Performance and Profitability of Growing Ginger Using Single Bud Technique under High Density Arecanut-based Multispecies Cropping System

Samima Sultana,[a] Partha S. Medda,[b] Sankar Saha,[a] Sandip Hembram,[a] Amarendra N. Dey,[c] Suraj Sarkar [a,*] and Prabhat K. Pal [d]

The performance of five known ginger cultivars of eastern India, namely Gorubathan, Suruchi, Suprabha, Bhaisay and a Local collection, were studied in an eight-year-old 2.7 m × 2.7 m spaced arecanut plantation at Uttar Banga Krishi Vishwavidyalaya within the Teraiagro-ecological region of West Bengal. Plantlets of ginger were raised through single bud sprout techniques (SBT) using 5 g cut piece of rhizome with a plump bud and transplanted under an arecanut-based high density crop model along with bay leaf and citrus as component crops. Different ginger cultivars showed considerable variations with respect to their growth behavior and yield. The Local cultivar produced vigorous growth with a higher average number of tillers (5.83) per plant with maximum height (57.6 cm). However, the cultivar Suprabha proved its superiority over other cultivars with respect to rhizome yield, producing 2.45 tons from one hectare of crop model, with 11% net cropped area of ginger and possessing a higher benefit cost ratio (6.51).

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*Contact information: a: Cooch Behar Krishi Vigyan Kendra, UBKV, Pundibari, Cooch Behar, West Bengal, India; b: Department of Plantation Crops and Processing, Faculty of Horticulture, UBKV, Pundibari, Cooch Behar, West Bengal, India; c: Department of Forestry, Faculty of Horticulture, UBKV, Pundibari, Cooch Behar, West Bengal, India; d: Department of Agril. Extension, Faculty of Agriculture, UBKV, Pundibari, Cooch Behar, West Bengal, India; *Corresponding author: suraj.cobkvk@ubkv.ac.in*

INTRODUCTION

Arecanut is an important commercial crop of the Northern part of West Bengal, spaced at 2.7 and 2.7 m, effectively utilizing only 30% land area and 40% incident solar radiation (Bhat *et al.* 2001). Integration of different component crops and their spatial arrangement in arecanut plantation for efficient utilization of the left-over land and solar energy is the most promising and perspective approach for sustainable horticultural crop productivity (Venkatesh 2015) for 90% small and marginal farming community of North Bengal through stabilizing family income and ensuring food, fuel, and employment over the year (Nair 1979). Areca nut-based cropping system provides not only greater economic return but also plays an important role in land use management (Nelliat 1973). Ginger is (*Zingiber officinale* Rosc.) the most ancient and widely used spice among the Zingiberaceae family, and it performs well under partial shade in the arecanut plantation (Ghosh and Hore 2011) as a subsidiary crop. India is the largest ginger-producing country in the world, contributing approximately 68.8% of the world's production from an area of about 1.64 lakh hectares. The share of ginger is 17.8% among all the spices grown in the country (Spice Board of India 2022). The traditional method of propagating ginger using seed rhizome cut pieces of 20 to 80 g weight with 3 to 4 buds and 15 to 25 tons of seed rhizome is required to accommodate one ha of land, depending on the size of the rhizome. The spacing (Parthasarathy *et al.* 2012) imposes a huge financial burden on the resource-poor north eastern region farming community (Jayachandran *et al.* 1980; Nybe and Miniraj 2005; Chandrashekhar 2021). The rhizome size and spacing between the plants have a substantial impact on plant growth and productivity of ginger (Monnaf *et al.* 2010).

A transplanting technique in ginger using single bud sprouts raised from 5 to 6 g rhizome pieces standardized by IISR, Kozhikode (IISR 2014) can produce vigorous and good quality disease-free planting material with reduced cost. The single bud sprouting approach produces ginger that is comparable to that grown through the traditional propagation method with respect to growth, yield, and quality of the produce (Prasath *et al.* 2018; Shil *et al.* 2018).

