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Organic vs Conventional Management in Cassava: Growth Dynamics, Yield and Soil Properties

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Abstract

Worldwide concerns regarding the food safety, anthropogenic degradation of the environment and the threats to human health have generated interest in sustainable alternative agricultural systems like organic farming. Cassava is a food and nutritional security crop with immense industrial uses. Lack of package of practices recommendations for organic production hinders the promotion of organic farming. Hence a field experiment was laid out during 2011 and 2012 in split plot design with three varieties, H-165, Sree Vijaya and Vellayani Hraswa in main plots and five nutrient management systems, traditional, conventional, integrated and two types of organic in sub plots at Central Tuber Crops Research Institute, Thiruvananthapuram, India, to develop technologies for organic production of cassava. Growth attributes and the phasic course of biomass production and partitioning to various plant parts were favoured under organic farming. Crop growth rate of cassava remained steady under organic management. Relative growth rate and tuber bulking rate at the mid and final phases, leaf area index and mean tuber bulking rate were seen promoted in organic practice. Organic management enhanced yield by 8% over conventional practice. At the end of second year, the pH was significantly higher in the organic practice (5.864) and organic C status was raised by 9.5% over the conventional system. There was no significant difference in the status of available N, P and K (after second crop) or secondary and micro nutrients (after first crop). However, exchangeable Ca, Mg, Fe, Cu and Zn were slightly favoured under organic practice. The study indicated that organic management, which advocates eco-friendly technologies, was equally good as that of conventional practice.

Key words: *Manihot esculenta*, eco-friendly management, productivity, soil health

Introduction

Global awareness of health and environmental issues has stimulated interest in alternative systems like organic farming. Organic farming has the potential to contribute to sustainable food cum nutritional security as well as livelihood security in the developing countries and enhancing biodiversity, while simultaneously reducing vulnerability to climate change. According to the International Federation of Organic Agriculture Movements, organic agriculture is a production system that relies on on farm generated organic resources and ecological processes such as waste recycling, rather than the use of synthetic inputs, such as chemical fertilizers and pesticides. Organic farming is essential for sustainable production, improved conservation of soil and vegetation besides restoration of degraded land. It is an efficient C management strategy that can mitigate climate change, enhanced nutrient use efficiency and soil organic C sequestration.

Tropical tuber crops form important staple or subsidiary food for about 500 million of the global population. Cassava is an important tropical tuber crop that plays a significant role in the food and nutritional security. It serves as a raw material for starch, sago and animal feed industries. There is a great demand for organically produced tuberous vegetables like cassava, elephant foot yam, yams etc. among affluent Asians and Africans living in Europe, USA and Middle East. The demand for organically produced food is also concentrated in Japan, South Korea, Singapore, Taiwan and Hongkong. At present there is no clear scientific evidence about the impact of organic nutrient management on growth, productivity and soil quality of cassava. Hence the objectives were to explore the comparative advantages of organic nutrient management practice over chemical in terms of growth dynamics, biomass production and soil physico-chemical properties under cassava.

Materials and Methods

Field experiments were conducted for two consecutive years (2011 and 2012) during June-December at Central Tuber Crops Research Institute (CTCRI) (8° 29'N, 76°57'E, 64 m altitude), Thiruvananthapuram, Kerala, India, to compare the varietal response, growth dynamics, yield and soil properties under various production systems in cassava. In the land used for this study, green manure cowpea was raised and incorporated. Chemical inputs were not used for an year before taking up the current research. The soil of the experimental site was acidic in reaction (pH: 4.78) with low available N (159.94 kg ha^{-1}), high available P (163.30 kg ha^{-1}) and organic C (1.01) and medium available K (162.33 kg ha^{-1}). The site experiences a typical humid tropical climate. The mean annual rainfall was 1817 mm, maximum and minimum temperatures were 31.52°C and 24.32°C respectively and mean relative humidity was 76.50%. The experiment was laid out in split plot design with three varieties, H-165, Sree Vijaya and Vellayani Hraswa in main plots and five production systems, traditional, conventional, integrated and two types of organic in sub plots (Table 1). The gross plot size was 5.4 m x 5.4 m accommodating 16 net plants.

Observations on total biomasss production and partitioning to leaf, stem and tuber were made at 2, 4 and 6 months after planting (MAP). Based on these, growth indices viz., leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR), harvest index (HI), tuber bulking rate (TBR) and mean TBR were computed using the growth analysis techniques of Hunt (1982).

