Research Article

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Organic management of tuberous intercrops for resilience, higher yield and profit from coconut plantations: Insights from validation experiments in Kerala, India

G. Suja, D. Jaganathan* and G. Byju

ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram-695 017, Kerala

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Abstract

Fifteen on-farm experiments were conducted in tropical tuber crops intercropped in coconut gardens in Thiruvananthapuram, Kollam and Pathanamthitta districts, Kerala, during 2018-2021 for validation of organic production technologies. The validation experiments were performed under the aegis of the ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, in a project funded by the Coconut Development Board, Kochi, Kerala. Three treatments viz., T_1: organic farming technology (OF), T_2: POP recommendation (POP) and T_3: farmer's practice (FP) were evaluated in cassava, elephant foot yam and greater yam intercropped with coconut. System productivity and profitability were worked out for the different treatments based on yield and income from coconut and tuber crops in the respective treatments. Pooled analysis indicated that the coconut yield under intercropping with tuber crops in organic mode was high by 7-13% in comparison to monocrop of coconut maintained by the farmers. Tuber yield under organic management was superior over POP by 14% and FP by 27%. On an average, the net income from coconut-tuber crop intercropping system under organic management was ₹ 2,36,133 ha^{-1}, whereas it was ₹ 1,56,904 ha^{-1} in POP and ₹ 1,32,706 ha^{-1} in FP and significantly outperformed sole coconut (₹ 7,764 ha^{-1}). Thus, the results indicated that organic management of coconut-tuber crop system offered resilience with higher system productivity and profitability.

Keywords: Organic management, intercropping, coconut, cassava, greater yam, elephant foot yam, validation

Introduction

Coconut, the most important of all cultivated palms, provides livelihood security to several millions of people across the world, and capacity of coconut in providing improved nutrition, employment and income generation are well known. In India, the palm is cultivated in 18 states and 3 Union Territories and supports the livelihood of over twelve million people (GOI, 2021). The unique architecture of the coconut tree offers ample scope for utilizing the greater portion (75%) of the unutilized area between the trees for intercropping with annuals and perennials. Tropical tuber crops such as cassava, elephant foot yam and greater yam have higher biological efficiency, can tolerate drought and shade, withstand flood and salinity to some extent, are adapted to marginal environments, low input situations and adverse soil and climatic conditions. Hence these crops are known as 'climate resilient' or 'future crops'. Cultivation of these tropical tuber crops in the interspaces of coconut palms will enhance farmers' income and enable employment opportunities and the compatibility/flexibility of tuber crops in coconut gardens have been established. Performance of cassava, yams (greater yam, lesser yam and white yam), elephant foot yam, tannia and arrowroot as intercrops in coconut garden has been evaluated and production technologies for these crops under intercropping situation has been standardized (Nayar and Suja, 2004; Suja *et al*., 2004; Suja, 2005). Experimental

**Corresponding Author: jaganathan.d@icar.gov.in*

results showed that yield was increased by 5-15% in coconut under intercropping with tuber crops (Nayar and Suja, 2004).

More than 15 years of research on organic farming of tropical tuber crops at ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI) suggests 10-20 per cent higher yield, 20-40 per cent more profit, besides improvement in tuber quality and soil health (Suja *et al*., 2012; Suja, 2013; Suja and Sreekumar, 2014; Suja *et al*., 2017; Suja and Jaganathan, 2021). However, the on-station developed technologies require large scale validation in farmers' fields for popularization and adoption. Hence, on-farm experiments (15) were taken up to confirm organic production technologies in tuber crops intercropped in mature coconut plantations in Thiruvananthapuram, Kollam and Pathanamthitta districts of Kerala during 2018-2021. Thus the objectives were to validate and popularize organic production technologies in cassava, elephant foot yam and greater yam intercropped in coconut gardens (through demonstrations and on-farm trials) and generate higher productivity and profit from coconut gardens.

Materials and methods

Three districts viz., Thiruvananthapuram, Kollam and Pathanamthitta in Kerala state were selected for implementation of the experiments. The area, production and productivity of coconut in the study areas of Kerala and India (CDB, 2020) are given in Table 1.

