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TECHNICAL AND ALLOCATIVE EFFICIENCY IN RATOON CULTIVATION OF BANANA - AN ECONOMIC ANALYSIS FROM TAMIL NADU INDIA

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ABSTRACT

The study was conducted to analyze the profitability, technical efficiency as well as resource use efficiency of banana cultivation adopting ratoon practice. The primary data was collected from 36 banana cultivators who followed ratoon practices in banana cultivation in Tiruchirappalli district of Tamil Nadu. The multistage sampling technique was employed to select the respondents who adopted Poovan and Rasthali varieties for ratoon cultivation of banana. Average agricultural land holding of sample banana growers was assessed to be 9.09 acres of which around 73% put under banana cultivation. Application of all inputs was decreased except biofertilizers and agro-chemical from 1st cycle to 2nd cycle (1st ratooning) and FYM in 2nd ratooning. 50% reduction in use of agrochemical was noticed in 2nd ratooning. The estimated overall total cost (Cost_{C₃}) of cultivation was computed at Rs 1,91,599.50 in the first cycle, which was sharply reduced in ratooning phases to tune of 29 to 31%. The magnitude of total cost for both Poovan and Rasthali varieties were identical of which about 40% expended as labour cost. The dominated cost component of operational cost were labour cost, cost of inorganic fertilizers, cost of farmyard manure and cost of pole for propping. The Cost_{A₁} constituted 73 to 74% in ratooning stages. The net income (Rs/acre) was observed to be highest in first ratooning compared to 1st cycle and 2nd ratooning. The technical ratio (discounted B:C ratio) is estimated at 1.52 for the Poovan variety and 1.63 for the Rasthali variety. With respect to allocative efficiency, explanatory variables could explain 77.22% and 54.35% variation of yield for Poovan and Rasthali varieties respectively. Micro-nutrient, Agrochemical and irrigation were over utilized in Poovan variety while human labour, urea, DAP, micronutrient and irrigation were underutilized in Rasthali variety. Adverse climatic conditions, labour intensiveness and weeds were the major constraints in ratoon cultivation of banana.

Key words: Allocative efficiency, Operational Cost, Ratoon cultivation, Technical efficiency, Variety

Introduction

Horticulture forms a significant component of Indian agriculture, contributing about 30–33% of India's agricultural Gross Value Added (GVA) while utilizing roughly 13% of the gross cropped area (Horticulture at a glance, 2024 and Annual Report 2024-25, MA&FW). Horticultural crops in India primarily include vegetables, fruits, plantation crops, ornamental plants, and medicinal plants. During 2023-24, fruits alone constituted 31.85% of total volume of horticultural production (Horticulture at a glance, 2024). Among horticultural fruits in India, banana is the second most important fruit next to mango

(Kumar and Nishad, 2018). Among fruits, Banana production contributed 33.29% of total fruit production occupied first position during 2023-24 (Horticulture at a glance, 2024).

India is the largest producer of banana, followed by China, Indonesia, the Philippines, and Brazil, with global banana production reaching nearly 32.73 million tons in 2023 contributing 26-27% of global banana production and contributes 2.8% of the agricultural GDP in India (Horticulture at a glance, 2024 and FAOSTAT 2025). The top five banana producing states in India are Maharashtra, Andhra Pradesh, Tamil Nadu, Uttar

Pradesh and Gujarat together accounting for about 67% of the country's output whereas Tamil Nadu alone contributed 12.55% of national production in 2023-24. (Horticulture at a glance, 2024).

Banana (*Musa* spp.), belonging to the family Musaceae, is one of the most important and fruit crops consumed worldwide. Originating from Southeast Asia (Vignesh *et al.*, 2022) mainly cultivated in tropical and sub-tropical regions of developing countries (Thorat *et al.*, 2014). Banana is popular due to its traditional, nutritional and medicinal uses. Bananas are the important source of potassium (358 mg/100 g) and carbohydrates (22.84 g/100 g) (Ranjha *et al.*, 2026). Banana is the sources of different minerals like potassium, calcium, phosphorus, sodium, magnesium, zinc, iron, manganese, boron, and copper and also high contents of vitamins A, C and B-complex and moderately rich in vitamin B6 (Qamar & Shaikh, 2018) and has antioxidant, antimicrobial, and antidiabetic properties due the presence of bioactive compounds (Kumari *et al.*, 2023). Due to rich content of potassium banana is also valuable for human health (Anyasi *et al.*, 2018). The potassium content in Banana plays a vital role in regulating blood pressure, supporting cardiovascular function, and muscle contraction (Anyasi *et al.*, 2013; Yadav, 2021). Banana is also called "Apple of Paradise" and a rich source of energy (104 kcal/100g) (Kumar and Nishad, 2018; Vinayagamoorthi *et al.*, 2019). Due to its multiple uses, is also called 'Kalpataru' plant (Vinayagamoorthi *et al.*, 2019) and banana fruit is called "fruit of the wise men (Vignesh *et al.*, 2022). Additionally, banana fibers are used in textile industries and handicrafts, contributing to the rural economy and sustainable livelihoods (APEDA, 2024). Banana cultivation thrives in tropical and subtropical climates, with optimal growth observed at temperatures ranging from 15°C to 35°C with relative humidity of 75-85% and annual rainfall between 650 and 750 mm (NHB). The country's diverse climate facilitates year-round banana cultivation, providing substantial income to farmers and highlighting its national economic importance (Petsakos *et al.*, 2019). The crop performs best in well-drained soils rich in organic matter, maintaining a pH between 5.5 and 7.5 (NHB, India). For optimal yield, according to TNAU, banana plants typically require 150–200 grams of nitrogen (N), 40–60 grams of phosphorus (P_2O_5), and 200–300 grams of potassium (K_2O) per plant per crop, depending on soil conditions and cultivar. Productivity of bananas varies with the size of the farm, with medium-sized farms often achieving higher yields compared to small and large farms. The overall net income from one hectare of banana cultivation can be

