High Density Banana Production in Taveta County Kenya: An Economic Assessment of Farmer Practices.

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ABSTRACT

Bananas are a major source of food, animal feed and cash income in most parts of Kenya. Bananas can be a profitable business and offer potential for high yields, particularly when taking into account factors such as demand, supply and efficient management techniques. A study was carried out comparing high density plantations of 2m x 2m with the recommended spacing (3m x 3m or 3m x 4m). The aim of the study is to assess the economic benefits of the different banana growing areas used by farmers in the Taveta sub-region. 329 farmers were interviewed using the structured questionnaire recorded in the Kobo Collect. SPSS Version 17 was used for data analysis, drawing up descriptive statistics for demographic data and calculating gross margins (costs and revenues) for different banana-growing areas. The results showed that the adoption by farmers of the 2 x 2m and 3 x 3m spacing of banana plants resulted in more production per unit area, using good agricultural practices. Where farmers used a spacing of 2 x 2m, the income base was higher at KES 803,250 and the gross margin was better at KES 364,350 per year for a 1-acre banana plantation, followed by a spacing of 3 x 3m. The maximum spacing of 2 x 2m is 1.83, followed by the maximum spacing of 3 x 3m at 1.73. Thus, the two ranges of 2 x 2m and 3 x 3m are profitable investments which should be encouraged as they yield better returns. Commercialization of bananas has the potential to transform the banana sector in Taveta; therefore, in order to reap the benefits of high-density banana production, farmers will need improved cultivation, efficient supply chain, economies of scale and access to markets.

Keywords: Spacing, gross margins profitability

INTRODUCTION

Bananas, together with plantain, are the world's fourth staple crop and are essential for maintaining the food and nutrition security of 400 million people in producing countries (Banana Link n.d.; Guinness World Records, 2022). Banana (*Musa spp.*) It is a major fruit crop in the world, grown on more than four million hectares and produces more than seventy million tons of annual production (Pappu, et al, 2016). It is the third most important starch staple after cassava and sweet potatoes (FAO, 2018). Banana production is one of Kenya's most commercially attractive fruit sub-sectors. Unemployment is around 11 percent in the domestic

horticultural sector and around 35 percent in fruit production and marketing (KNBS, 2024a). Bananas are Kenya's most important fruit crop, accounting for 35 percent of the total, followed by avocado at 23 percent, mangoes at 16 percent, oranges at 6 percent and melons at 5 percent (AFA 2024). In 2023, domestic production was 2,908,000 MT, domestic consumption was 2,471,000 MT, with a loss of 436,000 MT (KNBS 2024b). In Kenya, bananas are cultivated on 7,800 hectares in 2022 and 79,246 hectares in 2023. The yield was valued at 27,453.8 million tons in 2022 and 39,726 million tons in 2023 (KNBS, 2024b & c). At national level, the average annual production is around 1,882,564 MT, with an annual value of 216,868 million KES, while the national consumption is around 48 kg per year (AFA, 2024).

Bananas are a major source of food, animal feed and cash income in most parts of the world (Obaga and Mwaura, 2018; Okako *et al,* 2024). This sub-sector employs about 80 percent of the rural population and is therefore essential for food security, poverty reduction and economic development (Tinzaara *et. al.,* 2018). In Kenya, bananas are mainly produced and maintained by smallholder farmers, mostly women (Paul, J. *et al.,* 2018). The level of production varies widely within the country, owing to geographical and environmental factors, and the prevalence of good manufacturing practices (Okako *et. al.,* 2024). According to the AFA 2024 statistics, Meru County leads the production of bananas in Kenya with 20.9 percent, followed by Murang'a at 17.08 percent, Taita Taveta at 10.3 percent and Kirinyaga at 7.67 percent (AFA 2024).

According to Wahome *et al., (*2021), the most important factors affecting banana production are labour and the implementation of agronomic management practices, such as the use of quality planting material, appropriate use of fertilizers, mulch and manure. Commercial banana growing at a distance of 2 m x 2 m (7) is recommended (Benfica, 2024; FAO, 2017; TNAU, 2025). However, in terms of varieties and locations, many banana growers now grow bananas in closer proximity (Benfica, 2024; FAO, 2017; TNAU, 2025). According to them, the total yield is higher with a closer spacings. In addition, bananas are a higher botanical crop and their yield is also longer (10-14 months) (Benfica, 2024; FAO, 2017; TNAU, 2025). Closer spacing can help to prevent natural hazards, notably high-speed winds and storms. It is to be estimated whether a wider or narrower spacing will result in a higher flowering of the banana. This study compared the high-density plantation of 2m x 2m with the recommended spacing (3m x 3m or 3m x 4m) for optimal growth and for the components of banana yield and productivity (Benfica, 2024; FAO, 2017; TNAU, 2025).

Banana farming can be a profitable venture, offering potential for high returns, especially when considering factors like demand, supply, and efficient farming techniques. Various studies done by a number of authors looking at the gross margins and profitability (Mahfuzur et. al., 2020; Ranathilaka et. al., 2019) of banana production in the world. i.e. costs and returns per hectare of banana cultivation (Kumari et. al., 2021), nutrient use and economic viability of the banana (Thamires et. al., 2022), profitability, productivity and resource use efficiency, in banana production Nepal (Sharma et. al., 2021), socio-economic analysis, economics of production in commercialization of banana production in Nepal (Ghimire et al 2019), adoption of recommended banana production technology in Embu Kenya (Kathuri et. al., 2021) and cost, returns and profitability of banana fruit enterprises in Nigeria (Ajibade et. al., 2022) but limited studies have been carried out on the economics (Gross margins and profitability) of banana under different spacings. Thus, the objective of this study is to assess the economic benefits of different banana spacings being used by farmers in Taveta sub-county.

