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Harvesting of tender coconuts improves yields and profitability of coconut farming in India

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ABSTRACT

An experiment was conducted at Kasaragod, Kerala, India for six years to study the impact of different coconut harvesting treatments on growth, yield and return. The treatments were; harvesting tender nuts from January to June and mature nuts from July to December, harvesting tender nuts from July to December and mature nuts from January to June, harvesting tender nuts throughout the year, harvesting tender nuts in alternate years, harvesting alternate bunches for tender nuts and harvesting of mature nuts throughout the year. The results showed that palms that underwent tender nut harvesting throughout the year, compared with harvesting mature nuts throughout the year, recorded high yields (175 nuts/palm), three times high net returns, and 68.7% high energy use efficiency. This study demonstrated the potential of harvesting tender nuts to improve the profitability and energy balance of coconut production.

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Introduction

Coconut (*Cocos nucifera* L.) is an important crop known as 'Kalpavriksha' or 'Tree of Heaven' due to its many uses. The world coconut area is 11.97 M ha, with Indonesia (3.57 M ha), Philippines (3.52 M ha), India (1.98 M ha), Sri Lanka (0.44 M ha) and Thailand (0.20 M ha) accounting for 75% of the total cultivation (Asian and Pacific Coconut Community APCC, 2015). India produces 20,736.1 million nuts from 2198.9 thousand hectares, across 18 states and three union territories with 9430 nuts/ha (Coconut Development Board CDB, 2022) and more than 10 million people depend on the crop for their livelihood. Small farms represent significant proportions of the holdings. However, the income cannot sustain a family due to low prices, high cost of production, and low productivity (Anithakumari et al., 2012). Coconuts are generally used for making copra and oil, but the returns are highly volatile. It is essential to add value to coconut farming. Harvesting tender nuts is one such way as the demand for tender nut water is increasing.

Tender nut water has gained recognition as a healthy, non-alcoholic, natural beverage. It is rich in minerals, amino acids and vitamins B and C. It has a pleasant taste and has a lower sugar content than many other beverages. Awareness among consumers about the health benefits of tender coconut water has increased its market demand (Lal et al., 2003; Naik et al., 2022; Preetha et al., 2012; Yong et al., 2009). The availability of technologies like minimal processing of tender nuts and packaging of tender nut water have increased its export potential around the globe. However, in India, the share of tender coconut is only 10% of total production (Thamban et al., 2014). Expansion has been limited since land has become scarce. Increase in productivity may be achieved through high yielding cultivars and better management. Modifying the harvesting sequence can increase yields (Maravilla & Magat, 1993). However, there are concerns that continuous harvesting inhibits growth and development. Hence, an experiment was conducted to study the impact of tender nut harvesting on the growth and production of coconuts.

Materials and methods

Description of study site

An experiment was initiated in 2012–13 at the ICAR-Central Plantation Crops Research Institute Kasaragod, Kerala, India located at 12°30' N latitude and 75°00' E longitude and at an elevation of 10.7 m. The climate is humid tropical, with a mean annual rainfall of 3500 mm. The temperature ranges from 21 °C to 36 °C, while average relative humidity varies from 61% to 94%. The experiment was conducted in 45 year old palms (cv. WCT) planted at 7.5 m x 7.5 m. The soil

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was a red sandy loam with 76% sand, 1.92% silt and 22% clay. The field capacity was 10.0% and wilting point was 5.2%, with a bulk density of 1.54 kg/m^3.

Treatments

The experiment was laid out in a randomised block design with six treatments and four replications and six trees in each plot. The treatments were as follows, harvesting tender nuts from January to June and mature nuts from July to December; harvesting tender nuts from July to December and mature nuts from January to June; harvesting tender nuts throughout the year; harvesting tender nuts in alternate years (2012, mature nuts); harvesting alternate bunches for tender nuts and mature nuts throughout the year. The trees were supplied with ICAR-CPCRI, Kasaragod recommended nutrients (250 g N and 600 g K per palm) through the drip irrigation from November to May. Since the soil had >20 ppm available P, the nutrient was not applied. The sources of nutrient used were urea and muriate of potash. Organic manure in the form of farmyard manure was applied at 50 kg/tree in the basin and covered with soil in October. The tree basins were mulched with coconut leaves during summer in order to reduce the soil water evaporation.

Plant growth and yield

The date of opening of each inflorescence was recorded. Tender nut bunches were harvested at 210 ± 7 DAIE (days after inflorescence emergence) which is the optimum stage for quality (Sundarsana Rao et al., 2014). The harvested bunches were lowered to the ground using a rope and the number of nuts per bunch and number of female flowers recorded.

Plant height, girth at breast height and the number of leaves were recorded in May from two trees selected randomly from six trees per plot. The same palms were selected every year for the measurement of growth parameters.

