Research Article

doi:10.25081/jpc.2020.v48.i1.6216
Journal of Plantation Crops, 2020, 48(1):45-54

Validation of organic management in cassava intercropped in coconut plantation in the humid coastal tropics of Kerala, India

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(Manuscript Received: 06-02-2020, Revised: 16-03-2020, Accepted: 20-03-2020)

Abstract

Crop diversification and alternatives like organic farming assume importance for sustainable food production, especially during climate change. Besides, organic farming enables environmentally benign and clean food production. Cassava, an important food-cum-nutritional security crop with diversified uses in feed and industrial sectors, is a common intercrop in coconut plantations. On-station field experiments at ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI), Thiruvananthapuram conclusively proved that organic management promoted productivity, tuber quality and soil properties in cassava. Cost-effective technologies were also developed, which required large scale field validation. Hence, a field experiment was conducted under Network Project on Organic Horticulture during 2015-2017 at the Research Farm, ICAR-Central Plantation Crops Research Institute, Kasaragod, to validate the ICAR-CTCRI developed organic farming technologies in cassava under intercropping in an organically raised mature coconut garden. Three varieties of cassava (Sree Vijaya, Vellayani Hraswa and H-165) were tested under four production systems *viz*., traditional, conventional, integrated and organic, and replicated thrice in split-plot design in a 48-year-old coconut (var. Kera Keralam) garden. Organic and conventional practices were equally efficient in crop growth, yield, tuber quality and soil chemical properties. Averaging over the years, yield under organic management was 76 per cent of conventional farming. The domestic and industrial varieties of cassava performed similarly under the different production systems, with almost the same yield reduction (24%) under organic over conventional management. The organic technology package comprising farmyard manure, green manure cowpea, cassava crop residue and biofertilizers, resulted in significantly higher available N in soil and improvement in P, K, Mg, Mn and Zn contents in cassava tubers. However, cassava var. Vellayani Hraswa under an integrated production system resulted in the highest net income (₹ 1,97,830 ha^{-1}) and B:C ratio (1.99) when intercropped in coconut.

Keywords: Cassava, coconut, eco-friendly agriculture, economics, productivity, quality, soil nutrients

Introduction

Coconut is one of the major plantation crops of India, having the status of a high-value commercial crop, grown in an area of 2.1 M ha with a production of 117.1 Mt and productivity of 5577.2 kg ha^{-1} in the year 2018 (FAOSTAT, 2018). More than 80 per cent of the coconut holdings are small. The farmers face problems like lack of gainful employment opportunities to the family throughout the year, insufficient income to meet the family requirement, high degree of price fluctuations, increasing incidence of pests and diseases in addition to low and erratic rainfall (Basavaraju *et al*., 2018). Hence, there is a scope for crop diversification with compatible crops in coconut gardens to increase the productivity and income of the existing coconut plantations by efficient utilization of available resources like water, nutrients, light and space. The phyllotaxy and the unique plant architecture of the coconut tree offer ample scope for utilizing the greater portion of the unutilized area between the trees for intercropping.

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Intercropping tropical tuber crops *viz*., cassava, yams, edible aroids and sweet potato in perennials like plantation/fruit crops (coconut, arecanut, rubber, coffee, banana *etc.*) is widely prevalent in the humid tropics (Nayar and Suja, 2004). Amongst these, cassava, yams and edible aroids are the most preferred intercrops in coconut in South India (Nayar, 1995). The benefits of such a system include cash income from the main crop, food security by tuberous intercrops, insurance against risk and natural calamities, higher resource use efficiency, net income and employment opportunities (Nayar and Suja, 2004).