METHODOLOGY

Target study area

The study was conducted in the Taveta sub-county, in the area of the Taita Taveta County where bananas are grown most intensively. The County of Taveta has a population of 93,107 and an area of 6,399 km2 (KNBS, 2020). The Taveta sub-region comprises five wards, namely Challa, Mata, Bomani, Mahoo and Mboghoni (Figure 1), each with a population of 22901, 6823, 50531, 628 and 6524 inhabitants (KNBS, 2020).

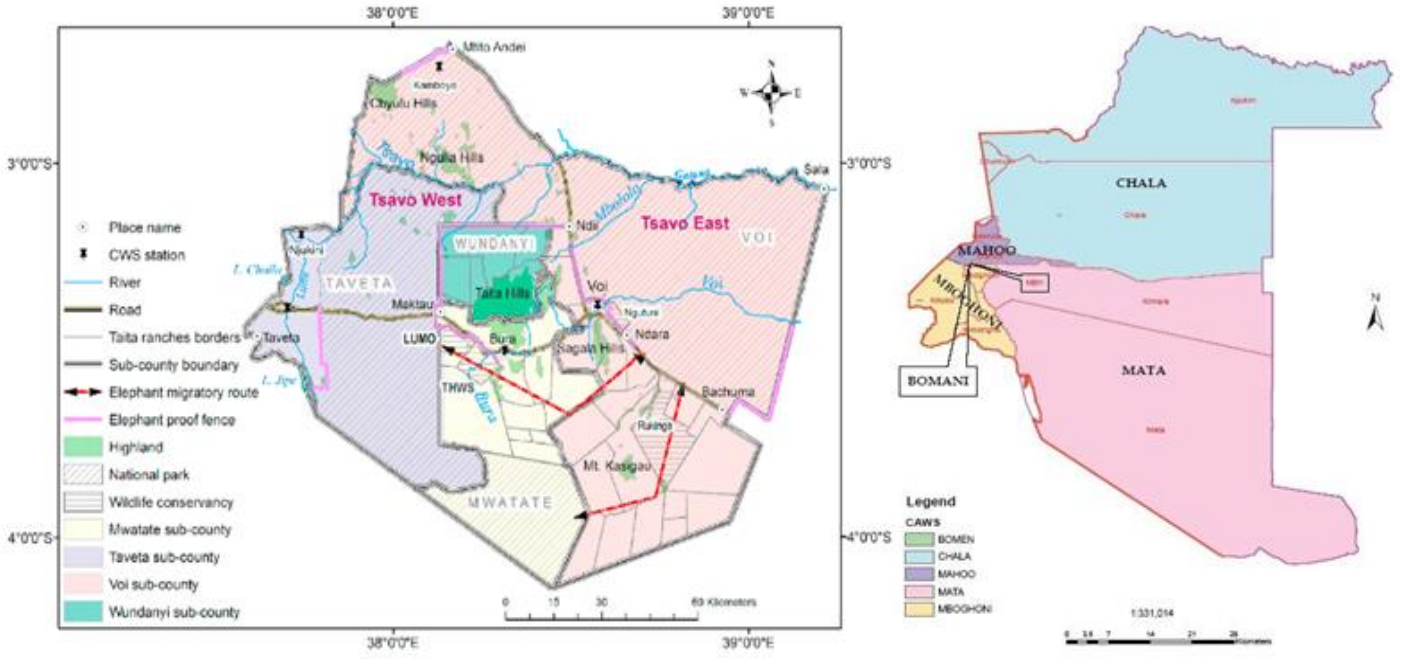

Figure 1. Map of Taita Taveta County Taveta Subcounty (study area)

Long rains are common from March to May, with 265 mm of rainfall per year in the highlands compared to 157 mm in the lowlands (Jaetzold *et al*., 2006). Short rains are expected from October to December, with annual precipitation averaging 1,200 mm (highlands) and 341 mm (lowlands) (Jaetzold *et al.,* 2006). The distribution of rainfall is generally uneven, with higher rainfall rates in mountainous areas than in lowlands. The average annual rainfall is 650 mm (Jaetzold *et al*., 2006). The primary data collection was based on information provided by the Taveta MESPT team, which was working to support banana production in the Taveta sub-county for the period 2022-2024. The different banana crop spacing used by farmers is as listed in Table 1. The total number of farmers participating in this study was 966, divided into 10 groups (Table 1).

Table 1: Distribution of Taveta farmers by different banana planting spacing

Cluster	**Spacing type**				**Total**
	2by 2m	**3by 4m**	**3by 3m**	**4by 4m**	
Chala	5	12	12	5	34
Kasokoni	15	33	28	31	108
Kitobo	1	16	14	54	85
Kitogotho	1		2	84	87
Mata	30	6	30	2	68
Mboghoni	15	58	103	36	212
Mrabani Moyamoya	4	33	49	57	143
Ngutini		4	6	42	52
Njukini		17	5	31	53
Timbila	3	33	38	50	124
Total	**74**	**212**	**287**	**392**	**966**

Sample size: Each farmer had an equal chance of being selected and the sample size was randomly selected using the equation below:

$n = \frac{N}{1+N(e)^2}$ *Yamane (1967)*

n= Sample Size N= Population Size e= Margin of Error

$$n = \frac{966}{1+966\ (0.05)^2}$$

$$n \approx 283$$

A margin of error of 10 percentage points or a level of significance was also applied (taking into account unforeseen drop-off rates, incomplete questionnaire filling and data cleaning measures). According to Mugenda and Mugenda (2019), the sample size has been adapted by 10 percentage points to 293 farmers as minimum sample size. The sample size was broken down by the administrative wards where the banana project was implemented. Additional farmers have been identified using a snowballing process to maximize and achieve the target number of respondents when a shortfall occurs.

During the interviews with farmers, a structured questionnaire programmed by Kobo Collect was used for the exercise. In addition, as there were four banana planting areas of interest (2 x 2 m, 3 x 4 m, 3 x 3 m and 4 x 4 m), a total of 329 farmers were interviewed. A total of 57 farmers were interviewed for a spacing of 2 x 2 m banana plants; 115 for a spacing of 3 x 4 m; 92 farmers for a spacing of 3 x 3 m; and 65 farmers for a spacing of 4 x 4 m (Table 2).