Farmers who possessed coconut gardens (of more than 20 years of age) with 50 cents each and who evinced interest in taking up scientific interventions were selected based on the principles of participatory research and the scoring procedure developed by the scientists of ICAR-CTCRI in consultation with the officials of Coconut Development Board, Krishi Bhavans and Krishi Vigyan Kendras. Validation of organic management of tuber crops as intercrops in coconut gardens of Kerala i.e., cassava and greater yam in Thiruvananthapuram; elephant foot yam and greater yam in Kollam and cassava and greater yam in Pathanamthitta districts was taken up (Fig.1 and detailed in Table 2). Thus, five on-farm experiments with three treatments viz., T_1: Organic farming technology (OF), T_2: Package of Practices recommendation (POP) and T_3: farmer's practice (FP) in cassava, elephant foot yam and greater yam were conducted in each district following the agro-techniques (Table 3) and technological specifications (Table 4). A total of 15 on-farm experiments were taken up covering 3 ha. The coconut gardens were managed as per the POP recommendations of ICAR-CPCRI, Kasaragod. Yield and income from coconut and tuber crops were collected from different treatments for estimating system productivity and profitability.

Table 1. Area, production and productivity of coconut in Kerala and India (2020-2021)

Sl. No	District/State/ Country	Area ('000 ha)	Production (million nuts)	Productivity (nuts/ha)
1	Thiruvananthapuram	70.49	392.0	5561
2	Kollam	46.76	268.0	5731
3	Pathanamthitta	15.79	80.0	5067
4	Kerala	768.81	4788.0	6228
5	India	2198.98	20736.12	9430

Table 2. Details of tuber crops and locations of on-farm experiments

Sl. No.	District and local bodies	Intercrop	No. of farmers	Area (cents)
1	Thiruvananthapuram (Chenkal and Thiruvananthapuram corporation)	Cassava Greater yam	3 2	150 100
2	Kollam (Panmana panchayat)	Greater yam Elephant foot yam	2 3	100 150
3	Pathanamthitta (Ayiroor, Pullad, Kozhencherry and Mallapally panchayats)	Cassava Greater yam	3 2	150 100
	Total		**15**	**750 cents (3 ha)**

Results and discussion

Productivity and economics

1. Thiruvananthapuram

In Thiruvananthapuram district, organic management resulted in highest tuber yield (24.10 t

Fig.1. On-farm validation of organic farming technology in cassava, greater yam and elephant foot yam

ha^{-1}), followed by farmer's practice (17.36 t ha^{-1}) and POP (16.10 t ha^{-1}) (Fig. 2). Seena Radhakrishnan *et al*. (2021) observed higher yield under organic management in cassava in on-station experiments. This result is encouraging and contradicts the earlier report by Suja *et al*. (2020) that organic management resulted in lower yield in cassava over conventional, integrated and traditional systems under intercropping situation. In greater yam, the highest tuber yield was obtained from organic farming (3.65 t ha^{-1}), followed by farmer's practice (3.60 t ha^{-1}) and POP (3.35 t ha^{-1}) (Fig. 2).

Table 3. Agro-techniques for tuber crops intercropped in coconut gardens

Main crop	Intercrops/Variety	Planting, spacing and population per ha	Duration (months)
Coconut (West Coast Tall)	Cassava (Sree Pavithra) (*Pullad kappa*)	Mound; 90x90 cm; 9000 plants	8-10 9-10
	Greater yam (Sree Keerthi)	Pit reformed to mound; 90x90 cm; 9000 plants	8-9
	Elephant foot yam (Gajendra)	Mound; 90x90 cm; 9000 plants	8-9

Table 4. Technological specifications and treatments for validation of organic farming technology