Cassava (*Manihot esculenta* Crantz) is the major tuber crop that ensures food and nutritional security of rural livelihoods. It is an excellent source of raw material for starch, sago and animal feed industries. Cassava has high biological efficiency, thrives better under marginal conditions with low external inputs, adverse soil and climatic conditions, exhibiting greater flexibility to establish under different environments (Ceballos *et al*., 2010). The global consciousness regarding food safety, environmental issues and human health have stimulated considerable interests in practising alternative agriculture systems like organic farming. Long-term research for over 10 years indicated that organic farming was beneficial in tropical tuber crops as it was environmentally sound with 10-20 per cent higher yield of quality tubers and improvement of soil fertility (Suja *et al*., 2009; 2010; 2012a; 2012b; Suja, 2013; Suja and Sreekumar, 2014; Suja *et al*., 2015; 2016a; 2017) and technologies have been standardized. Field experiments at ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI), Thiruvananthapuram for three consecutive years conclusively proved that organic management promoted yield, quality and soil health in cassava (Seena Radhakrishnan *et al*., 2013; Seena Radhakrishnan, 2017). However, the on-station developed organic production technologies required large scale field validation for the popularization of organic farming in cassava, a popular intercrop in coconut gardens in the humid coastal tropics. Therefore, the present investigation was conducted under Network Project on Organic Horticulture at ICAR-Central Plantation Crops Research Institute, Kasaragod, to validate the ICAR-CTCRI developed organic farming technologies in cassava under intercropping in an organically raised mature coconut garden and evaluate its impact on crop growth, yield, quality, soil properties and farm income.

Materials and methods

The field experiment was carried out for two consecutive years during May-January in 2015-2016 and 2016-2017 at the Research Farm, ICAR-Central Plantation Crops Research Institute, Kasaragod, to confirm the ICAR-CTCRI (on-station) developed organic farming technology in cassava under intercropping in a mature coconut garden. The experimental site was situated at 12°30’ N latitude, and 75°00’ E longitude with an altitude of 10.7 m above mean sea level. The climate of the site was typical warm, humid tropical. The mean rainfall, relative humidity, maximum and minimum temperatures during the growing seasons were 3462 mm, 67.8 per cent and 31.2^{0}C and 23.6^{0}C respectively.

The soil was red sandy loam (pH 5.07). At the commencement of the experiment, the soil was characterized as having high organic C (2.05%), low available N (223.63 kg ha^{-1}), high available P (151.47 kg ha^{-1}) and available K (191.37 kg ha^{-1}). The bulk density, particle density, water holding capacity, porosity and cation exchange capacity (CEC) were 1.35 g cm^{-3}, 2.36 g cm^{-3}, 27.56 per cent, 34.12 per cent and 5.89 cmol kg^{-1} respectively.

Three varieties of cassava, including two domestic and one industrial (Sree Vijaya, Vellayani Hraswa and H-165) were planted and tested under four production systems *viz*., traditional, conventional, integrated and organic, and replicated thrice in split-plot design in a 48-year-old coconut garden (var. Kera Keralam) during 2015-16 and 2016-17 (Fig. 1). Main plots consisted of varieties and subplots comprised production systems. Each experimental plot had a gross area of 5.4 m x 5.4 m, accommodating 16 net plants. Details of treatments used in the experiment are given in Table 1.

The test variety, Sree Vijaya is an early maturing variety with 6-7 months duration, released by ICAR-CTCRI. It is a selection from the germplasm collection of cassava. It yields 25-28 t ha^{-1} and has a starch content of 27-30 per cent. The tuber flesh

Table 1. Details of production systems

Production systems	Name of inputs and quantity	
	Cassava (per ha)	**Coconut (per palm)**
Traditional (Farmers' practice)	FYM @ 12.5 t ha^{-1} and ash @ 2 t ha^{-1}	FYM @ 30 kg, NaCl @ 1 kg and lime @ 1 kg
Conventional (Present Package of Practices (POP) recommendations)	FYM @ 12.5 t ha^{-1} and NPK @ 100:50:100 kg ha^{-1}	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 @ 12.5 t ha^{-1} and NPK @ 50:25:100 kg ha^{-1}+ *Azospirillum* + P solubilizer @ 3 kg ha^{-1} each	FYM @ 15 kg, cowpea 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 @ 12.5 t ha^{-1}, *in situ* green manuring with cowpea (normally produces green matter @ 15-20 t ha^{-1}), crop residue incorporation (generates dry biomass @ 3 t ha^{-1}), *Azospirillum* @ 3 kg ha^{-1}, phosphobacteria @ 3 kg ha^{-1} and K solubilizer @ 3 kg ha^{-1}	FYM @ 30 kg and cowpea green manure @ 30 kg

colour is light yellow, and tuber rind colour is cream (CTCRI, 2006). Vellayani Hraswa is a high yielding early maturing variety with 5-6 months duration released by Kerala Agricultural University. The plants are dwarf with good branching characteristics. The tuber rind is reddish-brown with good cooking quality, and tubers contain 27.8 per cent starch (KAU, 2016). H-165 is an erect hybrid released by ICAR-CTCRI, Thiruvananthapuram. Tubers are fusiform with cream coloured rind, white flesh with 23-25 per cent starch; yields 33-38 t ha^{-1} in 8-9 months (CTCRI, 2006).

