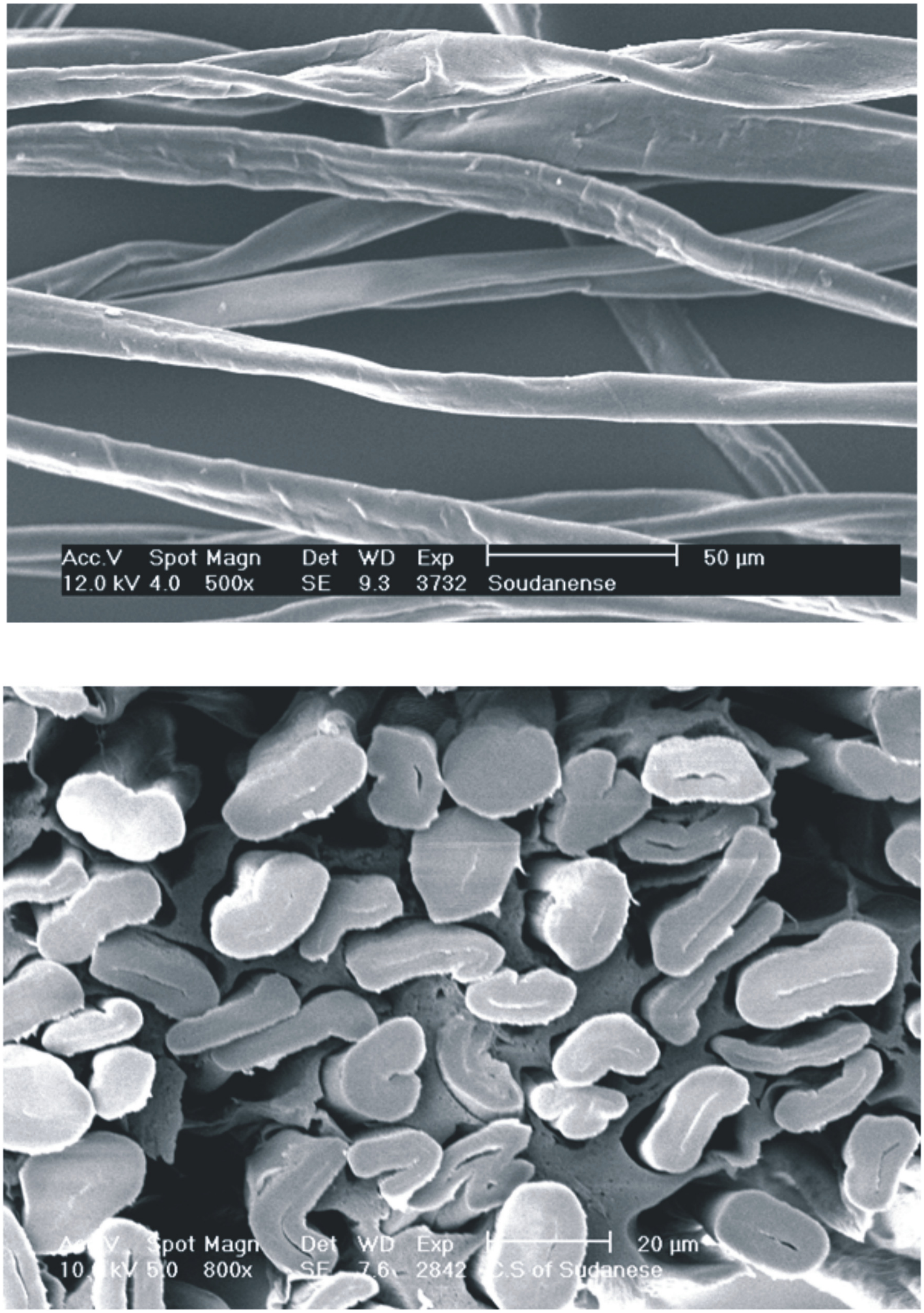
Morphological and structural properties **:** Longitudinal and the cross section profile of fibres observed by SEM are shown in micrograph-1 through 6**.**The morphological properties determined in terms of convolution frequency, convolution angle, reversal frequency as well as wall thickness and ribbon width of the fibre after swelling with 18 per cent caustic soda are presented in Table 3. Analysis of the data recorded indicates that there exists markedly significant variation among the different races of the species with respect to almost all the parameters. The race *bengalense* recorded highest value for wall thickness (9.8 m) as well as for ribbon width (21.4 mm). At the same time the reversal frequency varied from 6.3 to 10.7/ cm, whereas convolution frequency values were found to be in the range of 45-61 per cm.