Treatments	Quantity of inputs per ha		
	Cassava	Elephant foot yam	Greater yam
T_1(OF)	FYM @ 12.5 t, cowpea seeds sown in between cassava (@ 20 kg) and green matter incorporated at 45-60 days @ 10-15 t, crop residue incorporation fresh @ 7-9 t (generates dry biomass @ 2-3 t), *Azospirillum* @ 3 kg, phosphobacteria @ 3 kg and K solubilizer @ 3 kg	FYM @ 36 t, corm treatment with *Trichoderma* @ 5 g per kg seed, neem cake @ 1 t, cowpea seeds sown in between elephant foot yam (@ 20 kg) and green matter incorporated at 45-60 days @ 20-25 t, ash @ 3.0 t	FYM @ 15 t, neem cake @ 1 t, *Azospirillum* @ 3 kg, phosphobacteria @ 3 kg and K solubilizer @ 3 kg, cowpea seeds sown in between greater yam (@ 20 kg) and green matter incorporated at 45-60 days @ 10-15 t, ash @ 1.5 t
T_2(POP)	FYM @ 12.5 t NPK @ 100:50:100 kg	FYM @ 25 t NPK @ 100:50:150 kg	FYM @ 12.5 t NPK @ 80:60:80 kg
T_3(FP)	Farmer's practice		

OF- Organic farming; POP- Package of practices; FP-Farmer's practice

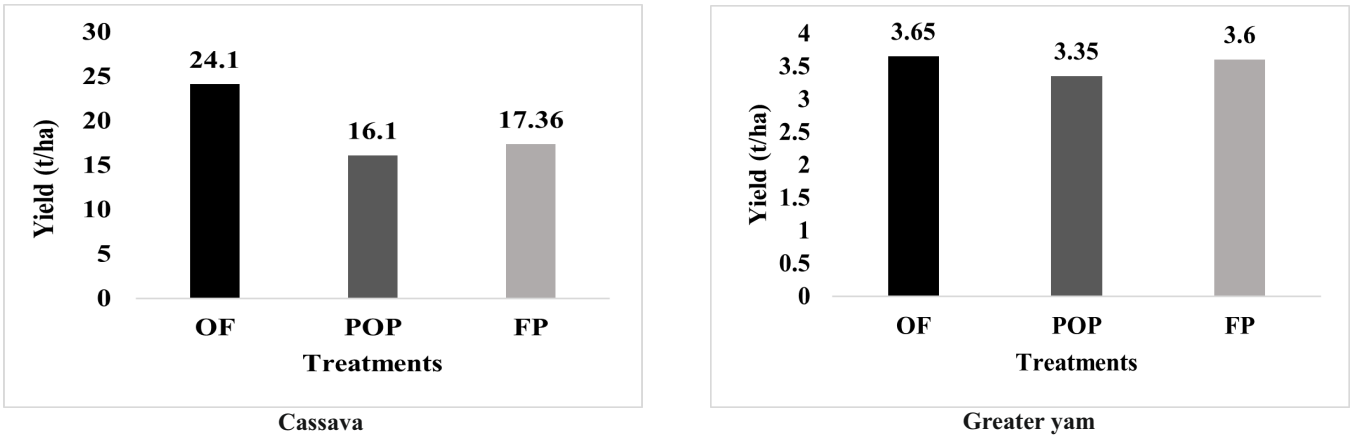

Fig. 2. Productivity of tuber crops in coconut gardens of Thiruvananthapuram district under various management practices

Net income of ₹ 3,51,330 ha^{-1} was realized from organic farming, followed by farmer's practice (₹ 2,02,513 ha^{-1}) and POP (₹ 1,51,490 ha^{-1}) in coconut + cassava intercropping system (Table 5). Cassava variety 'Sree Vijaya' performed well with higher returns under organic management (₹ 1,31,000 ha^{-1}) in intercropping system with coconut (Suja *et al*., 2020) under humid coastal tropical conditions of Kasaragod. In coconut + greater yam association, the net income was higher for organic farming (₹ 53,075 ha^{-1}), followed by farmer's practice (₹ 25,500 ha^{-1}) and POP (₹ 15,325 ha^{-1}).

