



## Improved microbial retting and quality jute (*Corchorus* spp.) fibre production in India – A review

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### ABSTRACT

Jute (*Corchorus* spp. L.), the second most important fibre crop next to cotton, is a biodegradable and eco-friendly crop and one of the main cash crops of eastern India. India is the largest producer of raw jute in the world earning about ₹2200 crores per annum through export of diversified jute goods for which quality jute fibre is needed. The jute fibre quality depends directly on retting process. In India, more than 90% jute farmers do not have the access to free flowing water, so they carry out jute retting in stagnant water. The quality of jute fibre is deteriorated in stagnant water retting because of several factors like less rainfall, repeated retting, absence of efficient retting microbes, direct use of mud, soil etc. In this review paper we have discussed the views of various research workers about the efficient retting microbes, their utilization as microbial consortium for faster retting and quality jute fibre production even in stagnant water retting. Latest molecular approaches for identification of retting microbes including whole genome sequencing of retting microbes and their utilization as talc based formulation, spore based liquid formulation, use of immobilized strain of efficient retting microbes for faster environment friendly jute retting towards quality jute fibre production under farmers' field conditions have also been discussed in detail.

**Keywords:** Fibre, Jute, Microbial retting consortia, Quality retting

Jute (*Corchorus* spp. L.), universally known as the “golden fibre” is the multi-cellular, viscoelastic bast fibre obtained from a unique crop of major economic importance of eastern India and most particularly of West Bengal. Jute is a bio-degradable, eco-friendly, versatile natural fibre, cultivated in India in about 0.75–0.85 million hectare (0.47% of the gross cropped area of India). It is a source of livelihood of about 4 million farm families and provides direct employment to about 0.4 million workers in organized mills and in diversified units including tertiary sector and allied activities (Das *et al.* 2015). In addition, there are large number of workers engaged in the trade of jute. Thus, these people have also indirectly got benefitted from the production of quality jute fibre. Being the largest producer of raw jute in the world, India today earns about ₹2200 crores per annum through export of jute goods. The continued environmental degradation due to the use of plastics/synthetics, jute based diversified products like jute office bag, folder, decorative items, carry bags, etc. are in great demand in addition to traditional use like sacs, twines etc.

A jute crop absorbs about 14.7 tonnes of carbon dioxide/ha (CO<sub>2</sub>/ha) from ambient air during its normal four months life cycle besides leaving approximately 11 tonnes O<sub>2</sub>/ha (oxygen/ha) in the air and indirectly helps in lowering pollution level from the environment. For making jute diversified products, high grade quality fibre is required in terms of strength, lustre, colour and fineness which again depends to a large extent on the process of retting, which is purely a biochemical process. Presently, In India out of total jute fibre production, 20–25% jute fibre is under high grade i.e. TD1-TD2 category, 40–50% belongs to TD3 category and 35–40% is under TD4-TD5 grade (CACF, 2018-19). Actually, jute fibre consists of cellulose cemented by non-cellulosic materials such as pectin, hemicelluloses, in which xylan is a major component. These so-called cementing agents are to be removed by the enzymes released by microbes in the process of retting to obtain fibre from the bark.

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 (Majumdar and Day 1977). The microorganisms, mostly bacteria from retting water enter the plant tissues through the stomata, epidermis and cambium or the cut end, when immersed in

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retting tank, and through their enzymatic action loosens the fibre strands from the woody core. The fibres are then mechanically extracted, washed, dried and marketed. Quality fibre production from a good jute and mesta crop in the field depends fully on the proper retting carried out in good quality water. Improper retting may lead to inferior quality of fibre in spite of good crop which ultimately may fetch lower price in the market and lower net return to the farmers. In case of improper retting, the basal part of the fibre remains hard, which is called “cuttings”. The higher is the cutting percentage of the fibre, lower is the fibre quality.

Whole plant retting of jute and mesta in stagnant water is traditionally followed by the farming community across the jute growing countries of the world. But 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 harvested jute plants in stagnant water following conventional method of retting (Das *et al.* 2015). Most of the fibre 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 led to the production of inferior quality fibre unless the tank is recharged with fresh water or rainfall after each retting.

