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ORGANIC MANAGEMENT OF CASSAVA FOR SUSTAINABLE YIELD AND SOIL RESTORATION

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Abstract: Organic farming is a sustainable alternative for safe food production, conservation of environment, soil and human health. Cassava is a food-nutritional security-industrial crop adapted to climate change. Field experiments were conducted at the Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India, for two years to compare the varietal response, growth dynamics and yield, quality and soil properties under various production systems in cassava.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. The biomass addition and nutrient contribution from crop residue and green manure cowpea was accounted. Observations on total biomasss production and partitioning, growth indices *viz*., leaf area index (LAI), crop growth rate (CGR), net assimilation rate (NAR), relative growth rate (RGR), harvest index (HI), tuber bulking rate (TBR), mean tuber bulking rate, NPK uptake and partitioning to leaf, stem and tuber at periodic intervals (2, 4 and 6 months after planting) and tuber yield and yield attributes at harvest were taken. Tuber quality (bio-chemical content), soil physico-chemical properties and microbial count were also assessed. There was substantial contribution of N from crop residue of cassava and green manure cowpea (72 and 30 kg ha^{-1}). Organic farming enhanced yield by 8% over conventional practice. The industrial as well as domestic varieties of cassava responded similarly, though, the industrial variety, H-165, yielded more under organic farming than conventional practice. The phasic course of biomass production and partitioning to various plant parts, CGR, LAI, TBR, plant uptake of N, P and K and its partitioning to leaf, stem and tubers at various stages were promoted under organic management. The organic practice resulted in significantly higher total and tuber biomass. Organic management favoured LAI and promoted CGR significantly throughout the crop cycle. The TBR under organic practice was significantly higher than conventional practice in the mid growth phase.The mean TBR was significantly higher in the organic plants than conventional plants. The cyanogenic glucoside content was reduced under organic management. At the end of second year, the pH was significantly higher and tended towards neutrality 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. Physical properties, viz., bulk density and particle density were slightly lower, water holding capacity and porosity slightly higher and aggregate stability favoured under organic management. The counts of microbes viz., bacteria, fungi and actinomycetes were appreciably higher in all the production systems other than conventional system. The two years' study enabled the development of on station technologies for organic production of cassava.

Key words: *Manihot esculenta*, Eco-friendly management, Productivity, Tuber quality, Soil health

INTRODUCTION

The growing public concern about food safety, environmental protection and human health have generated great interest in sustainable alternative agricultural systems like organic farming (Carter *et al*., 1993). The UN millennium ecosystem assessment ranks "land degradation" as one of the world's greatest environmental challenges. About 40% of the world's arable land is seriously degraded and 11% of such land is in Asia. The land quality for food production contributes to future peace. Hence "Organic farming" is essential for sustainable production, improved conservation of soil and vegetation besides restoration of degraded land. It is an efficient carbon management strategy that can mitigate climate change, by the avoidance of chemical fertilizers and sequestering soil organic carbon. 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. There is limited information on the effect of alternative management practices like organic farming on growth, yield, quality and soil health. Hence the objectives were to explore the comparative advantages of organic farming over chemical farming in terms of yield, quality and soil physico-chemical-biological properties under cassava.

MATERIALS AND METHODS

Study site, experimental design, treatments and test variety

Field experiments were conducted at the Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India for two years (2011 and 2012) to compare the varietal response, growth dynamics, yield, quality and soil properties under various production systems in cassava. The soil of the experimental site was acidic in reaction (pH: 4.789) with low available N (159.94 kg ha^{-1}), high available P (163.30 kg ha^{-1}) and organic C (1.01) and medium K (162.33 kg ha^{-1}). 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).

Plant measurements

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 tuber bulking rate were computed. The NPK uptake and partitioning to leaf, stem and tuber were also worked out at periodic intervals. The tuber yield and yield attributes *viz*., number of tubers, mean weight of tuber, length and girth of tuber were recorded at harvest. Bio-chemical constituents of tuber *viz*., dry matter, starch, cyanogenic glucosides (HCN content), sugar, fibre and ashwere estimated using standard procedures.

Soil measurements

Soil chemical properties *viz*., pH, organic C, available N, P, K, exchangeable Ca, Mg, Fe, Mn, Zn and Cu and soil physical properties *viz*., bulk density, particle density, water holding capacity, porosity and aggregate stability, microbial count (population of bacteria, fungi and actinomycetes) were determined at harvest using standard analytical methods.

