Proc. Natl. Acad. Sci., India, Sect. B Biol. Sci. (Oct–Dec 2018) 88(4):1351–1357
https://doi.org/10.1007/s40011-017-0872-x

RESEARCH ARTICLE

Comparative Study of Conventional and Improved Retting of Jute with Microbial Formulation

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Received: 8 September 2016 / Revised: 9 February 2017 / Accepted: 26 April 2017 / Published online: 8 May 2017

Abstract A comparative study between conventional and improved retting of jute (*Corchorus olitorius* L. and *C. capsularis* L.) with a talc based microbial formulation was carried out for three consecutive retting trials in the same water during 2014. Due to introduction of the microbial formulation consisting of three different strains of *Bacillus pumilus* in the improved method, retting duration reduced by 6–7 days, fibre recovery increased by 9.7–12%, with the improvement in fibre quality (colour, lustre, fibre strength etc.) as compared to conventional method. The net return of farmers also increased by Rs. 13,490 ha^{-1} over conventional retting. Moreover, the root content which is not desirable for quality fibre production was high (16–20%) in conventionally retted fibre as compared to fibre obtained from improved retting (3–4%). The polygalacturonase (3.6–5.3 IU ml^{-1}), pectin lyase (142–185 IU ml^{-1}) and xylanase activities (5.2–7.5 IU ml^{-1}) recorded in retting water after each retting of improved method was higher by more than 2 times as compared to conventional one. These higher enzymatic activities in the retting water resulted in reduced retting duration and improvement in fibre recovery and quality. Further, the quality jute fibre extraction from repeated retting in the same stagnant water was possible by using the highly efficient microbial formulation. This technology has the potential to meet the demand of quality jute fibre by jute industries and also to increase the net income of resource poor jute farmers with meagre initial input.

Keywords Jute · Conventional retting · Improved retting · Microbial formulation · Enzymatic activities

Introduction

Jute "the golden fibre" though occupies only 0.47% of the gross cropped area of India, provides livelihood to more than four million farming families. The productivity of raw jute (jute and mesta) in India has become more than double from nearly 10 q ha^{-1} (1950–1951) to 22 q ha^{-1} (2006–2007) [1] and about 24 q ha^{-1} at present (2016–2017). The area under jute, however, has been dwindling around 0.8 million hectares over the past six decades and the production of about 1.9 million tonnes, India earns about 2050 crores rupees annually by exporting various jute products [2].

Jute is the ligno-cellulosic, long bast fibre with versatile application prospects from low value geo-textiles to high value products like carpet, apparel, composites, decorative, upholstery furnishings, fancy non-woven decorative colour boards, etc. Quality fibre is essential for manufacturing of high value diversified jute products. Quality of jute fibre primarily depends on the bio-chemical processes of retting. The process of separation and extraction of fibres from non-fibrous tissues and woody part of the stem through dissolution and decomposition of pectins, gums and other mucilaginous substances is called retting [3, 4]. Retting does not produce any toxic substances, and materials released during the processes are fully bio-degradable [5]. Free flowing soft water is ideal for carrying out retting of jute and mesta, which is rarely available in Indian condition. In the absence of free flowing water, more than 90% of jute and mesta growers ret their plants in stagnant water following conventional method of retting. Most of the fibre

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produced following conventional retting method in stagnant water is unsuitable for manufacturing of high valued diversified products, and farming communities earn less return for their poor quality fibre. Further, the repeated retting of jute and mesta in stagnant water of same retting tank lead to the production of inferior quality fibre unless the tank is recharged with fresh water or rainfall [5] after each retting.