Ginger yield also depends considerably on the selection of suitable cultivar, climate, time of planting, and maturity of the crop at harvest (Peter *et al.* 2005). The potential of a cultivar alone fails to increase the profit, it is crucial to develop appropriate production technology of the respective cultivars (Yadav *et al.* 2014). Therefore, an experiment was carried out to evaluate the performance and profitability of growing ginger through single bud technique under high density areca nut-based multispecies cropping system.

EXPERIMENTAL

The study was carried out at Uttar Banga Krishi Vishwavidyalaya, in an eight-year-old areca nut (cv. 'Mohitnagar') plantation during 2019 to 2022. The experimental site is located within the latitude of 26°19'86" and 89°23'53" longitude, situated 43 m above mean sea level (MSL). The soil is sandy loam with a coarse-like texture and acidic in reaction. The integration of ginger intercrops was made for effective utilization of 70% of the remaining area and 40% of the incident solar radiation penetrating down within the canopy of the arecanut plantation along with two other perennial intercrops, bay leaf, and lime. Climate data is presented in Table 1 for the period from March, 2019 to February, 2021.

Ginger plantlets were planted on the raised bed prepared at the interspaces between two adjacent rows of areca nut palms, leaving sufficient space for irrigation and drainage channels. Bay leaf and lime were planted at the center of four areca palms in alternate rows spaced at 5.4 m × 5.4 m during the year 2019. The plants were maintained during subsequent years and started yielding from the second year of planting. The recommended cultivation practices were followed for areca nut and other perennial intercrops.

Planting Materials Preparation

Six different cultivars of ginger *viz.* Suruchi, Surabhi, Suprabha, Bhaisay, Gorubathan, and a Local selection (Pundibari local) were raised following Single Bud Techniques (SBT). Healthy, disease-free rhizome seeds of different cultivars were collected and cut into small pieces weighing 5 to 7 g with a plump bud. The cut pieces of rhizomes were put into Mancozeb solution (0.3%) for 30 min and spread under shade for drying and proper coating of the fungicide. The buds were placed in a portray filled with potting mixture containing coir pith, vermicompost, and soil (1:1:3) and kept in a partially shaded area.

Table 1. Meteorological Parameters Recorded during the Period of Field Experimentation

Months	Years	Temperature (°c)		Relative Humidity (%)		Rainfall (mm)	Sunshine (hrs.)
		Max.	Min.	Max.	Min.		
March	2019	27.20	14.00	80.00	53.00	33.80	6.10
	2020	29.00	16.10	74.70	51.20	43.40	6.20
	2021	31.00	15.00	68.00	46.00	50.00	5.00
April	2019	30.90	20.30	77.00	61.00	137.00	5.31
	2020	30.80	18.50	70.50	56.40	107.40	6.00
	2021	32.00	17.00	67.00	55.00	130.00	5.00
May	2019	30.40	22.70	87.00	75.00	254.80	3.00
	2020	30.60	21.60	83.00	71.50	393.50	4.60
	2021	31.00	19.00	84.00	72.00	269.00	3.00
June	2019	33.10	24.80	87.00	74.00	427.10	6.00
	2020	31.30	24.30	93.00	82.00	1107.80	3.00
	2021	32.00	22.00	88.00	76.00	574.00	3.00
July	2019	30.90	25.40	92.00	83.00	1135.70	4.00
	2020	30.60	24.70	96.50	86.00	1368.90	1.90
	2021	32.00	23.00	90.00	78.00	695.10	3.65
August	2019	34.30	26.10	86.00	73.00	349.70	6.00
	2020	33.20	25.40	89.00	76.00	409.80	4.20
	2021	31.00	22.00	94.00	84.00	869.00	2.00
September	2019	24.10	21.20	100.00	100.00	343.20	3.00
	2020	30.20	23.90	93.40	84.00	1426.70	2.10
	2021	34.00	22.00	84.00	70.00	323.00	5.00
October	2019	30.70	21.50	84.50	69.00	54.90	4.00
	2020	32.90	22.20	80.00	67.00	90.20	6.00
	2021	32.00	20.00	82.00	69.00	267.80	5.00
November	2019	30.10	17.70	79.80	57.60	4.20	6.00
	2020	29.60	14.00	71.00	49.00	0.00	6.40
	2021	29.00	12.00	74.00	51.00	0.00	6.00
December	2019	23.90	10.60	83.90	57.70	0.00	4.00
	2020	26.00	10.00	81.00	55.00	0.00	4.80
	2021	27.00	12.00	79.00	51.00	1.20	6.00
January	2019	26.00	9.00	79.00	43.00	0.50	6.00
	2020	22.80	9.90	91.10	59.70	0.80	3.20
	2021	22.80	8.30	86.00	65.00	0.00	3.00
February	2019	26.10	12.00	81.00	54.00	13.60	6.00
	2020	26.00	10.80	84.00	49.70	11.00	3.70
	2021	28.00	9.00	79.00	45.00	0.00	5.00

