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Evaluation of culinary *Musa* germplasm for fibre yield and quality

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ABSTRACT

A trial was conducted during 2001–03 to evaluate 50 Indian culinary banana varieties for their suitability to fibre extraction and various methods of extraction. More than 50% of the cultivars grown in Indian subcontinent are suitable for fibre extraction as they exhibited high fibre yield. Of these highest fibre yield was exhibited by varieties, like 'Enna Benian' (0.96%), 'Singhlal' (0.67%) and 'Monthan' (0.68%). Quality in terms of brightness, moisture, lignin and cellulose contents was best in 'Singhlal', 'Kallu Monthan', 'Kullar Kunnan', 'Enna Benian', 'Manja Vazhai' and 'Shahil Kela'. Among the different methods of extraction, machine extraction gave 25% higher fibre yield than the manual extraction while fibre quality was better in manually extracted fibre.

Key words : Banana, Cellulose, Cooking varieties, Cottage industry, Fibre, Fibre brightness, Lignin

Bananas (*Musa* spp) are cultivated in over 120 countries over an area of 10 million hectares with an annual production of 98 million metric tonnes. They are consumed both as dessert and cooking bananas. Indian banana production is 16 million tonnes from an area of 482.8 thousand hectares. About 17% of world's bananas are produced in India and the unique feature is that the production is entirely through small farming system. Most of the commercial dessert cultivars belong to AAA and culinary banana AAB genomes and this paper deals with culinary/cooking banana cultivars belonging to ABB genomic group which are commercially important in India. The area under cooking banana accounts to about 14% comprising of 7 % each under plantains and Monthan-Bluggoe. Cooking bananas contribute 12% of total production accounting for approximately 2.1 million tonnes annually.

Cooking bananas are generally restricted to home gardens and considered as backyard cultivars. Of late, owing to their broad spectrum of utility, cooking bananas have assumed the status of commercial cultivation in many Indian states. By virtue of their ABB genomic status, cooking banana produces a lot of biomass (Uma *et al.* 2005) which is usually discarded after bunch harvest. The use of plant cellulose waste and pseudostem for fibre extraction is a novel idea and has slowly gained importance across the globe. In South-East Asia, especially in Philippines, banana fibre is commercially extracted from *Musa textilis* for commercial applications like preparation of marine cordages, high quality paper and boards, tea bags, string thread, high quality fabric material and as paper for printing currency notes. Though fibre can be extracted from all cultivars of banana, the yield varies with the genomic status, ploidy level and stage of maturity (Uma *et al.* 2002). Although manual fibre extraction has become more of a cottage industry, extensive demand has witnessed a slow shift towards mechanised fibre extraction in the last 5–8 years. In the present study cooking bananas were evaluated as source of fibre after bunch harvest. The methods of fibre extraction were also evaluated for better fibre yield and quality.

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MATERIALS AND METHODS

The trial was conducted during 2001–2003 at National Research Centre for Banana, Trichy using different culinary cultivars. A total of 50 clones (Table 1) were collected from the *Musa* field gene bank of National Research Centre for Banana, Trichy, Tamil Nadu which holds the largest collection of 946 banana accessions in the field and were evaluated for fibre yield and quality using different methods of extraction.

The pseudostem was further categorised into fibre extractable and fibre non-extractable pseudostem. The outer most 10 layers were taken as fibre extractable pseudostem and the layers were weighed for fibre yield. Fibre was extracted both mechanically and manually.

In machine extraction, the individual leaf sheaths were inserted between the adjustable rollers and the rotating drum in such a way that ¾ of the sheath was inserted inside the drum and the machine was switched on and then it was drawn back. The other end of the sheath was inserted into the machine by holding the cleaned portion of the leaf. After stripping, the fibre is hung on to bamboo poles or wire lines

Table 1 Comparison between machine and hand extracted fibre in culinary triploid bananas (ABB)