Fibre cross sectional parameters : The fibres cross-sectional parameters (Table 3) evaluated for individual races, are presented in terms of averages values as well as the coefficient of variation (CV %). The race *bengalense* and *soudanese* recorded highest value (200mm^2) for area of cross section whereas the lowest value was recorded for the race *indicum* (115 mm^2) about 40(%) less than the highest value recorded. Similarly for wall area the highest value was recorded for the race *bengalense* (199mm$^{2)}$ followed by the race *soudanese* (198mm^2) where as the lowest value was recorded for the race *indicum* (113mm^2).

The race *bengalense* recorded highest value (0.78) for circularity, thus inferring that the fibre is more circular as compared to the fibres from other races analysed in the present study. The lowest circularity value (0.47) recorded for the race *indicum* was almost 40 per cent less than the value recorded for the race *bengalense*. It is interesting to note, that even the lowest value (0.47) of 'q' corresponds to maturity factor approaching '1' [when q >0.577, Maturity Factor (M) =1.0]. Close scrutiny of the micrographs (1 to 6) indicated that the fibres belonging to the race *indicum* showed an unusual shape, altogether a distinct structure, markedly different in comparison to other races. Though, fibres belonging to the race were fairly mature (% Maturity =75) and have recorded sufficient degree of thickening (q=0.47).

Fibrillar orientation, crystallinity index and crystallite size : In general, the average values of Herman's factor and 50 per cent X-ray angle recorded (Table 3) for all the races were found to be in the range of 0.68 to 0.73 and 21.0 to 24.4, respectively. The race *Sinea*se recorded highest value for Herman's factor (0.73) where as highest value for 50 per cent X-ray angle (24.4) was recorded for the race *Indicum*. Crystallinity and crystallite size are regarded to be associated with the rigidity of the fibre and higher values for these characteristics will mean the loss of flexibility in the fibre. Upto certain limit, Crystallinity contributes to the tenacity of the fibre but beyond that it affects the pliability (flexibility). Earlier studies have shown that the Crystallinity index has inherent variability (error) in repeated measurement of the order of ±2.5 per cent. Keeping this in view, it can be concluded that all the races possess similar values for Crystallinity index, and crystallite size**.**

Mechanical properties [Fibre bundle (stelometer)] : The statistical analysis of variance and comparison of individual means for various mechanical properties recorded (Table 3) reveal that there exists significant difference among the races of the *Gossypium arboreum* species with regards to stiffness and toughness. Toughness of fibre plays a significant role with regards to impact loading and is indicative of abrasion resistance and shock absorbency. The races *bengalense (*32.5) and *sinease* (35.5) recorded markedly lower values for toughness whereas the race *soudanese* recorded highest value (54.9). In general the species *Gossypium arboreum* is known to perform poorly with regards



Micrograph-5.*G. arboreum* race: *soudanese* [Longitudinal and cross sectional view]

