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Evaluating the effects of crijaf sona microbial retting technology on the technical, economic, and environmental sustainability of jute production in West Bengal

Debjyoti Majumder*, Ekta Jaju, Somedip Chatterjee, and Sayan Sau

Switch On Foundation, Kolkata, West Bengal-700025, India

ABSTRACT

The present research evaluates the economic, technical and environmental impacts of CRIJAF SONA microbial retting formulation on the cultivation of jute in West Bengal (Nadia District). CRIJAF SONA is an ICAR-CRIJAF-developed talc-based microbial consortium, which is a group of Bacillus strains, selective degraders of pectic components, and preserving cellulose, that accelerates retting. It was observed that a comparative survey on retting of Jute was carried out on 88 Jute farmers; 44 who employed CRIJAF SONA and 44 who applied traditional procedures. The ANOVA and estimation of effect sizes were used to analyse data on retting duration, fibre yield, quality and profitability. The findings indicated that the CRIJAF SONA decreased the retting period by half from 18 to 14 days, increased the fibre yield by almost 30 per cent and the quality of fibres, resulting in a 35-40 per cent higher price in the market. As a result, the gross income improved by approximately 77, which is equivalent to 80-90 thousand more per acre. Highly significant and practically meaningful differences between adopters and non-adopters with statistical significance (p < 0.001, Cohen's d to 10.0) were statistically proven. A farmer perception study revealed that it was very much satisfied and easy to use, and the Technology Effectiveness Index is 85.41, which shows that it can be adopted at a large level. The results indicate that CRIJAF SONA is not only a retting aid but a transformational technological intervention capable of boosting productivity, profitability, and environmental performance in the jute industry, helping to develop the rural area in eastern India into a climate-resilient and environment-friendly zone.

Keywords: *Jute, West Bengal, Nadia, CRIJAF SONA, Productivity, Economics.*

Introduction

Jute is almost a special crop in the agrarian situation in the Nadia district because of alluvial soils, sufficient rainfall and the availability of the natural water body in the area, it is the most favourable region to grow fibre. The district is an important component of the jute belt of the southern West Bengal region that provides a significant share of raw jute to local and foreign markets. Jute, in the case of Nadia, and thousands of smallholder farmers, is not only a commercial crop, but also a source of household income, rural employment and agro-based industries. But the quality and commercial value of jute fibre are subject to the retting of the fibre, which is a microbial digestion of pectin and hemicellulose that separates the fibre and plant stalks. Conventional processes of retting in stagnant water in the pond using mud and banana stems usually require 1821 days and result in low-quality fibre of high root content, dull colour, and poor tensile strength (Majumdar et al., 2013; Das et al., 2012). These inefficiencies lead to loss of income and the continuation of exposure of the small farmers to market fluctuations.

Central Research Institute of Jute and Allied Fibres (ICAR-CRIJAF) has formed CRIJAF SONA, a talc-based microbial consortium that is a significant breakthrough under fibre crop biotechnology with immense implications on the sustainability of agriculture, livelihoods in rural regions and economic growth. CRIJAF SONA, aimed at benefiting the retting of jute (*Corchorus olitorius* and *C. capsularis*), has become a revolution that can boost the quality of fibre, production, and environmental efficiency, revolutionising the jute farming sector in advancing the economic standing of the local populations. The current article aims to evaluate how CRIJAF SONA has influenced the economic and livelihood benefits among jute farmers in Nadia district in West Bengal, which is among the most viable jute-growing states in India. This research is aimed at critically analysing the use of the technology to deliver more profitable, labour-efficient, and sustainable results in the local jute economy by critically reviewing the existing authors and field-based evidence (Masum et al., 2024; Purba et al., 2024). The broader implications of this innovation to the production of sustainable fibres, climate-resilient agriculture, and socio-economic development in the areas prone to the variances of climate and resource scarcity are also analysed (Kundu et al., 2020).