Conventionally, retting with poor quality stagnant water of community pond and sometimes with insufficient quantum of water without supply of any microbial consortium, quality of fibre is affected and is not of internationally competitive. As a result, finer quality fibre worth ₹600 crores is to be imported every year. Thus, there is a strong need to bring innovation in retting process which will produce high quality fibre efficiently in short duration.

#### *Conventional whole plant retting*

The traditional whole plant retting method of jute and mesta is universally practiced since the initiation of jute cultivation. After the harvesting of jute and mesta, the plants are kept in the field for defoliation/leaf shedding for a duration of 3 to 4 days. During the period of leaf shedding, the living cells of jute and mesta plants start lysing and this is the initiation of retting process. The defoliated jute bundles are then transported to the nearby retting facilities, immersed in clean or stagnant water according to the availability in natural retting tank, road-side ditches or sometimes in river with locally available jak materials (Majumdar *et al.* 2013). Most of the farmers use mud/soil and banana logs as jak materials for immersion of jute/mesta bundles in water. In this method, the retting of jute is completed in 18–21 days. The fibre is then extracted manually by “beat-break-jerk” or single plant extraction method which varies from place to place. The farmers using or selling jute stick as fencing or roof materials prefer single plant extraction method, whereas, farmers using jute sticks for fuel purpose prefer beat-break-jerk method of extraction. After extraction, fibre

is sun dried, tied and transported to market for sale. Use of mud/soil and banana plants for retting purpose led to the production of ferrous tennate. The tannic acid content of banana plants and ferrous iron from retting water (mud and soil used as covering materials are the source of iron in retting water) led to the production of ferrous tennate, which imparts black colour to the fibre, known as “Shyamla”. The conventional method of retting has certain demerits like longer retting duration, less fibre recovery because of over retting, poor quality fibre mostly black or grey in colour with poor lustre and fibre strength. Very high root content in the resultant fibre due to improper retting is another area of great concern. Because of lower fibre quality, farmers get low price for their produced fibre in the market and most of the fibre produced by this method is unsuitable for production of high valued diversified products (Majumdar *et al.* 2013).

#### *Need for improvement*

The traditional method of jute retting requires a large volume of water (1:20: Plant: water) for proper retting. There is a sharp decline in the number of permanent water bodies in jute growing areas during last 3 to 4 decades because of urbanization, natural siltation and creation of modern facilities and industrialization. The reduction in permanent water bodies reduced the scope of retting in good quality water with efficient retting microbes. Besides the decline in permanent water bodies, the irregular rainfall pattern during retting period aggravated the situation. Under such a water scarce situation, retting following traditional method becomes a risky and non-profitable business. Sometimes farmers are compelled to ret their harvest in very low volume of muddy water resulting in very poor quality fibre and low net income (Majumdar *et al.* 2013).

Use of underground water for retting on payment basis needs extra investment without any extra return. Generally, 3–4 times watering is needed for completion of one time retting because of quick percolation and evaporation loss of water under intense prolonged summer. The repeated retting of jute and mesta in the same stagnant water of natural retting tank, artificially prepared polythene lined or concrete retting tank also led to the production of inferior quality fibre, if addition of fresh water either from rainfall or lifted ground water are not met after each retting. Moreover, retting of jute and mesta in artificial retting tank utilizing uplifted ground water prolongs retting period than required in the conventional retting because of very low population of retting microbes.

Addition of efficient retting microbes in artificial retting tank may enhance the pace of retting process. So, there is an urgent need for the search of efficient retting microbes as well as development of improved retting methods requiring less water and completion of retting in short period of time using efficient retting microbes for quality jute fibre production.

#### *Search for efficient retting microbes*

Microbes play a significant role in jute retting process through biochemical reactions producing plant cell

dissolving enzymes. Attempts have been made to isolate and identify the microbes responsible for retting by several workers across the world. Most of the earlier workers were restricted to use of either single bacteria or fungi as retting microbes. Among the fungi, *Aspergillus niger* and several *Penicillium* sp. have been found effective in retting. Several aerobic bacteria of the genus *Bacillus*, viz. *B. subtilis*, *Paenibacillus polymyxa*, *B. mesentericus*, *Paenibacillus macerans* have been isolated from retting water and were found effective in the retting process of jute and mesta.