Table 1. Treatment details

Production systems	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 @ 100:50:100kg 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}

Statistical analysis

The analysis of variance of data was done using SAS (2008) by applying analysis of variance technique.

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 (without biofertilizers) resulted 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 and nutrient contribution from crop residue of cassava and green manure cow pea was accounted and there was substantial contribution of N from crop residue of cassava and green manure cowpea (72 and 30 kg ha^{-1}). This might have favoured growth and biomass production in the organic treatment. Similar

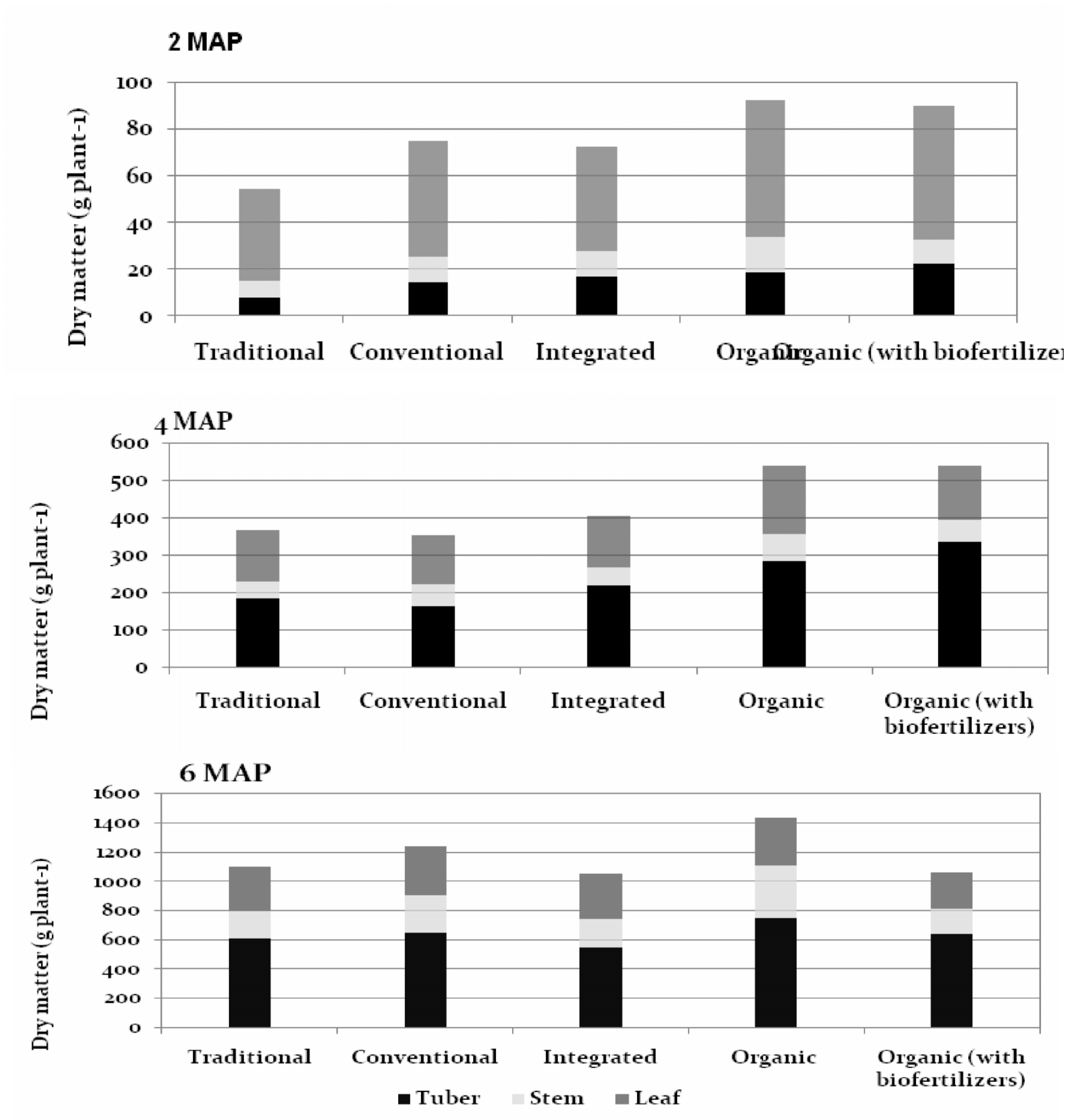

Fig.1. Phasic trend of biomass production and partitioning as affected by treatments

results were reported by Suja *et al.* (2012a and 2012b) in elephant foot yam.

