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Development and Evaluation of Handy Jute Fibre Bundle Strength Tester

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Jute is traditionally tested for bundle strength by breaking the fibers in the hand and using a manual bundle strength tester. Hand method is subjective and grade may vary from grader to grader. The manual bundle strength tester requires a lot of time for sample preparation and manual calculation of the strength of the fibre. In the present study, the goal was to develop an accurate and quick tester for measuring the strength of jute fibre bundles. The unit consists of a handle, fibre holder with clamp, pointer with an analog indicator, body, and a chain. The analog indicator has a colour code to indicate the strength of the fibre. This instrument has an overall dimension of 350 × 185 × 90 mm. Randomly twenty samples were selected from the bale sample to perform the test. The results of the developed instrument were compared with the results of a manual bundle strength tester. The T-test result showed that there was no significant ($p > 0.05$) difference between results from the handy type bundle strength tester and mechanical instrument. Strength of the jute measured from a handy jute fibre tester was almost on par with manual type instrument. The repeatability of the handy bundle strength tester at 95% confidence level is 3.02 and 2.90 g/tex, respectively for *Corchorus olitorius* and *Corchorus capsularis*. The instrument readings are repeatable since the difference between two readings is less than the r_p (repeatability) value at 95% confidence level. The study concluded that the time taken to measure bundle strength of jute was shorter than with a manual tool. In contrast to manual instruments, this instrument is easy to operate and can provides reliable results.

Keywords: CACP, Repeatability, Strength tester, Tenacity, T-test

Introduction

India is the largest producers of the jute in the world.[1] Jute is called as golden fibre of the future because of natural and environment friendly fibre, biodegradable, renewable and is considered a safe packaging material.[2] The quality of the fibre depends on the various factors like soil, climatic condition and type of water used for retting etc. End product of the jute depends on its quality. In India, jute is graded on hand and eye method and personal experience. Jute is sold to market via auctioning and there is no relationship between price and its quality.

Bundle strength of the fibres is an important property of jute fibre as a raw material for yarn and fabric preparation. Strength of fiber refers to its ability to resist rupture under stress.[3] Strength is calculated by dividing the breaking load of the sample by the linear density of the restrained fibre. The breaking strength is called tenacity. This is expressed in g/tex. Traditionally, it is measured by taking 10–15 fibres from the middle of the reed, gripping the reed between the thumb and forefinger of both hands, and breaking longitudinally without jerking.[4] A fiber that produces audible sound is a very good fibre, while a fibre that does not produce sound is a weak fibre. This is a simple, easy method that requires less time. It has a drawback like method is subjective and assessment depends on the grader to grader. There are different instruments available for measuring bundle strength viz., Mechanical bundle strength tester and Electronic bundle strength tester.[5] Mechanical bundle strength tester takes a lot of time for sample preparation and manual calculation.[1] Electronic bundle strength tester provides rapid reading of the strength. It has disadvantages that require regular power supply and regular calibration of the instruments. There may be a solution to the problems of the above instruments in the form of a handheld fibre bundle tester. Therefore, a present study was undertaken to develop the handy jute fibre bundle strength tester to quickly and precisely measure the strength. Performance was compared with mechanical type instrument to measure the strength of jute.

Materials and Methods

The development of handy jute fibre bundle strength tester was carried out in Quality Evaluation

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and Improvement Division, ICAR-NINFET, Kolkata. The instrument was developed to provide four different ranges of strength of jute. The unit consists of handle, fibre holder with clamp, analog indicator with pointer, body and chain. The schematic diagram of the developed bundle strength tester is shown in Fig. 1. The handle is made up of 10 mm aluminum rod having length of 350 mm. Analog indicator is having scale with colour coding. Scale is having degrees starting from 1° to 90°. The 0° to 15°, 15° to 50°, 50° to 70°, 70° to 90° indicates Red, Yellow, Blue and Green colour, respectively. Red, yellow, blue and green colour indicates poor, average, good and excellent of fibre, respectively. The fibre holder tightly grips the fiber bundle. An upper jaw attached to the clamp is movable and the lower jaw is fixed. In order to provide a better grip on the fiber, the jaw surface was made up of corrugated rubber. A chain allows the pointer to be returned to its original position. Arrangements have been made to prevent needle movement after the fibre has been broken. The body of the instrument is made up of Aluminum sheet. Overall dimension of the instrument is 350 × 185 × 90 mm. The prototype of the developed bundle strength tester is shown in Fig. 2.