A mixed pectinolytic bacterial culture was developed at ICAR-CRIJAF, Barackpore for faster retting of jute and fibre quality improvement. The same mixed pectinolytic bacterial culture was used for ribbon retting of jute and kenaf and was found efficient for retting along with fibre quality improvement (Banik *et al.* 2007). In recent studies, isolation, screening, identification and use of pectinolytic mixed bacterial inoculum proved beneficial for ribbon retting of jute (Das *et al.* 2011, Das *et al.* 2012b) along with fibre quality improvement. The search for efficient retting microbes were limited to the search of only efficient pectinolytic isolates and retting of jute ribbons. The whole plant retting, which is universally followed by the farming community was not tried with different pectinolytic mixed bacterial cultures.

The predominant task for extraction of jute fibre is to remove non-cellulosic substances in the bast without causing damage to the fibre cellulose. So, search for efficient retting microbes should be confined to those microbes which can degrade pectin and hemicellulose primarily xylan without having any cellulose degrading activity (Majumdar *et al.* 2013). A detailed study was initiated in the year 2007 at ICAR-CRIJAF, Barrackpore towards the search for efficient retting microbes secreting high levels of pectinolytic and xylanolytic enzymes, without the production of any traces of cellulase, to make the whole plant jute and mesta retting process faster, safer and efficient. A large number of retting water samples were collected from the quality jute fibre producing districts of West Bengal and efficient pectinolytic bacterial isolates were screened on the basis of high polygalacturonase and pectin lyase activity using various substrates of pectin (Majumdar *et al.* 2010).

A microbial consortium consisting of three bacterial strains isolated from natural jute retting water with very high polygalacturonase (PG) (5.1–6.0 IU/ml), pectin lyase (PNL) (185.7–203.7 U/ml), xylanase (15–16.2 IU/ml) activity, but devoid of any cellulase activity was used for jute and mesta retting under controlled and farmers' field conditions (Majumdar *et al.* 2009a, Majumdar *et al.* 2009b). The three isolates were identified as different strains of *Bacillus pumilus*, which were designated as PJRB1, PJRB2 and PJRB3 by ribotyping of a 977 bp fragment. The three strains, when used in a consortium mode, showed enhanced enzymatic activity and in a 1:2:1 ratio produced maximum activity of PG (21.7 IU/ml), PNL (238.0 U/ml), xylanase (15.8 IU/ml) (Das *et al.* 2015). A talc based microbial formulation called "CRIJAF Sona" was developed by using

the bacterial strains of the microbial consortium to increase its shelf life and easy transportation to distant places. This easy-to-handle talc based powdery formulation can be stored in room temperature for six months and can be used for retting of jute and mesta as and when it is required and was found to ret jute in 13–15 days with fibre strength of 27.8–29.9 g/tex in field trials (Majumdar *et al.* 2011).

Three pectinolytic microbial consortia (MC1, MC2 & MC3) developed for faster retting of jute (*Chorchorus olitorius* L. and *Chorchorus capsularis* L.) were subjected to various pH (4 to 12) and media with variable nitrogen and fixed carbon sources for optimization of fermentation conditions of the consortia for cost-effective pectin degrading enzyme production. The microbes of MC1 & MC2 have cellulolytic activities whereas; the microbes of MC3 do not have any cellulolytic activities. The maximum polygalacturonase and pectin lyase enzyme production by pectinolytic microbial consortia could be achieved by using yeast extract pectin media at alkaline pH (8–10). Among the three microbial consortia under study, the polygalacturonase and pectin lyase production in yeast extract pectin agar media by microbial consortium 3 were significantly higher over microbial consortium 1 and 2 (Nath *et al.* 2017).