Biochemical analysis

From the same two trees, that were selected randomly from six trees per plot, tender nuts were collected and total sugar content (Hodge & Hofreiter, 1962), free amino acid content (Moore & Stein, 1948), reducing sugar (Somogyi, 1952), protein (Lowry et al., 1951), and pH of the coconut water were analysed by following standard procedures.

Economic analysis

The costs of cultivation including the material costs and the output from each treatment were recorded to calculate the cost benefit ratio. Since the annuity value was the same for all the treatments, it was not considered. The annual cost of production included fertilisers, manure, pesticides, labour for cultivation, irrigation, and harvesting. The average of five years was considered for final analysis. The net returns were calculated after deducting the total cost of cultivation for each treatment from the gross returns and expressed in USD/ha. The net profit per dollar of investment was calculated as the quotient of total cost of cultivation over the net profit per hectare and expressed in USD/ha

Energy analysis

The inputs and outputs during the study were used to calculate energy inputs and outputs. The inputs consisted of human labour, tractor, electricity, irrigation, manures, nutrients, insecticides, and fungicides. The outputs comprise the husk and shell yield. The energy equivalents/coefficients from published reports (Amoako & Mensah-Amoah, 2019; Lim et al., 2000; Zhang et al., 2015) were used to estimate inputs and outputs (kilojoules, kJ). The energy use indicators, such as net energy (NE), energy productivity (EP), energy use efficiency (EUE), and energy profitability (EPF) were computed using the following equations (Shen & Shaobing, 2017) (Table 1).

(i) Energy use efficiency (EUE) = Energy output (kJ/ha)/Energy input (kJ/ha)
(ii) Net energy (NE) (kJ/ha) = Energy output (kJ/ha) − Energy input (kJ/ha)
(iii) Energy productivity (EP) (kg/kJ) = Economic yield (nuts/ha)/Energy input (kJ/ha)
(iv) Energy profitability (EPF) = Net energy (kJ/ha)/Energy input (kJ/ha)

Statistical analysis

Statistical analysis was undertaken for each parameter based on randomised block design (RBD) using SAS 9.3 (SAS Institute, Cary NC). Differences in parameters were compared using replicated measures of analysis of variance (ANOVA). After a one-way ANOVA test, to determine if there are significant differences between means, Duncan's multiple range test (DMRT) was used to measure the specific differences between means at a significance threshold of 5%.

Results

Growth parameters

Plant height, girth, and the number of leaves in 2014–15 ranged from 8.8–9.9 m, 0.9–1.0 m, and 31–34,

Table 1. Energy equivalent of inputs and outputs in coconut production in India.

Inputs/outputs	Unit	Energy equivalent (MJ/Unit)	Reference
A. Inputs			
1. Labour	H	1.96	Singh et al. (2002)
2. Tractor	H	27.6	Fluck (1992)
3. Nitrogen (N)	Kg	60.6	Singh et al. (2002)
4. Potassium (K_2O)	Kg	6.7	Singh et al. (2002)
5. FYM	Kg	0.3	Singh et al. (2002)
6. Insecticides	Kg	102.2	
7. Fungicides	Kg	181.9	
8. Water	m^3	0.6	Akbolat et al. (2006)
9. Electricity	Kwh	3.6	
B. Outputs			
1. Coconut Husk	Kg	10.01	Akbolat et al. (2006)
2. Coconut Shell	Kg	17.40	Akbolat et al. (2006)
3. Copra	Kg	20.64	Lim et al. (2000)

respectively. In 2017–18, plant height ranged from 10–12 m, girth from 0.9–1.0 m, and number of leaves from 32–35. Average values of the growth over the experiment did not significantly differ amongst the treatments (Table 2).

Yield

The greatest number of bunches was observed when the tender nuts were harvested throughout the year or by harvesting tender nuts from July to December (Table 3). The other treatments had fewer bunches than these two treatments.

The highest yield was recorded when all the nuts were harvested as tender nuts (Table 3). Yield was 72% higher than when mature nuts were harvested. The next higher yield was recorded when the tender nuts were harvested from July to December. Harvesting tender nuts on alternate years or as alternate bunches gave similar yields. The lowest yield was recorded when all the nuts were harvested when mature.

Tender nut water quality

There was no significant difference in the water quality amongst the treatments. The pH ranged from 5.13 to 5.16, total sugars from 3.06–3.49 g/100 mL, reducing sugar from 2.8–3.07 g/100 mL, amino acids from 47.76–58.33 mg/100 mL, and protein from 0.32–0.47 g/100 mL.