Randomly twenty samples were selected from the bale sample to perform the test. Sample length of 125 mm was selected from the middle region of the fibre reed. The weight of the fibre bundle was 200-400 ± 3 mg. Before doing the test, pointer was positioned at zero by pulling the chain attached to the instrument. Sample was placed in the fibre holder and force applied gradually until sample breaks into two halves. The position of the pointer at the time of the breaking indicated the strength of the fibre. If the pointer shows red, yellow, blue and green area on the scale means strength of fibre is poor, average, good and excellent, respectively. Temperature and relative humidity of the surrounding during evaluation were 10–40°C and 60–90%, respectively. Conversion Table (Table 1)

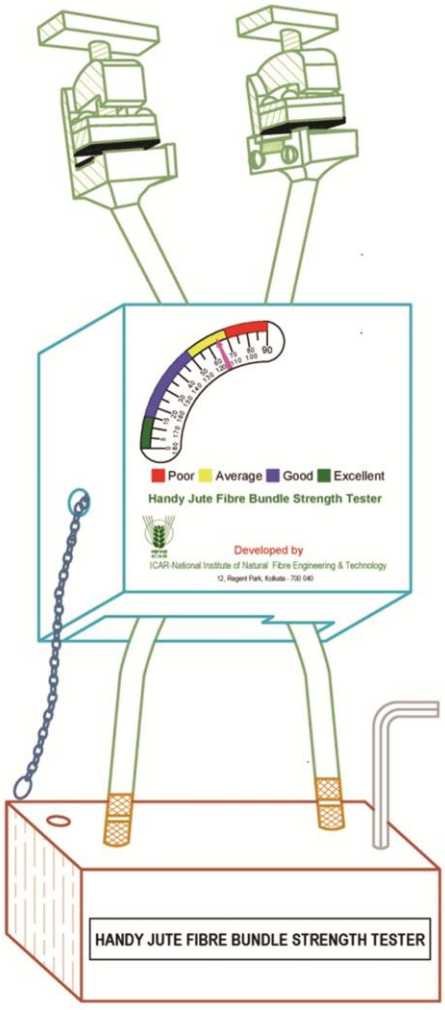

Fig. 1 — Schematic diagram of the developed bundle strength tester

Fig. 2 — Prototype of the developed bundle strength tester

Table 1 — Conversion Table for jute fibre strength (*Capsularis/Olitorius*) as per CACP for jute (Commission of Agricultural Cost and Price), 2015

Degree	Tenacity (g/tex)	Colour	Strength
10	>25.0	Green	Excellent
15	25	Green	Excellent
15.1	24.9		Good
20	24.2	Blue	Good
25	23.5		Good
30	22.8		Good
35	22.0		Good
40	21.3		Good
45	20.6		Good
50	20.0		Good
50.1	19.9		Average
55	18.8	Yellow	Average
60	17.5		Average
65	16.3		Average
70	15.0		Average
70.1	14.9	Red	Poor
80	<15.0		Poor

has been developed to read strength of fibre in terms of g/tex. The results have been compared with mechanical bundle strength tester. The entire test was replicated thrice and average was reported. To compare the results obtained from the two instruments, a paired sample T-test was performed in SPSS 9.0 with two tailed. Bundle strength of the mechanical type instrument was calculated by using following formula.[4]

$$\text{Tenacity}\left(\frac{\text{g}}{\text{tex}}\right) = 125 \times \left(\frac{\text{Breaking load in kg}}{\text{Weight of the bundle in mg}}\right) \quad \ldots (1)$$

