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RESEARCH ARTICLE

Boosting farm resilience: Integrating vegetables and spices in nutmeg and arecanut agroforestry

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Abstract

Experiments were conducted to develop a suitable intercropping model under a nutmeg and areca nut-based mixed farming system for higher productivity in the Thondamuthur region of Coimbatore district of Tamil Nadu. Coriander cv.CO4, Fenugreek cv.CO2, Okra hybrid Co 4, Cluster beans cv. MDU 1, Vegetable cowpea cv.PKM 1, Lablab (bush type) Co(Gb-16)) and Small onion cv.CO 4 was intercropped under 14-year-old Arecanut and 18-year-old Nutmeg trees. The design followed was RBD with three replications. Results revealed that the growth and yield of intercrops were reduced under intercropping compared to pure cropping. Among the intercrops, okra was the least affected, yielding 19.8t/ha, 7.78% lower than pure cropping. Coriander and fenugreek were the most affected. The yield of coriander and fenugreek was 0.43 and 0.47 t/ha, respectively 24.88% and 25.05% lower than pure cropping. The growth of nutmeg and areca nut trees were also influenced due to intercropping with vegetable cowpeas. The increment in DBH of nutmeg was maximum (0.52 cm) with vegetable cowpea intercropping and minimum (0.33 cm) with coriander intercropping. The increment in DBH of arecanut was maximum (0.42 cm) with vegetable cowpea intercropping and minimum (0.25 cm) with fenugreek intercropping. The B:C ratio was highest (2.17) under small onion intercropping. Small onion cultivation was successful under nutmeg and arecanut-based mixed farming systems.

Keywords

arecanut; compatible crop; intercropping; mixed farming; nutmeg

Introduction

Arecanut (*Areca catechu* L.) belongs to the family Arecaceae. It is a tropical crop popularly known as betel nut. It is an essential commercial plantation crop grown in India, mainly used for chewing and extracting alkaloids, which have narcotic, antihelmintic, astringent and vermifuge properties. Studies at Central Plantation Crop Research Institute, Kasargod, Kerala, have revealed that the orientation and structure of the arecanut canopy permit 32.7-47.8 % incident radiation to penetrate down depending on the time of day (1). The rooting pattern revealed that arecanut palms planted at 2.75 m x 2.75 m spacing could effectively use only 30% of the land area (2). Therefore, excluding the active root zone of arecanut, which is confined to only thirty per cent of the available land area, the remaining land area can be utilized for cultivating the subsidiary crops to enhance farm income from the same piece of land. Nutmeg (*Myristica fragrans* Houtt.) belonging to the family of Myristicaceae prefers a fertile, well-drained soil, a humid and warm climate and a moderate shade for its growth and development (3). Arecanut and nutmeg can be grown together in a mixed farming system, where arecanut is planted as a mixed crop in between two rows of nutmeg. This system can utilize the available space and light in the arecanut plantation over 18 years old. Nutmeg is a shade-loving plant that can benefit from protecting arecanut palms from extreme weather events and soil erosion. Nutmeg can improve soil fertility by fixing atmospheric nitrogen and adding organic matter. Arecanut and nutmeg have different harvesting seasons, which can provide a regular and sustainable income to the farmers. Arecanut and nutmeg are also compatible in terms of pest and disease management, as they do not share common pests and diseases.

Intercropping is the practice of growing two or more compatible crops. It can increase yield and soil fertility compared to monocropping. The grain yield in intercropped systems was, on average, 22% greater than monocultures and had greater yield stability. The benefits of intercropping seemed to increase over time as it may improve soil health. Wider intercropping adoption could increase crop production and long-term sustainability (4). Intercropping of compatible crops can be of great value in achieving improved productivity with sustainable soil health. Korikanthimath et al. (5) reported that the tree-based intercropping systems help mitigate climate change -induced impacts by lowering canopy temperature in the understory, leading to biodiversity conservation and carbon sequestration. The potential for increasing the productivity per unit area of land, time and inputs through the cultivation of arecanut-based intercropping systems is considerably higher in perennial crops (6). Growing vegetable and spice crops as intercrop under trees will provide additional income and improve soil fertility. Being short-term crops, their cultivation is intensive and in a year, two to three crops with yields varying from 40 -60 tonnes per ha per annum can be obtained. Short-term crops like vegetables can be fitted into many cropping patterns, such as intercropping (7).