Planting and Cultivation Practices

The available interspaces of the cropping system model were ploughed thoroughly to achieve fine tilth incorporating well-rotten farmyard manure @ 15 tons per ha along with a full dose P_2O_5 of the recommended dose of fertilizers (75:50:50 kg/ha). A raised bed of 3 m ×1 m dimension was made in between the two rows of palms of the eight-year-old established areca nut plantation, leaving a 50 cm radius from the base of each palm. The experimental plots were laid out in Randomized Block Design with four replications. The 35-days-old healthy plantlets raised from single bud sprouts were transplanted carefully at a spacing of 25 cm × 25 cm and mulched with paddy straw. Nitrogen and potassic fertilizers were applied as top dress at 45, 90, and 120 days after transplanting in three equal splits followed by removing weeds and earthing up to cover up the growing rhizomes. The entire crop was grown as rainfed crop.

Five plants were randomly selected from each replication and were used to record data on growth and yield. The harvested rhizomes were analyzed for assessing the quality attributes. The crop was harvested after complete drying of the above ground plant parts after approximately eleven months after planting. The economics of ginger cultivation were calculated based on yield and prevailing market price. The cost of cultivation of single bud technology of different cultivars over conventional method in areca nut-based cropping system was also calculated for finding out the benefit cost ratio. Various quality indicators for each cultivar were calculated in the following procedure.

Recovery Percentage

The freshly harvested ginger rhizomes were cut into thin slices after thorough washing. The ginger slices were dried at 65 °C in a hot air drier until they attained a consistent weight. The formula used to calculate the dry recovery percentage of the ginger rhizomes is as follows:

$$\text{Recovery of ginger (\%)} = \frac{\text{Dry weight of sample (g)}}{\text{Fresh weight of sample (g)}} \times 100 \quad (1)$$

Essential Oil Content

Hydro-distillation was used to determine the essential oil concentration of the powdered and dried ginger rhizomes. A total of 100 g of fresh ginger rhizomes were hydro-distilled in a Clevenger apparatus for 6 h using 500 mL of distilled water. The separated oil was gathered into glass vials. The remaining moisture was eliminated by drying it over anhydrous sodium sulphate (Jayashree e*t al*. 2014). The following formula was used to calculate the essential oil content:

$$\text{Essential oil content (\%)} = \frac{\text{Weight of essential oil (g)}}{\text{Weight of fresh sample (g)}} \times 100 \quad (2)$$

Oleoresin Content

Oleoresin content of the dried ginger powder was estimated through solvent extraction using petroleum ether as the solvent in Soxhlet apparatus. Below is the formula:

$$\text{Oleoresin (\%)} = \frac{\text{Weight of oleoresin (g)}}{\text{Solid present in 5 g of sample (g)}} \times 100 \quad (3)$$