Repeatability of Developed Bundle Strength Tester

A one-way analysis of variance (ANOVA) can be used to determine the within-subject standard deviation (S_w) when two repeated measurements are taken on a number of subjects and factors 1 to 5 are constants.[6] S_w is calculated by taking the square root of the mean square within each group from ANOVA. Two repeated measurements of bundle strength for both the species were obtained by 1 examiner with twenty readings each. The repeatability of test values at 95% confidence level is calculated by using following Eq. 2,

$$r_p = 2^{\left(\frac{3}{2}\right)} \times S_w \quad \ldots (2)$$

Results and Discussion

The performance of the developed handy jute bundle strength tester was carried out in the Testing laboratory at ICAR-NINFET for both *Corchorus olitorius* and *Corchorus capsularis* species of the jute. Bundle strength of the jute species *capsularis* and *olitorius* under developed handy jute fibre bundle strength and mechanical bundle strength is presented in Table 2 and results of T-test are presented in Tables 3 & 4. There was no significant difference between the scores for handy type strength tester (M = 20.48, N = 60) and mechanical instrument (M = 20.28, N = 60) at t = 1.01, p = 0.32 for *Corchorus olitorius* (Table 3). Results of t-test (Table 4) showed that there is no significant (p > 0.05) difference between handy type strength tester (M = 20.27, N = 60) and mechanical instrument (M = 19.97, N = 60) at t = 1.76, p = 0.09 for *Corchorus capsularis.* Bundle strength results for both jute species indicate developed instrument readings are on par with manual readings. The standard deviation of handy type fibre bundle strength tester was low compared to mechanical instrument. The results of the handy type fiber bundle tester were compared with those obtained with a mechanical instrument, revealing that the standard deviation was low. In manual instruments, it is difficult to maintain constant loading rate and speed of operation, leading to inaccuracy of reading.[1] Slower or faster speed may give erroneous results. Constant force loading arrangement (absorption spring) in developed instrument made it more precise in measuring bundle strength of fibres. Constant force loading by a dc motor in an electronic bundle strength tester increased instrument repeatability (Roy *et al*., 2009).[(5)]

It was also found from the study that the time to measure strength of fibre (5 min) in the handy jute fibre strength tester is less than that required by the mechanical bundle strength tester (15 min) which takes considerably longer time in preparing and clamping the sample into the clamp holder of the instrument. In manual instruments, data was further processed manually to calculate tenacity value, which was time consuming.

Repeatability

The result of the one-way ANOVA of repeatability test of handy type bundle strength tester is shown in Table 5. The mean square within the groups for *Corchorus olitorius* and *Corchorus capsularis* is 1.15 and 1.07, respectively and corresponding square root of the mean square (S_w) is 1.07 and 1.03. The repeatability of the handy bundle strength tester at 95% confidence level is 3.02 and 2.90 g/tex,

Table 2 — Bundle Strength of Jute capsularis and olitorius under developed and manual instrument

Type of Jute	Sl. No.	Handy type jute strength tester	Manual Instrument	Strength	
		Tenacity (g/tex)	Tenacity (g/tex)	Handy jute tester	Manual Instrument
Corchorus Olitorius/ Tossa Jute	1	14.9	14.27	Poor	Poor
	2	20.0	20.32	Good	Good
	3	20.0	20.50	Good	Good
	4	20.6	20.90	Good	Good
	5	17.5	17.15	Average	Average
	6	21.3	19.13	good	Average
	7	17.5	18.20	Average	Average
	8	18.8	20.30	Average	Good
	9	22.8	22.60	Good	Good
	10	22.0	22.30	Good	Good
	11	25.0	25.80	Excellent	Excellent
	12	23.5	22.75	Good	Good
	13	24.2	24.65	Good	Good
	14	18.8	18.32	Average	Average
	15	24.2	23.10	Good	Good
	16	17.5	18.00	Average	Average
	17	25.0	24.20	Excellent	Good
	18	18.8	17.80	Good	Good
	19	16.3	15.40	Average	Average
	20	20.9	20.00	Good	Average
Corchorus capsularis/White Jute	1	20.0	20.75	Average	Average
	2	25.0	25.62	Good	Excellent
	3	22.0	22.16	Good	Good
	4	25.0	25.60	Good	Excellent
	5	25.0	26.10	Good	Excellent
	6	18.8	19.50	Average	Average
	7	25.0	24.60	Good	Good
	8	20.6	20.00	Good	Average
	9	15.0	14.80	Average	Poor
	10	20.6	19.20	Good	Average
	11	21.3	20.80	Good	Good
	12	15.0	14.30	Average	Poor
	13	17.5	17.00	Average	Average
	14	20.6	20.6	Good	Good
	15	14.9	13.60	Poor	Poor
	16	20.6	19.86	Good	Average
	17	18.8	18.00	Average	Average
	18	16.3	15.80	Average	Average
	19	22.8	22.10	Good	Good
	20	20.6	19.10	Good	Average