Table 5. Economic analysis of coconut + tuber crop intercropping systems in Thiruvananthapuram district (One ha): OF Vs POP Vs FP

Technology	Coconut yield (nuts ha^{-1})	Tuber yield (t ha^{-1})	Gross income (₹)	Gross cost (₹)	Net income (₹)	BC ratio
Coconut monocrop before intervention						
FP	14525	-	145250	128000	17250	1.13
Coconut + cassava cropping system						
OF	15400	24.10	587380	236050	351330	2.49
POP	14175	16.10	431490	280000	151490	1.54
FP	13650	17.36	462513	260000	202513	1.78
Coconut + greater yam cropping system						
OF	15050	3.65	278075	225000	53075	1.24
POP	13825	3.35	255325	240000	15325	1.06
FP	12950	3.60	255500	230000	25500	1.11

2. Kollam

In Kollam district, the highest corm yield of elephant foot yam was obtained from organic farming (11.40 t ha^{-1}), followed by POP (9.78 t ha^{-1}) and farmer's practice (7.98 t ha^{-1}) (Fig. 3). Organic farming of elephant foot yam yielded 42.86% higher over FP and 16.56% over POP . In on-station experiments at ICAR-CTCRI, organic farming resulted in 20% higher corm yield over conventional practice (Suja et al., 2012). In greater yam, the highest tuber yield was obtained from organic farming (4.59 t ha^{-1}), followed by POP (3.99 t ha^{-1}) and farmer's practice (3.96 t ha^{-1}) (Fig. 3). Organic farming yielded higher over FP and POP by about 15% in greater yam. Suja and Sreekumar (2014) reported that organic management produced significantly higher tuber yield (+9%) over conventional system in yams in long-term experiments at ICAR-CTCRI. There was increase in yield of coconut in root (wilt) affected coconut garden intercropped with elephant foot yam and yam (Menon and Nayar, 1978).

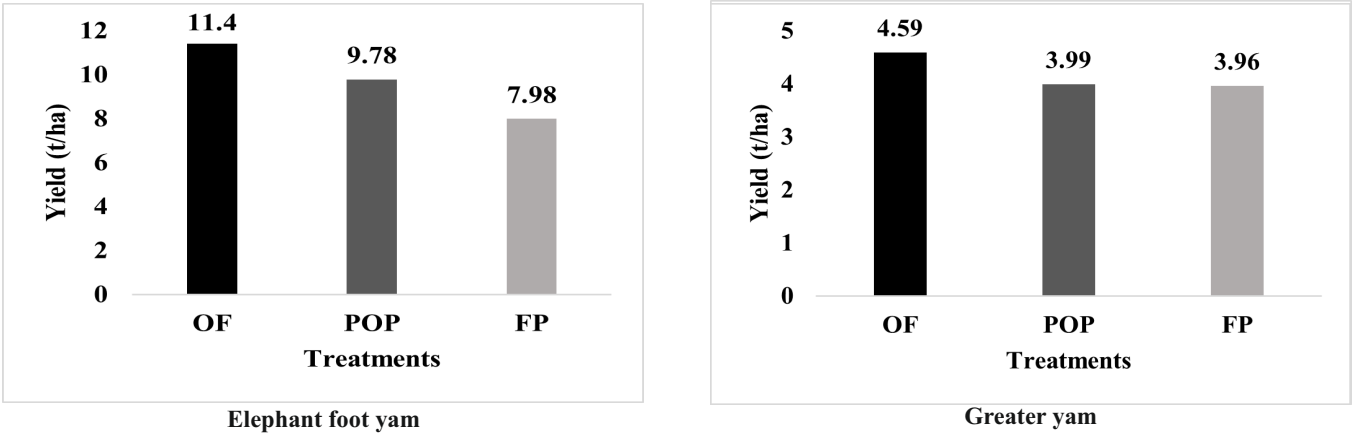

Fig. 3. Productivity of tuber crops in coconut gardens of Kollam district under various management practices

A perusal of data in Table 6 indicates that net income of ₹ 2,08,500 ha^{-1} was obtained under organic farming, followed by POP (₹ 1,42,200 ha^{-1}) and farmer's practice (₹ 83,450 ha^{-1}) in coconut + elephant foot yam cropping system. Similarly in coconut + greater yam system, net income of ₹ 82,900 ha^{-1} was obtained under organic farming, followed by POP (₹ 39,400 ha^{-1}) and farmer's practice (₹ 32,850 ha^{-1}).