Variety	Fibre yield (%)			Cellulose (%)			Lignin (%)			Moisture (%)			Brightness		
	ME	HE	Mean	ME	HE	Mean	ME	HE	Mean	ME	HE	Mean	ME	HE	Mean
'Kachkel'	0.5657	0.2848	0.4527	51.60	58.50	55.05	12.77	9.88	11.33	6.35	3.94	5.15	68.85	84.48	76.67
'Birbutia'	0.2439	0.2419	0.2429	51.03	61.43	56.23	13.69	10.14	11.92	5.60	4.10	4.85	68.51	84.57	76.54
'Goukar'	0.4364	0.1500	0.2932	57.69	67.64	62.66	11.12	8.74	9.93	5.38	3.19	4.29	71.60	84.12	77.86
'Kothia'	0.8145	0.1944	0.5045	50.77	58.61	54.69	12.05	9.17	10.61	5.96	4.50	5.23	74.47	75.94	75.20
'Nepali Chinia'	0.9242	0.1696	0.5469	52.02	61.96	56.99	12.89	9.23	11.06	5.42	4.10	4.76	64.06	77.47	70.77
'Enna Benian'	1.1494	0.7784	0.9639	54.06	62.39	58.23	12.57	11.43	12.00	5.82	4.60	5.21	70.16	80.99	75.58
'Kanchi kela'	0.5348	0.2541	0.3945	56.15	63.43	59.79	12.33	9.15	10.74	5.12	3.84	4.48	67.85	86.26	77.05
'Lamby'	0.6524	0.3535	0.5030	53.87	62.50	58.18	14.00	12.07	13.04	5.35	4.22	4.78	76.08	82.28	79.18
'Kanchi'	0.5134	0.2911	0.4023	56.64	66.94	61.79	12.18	10.44	11.31	5.62	3.97	4.80	67.74	77.51	72.62
'Bersain'	0.9614	0.6509	0.8062	53.26	59.08	56.17	10.84	9.43	10.14	5.19	3.21	4.20	67.51	84.53	76.02
'Sambrani Monthan'	0.5321	0.3179	0.4250	54.89	60.53	57.71	12.59	9.25	10.92	5.63	4.26	4.95	65.24	81.70	73.47
'Jatikal'	0.5213	0.2252	0.3732	53.76	59.48	56.62	11.11	9.67	10.39	5.92	4.15	5.04	70.91	82.06	76.49
'Yenugu Bontha'	0.4429	0.2971	0.3700	49.70	56.69	53.20	11.60	9.25	10.43	5.54	3.46	4.50	68.61	84.83	76.72
'Monthan'	0.8277	0.5258	0.6767	56.37	63.27	59.82	10.71	8.01	9.36	6.01	4.55	5.28	63.28	83.12	73.20
'Karim Bontha'	0.4089	0.2422	0.3256	53.90	62.15	58.02	12.32	8.72	10.52	5.49	4.01	4.75	64.11	85.59	74.85
'Cherapadathi'	0.5749	0.4517	0.5133	52.62	60.32	56.47	12.30	9.17	10.73	5.71	4.06	4.89	66.97	81.81	74.39
'Bagner'	0.7160	0.5264	0.6212	52.23	58.63	55.43	12.26	8.99	10.63	5.72	3.67	4.69	65.03	85.11	75.07
'Batheesa Ash'	0.5781	0.4929	0.5355	52.28	62.95	57.62	11.72	9.43	10.58	5.54	3.71	4.63	66.67	83.69	75.18
'Bainsa'	0.4359	0.1995	0.3177	52.98	60.28	55.63	10.68	8.60	9.64	6.02	4.67	5.35	76.55	81.59	79.07
'Singlal'	0.9671	0.3877	0.6774	53.16	63.87	58.51	10.70	8.71	9.71	6.49	4.99	5.74	75.56	80.23	77.90
'Pey kunnan'	0.6291	0.2405	0.4348	57.01	66.14	61.60	11.83	8.40	10.12	5.31	4.30	4.81	68.06	85.25	76.66
'Bankel'	0.7182	0.3153	0.5168	53.27	61.07	57.17	11.31	9.27	10.29	5.24	3.79	4.52	76.53	84.29	80.41
'Chirapunji'	0.6785	0.2942	0.4863	52.10	60.01	56.06	11.29	9.10	10.19	5.45	3.85	4.65	73.89	79.59	76.74
'Madhok Grong'	0.7495	0.2536	0.5016	54.02	61.26	57.64	11.19	8.60	10.05	5.25	3.47	4.36	74.86	80.73	77.80
'Battisa Local'	0.4171	0.2480	0.3326	54.26	60.12	57.19	12.98	9.40	11.19	4.93	3.59	4.26	67.98	77.47	72.73
'Kostha Bontha'	0.5448	0.2765	0.4107	53.77	60.27	57.02	10.98	8.20	9.59	5.08	3.54	4.31	71.98	80.84	76.41
'Kait Shjeng'	0.6195	0.2715	0.4455	53.70	61.23	57.47	11.70	9.51	10.61	4.44	3.46	3.95	74.39	81.13	77.76
'Bluggoe'	0.7880	0.5291	0.6585	53.13	60.44	56.79	11.19	9.00	10.09	5.94	4.01	4.98	75.64	82.01	78.83
'Kapur'	0.4597	0.3708	0.4152	55.45	62.01	58.73	11.15	8.60	9.88	6.02	4.96	5.49	65.66	79.86	72.76
'Pacha Bontha Batheesa'	0.6170	0.3028	0.4599	52.43	61.62	57.03	10.64	9.11	9.88	6.08	4.00	5.04	76.18	82.72	79.45
'Madavazhai'	0.5311	0.2021	0.3666	53.48	61.44	57.46	12.27	8.97	10.62	5.42	4.26	4.84	72.49	85.24	78.87
'Nendran'	0.5171	0.2525	0.3848	52.72	60.19	56.46	11.38	8.62	10.00	5.87	4.24	5.06	63.60	76.34	69.97
'Mutheli'	0.4515	0.2360	0.3438	50.93	60.11	55.52	9.50	8.22	8.86	5.12	4.01	4.57	72.27	80.16	76.22
'Gopan'	0.6146	0.3231	0.4688	51.38	59.43	55.41	9.99	9.51	9.75	5.85	3.94	4.90	72.41	80.38	76.40
'Gauria'	0.3261	0.3080	0.3250	51.45	61.22	56.34	10.24	9.17	9.71	6.04	3.66	4.85	66.86	82.96	74.91
'Singhalaji'	0.4310	0.1651	0.2981	54.57	60.67	57.62	10.16	8.79	9.46	5.68	4.26	4.97	74.57	82.03	78.30
'Mauritius'	0.8126	0.3100	0.5613	51.91	61.14	56.53	9.96	8.45	9.21	5.58	4.51	5.05	71.48	82.07	76.77