To cope with them, ICAR–CRIJAF launched CRIJAF SONA, a microbial retting solution, which includes highly efficient Bacillus strains: *B. safensis, B. velezensis*, and *B. altitudinis*, with high pectinolytic and xylanolytic activities but no cellulolytic degradation (Das et al., 2015; Datta et al., 2020). The property allows a quicker and more uniform retting process to occur because the non-fibrous components are selectively broken down whilst the cellulose remains undamaged, allowing fine lustrous fibres of high-strength and colour to be produced.

Corresponding Author: **Debjyoti Majumder*

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Widespread tests in jute-growing areas such as Nadia have indicated that CRIJAF SONA has shortening of retting period to 11-13 days, an increase of fibre recovery by 9-11% and improvement of tensile strength and a decrease in root content of over 50 per cent (Majumdar et al., 2024). These technological advantages have been directly converted into great economic profits of 15,000-18,000 per hectare of greater profits compared to farmers who employ traditional retting practices, coupled with labour and water savings.

Alteration of perception in regards to Farmer perception is another study where Farmer perception becomes very acceptable in Nadia and North 24 Parganas with indices of technology attribute showing that relative advantage, observability and trialability of the technology is over 90 per cent, and the general technology effectiveness index is 85.41 per cent, which symbolizes that users are high in terms of their confidence and potential sustainability (Chatterjee and Mondal, 2022). The above results of Nadia indicate not only the agronomic superiority of CRIJAF SONA but also that it has the potential to raise the farm level economics as well as sustainable rural development.

The current article is a synthesis of evidence in the systematic review of scientific and extension literature, based on databases like Scopus, Web of Science, ScienceDirect, and PubMed. Boolean operators such as AND, OR, and NOT were used to select the literature because the topic of fibre crops and their utilisation in economic and social fields is novel (Ramifehiarivo et al., 2022; Aryal et al., 2023; Kundu et al., 2020; Purba et al., 2024; Konfo et al., 2024).

This synthesis aims at offering a comprehensive insight into how CRIJAF SONA helps economic empowerment, efficiency in operations and climate resilience among jute farmers in Nadia district. Through connecting microbial innovation with farmer-focused adoption, this paper places special attention on CRIJAF SONA as an example of science-based change in the jute industry in India (Jamanal & Sadaqath, 2018). In addition to the immediate technical advantages, the formulation is aligned to the larger agenda of low-carbon, climate-resilient agriculture, a method of aligning agricultural modernisation with sustainable livelihood and circular bioeconomy goals (Majumdar et al., 2014; Singh et al., 2018; Singh et al., 2019).

2. Materials and Methods

2.1 Study Area and Sampling Framework

The research was done in the Nadia district of West Bengal, one of the major jute-producing areas of eastern India with fertile alluvial soils, a humid subtropical climate and a large availability of surface water resources that facilitate jute farming and retting. The district is a good source of the overall volume of jute production in the state and the heterogeneous blend of old-fashioned and innovative retting methods, which provides an appropriate background to examine the impact of using CRIJAF SONA formulation comparatively. The survey was conducted in the period of the 2025 retting (July-September) season in some of the blocks where the jute is concentrated, such as Krishnagar-I, Hanskhali and Ranaghat-I.

Eighty-eight farmers were sampled purposely and divided into two equal groups according to their retting practices. In the treatment group, 44 farmers were involved in using the CRIJAF SONA retting formulation, whereas in the control group, 44 farmers were involved in applying conventional retting techniques of pond water and natural weighting materials (e.g., banana stems, soil clods).

The sampling was done to provide homogeneity in terms of agro-climatic conditions, and how the crops were grown, as well as in terms of socio-economic background, to reduce the external variance. The purposive-cum-random sampling methods served to inform sampling on the need to include small and medium-scale jute growers.

2.2 Data Collection and Survey Design

Data were collected through a structured questionnaire survey, designed and pre-tested to capture both quantitative and qualitative dimensions of CRIJAF SONA adoption and its economic outcomes. The questionnaire consisted of sections covering:

1. Demographic and socio-economic profile — including age, education, farm size, family labour, and farming experience.

2. Operational parameters — retting duration, number of labourers engaged, water requirement, and ease of operation.

3. Yield and quality indicators — total fibre yield (kg/ha), fibre recovery rate (%), fibre fineness, strength, and root content (%).