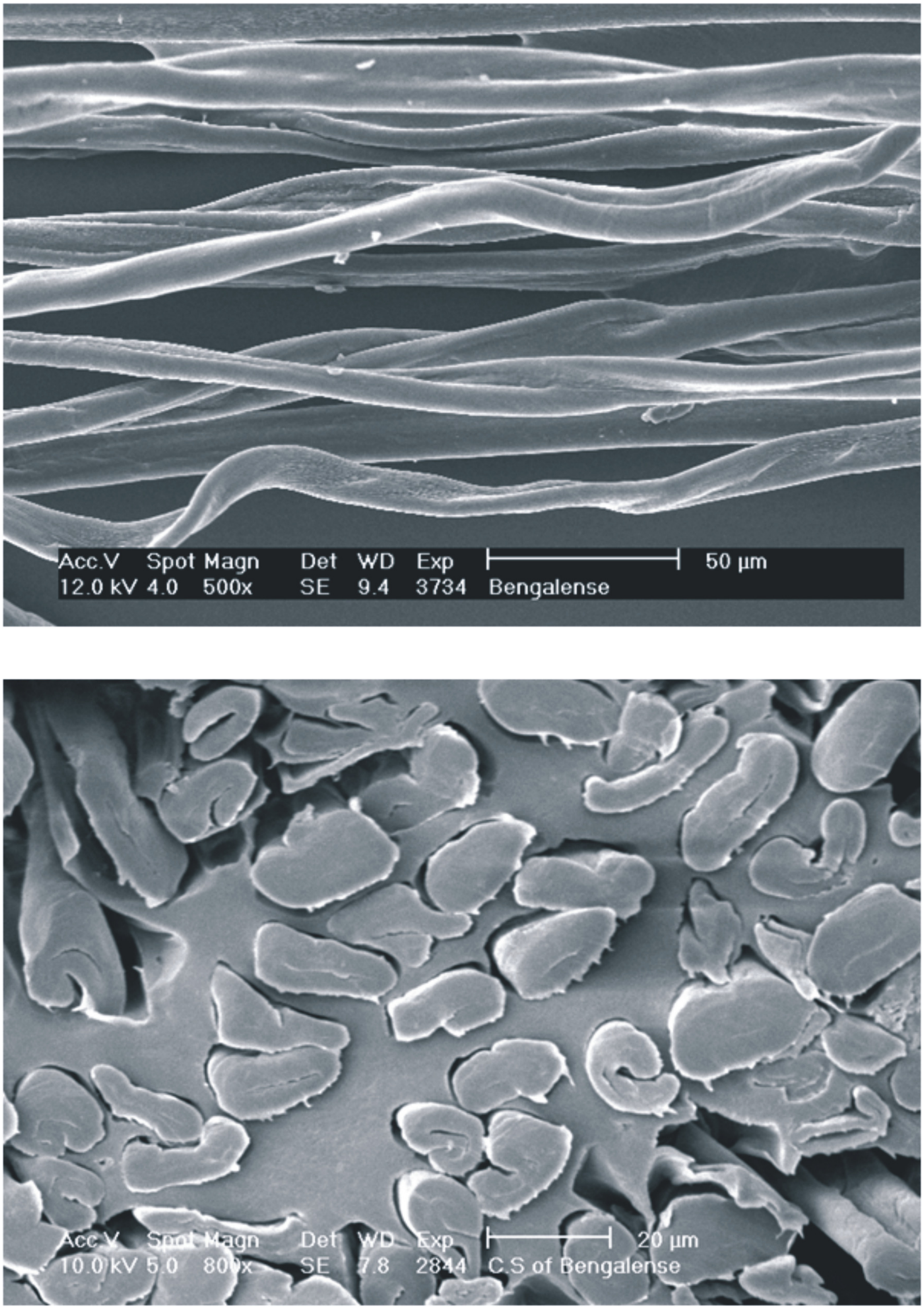
Table 3. Morphological, structural, linear density and mechanical properties