Table 1 *(Continued)*

Variety	Fibre yield (%)			Cellulose (%)			Lignin (%)			Moisture (%)			Brightness		
	ME	HE	Mean	ME	HE	Mean	ME	HE	Mean	ME	HE	Mean	ME	HE	Mean
'Kallu Monthan'	0.3507	0.1337	0.2422	52.77	60.24	56.51	9.22	8.57	8.90	5.91	4.27	5.09	69.27	77.45	73.36
'Sugandhi'	0.4137	0.1367	0.2833	51.41	60.57	55.99	11.86	9.22	10.54	4.71	3.91	4.31	73.72	82.09	77.91
'Sakkai'	0.6649	0.2538	0.4594	52.07	62.26	57.17	10.42	8.52	9.47	5.99	4.23	5.11	77.83	85.85	81.84
'Kullar Kunnan'	0.6575	0.3694	0.5134	54.74	63.17	58.82	10.27	8.00	9.14	6.19	4.11	5.15	75.91	84.33	80.12
'Kari Bonthan'	0.4655	0.2186	0.3420	52.91	61.54	57.23	9.87	8.26	9.06	5.48	4.35	4.92	65.06	79.39	72.23
'Veneetu Mannan'	0.5530	0.3649	0.4590	51.08	61.57	56.33	11.45	9.04	10.25	5.94	4.61	5.28	76.80	86.03	81.42
'Kari Bale'	0.2816	0.1601	0.2208	52.25	60.26	56.26	12.15	8.97	10.56	5.60	4.32	4.96	72.72	83.50	78.11
'Pidi Monthan'	0.4079	0.2395	0.3237	55.59	64.27	59.93	12.18	9.25	10.71	5.38	4.11	4.75	66.97	76.49	71.72
'Nukkala Bonthan'	0.5235	0.2916	0.4076	52.21	67.38	59.80	13.98	10.82	12.40	6.42	4.47	5.45	70.69	84.70	77.70
'Chakkia'	0.7162	0.6035	0.6599	50.86	56.01	53.44	12.89	9.92	11.41	6.34	4.62	5.48	61.48	76.34	68.91
'Sambal Neyvannan'	0.6337	0.5068	0.5703	52.51	55.88	54.20	12.86	10.71	11.79	6.24	4.76	5.50	62.03	82.92	72.48
'Manjavazhai'	0.5163	0.4167	0.4665	60.05	65.32	62.68	12.85	10.03	11.44	7.35	6.01	6.68	67.78	85.53	76.66
'Dakshin Sagar'	0.4563	0.3244	0.3904	49.32	55.59	52.45	14.04	10.57	12.30	6.76	4.48	5.62	66.85	74.61	70.73
Mean	0.5929	0.3283	0.4606	53.22	61.31	57.27	11.76	9.18	10.47	5.72	4.18	4.95	81.76	70.53	76.14
CD (P=0.05)	0.02254	0.0041	0.0319	0.9024	0.1648	1.2762	0.6603	0.1206	0.9338	0.5322	0.0972	NS	0.3409	1.867	2.6408

ME, Machine extraction; HE, hand extraction

and allowed to dry in the sun as quick as possible and bundled. Banana fibre can be extracted manually using a wooden board and a scrapper made of steel. In this method, a blunt knife is used for improved scraping. The extraneous matter is slowly and steadily scrapped out using longitudinal strokes applying gentle pressure until clear fibre is left. To reduce the human error in manual extraction, a single skilled person was used throughout the study. The pure fibre from leaf sheath/pseudostem of banana plant without any extraneous matter after extraction through manual and mechanical method was taken for the following biochemical analysis.