The pH, organic C, available N, P, K, Ca, Mg, Fe, Mn, Zn and Cu status of the soil were estimated by standard analytical methods (Page et. al., 1982). Physical characters of the soil such as bulk density, particle density, water holding capacity and porosity were estimated by the methods of Gupta and Dakshinamoorthy (1980). The analysis of variance of data was done using SAS (2010).

Results and Discussion

Biomass production and partitioning

The phasic course of biomass production and its partitioning to various plant parts were higher in organically grown plants, in comparison to conventional plants (Fig.1). By harvest, the organic treatment resulted

Table 1. Description of treatments

Treatments	Name of inputs and quantity
Traditional (farmers' practice)	FYM @ 12.5 t $ha^{-1}$and ash @ 2 t ha^{-1}
Conventional (present Package of Practices (POP) Recommendations)	FYM @ 12.5 t $ha^{-1}$and NPK @ 100:50:100 kg ha^{-1}
Integrated	FYM @ 12.5 t ha^{-1} + NPK @ 50:25:100 kg ha^{-1}+ *Azospirillum* @ 3 kg ha^{-1} and phosphobacteria @ 3 kg ha^{-1}
Organic	FYM @ 12.5 t ha^{-1}, *in situ* green manuring (normally produces green matter @ 15-20 t ha^{-1}), crop residue incorporation (generates dry biomass @ 3 t ha^{-1}) and ash @ 2 t ha^{-1}
Organic (including biofertilizers)	FYM @ 12.5 t ha^{-1}, *in situ* green manuring (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}

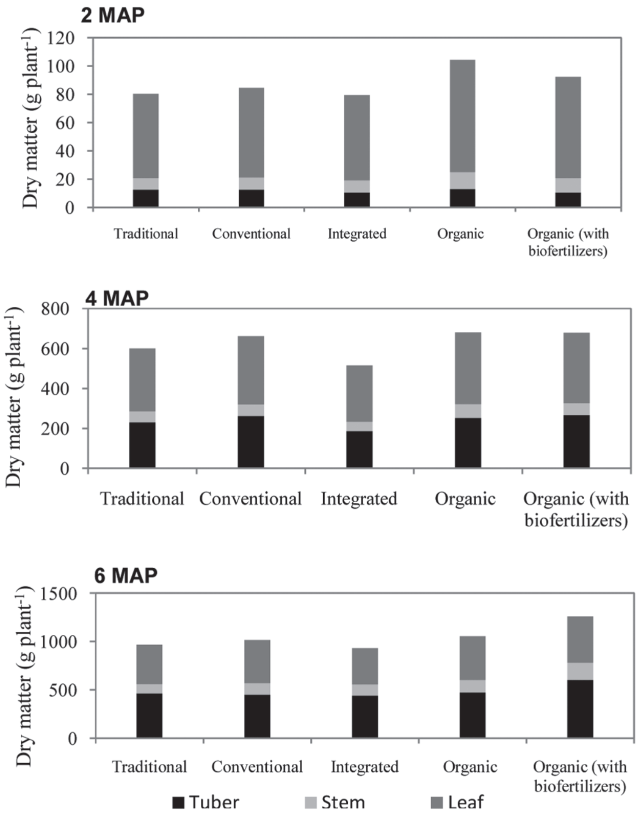

Fig. 1. Phasic trend of biomass production and partitioning as affected by treatments

in significantly higher total and tuber biomass. The two major organic sources used in the organic treatment were crop residue and green manure cowpea. Biomass addition from crop residue of cassava and green manure cowpea substantially contributed to N (72 and 30 kg ha^{-1}). This might have favoured growth and biomass production in the organic treatment. Similar results were reported by Suja et al. (2012a; 2012b) in elephant foot yam.

Growth indices

Leaf Area Index (LAI) showed an increasing trend, peaked at the fourth month and decreased slightly towards harvest (Fig.2). The LAI did not vary among the varieties. The treatments did not significantly influence the LAI, though it was slightly higher for the organic practice involving biofertilizers.