Table 6. Economic analysis of coconut + tuber crop intercropping systems in Kollam district (One ha): OF Vs POP Vs FP

Technology	Coconut yield (nuts ha^{-1})	Corm/Tuber yield (t ha^{-1})	Gross income (₹)	Gross cost (₹)	Net income (₹)	BC ratio
Coconut monocrop before intervention						
FP	10850	-	108500	107000	1500	1.01
Coconut + elephant foot yam cropping system						
OF	12250	11.40	578500	370000	208500	1.56
POP	12600	9.78	517200	375000	142200	1.38
FP	12425	7.98	443450	360000	83450	1.23
Coconut + greater yam cropping system						
OF	11725	4.59	277900	195000	82900	1.43
POP	11375	3.99	253400	214000	39400	1.18
FP	11025	3.96	248850	216000	32850	1.15

3. Pathanamthitta

As observed in other districts, the highest cassava tuber yield was obtained from organic farming (64.14 t ha^{-1}), followed by POP (62.05 t ha^{-1}) and farmer's practice (52.47 t ha^{-1}) in Pathanamthitta district. Organic farming yielded 22.25% higher over FP and 3.37% higher over POP in cassava. (Fig. 4). In greater yam, the highest tuber yield was obtained from organic farming (6.52 t ha^{-1}), followed by POP (5.74 t ha^{-1}) and farmer's practice (5.61 t ha^{-1}). In greater yam, organic farming yielded higher over FP by 16.13% and POP by 13.62%. (Fig. 4).

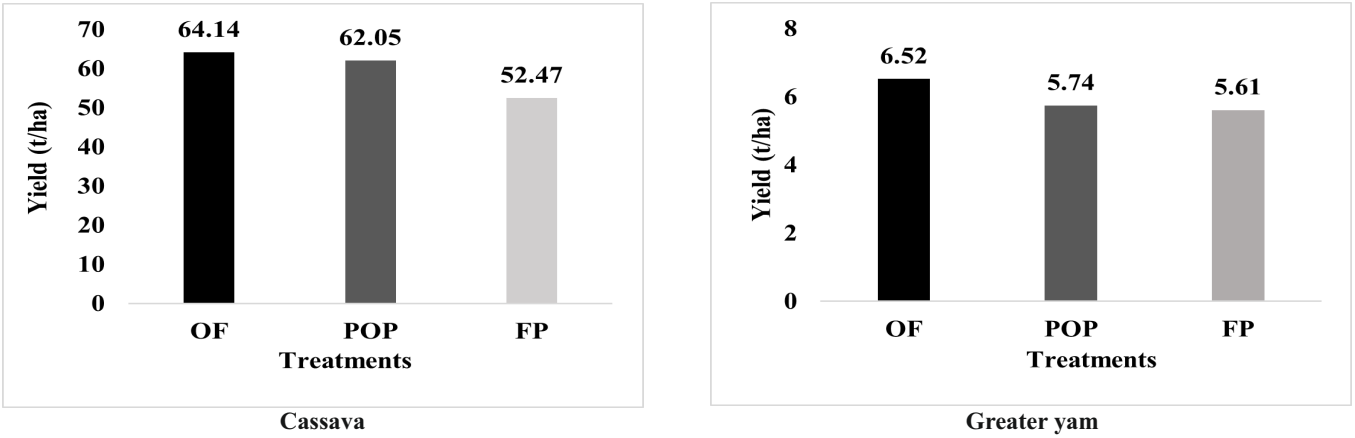

Fig. 4. Productivity of tuber crops in coconut gardens of Pathanamthitta district under various management practices

A net income of ₹ 4,45,785 ha^{-1} was obtained from organic farming, followed by POP (₹ 3,97,950 ha^{-1}) and farmer's practice (₹ 3,25,855 ha^{-1}) in coconut + cassava intercropping system (Table 7). Likewise, in coconut + greater yam system, higher net income was obtained from organic farming (₹ 1,68,050 ha^{-1}), followed by POP (₹ 1,06,650 ha^{-1}) and farmer's practice (₹ 93,100 ha^{-1}).