Economics

Harvesting of tender nuts throughout the year gave higher net returns (USD 3373/ha) than the other treatments (Figure 1). This was 3 times higher than harvesting mature nuts (USD 809/ha). The next highest income (USD 2872/ha) was when the tender nuts were harvested from July to December. Harvesting tender nuts from January to June, in alternate years and from alternate bunches gave similar incomes (USD 1853 to USD 2067/ha).

Table 2. Effect of different sequences of harvesting on tree height, girth and number of leaves of coconut in India.

Treatment	Height (m)	Girth (m)	Number of leaves/tree
Harvesting tender nuts from January to June and mature nuts from July to December	10.5	0.90	33
Harvesting tender nuts from July to December and mature nuts from January to June	10.8	1.00	34
Harvesting tender nuts throughout the year	10.9	0.90	35
Harvesting of tender nuts in alternate years (2012, as mature nuts)	9.9	0.90	32
Harvesting alternate bunches for tender nuts	9.4	0.90	33
Harvesting mature nuts throughout the year	9.9	0.90	33
CD ($P < 0.05$)	NS	NS	NS

Note: Data are the means over five years, with four replications per treatments.

Table 3. Effect of different sequence of harvesting on number of bunches/palm and nut yield/palm in India.

Treatment	Pre experimental yield	Number bunches/palm	Nut/ palm	% increase over mature nut harvest alone
Harvesting tender nuts during January to June and mature nuts from July to December	115	11	118	17
Harvesting tender nuts during July to December and mature nuts from January to June	89	13	147	45
Harvesting of tender nuts throughout the year	108	14	175	73
Harvesting of tender nuts during alternate years (2012- mature nuts)	100	12	131	30
Harvesting alternate bunches for tender nuts	88	11	124	22
Harvesting of mature nuts throughout the year	104	10	101	0
CD ($P < 0.05$)	12.3	1.87	12.0	

Note: Data are the means over two years for pre-experimental yield and five years for number bunches/palm and nuts/palm, with four replications per treatment.

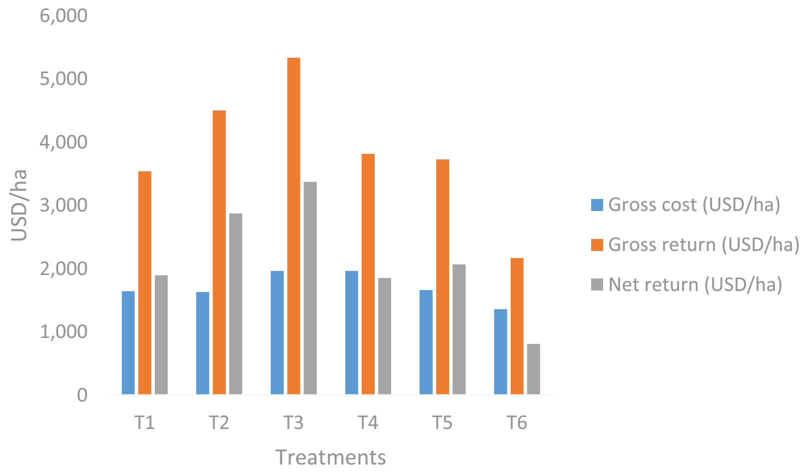

Figure 1. Economics of coconut farming with harvesting of tender nuts and mature nuts in India. T1: Harvesting tender nuts from January to June and mature nuts from July to December; T2: Harvesting tender nuts from July to December and mature nuts from January to June; T3: Harvesting tender nuts throughout the year; T4: Harvesting tender nuts in alternate years (2012, as mature nuts); T5: Harvesting alternate bunches for tender nuts; T6: Harvesting mature nuts throughout the year.

Energy

The energy input varied from 18.62 kJ/ha to 19.08 kJ/ha (Table 4). The input energy from harvesting tender nuts throughout the year was only 2.5% more than from harvesting mature nuts throughout the year. The energy output (457.69 kJ/ha) was high in harvesting tender nuts throughout the year compared with the other treatments. The lowest energy output (264.90 kJ/ha) was recorded when mature nuts were harvested throughout the year. Similar trends were noticed for net energy, energy use efficiency, energy productivity, and energy profitability (Table 4).

Discussion

In general, coconut is harvested after 12 months of maturity. The nuts harvested as tender nut are of 6–7 months maturity and hence, they remain on the palm for 5–6 months less compared to mature nuts. This early harvest saves the burden on the palm for providing photosynthates to the nuts for 5–6 months which may in turn lead to better development of subsequent inflorescences and nut set leading to the higher production of nuts (Niral & Ranjini, 2018) which is corroborated in production of more bunches compared to harvesting mature nuts alone. This has resulted in a 74% higher nut yield with the harvest of tender nuts as compared to harvesting mature nuts.