Fig. 1. Nutmeg and Arecanut based mixed farming system

Materials and Methods

The present experiment was conducted in Farmers field from February to July 2024 at Thondamuthur village, Coimbatore district in the Western zone of Tamil Nadu (10.98645° N longitude and 76.85668° E latitude). The soil type is sandy clay loam with a pH of 8.0 and EC of 0.13 dsm^{-1}. Coriander (CO 5), fenugreek (CO 2), vegetable cowpea (PKM 1), Lablab (bush type) CO(Gb-16), Cluster bean (MDU 1), Okra (Hybrid CO4), small Onion (CO 4) were sown in between arecanut (14 years old) and nutmeg trees (18 years old) on 29.02.2024 with the plot size of 5.4 m × 5.4 m to study their growth and productivity as well as their effect on the tree growth to evaluate the compatible intercrop for nutmeg and arecanut based mixed farming system (Fig 1 and 2). The plots of sole trees and intercrops alone were also maintained for comparison. Arecanut and nutmeg were planted at 2.7 m × 2.7 m and 5.4 m × 5.4 m, respectively. Seeds of Coriander and fenugreek were soaked in water for 12 hrs and then sown in lines formed at 15 cm space in the flat bets. Seeds of vegetable cowpea, lablab (bush type), cluster bean, okra were planted at the spacing of 45 cm × 15 cm, 60 cm × 30cm, 45cm × 15 cm, and 45 cm × 30 cm in the flatbeds, respectively. For small onions, ridges and furrows were formed at 45cm spacing, and the bulbs were planted on both sides of the ridges 10 cm apart.

The agronomic practices like weeding at 30 DAS, irrigation twice weekly, fertilizer application, etc., for all the intercrops were done as per the recommendations. A basal application of 25 kg N, 25 kg P and 50 kg K per hectare and 25 tons of farmyard manure (FYM) per hectare was done. An additional 25 kg of nitrogen per hectare was applied 30 days after sowing for coriander and fenugreek for top dressing. In the case of Vegetable cowpea, 25 kg of nitrogen per hectare was applied. In cluster beans, 20 kg of nitrogen was used in two splits: 10 kg at first flowering and another 10 kg at ten days after flowering. Okra required a basal application of 30 kg N, 60 kg P and 30 kg K per hectare, with an additional 30 kg of nitrogen applied 30

Fig. 2. Experimental plot

days after sowing to optimize growth and yield. In small onion, FYM 25 t/ha, N 30 kg, P 60 kg, and K 30 kg/ha are applied as basal, and 30 kg N/ha is used on the 30th day of sowing.

The experiment was laid out in a randomized block design with three replications. The following growth and yield parameters of intercrops *viz.*, plant height and number of branches at harvest stage and yield per plot (kg) were recorded by sampling ten crops per replication in both sole cropping and under mixed farming system. The estimated yield per hectare (tonnes) was also derived from the individual plot yield. Collar diameter (cm) and diameter at breast height (DBH) (cm) in the case of tree crop were also recorded for both sole trees and intercrops. The Collar diameter was measured using measuring tape and expressed in cm. The DBH of trees was arrived at by using the formula viz., G/3.14 and expressed in cm.‘ G denotes the girth. The land equivalent ratio (LER) was computed using Mead and Willey's formula.

$LER_{ab} = Y_{ab}/Y_{aa} + Y_{ba}/Y_{bb} = L_a + L_b$

LER_{ab} is the land equivalent ratio for the ab intercrop

Y_{ab} is the yield of crop a in the ab intercrop

Y_{ba} is the yield of crop b in the ab intercrop

Y_{aa} and Y_{bb} are the yields of crops a and b in monoculture

L_a and L_b are the component LERs for crops a and b

The benefit-cost ratio was computed using the formula provided by Palaniappan (8).

$$BCR \quad \frac{\text{Gross return (Rs ha}^{-1}\text{)}}{\text{Total return (Rs ha}^{-1}\text{)}}$$

Statistical Analysis:

Data were analyzed using GRAPES Statistical software in Randomized Block Design, which had seven treatments and three replications. A one-way analysis of variance (ANOVA) was performed on all datasets using GRAPES Statistical software. Significant differences between monoculture and mixed farming were determined with an LSD test at the 5% level. The standard error between the replicates was also calculated.