Table 2: The number of farmers interviewed for each banana planting spacing in Taveta sub-county per each ward

Spacing	**Study wards in Taveta Sub-county**					**Total**
	Bomani	**Chala**	**Mahoo**	**Mata**	**Mboghoni**	
2mx2m	3	22	3	15	14	57
3mx3m	22	5	23	2	63	115
4mx3m	5	15	21	4	47	92
4mx4m	2	14	13	2	34	65
Total	32	56	60	23	158	329

For each banana planting area, the authors took the size of the area of 1 acre and calculated the number of plants per acre (number of banana stools per acre) (Coder 2023). According to Coder, Kim D. (2023), the estimated number of hectares under each plot is estimated as described in Table 3.

Table 3: Recommended banana planting spacing by type and plant population

Spacing type (m)	**Spacing type (Ft)**	**Plants population per acre**
2by 2	6.5by 6.5	1000
3by3	9.8by 9.8	444
3 by 4	9.8by 13.1	333
4by 4	13.1by 13.1	250

Method of data analysis

Version 17 of Statistical Package for Social Sciences (SPSS) software was used for data entry and analysis. Descriptive statistics, such as totals, averages, percentages, etc., were used to illustrate the message. In addition, average comparison techniques such as ANOVA and independent sample t-tests were used to compare the socio-economic characteristics of the farmers in different banana growing areas and the plant spacings. For the purpose of determining the profitability of each banana planting area used by farmers, gross margins were calculated and assumptions made and documented. Gross margins provide simple information on the financial performance of individual agricultural holdings (Jakupi, Statovci and Hajrizi, 2017; Adedeji, and Ituma, 2020).

A Gross Margin of an enterprise = Gross Income of enterprise – Variable Costs of that enterprise

Figure 2: Gross Margin illustration

Calculation of the benefit cost Ratio (BCR) (Jakupi, Statovci and Hajrizi, 2017; Adedeji, and Ituma, 2020).

The Benefit-Cost Ratio (BCR) for banana production is calculated by dividing the total benefits (gross revenue or income) by the total costs of production. Formula: (Kumari *et al.,* 2021:

BCR = Total Benefits / Total Costs

Benefits:

This refers to the total revenue or income generated from banana production, including the value of the banana crop and any other related income.

Costs:

This includes all expenses incurred in banana production, such as labor, materials, land preparation, fertilizers, pesticides, and other inputs.

Interpretation:

A BCR greater than 1 indicates that the benefits outweigh the costs, suggesting a profitable venture.

A BCR less than 1 suggests that the costs are greater than the benefits, potentially indicating an unprofitable investment.

A BCR equal to 1 means that the benefits and costs are equal.

RESULTS AND DISCUSSIONS

Socio-economic characteristics of Taveta sub-county banana farmers

The socio-economic characteristics of farmers in the study area, the age of the farmers, the level of education, the main source of income, the ownership of land or lease and banana acreage were statistically significant for the various margins between 90 and 95 percent. (Table 4) A representative number of farmers were interviewed at each of the banana plantations. Male farmers were 70.2, 51.3, 57.6 and 64.6 per cent who used a planting distance of 2 x 2 m, 3 x 3 m, 4 x 3 m and 4 x 4 m respectively (Table 4).

The results of this study show that the majority of banana growers (68.42) are aged between 35 and 54. Most farmers (36.84) aged 35-44 used a planting distance of 2 x 2 m for bananas, followed by farmers aged 45-54 (31.58). The spacing for banana plants was 3 x 3 m and 35.65 percent of the farmers were aged 45 to 54 years old and 27.83 percent were aged 35 to 44 years old. With a planting distance of 4 x 3 m, 43.48 percent of

farmers were aged between 35 and 44 years and 36.96 percent were aged 45 to 54 years. For the 4 x 4 m planting area, 49.23 percent of farmers were aged 45 to 54 years and 26.15 percent were aged 35 to 44 years (Table 4).

Farmers were also ranked according to their level of education. Education levels were primary, secondary and tertiary (secondary and university) level. The spacing of the banana plants, 2 x 2 m and 3 x 3 m, was approximately 43.86 and 46.09 percent respectively of farmers with secondary education. Whereas farmers who practiced 4 x 3 or 4 x 4 m spacing for banana plants had 58.70 and 61.54 per cent of primary level education (Table 4). The sources of income which farmers use for banana production are either from outside the farm or from within the farm. About 59.89 percent of farmers using a spacing of 2 x 2 m used their income from non-farm land for banana cultivation. Farmers using 3 x 3 m, 4 x 3 m and 4 x 4 m spacing on their farms at 60.87, 72.83 and 70.77 percent, respectively (Table 4).

The farmers owned at least 0.25 acres and not more than 30 acres. Depending on the ability of the farmers (capital, manpower), they were able to increase the size of the plots of land for banana production. The average size of the banana plots was 1.15, 1.28, 0.97 and 1.13 hectares, respectively (Table 4).