substantial, with studies indicating average gross returns of approximately Rs 10.82 lakh per hectare (Gorain *et al.*, 2020, Bright *et al.*, 2025, Maseko *et al.*, 2023). India cultivates several major banana varieties, including Poovan, Monthan, Robusta, Nendran, and Yelakki. These varieties are extensively grown across states like Tamil Nadu, Maharashtra, Andhra Pradesh, Karnataka, and Kerala. Poovan is widely cultivated in Tamil Nadu and Kerala; Monthan is prevalent in Tamil Nadu and Andhra Pradesh; Robusta is common in Maharashtra and Karnataka; Nendran is primarily grown in Kerala, Tamil Nadu, and Karnataka; and Yelakki is mainly cultivated in Karnataka and Tamil Nadu (National Horticulture Board, 2024; Agri times, 2024; Global Agriculture, 2023). As of 2024, Tamil Nadu has approximately 118,420 hectares (about 2.79 lakh acres) under banana cultivation. Major growing regions include Theni, Tiruchirappalli, Erode, Thoothukudi, Coimbatore, Kanyakumari, Thanjavur, and Dindigul districts (Source: CEIC Data; Tamil Nadu Department of Horticulture, 2024). Varieties like Poovan, Rasthali, and Karpooravalli are popular in traditional belts particularly for sucker method and ratooning, while Grand Naine (a tissue culture variety) has gained ground due to export potential and better shelf life (TNAU Horticultural Crop Production Guide, 2021). Around 70% of the banana growers followed a sucker propagated method of banana cultivation due more risk and efficient management required in the tissue culture method (Suneetha R and Bharathi R., 2024). Farmers practiced ratooning cultivation of banana only for sucker propagated method, influenced by retention parent pseudo stem fetching higher productivity as well as less management cost than other methods (Tumuhimbise & Talengera, 2018). Tiruchirappalli district is one of the leading banana-producing regions in Tamil Nadu, primarily due to the presence of the Cauvery river, which ensures irrigation availability and fertile alluvial soil. Despite favourable conditions, banana cultivation in Tamil Nadu faces several challenges including lack of technical guidance, non-availability of labor, high incidence of pests and diseases and high labor wages (Dineshkumar, *et al.*, 2024). Price fluctuation, inadequate storage facilities and high competition were the major problems in Tamil Nadu district (Vignesh and Selvakumar, 2025). Furthermore, factors such as degraded land quality, lack of credit availability, inadequate irrigation water quality, price volatility, insufficient storage and processing facilities, and absence of proper farmer training adversely affect banana production (Dineshkumar *et al.*, 2024; Kumari *et al.*, 2018). Further, it was observed that most studies covered the cost and return analysis of suckers propagated for

one cycle and tissue culture method of banana cultivation. In this context, the present study was conducted for assessing the economic viability of rooting cultivation of bananas following the sucker method.

Materials and Methods

The present investigation was carried out in Tamil Nadu state based on primary data collected through a field survey during 2025-26. The primary data was collected from 36 banana cultivators who followed ratoon practices in banana cultivation using a multi-stage sampling technique. In the first stage, Tiruchirappalli district was selected purposely. In the second stage, out of fourteen blocks in Tiruchirappalli district, three blocks viz. Lalgudi, Anthanallur, and Thottiyam were selected purposely based on the maximum concentration of banana cultivation, accounting for 70.66 percent in terms of area, as reported by the District Horticulture Department. In the third stage, two villages from each block were selected randomly. Thus, a total of six villages (Jeeyapuram and Andanallur villages from Andanallur Block, Lambisekapuram and Kookur from Lalgudi block and Thottiyam and Kattuputhur from Thottiyam block) were selected randomly. For the selection of respondents, In the fourth stage, a comprehensive list of banana farmers from the selected six villages were collected with the help of local agricultural officers, subsequently a list of banana growers adopted ratoon practices and among them six respondents from each village were selected randomly. Thus, a total of 36 banana growers were selected and considered as a sample size for the study. The primary data was collected with a developed schedule from the respondents through the personal interview method.

Analytical technique

Descriptive statistical analysis, particularly mean, percentage etc., was used to estimate the cost of cultivation. The farm management cost concepts farmed by CACP were used to compute the farm income and profitability measures against CostA₁, CostA₂, CostB₁, CostB₂, CostC₂ and CostC₃. Interest on working capital was worked out @ 10 % per annum for the entire duration of the crop. Interest on fixed capital was calculated @ 10 % per annum on the value of fixed assets (implements, machinery, farm buildings, irrigation structures if any, and drought animals). It excludes interest on land as the rental value of owned land is calculated separately.