Further, the yield was high when tender nuts were harvested from July to December as compared to harvesting from January to June. This difference in yield may be attributed to the time of inflorescence opening. The inflorescences opened during the monsoon were harvested from January to June and the inflorescences opened during winter and summer were harvested from July to December. Prasad Rao and Nair (1988) reported shedding of 83% of nuts from the inflorescences that open during the monsoon while it was only 39% from inflorescence which open during the winter. Nambiar et al. (1970) also reported that, during summer there is more emergence of the inflorescence which indirectly increases the number of female flowers, spikes and reduces the proportion of sterile spikes. These previous findings support the results of the present study. Tree height, girth at breast height, and number of leaves were on a par in all the treatments during the years of investigation. Thus, it can be concluded that continuous

Table 4. Energy parameters as influenced by tender nut harvesting sequences.

Treatment	Input energy kJ/ha	Output energy kJ/ha	Net energy kJ/ha	Energy use efficiency	Energy productivity (nuts/kJ)	Energy Profitability
Harvesting tender nuts from January to June and mature nuts from July to December	18.7^{cd}	307.2^{d}	288.47^{d}	16.40^{d}	1107.3^{d}	15.40^{d}
Harvesting tender nuts from July to December and mature nuts from January to June	19.0^{ab}	382.2^{b}	363.3^{b}	20.2^{b}	1361.1^{b}	19.2^{b}
Harvesting tender nuts throughout the year	19.1^{a}	457.7^{a}	438.6^{a}	24.0^{a}	1620.2^{a}	23.0^{a}
Harvesting tender nuts in alternate years (2012, as mature nuts)	18.9^{bc}	346.5^{c}	327.6^{c}	18.4^{c}	1241.3^{c}	17.4^{c}
Harvesting alternate bunches for tender nuts	18.7^{cd}	322.6^{d}	303.9^{d}	17.2^{d}	1162.9^{d}	16.2^{d}
Harvesting mature nuts throughout the year	18.6^{d}	264.9^{e}	246.3^{e}	14.2^{e}	960.7^{e}	13.2^{e}
CD ($P < 0.05$)	0.14	18.9	18.9	0.99	66.98	0.99

Note: The means followed by the same lower case letter (a-e) do not differ significantly at the 0.05% probability.

harvesting of nuts for tender nut water will not adversely affect the growth of the palm.

The different harvesting schedules did not show significant influence on the quality of tender nut water as the nuts are harvested at the same maturity stage (210 ± 7 DAIE) in all the treatments.

The real value of any farm technology is measured in terms of proportionate increase in farm income. The net income achieved, when nuts were harvested for the tender nut, was three times higher than the income achieved in harvesting mature nuts which suggests a potent value addition to the coconut farming for the benefit of the farming community. All the treatments resulted in higher income over harvesting mature nut alone. Farmers get a better price for tender nuts at the farm level and they can get ready cash immediately after harvesting. Niral et al. (2014) also advocated harvesting tender nuts to enhance the profitability and to avoid the risk of market fluctuations.

Sustainable technology would increase the energy output from a given input. In the present study, the 2.47% higher input energy in tender nut harvesting throughout the year has resulted in 72.8% increase in output energy over mature nut harvesting. This energy efficiency highlights the superiority of harvesting tender nut over the mature nut. This is further supported by the significantly higher net energy (78.1%), EUE (68.7%), EP (68.6%), and EPF (73.9%) with tender nut harvesting over mature nut harvesting. The literature on the energy efficiency of plantation crops specifically on harvesting method is meagre. However, there are many reports on field crops. Kulig et al. (2019) reported higher energy efficiency in willow cultivars harvested in a two year cycle than in the one year cycle. Tian et al. (2019) reported in Guangxi China, two harvests – a year grape cultivation is at the high level of energy utilisation – with an energy efficiency of 0.687, which is higher than that of the one harvest a year grape.

Conclusion

Harvesting of tender nuts, at 210 ± 7 DAIE, increased yield without impacting the growth and development of the palms. This improved productivity and enhanced profitability. The energy consumption and energy use efficiency, energy productivity, and energy profitability confirm the superiority of harvesting tender nuts over mature nuts. This strategy increased farm income by three times over traditional harvesting.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Data availability statement

All the data pertaining to manuscript are already presented in this manuscript. Further, the data can be availed from the corresponding author on request.

Author contributions

Ravi Bhat- visualisation, project administration, formal analysis, writing original draft, review and editing; **Surekha** - methodology, investigation, validation, formal analysis, writing original draft, review and editing; **P. Subramanian** - conceptualization, methodology, resources, supervision; **V. Selvamani** - soil and leaf sample analysis for nutrients; **M. Arivalagan** - biochemical analysis of the coconut water; **H. P. Maheswarappa** - conceptualization, methodology.

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