Table 4: Socio-economic farmer characteristics

Variable	**Description**	**2M by 2M**	**3M by 3M**	**4M by 3M**	**4M by 4M**	**Pooled**	**Chi2 test**
		N=65	N=92	N=115	N=57	N=329	
Gender of the farmer	Male	70.18	51.30	57.61	64.62	58.97	6.68
	Female	29.82	48.70	42.39	35.38	39.85	
Age of the farmer in years	18-24	0.00	1.74	0.00	0.00	0.61	25.56**
	25-34	5.26	15.65	6.52	7.69	9.73	
	35-44	36.84	27.83	43.48	26.15	33.43	
	45-54	31.58	35.65	36.96	49.23	37.99	
	55-64	14.04	10.43	9.78	13.85	11.55	
	Over 64	12.28	8.70	3.26	3.08	6.69	
Level of education	Primary	22.81	36.52	58.70	61.54	45.29	37.23***
	Secondary	43.86	46.09	34.78	26.15	38.60	
	Tertiary	33.33	17.39	6.52	12.31	16.11	
Main source of income	Off-farm	57.89	39.13	27.17	29.23	37.08	16.37***
	On Farm	42.11	60.87	72.83	70.77	62.92	
Land ownership/ own	Owned	82.46	90.43	96.74	96.92	92.10	12.51***
	Otherwise	17.54	9.57	3.26	3.08	7.90	
Land ownership/ leased	Leased	17.54	10.43	3.26	3.08	8.21	12.61***
	Otherwise	82.46	89.57	96.74	96.92	91.79	
How much land under Bananas	.035	1	0	0	0	1	130.79***
	.05	1	0	2	0	3	
	.1	0	0	1	0	1	
	.12	0	0	1	0	1	
	.125	1	1	4	3	9	
	.22	1	0	0	0	1	
	.25	11	7	6	5	29	
	.4	1	0	0	0	1	
	.5	10	21	24	10	65	
	.51	1	0	0	0	1	
	.52	1	0	0	0	1	
	.56	1	0		0	1	
	.75	5	7	16	6	34	

	.8	0	0	0	1	1	
	.85	1	0	0	0	1	
	1	7	50	23	28	108	
	1.075	0	1	0	0	1	
	1.5	3	1	3	1	8	
	1.75	1	0	1	1	2	
	2	3	18	8	4	33	
	2.5	0	0	0	1	1	
	2.75	1	0	0	0	1	
	2.8	1	1	0	0	2	
	3	3	2	1	2	8	
	3.5	0	0	0	3	7	
	4	1	3	0	3	7	
	5	1	0	0	0	1	
	6	0	2	0	0	2	
	8	1	1	0	0	2	
	12	0	0	1	0	1	

** Significant At 90% and *** at 95%

The cost of production for banana

In four banana plant areas of 2 x 2 m, 3 x 3 m, 4 x 3 m and 4 x 4 m, 47, 94, 84 and 57 per cent were unaware of banana production costs (Figure 3). This was in contrast to the information provided by the Taita Taveta Banana Cooperative Society (TATABA), which calculated with farmers that banana production costs ranged from KES 8 to 10 per kilogram.

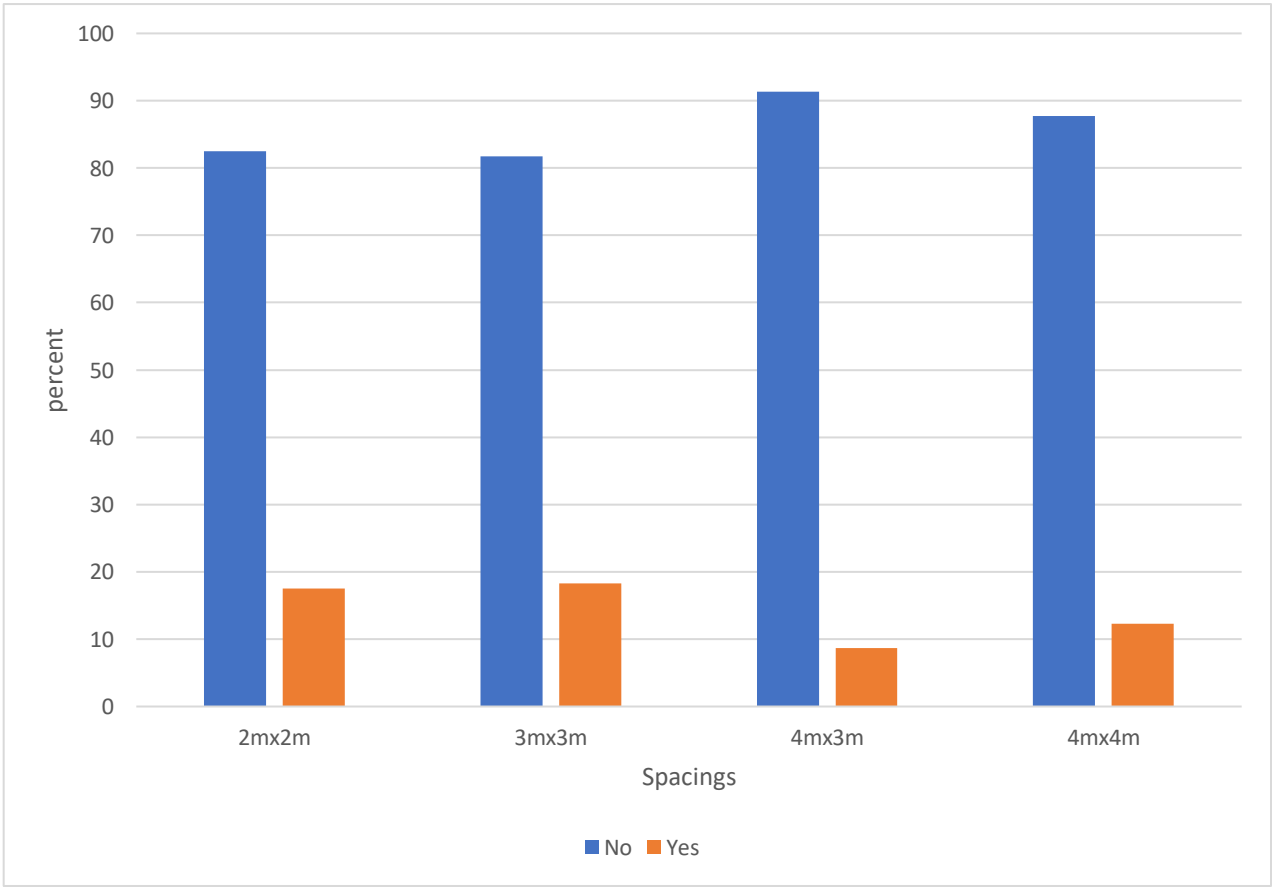

Figure 3: Percentage of farmers aware of the cost of banana production

Ndambi *et al.* (2017) in the paper on calculating the on-farm cost of milk production in Kenya: Assessing the suitability of five methods being used in Kenya and Gollins (2014), farm size and productivity: lessons from recent literature found that farmers are not that keen on the inputs that go into production but on the output (price) of the commodity. Even though the farmers were aware of what was required to produce the commodity, only a handful of farmers keenly kept track of input costs of the production process for fear of having overspent on the crop operations and having multiple sources of income for producing the commodity.

