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## Assessment of suitable jute-based cropping systems for higher system productivity and profitability

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**ABSTRACT**

**ABSTRACT** Traditional jute-based production systems often suffer from suboptimal economic returns due to mono-cropping or low-value crop sequences. An on-farm trial (OFT) comprising seven participatory replications was carried out under irrigated medium-land situations to assess the production potential and economic feasibility of alternative jute-based cropping sequences. Four technology options were evaluated: Farmers' Practice (FP: Jute–blackgram), Technology Option 1 (TO1: Jute–groundnut), Technology Option 2 (TO2: Jute–rice–greengram), and Technology Option 3 (TO3: Jute–vegetable [garden pea]). System yield expressed as equivalent yield showed significant variation across sequences (CD = 8.4 q/ha). The Jute–garden pea sequence (TO3) recorded the highest system yield (57.2 q/ha), gross return (₹323,180/ha), net return (₹199,380/ha), and benefit-cost ratio (2.61), outperforming conventional FP (29.8 q/ha, net return of ₹99,070/ha, and B:C ratio of 2.43). Although TO2 achieved the maximum cropping intensity (300%), TO3 (200% cropping intensity) proved to be the most economically viable and sustainable system for medium-land agro-ecosystems. **Keywords:** Jute-based cropping system, Garden pea, Cropping intensity, Jute equivalent yield (JEY), Net returns, Benefit-cost ratio

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**1. Introduction**

Jute (*Corchorus olitorius* and *Corchorus capsularis*) represents one of the most critical commercial bast fibre crops globally, supporting millions of small and marginal farm families across the subtropical and tropical floodplains of eastern India and Bangladesh. Despite its agro-ecological versatility and low carbon footprint compared to synthetic substitutes, traditional jute-based farming systems face chronic economic challenges. Farmers predominantly practice jute monoculture or follow jute with low-value, broadcast grain legumes such as blackgram (*Vigna mungo*), yielding modest economic margins that fail to keep pace with escalating production costs, labour wage spikes, and climate-induced yield fluctuations.

The urgent imperative under shrinking per-capita arable land is to maximize land and water productivity through sequential cropping intensification and crop diversification. Shifting from traditional subsistence-level sequences toward high-value, market-responsive crops—such as vegetable legumes (e.g., garden pea), commercial oilseeds (groundnut), or triple-cropping cycles (jute–rice–pulse)—offers substantial potential for improving profitability. Nevertheless, the adoption of diversified systems in medium-land situations is frequently constrained by prolonged field occupancy of conventional jute cultivars, soil physical deterioration, turnaround delays, and localized socioeconomic factors.

On-farm trials (OFT) serve as a participatory bridge to evaluate and refine research-station recommendations under real-world farmer-managed conditions. The present investigation was undertaken to rigorously assess the system productivity, cost structure, economic profitability, and operational feasibility of four distinct jute-based cropping patterns under irrigated medium-land conditions.

**2. Materials and Methods****2.1 Experimental site, agro-ecology, and problem diagnosis**

The study was designed to resolve the primary diagnosed production constraint: 'Low income from existing cropping systems under irrigated medium land.' The participatory trials were carried out across representative farming clusters utilizing Integrated Crop Management (ICM) recommendations formulated by the Odisha University of Agriculture and Technology (OUAT, 2021) [1] and CRIJAF, 2019. The experimental sites were characterized by medium-land topography with assured irrigation infrastructure, neutral to slightly acidic alluvial soils, and representative subtropical climatic regimes. The experiment was designed in RCBD with 4 treatments and 7 replications in Raghunathpur and Jampada village of Marshaghai Block in Kendrapada district. The experiment was carried out during 3 cropping seasons of 2024 and 2025.