In a previous study, three potential pectinolytic bacterial isolates as '*Bacillus pumilus*' having high range of polygalacturonase (5.1–6.0 IU ml^{-1}), pectin lyase (185.7–203.7 U ml^{-1}) and xylanase (15–16.2 IU ml^{-1}) activities without cellulase activity have been reported which were isolated from retting water [6]. A microbial consortium consisting of these three microbes can be used very effectively to accelerate the retting process of jute and mesta with improvement in fibre quality [7]. The authors have also reported user friendly talc based microbial formulation of the microbial consortium with a viability of more than 8 months in room temperature [8]. The total population of *B. pumilus* in the formulation was in the range of 10^8–10^{10} g^{-1} of formulation. Three types of *B. pumilus* (*Bacillus pumilus* IMAU80221; *Bacillus pumilus* GVC 11 and *Bacillus pumilus* SYBC-W) were mixed in the carrier in a 1:2:1 (v/v) ratio respectively. The technology has been tested in limited scale and there is a need to compare the improved retting method with conventional one to establish the effectiveness and feasibility. Therefore, a comparative study of conventional and improved stagnant water retting of jute with microbial formulation was conducted to assess the retting duration, fibre recovery, fibre quality, microbial properties and economics etc.

Material and Methods

A comparative study of conventional stagnant water retting and improved stagnant water retting with microbial formulation was carried out during retting season of 2014 (15th July to 20th September). Both the retting trials were conducted in natural retting tanks situated at the same site, having similar quality of water and using green jute plants harvested from 0.13 ha area. The retting trials were replicated thrice and the three consecutive retting were carried out in the same tank. No additional water was added except the natural precipitation. Green harvested jute plants were used for retting, after keeping in the field for 3–4 days for leaf shedding. Same amount of green jute plants (by weight) were used for the retting trials. The details of both the retting trials are discussed below.

Conventional Stagnant Water Retting

Under conventional method of retting, defoliated jute bundles were steeped in clean stagnant water with proper jak materials (covering materials for proper immersion of jute bundles). After the completion of 'Jak' (arrangement of jute bundles for retting in the retting tank) mud and banana plants were used as weighing materials for immersion of jute bundles in water [9]. Fibre was extracted manually by single plant extraction method after the retting of jute was completed. After that, fibre was washed in the water and sundried in the vicinity of the retting tank.

Improved Stagnant Water Retting with Microbial Formulation

In the improved stagnant water retting, at the time of making 'Jak' with defoliated jute bundles (2–3 layers), microbial formulation was applied in each layer on the jute bundles. The microbial formulation was applied @ 25 kg for harvested green jute plants from one ha area. After completion of jak, the empty cement bags filled with mud were kept on the jak of jute bundles for immersion in the water instead of direct placement of mud on the jak. Other processes after completion of retting like extraction of fibre, washing and sun drying of fibre were same as followed in the conventional method. In the second retting at the same retting tank, the microbial formulations was used half of the amount applied for first retting [6] and for 3rd retting, no microbial formulation was used.

Fibre Quality Determination

After the completion of retting in conventional and improved method, fibre was extracted manually, washed in clean water, dried and its strength was estimated following the method of Roy et al. [10] using electronic fibre bundle strength tester and fibre fineness by airflow fineness method [11]. Lustre is a characteristic of shine (when light fall on the fibre, the more the shine, and the better is the quality) was recorded by visual observation of fibre in the sun. The hardy, incompletely decomposed barky region at the basal or lower end of the fibre is called root. The root content in terms of weight percentage was recorded by the method of Roy and Saha [12]. Colour means the property of a fibre, which distinguishes its appearance as redness, yellowness, greyness etc. The colour of the dried fibre was recorded by visual observation.