The quantity harvested frequency, quantity sold and price per unit

Bananas harvested from farmers' holdings were sold either in bunches, in boxes or in kilograms, and all were sold by the farmers' cooperative. The size of the box was the 45 kg standard used for packaging the standardized variety of the fruit. The average quantity harvested per month for 2 x 2 m spacing was 35 banana bunches, 71.3 tons and 1,274.8 kilograms, with a total of 32.1 bunches, 87.6 tons and 542.6 kilograms harvested per month. Harvesting took place mostly once or twice a month, depending on the size of the banana plantation and the sales unit (table 5).

Table 5: Banana quantity harvested frequency, quantities sold and price per unit

Spacing	Unit of sale	Quantity harvested per month	No of times harvested per month	Quantity sold	Price per unit
		Mean	Mean	Mean	Mean
2mx2m	Bunches	35.0	1	34.4	381.4
	Crates	71.3	1	71.3	950.0
	Kgs	1274.8	2	1274.8	17.2
3mx3m	Bunches	25.8	4	25.0	292.0
	Crates	96.5	2	96.5	750.0
	Kgs	509.6	1	506.1	61.6
4mx3m	Bunches	41.7	1	40.4	333.2
	Crates	64.3	1	64.3	875.0
	Kgs	118.6	1	116.8	98.4
4mx4m	Bunches	33.4	1	32.7	337.0
	Crates	150.0	2	150.0	850.0
	Kgs	915.0	1	615.0	17.5
Total	Bunches	32.1	2	31.2	317.6
	Crates	87.6	1	87.6	868.2
	Kgs	542.6	1	521.6	59.7

Wani 2021 noted that the average plantation produced 17.7 kg of weight, 9.1 hands and 134 fingers per lot. Ghimire 2019 and Gowri 2019 also stated that the well-filled bag of the dwarf cavendish produced 150 to 200 fruits. The higher number of bundles per hectare was observed at the spacing of 2 x 2 m and 3 x 3 m for the two varieties of vine. The spacing of 2 x 2 m and 3 x 3 m bananas yielded higher yields because of the higher number of plant populations. Murigi 2024 and Saudamini 2020 found that closer spacing resulted in higher yields and less weed and reduced the weight of the crop. Rathod *et al.,* 2021 and Sanjit *et al*., 2021, found that the yield of fruit increased significantly with increasing crop density. They also found that high density reduced the number of fruits, the number of hands per lot, the weight of fruit and the weight of lot. Sanjit *et al*., 2021, found that total yield increased with increasing plant density at all spacings.

Gross margin analysis of banana spacings in Taveta sub-county first year after planting

Farmers indicated that after planting, harvesting begins between the 10th and 11th month of the first year. At the first harvest, most farmers report around 60 per cent of their harvest. Additional assumptions used in the calculation of the gross margin are set out in Table 6 below.

Table 6 Assumptions made in the calculations of banana Gross margin using different spacings

	Description	Spacings				Remarks
		2 by 2m	3 by 3m	4 by 3m	4 by 4m	
1	Number of stools per spacing	1000	444	333	250	
2	Banana seedlings sold @ KES 150	150	150	150	150	
3	Supplemental irrigation may be necessary during this time 40-60 litres/plant per week split into 16L (in two splits) (Litres)	16000	7104	5952	4000	
4	Bananas are grown and harvested all year round and are ready to be harvested 10 to 11 months after planting.	harvest 10th month, 12th, 14th, 16th, 18th, 20th, and 24th,				
5	Cooperative buys @ KES 17/- per kg while brokers and traders buy @ KES 15/-					
6	Banana bunches weigh between 25-65 and using the average weight of	45	45	45	45	
7	First year of harvest the farmer gets 70% of the plants yielding	700	310.8	260.4	175	mother plant
8	Second harvest 2nd month after first harvest @ 30% of the plants yielding	300	133.2	111.6	75	mother plant
9	Third harvest 4th month @ 40% of the plants yielding	400	177.6	148.8	100	daughter
10	Fourth harvest 6th month @ 30% of the plants yielding	300	133.2	111.6	75	daughter
11	Fifth harvest 8th month @ 40% of the plants yielding	400	177.6	148.8	100	daughter/ grand-daughters
12	Sixth harvest 4th month @ 50% of the plants yielding	500	222	186	125	grand-daughter
13	Seventh harvest 4th month @ 40% of the plants yielding	400	177.6	148.8	100	grand-daughter
14	1st year	700	310.8	260.4	175	
15	2nd year	2300	1021.2	855.6	575	

The production aspects highlighted above were costed by the farmers, and the results showed that the 2 x 2 m spacing has a higher revenue base and better gross margins per year for a 1-acre banana plantation, followed by the 3 x 3 m spacing in the first year with a crop maturing and ready for harvesting from the 10th month (Table 7).

On the benefit-cost ratio (BCR), if a project or investment has a BCR greater than 1.0, the investment is expected to deliver a positive net present value to a firm and its investors. If an investment's BCR is less than 1.0, the investment's costs outweigh the benefits, and it should not be considered. All four-banana plant spacings had a BCR greater than 1.0, and this would deliver a positive value to its investors. However, the 2 x 2 m spacing had the highest BCR, followed by 3 x 3 m spacing.