4. Economic variables — cost of retting, total variable cost, gross return, net return, and benefit–cost (B: C) ratio.

5. Perceptual aspects — farmers' satisfaction, perceived advantages, and constraints related to the CRIJAF SONA application.

The interviews were conducted face-to-face in the local language using trained enumerators, ensuring consistency and reliability in data recording. Field observations and direct verification of retting pits were also performed to validate the responses. The questionnaire ensured both closed-ended and open-ended questions to enable descriptive and inferential statistical analyses.

2.3 Experimental Design

To evaluate the impact of CRIJAF SONA, a comparative quasi-experimental design was adopted with two farmer groups:

- **Treatment Group (T_1):** Farmers using the *CRIJAF SONA* microbial retting formulation during the 2025 season.
- **Control Group (T_2):** Farmers following traditional retting practices under similar agro-climatic conditions and water availability.

The study design was such that both groups were going to be subjected to similar agronomic conditions, with the similarity in the type of jute (*Corchorus olitorius*) and production inputs. This method reduced the effect of confounding, and differences in the quality of fibres and profitability could be ascribed to the retting method in the first place.

Statistical comparison of the data that had been gathered in each group was done to determine differences in operational efficiency, quality of fibres, and economic indicators. The statistical power sufficient to identify medium and large effect sizes (Cohen's $d \geq 0.5$) at a 95 per cent level was sufficiently large (n=44 per group).

2.4 Statistical Analysis

1. The analysis of the data was performed with the help of Python (version 3.12) along with such libraries as Statsmodels, SciPy, and Seaborn to conduct statistical and graphical analysis. The following steps were implemented in the analysis:

Descriptive Statistics

Mean, standard deviation (SD) were computed for all parameters to summarise central tendency and variability across treatment and control groups. The mean ($\bar{x}$) was calculated as:

$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} xi$ ...... (i)

where x_i is each observation and n is the total number of observations. The standard deviation (SD) was computed using:

$SD = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$.........(ii)

which measures the spread of data around the mean. The coefficient of variation (CV), expressing relative variability as a percentage, was calculated by:

1. One-Way Analysis of Variance (ANOVA)

A one-way ANOVA was performed to test for statistically significant differences between CRIJAF SONA users and non-users for each continuous variable—such as retting duration, fibre yield, root content, and net return. The significance level was set at α = 0.05.

2. Tukey's Honest Significant Difference (HSD) Post-hoc Test

Tukey's HSD test is a post-hoc analysis performed after a significant ANOVA result to identify which specific group means differ. The HSD value is calculated as:

$HSD = q \times \sqrt{\frac{MSW}{n}}$......... (v)

where q is the critical value from the studentized range distribution, MSW is the mean square within groups (error variance), and n is the number of observations per group. Group mean differences larger than this HSD value are considered statistically significant.

3. Effect Size Measurement (Cohen's d): Cohen's d was calculated to quantify the magnitude of differences between groups for all key parameters. It is computed as:

$d = \frac{M_1 - M_2}{SD_{\text{pooled}}}$ .... (vi)

where M_1 and M_2 are the means of the two groups, and SD_{pooled} is the pooled standard deviation:

$SD_{\text{pooled}} = \sqrt{\frac{(SD_1^2 + SD_2^2)}{2}}$........(vii)

Effect sizes were interpreted as small (0.2–0.49), medium (0.5–0.79), and large (≥0.8), providing additional insight into the magnitude beyond statistical significance.

Graphical Representation:

Seaborn was used to generate box-and-whisker plots to visualise the distribution of data, median values, interquartile ranges and possible outliers of the key variables, including retting duration, fibre yield and net income. Such visualisations served to demonstrate how well CRIJAF SONA users and non-users perform.

