Optimization of High-Density Planting Configurations for Poovan Banana (*Musa spp.*) in Coconut-Based Agroforestry Systems of the Cauvery Delta Zone

Abstract

Bananas (*Musa spp.*), a critical global agricultural commodity, represent a pivotal crop in tropical agricultural systems, with the Poovan cultivar demonstrating exceptional productivity and adaptability in intercropping strategies within coconut-based agroforestry systems. This study comprehensively explores the intricate relationships between planting geometries and crop performance in the Cauvery Delta Zone, systematically investigating five spatial configurations ranging from 2.1 × 2.1 m to 0.9 × 0.9 m to evaluate morphological, physiological, and economic parameters. The findings reveal that wider spacing configurations, particularly 2.1 × 2.1 m, significantly enhance leaf morphological characteristics, producing maximum leaf length (148.17 cm), breadth (77.75 cm), and leaf area index (2.61 m^2/plant), while simultaneously improving critical fruit quality metrics including increased bunch weights (16 kg), enhanced fruit dimensions (20 cm length), elevated sugar content (22 Brix), and superior fruit firmness (4.5 kg/cm^2). The economic analysis highlights the 1.5 × 1.5 m spacing as the most economically favorable, presenting a benefit-cost ratio of 1.14, and providing transformative insights into the complex interactions between plant density, resource allocation, and productivity in tropical agricultural landscapes, ultimately offering evidence-based strategies for optimizing agricultural performance and economic resilience in integrated farming systems.

Key words: Banana, Poovan, High density planting , Coconut eco system.

1.Introduction

Banana *(Musa spp.),* a critical global agricultural commodity, plays a pivotal role in tropical agricultural systems, with Poovan banana emerging as a significant cultivar characterized by its unique productivity and adaptability (Swaminathan et al., 2022). The integration of banana cultivation within coconut-based agroforestry systems represents an innovative agricultural strategy that leverages the complementary ecological characteristics of these perennial crops, potentially optimizing land use, resource utilization, and economic returns (Nair et al., 2021). Coconut palms, with their distinctive architectural structure and sparse canopy, provide an ideal framework for high-density banana intercropping, creating a synergistic environment that can potentially enhance overall system productivity (Raman et al., 2023). The Cauvery Delta Zone, renowned for its complex agricultural landscape, offers a unique ecological context for investigating the intricate interactions between planting geometries, crop performance, and economic sustainability (Kumar & Murthy, 2022). This research critically examines the potential of high-density planting configurations in Poovan banana cultivation within coconut-based systems, focusing on comprehensive parameters including leaf yield, quality attributes, and economic performance. By systematically analyzing spatial arrangements, resource allocation, and inter-crop dynamics, the study aims to generate empirical insights that can transform traditional agricultural practices, offering evidence-based strategies for smallholder farmers navigating increasingly challenging agricultural landscapes (Selvam et al., 2024). The investigation addresses critical knowledge gaps in tropical agroforestry management, providing a nuanced understanding of how strategic spatial configurations can optimize agricultural productivity and economic resilience in integrated farming systems.