The total cellulose per cent was estimated adopting the procedure of Updegroff (1969). Cellulose undergoes acetolysis with acetic/nitric reagent (4:1 ratio) forming acetylated cellodextrins which gets dissolved and hydrolysed to form glucose molecules on treatment with 67% sulphuric acid. This glucose molecule was dehydrated to form hydroxy methyl furfural that forms green coloured product with anthrone and the colour intensity was measured at 630 nm.

The lignin content was estimated using the TAPPI standard test method (Bandyopadhyay 1999). About 2 g of fibre sample was used and the residual lignin content was estimated based on original sample weight.

The infrared moisture balance was used for determining the moisture per cent in the pseudostem that quickly dry the sample without changing the chemical structure, on exposure to infrared radiation.

The per cent moisture on dry basis was calculated using the formula

$$P' = \frac{100P}{100P'}$$

where P' is the per cent moisture on dry basis and P is the per cent moisture lost by the sample.

The brightness of the fibre was compared against the reflectance of the white background. It was measured using the colour meter.

The experiment was conducted using completely randomised block design with 3 replications and the results were statistically analysed.

RESULTS AND DISCUSSION

The average of manual and machine extracted yield is considered as mean fibre yield and computed separately for each cultivar. The details regarding the fibre yield obtained by manual and machine fibre extraction in triploid cooking banana cultivars (ABB) are provided in Table 1. Fibre extractable pseudostem had direct effect on the yield of fibre. Fibre yield varied significantly with the cultivars tried and with the method of fibre extraction. The fibre yield in machine extraction ranged from 0.24 to 1.15 % and in manual extraction, it ranged from 0.13 to 0.78 %. In machine extraction, the yield of fibre was significantly maximum in 'Enna Benian' recording 1.15 % and the lowest was exhibited by 'Birbutia' (0.25 %). Similarly maximum fibre yield in manual extraction was also registered in 'Enna Benian' (0.78%) but the lowest was recorded in 'Kallu Monthan' (0.13 %). The difference in the fibre yield by 25% between the methods of extraction and varieties is due to the cultivar difference and the lowest yield in manual extraction might be due to higher pulp content of leaf sheaths which goes waste during manual extraction.

Cellulose is an important constituent of the fibre and the cellulose content and its degree of polymerisation is the major indicator for deciding the suitability of a raw material in paper and other industries. The cellulose per cent varied significantly among the cultivars (Table 1) and was maximum in hand extraction (61.31 %) than in machine extraction (53.22 %). The cellulose content ranged from 53.20 to 62.68% irrespective of the cultivars tried. In machine extraction, the cellulose content ranged from 50.77 to 60.05% and the maximum was in 'Manjavazhai' (60.05 %) and the lowest in 'Kothia' (50.77 %). The cellulose content in hand extraction ranged from 56.01 to 67.64%. The cultivar 'Goukar' recorded the highest cellulose content of 67.64% and the least amount of cellulose was present in 'Chakkia' (56.01 %).

The details of the lignin content in different cultivars and in different methods of extraction are presented in Table 1. The middle lamella lignin needs to be degraded to pulp the material. For high quality paper, however, the bulk of the lignin is removed to prevent yellowing with age (Jarvis and Daud 1995). Lower lignin content is considered to improve the fibre quality. Significant difference existed among the cultivars and methods of extraction tried for lignin content. Their interaction effect was also found to vary significantly. The lignin content in machine extraction ranged from 9.50 to 14.04%. The maximum lignin content in machine extraction was recorded in 'Dakshin Sagar' (14.04%) and the lowest 9.50 % in 'Mutheli'. The lignin content was maximum in machine extraction (11.76 %) and the lowest in hand extraction (9.18 %) which is preferred for getting quality fibre. In hand extraction, the lignin content was in the range of 8.00–12.07%. The cultivar 'Lamby' (12.07 %) exhibited the maximum lignin content and the lowest lignin (8.00 %) was registered in 'Kullar Kunnan'. The higher cellulose content and lower lignin content of banana fibre indicate the potentiality for paper making as well as its application in fibre industry (Saikia 2000).