Discounted Benefit-Cost Ratio: The Benefit-Cost Ratio (BCR) is a foundational concept in project analysis and cost-benefit analysis. The Benefit-Cost Ratio is a foundational decision-making tool for project analysis. It

serves as a financial metric to evaluate whether a project or investment is economically viable by comparing the present value (PV) of expected benefits to the present value of costs over the project's lifecycle. The BCR is the ratio of the discounted present value of all benefits provided by a project to the discounted present value of all its associated costs. Both benefits and costs are to be adjusted to their present values using a suitable discount rate. It is expressed as:

$$BCR = \frac{\text{Present value of Benefits (PVB)}}{\text{Present value of Costs (PVC)}}$$

Where:

- **Present Value of Benefits (PVB):** The sum of all expected benefits from the project, discounted to present value.
- **Present Value of Costs (PVC):** The sum of all estimated costs for the project, also discounted to present value.

The mathematical formula of discounted PVB and discounted PVC and BCR are as follows:

$$PVB = \sum_{t=0}^N \frac{B_t}{(1+r)^t}$$

$$PVC = \sum_{t=0}^N \frac{C_t}{(1+r)^t}$$

$$BCR = \frac{\sum_{t=0}^N \frac{B_t}{(1+r)^t}}{\sum_{t=0}^N \frac{C_t}{(1+r)^t}}$$

Where,

B_t : Benefit at time t , C_t : Cost at time and : Number of years

When,

BCR > 1: Project is economically viable,

BCR = 1: Project breaks even and

BCR < 1: Project is not viable.

Resource Use Efficiency (RUE): In order to examine the RUE of inputs, among the different types of production function, the Cobb-Douglas production function in logarithmic form was employed.

Cobb-Douglas production function is expressed as:

$$Y = aX_1^{b_1}X_2^{b_2}X_3^{b_3}X_4^{b_4}X_5^{b_5}X_6^{b_6}X_7^{b_7}e^U$$

The Cobb-Douglas production function is transformed into log linear form to use the least square method.

$$\ln Y = \ln a + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + b_6 \ln X_6 + b_7 \ln X_7 + U$$

Table 1: Socio-economic and land utilization attributes of the banana growers.

S.	Particular	Value
1.	Average age of banana growers	51.79
2.	Average Family size	5.28
3.	Average land holding	9.49 acres
3.a	Average Agricultural land holding	9.09
3.b	Area under banana cultivation	6.61 (72.72%)
4	Educational level	
4.a	Non-educated	5.56%
4.b	Up to class viii	25.00%
4.c	Secondary	30.56%
4.d	Higher Secondary	22.22%
4.e	Graduate	16.67%
5	Average family income	Rs 3.92 lakh / annum
5.a	Income supported from Banana cultivation	Rs 2.64 lakh
6	Average family expenditure	Rs 1.77 lakh
7	Banana cultivation experience	22.94 years

Where,

Y = production (q/Acre), X_1 = Seeds (kg/Acre), X_2 = Human labour (person-days), X_3 = Manures (q/Acre). X_4 = Irrigation (hrs/Acre), X_5 = Inorganic fertilizers (kg/acre), X_6 = Agrochemical (kg/Acre), X_7 = Vermicompost (q/Acre) and U = Error term

The estimated coefficients of independent variables were used to determine the Marginal Value Product (MVP) at their respective geometric mean and Marginal Factor Cost (MFC). Here, MFC was taken as the unit price of the respective factor. To examine the efficiency of resource use, the MVP of each factor was compared with its factor cost. The RUE ratio indicates the potential for further use of input. In this study, it is denoted by r . The resource is said to be allocated efficiently or optimally

if $r=1$ or $MVP = MFC$. If there is less than one, it indicates that the resource is being over-utilized and the RUE of more than one indicates under-utilization of the resource. The resources use efficiency (RUE) was worked out using the formula given by Rahman and Lawal (2003) as follows.

$$RUE (r) = MVP/MFC$$

$$\text{and } MVP_i =$$

Where, MVP_i = Marginal value product of the i^{th} input, = Estimated partial elasticity co-efficient of the i^{th} input, = Geometric mean of output, = Geometric mean of i^{th} input and = Price of output

Garrett Ranking: The Garrett's ranking technique was used to analyze the constraints faced by farmers in the cultivation of garlic. The constraints were ranked by using Garrett's technique. The percent position of each rank is converted into scores by referring to tables given by Garrett and Woolworth (1969). The mean scores for all the factors are ranked by arranging in descending order.

$$\text{Present Position} = \frac{100 (R_{ij} - 0.5)}{N_{ij}}$$

Where,

R_{ij} = Rank given for the i^{th} item by the j^{th} individual.

N_{ij} = Number of items ranked by the j^{th} individual.

Results and Discussion

The efficiency and profitability in agricultural production and decision making of the farming folk greatly influenced by the socio-economic conditions, agricultural holding and its utilization pattern as well as adoption of technology. Therefore, a brief sketch of the socio-economic and land utilization attributes of banana cultivators were recorded and presented in Table 1. The

Table 2: Per acre utilization of inputs for banana cultivation with ratooning practice.