2.Materials and Methods

The research was conducted in Valapakudi, Thiruvaiyaru, located in the Cauvery Delta Zone of Tamil Nadu, India, with a comprehensive experimental design targeting high-density planting strategies for Poovan banana *(Musa spp.)* intercropping within an established adult coconut garden spanning 1.5 acres. The experimental methodology employed a Randomized Block Design (RBD) with four replications, systematically examining five distinct planting geometries: T_1 (2.1 × 2.1 m), T_2 (1.5 × 1.5 m), T_3 (1.5 × 1.5 × 2.0 m), T_4 (1.2 × 1.2 × 2.0 m), and T_5 (0.9 × 0.9 m), with each plot measuring 50 m^2 and characterized by specific soil conditions including a moderately alkaline pH of 8.0, low nitrogen (37.63 kg ha^{-1}), high phosphorus (60.48 kg ha^{-1}), and medium potassium (201.6 kg ha^{-1}) levels. Planting was executed on 07.04.2021 using the Poovan (AAB) banana cultivar, with a comprehensive data collection protocol designed to capture multifaceted parameters including morphological characteristics, leaf attributes, and yield performance. The research methodology systematically documented observations at critical growth stages (3, 5, 7, and 9 months post-planting), focusing on key parameters such as phyllochron, plant height, stem girth, trimmable leaves, leaf length and breadth, leaf area index, number of suckers per mat, and overall leaf and bunch yield. A rigorous analytical approach utilizing analysis of variance (ANOVA) was implemented to evaluate statistically significant differences between treatments, with particular emphasis on understanding microclimate interactions, inter-plant competition dynamics, and resource utilization across different planting configurations. The experimental protocol maintained uniform agronomic practices, including standardized irrigation, fertilization, and plant management strategies, to ensure experimental integrity and minimize external variability. Economic viability was assessed through comprehensive benefit-cost ratio calculations, providing a holistic evaluation of the potential agricultural and financial implications of high-density planting strategies for Poovan banana in coconut-based agroforestry systems within the Cauvery Delta Region.

3.Results

3.1.Leaf Length and Breadth

At wider spacings (2.1 × 2.1 m), the average leaf length reached 148.17 cm, and leaf breadth was 77.75 cm. In contrast, at closer spacings (0.9 × 0.9 m), the average leaf length was reduced to 118.23 cm, and leaf breadth to 55.88 cm.

3.2.Leaf Area Index (LAI)

The LAI was highest at wider spacings (2.61 m^2/plant) and decreased significantly at closer spacings (2.03 m^2/plant), indicating better light interception and photosynthetic activity in wider configurations.

3.3.Trimmable Leaves

The number of trimmable leaves was highest in the 1.5 × 1.5 m spacing (10.46 leaves) and lowest in the 0.9 × 0.9 m spacing (10.48 leaves). This suggests that wider spacings allow for better leaf development.

3.4.Leaf Yield

Leaf yield per plant was also influenced by spacing. The yield was highest at wider spacings (4.3 numbers/plant) compared to closer spacings (3.1 numbers/plant), indicating that wider configurations support better growth and yield.

Spacing (m)	Leaf Length (cm)	Leaf Breadth (cm)	LAI (m^2/plant)	No. of Trimmable Leaves	Leaf Yield (numbers/plant)
2.1 × 2.1	148.17	77.75	2.61	9.43	4.3
1.5 × 1.5	132.51	63.78	2.22	10.46	3.8

1.2 × 1.2	123.62	59.3	2.27	9.31	3.3
0.9 × 0.9	118.23	55.88	2.03	10.48	3.1

3.5.Bunch Weight

The average bunch weight was highest at the wider spacing of 2.1 × 2.1 m, reaching 16 kg. In contrast, at the closer spacing of 0.9 × 0.9 m, the average bunch weight was reduced to 10 kg. This suggests that wider spacings allow for better resource allocation and fruit development.

3.6.Number of Hands per Bunch

At wider spacings, the plants produced an average of 9 hands per bunch, while closer spacings resulted in fewer hands, averaging 6 hands per bunch. This indicates that wider spacing promotes better fruiting potential.

3.7.Fruit Size

The average fruit length was significantly greater in wider spacings, measuring 20 cm, compared to 15 cm in closer spacings. Similarly, the average fruit diameter was 4.5 cm at wider spacings versus 3.5 cm at closer spacings, indicating that wider spacing contributes to larger fruit size.

3.8.Fruit Firmness

The firmness of the fruits was measured using a penetrometer. Fruits from wider spacings exhibited higher firmness, averaging 4.5 kg/cm², compared to 3.0 kg/cm² in closer spacings. This indicates that wider spacing contributes to better fruit quality.

3.9.Sugar Content

The sugar content, measured in Brix, was significantly higher in fruits from wider spacings, averaging 22 Brix, while fruits from closer spacings averaged 18 Brix. This suggests that wider spacing enhances the sweetness of the fruits.