Growth indices

The production systems did not significantly influence the LAI, except at the mid growth phase (Fig. 2). Organic practice promoted LAI similar to that of conventional practice, where fertilizers were used. Among the production systems, organic practice favoured the CGR significantly, throughout the crop growth cycle (Fig. 3).The organic and conventional management imparted similar effects on NAR at the mid phase. The traditional practice, which advocates the non use of chemicals, resulted in significantly higher NAR particularly by the last phase. The production systems affected the RGR significantly; all the management practices that advocated the non use (traditional and organic) or lesser use (integrated) of chemical inputs resulted in higher RGR during the mid phase and conventional practice during the last phase (Table 2).

The TBR increased progressively with advancing age of the crop attaining peak values at harvest in all the production systems, except organic (involving biofertilizers) (Fig. 4). The TBR was at a slow pace in the last phase in the organic practice (involving biofertilizers). The TBR under organic practice was significantly higher than conventional practice in the mid growth phase. By harvest both the practices were on par. The

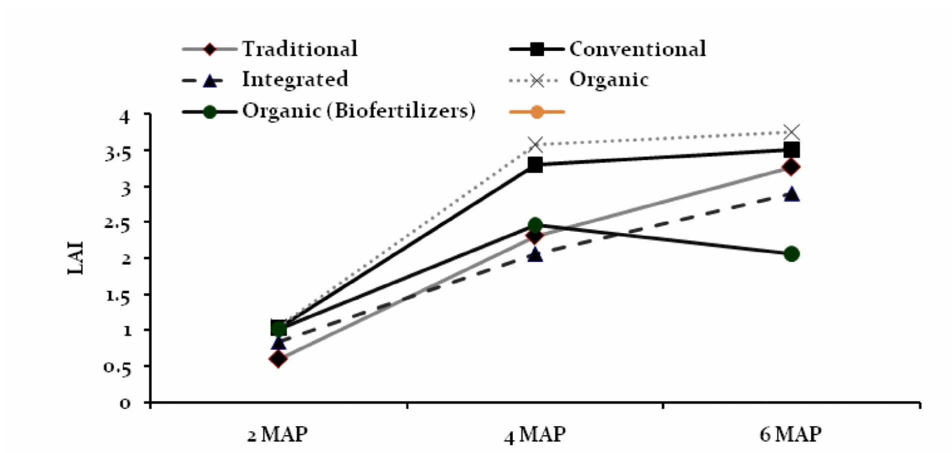

Fig. 2. Leaf area index as affected by production systems

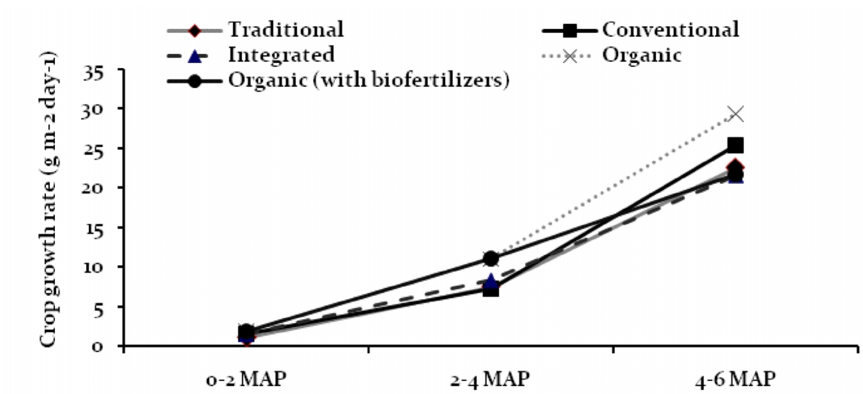

Fig. 3. Crop growth rate as affected by production systems

mean TBR was significantly higher in the organically grown plants (4.266 g day^{-1}) than conventional plants (3.581 g day^{-1}) (Table 2). Thus the higher TBR in the first and mid phases and the greater mean TBR might have contributed to a higher tuber yield under organic management.In general, there was an increment in HI with progressing stages in all the production systems (Fig. 5). The increase in HI was more conspicuous towards the mid phase under organic management (involving biofertilizers). This factor might have also favoured tuber yield in this treatment.