#### Verification trials of microbial formulation for retting

The efficacy of CRIJAF microbial formulation (CRIJAF Sona) had been tested and verified under variable agro-climatic conditions across the country at different state Agricultural Universities, viz. BCKV, Nadia, West Bengal; UBKV, Coochbehar, West Bengal; AAU, Nagaon, Jorhat, Assam; BAU, Katihar, Bihar; OUAT, Kendrapara, Odisha; ANGRAU, Amadalavalasa, Andhra Pradesh; NDUAT, Bahraich, Uttar Pradesh and TNAU, Aduthurai, Tamilnadu under All India Network Project on Jute and Allied Fibres (AINP-JAF) for 3 to 4 years (2011 to 2014). At all these research stations, jute retting with microbial formulation "CRIJAF SONA" was completed in 8 to 14 days, whereas, retting without microbial formulation completed in 15 to 21 days, so there was a reduction of retting duration by 6 to 7 days and improvement in fibre colour, lustre and strength by 3 to 4 g/tex (Majumdar *et al.* 2015a).

Large scale whole plant retting trials of jute with microbial consortium under controlled conditions continuously for two years (2009 and 2010) reported reduction of the retting duration by 7 days for jute (Table 1), with improved fibre quality i.e., colour, lustre, fibre strength (27.0–28.1 g/tex), fineness (2.7–2.8 tex) and fibre recovery by 13.8–15.24% over control (Das *et al.* 2015). The microbial formulation developed by CRIJAF was extensively demonstrated in various jute growing districts of West Bengal, Baharaich district of Uttar Pradesh and mesta growing district of Srikakulam in Andhra Pradesh during retting seasons of 2012 and 2013 (Majumdar and Satpathy 2014). By using this microbial formulation farmers could earn an additional income of ₹6000–9000/ha by spending only ₹675–900 from one ha of jute/mesta crop (Majumdar and Satpathy 2014).

Table 1 Effect of microbial retting consortium on retting duration, fibre recovery and quality parameters of jute fibre (Two years pooled data)

| Fibre quality parameter | Polythene lined retting tank |                              | Concrete retting tank     |                              |
|-------------------------|------------------------------|------------------------------|---------------------------|------------------------------|
|                         | With microbial consortium    | Without microbial consortium | With microbial consortium | Without microbial consortium |
| Retting duration (days) | 14                           | 21                           | 13                        | 20                           |
| CD (P=0.01)             |                              |                              | 1.52                      |                              |
| Fibre strength (g/tex)  | 27.00                        | 22.80                        | 28.10                     | 23.5                         |
| CD (P=0.01)             |                              |                              | 1.04                      |                              |
| Fibre fineness (tex)    | 2.8                          | 3.0                          | 2.7                       | 3.1                          |
| CD (P=0.01)             |                              |                              | 0.26                      |                              |
| Fibre recovery (q)      | 3.75                         | 3.27                         | 3.82                      | 3.34                         |
| CD (P=0.01)             |                              |                              | 0.21                      |                              |
| Root content            | No                           | Yes                          | No                        | Yes                          |
| Lustre                  | Bright and shining           | Dull                         | Bright and shining        | Dull                         |

Source: Das *et al.* (2015)

#### Fibre quality improvement with microbial consortium

The demand for quality jute fibre in India is increasing gradually to meet the demand of jute industries for manufacturing of high valued diversified products, most of which are exported to the foreign markets. In absence of quality jute fibre within the country, jute industries of India import finer quality fibre costing approximately rupees 600 crores every year. As per latest grading of jute fibre by the Bureau of Indian Standard (BSI) on December, 2020, five fibre quality characters of jute fibre, viz. a) fibre strength, b) fibre colour, c) fibre fineness, d) root content in jute fibre and e) defects in jute fibre were considered for determination of jute fibre grading. In general, finer quality jute fibre is produced, when retting process is carried out in slow moving soft water.

Use of CRIJAF microbial consortium in stagnant water retting across jute growing states of India for fibre quality improvement have been reported by several workers (Majumdar *et al.* 2012, Majumdar and Satpathy

2014, Majumdar *et al.* 2014, Majumdar *et al.* 2015b, Majumdar *et al.* 2017). The beneficiary tribal farmers of West Bengal, Odisha and Assam got additional higher price of ₹300–500/q for quality jute fibre production by using CRIJAF microbial formulation “CRIJAF Sona” for jute retting over conventionally retted jute fibre (Majumdar *et al.* 2015a, Sarkar *et al.* 2018).