Table 7: One acre banana Gross margin analysis based on the data first year

	Spacing			
VARIABLES	**2 by 2m**	**3 by 3m**	**4 by 3m**	**4 by 4m**
REVENUE				
Yield/ACRE (Kg)	31,500.00	13,986.00	11,718.00	7,875.00
PRICE PER (Kg)	17.00	17.00	17.00	17.00
Total Revenue	535,500.00	237,762.00	199,206.00	133,875.00

VARIABLE COSTS				
Inputs	140,000.00	88,800.00	68,820.00	50,000.00
Labour	21,000.00	18,900.00	16,800.00	12,900.00
Others	195,046.00	94,800.00	80,400.00	56,000.00
TOTAL VARIABLE COSTS	356,046.00	202,500.00	166,020.00	118,900.00
GROSS MARGIN/ACRE	179,454.00	35,262.00	33,186.00	14,975.00
COST OF PRODUCTION PER UNIT	11.3	14.5	14.2	15.1
MONTHLY PROFIT/LOSS	14,954.5	2,938.5	2,765.5	1,247.9
Break Even Yield	20,943.88	11,911.76	9,765.88	6,994.12
Min Area	0.66	0.85	0.83	0.89
BCR	1.50	1.17	1.20	1.13

Authors calculations based on survey data collected

In the second year the farmers get more production per harvest depending on the number of stools harvested and the crop management practices of desuckering, pruning, watering and fertigation. The same assumption as the first year is taken into consideration, plus additional ones that relate to the second harvest (3rd month at 40% of the plants yielding) and the third harvest (6th month at 30% of the plants yielding). In the 2 x 2 m plant spacing has a higher revenue base and better gross margins per year for a 1-acre banana plantation, followed by the 3 x 3 m plant spacing in the second year (Table 8). On the benefit-cost ratio If a project or investment has a BCR greater than 1.0, the investment is expected to deliver a positive net present value to a firm and its investors. If an investment's BCR is less than 1.0, the investment's costs outweigh the benefits, and it should not be considered. All the four-banana plant spacings had a BCR greater than 1.0, and this would deliver a positive value to its investors. However, the 2 x 2 m spacing had the highest BCR, followed by 3 x 3 m spacing.

Table 8: One acre banana gross margin analysis based on the data 2nd to 8th year

	Spacing type			
VARIABLES	**2 by 2m**	**3 by 3m**	**4 by 3m**	**4 by 4m**
REVENUE				
Yield/ACRE (Kg)	103,500.00	45,954.00	38,502.00	25,875.00
PRICE PER (Kg)	17.00	17.00	17.00	17.00
Total Revenue	1,759,500.00	781,218.00	654,534.00	439,875.00
VARIABLE COSTS				
Inputs	50,000.00	26,640.00	37,200.00	31,250.00
Labour	18,600.00	16,800.00	13,800.00	11,700.00
Others	160,000.00	133,200.00	111,600.00	93,750.00
TOTAL VARIABLE COSTS	228,600.00	176,640.00	162,600.00	136,700.00
GROSS MARGIN/ACRE	1,530,900.00	604,578.00	491,934.00	346,125.00
COST OF PRODUCTION PER UNIT	2.2	3.8	4.2	3.6
MONTHLY PROFIT/LOSS	127,575.0	50,381.5	40,994.5	28,843.8
Break Even Yield	13,447.06	10,390.59	9,564.71	5,514.71
Min Area	0.13	0.23	0.25	0.21
BCR	7.70	4.42	4.03	3.22

Authors calculations based on survey data collected

Note: Labour is considered as per the different spacing taking into account that 2 by 2 m is more labour intensive than in the 4 by 4 m.

All other assumptions made as in the table 11 above.

When labour costs held constant

During data collection, farmers in Taveta Sub- County, as in the coastal region, apportion labour activities in the farm based on 10 m by 10m. This is paid at KES 100. Also, this does not take into account the different banana spacings. Thus, the hired labourer was paid KES 100 for completing the 10 by 10 m task given. Using the above scenario, then the farmers make the following in the first year: The production aspects highlighted above were costed by the farmers, and the results show that the 2 x 2 m spacing has a higher revenue base and better gross margins per year for a 1-acre banana plantation, followed by the 3 x 3 m spacing in the first year with a crop maturing and ready for harvesting from the 10th month (Table 9).

On the benefit-cost ratio (BCR), if a project or investment has a BCR greater than 1.0, the investment is expected to deliver a positive net present value to a firm and its investors. If an investment's BCR is less than 1.0, the investment's costs outweigh the benefits, and it should not be considered. All four-banana plant spacings had a BCR greater than 1.0, and this would deliver a positive value to their investors. However, the 2 x 2 m banana spacing had the highest BCR, followed by 3 x 3m.

Table 9: One acre banana Gross margin analysis based on the data first year

	Spacing			
VARIABLE	**2 by 2m**	**3 by 3m**	**4 by 3m**	**4 by 4m**
REVENUE				
Yield/ACRE (Kg)	31500	13986	11718	7875
PRICE PER (Kg)	17.00	17.00	17.00	17.00
Total Revenue	535,500.00	237,762.00	199,206.00	133,875.00
VARIABLE COSTS				
Inputs	140,000.00	88,800.00	68,820.00	50,000.00
Labour	12,900.00	12,900.00	12,900.00	12,900.00
Others	195,046.00	94,800.00	80,400.00	56,000.00
TOTAL VARIABLE COSTS	347,946.00	196,500.00	162,120.00	118,900.00
GROSS MARGIN/ACRE	187,554.00	41,262.00	37,086.00	14,975.00
COST OF PRODUCTION PER UNIT	11.0	14.0	13.8	15.1
MONTHLY PROFIT/LOSS	15,629.5	3,438.5	3,090.5	1,247.9
Break Even Yield	20,467.41	11,558.82	9,536.47	6,994.12
Min Area	0.65	0.83	0.81	0.89
BCR	1.54	1.21	1.23	1.13

This study also confirms what other authors found such as Ajibade et. al., 2022 study on banana also found that the enterprises profitable as used the cost, returns and profitability of banana fruit enterprises in Nigeria. Whereas, Jakupi, Statovci and Hajrizi, 2017 found that the cost-volume-profit analysis (CVP Analysis) is a powerful tool for planning and making decisions for enterprise growth.