Reliability and Validation:

Before inferential analysis, data normality was verified using the Shapiro–Wilk test, which tests the null hypothesis that the data come from a normally distributed population. The Shapiro–Wilk test statistic *W is calculated as:*

$$W = \frac{(\sum_{i=1}^{n} a_i x_{(i)})^2}{\sum_{i=1}^{n} (x_i - \bar{x})^2}......(vii)$$

where $x_{(i)}$ is the i^{th} ordered sample value, $\bar{x}$ is the sample mean, and the coefficients a_i based on expected normal order statistics. Homogeneity of variances was confirmed using Levene's test.

Before analysis, missing or inconsistent data entries were carefully screened, and only validated datasets were included for final statistical computations.

All statistical interpretations were made at a 95% confidence interval. Results were tabulated and graphically represented to facilitate clear comparison and interpretation of CRIJAF SONA's effects on productivity and profitability parameters.

2.5 Ethical Considerations

The study adhered to ethical standards of participatory agricultural research. Informed consent was obtained from all farmer participants before data collection. Respondents were briefed on the objectives of the survey, assured of data confidentiality, and informed that participation was voluntary.

3. Results and Discussion

3.1 Descriptive Analysis

A comparative descriptive analysis was performed to evaluate the impact of the *CRIJAF SONA* retting formulation on operational efficiency, fibre yield, and economic performance among jute farmers in Nadia district. The mean and standard deviation (Mean ± SD) values for key parameters retting duration, yield, market price, and gross income are presented in Table 1.

Table 1. Descriptive statistics of key performance parameters

Parameter	CRIJAF_SONA (Mean ± SD)	Control (Mean ± SD)
Retting Duration (days)	14.0 ± 2.0	18.0 ± 2.0
Yield (kg/acre)	3050 ± 120	2400 ± 120
Market Price (Rs/qtl)	6420 ± 60	4700 ± 300
Gross Income (Rs/acre)	195000 ± 8000	110000 ± 8000

In every variable that was measured, the results clearly demonstrate that CRIJAF SONA users performed much better than non-users. On average, the retting time was shortened by four days, indicating increased microbial breakdown efficiency. Fibre yield increased by about 27–30%, although market price and gross income increased by 36–40% and 77%, respectively. These findings demonstrate that the application of CRIJAF SONA significantly improved both technical and economic outcomes in Nadia under similar agroclimatic conditions.

3.2 Analysis of Variance (ANOVA)

To statistically verify the observed differences between *CRIJAF SONA* users and control farmers, a one-way ANOVA was conducted for all major variables (Table 2).

Table 2. One-way ANOVA results comparing CRIJAF SONA users and control farmers

Variable	F-value	p-value	Significance
Retting Duration	131.26	< 0.001	Highly Significant
Yield	571.34	< 0.001	Highly Significant
Market Price	1657.35	< 0.001	Extremely Significant
Gross Income	3418.54	< 0.001	Extremely Significant

All of the p-values were less than 0.001, which provided strong statistical proof that CRIJAF SONA significantly affected retting efficiency, yield performance, market value, and income generation. The F-values demonstrate that a significant amount of variability was explained by the treatment effect, particularly for market price and gross revenue. This implies that rather than chance or background noise, the implementation of CRIJAF SONA was the primary cause of the improved outcomes.

3.3 Post-hoc Comparison (Tukey's HSD Test)

Tukey's Honest Significant Difference (HSD) post-hoc analysis was carried out after ANOVA in order to confirm the validity of observed mean differences. In all assessed parameters, the post-hoc comparisons showed statistically significant differences ($p < 0.001$) between farmers in the control group and those who adopted CRIJAF SONA. In terms of operational, yield-related, and economic aspects, these results offer more proof that the enhanced retting technique performs better than traditional methods.

3.4 Effect Size (Cohen's d)

Beyond statistical significance, the magnitude of impact was evaluated using Cohen's d to assess practical relevance. The calculated effect sizes are summarised in Table 3.

