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Organic management for yams (*Dioscorea* spp.) intercropped in coconut (*Cocos nucifera*) plantation: Evidences from a validation trial in the coastal humid tropics of Kerala, India

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ABSTRACT

A field experiment was conducted under Network Project on Organic Horticulture during 2015–17 (April-January) at ICAR-Central Plantation Crops Research Institute (ICAR-CPCRI), Kasaragod, to validate the ICAR-CTCRI developed organic farming technologies in yams under intercropping in an organically raised mature coconut garden (>48 years). Three species of *Dioscorea* [(greater yam (*D. alata),* lesser yam (*D. esculenta*) and white yam (*D. rotundata*)] were tested under four production systems, viz. traditional, conventional, integrated and organic, and replicated thrice in split plot design in a mature coconut garden. Organic practice was similar to conventional as revealed from the identical impacts on yield, tuber quality and soil chemical properties. Yield under organic management was 98.6% of conventional farming. *D. alata* and *D. esculenta* were more responsive (+8 to 10%) to organic management, but organic management lowered yield by 30% in dwarf white yam (*D. rotundata*). The organic farming package comprising farmyard manure, green manure cowpea, neem cake and ash resulted in higher available N, exchangeable Ca and available Zn in soil and significant improvement in K, higher P and Mg contents in yam tubers. However, the highest profit was realized from coconut + *D. alata* in integrated system (₹1,87,057/ha). Among yams, greater yam (*D. alata*) was the most productive and profitable under organic management (₹1,46,634/ha) in intercropping set up.

Keywords: Alternative agriculture, Cost:benefit analysis, Soil fertility, Tuber proximate composition, Yield

Coconut (*Cocos nucifera* L.) is a plantation crop, which provides livelihood security and contributes to health, nutrition and wellness of human beings. Intercropping tropical root and tuber crops, viz. cassava, yams, and edible aroids, in coconut gardens is popular throughout the humid tropics (Nayar and Suja 2004). In coconut and tuber crop association, the tuberous intercrops serve as high energy secondary staple to the farm family and feed for farm animals, behave as insurance crop against risk and natural calamities, enhance the resource use efficiency, ensure food security, augment net income and enhance employment opportunities (Nayar and Suja 2004).

Yams (*Dioscorea* spp.) are a major starchy staple food widely cultivated in the tropics of West Africa, Asia, Central and South America, which play a vital role in food security and livelihood improvement (Suja *et al*. 2003, IITA 2012, Enesi *et al*. 2018). Among edible yams, Asiatic yams, viz. greater yam (*Dioscorea alata*) and lesser yam (*Dioscorea esculenta*) are common intercrops in many coconut growing regions of Asia. African white yam (*Dioscorea rotundata*), an introduction to India is also gaining popularity among farmers due to its high yield potential (35–40 t/ha), wide adaptability, good taste and flavor and potential as a vegetable.

Alternative agriculture systems like organic farming are gaining popularity worldwide due to growing concern regarding food safety, environmental pollution and human health. On-station field experiments at ICAR-CTCRI, Thiruvananthapuram and on-farm trials done for nine consecutive years conclusively proved that organic management promoted yield, quality and soil health in yams (Suja *et al*. 2012a, Suja 2013, Suja and Sreekumar 2014, Suja *et al*. 2015, Suja *et al*. 2016). However, the organic production technologies need to be field validated for promotion of organic farming in yam, which is a popular intercrop in coconut gardens in the coastal humid tropics. Therefore, the present investigation was conducted under Network Project on Organic Horticulture at ICAR-CPCRI, Kasaragod, to validate the ICAR-CTCRI developed organic farming technologies in yams, under intercropping in an organically raised mature coconut garden and evaluate its impact on yield, quality, soil properties and economics.

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MATERIALS AND METHODS

The field experiment was carried out for two consecutive years during April-January in 2015–2016 and 2016–2017 at the Research Farm, ICAR-CPCRI, Kasaragod, to validate the on-station (ICAR-CTCRI) developed organic farming technology in yams under intercropping in a mature coconut garden (>48 years). The experimental site is situated at 12° 30' N latitude and 75° 00' E longitude with an altitude of 10.7 m amsl. The climate of the site is typical warm humid tropical. The mean rainfall, relative humidity, maximum and minimum temperature during the growing seasons were 3462 mm, 67.83% and 31.2°C and 23.6°C, respectively.

The soil is red sandy loam (*p*H: 5.07). At the beginning of the experiments, the soil was characterized as having high organic C (0.88%), low available N (149.05 kg/ha), high available P (123.21 kg/ha) and available K (226.76 kg/ha). The bulk density, particle density, water holding capacity, porosity and cation exchange capacity (CEC) were 1.44 g/cm^3, 2.50 g/cm^3, 25.54%, 34.46% and 5.85 cmol/kg, respectively.