CONCLUSION AND RECOMMENDATIONS

The adoption of the 2 x 2 m and 3 x 3 m spacing of banana plants by farmers has resulted in increased production per unit area, thanks to the application of good agricultural practices. The farmers were able to harvest on average 35 bundles, 71 boxes and 1,250 kg of bananas per month. Improved agricultural management means better yields for farmers and ultimately good returns on investment in the Taveta subcounty. The use of irrigation and fertilizer by farmers at different planting distances has the potential to increase banana production, in line with the findings of other studies which suggest that the use of fertilizers can improve banana production, but the recommendations should be site-specific and address the current nutrient deficiencies in the farmer's fields

Where the 2 x 2 m plant spacing was used by the farmers, there was a higher revenue base of KES 803,250 and better gross margins of KES 364,350 per year for a 1-acre banana plantation, followed by the 3 x 3 m plant

spacing, a revenue of KES 339,660 and gross margins of KES 143,160. The 2 x 2 m plant spacing has the highest BCR of 1.83, followed by 3 x 3 m plant spacing with 1.73. Thus, the two spacings of 2 x 2 m and 3 x 3 m are profitable investments that should be promoted, as they show better returns on the investments for the farmers.

The commercialization of banana has the potential to transform the banana industry in Taveta subcounty in several key ways:

Improved cultures: Investment in R&D can lead to the development of banana varieties that are not only more disease resistant but also more suitable for long-distance transport. This would help to secure new markets for the banana producers. *Efficient supply chains*: Businesses can implement more efficient logistics, reduce the amount of lost fruit in transit and get bananas from the farm to the consumer faster. *Economy of scale*: Large-scale production allows more advanced cultivation techniques to be used, which further increases yields and reduces costs. *Market access*: Commercial banana companies can secure lucrative contracts with large retailers, which provide a stable outlet for the producers. It will be essential to introduce models that allow these farmers to benefit from commercialization, such as the out-grower system, where bananas are delivered to a central processing centre. With careful planning and execution, it can also increase farm incomes, reduce food waste, and increase access to these nourishing fruits for millions of consumers.

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REFERENCES

1. Adedeji, E. A., and Ituma N. K., 2020, Break Even Analysis as A Management Tool for Decision Making in Babcock University Water Corporation European Journal of Business and Management www.iiste.org ISSN 2222-1905 (Paper) ISSN 2222-2839 (Online) Vol.12, No.21, 2020
2. Ajibade, Y.E., Ameh, O.E., Onoja, N.M. and Jeremiah D. J., 2022, Banana Fruits Enterprises Profitability Analysis in Odigbo Local Government Area, Ondo State, Nigeria International Journal of Innovative Science and Research Technology ISSN No:-2456-2165 Volume 7, Issue 3, March – 2022
3. AFA 2024 year book of statistics Agriculture and Food Authority Nairobi Kenya
4. Banana Link. (n.d.). All about bananas. https://www.bananalink.org.uk/all-about-bananas/
5. Benfica, Rui; Hossain, Marup; Davis, Kristin E.; Boukaka, Sedi Anne; and Azzarri, Carlo. 2024. The true costs of food production in Kenya and Viet Nam. IFPRI Discussion Paper 2269. Washington, DC: International Food Policy Research Institute. https://hdl.handle.net/10568/152074
6. Coder, Kim D. 2023. Number of trees per acre by spacing distance. University of Georgia, Warnell School of Forestry & Natural Resources Outreach Publication WSFNR23-02C. Pp.6.
7. FAO 2017 Methodology for Estimation of Crop Area and Crop Yield under Mixed and Continuous Cropping framework of the Global Strategy to improve Agricultural and Rural Statistics Rome Italy
8. FAO Food and Agricultural Organization Statistics (FAOSTAT) (2018). Food and agricultural organization of the United Nations, Rome, Italy.
9. Ghimire S, Koirala B, Devkota S and Basnet G 2019, Economic analysis of commercial banana cultivation and supply chain analysis in Chitwan, Nepal Journal of Pharmacognosy and Phytochemistry 2019; SP5: 190-195
10. Gollin, D., & Rogerson, R. (2014). Productivity, transport costs and subsistence agriculture. Journal of Development Economics, 107(1), 38–48. https://doi.org/10.1016/j.jdeveco.2013.10.007