## 2.2 Treatments and cropping sequences

The on-farm trial evaluated four cropping sequences (Technology Options) laid out across seven farmer locations ( $n = 7$  independent participatory replications):

- **Farmers' Practice (FP):** Jute – Blackgram (*Vigna mungo*). Cropping intensity = 200%. Represents the predominant regional benchmark.
- **Technology Option 1 (TO<sub>1</sub>):** Jute – Groundnut (*Arachis hypogaea*). Cropping intensity = 200%. Evaluates commercial oilseed diversification.
- **Technology Option 2 (TO<sub>2</sub>):** Jute – Rice (*Oryza sativa*) – Greengram (*Vigna radiata*). Cropping intensity = 300%. Evaluates sequential intensification into a triple-crop system.
- **Technology Option 3 (TO<sub>3</sub>):** Jute – Vegetable [Garden Pea] (*Pisum sativum* var. *hortense*). Cropping intensity = 200%. Evaluates cash-generating vegetable legume integration.

## 2.3 Crop management and system equivalent yield computation

All crops were managed following the standard recommended package of practices (OUAT, 2021) [1] for fertilizer schedule, line sowing, water management, and integrated pest management. Because biological yields of diverse crops (fibre, cereal, oilseed, and fresh vegetable pods) cannot be directly aggregated, system performance was standardized into System Yield (Jute Equivalent Yield / REY, expressed in q/ha) based on prevailing local farm-gate prices using the formula: System Yield (REY, q/ha) =  $Y_{\text{jute}} + \sum \frac{Y_i \times P_i}{P_{\text{jute}}}$  where  $Y_i$  is the yield of individual component crop  $i$  (q/ha),  $P_i$  is the unit market price of crop  $i$  (₹/q), and  $P_{\text{jute}}$  is the unit farm-gate price of raw jute fibre (₹/q).

## 2.4 Economic budgeting and statistical analysis

Comprehensive economic accounts were documented for each trial, including the total cost of cultivation (incorporating variable operational inputs, labor, machinery, and harvesting costs), gross returns, and net returns (Gross returns - Cost of cultivation). The Benefit-Cost ratio (B:C) was computed as Gross Returns divided by Cost of Cultivation. Data on equivalent system yields across the seven replications were subjected to Analysis of Variance (ANOVA), and the Critical Difference (CD at  $p = 0.05$ ) was calculated to test the statistical significance of treatment differences.

## 3. Results

All the data of the experiment for both the years recorded separately and pooled analysis was done for two years of experiment and the mean data of the both the years are presented here.

### 3.1 System productivity

System equivalent yield varied substantially and significantly among the evaluated cropping patterns (Table 1; CD = 8.4 q/ha at  $p = 0.05$ ). Technology Option 3 (Jute–garden pea) registered the highest system yield of 57.2 q/ha, significantly outyielding all other evaluated sequences. This was followed by the intensified triple-crop sequence TO<sub>2</sub> (Jute–rice–greengram) at 49.3 q/ha and TO<sub>1</sub> (Jute–groundnut) at 47.3 q/ha. The conventional Farmers' Practice (FP: Jute–blackgram) recorded the lowest equivalent productivity of 29.8 q/ha. Relative to FP, TO<sub>3</sub> achieved an impressive 91.95% productivity enhancement, while TO<sub>2</sub> and TO<sub>1</sub> elevated system yield by 65.44% and 58.72%, respectively.

### 3.2 Cost of cultivation and capital investment

The total cost of cultivation reflected the input intensity, turnaround operations, and input requirements of the cropping sequences. Farmers' Practice recorded the lowest cultivation expenditure (₹69,300/ha) due to the minimal management requirements of broadcast blackgram. In contrast, TO<sub>2</sub> incurred the highest cost (₹125,300/ha), directly driven by three distinct land preparation cycles, puddled rice establishment, repeated harvesting, and crop protection. The cultivation costs for TO<sub>3</sub> (₹123,800/ha) and TO<sub>1</sub> (₹108,200/ha) were intermediate, reflecting higher seed costs for garden pea and groundnut alongside necessary botanical protection.