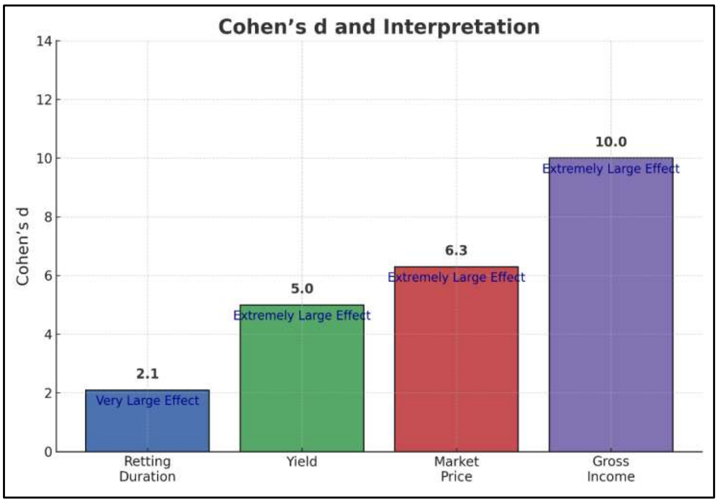


Fig.2 Cohen's d values indicating the magnitude of differences

According to Cohen's (1988) guidelines, all observed values indicate very large to extremely large effects, implying that the impact of *CRIJAF SONA* on retting duration, fibre yield, price, and profitability is not only statistically significant but also highly meaningful in practical terms (Fig.2). The extremely high effect size for gross income ($d = 10.0$) underscores the transformative economic potential of the microbial retting formulation for small and medium-scale jute farmers in Nadia.

4. Discussion

The results from this comparative analysis clearly demonstrate that the use of *CRIJAF SONA* retting formulation has a transformative effect on fibre processing efficiency, product quality, and farmer profitability under the agro-ecological conditions of Nadia district.

4.1 Reduction in Retting Duration

CRIJAF SONA reduced the retting duration from an average of 18 days (traditional method) to 14 days, a 22% reduction. This improvement is attributed to the enhanced activity of the *Bacillus* strains (*B. safensis*, *B. velezensis*, and *B. altitudinis*) that accelerate the decomposition of pectic substances and facilitate fibre separation without degrading cellulose (Datta et al., 2020; Majumdar et al., 2024). Shorter retting cycles allow for quicker field turnover, better water resource management, and reduced stagnation, enabling farmers to plan subsequent crops more efficiently.

4.2 Increase in Fibre Yield

According to the current study, CRIJAF SONA users increased their fibre yield by 27–30% when compared to the control group. Reduced fibre loss during the extraction process and improved microbial breakdown of non-cellulosic plant components could be the causes of this improvement.

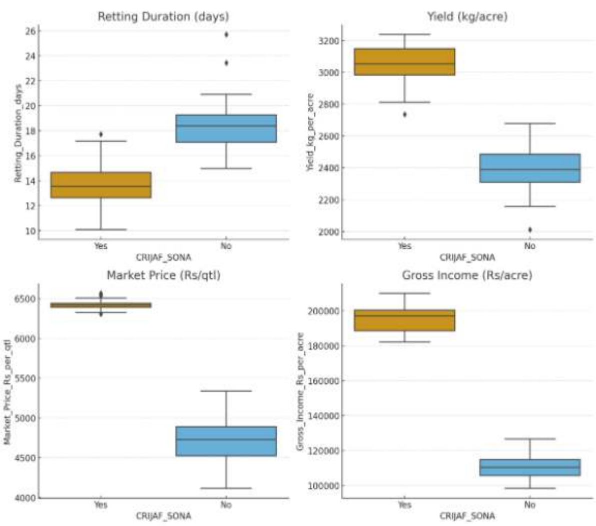
In line with earlier findings published by Majumdar et al. (2021) and Das et al. (2015), the increased retting efficiency led to higher fibre recovery rates and more homogeneity in fibre texture. The economic returns per unit crop area are directly impacted by these productivity gains, which could increase the jute production systems' competitiveness and commercial viability.