Parameter	*Indicum*	*Cernuum*	*Bengalense*	*Sinease*	*Burmanicum*	*Soudanese*
Morphological						
Wall thickness, (mm)	5.7^{a}	6.1^{a}	9.8^{b}	6.4^{a}	5.9^{a}	6.3^{a}
Ribbon width, (mm)	16.1^{a}	17.6^{b}	21.4^{d}	18.1^{bc}	18.7^{c}	18.4^{bc}
Convolution angle, (q^{0})	5.6^{c}	4.5^{a}	4.7^{ab}	5.1^{b}	4.9^{ab}	5.1^{b}
Reversal frequency/cm	9.7^{c}	10.6^{d}	6.3^{a}	6.9^{a}	8.1^{b}	10.7^{d}
Convolution frequency/cm	61^{c}	45^{a}	49^{ab}	51^{ab}	54^{b}	49^{ab}
Linear density, (m.tex) (cut and weigh method)	168^{ab}	176^{ab}	204^{c}	174^{ab}	184^{b}	163^{a}
Structural						
Area of cross section, (mm^2)	115 (30)	157(44)	200(28)	164(38)	145(35)	200(32)
Wall area, (mm^2)	113(30)	152(44)	199(28)	162(37)	142(36)	198(32)
Perimeter, (mm)	57(16)	57(21)	57(13)	59(15)	55(16)	60(16)
Degree of thickening, (q)	0.46(29)	0.59(33)	0.78(17)	0.59(32)	0.59(24)	0.70(23)
Circularity, Shape factor	0.47(29)	0.61(32)	0.78(17)	0.60(32)	0.61(24)	0.71(23)
50 per cent X-ray angle	24.4	23.6	21.0	23.6	21.8	21.8
Herman's factor / f(x)	0.68	0.70	0.71	0.73	0.72	0.72
Crystallite size and crystallinity index						
Crystallinity Index, (%)	77	78	77	78	78	77
Crystallite size, (A^{0})	43	43	43	43	43	43
Mechanical (Stelometer)						
Tenacity at 0 gauge, (g/tex)	49.3^{c}	51.4^{d}	41.7^{b}	38.9^{a}	50.4^{d}	48.6^{c}
Tenacity at 3.2mm gauge, (g/tex)	21.3^{c}	20.7^{b}	17.1^{a}	16.9^{a}	21.9^{d}	21.1^{bc}
Elongation,(%)	4.7^{c}	4.9^{cd}	3.8^{a}	4.2^{b}	4.3^{b}	5.2^{d}
Strength uniformity ratio	0.43^{a}	0.40^{a}	0.41^{a}	0.43^{a}	0.44^{a}	0.43^{a}
Stiffness (Secant modulus)	4.5^{c}	4.2^{ab}	4.5^{c}	4.0^{a}	5.1^{d}	4.1^{ab}
Toughness (Rupture)	50.1^{d}	50.7^{d}	32.5^{a}	35.5^{b}	47.1^{c}	54.9^{e}

Figures in parenthesis are CV values.

·Any two mean values not sharing a letter in common differ significantly at 0.05 level of probability (Duncan's Multiple Range Test).

to fibre strength/mechanical properties, in this context race *soudanese* with comparatively higher values of toughness needs to be exploited to bring desired improvement in fibre strength parameters. The race *burmanicum* recorded highest value for stiffness (5.1) and the lowest value was recorded for the race *sinease* (4.0). Fibre stiffness enacts a significant role during processing, primarily, when rolling, revolving, twisting movements are involved. In fact it is difficult to get stiff fibre bound into the yarn, as a stiff fibre has difficulty in adapting to the movements, which in turn results in higher values for hairiness. At the same time fibres which are not stiff enough have too little springiness and such type of fibres do not return to shape after deformation and this in general leads to formation of neps. With stiffness values in the range of 4.0 (*sinease)* to 5.1 (*Burmanicum*), it can be concluded that there exist sufficient variability to plan and bring about further qualitative improvement. The strength uniformity ratio (SUR) denotes the percent reduction the bundle strength at zero gauge



Micrograph-6. *G. arboreum* race: *bengalense* [Longitudinal and cross sectional view] suffers when tested at higher lengths. The difference in SUR values recorded for all the races were found to be non significant i.e. the reduction in bundle strength with the increase in test length is uniform throughout the spectrum.

CONCLUSIONS

- There exists a wide range of exploitable genetic variations amongst the races of cotton species *Gossypium arboreum* for various fibre properties which can be used efficiently and effectively by the agricultural scientists especially the breeders**.**
- Micronaire values (fineness) recorded for all the races were found to be in the range of 4.0-5.7, in this context it is important to enunciate that lower micronaire values (<3.5) are usually considered to reflect immature fibre, this implies that the fibres obtained from different races are inherently mature and the micronaire values obtained reflect the genetic as well as gravimetric fineness in true sense.
- The results obtained suggest and underline the fact that it is pragmatic to envisage a *Gossypium arboreum* strain which possess fairly long fibre (2.5 % Span Length >25.0mm), fine and mature fibre (3.5 < micronaire value <4.5) and good fibre bundle strength (>23.0g/tex) with keeping the inherent agronomical, physiological traits associated with the species intact.
- Cotton strains belonging to the race *bengalense* are predominantly cultivated, suitable breeding initiatives needs be taken to bring other races also in the domain since these races possess quite favourable fibre quality traits. Development of *arboreum* cotton varieties belonging to other races will help to increase the diversity to a great extent.

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