A comparative study was carried out between conventional retting and retting with CRIJAF microbial formulation in stagnant water for three consecutive retting trials using the same water to observe the effect on fibre quality. The fibre quality parameters, viz. fibre colour, strength, fineness, lustre, root content of the resultant jute fibre (Table 2) improved significantly compared with the conventional retting in repeated retting trials and the demand of quality fibre by the jute industries for manufacturing of diversified products could be met following this improved method of retting. The net return of farmers also increased by ₹13,490/ha (Table 3) over conventional retting because

Table 2 Comparative assessment of improved and conventional retting of jute on retting duration, fibre recovery and quality

| Quality parameter       | 1 <sup>st</sup> retting            |                      | 2 <sup>nd</sup> retting            |                      | 3 <sup>rd</sup> retting            |                      | C.D.<br>(P=0.05) |
|-------------------------|------------------------------------|----------------------|------------------------------------|----------------------|------------------------------------|----------------------|------------------|
|                         | Retting with microbial formulation | Conventional retting | Retting with microbial formulation | Conventional retting | Retting with microbial formulation | Conventional retting |                  |
| Retting duration (days) | 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                 | -                |

Source: Das *et al.* (2018)



Table 3 Economic comparison between improved and conventional retting of jute

| Parameter                                          | Retting methods |          | Effect of new retting technology                                                |
|----------------------------------------------------|-----------------|----------|---------------------------------------------------------------------------------|
|                                                    | Conventional    | Improved |                                                                                 |
| Fibre yield (q/ha)                                 | 25.4            | 28.2     | Fibre yield increased by 2.8 q/ha (11% increase)                                |
| Selling price of per q fibre (₹)                   | 2700            | 2950     | Higher selling price of ₹250/q over conventionally retted fibre                 |
| Total return                                       | 68580           | 83190    | Total return increased by ₹14610/ha                                             |
| Cost of 25 kg microbial formulation @ ₹40/per kg   | -               | 1000     | Retting cost is higher by ₹1120/ha over conventional retting                    |
| Cost of empty cement bags (40 nos) @ ₹3/per bag    | -               | 120      |                                                                                 |
| Additional return (₹/ha) over conventional retting | -               | 13490    | Selling price of additional 2.8 q fibre + higher selling price for 28.2 q fibre |

Source: Das *et al.* (2018)

of quality improvement and higher fibre recovery (Das *et al.* 2018).

In a ribbon retting trial with jute and mesta, it was reported that the retting with microbial consortium (CRIJAF Sona) was completed in 7–10 days against 13–15 days without microbial consortium. Microbial consortium mediated retting also improved the fibre strength by 10–12% and 30–35% for jute and mesta, respectively due to acceleration in retting period compared to ribbon retting without microbial consortium (Naik *et al.* 2018). After 3 years of the implementation of Jute-ICARE project by National Jute Board, the impact analysis by National Productivity Council (NPC) revealed that, 63% of the targeted farmers have adopted improved retting using CRIJAF Sona formulation which was non-existent before the start of the project. Higher fibre recovery to the tune of 8 to 10% more, and quality improvement by 1 to 2 grades because of yellowish to bright golden fibre colour and very good strength, helped to get an additional price. Application of CRIJAF Sona also decreased the labour requirements and drudgery of the persons involved (Jha *et al.* 2018).

#### Molecular approach

The molecular characterization including identification of various pectinolytic bacterial isolates screened out from the jute retting environment was carried out by several researchers across the country (Das *et al.* 2012a, Das *et al.* 2012b, Das *et al.* 2015). In recent development, the whole genome sequencing of promising retting microbes was also carried out for the first time in India (Datta *et al.* 2020).

Das *et al.* (2012b) characterized the four pectinolytic bacterial isolates used for jute retting in different combination. The isolates were identified by 16S rDNA analysis and subsequent comparison with Gene Bank as SO14 – *Bacillus pumilus* strain IK-MB12-518F (GQ891105), BA15 – *B. pumilus* strain EK-17 (GQ891098), BA1 – *Bacillus* sp. L6 (GQ891097) and SO7 – *B. pumilus* strain Geo-03-422 (GQ891103). Out of 40 pectinolytic bacterial isolates from retting water samples tested for their polygalacturonase, pectin lyase, xylanase and cellulase enzymatic activities,

only 3 isolates were found to have very high pectinolytic and xylanase activity with very less cellulase activity. Out of these three strains two were identified as different strains of *Bacillus pumilus* and another strain as *Bacillus licheniformis* by using Biolog microbial identification system (Ray *et al.* 2015).