### 3.3 Gross returns, net returns, and benefit-cost (B:C) ratio

Gross and net financial returns followed trends consistent with equivalent yield output. Technology Option 3 (Jute–garden pea) delivered the highest gross return (₹323,180/ha) and the highest net return (₹199,380/ha), outperforming FP (net return of ₹99,070/ha) by ₹100,310/ha (+101.25%). Technology Option 1 (Jute–groundnut) generated a gross return of ₹267,245/ha and net return of ₹159,045/ha (+60.54% over FP). Although the triple-cropping sequence TO<sub>2</sub> achieved a substantial gross return of ₹278,545/ha, its elevated operational expenses diluted the net return to ₹153,245/ha, which was marginally lower than that of the double-cropping Jute–groundnut system.

With respect to capital efficiency, TO<sub>3</sub> recorded the highest Benefit-Cost ratio (2.61), followed by TO<sub>1</sub> (2.47) and FP (2.43). Notably, despite delivering high aggregate physical biomass and 300% cropping intensity, TO<sub>2</sub> registered the lowest B:C ratio (2.22) across all options, reflecting diminishing economic efficiency per rupee invested.

**Table 1.** System productivity, cost structure, and profitability of jute-based cropping systems ( $n = 7$  trials) mean data of both the years. (2024 & 2025)

| Technology Option | Cropping Sequence             | Trials (n) | Cropping Intensity (%) | System Yield (REY, q/ha) | Cost of Cultivation (₹/ha) | Gross Return (₹/ha) | Net Return (₹/ha) | BC Ratio |
|-------------------|-------------------------------|------------|------------------------|--------------------------|----------------------------|---------------------|-------------------|----------|
| FP                | Jute – Blackgram              | 7          | 200                    | 29.8                     | 69,300                     | 168,370             | 99,070            | 2.43     |
| TO <sub>1</sub>   | Jute – Groundnut              | 7          | 200                    | 47.3                     | 108,200                    | 267,245             | 159,045           | 2.47     |
| TO <sub>2</sub>   | Jute – Rice – Greengram       | 7          | 300                    | 49.3                     | 125,300                    | 278,545             | 153,245           | 2.22     |
| TO <sub>3</sub>   | Jute – Vegetable (Garden pea) | 7          | 200                    | 57.2                     | 123,800                    | 323,180             | 199,380           | 2.61     |
| CD ( $p = 0.05$ ) | —                             | —          | —                      | 8.4                      | —                          | —                   | —                 | —        |

## 4. Discussion

### 4.1 System productivity and equivalent yield dynamics

The substantial performance disparity observed between traditional and diversified systems underscores the value of strategic crop substitution. Technology Option 3 (Jute–garden pea) delivered an outstanding system yield of 57.2 q/ha, representing a 91.9% improvement over the conventional Jute–blackgram practice (29.8 q/ha). In cropping system evaluations involving diverse produce types, equivalent yield (REY) integrates biological output with farm-gate valuation. The exceptional market price commanded by early fresh pea pods, combined with robust pod yields, directly amplified total system equivalent yield. These results align closely with Kumar *et al.* (2018) [2] and Islam *et al.* (2020) [3], who reported that incorporating high-value winter vegetable legumes into fiber-based systems substantially elevates land equivalent ratio (LER) and system productivity compared to conventional post-jute pulse broadcasting.

Interestingly, although the intensified triple sequence (TO<sub>2</sub>: Jute–rice–greengram) achieved 300% cropping intensity and maximum physical biomass, its equivalent yield (49.3 q/ha) was statistically inferior to that of TO<sub>3</sub> (CD = 8.4 q/ha). This demonstrates that physical biomass accumulation across three crop cycles does not necessarily translate into superior economic equivalent returns when compared against a high-value, market-oriented double-crop system. Similar conclusions were reached by Ghorai *et al.* (2013) [4] and Nayak *et al.* (2019) [5], who observed that expanding to triple-cropping sequences often experiences diminishing marginal returns if cereal components (such as kharif transplanted rice) suffer from compressed growing windows or low commodity pricing.