The observations on growth attributes of cassava like plant height, number of leaves and stem girth were recorded at 2, 4 and 6 months after planting (MAP). Tubers from each net plot, were harvested and fresh weight of tubers was recorded, and tuber yield was expressed in t ha^{-1}. Biochemical properties of tuber such as dry matter, starch, crude protein and total sugars (AOAC, 2005; Dubois *et al*., 1956) and mineral constituents like P, K, Ca, Mg, Fe, Mn, Zn and Cu contents (Piper, 1970) as well as soil chemical properties like pH, organic C, available N, P, K, Fe, Mn, Zn and Cu status (Page *et al*., 1982) were measured at harvest using standard analytical procedures. Based on the average cost of all inputs, labour cost for the different agricultural operations and the average market price of the product during the period of investigation, the gross cost and gross income were calculated. Based on this, net income and benefit:cost ratio (B:C ratio) were computed as follows:

Net income (₹/ha) = Gross income - Gross cost of cultivation

B: C ratio = Gross income ÷ Gross cost

Analysis of variance (ANOVA) technique for the split-plot design was done using SAS (2010). The differences between treatment means were tested using the least significant difference (LSD) test at 0.05 level of probability.

Results and discussion

Growth dynamics

Varieties varied significantly for plant height at different stages in the first year. Sree Vijaya and H-165 were significantly taller over Vellayani Hraswa. But the leaf retention and total leaf production at 4 MAP were significantly higher for Vellayani Hraswa. In the subsequent year, the plant height, stem girth and leaf production of varieties were similar throughout the growth period (Table 2).

It is worthy of mentioning that the effect of production systems was of more importance in the present investigation. At all stages, except at 4 MAP in the second year, the plants were significantly taller

Fig. 1. Validation trial on organic management of cassava in coconut garden at ICAR-CPCRI, Kasaragod

in the integrated or conventional practices (Table 2). At the maturity stage, leaf retention also followed a similar trend. The integrated or conventional management retained significantly more leaves. Leaf fall was to the same extent in the different management options during the course of experimentation. It was more in conventional or integrated treatments and lesser in organic or traditional treatments, where chemical fertilizers were not used. The total number of leaves was also significantly higher in the conventional or integrated practices. Stem girth also did not vary significantly due to the production systems. However, conventional or integrated practices resulted in greater stem girth. Plant growth was promoted under conventional or integrated practices, probably due to comparatively faster release and availability of nutrients from chemical fertilizers over organic manures. The partial shade in the coconut garden might have slowed down the decomposition process of the organic manures resulting in slower availability for uptake by the crop. However, the varieties x production systems interaction was absent during the period of experimentation.

Tuber yield

The effects of varieties, production systems and varieties x production systems interaction were not significant in both the years (Table 3; Fig. 2). In cassava intercropped in coconut, organic management was identical to the conventional system, with yield reduction of 26 per cent and 22 per cent, respectively, during both the years. Averaging over two years, organic management resulted in 24 per cent, 8 per cent and 14 per cent yield reduction over conventional, integrated and traditional practices, respectively (Fig. 2). These results are contrary to the on-station results that organic management insignificantly increased yield by 2.4 per cent over the conventional practice in cassava (Seena Radhakrishnan, 2017). This might be due to the slower rate of decomposition and