Table 3 — Results of T-test for bundle strength of jute (*Corchorus olitorius*)

Particulars		Mean	N	Std. Deviation	Std. Error Mean
	Handy type strength tester	20.48	60	2.99	0.66
	Mechanical	20.28	60	3.07	0.68

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Handytype-Mechanical	0.19	0.86	0.19	−0.20	0.59	1.01	59	0.32

Table 4 — Results of T-test for bundle strength of jute (*Corchorus capsularis*)

Particulars	Mean	N	Std. Deviation	Std. Error Mean
Handytype strength tester	20.27	60	3.34	0.74
Mechanical	19.97	60	3.73	0.83

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Handytype-mechanical	0.29	0.74	0.16	−0.05	0.64	1.76	59	0.09

Table 5 — One-way anova of repeatability test of handy type bundle strength tester

	Sum of Squares		df	Mean Square		F		Sig.	
	CO	*CP*		*CO*	*CP*	*CO*	*CP*	*CO*	*CP*
Between Groups	66.73	245.64	19	3.51	12.92	3.03	12.00	0.009	0.000
Within Groups	23.12	21.54	20	1.15	1.07				
Total	89.85	267.18	39						

CO = Corchorus olitorius, CP = Corchorus capsularis.

respectively for the species of *Corchorus olitorius* and *Corchorus capsularis*. The instrument readings are repeatable since the difference between two readings is less than the r_p (repeatability) value at 95% confidence level. Furthermore, it was observed from the ANOVA that there is a significant difference between groups at $p < 0.05$ for results of two species.

Conclusions

To measure bundle strength accurately and quickly, a hand held type bundle strength tester has been developed and its results were compared with conventional mechanical instrument. Results of paired T-test showed that there was no significant ($p > 0.05$) difference between results of hand type and mechanical bundle strength tester. Study results also demonstrate that the handy jute fibre strength tester takes less time than the mechanical bundle strength tester to measure fibre strength. The repeatability of the handy bundle strength tester at 95% confidence level is 3.02 and 2.90 g/tex, respectively for *Corchorus olitorius* and *Corchorus capsularis* species of jute. The instrument readings are repeatable since the difference between two readings is less than the r_p (repeatability) value at 95 % confidence level. The developed instrument can be used to grade jute in accordance with CACP, 2015 or BIS Standard (IS-271, 2003). It can also be used to measure the strength of other fibre bundles by simply adjusting the weight of the sample.

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References

1 Roy G, Saha S C, Sarkar A & Sardar G, An innovative integrated jute grading instrument, *J Sci Ind Res*, **76** (2017) 51–518.

2 Meena J K, Bhandari H R, Mangal V, Chourasia K N, Thribhuvan R, Kar C S & Mitra J, Genetic diversity analysis by D2 clustering of yield and yield attributing traits in Jute (Corchorus olitorius) germplasm lines, *Vegetos*, (2021), https://doi.org/10.1007/s42535-021-00271-5.

3 Saha B & Nageshkumar T, *Fibre quality evaluation and grading system-study material for training* (ICAR-NINFET, Kolkata, India) 2021, 1–88.

4 Saha S C & Bhaduri S K, *Handbook of grading of jute fibre* (*National Institute of Research on Jute and Allied Fibre Technology*, Kolkata, India) 2008, 15–25.

5 Roy G, Bhattacharyya G K, Sengupta S & Mukherjee M, A new electronic fibre bundle strength tester for jute, *J Inst Eng*, **89** (2009) 10–13.

6 McAlinden C, Khadka J & Pesudovs K, Precision (repeatability and reproducibility) studies and sample-size calculation, *J Cataract Refract Surg*, (2015) 2598–2604.