Estimation of Microbial Population in Retting Water

Retting water samples were serially diluted in sterile water and pour-plated on yeast extract pectin (1% yeast extract, 0.5% NaCl, 1% pectin, 1.8% agar, at pH 7.0) agar plate for estimating pectin degrading bacteria. Sterile cycloheximide solution (0.05%) was mixed with agar medium before plating to inhibit the fungal growth. Plates were incubated for 48 h at 34°C, (the optimum temperature for jute retting) and then colonies were counted with the help of digital colony counter. In the same way, for estimating xylanolytic isolates, after serial dilution, retting water samples were inoculated in xylan agar (0.5%, xylan, 0.5% yeast extract, 0.5% NaCl, 2% agar, at pH 8.0), for 72 h at 34°C and then colonies were counted. The polygalacturonase (PG) activity of retting water was estimated by the method of Phutela et al. [13]. One unit (IU) of PG activity corresponds to the release of 1 μmol of galacturonic acid min^{-1} ml^{-1} of supernatant culture by keeping D-galacturonic acid as standard. Pectin lyase (PNL) activity of retting water samples was determined by the modified TBA method [14]. The amount of enzyme that caused a change in absorbance of 0.01 under the assay condition was defined as 1 Unit (U) of PNL activity. Xylanase activity of water samples were estimated by reducing sugar estimation method using 3, 5 di-nitro salicylic acid [15]. One unit of xylanase activity (IU) corresponds to the μmol of xylose min^{-1} ml^{-1} of cell-free culture supernatant. The experimental data was statistically analysed by using SPSS10 software (SPSS Inc., Chicago, IL, USA).

Results and Discussion

Retting Duration

Use of microbial formulation reduced the retting duration by 6–7 days as compared to conventional method in three consecutive retting trials using same stagnant water (Table 1). Higher microbial activities at the initial stage accelerated the retting process by secreting targeted enzymes (polygalacturonase, pectin lyase and xylanase). Hence, degradation of cementing agents present in the jute plants (pectin and xylan) was fast as compared to conventional retting which is characterized by relatively less efficient retting microbes and microbial activities. The desirable microbial population for retting in conventional method was observed only after 4–5 days of immersion of jute, as during that time bursting/cracking of jute plants and dissolution of soluble salts had taken place which subsequently helped in the enhancement of microbial population. Whereas, in the improved retting method, desirable microbial population and enhanced microbial activity is generally obtained from the very first day [16].

Fibre Recovery

The fibre recovery under improved retting with microbial formulation ranged between 27.2–29 q ha^{-1} as compared to 24.8–25.9 q ha^{-1} under conventional method, in all three consecutive retting at the same retting tank (Table 1). There was 9.7–12% higher fibre recovery in improved method as compared to conventional one. The top portion of jute plants have less complex structure of pectin as compared to highly methyl esterified pectin of middle to bottom portion of the plants, hence bio-degradation of top portion requires lesser time as compared to mid and basal portion. So, longer retting duration leads to the loss of fibre from the top portion of jute. Conventional retting required more time by 6–7 days than the improved retting. Higher duration for retting (19–21 days), under conventional method, in the absence of ample quantity of efficient microbes, results in lesser fibre recovery as the top portion of fibre is over retted and dissolved in water. The results were in agreement with the finding of Majumdar et al. [17] who reported additional fibre recovery in the range of 8–10% over conventional retting in field demonstration trials.

Fibre Colour and Lustre

The fibre obtained from improved retting method was golden to golden-yellowish in colour as compared to grey to black colour fibre obtained from conventional retting method in three consecutive retting trials (Table 1; Fig. 1). The tannic acid content of banana plants and ferrous iron from retting water (mud used as covering materials are the source of iron in retting water) led to the production of ferrous tannate, which imparts black colour to the fibre, known as “Shyamla” [18]. Avoiding the use of banana plants and direct use of mud above the jak of jute bundles prevents the formation of ferrous tannate responsible for black colour of fibre. Further, microbes present in the formulation, by their bleaching action helped in the improvement of lustre and colour (i.e. golden to yellowish-golden). We found the lustre of the resultant fibre from improved retting with microbial formulation was bright and shining, whereas, dull grey to black fibres were observed in conventional stagnant water retting.