Three species of *Dioscorea* (Greater yam: *Dioscorea alata* var. Sree Keerthi, Lesser yam: *D. esculenta* var. Sree Latha and Dwarf white yam: *D. rotundata* var. Sree Dhanya) were planted and tested under four production systems, viz. traditional, conventional, integrated and organic, and replicated thrice in split plot design in a mature coconut garden. The species were assigned to main plots and production systems to sub plots. The gross plot size was 7.2 m × 3.6 m (25.92 m^2). Details of sub plot treatments used in the experiment are given in Table 1.

Sree Keerthi, a clonal selection from germplasm of ICAR-CTCRI, is a high yielding (25–30 t/ha) greater yam variety of 9–10 months duration with white flesh. It is suitable for intercropping in mature coconut gardens and banana (CTCRI 2006). Sree Latha, a high yielding lesser yam variety (25 t/ha), with 8 months duration and creamy white flesh, is a selection from indigenous germplasm of ICAR-CTCRI. It has excellent cooking quality and wide adaptability (CTCRI 2006). Sree Dhanya is the first dwarf bushy non-climber released by ICAR-CTCRI. It is a seedling selection that yields 20 t/ha in 9 months and has white tuber flesh (CTCRI 2006).

Tubers from the inner plants of each net plot, after discarding border plants, were harvested and fresh weight of tubers were recorded and tuber yield was expressed in t/ha. Tuber biochemical properties such as dry matter, starch and crude protein (AOAC 2005**)** and mineral constituents like P, K, Ca, Mg, Fe, Mn, Zn and Cu contents (Piper 1970) as well as soil chemical properties like *p*H, organic C, available N, P, K, Fe, Mn, Zn and Cu status (Page *et al*. 1982) were measured at harvest using standard analytical procedures. Total cost of cultivation and gross returns were calculated from average input cost and labour cost for all operations and average market price of the produce respectively during the period of investigation. Based on this, net income and benefit:cost ratio (B:C ratio) were computed. The analysis of variance of data was done using SAS (2010) by applying analysis of variance technique (ANOVA) for split plot design. The least significant difference (LSD) test was used at the 0.05 level of probability to test the differences between treatment means.

RESULTS AND DISCUSSION

Tuber yield: The species effect was significant and *D. alata* produced significantly higher yield over the rest in both the years (Table 2). The effects of production systems and species × production systems interaction was not significant. All the species responded equally well to both the organic and conventional systems. In yams intercropped in coconut, considering the mean yield of species, organic management was at par with conventional system in both the years, with slight reduction in mean yield in the first year (-3.6%) and slightly higher mean yield in the second year (+1.09%) over conventional. In other words, under intercropping situation in coconut gardens, the yield of yams under organic management was 96% and 101% that of chemical farming, during the two experimental years. Mean yield of two years indicated that organic management lowered yield slightly by 1.4%, 8.7% and 7% over conventional, integrated and traditional systems, respectively.

The slightly lower yield under organic management in the validation experiment is inconsistent to the yield increment of 9% under organic farming in the on-station experiment (Suja and Sreekumar 2014, Suja *et al*. 2016**.** The partial shade as existing in the coconut plantation in the

Table 1 Sub plot treatment details of the experiment

Production system	Name of the inputs and quantity	
	Yams (per ha)	Coconut (per palm)
Traditional (Farmers' practice)	FYM @15 t/ha and ash @1.5 t/ha	FYM @30 kg, NaCl @1 kg and lime @1 kg
Conventional (Present Package of Practices (POP) recommendations)	FYM @10 t/ha and NPK @80:60:80 kg/ha	FYM @30 kg and RDF 100% + 0.5:0.32:1.2 kg N, P_2O_5 & K_2O per palm per year
Integrated	FYM @10 t/ha and NPK @60:30:60 kg/ha + *Azospirillum* + P solubilizer + K solubilizer @3 kg/ha each	FYM @15 kg, green manure @15 kg and RDF 50% + 0.25:0.16:0.6 kg N, P_2O_5 & K_2O per palm per year
Organic	FYM @15 t/ha, green manure, neem cake @1 t/ha, ash @1.5 t/ha	FYM @30 kg and green manure @30 kg

Table 2 Yield response of *Dioscorea* species to production systems (t/ha)

Species /Production system	Traditional		Conventional		Integrated		Organic		Mean of *Dioscorea* species	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Dioscorea alata	11.37	8.08	10.32	9.16	9.94	8.62	10.62	10.80	10.56	9.17
Dioscorea esculenta	7.14	5.82	5.93	4.71	8.43	6.49	6.23	5.27	6.93	5.57
Dioscorea rotundata	6.85	4.69	6.08	5.24	6.60	4.67	4.68	3.25	6.05	4.46
Mean of production systems	8.45	6.20	7.44	6.37	8.32	6.59	7.18	6.44		
CD (P=0.05)	Species: 1.342, 1.438; Production systems: NS Species × Production systems: NS									

validation trial might have slowed down the decomposition process and release of plant nutrients from the organic manures when compared to the chemical fertilizers. Of the three species, *D. alata* and *D. esculenta* were more responsive (+8 to 10%) to organic management, but organic management lowered yield by 30% in dwarf white yam (*D. rotundata*). Greater yam and lesser yam, the two Asiatic yams evaluated, showed a preference for the use of traditional organic manures by virtue of their ethnic nature (Suja and Sreekumar 2014).