The microbial retting consortium consisting of three different strains of *Bacillus* spp. (PJRB1, PJRB2 and PJRB3) developed at ICAR-CRIJAF were identified up to the species level by Biolog Inc. (Hayward, U.S.A), an advanced tool for characterization and identification of microorganisms based on the metabolic fingerprinting pattern of the isolates using the software ML\_51\_01\_ml3 as *Bacillus pumilus* with varying degree of similarity (Das *et al.* 2015). The three strains (PJRB1, PJRB2 and PJRB3) of the microbial consortium were also identified as different strains of *Bacillus pumilus* namely, *Bacillus pumilus* IMAU80221, *Bacillus pumilus* GVC 11 and *Bacillus pumilus* SYBC-W, respectively by 16S rDNA sequencing (ribotyping) of a 977 bp fragment with 99% maximum identity in individual BLAST analysis (Das *et al.* 2015). These three strains of *Bacillus pumilus* were later identified as *Bacillus safensis*, *Bacillus velezensis* and *Bacillus altitudinis* respectively through whole genome sequencing based on taxonomic affiliation of the isolates (Datta *et al.* 2020).

The partial sequences of 16s rRNA gene and genome sequences of the PJRB1, PJRB2 and PJRB3 have been submitted to National Centre for Biotechnology Information (NCBI) with accession number KM091823, KM091824 and KM091825, and VFLO00000000, VFLN00000000 and VFLM00000000 respectively (Das *et al.* 2015, Datta *et al.* 2020). High-resolution SEM imaging of the PJRB isolates (Fig 1) showed that all three strains are rod shaped and have comparable shapes and size (length ~1.5 µM, width ~0.5 µM) (Datta *et al.* 2020).

The comprehensive genomic analyses of these three bacterial strains of the microbial consortium (Fig 2) resolved their taxonomic status, genomic features, variations, and pan-genome dynamics. Phylogeny and structural features of pectate lyase proteins of PJRB strains divulge their

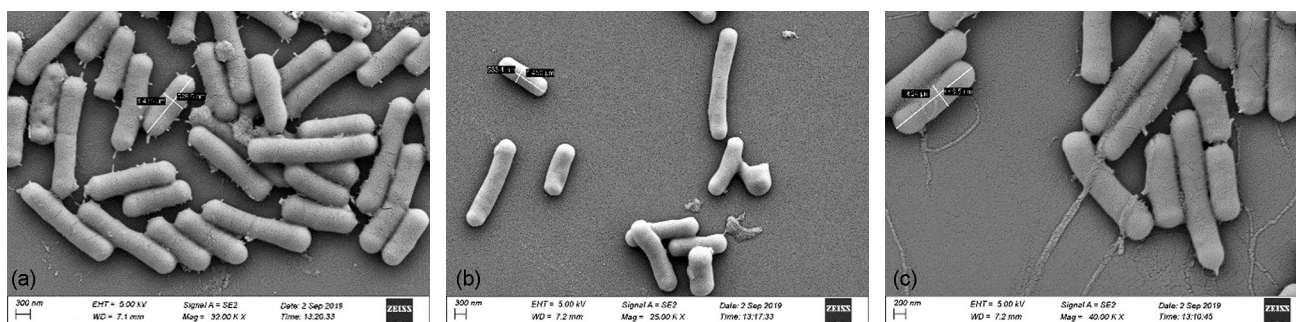


Fig 1 Rod-shaped gram-positive bacterial cells of PJRB strains (a; PJRB1, b; PJRB 2 & c; PJRB 3) through scanning electron microscopy (SEM). Source: Datta *et al.* (2020)

functional uniqueness and evolutionary convergence with closely related *Bacillus* strains. Genome-wide prediction of genomic variations revealed 12461 to 67381 SNPs, and notably many unique SNPs were localized within the important pectin metabolism genes. The variations in the pectate lyase genes possibly contribute to their specialized pectinolytic function during the retting process (Datta *et al.* 2020). The presence and organization of different carbohydrate degrading CAZymes classes, viz. PL1, PL9, GH28, CE8, and CE12 in all the three PJRB genomes

establishes the earlier findings of the microbial consortium having very high petinolytic and xylanolytic activities by Das *et al.* (2015).