Fibre Strength

The fibre strength of jute ranged between 25.3 and 26.4 g tex^{-1} in improved retting as compared to 20.7–23.0 g tex^{-1} in conventional retting (Table 1). In

Table 1 Comparative assessment of improved and conventional retting of jute on retting duration, fibre recovery and quality

Quality parameters	1st retting		2nd retting		3rd retting		C.D. ($P = 0.05$)
	Improved retting	Conventional retting	Improved retting	Conventional retting	Improved retting	Conventional retting	
Retting duration (day)	14	21	13	20	13	19	2.09
Fibre recovery (q/ha)	27.2	24.8	28.5	25.5	29.0	25.9	1.68
Fibre strength (g/tex)	26.4	23.0	25.7	21.7	25.3	20.7	1.44
Fibre fineness (tex)	2.76	3.10	2.82	3.20	2.93	3.25	0.20
Fibre colour	Golden	Greyish	Golden yellowish	Blackish	Golden yellowish	Blackish	–
Root content (%)	03	15	04	17	04	17	–
Lustre	Bright and shining	Dull	Bright and shining	Dull	Bright and shining	Dull	–

Black coloured fibre from conventional method of retting

Lustrous golden coloured fibre from improved method of retting

Fig. 1 Comparison of *colour* and texture of the fibre obtained from conventional and improved retting

both the cases, the fibre strength reduced gradually from 1st to 3rd retting at the same retting tank. Lesser retting duration in improved method recorded higher fibre strength (3.4–4.6 g tex^{-1} over conventional method; Table 1). Longer retting duration usually led to poor quality fibre with less fibre strength which is one of the very important fibre quality parameter. Higher fibre strength of jute with microbial consortium was also reported by earlier workers [7, 19, 20].

Fibre Fineness

The fibre obtained from conventional retting was of coarser in nature compared to improved method. The fibre fineness ranged between 3.10 and 3.25 tex in conventional retting, whereas, it was ranged between 2.76 and 2.93 tex in case of improved retting (Table 1). Fine fibre with microbial inoculation/formulation compared to control was also reported by other workers [7, 19, 20]. As fibre fineness is an important criterion of fibre quality and fine fibre is used for high valued diversified products, the coarse fibre obtained from conventional retting cannot be used for diversified use. In the present study, the fibre from repeated stagnant water retting with microbial formulation at the same retting tank was also produced fine fibre consecutively as compared to conventional retting.

Root Content and Ease in Fibre Extraction

Uniform and proper retting by the action of microbes helped either to minimize or entirely remove root content in the fibre. Improved retting with microbial formulation recorded 3–4% of root content in resultant fibre, whereas, the resultant fibre from conventional retting recorded as high as 18–20% root content (Table 1). Higher root content in jute fibre under conventional retting as compared to improved method indicates poor quality fibre. No or negligible root content and improvement in fibre quality under improved method of retting over conventional method was also reported by earlier workers [7, 17, 19]. Uniform retting in stagnant water with the microbial formulation helps in the acceleration of extraction process and in turn helps in the reduction of man power for extraction up to the extent of 3 man days ha^{-1}. On the other hand, non-uniform retting and presence of high root content delays the extraction process and ultimately more man power was consumed in conventional method of retting.

Feasibility of Repeated Retting

Large scale field trials on repeated retting (3 times) in stagnant water with microbial formulation decreases retting duration by 6–7 days as compared to conventional retting (Table 1). Fibre recovery was also increased by 9.7–12% over conventional retting. Further, fibre quality parameters like fibre colour, strength, fineness, lusture and root content were well maintained in improved retting with microbial formulation as compared to conventional retting (Table 1). Hence, repeated retting of jute can be carried out with microbial formulation in the same stagnant water without affecting fibre quality and productivity.

Microbial Population and Enzymatic Activities

The total microbial population as well as pectin and xylan degraders in retting water were higher under improved retting with microbial formulation as compared to conventional retting even after first retting of jute (Table 2). The higher pectin and xylan degraders in retting water with improved method after first retting was because of high colony forming unit (cfu) (10^8–10^{10}) content of microbial formulation added in improved retting. The microbial, pectin and xylan degraders' population gradually increases in case of conventional retting and recorded higher values after third retting of jute as compared to improved retting. In improved retting, the dose of microbial formulation was half at the time of 2nd retting as compared to 1st retting and no microbial formulation was applied at the time of 3rd retting, whereas in case of conventional retting, the mud was directly applied during 1st, 2nd and 3rd retting which might have increased the microbial population.