Sl. No.	Particular	Unit	first cycle			1 st Ratooning			2 nd Ratooning		
			Poovan	Rasthali	Overall	Poovan	Rasthali	Overall	Poovan	Rasthali	Overall
1	Human Labour	Mandays	200.28	201.98	201.18	155.27	160.50	158.03	130.99	129.72	130.32
2	Machinery charges	Rs	3441.18	3421.05	3430.56	-	-	-	-	-	-
3	Sucker	No./acre	942.94	1004.74	975.56	-	-	-	-	-	-
4	FYM	Qtl/acre	22.86	24.55	23.75	20.51	21.76	21.17	37.72	40.19	39.02
5	Urea	Kg/acre	275.88	229.47	251.39	206.91	172.10	188.54	155.18	129.08	141.41
6	DAP	Kg/acre	285.29	274.74	279.72	142.21	136.62	139.26	106.66	102.47	104.45
7	MOP	Kg/acre	372.35	394.73	384.17	317.62	337.43	328.08	238.21	253.07	246.05
8	Micronutrient	Kg/acre	186.65	206.84	197.31	120.81	133.35	127.43	120.81	133.35	127.43
9	Bio-fertilizer	Kg/acre	14.24	20.65	17.62	25.29	26.55	25.96	23.82	21.24	22.46
10	Irrigation	Number	29.29	29.74	29.53	25.46	22.57	24.00	20.36	18.16	19.20
11	Agro- chemicals	Rupees	2736.76	3975.79	3390.69	4270.59	4088.42	4174.44	2135.29	2044.68	2087.47
12	Wooden poles for Propping	Number	942.94	1004.74	975.56	-	-	-	-	-	-

Table 3: Components of Total cost of cultivation of different varieties of banana cultivated through sucker method with ratooning by A₂ category of farms (Rs/ acre).

Particulars	1 st Cycle			1 st Ratooning			2 nd Ratooning		
	Poovan	Rasthali	Overall	Poovan	Rasthali	Overall	Poovan	Rasthali	Overall
Planting material (suckers)	6364.85	7786.74	7115.29 (3.71)	-	-	-	-	-	-
Pole for propping	11315.28	12056.88	11706.68 (6.11)	-	-	-	-	-	-
Hired labour	73747.00	74652.00	74224.64 (38.74)	54441.50	56200.00	55369.60 (41.12)	45582.00	46047.50	45827.69 (35.06)
Machinery charges	3441.18	3421.05	3430.56 (1.79)	-	-	-	-	-	-
Farmyard manures	14287.50	15343.75	14844.97 (7.75)	12818.75	13600.00	13231.08 (9.83)	23573.53	25118.75	24389.06 (18.66)
Inorganic fertilizers	17482.42	17720.95	17608.3 (9.19)	11916.81	12159.53	12044.90 (8.95)	9420.85	9653.14	9543.45 (7.30)
Biofertilizers	249.20	361.38	308.40 (0.16)	442.58	464.63	454.21 (0.34)	416.85	371.70	393.02 (0.30)
Agro chemicals	2736.76	3975.79	3390.69 (1.77)	4270.59	4088.42	4174.44 (3.10)	2135.29	2044.68	2087.47 (1.60)
Fuel charges	3903.50	3917.38	3910.82 (2.04)	3302.25	2997.00	3141.15 (2.33)	2639.95	2397.60	2512.04 (1.92)
Miscellaneous	213.00	256.25	235.83 (0.12)	270.50	266.74	268.52 (0.20)	270.50	266.74	268.52 (0.21)
Interest on working capital	13696.47	14217.37	13971.39 (7.29)	9316.10	9661.15	9498.21 (7.05)	8989.16	9256.02	9130.00 (6.98)
Depreciation	975.65	1058.45	1019.35 (0.53)	975.65	1058.45	1019.35 (0.76)	975.65	1058.45	1019.35 (0.78)
Land revenue	0.00	0.00	0.00(0.00)	0.00	0.00	0.00 (0.00)	0.00	0.00	0.00 (0.00)
Cost A₁/A₂	148412.81	154767.99	151766.92 (79.21)	97754.73	100495.92	99201.46 (73.68)	94003.78	96214.58	95170.60 (72.81)
Interest on fixed capital	3547.45	5755.62	4712.87 (2.46)	3547.45	5755.62	4712.87 (3.50)	3547.45	5755.62	4712.87 (3.61)
Cost B ₁	151960.26	160523.61	156479.79 (81.67)	101302.18	106251.54	103914.33 (77.18)	97551.23	101970.20	99883.47 (76.41)
Rental value of own land	14647.06	14868.42	14763.89 (7.71)	14647.06	14868.42	14763.89 (10.97)	14647.06	14868.42	14763.89 (11.29)
Cost B ₂	166607.32	175392.03	171243.68 (89.38)	115949.24	121119.96	118678.22 (88.14)	112198.29	116838.62	114647.36 (87.71)
Imputed value of family labour	3224	2681.5	2937.68 (1.53)	3175.00	4219.50	3726.27 (2.77)	3841.00	4494.00	4185.64 (3.20)
Cost C ₁	155184.26	163205.11	159417.47 (83.20)	104477.18	110471.04	107640.60 (79.94)	101392.23	106464.20	104069.11 (79.61)
Cost C ₂	169831.32	178073.5	174181.36 (90.91)	119124.24	125339.46	122404.49 (90.91)	116039.29	121332.62	118833.00 (90.91)
Cost C₃	186814.45	195880.88	191599.50 (100)	131036.66	137873.41	134644.94 (100)	127643.22	133465.88	130716.30 (100)