Crude Fibre Content

The dried ground sample was de-fattened using petroleum ether and subsequently digested with a solution of sodium hydroxide (1.25% w/v) and sulfuric acid (1.25% w/v) and dried. Cleaned residue was placed in a boiling NaOH (1.25 N) solution for 30 min. The solution was cleaned using linen towels. The residue was completely cleaned using petroleum ether, alcohol, and hot water. The cleaned sample was coated with a thin layer of asbestos in a Gooch crucible and dried in a hot air oven at a temperature of 105 °C for consecutive 3 h. The weight of the cooled sample was recorded until the difference of two subsequent measurements was less than 1 mg. The residue was burnt at 550 °C for 3 h in a muffle furnace and the final dried sample was weighted. Crude fiber content of the sample was calculated using the following formulas,

$$\text{Loss in weight on ignition} = (W_2 - W_1) - (W_3 - W_1) \quad (4)$$

$$\text{Crude fiber content (\%)} = \frac{(W_2 - W_1) - (W_3 - W_1)}{\text{Sample weight (g)}} \times 100 \tag{5}$$

where W_1 is the weight of residue before drying (g), W_2 is the weight (g) of residue after drying, and W_3 is the weight of residue after ignition (550 °C) for 3 h.

A pooled analysis of two years data was made (Gomez and Gomez 1984) and treatment variations were tested for significance using critical difference at 5% level consulting Fisher and Yates tables using the statistical software SPSS statistics 17.0. A Duncan's multiple range test (DMRT) was made for comparing the treatment means.

RESULTS AND DISCUSSION

Data collected on various growth, yield attributing characteristics of six distinct ginger cultivars were subjected to a pooled analysis. A significant variation on growth at the active rhizome development phase of ginger and yield were observed. Figures 1 through 4 show the plants raised in portrays, the ginger planted in ABCS, clumps of Suprabha, and clumps of Bhaisay, respectively.

Fig. 1. Plant raised in portrays

Fig. 2. Ginger planted in ABCS

Fig. 3. Clump of Suprabha

Fig. 4. Clump of Bhaisay

The local cultivar had exhibited maximum plant height (57.64 cm) along with highest number of tillers (5.83) at 150 days after transplanting (Table 2). The variation in plant height and number of tillers might be due to genotypic response of cultivars as well as the presence of a greater number of buds with shorter internodes of the rhizome. Tamang *et al.* (2022) observed comparatively lower plant height of the plant raised from single bud sprout even after 180 days of transplanting in open field condition. Higher plant height under ABCS might be attributed to the natural tendency of the plant to become bushy, thus receiving lower solar radiation under shade (Sangeetha and Subramanian 2015).

The number of leaves per tiller, as well as their respective length and breadth also significantly varied among the cultivars. The highest number of leaves (22.2) were recorded by cv. 'Gorubathan', followed by the local cultivar (18.5); however, the longest leaf (21.1 cm) was recorded by the Suravi and the cv. 'Bhaisay' produced wider leaf by cv. (2.77 cm). Different germplasm under areca nut-based cropping system exhibited luxuriant vegetative growth that might be due to a microclimatic situation prevailing under the canopy of areca palms and other subsidiary crops in lower light intensity and high humidity.

Table 1. Effect of Arecanut-Based Cropping System on Growth of Different Ginger Cultivars Raised Through SBT