Crop Growth Rate (CGR) of cassava varieties was very slow in the first phase and almost same in the various treatments due to similar and slow rate of total biomass production and diversion to the leaves, stems and tubers. The CGR increased rapidly, peaked at the second phase

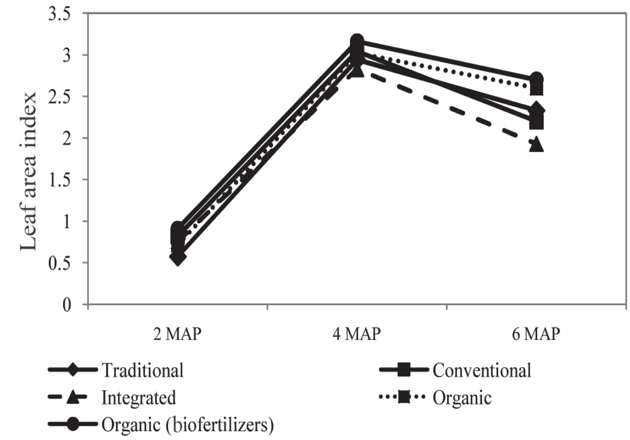

Fig. 2. Leaf area index as affected by treatments

and then declined towards harvest in all the production systems, except organic (involving biofertilizers) and integrated, wherein the CGR remained steady (Fig. 3).

Relative Growth Rate (RGR) was higher during the second phase (2-4 MAP) than the third phase (4-6 MAP), which indicates the declining trend of RGR with crop age. The treatments did not affect RGR significantly, though the organic practice, involving biofertilizers, produced higher RGR at the second phase (Table 2).

Tuber Bulking Rate (TBR) increased progressively with advancing age of the crop attaining peak values at harvest in the organic (involving biofertilizers), integrated and traditional production systems, where there was non use or lesser use of chemical inputs. But there was decline in TBR in the last phase in the conventional system (Fig. 4). The mean TBR was also appreciable in the organically grown plants (3.351 g day^{-1}) (Table 2). The higher TBR in the first and mid phases and the greater

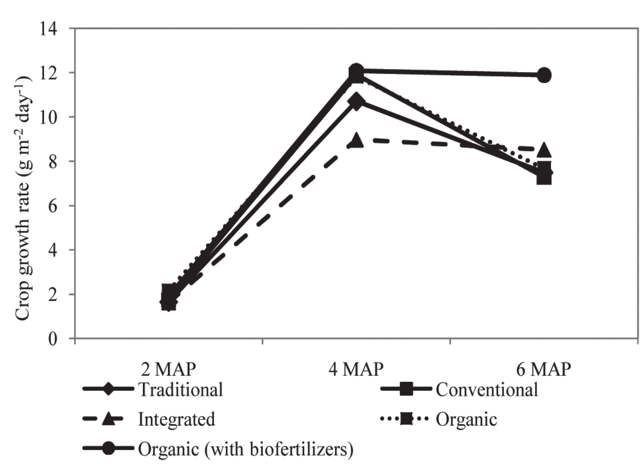

Fig. 3. Crop growth rate as affected by treatments

Table 2. RGR and mean TBR of cassava as influenced by nutrient management practices

Varieties/ Production systems	RGR ($mg\ g^{-1}\ day^{-1}$) 2 MAP	4 MAP	Mean TBR ($g\ day^{-1}$)
Varieties			
H-165	33.9	7.64	2.558
Sree Vijaya	31.6	8.87	2.805
Vellayani Hraswa	33.6	9.67	2.738
CD (0.05)	NS	NS	NS
Production systems			
Traditional	33.9	8.20	2.576
Conventional	34.2	7.77	2.502
Integrated	30.6	10.04	2.445
Organic	32.3	7.37	2.627
Organic (with biofertilizers)	34.0	10.25	3.351
CD (0.05)	NS	NS	NS

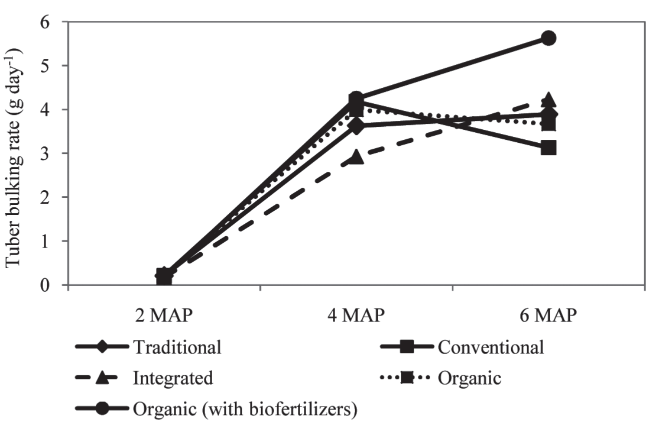

Fig. 4. Tuber bulking rate as affected by treatments

mean TBR might have contributed to a higher tuber yield under organic management.