average age of the banana growers was found to be 51.79 years with an average family size of 5.28 who had around 23 years of experience in Banana cultivation. The above findings indicated that mostly middle-aged experienced farmers were more interested in ratoon cultivation of bananas. Nearly 70% of the banana cultivators had an educational level from secondary onwards that led them to scientifically understand and adopt ratoon cultivation techniques. The average annual income of the banana cultivators was estimated at ¹ 3.92 lakh of which 67.35% contribution fetched from banana cultivation. The banana growers mostly belonged to small category of farmer with average land holding of 9.49 acre and the net cropped area was 9.09 acre of which 72.72% (6.61 acre) was used for banana cultivation inferred. The above findings inferred that banana cultivation was the primary source of farm family income. It was investigated that the varieties Poovan and Rasthali were used for banana cultivation with ratoon practice.

The productivity of a particular crop and return from it has a strong relationship with the level of inputs used. The quantitative relationship between the output and inputs determines the technical efficiency. Therefore, it was pertinent to examine the level of different inputs to obtain optimum level of production. A summary of level of inputs use for one-acre banana cultivation for two cultivated variety i.e. Poovan and Rasthali in 1st cycle, 2nd cycle or 1st ratooning and 3rd cycle or 2nd ratooning was computed and presented through Table 2. The comparison of the application of various inputs across three cycles of production showed that utilization of all inputs was reduced except biofertilizers and agro-chemical from 1st cycle to 2nd cycle (1st ratooning). The reason might be due to the more infestation of diseases and pests in 1st ratooning than 1st cycle. Whereas from 1st ratooning to 2nd ratooning all inputs were decreased except FYM. Particularly agrochemical application was reduced by 50%. It might be due to the last ratooning, farmers went for minimum application plant protection measures or reduced pest/disease pressure or crop resilience after heavy plant protection treatment in 1st ratooning. Usage of human labour was reduced successively over the three cycles of production and across the variety also. Overall human labour usage was reduced by 21.45% in 1st ratooning

Table 4: Profitability of different varieties of Banana cultivated for ratooning in first cycle.

Items of Cost	Poovan	Rasthali	Overall
Total Cost (CostC ₃)	186814.45	195880.88	191599.50
Yield (q/acre)	149.06	147.74	148.36
Cost of Production (Rs/q)	1253.28	1325.85	1291.45
Gross Return (GR)	260855.00	280706.00	271375.66
Net Income (GR-CostC ₃)	74040.55	84825.12	79776.16
Farm Business Income (FBI)	112442.19	125938.01	119608.74
Family Labor Income (FLI)	94247.68	105313.97	100131.98
Farm Investment Income (FII)	109218.19	123256.51	116671.06
Technical efficiency			
a. Based on Cost A₁/A₂	1.76	1.81	1.79
a. Based on CostC₂	1.54	1.58	1.56
b. Based on CostC₃	1.40	1.43	1.42

and 35.22% in second ratooning against the first phase of production. However, farmyard manure (FYM) was significantly increased in 2nd ratoon (39.02 qtl/acre) compared to the 1st (21.17) might be due to maintaining soil health by applying more organic input. Application of inorganic fertilizers viz. Urea, DAP, and MOP use were decreased from 1st to 2nd ratooning by 188.54 kg. to 141.41, 139.26 kg. to 104.45 kg. and 328.08 kg. to 246.05 kg. However, an equal quantity of micronutrients used (127.43 kg/acre) across both ratoons suggests continued focus on micronutrient support. Bio-fertilizer application was increased by 47.33% in first ratooning and 27.47% against first cycle of production. slightly reduced (from 25.96 to 22.46 kg/acre) from 1st to 2nd ratoon. The above findings inferred that there was a gradual reduction in input use over successive rounds of production, particularly in labour, fertilizers, irrigation, and agrochemicals, though FYM application increased, indicating an attempt to sustain soil fertility naturally as the ratoon cycles progress.

The composition of different types of cost measures i.e. CostA₁, CostA₂, CostB₁, CostB₂, CostC₁, CostC₂ and CostC₃ as per CACP of banana cultivation through the sucker method with ratooning was computed and presented through Table 3. It showed variation across the first cycle, first ratoon, and second ratoon for the Poovan and Rasthali varieties. In the first cycle, planting material costs, cost of pole for propping accounted for 3.71% and 6.11% respectively of the total cost overall, but these costs were absent in subsequent ratoon crops, reflecting the reuse of them. In ratooning, the cost of machinery charges was also absent due to no requirement of land preparation. The overall cost of cultivation

Table 5: Profitability of different variety of Banana cultivated for ratooning.