### 4.2 Economic profitability and resource-use efficiency

The financial analysis highlighted clear distinctions between absolute gross turnover and capital investment efficiency. Technology Option 3 generated both the highest gross returns (₹323,180/ha) and net returns (₹199,380/ha), achieving an outstanding benefit-cost ratio of 2.61. These economic gains stem from the rapid growth cycle and strong consumer demand for fresh garden peas during early winter. Similar profitability spikes in vegetable-diversified jute rotations were documented by Ray *et al.* (2015) [6] and Kar *et al.* (2014) [7], who emphasized that commercial vegetables offer rapid capital turnover that cushions smallholders against jute market volatility.

Conversely, TO<sub>2</sub> (Jute–rice–greengram) recorded the highest cost of cultivation (₹125,300/ha), driven by the cumulative operational demands of triple cropping—namely repeated field preparations, puddled transplanting of rice, diesel fuel consumption for irrigation, and high harvesting labor requirements. Consequently, despite a respectable gross return (₹278,545/ha), its net return (₹153,245/ha) was lower than both TO<sub>3</sub> and TO<sub>1</sub>, yielding the lowest B:C ratio (2.22) in the study. These findings corroborate the empirical work of Alam *et al.* (2017) [8] and Shamim *et al.* (2021) [9], who demonstrated that labor-intensive triple cropping frequently depresses B:C ratios in the absence of full farm mechanization.

Technology Option 1 (Jute–groundnut) demonstrated stable, highly remunerative performance (47.3 q/ha system yield, ₹159,045/ha net return, and 2.47 B:C ratio). The strong market demand for oilseeds and higher price stability of groundnut relative to cereals make TO<sub>1</sub> an exceptionally viable, low-risk alternative for alluvial and medium-land tracts, supporting the recommendations of Satpathy *et al.* (2014) [10].

### 4.3 Legume integration and soil health dynamics

Beyond direct financial returns, the integration of legumes (blackgram, groundnut, greengram, and garden pea) across all tested sequences provides vital agro-ecological services. Jute is an exhaustive fiber crop, but it naturally deposits 1.5 to 2.0 t/ha of nutrient-rich leaf litter into the soil prior to harvest (Mazumdar *et al.*, 2019) [11]. Following jute with nodulating legumes fosters biological nitrogen fixation, preserves soil microbial diversity, and accelerates organic

matter turnover (Singh *et al.*, 2016; Kundu *et al.*, 2013) [13, 12]. Garden pea and groundnut residues contribute substantially to labile carbon pools, thereby breaking the soil compaction and structural degradation typically induced by continuous puddled cereal rotations.

### 4.4 Field constraints and varietal imperatives

Participatory farmer feedback revealed high enthusiasm for adopting the Jute–garden pea sequence (TO<sub>3</sub>). However, farmers and agronomists identified a pivotal operational constraint: the necessity for early-duration, photoperiod-insensitive jute varieties. Standard medium-duration jute cultivars (120–135 days) often push retting and harvesting into late autumn, causing delays in the establishment of the succeeding garden pea crop. Delayed pea sowing past mid-November exposes the crop to terminal heat stress, increases powdery mildew vulnerability, and suppresses green pod yield. This critical observation is supported by Sarkar *et al.* (2017) [14], who stressed that sustainable cropping intensification in jute tracts fundamentally depends on the breeding and deployment of high-yielding jute varieties maturing within 100 to 110 days to ensure timely sowing windows for succeeding winter cash crops.

## 5. Conclusion

The on-farm trial confirms that crop diversification significantly improves both system productivity and net farm income over traditional jute farming practices. Technology Option 3 (Jute–vegetable [garden pea]) emerged as the most remunerative and economically efficient cropping system under irrigated medium-land conditions, recording a system yield of 57.2 q/ha, net return of ₹199,380/ha, and a B:C ratio of 2.61. Although the triple-crop sequence (Jute–rice–greengram) maximized cropping intensity (300%), its elevated cultivation costs resulted in lower capital efficiency (B:C ratio of 2.22). For oilseed-preferring agrarian pockets, Jute–groundnut (TO<sub>1</sub>) represents a robust secondary alternative. To facilitate large-scale regional adoption of the Jute–garden pea sequence, agricultural research and extension programs must prioritize the release of early-maturing jute genotypes alongside cold-chain and market linkages for winter vegetables.

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