On the other hand, the polygalacturonase, pectin lyase and xylanase activities were very high in retting water under improved method of retting with microbial formulation as compared to conventional retting (Table 2). There was an increase in enzymatic activities after each retting, although increments were higher in case of improved retting. The higher PG, PNL and xylanase activities in case of improved retting implies that, the efficient pectin and xylan degraders were used for improved retting, which was further reflected in shortening the retting duration and improvement in fibre quality.

User Friendly

The improved method of jute retting in stagnant water with microbial formulation is only minor modification over the conventional (farmers' practice) method; hence the usual practice of retting is not affected. Farmers need not to acquire any special skill for using the new method of retting. Further, utilization efficiency of water for retting is also increased directly by using the same water for repeated retting without degradation in fibre quality.

Environmentally Safe

The microbial formulation used in the improved method of stagnant water retting does not have any harmful effect on human, plant and aquatic life such as fish spp. This has been confirmed from the feedback report of farming community across the country who have used this microbial formulation, and also from the report of All India Network Project on Jute and Allied Fibres (AINP on JAF),

Table 2 Effect of repeated stagnant water retting of jute on microbial load and enzymatic activities in retting water

Microbial population in retting water	After 1st retting		After 2nd retting		After 3rd retting		C.D. ($P = 0.05$)
	Improved retting	Conventional retting	Improved retting	Conventional retting	Improved retting	Conventional retting	
Total microbial population (cfu ml^{-1})	45×10^8	55×10^4	42×10^5	43×10^5	38×10^5	12×10^7	–
Pectin degraders (cfu ml^{-1})	17×10^8	26×10^3	78×10^4	10×10^4	71×10^4	60×10^5	–
Polygalacturonase activity (IU ml^{-1})	3.6	1.5	4.2	1.7	5.3	2.1	0.61
Pectin lyase activity (IU ml^{-1})	142	61	160	70	185	85	12.85
Xylan degraders (cfu ml^{-1})	23×10^8	33×10^3	42×10^4	65×10^3	47×10^4	34×10^4	–
Xylanase activity (IU ml^{-1})	5.2	2.0	6.5	2.5	7.5	2.8	0.85

Table 3 Economic comparison between improved and conventional retting

Parameters	Retting methods		Effect of new retting technology
	Conventional	Improved	
Fibre yield (q ha^{-1})	25.4	28.2	Fibre yield increased by 2.8 q ha^{-1} (11% increase)
Selling price of /q fibre (Rs.)	2700	2950	Higher selling price of Rs. 250 q^{-1} over conventionally retted fibre
Total return	68,580	83,190	Total return increased by Rs. 14,610 ha^{-1}
Cost of 25 kg microbial formulation @ Rs. 40/- per kg	–	1000	Retting cost is higher by Rs. 1120 ha^{-1} over conventional retting
Cost of empty cement bags (40 nos) @ Rs. 3/- per bag	–	120	
Additional return (Rs. ha^{-1}) over conventional retting	–	13,490	Selling price of additional 2.8 q fibre + higher selling price for 28.2 q fibre

National Food Security Mission (NFSM), Department of Agriculture, Govt. of West Bengal [6, 17, 21–23].

Higher Net Return

The additional net return of Rs. 13,490 ha^{-1} by following the improved method of retting with microbial formulation was recorded over conventional method mainly because of additional fibre recovery (2.8 q ha^{-1}) and higher price (higher by Rs. 250 q^{-1} fibre over conventionally produced fibre) for quality fibre (Table 3). High price for better quality fibre and increase in net return with improved retting was also reported by Majumdar and Satpathy [23].

Conclusion

This user friendly, economically viable and environmentally safe retting technology leads to the wise utilization of the precious water resource by utilizing the same water for repeated retting. The demand of quality fibre by the jute industries for manufacturing of diversified products can be met by the introduction of this improved retting technology and also to minimize the loss of foreign currency towards the import of quality fibre.

Acknowledgements The authors are grateful to the Director, ICAR-Central Research Institute for Jute & Allied Fibres for the necessary facilities provided for carrying out the work.

Funding Indian Council of Agricultural Research.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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