Tuber quality: The biochemical and mineral composition of tubers, except K content of tubers, was not significantly different among species, production systems and species × production systems. As reported by Chhonkar (2008), plants absorb nutrients as inorganic ions whether it is from organic manure or inorganic fertilizer. These absorbed nutrients are re-synthesized into compounds that determine the quality of the produce, which is predominantly the function of genetic makeup of the plants.

The K content of tuber was significantly higher in the organic system. Dry matter, starch, crude protein and Cu contents of tuber were higher in the integrated system. The content of P and Mg was higher in the organically grown tubers and Fe, Mn and Zn were higher in the conventionally produced tubers. Higher mineral composition, especially K, Ca and Mg, has been earlier documented in other tropical tuber crops under organic management. In elephant foot yam, organic corms had 3–7% higher K, Ca and Mg contents under organic farming (Suja *et al*. 2012b). Tuber quality was improved with significantly higher Ca, slightly higher K and Mg contents in yams (Suja and Sreekumar 2014). Cormel quality was better under organic management, with higher P, K, Ca and Mg contents in taro (Suja *et al*. 2017).

Soil chemical properties: The chemical properties of soil were not significantly influenced by the different treatments. The *p*H and available P were higher in the traditional practice, organic C, available N, exchangeable Ca and available Zn in the organic practice. Almost similar results were reported under organic management in yams in the on-station experiment (Suja and Sreekumar 2014, Suja *et al*. 2016a). The integrated practice favoured available K and available Cu status in the present experiment.

Table 3 Economics of different production systems on coconut + yam association

Species/Production system	Coconut yield (Nuts/ha)	Tuber yield (t/ha)	Gross cost (₹/ha)	Gross income (₹/ha)	Net income (₹/ha)	B:C ratio
D. alata						
Traditional	17675	9.73	366335	506180	139845	1.38
Conventional	19163	9.74	365335	523665	158330	1.43
Integrated	19688	9.28	326948	514005	187057	1.57
Organic	18988	10.71	407786	554420	146634	1.36
D. esculenta						
Traditional	15313	6.48	302580	374005	71425	1.24
Conventional	16013	5.32	292334	343038	50703	1.17
Integrated	16975	7.46	293636	423273	129637	1.44
Organic	16100	5.75	325786	358145	32359	1.10
D. rotundata						
Traditional	17325	5.77	289768	371418	81650	1.28
Conventional	17675	5.66	294999	372823	77823	1.26
Integrated	17938	5.64	297223	374253	77029	1.26
Organic	17350	3.97	329989	312643	-17346	0.95

Economic analysis: Even though the tuber yield of *D. alata* was the highest under organic practice among the treatments, due to higher coconut yield under integrated practice, highest profit was realized from coconut + *D. alata* in integrated system (₹1,87,057/ha) (Table 3). The next profitable system was coconut + *D. alata* under conventional practice (₹1,58,330/ha) due to higher yields from both the crops. In coconut + *D. esculenta* association, the integrated practice, where there was a reduction in the use of chemical inputs, resulted in higher returns (₹1,29,637/ha). In coconut + *D. rotundata*, traditional practice, where there was non-use of chemical inputs, was economically viable (₹81,650/ha). Among the yams, greater yam (*D. alata*) responded well with the highest productivity and farm income under organic management (₹1,46,634/ha) in intercropping situation.

The economic analysis indicated that due to slight yield reduction under organic practice (yield reduction to the extent of 1.4%, 8.7% and 7% over conventional, integrated and traditional systems respectively) and also since premium prices were not accounted in this investigation, greater profits were obtained from towards organic practices (integrated or traditional). This indicates that there is a scope for organic management. The present experiment was carried out only for two years and long-term studies are needed to confirm the sustainability of yield and profit of organic systems.

It can be concluded that in yams under intercropping in coconut plantation, organic practice proved to be an alternative to conventional due to similar impacts on yield, tuber quality and soil chemical properties. Yield under organic management was 98.6% of conventional farming and the Asiatic yams, *D. alata* and *D. esculenta* responded better to organic management. Organic management had other benefits like higher available N, exchangeable Ca and available Zn in soil and significant improvement in K, higher P and Mg contents in yam tubers. However, highest profit was realized from coconut + *D. alata* in integrated system (₹1,87,057/ha).

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