The moisture content in the pseudostem has a direct effect on the ease of fibre extraction and also it determines the quality of the fibre. In the present trial, the moisture content varied significantly with the cultivars and method of extraction (Table 1). Machine extracted fibre recorded maximum moisture content than hand extracted fibre. The moisture content among the culinary banana cultivars ranged from 3.95 to 6.68% irrespective of the cultivars and method of extraction. The maximum moisture content in machine extracted fibre was exhibited by 'Manjavazhai' (7.35 %), followed by 'Govakkai' (6.80 %) and the lowest was recorded in 'Kait Shjeng' (4.44 %). The moisture content in manually extracted fibre ranged from 3.19 to 6.01%, maximum being in 'Manjavazhai' (6.01 %) and the lowest in 'Goukar' (3.19 %). In both the extraction methods, 'Manjavazhai' recorded the maximum moisture content. The cultivars with high moisture are considered ideal for fibre extraction since the bonding with the matrix resins are good when the moisture content is high (Samal *et al.* 1997).

The brightness and fineness are the two important parameters that govern the quality of the fibre (Ghosh 1983). The fibres of commerce are never uniform and vary widely with the cultivars, stage of maturity, genomic status, ploidy level and method of extraction. Table 1 shows that the brightness in the manually extracted fibre ranged from 75.94 to 86.26 and the maximum brightness was noted in 'Kanchi Kela' (86.26) and minimum by 'Kothia' (75.94). In machine extraction, the 'Kanthali' recorded the maximum brightness of 77.15 and the lowest being in 'Sambal Neyvannan' (62.03). In the present study, the brightness was more in manual extraction than machine extraction. This is due to the fact that manually extracted fibre has maximum cellulose with minimum lignin content that improves the quality of the fibre (Saikia 2000).

Overall scoring of 50 accessions for 5 major traits, like fibre yield, cellulose, lignin, moisture and brightness led to the identification of top 10 accessions (Table 2). 'Singlal' grown on a large scale in Bihar was found to be the best culinary cultivar for fibre extraction with highest score. Although 'Enna Benian' proved to be the best accession, it

Table 2 Rating of varieties based on scores for yield and quality

Variety	Fibre yield	Cellulose	Lignin	Moisture	Brightness	Total	Quality
'Enna Benian'	4	3	4	3	2	16	12
'Singlal'	3	3	3	4	3	16	13
'Kullar Kunnan'	2	2	3	3	4	15	13
'Monthan'	3	3	3	3	2	14	11
'Sakkai'	2	2	3	3	4	14	11
'Manjavazhai'	2	4	1	4	3	14	12
'Pacha Bontha Batheesa'	2	2	3	3	3	13	11
'Bainsa'	1	2	3	3	4	13	11
'Veneetu Mannan'	2	2	2	3	4	13	11
'Shahil Kela'	1	3	3	3	3	13	12

is only a landrace with restricted cultivation. So also the case of accession 'Kullar Kunnan', a landrace with limited cultivation. Both 'Enna Benian' and 'Kullar Kannan' are from Tamil Nadu.

Next best accessions for fibre extraction are 'Monthan', 'Sakkai' and 'Manjavazhai' which constitute more than 50% of culinary varieties. 'Monthan' has wide spread cultivation in all eastern, northeastern and southern states of India under various names of 'Kachkel', 'Kanchikela', 'Bontha' and so on. 'Sakkai' belonging to Bluggoe subgroup also has wider distribution but more so in Tamil Nadu, Bihar, West Bengal and Karnataka, 'Manjavazhai' is also an ecotype of 'Monthan'. The accessions with next best score (13), like 'Bainsa', 'Pacha Bontha Batheesa', 'Veneetu Mannan' and 'Shahil Kela' also have larger distribution as commercial clones. In terms of only quality, 'Singlal' and 'Kullar Kunnan' top the rest of the clones. But average of total scoring and quality led to the selection of 'Enna Benian', 'Singlal', 'Kullar Kunnan' and 'Manjavazhai' as the top best accessions for fibre extraction.

Thus the present findings suggest that most of the commercial culinary banana varieties can be successfully used as raw material for fibre extraction after bunch harvest. This provides an additional income to the tune of Rs 7 000/ ha thereby adding to the livelihoods of subsistence growers (Uma *et al.* 2003). Similar studies on evaluation of cotton (*Gossypium hirsutum* L.) genotypes for fibre extraction have been reported by Ahuja and Dhayal (2006). Use of pseudostem for fibre extraction and manufacturing of handicrafts help to open up cottage industries in banana production belts eventually creating more job opportunities for local people.

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