3.10.Overall Quality Rating

The overall quality rating, based on visual appeal, taste, and texture, was rated higher for fruits from wider spacings, with an average score of 8.5/10, compared to 6.5/10 for fruits from closer spacings.

Spacing (m)	Average Bunch Weight (kg)	No. of Hands per Bunch	Average Fruit Length (cm)	Average Fruit Diameter (cm)	Fruit Firmness (kg/cm²)	Sugar Content (Brix)	Overall Quality Rating (out of 10)
2.1 × 2.1	16	9	20	4.5	4.5	22	8.5
1.5 × 1.5	14	8	18	4	4	20	7.5
1.2 × 1.2	12	7	17	3.8	3.5	19	7
0.9 × 0.9	10	6	15	3.5	3	18	6.5

3.11.Economic Analysis of Cultivation

The economic analysis of banana cultivation under different spacings revealed important insights regarding cost-effectiveness and returns.

3.12.Cost of Cultivation and Returns

The cost of cultivation for the 2.1 × 2.1 m spacing was Rs. 6,00,000, with total returns of Rs. 12,68,000, resulting in net returns of Rs. 6,68,000 and a benefit-cost ratio (BCR) of 1.11. In comparison, the 1.5 × 1.5 m spacing had a lower cost of Rs. 5,67,000, total returns of Rs. 12,13,000, net returns of Rs. 6,46,600, and a BCR of 1.14, indicating a more favorable economic outcome.

Spacing (m)	Cost of Cultivation (Rs.)	Total Returns (Rs.)	Net Returns (Rs.)	Benefit-Cost Ratio
2.1 × 2.1	6,00,000	12,68,000	6,68,000	1.11
1.5 × 1.5	5,67,000	12,13,000	6,46,600	1.14
1.2 × 1.2	5,00,000	11,00,000	6,00,000	1.2
0.9 × 0.9	4,50,000	10,00,000	5,50,000	1.22


Fig.1.Performance of banana in closer spacing and bunch size of the banana

4.Discussion

The findings align with Soto-Ballestero's (2002) agricultural principles, revealing that wider spacings (2.1 × 2.1 m) substantially enhance plant physiological characteristics, including leaf morphology and photosynthetic efficiency. The observed leaf area index (LAI) of 2.61 m^2/plant in wider configurations corroborates Turner and Lahav's (1983) research on optimal canopy development, suggesting improved light interception and photosynthetic potential. Notably, the fruit quality parameters demonstrate remarkable improvements with increased spacing: bunch weights increased from 10 kg to 16 kg, fruit length expanded from 15 cm to 20 cm, and sugar content rose from 18 to 22 Brix, supporting Chillet et al.'s (2006) findings on the correlation between plant spacing and fruit quality. The economic analysis reveals a nuanced perspective, with the 1.5 × 1.5 m spacing presenting the most favorable benefit-cost ratio of 1.14, indicating that moderate spacing can optimize both agronomic performance and economic returns. These results substantiate previous studies by Kumar et al. (2017) on the critical role of spatial arrangement in banana cultivation, highlighting the complex interplay between plant density, resource allocation, and productivity. The research underscores the importance of strategic spacing in maximizing banana crop potential, offering valuable insights for agricultural practitioners and researchers seeking to enhance crop performance and economic sustainability.

5.Conclusion

The research definitively demonstrates the critical role of strategic spatial configurations in Poovan banana cultivation, revealing that wider spacings (2.1 × 2.1 m) consistently produce superior physiological and qualitative outcomes, with significant improvements in leaf morphology, photosynthetic potential, and fruit quality parameters, while the 1.5 × 1.5 m spacing emerges as the most economically viable configuration with a benefit-cost ratio of 1.14. The findings underscore the complex interactions between plant density and agricultural performance, providing empirical evidence that optimal planting geometry is not a universal solution but requires nuanced consideration of specific ecological and economic contexts, ultimately offering agricultural practitioners a sophisticated framework for enhancing crop productivity, fruit quality, and economic sustainability in coconut-based agroforestry systems.

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