4.3 Improvement in Fibre Quality and Market Price

A 35–40% price premium that CRIJAF SONA adopters were able to secure in market negotiations demonstrated improvements in fibre quality. The treated fibres met the grading requirements set by both domestic textile mills and foreign export markets, demonstrating superior qualities in terms of colour retention, lustre, and tensile strength (Chatterjee & Mondal, 2022). Improved spinnability and reduced processing waste are expected to result from increased fibre homogeneity and decreased root content, which will ultimately enhance overall value chain efficiency.

4.4 Economic Advantage and Farmer Profitability

A major outcome of this study is the substantial economic advantage associated with *CRIJAF SONA* adoption. On average, farmers achieved an additional gross income of ₹ 80,000–90,000 per acre, marking a 77% increase over traditional retting (Fig. 2). The higher returns stem from improved fibre yield and superior market price, with relatively low incremental costs for the microbial formulation. This demonstrates a high benefit–cost ratio, validating the economic feasibility of *CRIJAF SONA* as a sustainable and profitable retting innovation for smallholder farmers.



4.5 Statistical Robustness and Practical Implications

The highly significant ANOVA results ($p < 0.001$) and extremely large Cohen's d values confirm the statistical robustness of the observed differences. These findings underscore that *CRIJAF SONA*'s benefits are consistent, replicable, and economically meaningful across diverse farmer profiles. The large effect size for income particularly highlights its transformative role in improving rural household economics, aligning with previous adoption studies that reported strong farmer satisfaction and perceived advantage indices above 90% (Chatterjee & Mondal, 2022).

4.6 Environmental and Sustainability Perspectives

Beyond economic outcomes, *CRIJAF SONA* offers environmental co-benefits by reducing the biological oxygen demand (BOD) and chemical oxygen demand (COD) of retting water, minimising pollution and odour typically associated with conventional retting (Majumdar et al., 2013; Singh et al., 2018). The shortened retting cycle also reduces water use and limits methane emissions from anaerobic decomposition, contributing to a lower carbon footprint in fibre production (Singh et al., 2019). These attributes position *CRIJAF SONA* as an integral component of climate-resilient and low-carbon agricultural systems in eastern India.

CONCLUSION

The study shows that for jute production in West Bengal's Nadia district, the CRIJAF SONA microbial retting formulation offers strong technical, financial, and environmental benefits. The method optimises water management and allows for faster crop turnover by cutting the retting period from 18 to 14 days. A notable 77% increase in gross income, or ₹80,000–90,000 per acre, was achieved as a result of improvements in quality, which secured 35–40% higher market prices, and a roughly 30% increase in fibre output and recovery. Statistical analysis provides substantial validation of these results ($p < 0.001$, Cohen's d 5.0–10.0), indicating that the advantages are both practically significant. Benefits to the environment include less water pollution from retting, less biological and chemical oxygen demand (BOD/COD), less unpleasant odour, and fewer greenhouse gas emissions, all of which help the country achieve its goals for cleaner production and climate-resilient agriculture. Its high Technology Effectiveness Index (85.41%), ease of use, and strong farmer satisfaction all speak to its preparedness for wider distribution.

State and national jute development plans run by organisations like the National Jute Board, ICAR, and the Ministry of Textiles should incorporate CRIJAF SONA at the policy level in light of these changes in society. Incorporating the formulation into Krishi Vigyan Kendra demonstration programs and input subsidy schemes, launching focused farmer education and awareness campaigns, bolstering local production and distribution through public-private partnerships and rural entrepreneurship, and encouraging adoption through environmental certification as an environmentally friendly procedure are some of the suggested actions. Performance across various agro-ecological zones should be guaranteed by ongoing field testing and effect monitoring, which should also improve usage recommendations. In the end, CRIJAF SONA is more than just a retting aid; it is a catalyst for climate-smart, low-carbon growth in India's natural fibre industry, boosting sustainability, productivity, and profitability while solidifying India's position as a leader in the production of environmentally friendly fibre and providing stable livelihoods for rural communities that depend on jute.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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