Table 7. Economic analysis of coconut + tuber crop intercropping systems in Pathanamthitta district (One ha): OF Vs POP Vs FP

Technology	Coconut yield (nuts ha^{-1})	Tuber yield (t ha^{-1})	Gross income (₹)	Gross cost (₹)	Net income (₹)	BC ratio
Coconut monocrop						
FP	9538	-	138301	130000	8301	1.06
Coconut + cassava cropping system						
OF	10675	64.14	737385	291600	445785	2.53
POP	9800	62.05	705450	307500	397950	2.29
FP	9275	52.47	611355	285500	325855	2.14
Coconut + greater yam cropping system						
OF	10500	6.52	385700	217650	168050	1.77
POP	10850	5.74	363650	257000	106650	1.41
FP	9450	5.61	338100	245000	93100	1.38

Pooled analysis of yield and income

Pooled analysis indicated that the coconut yield in organic farming experiments was higher by 7-13% with intercropping of tuber crops in comparison to monocrop (8.36% increase with cassava, 12.90% increase with elephant foot yam and 6.76% with greater yam as intercrops) (Table 8).

Yield of tuber crops in organic farming were superior over POP and FP (12.90% increase over POP and 26.35% increase over FP in cassava; 16.56 % increase over POP and 42.86% increase over FP in elephant foot yam and 12.61% increase over POP and 11.85% increase over FP in greater yam). On the whole, net income from coconut + tuber crop intercropping

system under organic farming was superior over POP and FP (45.08% increase over POP and 50.86% increase over FP in coconut + cassava system; 46.62 % increase over POP and 149.85% increase over FP in coconut + elephant foot yam system and 88.40% increase over POP and 100.74% increase over FP in coconut + greater yam system). This increase in profit due to organic management was substantial when compared to the cost:benefit analysis done in the on-station experiments at ICAR-CTCRI, wherein 20–40% higher net income was obtained under organic management over state package of practices (POP) in tuber crops (Suja *et al.,* 2015).

Table 8. Pooled analysis of yield and income from coconut + tuber crop intercropping systems (One ha) OF Vs POP Vs FP

Particulars	Coconut + cassava system				Coconut + elephant foot yam system				Coconut + greater yam system			
	Coconut monocrop	Coconut + cassava			Coconut monocrop	Coconut + elephant foot yam system			Coconut monocrop	Coconut + greater yam		
		OF	POP	FP		OF	POP	FP		OF	POP	FP
Coconut yield (Nuts)	12032	13038	11988	11463	10850	12250	12600	12425	11638	12425	12017	11142
% increase/ decrease		8.36	-0.37	-4.73		12.90	16.13	14.52		6.76	3.26	-4.26
Tuber/corm yield(t)		44.11*	39.07	34.91		11.4**	9.78	7.98		4.91***	4.36	4.39
Net income (₹)	12776	398558	274720	264184	1500	208500	142200	83450	9017	101342	53792	50483

* 12.90% increase over POP and 26.35% increase over FP
**16.56% increase over POP and 42.86% increase over FP
*** 12.61% increase over POP and 11.85% increase over FP

Conclusion

On-farm validation experiments established in 15 coconut gardens of Thiruvananthapuram, Kollam and Pathanamthitta districts of Kerala have proved that organic management of tuberous intercrops in coconut plantations was beneficial for realizing higher yield and better income. In addition, improved food-cum-nutrition security and safe food production can be ensured through popularisation of high yielding and nutritionally rich varieties of tuber crops as intercrops in the coconut plantations, especially following ecologically sound practices.

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