Harvest Index (HI) showed an increment with progressing stages in all the treatments. The increase in HI was more conspicuous towards the mid phase under organic management (involving biofertilizers) (Fig.5). This factor might have also favoured tuber yield in this treatment.

Tuber yield

During the first year there was no significant difference among the various production systems on yield and yield attributes (Table 3). Also, varieties x production systems interaction were absent, which indicated that the varieties responded similarly to the various production systems.

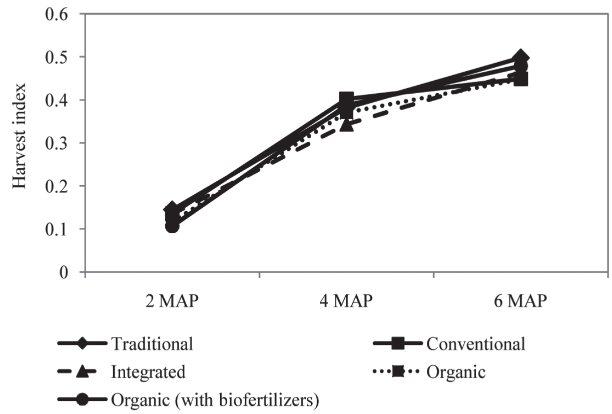

Fig. 5. Harvest index as affected by treatments

Among the varieties, H-165 produced higher tuber yield (30.10 t ha^{-1}). Among the production systems, organic practice produced 9% higher tuber yield (29.40 t ha^{-1}) over conventional practice (26.90 t ha^{-1}). This was followed by the organic practice that included biofertilizers (27.20 t ha^{-1}). During the second year, there was significant difference among the various production systems on tuber yield. Organic practice produced 8% higher yield (29.24 t ha^{-1}) on par with conventional practice (27.45 t ha^{-1}) (Table 3). Suja et al. (2012a and 2012b) reported that organic management produced 10-20% higher yield over conventional practice in tuber crops. Though the varieties x production systems effect was significant, the industrial as well as domestic varieties of cassava were on a par under both systems (Table 4). Among

Table 3. Yield of cassava as influenced by nutrient management systems

Varieties/ Production systems	Tuber yield ($kg\ plant^{-1}$)		Tuber yield ($t\ ha^{-1}$)	
	2011	2012	2011	2012
Varieties				
H-165	2.441	1.776	30.10	21.93
SreeVijaya	2.149	2.625	26.50	32.40
Vellayani Hraswa	1.822	1.725	22.50	21.30
CD (0.05)	NS	NS	NS	NS
Production systems				
Traditional	1.886	1.790	23.30	22.09
Conventional	2.179	2.223	26.90	27.45
Integrated	2.039	1.767	25.20	21.81
Organic	2.379	2.369	29.40	29.24
Organic (biofertilizers)	2.204	2.062	27.20	25.45
CD (0.05)	NS	0.323	NS	3.985

Table 4. Performance of cassava varieties under various nutrient management systems (tuber yield, t ha^{-1})

Varieties/ Production systems	Traditional	Conventional	Integrated	Organic	Organic (biofertilizers)
H-165	19.17	19.03	19.87	28.06	23.51
Sree Vijaya	29.75	37.68	32.33	34.96	27.28
Vellayani Hraswa	17.36	25.63	13.23	24.71	25.56
CD (0.05)	12.547				

the varieties, Sree Vijaya produced higher tuber yield (32.40 t ha^{-1}). Moreover the yield attributes viz., mean weight of tubers, length and girth of tubers were also higher under organic management. The higher yield may be due to the overall improvement in soil physico-chemical and biological properties under the influence of organic manures (Clark et al., 1998; Colla et al., 2000; Stockdale et al., 2001).