Table 2. Effect of production systems on growth attributes of cassava

Varieties/	2015-2016			2016-2017		
Production systems	2 MAP	4 MAP	6 MAP	2 MAP	4 MAP	6 MAP
a. Plant height (cm)						
Varieties						
Sree Vijaya	46.2	187.1	217.6	95.9	184.0	219.6
Vellayani Hraswa	31.1	157.1	165.4	97.0	209.2	238.0
H-165	43.8	178.4	229.1	110.7	232.3	257.4
CD (0.05)	10.6	18.2	32.3	NS	NS	NS
Production systems						
Traditional	41.4	164.6	189.9	89.3	168.3	198.7
Conventional	38.2	195.8	222.8	111.2	247.9	287.1
Integrated	46.6	193.5	246.6	110.8	238.1	254.6
Organic	35.1	142.7	156.8	93.5	179.8	213.0
CD (0.05)	7.3	34.7	58.4	14.1	NS	35.1
b. No. of leaves retained						
Varieties						
Sree Vijaya	42	117	107	68	164	108
Vellayani Hraswa	24	164	161	65	162	95
H-165	32	106	69	62	130	64
CD (0.05)	NS	27.9	NS	NS	NS	NS
Production systems						
Traditional	31	127	95	64	139	77
Conventional	35	145	135	71	185	108
Integrated	39	146	130	69	168	115
Organic	26	97	87	55	117	86
CD (0.05)	6.7	29.3	NS	NS	34.6	NS
c. No. of leaves fallen						
Varieties						
Sree Vijaya	2	16	143	4	32	122
Vellayani Hraswa	2	11	131	3	24	76
H-165	2	10	111	3	29	78
CD (0.05)	NS	NS	NS	NS	NS	NS
Production systems						
Traditional	2	11	126	3	25	100
Conventional	2	13	150	3	31	120
Integrated	2	14	139	4	36	105
Organic	3	12	99	4	21	73
CD (0.05)	NS	NS	32.9	NS	NS	NS
d. Total no. of leaves						
Varieties						
Sree Vijaya	44	133	250	72	196	230
Vellayani Hraswa	26	175	292	68	186	171
H-165	34	116	180	65	159	142
CD (0.05)	NS	33.4	NS	NS	NS	NS

Production systems						
Traditional	33	138	221	67	164	177
Conventional	37	158	285	74	216	228
Integrated	41	160	269	73	204	220
Organic	29	109	186	59	138	159
CD (0.05)	7.2	29.7	71.6	NS	35.3	NS
e. Stem girth (cm)						
Varieties						
Sree Vijaya	3.5	6.7	7.0	4.8	5.7	5.2
Vellayani Hraswa	2.8	6.6	6.5	4.9	6.3	6.1
H-165	2.9	7.0	7.0	5.4	6.1	6.5
CD (0.05)	NS	NS	NS	NS	NS	NS
Production systems						
Traditional	3.1	6.6	6.4	5.1	5.5	5.4
Conventional	2.8	7.0	7.4	5.2	6.7	6.6
Integrated	3.2	7.0	7.4	5.0	6.3	6.5
Organic	3.0	6.5	6.1	4.9	5.6	5.2
CD (0.05)	NS	NS	0.8	NS	NS	NS

release of plant nutrients from the organic manures compared to the chemical fertilizers, under the partial shade in the coconut plantation.

In the present validation trial, the cassava varieties responded similarly to organic and conventional management as in the case of on-station experiments (Seena Radhakrishnan, 2017; Seena Radhakrishnan *et al*., 2013). The three varieties of cassava, Sree Vijaya, Vellayani Hraswa and H-165, exhibited similar yield reduction (22%, 27%, 23%, respectively) under organic management over the conventional system. This observation is consistent to the earlier reports that the improved and local varieties of elephant foot yam (Suja *et al*., 2016b; 2017) were equally suitable for conventional and organic agriculture owing to their almost similar yields, corm/cormel quality and impact on soil physico-chemical-biological properties.

The major challenge in the popularization of organic farming is the lack of locally adapted crop varieties that can thrive under organic management in the absence of chemical supports (Maddox, 2015). Fagnano *et al.* (2012) have rightly stated that there was a lack of evidence on the adaptation of varieties developed for chemical-intensive system to organic management. Hence, the current validation research done for two years conclusively proves the adaptation of industrial and domestic