Nutrient uptake and partitioning

At 2 MAP, the leaf and stem uptake of N, P and K was higher in organically raised plant, whereas tuber uptake of N, P and K was higher in conventional plants. The uptake of N was significantly higher under organic practice at 4 and 6 MAP. During these stages there was no significant difference among the treatments in the uptake of P and K and its partitioning to leaf, stem and tuber, though these were observed to be promoted in the organic plants.

Yield and quality

Organic farming produced higher yield, but on par with conventional practice (Table 3). Organic practice produced 8% higher tuber yield (29.24 t ha^{-1}) over conventional practice (27.45 t ha^{-1}). 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 were significant, the industrial as well as domestic varieties of cassava were on a par under both systems. However, H-165, the industrial variety of cassava, yielded more under organic farming than conventional practice. Moreover the yield attributes *viz*., mean weight of tuber, length and girth of tubers were also promoted 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). Organic management lowered the HCN content, favoured the sugar and fibre contents

Table 2. RGR and mean TBR of cassava as influenced by production systems

Varieties/Production systems	RGR (mg g^{-1} day^{-1})		NAR (g m^{-2} day^{-1})		Mean TBR (g day^{-1})
	4 MAP	6 MAP	4 MAP	6 MAP	
Varieties					
H-165	30.58	24.11	4.08	8.31	2.560
Sree Vijaya	31.18	14.01	7.40	5.10	4.775
Vellayani Hraswa	25.84	17.84	4.59	7.45	3.353
CD (0.05)	NS	4.439	1.946	NS	NS
Production systems					
Traditional	31.92	20.79	6.43	8.69	3.437
Conventional	24.19	23.81	2.96	6.98	3.581
Integrated	29.67	17.40	5.75	6.87	3.005
Organic	29.64	18.22	5.87	6.96	4.266
Organic (with biofertilizers)	30.56	13.04	5.77	5.25	3.523
CD (0.05)	4.973	5.154	NS	1.483	0.5322

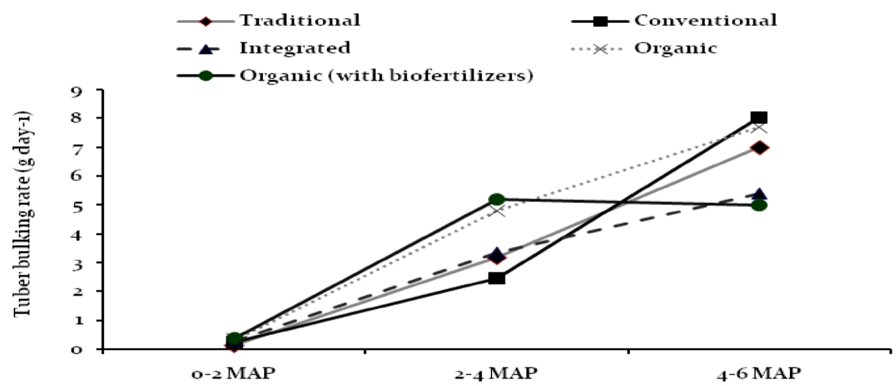

Fig. 4. Tuber bulking rate as affected by production systems

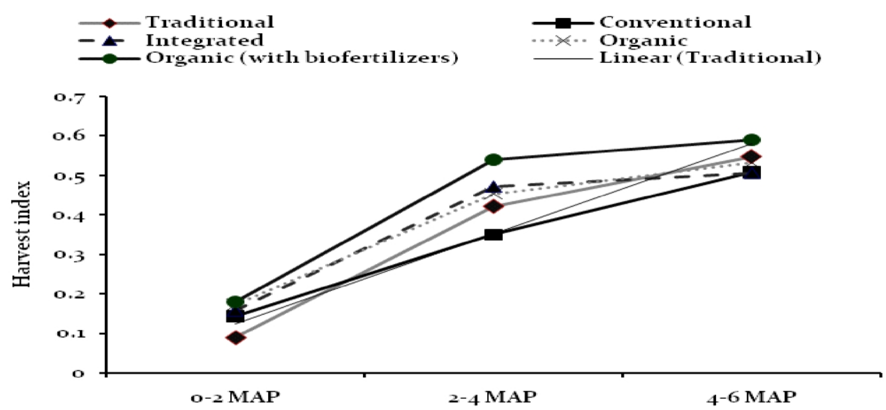

Fig. 5. Harvest index as affected by production systems

Table 3. Yield and yield attributes of cassava as influenced by production systems