The optimization of the extra-cellular cellulase free xylanase production by the immobilized cell of the *Bacillus pumilus* IMAU80221 strain (PJRB1) of the microbial consortium developed by ICAR-CRIJAF using Ca-alginate beads along with standardization of the various parameters for a higher xylanase production were studied. The immobilized *Bacillus pumilus* can also be

reused in eight sequential fermentation cycles for xylanase production, although the entrapped cell retained 83.5% of its production at the 4<sup>th</sup> cycle. Furthermore, the entrapped cells retained 68% of xylanase production after six months of storage at 4°C. The immobilized strain of *Bacillus pumilus* in 5% calcium alginate produced higher cellulase free extracellular xylanase compared to free cells in a very shorter duration of 48 h and continued to produce higher xylanase up to 72 h and hence had a tremendous scope of its industrial application for extracellular xylanase production without any cellulase activity (Kundu and Majumdar 2018).

The talc based microbial formulation (CRIJAF Sona) developed by ICAR-CRIJAF has a shelf life of six months at room temperature. Further, as the constituent bacterial strains are present as vegetative form in talc based formulation, they are vulnerable to external

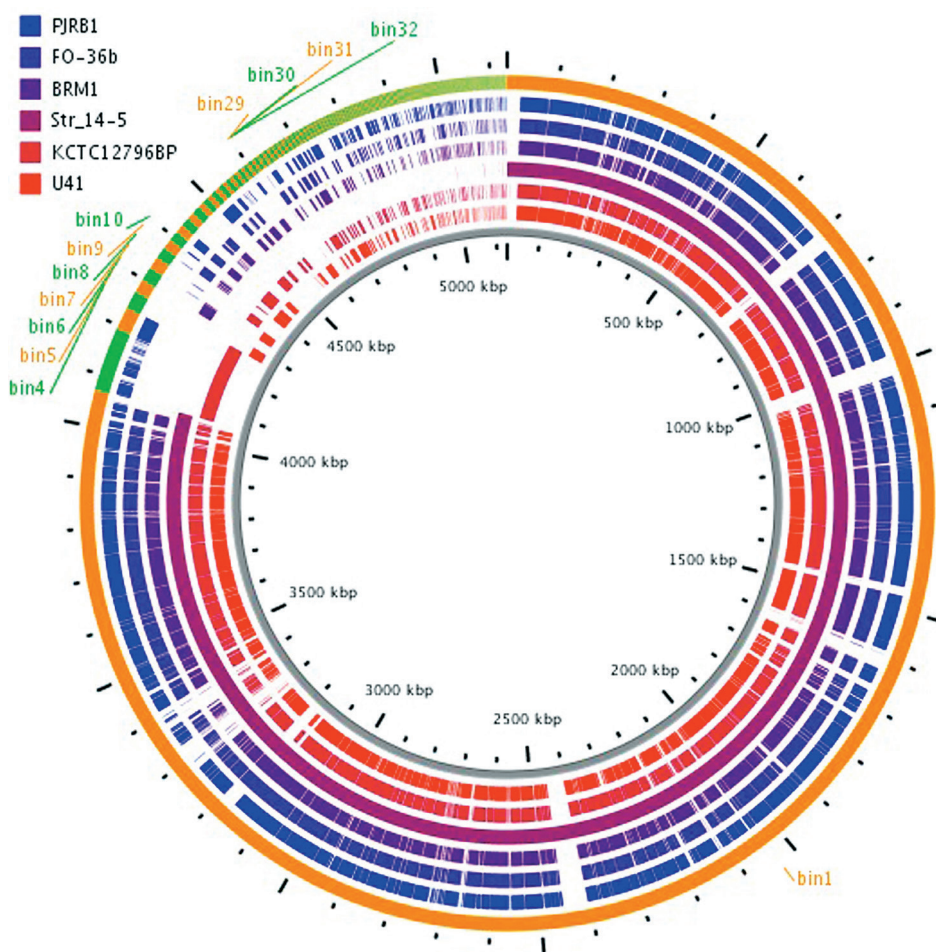


Fig 2 Comparative genome analyses of CRIJAF Sona strain PJRB1 with other *Bacillus* strains. ClustAGE analysis of accessory genomic elements (AGEs) indicates the distribution of each accessory genomic element among the selected *Bacillus* genomes.