11. Gowri MU, Shanmugam TR. 2015 An economic analysis of production and marketing of banana in India. American International Journal of Research in Humanities, Arts and Social Sciences;9(3):234-240.
12. Guinness World Records. (2022). Most popular fruit. https://www.guinnessworldrecords.com/ world-records/74279-most-popular-fruit
13. Jaetzold, R., Schmidt, H., Hornez, D., & Shisanya, C. (2006) Farm Management Handbook of Kenya Vol 2 Natural Conditions and Farm Management Information Part B, Central Kenya 2nd Ed, Ministry of Agriculture Publisher, Nairobi.
14. Jakupi S., Statovci B., and Hajrizi B., 2017, Break-even analysis as a powerful tool in decision making International Journal of Management Excellence (3):1169-1171. DOI:10.17722/ijme.v9i3
15. Kathuri D. N., Ndirangu S. N., and Gichimu B., 2021 Adoption of Banana (Musa spp) Production Technology among Small-Scale Farmers in Embu West Sub-County, Kenya. Journal of Agricultural Extension Vol. 25 (4) October, 2021https://dx.doi.org/10.4314/jae.v25i4.12
16. Kenya National Bureau of Statistics. (2020). The 2019 Kenya population and housing census report.
17. KNBS 2024a National agricultural production report 2023-2024, Nairobi Kenya
18. KNBS 2024b Economic survey 2024, Nairobi Kenya
19. KNBS 2024c Statistical Abstract 2024 Nairobi Kenya
20. Kumari S., Mishra R. R., Mishra A. and Jhariya P. N. 2021, Estimation of costs and returns per hectare of banana cultivation in Vaishali district of Bihar The Pharma Innovation Journal 2021; SP-10(10): 1347-1350
21. Mahfuzur Rahman, Farzana Ahmed Mukta, Md. Wahidul Islam., 2020 Farmer's Profitability of Banana Cultivation at Narsingdi District. International Journal of Multidisciplinary Informative Research and Review. Vol. 1, No. 1, 2020, pp. 15-23.
22. Mugenda O., & Mugenda A. (2019). Research methods: Quantitative and qualitative approaches. 3nd. Rev. Ed. Nairobi.
23. Murigi Michael, Ngui Dianah & Ogada Maurice Juma (2024) Impact of smallholder banana contract farming on farm productivity and income in Kenya, Cogent Economics & Finance, 12:1, 2364353, DOI: 10.1080/23322039.2024.2364353
24. Ndambi A., J. Zijlstra, M. Ngigi, J. van der Lee, and C. Kilelu (2017): Calculating on-farm cost of milk production in Kenya Assessing the suitability of five methods being used in Kenya. 3R Kenya project Practice brief 001. Wageningen Livestock Research, Wageningen University & Research, Wageningen.
25. Obaga, B., & Mwaura, F. (2018). Impact of farmers' participation in banana value addition in household welfare in Kisii central sub-county. International Academic Journal of Social Sciences and Education, 2(1), 25–46.
26. Okoko, N., Nyaga A.N., Mogaka J., Gatambia E., Gathambiri C., Amata R., Wandera F.M., Wanyama J., Kirigua V.O and Wasilwa L.A. 2024, Banana agronomy, KALRO/NAV CDP/BANANA/Pamphlet No. 115/2024.
27. Pappu, A., Patil, V., Jain, S., Mahindrakar, A., Haque, R., & Thakur, V. K. (2016). Advances in industrial prospective of cellulosic macromolecules enriched banana bio-fibre resources. International Journal of Biological Macromolecules, 79, pp .449– 458.
28. Paul, J. Y., Harding, R., Tushemereirwe, W., & Dale, J. (2018). Banana21: From Gene Discovery to Deregulated Golden Bananas. Frontiers in plant science, 9, 558. https://doi.org/10.3389/fpls.2018.00558.
29. Ranathilaka, M. B., Lashmi, N., & Atukorala, W. (2019). Production And Marketing Of Banana: Estimating the Profitability using Walawa Region in Sri Lanka. Journal of Business and finance in emerging markets (JBFEM), 2(1), 23-32. https://doi.org/10.32770/jbfem.vol223-32
30. Rathod SR and Gavali AV 2021 Economic analysis of banana production from Western Maharashtra The Pharma Innovation Journal 2021; SP-10(8): 379-384
31. Saudamini Swain, Bipin Pradhan and Prakash Patil 2020 Evaluating Efficacy of High Density Planting in Banana under Coastal Plain Zone of Odisha International Journal of Current Microbiology and Applied Sciences ISSN: 2319-7706 Volume 9 Number 11 152-160 https://doi.org/10.20546/ijcmas.2020.911.018

32. Sanjit, Debnath; Bauri, F.K; Swain, S; Patel, A.N; Patel, A.R.; Shaikh, N.B.; Bhalerao, V.P.; Baruah, K; Manju, P.R.; Suma, A; Menon, R; Gutam, S. 2021, Studies on High Density Planting and Nutrient Requirement of Banana in Different States of India Journal of Horticultural Sciences, vol. 16, núm. 2, Society for Promotion of Horticulture, India https://www.redalyc.org/articulo.oa?id=577074107004
33. Sharma Manoj, Shiva Chandra Dhakal, Raj Kumar Adhikari & Ujjal Tiwari| (2021) Profitability, productivity and resource use efficiency of banana production in Hetauda-Dumkibas road corridor, Nepal, Cogent Food & Agriculture, 7:1, 1917134, DOI: 10.1080/23311932.2021.1917134
34. SPSS, I. (2019). IBM SPSS statistics version 17. Boston, Mass: International Business Machines Corp, 126
35. Thamires Monteiro Silva Maués, Rafael Rodrigo da Silva Costa, Marcos Antônio Souza dos Santos and Gisele Barata da Silva, 2022 Agroeconomic performance of banana tree under nutritional management with "Trichoderma asperellum", in a family production system, AIMS Agriculture and Food Volume 7, Issue 2, 297–311 DOI: 10.3934/agrfood.2022019
36. Tamil Nadu Agricultural University (TNAU) 2025 Expert system for banana https://www.agritech.tnau.ac.in/expert_system/banana/cultivation.html#B accessed on 4th march 2025
37. Tinzaara, W.; Stoian, D.; Ocimati, W.; Kikulwe, E.; Otieno, G.; Blomme, G. (2018) Challenges and opportunities for smallholders in banana value chains. In Achieving sustainable cultivation of bananas. Vol. 1 Cultivation techniques. (Kema, G.; Drenth, A. (eds.)) Burleigh Dodds. ISBN:9781786761569,.
38. Wahome, C. N., Maingi, J. M., Ombori, O., Kimiti, J. M., & Njeru, E. M. (2021). Banana production trends, cultivar diversity, and tissue culture technologies uptake in Kenya. International Journal of Agronomy, 20 (3) pp.1234-1247.
39. Wani M. H., Arshad Bhat & S. H. Baba (2021) Economic Evaluation of High-Density Apple (Ex-Ante) in Kashmir, International Journal of Fruit Science, 21:1, 706-711, DOI:10.1080/15538362.2021.1926393
40. Yamane, T. (1967). Statistics: An introductory analysis (2nd edition). Harper and Row.