Results and Discussion

Growth and yield of Intercrops

The results revealed that among the intercrops tried, the lowest reduction in plant height at the harvest stage was observed in okra, with a decrease of 7.08 % due to intercropping, which was significant. The highest reduction in plant height was recorded in fenugreek (10.67%) at the harvest stage (Table 1) under intercropping. However, compared to open conditions, coriander also showed a decrease of 10.64 % in plant height during the harvesting stage. Similar results were reported by Channabasappa et al. (9), who observed a decreased plant height and number of leaves in medicinal plants grown under arecanut shade compared to an open field. This reduction in the plant height of intercrop might be due to competition with trees for resources, such as light, moisture, and nutrients (10).

The lowest percentage reduction in the number of branches at harvest was observed in okra, with a percentage reduction of 5.31 %, and the highest percentage reduction in fenugreek, with a percentage reduction of 9.95%, respectively (Table 1). The decrease in the number of branches of Black gram (13%) when grown as intercrop compared to sole crop was also observed in the *Melia dubia*-based agroforestry system (11). The lowest

Table 1. Effect of intercropping in nutmeg and arecanut-based mixed farming system on plant growth parameters of intercrops at harvest stage

S. No	Intercrops	Plant Height (cm)		No. of. branches	
		Inter cropping	Pure cropping	Intercropping	Pure cropping
1	Coriander	34.67 (10.64)	38.36	7.05 (8.79)	7.67
2	Fenugreek	60.15 (10.67)	66.57	8.14 (9.95)	8.95
3	Vegetable cowpea	56.67 (7.87)	61.13	21.83 (5.36)	23
4	Lablab (bush type)	120.45 (8.67)	130.89	13.02 (6.53)	13.87
5	Cluster bean	90.1 (7.91)	97.23	28.92 (5.53)	30.52
6	Okra	86.2 (7.08)	92.3	11.68 (5.31)	12.3
7	Small onion	34.57 (9.29)	37.78	NA	NA
	SE(d)	0.409		0.298	
	CD	0.891		0.665	

*NA-Not applicable. Since Small onion has tillers, No. of branches is not applicable.

Figures in the parenthesis denote the reduction percentage over pure cropping.

percent reduction of total dry matter at harvest was observed in fenugreek at 0.26 %, and the highest per cent reduction in okra at 14.12%.

Compared to open fields, the yield and yield attributing characters of intercrops were reduced under nutmeg and arecanut-based mixed farming. The reduction in the number of pods of intercrops under agroforestry practice than in mono-cropping was reported earlier by Naugraiya and Jhapatsingh 2004 (12). Among the intercrops, the minimum reduction in yield per plot was noticed in okra (6.73 %), while the maximum reduction was recorded in fenugreek (25.57 %). (Table 2)

The yield per hectare of intercrops was also significantly reduced under nutmeg and arecanut-based mixed farming. Among the intercrops, the maximum reduction in yield per ha was noticed in fenugreek (25.05%), while the minimum reduction was recorded in okra (7.78%). Among the seed spices, the maximum reduction in yield per ha was recorded in fenugreek (25.05%), and the minimum was observed in coriander (24.88 %). Qiao et al. (13) quoted a significant decrease in grain yield, number of grains per spike and thousand-grain weight when wheat was intercropped with apricot, compared to monoculture configurations in both years. Among the vegetable crops, the maximum reduction in estimated yield per ha was recorded in small onion (16.81 %), and it was followed by lablab (bush type) (14.71%) and the least reduction in yield was recorded in okra (7.78 %) (Table 2). A similar decrease in yield and yield attributes of intercrops under trees was observed under the *Ailanthus excelsa*-based agroforestry system (7, 14).

Effect of Intercrops on tree growth

The results revealed that the collar diameter of Arecanut varied between 49 cm and 58.8 cm before sowing and from 49.57 cm to 59.54 cm after harvesting the intercrops. The collar diameter of Nutmeg varied between 43.53 cm and 54.6 cm before sowing and from 44.25 to 55.7 cm after harvesting the intercrops (Table 3). The maximum increment in both trees was recorded when vegetable cowpea was sown as an intercrop (1.05 cm in arecanut and 1.35 cm in nutmeg). At the same time, the least increment was observed in plots intercropped with coriander in arecanut (0.57 cm) and fenugreek in nutmeg (0.72 cm). Similar findings were observed in babul (*Acacia nilotica*) planted with intercrops (15) and in *Gmelina arborea* (16).