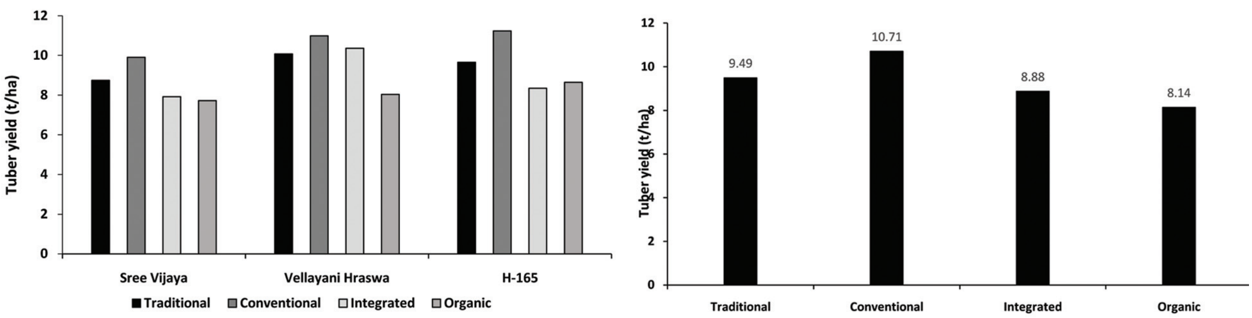

Fig. 2. The response of cassava varieties to management practices in the coconut plantation (Mean of two years)

Table 3. Yield response of varieties of cassava to production systems (t ha^{-1})

Varieties/	Traditional		Conventional		Integrated		Organic		Mean of varieties	
production systems	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year1	Year 2	Year 1	Year 2
Sree Vijaya	9.45	8.03	9.75	10.07	7.78	8.06	8.41	7.04	8.85	8.30
Vellayani Hraswa	8.73	11.42	12.40	9.57	11.20	9.53	7.72	8.36	10.01	9.72
H-165	8.74	10.57	10.44	12.03	8.03	8.67	8.03	9.26	8.81	10.13
Mean of production systems	8.97	10.01	10.86	10.55	9.00	8.75	8.06	8.22		

CD (0.05) Varieties: NS; Production systems: NS Varieties x Production systems: NS

varieties of cassava, originally developed for a chemical system, to organic management.

Tuber quality

There were no significant effect of varieties, production systems and varieties x production systems on tuber quality. The quality of the produce is determined by various factors, like variety, genetic makeup, location, fertilization and weather conditions during crop growth. As per the fundamental principle suggested by Chhonkar (2008), plants absorb nutrients as inorganic ions regardless of the source. After absorption, the nutrients are re-synthesized into compounds that determine the quality of the produce, which is mainly governed by the genetic potential of the plant (Chhonkar, 2008). However, product quality also means the absence of harmful compounds, which is influenced by management practices (Neuhoff *et al*., 2011).

Traditional practice, which also advocated organic inputs in the present experiment, favoured dry matter (36.50%), starch (24.32%), crude protein (1.17%) and sugar contents (2.61%) in cassava. The organic system improved the P (168 mg 100 g^{-1}), K (416 mg 100 g^{-1}), Mg (267 mg 100 g^{-1}), Mn (6.96 mg 100 g^{-1}) and Zn (7.56 mg 100 g^{-1}) contents in cassava. In the on-station experiment on cassava (ICAR-CTCRI), organic management (with or without biofertilizers) could enhance the P, K, Ca, Mg, Fe, Mn and Zn status of the tubers by 1.25, 10.13, 12.89, 40.79, 59.03, 6.92 and 27.40 per cent respectively over conventional practice (Seena Radhakrishnan and Suja, 2017). The higher mineral composition has been earlier documented in other tropical tuber crops under organic management. In elephant foot yam, organic corms had 3-7 per cent 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 soil chemical properties at the end of experimentation indicated that in general there were no significant variation under the influence of varieties, production systems and varieties x production systems, except for available N and Mn, which were significantly higher in organic and conventional systems respectively (Tables 4 and 5). The significant enhancement in available N status of the soil was solely due to the direct addition of N from the organic manures, especially green manure

Table 4. Effect of production systems on major chemical properties of the soil in cassava

Production systems	pH	Electrical conductivity (dS m-1)	Organic C (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Traditional	4.95	0.079	2.08	186.7	47.7	123.8
Conventional	4.71	0.066	2.29	189.5	46.1	158.5
Integrated	4.61	0.094	2.07	188.1	51.4	140.0
Organic	4.88	0.107	2.11	207.6	45.6	125.7
CD (0.05)	NS	NS	NS	11.02	NS	NS