Variety	Cycle	TC	GR	NR	BC
Poovan	1	186814.45	260855.00	74040.55	1.52
	2	131036.66	221077.50	90040.84	
	3	127643.22	205187.50	77544.28	
Rasthali	1	195880.88	280706.00	84825.12	1.63
	2	137873.01	250458.00	112584.99	
	3	133465.88	235182.00	101716.12	
Overall	1	191599.50	271375.66	79776.16	1.58
	2	134644.94	236383.64	101738.70	
	3	130716.30	220780.82	90064.52	
TC: TotalCost (Rs/ acre); GR: GrossReturn(Rs/ acre); NR: Net Return(Rs / acre); BC: Discounted B:C ratio					

(CostC₃) computed at Rs 1,91,599.50 in the first cycle, Rs 1,37,474.05 in the first ratooning, and Rs 1,33,018.79 in the second ratooning indicated that there was sharp reduction of overall cost cultivation between main crop (1st cycle) and ratooning to tune of 29 to 31% in both ratooning. This decline primarily might be due to the elimination of the cost of planting material, pole for propping and reduction in labour cost. Subsequently, the total operational cost (CostA₁/A₂) constituted 79.21% in first cycle, 73.68% in first ratooning and 72.81% in second ratooning on an overall basis. Between the varieties slight variation was observed in total cost of cultivation which was higher in Rasthali variety than Poovan variety to the tune of 4.85% in first cycle, 5.22% in first ratooning and 4.56% in second ratooning. In respect to proportional distribution of total cost, charges for hired labour revealed to be the dominant cost component across all cycles which was 38.74% in the first cycle, raising slightly to 41.12% in the first ratooning and then declining to 35.06% in the second ratooning. But in absolute terms, the labour cost was reduced by 25.40% in first ratooning and 38.26% in second ratooning against first cycle might be due to reduced field preparation, planting and propping needs. Whereas, expenditure for farm yard manure was examined to be remained identical in first ratooning compared to first cycle but it was sharply increased in second ratooning to the tune of around 65% against first cycle implying that to maintain the soil fertility after higher use of inorganic fertilizers and agrochemical in first cycle and first ratooning, farmers cautiously applied more FYM.

Yield, gross return, net return, family labour income, farm business income and return cost ratio termed as technical efficiency (return to cost ratio) are the tools used for computing the profitability measures in banana cultivation. The profitability and technical efficiency of banana cultivation per acre in 1st cycle and successive ratooning were worked out and delineated in Table 4 and

Table 6: Production function coefficients of Poovan variety ($n_1 = 17$) and Rasthali variety ($n_2 = 19$).

Independent variables	Poovan variety (n ₁ = 17)				Rasthali variety (n ₂ = 19)			
	CE	SE	TV	PV	CE	SE	TV	PV
Intercept	0.5047	2.9883	0.1689	0.8701	0.9948	2.0820	-0.4778	0.6431
X ₁ (Human Labour)	0.1513	0.5446	0.2778	0.7882	0.5208	0.3104	1.6781	0.1243
X ₂ (FYM)	0.9784***	0.2321	4.2150	0.0029	-0.1080*	0.0558	-1.9346	0.0818
X ₃ (Urea)	0.0262	0.0925	0.2830	0.7843	0.2662***	0.0768	3.4665	0.0061
X ₄ (DAP)	0.0390	0.0814	0.4789	0.6448	0.2367***	0.0587	4.0327	0.0024
X ₅ (Potash)	0.2371***	0.0636	3.7264	0.0058	-0.0297	0.0650	-0.4567	0.6577
X ₆ (Micronutrient)	-0.0458*	0.0217	-2.1131	0.0676	0.0343	0.0269	1.2731	0.2318
X ₇ (Agrochemical)	-0.0599	0.0470	-1.2746	0.2382	-0.0992	0.0818	-1.2132	0.2529
X ₈ (Irrigation)	-0.1256*	0.0617	-2.0338	0.0764	0.4764***	0.1333	3.5728	0.0051
Return to scale (Σbi)	1.20				1.30			
R ²	0.8881				0.7264			
Adjusted R ²	0.7762				0.5435			
F-value	7.93*** (0.0041)				3.67** (0.0289)			
CE: Coefficients of elasticity; SE: Standard error; TV: t-value; PV: p-value								
R ² = Coefficient of multiple determinations; ***, ** and *shows significant at 1%, 5% and 10% level of probability respectively								

Table 5. The estimated overall mean yield realized in the first cycle was 148.36 quintals per acre, with Poovan yielding slightly higher at 149.06 q/acre compared to Rasthali at 147.74 q/acre. It was observed that the cost of production per quintal was lower for Poovan variety (Rs 1253.28) compared to Rasthali variety (Rs 1325.85). Gross returns fetched from cultivation Rasthali variety was Rs 2.81 lakhs/acre, and for Poovan variety Rs 2.61 lakhs/acre, averaging to Rs 2.71 lakhs/acre overall. Consequently, overall net income at Cost C_3 stood at Rs 79,776/acre, with Rasthali leading at Rs 84,825, followed by Poovan at Rs 74,040. Farm Business Income (FBI), Family Labour Income (FLI), and Farm Investment Income (FII) also followed a similar trend, being highest in Rasthali (Rs 1.26 lakhs, Rs 1.05 lakhs, Rs 1.23 lakhs respectively) compared to Poovan. These figures confirmed that both varieties were profitable, with Rasthali slightly more rewarding in profitability terms. From an efficiency standpoint, the return to cost ratio (technical ratio) based on Cost A_1/A_2 and Cost C_3 were found to be identical in both varieties which were estimated to be 1.79 and 1.42 on overall basis. The above findings inferred that a sound return on investment could be realized in both varieties chosen for ratooning practices, revealing the economic viability in the first cycle even after accounting for full costs.