Cultivar	Plant Height (cm)	No. of Tiller	No of Leaf Per Tiller	Leaf Length (cm)	Leaf Breadth (cm)
Suprabha	45.79^{e}	5.38^{c}	16.98^{c}	20.25^{b}	2.28^{b}
Suruchi	54.14^{bc}	5.71^{b}	17.46^{c}	20.36^{b}	2.31^{b}
Suravi	53.06^{c}	4.97^{d}	17.13^{c}	**21.06^{a}**	2.43^{b}
Gorubathan	54.91^{b}	4.80^{e}	**22.17^{a}**	21.00^{a}	2.49^{ab}
Bhaisay	48.12^{d}	5.36^{c}	12.90^{d}	20.37^{b}	**2.77^{a}**
Local	**57.64^{a}**	**5.83^{a}**	18.46^{b}	20.80^{a}	2.47^{b}
S.Em (±)	**0.48**	**0.02**	**0.27**	**0.11**	**0.09**
CD (0.05)	**1.45**	**0.08**	**0.82**	**0.34**	**0.29**

Table 2. Effect of Arecanut-Based Cropping System on Yield and Yield Attributing Characteristics of Different Ginger Cultivars Raised Through SBT

Cultivar	Weight of Clump (g)	Length of Clump (cm)	Breadth of Clump (cm)	No. of Primary Finger	Weight of Primary Finger (g)	No. Secondary Finger	Weight of Secondary Finger (g)	Yield Per Plot (3 m x 1 m) kg	Yield Per ha (Tons)	Yield Increase (%)
Suprabha	**208.2^{a}**	**17.1^{a}**	7.81^{ab}	**3.94^{a}**	**55.8^{a}**	5.30^{d}	**125.0^{a}**	**6.80^{a}**	**2.45^{a}**	62.2
Suruchi	150.5^{d}	15.7^{b}	7.72^{ab}	3.28^{c}	45.4^{b}	6.70^{b}	91.4^{c}	4.92^{c}	1.77^{c}	17.2
Suravi	157.1^{cd}	16.4^{ab}	**8.17^{a}**	3.52^{b}	40.9^{d}	6.07^{c}	85.0^{d}	5.13^{bc}	1.85^{bc}	22.5
Gorubathan	162.2^{bc}	16.2^{ab}	7.34^{b}	3.24^{c}	42.0^{cd}	5.21^{d}	106.7^{b}	5.30^{b}	1.91^{b}	26.5
Bhaisay	165.8^{b}	16.8^{ab}	7.75^{ab}	2.70^{d}	44.0^{bc}	4.11^{e}	96.4^{c}	5.41^{b}	1.95^{b}	29.1
Local	128.0^{e}	16.0^{ab}	7.44^{b}	**4.01^{a}**	25.0^{e}	**7.93^{a}**	66.1^{e}	4.19^{d}	1.51^{d}	-
S. Em (±)	**2.87**	**0.40**	**0.19**	**0.08**	**0.92**	**0.18**	**1.82**	**0.09**	**0.034**	-
CD (0.05)	**8.66**	**1.19**	**0.57**	**0.23**	**2.79**	**0.54**	**5.52**	**0.28**	**0.104**	-

The data presented in Table 3 on the rhizome characters *viz.* length and weight of clump, number, and cumulative weight of primary and secondary fingers, per plot yield, projected yield per ha under ABCS showed significant difference among the cultivars. Higher individual clump weight (208 g), plot yield (6.80 kg), and projected yield per ha of model (2.45 t) were recorded by the cultivar Suprabha with larger size fingers, followed by Bhaisay and Gorubathan. The smaller individual clump (128 g) was recorded by the Local cultivar might be due to its very closely spaced bud on the rhizome having shorter inter-nodal length, reflected in its inherent character of producing a greater number of small-sized primary and secondary fingers. Variability with respect to rhizome weight among the cultivars under ABCS may be due to their differential adoptability in this microclimatic condition and translocation of photosynthates to under-ground rhizome (Durgavathi 2011). Singh *et al.* (2015) found that Suprabha had the highest yielding germplasm with bigger size rhizome (230 g) than other genotypes grown under partial shade condition under integrated nutrient management system, confirming its better adaptability to a cool shady eco-system. Suprabha and Bhaisay produced significantly increased the yield of fresh rhizome with 2.45 tons and 1.95 tons, respectively, from 11% cultivated area of 1 ha ABCS model and comparable to that of conventional propagation methods of ginger (Prasath *et al.* 2018), may be because of better adaptability of these cultivars to the sub-Himalayan foothills of North Bengal.