Table 2. Effect of Intercropping in Nutmeg and Arecanut-Based Mixed farming system on yield of intercrops

S. No	Intercrops	Yield (Kg/plot)		Estimated yield (t/ha)		Total dry matter production (g/plant)	
		Inter cropping	Pure cropping	Inter cropping	Pure cropping	Inter cropping	Pure cropping
1	Coriander	3.89 (24.94)	4.86	0.434 (24.88)	0.542	7.26 (0.29)	8.12
2	Fenugreek	1.703 (25.57)	2.14	0.475 (25.05)	0.594	12.01 (0.26)	13.16
3	Vegetable cowpea	25.9 (10.08)	28.51	6.01 (9.98)	6.61	15.82 (4.08)	18.76
4	Lablab (bush type)	11.3 (14.69)	12.96	7.82 (14.71)	8.97	30.23 (3.02)	34.75
5	Cluster bean	32.35 (13.51)	36.72	5.72 (13.64)	6.5	38.35 (5.95)	44.49
6	Okra	144.72 (6.73)	154.46	19.8 (7.78)	21.34	70.84 (14.12)	75.30
7	Small onion	20.088 (16.18)	23.338	13.56 (16.81)	15.84	2.71 (0.80)	3.18
	SE(d)	**0.591**		**0.317**		**0.694**	
	CD	**1.288**		**0.692**		**1.512**	

Figures in the parenthesis denote the reduction percentage over pure cropping.

Table 3. Effect of Intercrops on Collar Diameter (cm) of Arecanut and Nutmeg

S. No	Treatments	Collar diameter (cm) of arecanut			Collar diameter (cm) of nutmeg		
		Before sowing Intercrops	After Sowing Intercrops	Increment	Before sowing Intercrops	After Sowing Intercrops	Increment
1	Coriander	49	49.57	0.57	54.2	54.95	0.75
2	Fenugreek	52.5	53.16	0.66	43.53	44.25	0.72
3	Vegetable Cowpea	57.6	58.65	1.05	50.85	52.2	1.35
4	Lablab (bush type)	54.25	55.28	1.03	49.45	50.64	1.19
5	Cluster bean	49.1	50	0.9	51.08	52.15	1.07
6	Okra	56.2	57.14	0.94	54.6	55.7	1.1
7	Small onion	58.8	59.54	0.74	47.4	48.35	0.95
8	Tree alone	52.7	53.1	0.4	48.5	49.05	0.55
	SE(d)		**0.032**				**0.056**
	CD		**0.069**				**0.123**

The increment in diameter at breast height (DBH) of trees due to intercropping was significant (Table 4). Among the intercrops, the maximum increment in the diameter at breast height (DBH) in the arecanut tree was recorded with vegetable cowpea (0.42 cm) and the minimum was recorded while intercropped with fenugreek (0.25 cm) (Table 4). In the case of the Nutmeg tree, the maximum increment was recorded in vegetable cowpea (0.52 cm) and the minimum with coriander (0.33 cm) as intercrop. The growth performance of different clones of *Populus deltoides* under farm forestry revealed that all growth parameters of poplar clones, i.e. DBH, height and crown spread, exhibited better performance under agroforestry plantation (17).

When arecanut and nutmeg were grown as mono-crop in farmer practices, regular agronomic practices were not practised, and no intercropping was followed, which led to non-enhancement of soil nutrient status in the field, which resulted in decreased soil fertility status (18, 19). Intercropping with short-duration vegetables and spices allows optimal land utilization, enhancing overall system productivity. This practice promotes improved nutrient cycling and soil health while leveraging the favourable microclimate of the tree canopy. Additionally, intercropping serves as a means to diversify income, offering economic benefits during the long growth period of the perennial crops.