Soil properties

Physical parameters

The physical properties of the soil viz., bulk density, particle density and water holding capacity remained unaltered under the influence of the various production systems. However, bulk density and particle density were slightly lower and water holding capacity and porosity slightly higher in organic plots as compared to conventional plots (Table 5). This is normally expected as significant changes in the physical parameters cannot be brought about within a short period. Colla et al. (2000) reported that *in situ* water holding capacity was highest in organic system. Increased aeration, porosity and water holding capacity of soils have been observed under organic management (Gerhardt, 1997).

Table 5. Physical properties of the soil as influenced by treatments

Production systems	Bulk density (g cm^{-3})	Particle density (g cm^{-3})	Water holding capacity (%)	Porosity (%)
Traditional	1.785	2.441	15.59	28.60
Conventional	1.825	2.641	14.73	25.67
Integrated	1.802	2.436	15.29	28.34
Organic	1.818	2.514	15.90	28.52
Organic (biofertilizers)	1.849	2.527	14.79	27.75
CD (0.05)	NS	NS	NS	NS

Chemical parameters

After the harvest of first crop there was no appreciable difference in the chemical properties viz., electrical conductivity, pH, organic C, available N, P and K status under various production systems (Table 6). However, there was slight improvement in the pH (by 0.35 units), organic C (by 10.70%), available N (by 13%), exchangeable Ca (by 30.86%) and Mg (by 25.94%), Fe, Zn and Cu contents under organic practice (Table 7). At the end of second year, the pH and organic C status of the soil varied significantly among the nutrient management systems (Table 6). The pH was significantly higher in the organic practice (5.864). Organic management raised the pH by 1.061 unit over the conventional system. The organic C status was also promoted by 9.5% over conventional practice. Higher organic C status in organic plots might be attributed to considerable addition of organic manures particularly green manure cowpea (Suja et al., 2009; 2010; 2012a; 2012b). There was no significant difference in the status of available N, P and K after the second crop. Though the available N status was slightly lower under organic management, the available P and K status were higher under organic nutrient management. Improvement of soil reaction might have enabled the availability of major and secondary nutrients to some extent as reported by Prakash et al. (2002). Organic farming involving the use of organic manures helps to restore and improve soil health, by enhancing organic matter levels, neutralising soil acidity, supplying almost all essential nutrients in available form and thereby maintaining soil fertility in tuber crops (Suja et al., 2012a; 2012b).

Technologies for organic production

On station technologies for eco-friendly production of cassava comprising of FYM @ 12.5 t ha^{-1}, *in situ* green manuring (green matter @ 15-20 t ha^{-1}), crop residue

Table 6. Major chemical properties of soil as influenced by production systems

Production systems	Electrical conductivity (dS m^{-1})	pH		Organic C (%)		Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})	
		2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Traditional	0.246	5.806	5.608	1.203	0.932	280	100.2	165.8	280	266	398
Conventional	0.241	5.547	4.803	1.093	1.208	290	146.7	173.4	319	321	395
Integrated	0.226	5.820	4.972	1.127	0.911	242	123.2	162.8	277	266	384
Organic	0.254	5.900	5.864	1.210	1.215	328	124.7	171.8	354	309	458
Organic (biofertilizers)	0.204	5.568	5.320	1.037	1.323	236	138.5	163.6	297	237	318
CD (0.05)	NS	NS	0.4959	NS	0.3008	NS	NS	NS	NS	NS	NS

Table 7. Secondary and micronutrient status of the soil as influenced by production systems

Production systems	Ex.Ca (meq $100g^{-1}$)	Ex. Mg (meq $100g^{-1}$)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
Traditional	1.782	0.586	14.52	20.71	4.11	0.869
Conventional	1.309	0.505	16.60	21.27	4.10	0.767
Integrated	1.456	0.487	13.66	22.38	3.77	0.712
Organic	1.713	0.636	18.43	19.48	4.02	0.709
Organic (biofertilizers)	1.250	0.469	19.41	21.23	4.47	0.830
CD (0.05)	NS	NS	NS	NS	NS	NS

incorporation (dry biomass @ 3 t ha^{-1}) and ash @ 2 t ha^{-1} (or) FYM @ 12.5 t ha^{-1}, *in situ* green manuring (green matter @ 15-20 t ha^{-1}), crop residue incorporation (dry biomass @ 3 t ha^{-1}), *Azospirillum* @ 3 kg ha^{-1}, phosphobacteria @ 3 kg ha^{-1} and K solubilizer @ 3 kg ha^{-1} was developed. However, this needs confirmation by conducting on farm trials

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