Table 3. Effect of Areca Nut-Based Cropping System on Quality Attributes of Ginger Rhizome Raised through SBT

Cultivar	Essential Oil Content (%)	Crude Fibre Content (%)	Oleoresin Content (%)	Dry Recovery (%)
Suprabha	2.08[a]	5.08[b]	9.09[b]	20.54[e]
Suruchi	1.99[b]	4.62[c]	11.66[a]	23.29[c]
Suravi	1.89[c]	4.78[b]	11.75[a]	24.42[b]
Gorubathan	1.55[e]	5.53[a]	12.28[a]	22.51[d]
Bhaisay	1.73[d]	4.69[c]	4.68[d]	25.22[a]
Local	1.92[c]	5.77[a]	5.57[c]	24.65[ab]
S. Em (±)	**0.02**	**0.11**	**0.21**	**0.25**
CD (0.05)	**0.06**	**0.32**	**0.63**	**0.76**

Table 4. Economics of Ginger Cultivation Under Arecanut-Based Cropping System

Cultivars	Cost of Cultivation Per ha Model (Rs)	Yield Per ha ABCS Model	Return Per ha (Rs)	Net Return Per ha (Rs)	B:C
Ginger Cultivars Raised Through SBT					
Suprabha	37604	2.45 t	245000	207396	6.51
Suruchi	37604	1.77	177000	139396	4.71
Suravi	37604	1.85	185000	147396	4.92
Gorubathan	37604	1.91	191000	153396	5.08
Bhaisay	37604	1.95	195000	157396	5.19
Local	37604	1.51	151000	113396	4.02
Ginger Raised Through Conventional Method					
Suprabha	72704	2.47t	247000	174296	3.39

Different quality attributes of the harvested ginger rhizome, such as essential oil, oleoresin, crude fibre content, and recovery percentage of the six ginger cultivars are shown in Table 4. Cultivar Suprabha recorded the highest essential oil (2.08%) content, followed by Suruchi (1.99%), and the result was in accordance with Babu *et al*. (2017) under partial shaded conditions of coastal Andhra Pradesh. The lowest crude fibre content (4.62%) was registered by the cultivar Suruchi, though it was slightly lower than the open field condition as observed by Tamang *et al.* (2022). This might be due to low light intensity (Ajith Kumar and Jayachandran 2003). The highest oleoresin concentration of dried ginger rhizomes was found in Gorubathan (12.3%), and the maximum dry recovery percentage was found in Bhaisay (25.2%).

The economics of ginger cultivation was calculated considering best performing cultivar of ginger both through single bud sprout technology (SBT) and the conventional method of propagation under arecanut-based cropping system based on the prevailing market price. The net return and benefit cost ratio (BCR) were markedly influenced by the cost of seed rhizome and the yield of ginger obtained from 11% area of one-hectare ABCS model. The result (Table 5) indicated that the higher yield and minimum seed rhizome requirement almost doubled the BC ratio (6.51) through SBT over the conventional method (3.39) of cultivation.

CONCLUSIONS

The integrating of ginger as an inter-crop in arecanut based plantation was shown to be a viable option for boosting farming income for small and marginal farmers of Northern parts of West Bengal because presently farmers do not get sufficient income from the monocropping system. The ginger cultivar Suprabha was profitably grown and performed luxuriously under partial shade of areca plantations component crop without negatively affecting the performance of the main crop and effectively utilized the natural resources and solar radiation. From an economic point of view, the single bud techniques in ginger proved its superiority for the small and marginal farming community of Terai region of West Bengal due to its minimum requirement of planting materials and production of disease-free quality planting materials. The single bud sprouting approach produced ginger that was comparable to that grown using the traditional propagation method in terms of growth, yield, and quality of ginger.

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