The banana cultivation with ratooning adopted by the farms for three consecutive cropping cycles (initial + two ratooning cycles) revealed improved cost-effectiveness and profitability in subsequent ratooning presented in Table 5. The net income fetched from one-acre cultivation of Poovan variety was worked out to be Rs 74040.55, Rs 90040.84 and Rs 77544.28 respectively in first cycle, first

ratooning and second ratooning. Further, although total cost of cultivation for Rasthali variety was found to be 4 to 5% higher than Poovan variety in all crop cycles but, the net income realized from cultivation of Rasthali variety revealed to be 14.57%, 25% and 31% higher than Poovan variety in first cycle, first ratooning and second ratooning respectively. Consequently, the discounted B:C ratio was also higher in Rasthali variety (1.63:1) than Poovan variety (1.52:1) indicating that Rasthali variety was more profitable in ratooning stages.

The prime objectives of farmers to realize maximum returns from cultivation of crops using their available limited resources, depends on the optimum allocation of resources. The profitability analysis is not enough to validate the efficient use of resources. Therefore, the fitted Cobb-Douglas production function was employed to assess the allocative efficiency of various farm resources used for banana cultivation. The regression coefficients are the direct measure of elasticity of production for resources in Cobb-Douglas production function. In the present study, the resource use efficiency in the first cycle of banana cultivation with sucker method following ratooning practices was estimated for both varieties adopted for ratooning practices and presented in Table 6. Yield was taken as dependent variable and Human Labour (X_1), FYM (X_2), Urea (X_3), Diammonium Phosphate (X_4), Potash (X_5), Micro-nutrient (X_6), Agro-chemicals (X_7) and Irrigation (X_8) were included as explanatory independent variables for all category of farms. From the analysis of production function coefficients of Poovan and Rasthali variety, the co-efficient of elasticity of FYM (X_2) and Potash (X_7) revealed most significant factors at 1% level of probability

Table 7: Resource use efficiency of different varieties of banana in first cycle of cultivation through sucker method.

Independent variables	MFC	Poovan variety ($n_1 = 17$)				Rasthali variety ($n_2 = 19$)			
		Coefficients	MPP	MVP	r	Coefficient	MPP	MVP	r
X_1 (Human Labour)	400	0.1513	0.11	196.89	0.49	0.5208	0.38	723.48	1.81
X_2 (FYM)	625	0.9784	6.38	11161.06	17.86	-0.1080	-0.67	-1265.19	-2.02
X_3 (Urea)	5.5	0.0262	0.01	24.86	4.52	0.2662	0.17	328.19	59.67
X_4 (DAP)	22	0.0390	0.02	35.75	1.62	0.2367	0.13	243.43	11.07
X_5 (Potash)	18	0.2371	0.10	166.66	9.26	-0.0297	-0.01	-21.21	-1.18
X_6 (Micronutrient)	16	-0.0458	-0.04	-66.09	-4.13	0.0343	0.03	47.71	2.98
X_7 (Agrochemical)	1	-0.0599	0.00	-5.75	-5.75	-0.0992	0.00	-7.04	-7.04
X_8 (Irrigation)	150	-0.1256	-0.64	-1128.38	-7.52	0.4764	2.38	4518.39	30.12

for Poovan variety whereas micronutrient (X_6) and irrigation became negatively significant at 10% level of probability indicated that these two inputs were over utilized in cultivation of Poovan variety. The variable FYM had the highest effect on yield on Poovan variety which was evident from highest magnitude of coefficient (0.9784) indicating that with increase in 1% use of this input, yield could be enhanced by 0.97%. On the contrary, for cultivation of Rasthali variety, the most significant factors were observed to be irrigation (X_8), Urea (X_3) and DAP (X_4) which were significant at 1% level of probability. The most positive effects on yield were exerted by human labour (X_1) and irrigation (X_8) which were evident from the magnitude of elasticity of coefficients for Rasthali variety. The variable FYM (X_2) revealed negatively significant at 10% level of probability implying over use of this variable. The said type of farms for both varieties were operating under increasing returns to scale as the sum of coefficient was found greater than one i.e. 1.20 for Poovan variety and 1.30 for Rasthali variety inferring that there was a scope for enhancement of productivity by optimum utilization of resources with given state of technology in successive cycle of cultivation i.e. in ratooning. Further, each individual independent explanatory variable for both varieties shows decreasing marginal productivity to each variable evident from their elasticity of coefficients i.e. less than one. While the value of adjusted R^2 (0.7762 for Poovan variety and 0.5435 for Rasthali variety) indicated 77.62% and 54.35% variation in yield of Poovan variety and Rasthali variety respectively explained by the used independent variables. The R^2 value revealed significance at 1% level of probability in the Poovan variety and 5% at the Rasthali variety evident from F-values.