The benefit-cost ratio of intercrops nutmeg and arecanut -based intercropping system

In a mixed farming system, the B: C ratio indicates economic viability by comparing returns to costs, while the land equivalent ratio assesses resource efficiency by measuring the productivity of intercropping compared to monocropping. Economics of different intercrops under the nutmeg and arecanut-based mixed farming system tabulated in Table 5 revealed that the small onion has the highest net returns of Rs.1,83,300/- per ha with the B: C ratio of 2.17 and it was followed by vegetable cowpea with net income of Rs. 92,450/- per ha with the B:C ratio of 2.05. Conversely, coriander had the lowest B:C Ratio (1.13), reflecting its lower efficiency in converting inputs into financial returns. This might be because the cost of cultivation and gross income are nearly the same, leading to low net returns. The present findings agreed with the results of Gajbhiye et al. (20) who obtained the lowest B:C ratio in coriander (0.73) under a based intercropping system. Even though the okra yielded more than small onion and vegetable cowpeas, the cost of the produce at the time of harvest was low. When the demand is lower, the crop price will also be lower. While small onions generate the highest gross income, it's essential to consider other factors like production costs, market demand, and labour requirements to determine overall profitability. The land Equivalent ratio of all the intercrops were more than 1 (Table 5). It indicates that this intercropping system is advantageous. Higher LER values under nutmeg and arecanut-based mixed farming systems were due to the satisfactory yield of intercrops. Vegetable cowpea has the highest LER of 3.29, which implies that the crop has the propensity to utilize the land most efficiently when intercropped due to its compatibility and synergetic effect with other inter-grown crops. LER values of Lablab and Cluster Bean were also relatively high and they have the potential for intercropping. Coriander yielded the lowest LER of the treatments with a value of 2.89, but its land use efficiency was relatively high compared to monocropping.

Table 4. Effect of Intercrops on Diameter at Breast Height (cm) of Arecanut and Nutmeg

S. No	Treatments	DBH (cm)of arecanut			DBH (cm)of nutmeg		
		Before sowing Intercrops	After Sowing Intercrops	Increment	Before sowing Intercrops	After Sowing Intercrops	Increment
1	Coriander	11.43	11.75	0.32	15.72	16.05	0.33
2	Fenugreek	11.52	11.77	0.25	12.27	12.63	0.35
3	Vegetable cowpea	11.96	12.37	0.42	13.41	13.93	0.52
4	Lablab (bush type)	13.57	13.95	0.38	14.43	14.86	0.43
5	Cluster bean	12.90	13.20	0.30	17.05	17.45	0.39
6	Okra	12.15	12.48	0.33	14.67	15.11	0.45
7	Small onion	12.12	12.40	0.28	14.52	14.90	0.38
	Tree alone	10.32	10.54	0.22	15.45	15.72	0.27
	SE(d)	**0.011**			**0.018**		
	CD	**0.023**			**0.039**		

Table 5. Cost of intercrops nutmeg and arecanut-based intercropping system

S. No	Treatments	Cost of Cultivation (Rs.)	Gross Income (Rs.)	Net Returns (Rs.)	B:C ratio	LER
1	Coriander	57,350	65,100	7,750	1.13	2.89
2	Fenugreek	58,250	95,000	36,750	1.63	2.91
3	Vegetable cowpea	87,850	1,80,300	92,450	2.05	3.29
4	Lablab	85,150	1,56,400	71,250	1.83	3.13
5	Cluster bean	88,750	1,58,100	69,350	1.78	3.13
6	Okra	1,07,090	1,98,000	90,910	1.84	3.18
7	Small onion	1,55,700	3,39,000	1,83,300	2.17	3.02

Conclusion

Intercropping presents a viable strategy for enhancing the sustainable and resilient agroecosystem. By introducing crop diversity within a single field, farmers can optimize resource utilization and ecosystem services. While the transition to intercropping may incur short-term economic costs, the long-term benefits, such as increased yield stability and improved profitability, make it a promising avenue for sustainable agriculture. In this experiment, small onion was identified as a profitable intercrop based on the B:C ratio and vegetable cowpeas were recognized as a compatible intercrop based on LER and its effect on trees under nutmeg and arecanut-based mixed farming systems.

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Authors' contributions

SG conducted the literature search, organized the data and contributed significantly to writing the original draft and editing the manuscript. RGV conceptualization of the review, methodology design, manuscript editing, and overall supervision. IP AND RGV contributed to data visualization and manuscript formatting. VK played a crucial role in writing parts of the original draft and the review and editing process. MP Contributed to the formal analysis and validation of the data and ensured the integrity of the review process.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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