factors like high temperature, UV irradiation etc. during transportation and their activity decline because of these factors. To overcome this, the endospores of the *Bacillus* strains were used instead of their vegetative cells in development of liquid formulation of the microbial consortium. The endospores of *Bacillus* strains recorded very high colony forming unit ( $10^9$  to  $10^8$ /ml) compared to their vegetative cells ( $10^6$  to  $10^4$ /ml) after 6 to 18 months of their preservation. Endospores also showed higher resistance to temperature, pH, UV irradiation and antibiotics. High colony forming unit and higher release of pectinolytic and xylanolytic enzymes during retting of jute by 18 months old endospores resulted in completion of jute retting in 10 days with better quality jute fibre (Fibre strength of 27.6 g/tex and fibre fineness of 2.51 tex) as compared to the fibre (Fibre strength of 21.8 g/tex and fibre fineness of 2.84 tex) obtained by using talc based formulation. Thus the endospores of *Bacillus* strains can be used in place of talc based microbial formulation for higher shelf life of the product, faster retting and better fibre quality of jute (Chattopadhyay *et al.* 2019).

The lignin content in jute fibre varies from 13.3–15% (Sengupta and Palit 2004, Chakraborty *et al.* 2015) and higher lignin content in jute fibre is restricting its use as a textile fibre. To overcome this problem, a study was carried out for reduction of lignin content in jute (*Corchorus spp.* L.) with promising lignin degrading bacterial isolates as an alternative to chemical delignification. A promising ligninolytic bacterial isolate (L9) identified as *Bacillus* spp. performed best among the five isolates used for delignification study which could reduce lignin content of jute fibre from 11.33–8.84% i.e., a favourable reduction of 21.97%. The environmental pollution from chemical process of delignification can be overcome by using the biological method of delignification using lignin degrading bacterial isolates in place of chemical delignification (Barai *et al.* 2020).

#### Way forward

Metagenomics study of retting water in important jute growing areas to screen out more efficient retting microbes for the upscaling of present microbial formulation must be carried out in systematic manner. Study should also be conducted to identify the end point of jute retting process with sensor based monitoring system, so that the jute industry can adopt the technology. Possibility of cloning of more efficient pectin degrading gene from highly efficient retting fungi to the present microbial formulation should be initiated. Water requirement in jute retting is still a grey area of concern, hence future research on retting should focussed for minimization of water requirement and reuse of retting water by purifying the used water. The improved retting technology developed should reach to the farming community in a larger way, so that the marginal jute growers can get the benefit out of that.

#### Conclusion

The demand for jute based diversified products like

jute office bag, folder, decorative items, carry bags, etc. has increased because of complete ban of single use plastics by Government of India. The quality jute fibre required for making diversified jute products requires improvement in retting process over conventional retting generally practiced by the farming community. The pectinolytic microbial consortium developed by the researchers for faster retting of jute has been found beneficial not only in minimizing the retting duration but also in improvement of fibre quality across the jute growing states of the country. The improved retting method has helped to increase the net income of farmers by ₹13,490/ha over conventional retting practice. Molecular approach has been used to identify for whole genome sequencing of retting microbes, which can further helped to improve the efficiency of retting microbes. Due to improved retting technology adopted by National Jute Board under Ministry of Textiles, Govt. of India, farmers are getting direct benefit of it through a pilot scale project named “Jute-ICARE”. The impact analysis by National Productivity Council (NPC) after 3 years of its implementation revealed that, 63% of the targeted farmers have adopted improved retting practice which was non-existent before the start of the project. Higher fibre recovery to the tune of 8 to 10% more, and quality improvement by 1 to 2 grades, helped to get additional price. The spore based liquid formulation of the microbial consortium over its talc based formulation has been developed to increase its shelf life and requirement, which is very cost effective.

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