The optimum utilization of inputs is determined by the resource use efficiency (RUE). The use of the particular input is supposed to be optimum, when the RUE is one. If it is less than one, it specifies that the resource is being over-utilized and if the ratio is more than one indicates under-utilization of resource. In this study it is

denoted by r . The RUE of different inputs used in the first cycle of Banana cultivation through sucker method following ratooning was estimated and presented through Table 7. The MVP as well as RUE for factors human labour, FYM and all inorganic fertilizers were found positive and greater than one for Poovan variety implying that these variables exerted positive impact on yield and also under-utilized. Therefore, there is a further scope to enhance the yield of banana of Poovan variety through more use of the said inputs with the changes in production technology. The MVP was observed highest for FYM (Rs 11161.06) followed by human labour (Rs 196.89) and potash (Rs 166.66) indicating that one-unit extra use of these inputs could increase yield by the said monetary value. On the contrary all other inputs viz. micronutrient, agrochemical and irrigation were over utilized, evident from the negative value of MVP and RUE. Whereas, in case of the Rasthali variety MVP and RUE for factors human labour, urea, DAP, micronutrient and irrigation were worked out to be positive and greater than one inferred that these variables were under-utilized. Whereas, FYM, potash and agro-chemical were overutilized in cultivation of Rasthali variety. The MVP value was found to be highest for factor human labour (Rs 723.48) and lowest

Table 8: Production constraints of banana cultivation following ratooning practice.

Constraints	Total score	Mean score	Rank
Non-availability of credit	1829	50.81	IX
Emergence of weeds	2058	57.17	III
Disease & pest attack	1939	53.86	VII
Labour scarcity in peak time	1965	54.58	V
Adverse climatic condition like cyclone (wind)	2239	62.19	I
High cost of labour	1911	53.08	VIII
labour intensive crop	2118	58.83	II
More intensity of pest and disease in ratoon crop	1949	54.14	VI
Yield reduction after 2 ratoons	1773	49.25	X
Increased use of inputs	1999	55.53	IV

in agrochemicals (-Rs 7.04). In both varieties, RUE came out negative and less than one for agrochemicals indicating the overutilization might be due to the more attack of diseases and pests. The most significant factors were FYM and potash in Poovan variety and human labour and irrigation for Rasthali variety revealed from elasticity of coefficients of production. Further, the RUE of FYM and Potash was estimated to be 17.86 and 9.26 for Poovan variety, inferring that by using one extra unit of FYM and potash, the quantity of yield would add by 6.21 units and 2.30 units respectively. Whereas for the Rasthali variety one unit extra use of human labour and irrigation would enhance the yield by 1.81 units and 30.12 units respectively.

Production Constraints in banana cultivation, especially when involving ratooning, present multiple challenges that impact yield and profitability. A total of ten production-related issues were identified and displayed in Table 8. Adverse climatic conditions like cyclones and strong winds ranked as the most severe constraint with the highest mean score of 62.19 (ranked I), indicating a major threat to crop survival and yield stability particularly for ratooning practices. The labour intensive nature of banana cultivation revealed as second most important operational constraints with mean score 50.19 limits the timely operation of intercultural activities and hinders the growth of plants. Emergence of weeds with mean score 57.17 (rank III), reflecting a serious management burden during consecutive crop cycles for ratooning. This was followed by increased use of inputs in ratooning with mean score 55.53 (rank IV), which led to increase production costs. Labour scarcity during peak times and ratoon-specific pest and disease pressure ranked V and VI with mean scores of 54.58 and 54.14 respectively. These highlight the challenges of managing the crop during critical stages and with repeated cycles. Disease and pest attacks before ratooning in general were also significant problems being seventh major constraint with mean score 53.86, further affecting productivity. High labour costs (rank VIII) and non-availability of credit (rank IX) were notable financial constraints affecting input use and timely operations. Finally, yield reduction after two ratoons ranked last with mean score 49.25 (rank X), but still indicates a concern about declining productivity in prolonged cultivation cycles. These findings inferring the need for climate-resilient practices, improved input and sucker availability, effective pest and weed management, and better financial and labour planning to sustain banana production under ratooning systems.

Conclusion

The study analysed profitability and technical

efficiency of banana cultivation adopted for ratooning. The study revealed that mostly small farmers adopted ratoon cultivation banana as primary source of income, supporting 67% of total family income. Usage of all inputs was reduced in ratooning phases except biofertilizers and agro-chemical from 1st cycle to 1st ratooning and FYM in 2nd ratooning. The use of FYM was augmented in the ratoon stage to maintain soil fertility. The magnitude of total cost was reduced by 29 to 31% in ratoon stages of banana cultivation particularly due to immense reduction of labour cost around 25% in first ratooning and 40% in second ratooning against first cycle and also due to the elimination of the cost of planting material, pole for propping. Human labour cost constituted a prime share (38 to 44%) of total cost ($CostC_3$) in all cycles. The magnitude of operational cost ($CostA_1$) as well as total cost ($CostC_3$) of cultivation of Poovan and Rasthali variety revealed almost identical in first cycle as well as ratooning stages. The realized net income was estimated around 22% and 5% higher in first and 2nd ratooning respectively for Poovan variety. Whereas for Rathali variety it was 33% and 20% respectively. The inputs FYM and Potassic fertilizer were revealed as the most significant factors in for Poovan variety while for Rasthal variety human labour and irrigation were exposed to be the most significant contributors in the first cycle of production. Cultivation of both varieties were operating under increasing return to scale in the first cycle, implying that productivity could be enhanced through efficient utilization of inputs in ratooning stages. Hence, the farmers adopted ratoon cultivation of banana as a cost-effective venture on one side and augmented income generated enterprise on the other side. Adverse climatic conditions, labour intensiveness and weed infestation were identified as the prime constraints. Such a venture could be more fruitful with the intervention of capacity-building training, institutional linkage for efficient marketing as well as infrastructural facilities, particularly for grading, storage and value addition.

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