Table 5. Effect of production systems on secondary and micronutrient status of the soil in cassava

Production systems	Exch. Ca (meq 100 g^{-1})	Avail. Mn (ppm)	Avail. Zn (ppm)	Avail. Cu (ppm)
Traditional	0.65	49.52	4.75	3.61
Conventional	0.49	58.97	5.23	3.24
Integrated	0.50	55.64	5.95	3.81
Organic	0.57	46.78	5.07	3.36
CD (0.05)	NS	7.91	NS	NS

cowpea. The pH and exchangeable Ca were higher in the traditional practice due to contribution of Ca from wood ash, available P in the integrated system due to the activity of the biofertilizer, P solubilizer and organic C and available K in the conventional system mainly contributed by the fallen leaves on account of vigorous growth under the influence of chemical fertilizers.

Economic analysis

Among the treatments, cassava var. Vellayani Hraswa under an integrated production system resulted in the highest net income (₹ 1,97,830 ha^{-1}) and B:C ratio (1.99) when intercropped in coconut due to higher yield (Table 6). This was followed by Vellayani Hraswa under the conventional system (₹ 1, 80,076 ha^{-1}; B:C ratio 1.86). In the case of Sree Vijaya and the industrial var. H-165, the conventional practice was the most profitable under intercropping with coconut. Among the varieties, Sree Vijaya performed reasonably well with the highest return under organic management (₹ 1,31,190 ha^{-1}) in the intercropping situation. It is to be noted that economic analysis was done without considering the premium price for the organic produce.

In the experiment, though the tuber yield among the various production systems was not significantly different, organic management resulted in lower yield over conventional, integrated and traditional systems by 24 per cent, 8 per cent and 14 per cent respectively leading to lower profits. Thus the strategy to compensate for reduced yields and result in similar or higher gross margins for organic crops than conventional produce was to include the higher premium price for the organic produce in addition to devising techniques to lower costs of organic production (Stockdale *et al*., 2001).

Conclusions

In coconut intercropped with cassava, the organic and conventional practices for cassava were equally efficient in terms of crop growth,

Table 6. Economics of various production systems on coconut + cassava cropping system (Mean of two years)

Variety/ Production systems*	Coconut yield (Nuts per ha)	Cassava tuber yield (t ha^{-1})	Gross cost (₹ ha^{-1})	Gross income (₹ ha^{-1})	Net income (₹ ha^{-1})	B:C ratio
Sree Vijaya						
Traditional	20738	8.74	193776	353165	159389	1.82
Conventional	21613	9.91	210334	380573	170238	1.81
Integrated	22575	7.92	199797	359693	159895	1.80
Organic	21613	7.73	214830	346020	131190	1.61
Vellayani Hraswa						
Traditional	19338	10.08	193776	360448	166671	1.86
Conventional	21000	10.99	210334	390410	180076	1.86
Integrated	22575	10.37	199797	397628	197830	1.99
Organic	20650	8.04	214830	342305	127475	1.59
H-165						
Traditional	18200	9.66	193776	342873	149096	1.77
Conventional	20388	11.24	210334	390410	179806	1.85
Integrated	21175	8.35	199797	353585	153788	1.77
Organic	19600	8.65	214830	340455	125625	1.58

*Yield of pepper not included in the economic analysis productivity, tuber biochemical and mineral composition and soil chemical parameters. However, the yield under organic management was 24 per cent lower than conventional farming. The edible and industrial varieties of cassava yielded statistically similar in different production systems. The organic practice resulted in significantly higher available N in soil and improvement in mineral contents of tubers. However, cassava var. Vellayani Hraswa under an integrated production system resulted in the highest net income (₹ 1,97,830 ha^{-1}) and B:C ratio (1.99) when intercropped in coconut. Overall, the coconut+cassava association managed under the various production systems resulted in additional income, conserving the resource base and maintaining soil fertility.

Acknowledgements

The authors gratefully acknowledge the Network Project on Organic Horticulture, ICAR-Indian Institute of Spices Research, Kozhikode, for financial support. The authors also thank the Directors, ICAR-Central Plantation Crops Research Institute, Kasaragod and ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram Kerala, India, for providing field and laboratory facilities respectively for carrying out the above work.

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