Varieties/Production systems	Yield (kg plant $^{-1}$)	Yield (t ha^{-1})	Number of Tubers	Mean weight (kg)	Length (cm)	Girth (cm)
Varieties						
H-165	1.776	21.93	5	398	23.54	19.77
Sree Vijaya	2.625	32.40	6	472	25.28	20.46
Vellayani Hraswa	1.725	21.30	4	467	26.35	18.08
CD (0.05)	NS	NS	NS	NS	NS	NS
Production systems						
Traditional	1.790	22.09	4	428	26.11	19.00
Conventional	2.223	27.18	5	480	24.46	19.50
Integrated	1.767	21.81	5	338	24.15	18.83
Organic	2.369	29.32	5	496	25.72	20.38
Organic Biofertilizers)	2.062	25.45	5	487	24.86	19.49
CD (0.05)	0.323	3.985	NS	NS	NS	NS

Table 4. Effect of production systems on biochemical composition of tubers

Varieties/Production systems	HCN ($\mu g\ g^{-1}$)	Dry matter (%)	Starch (%)	Sugar (%)	Ash (%)	Fibre (%)
Varieties						
H-165	85.0	29.75	18.72	2.994	2.378	1.213
Sree Vijaya	57.9	32.96	21.16	2.847	2.201	0.830
Vellayani Hraswa	42.1	40.26	27.14	2.529	1.721	0.606
CD (0.05)	15.25	6.694	NS	NS	NS	0.1047
Production systems						
Traditional	69.4	35.85	23.81	2.949	2.380	0.918
Conventional	60.0	34.42	22.27	2.662	1.903	0.827
Integrated	67.3	33.97	22.10	2.838	1.673	0.923
Organic	48.8	32.58	21.80	2.685	2.630	0.997
Organic (Biofertilizers)	62.8	34.78	21.72	2.815	1.913	0.750
CD (0.05)	NS	NS	NS	NS	0.4574	NS

Table 5. Chemical properties of soil as influenced by production systems

Production systems	pH	Organic C (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
	After second crop					After first crop			
Traditional	5.608	0.932	100.2	280	398	14.52	20.71	4.11	0.869
Conventional	4.803	1.208	146.7	319	395	16.60	21.27	4.10	0.767
Integrated	4.972	0.911	123.2	277	384	13.66	22.38	3.77	0.712
Organic	5.864	1.215	124.7	354	458	18.43	19.48	4.02	0.709
Organic (Biofertilizers)	5.320	1.323	138.5	297	318	19.41	21.23	4.47	0.830
CD (0.05)	0.4959	0.3008	NS	NS	NS	NS	NS	NS	NS

Table 6. Microbial population of the soil as influenced by production systems (cfu/g soil)

Production systems	Bacteria (* 10^6)	Fungi (* 10^4)	Actinomycetes
Traditional	5.50	6.17	7.50
Conventional	2.50	4.83	6.00
Integrated	4.00	6.67	5.67
Organic	4.17	6.17	5.67
Organic (Biofertilizers)	3.33	6.17	6.67
CD (0.05)	NS	NS	NS

slightly and ash content significantly when compared to conventional practice (Table 4).

Soil quality indicators

Physical parameters

Bulk density and particle density were slightly lower and water holding capacity and porosity slightly higher in organic plots. The aggregate stability, which is the most important determinant of soil quality, was enhanced by 25% under organic management over conventional practice. Several earlier workers have reported that aeration, porosity and waterholding capacity of soils increased under organic management (Colla *et al*., 2000; Radhakrishnan *et al*., 2006; Ramesh *et al*., 2010). The improvement in soil physical conditions can be attributed to the increase in soil organic matter content, which dilutes the denser fractions of soil, reduces the streangth of the surface crusts, favours the formation of stable soil aggregates especially macro aggregate stability and macro porosity (Stockdale *et al*., 2001)

Chemical parameters

At the end of second year, the pH and organic C status of the soil varied significantly due to the production systems (Table 5). The pH was significantly higher and tended towards neutrality 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; Suja *et al*., 2010; Suja *et al*., 2012a; Suja et al. 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 favoured due to organic management. The chemical analysis of soil samples for secondary and micro-nutrients after the first crop indicated that the production systems did not impart significant effect on them. There was slight improvement in exchangeable Ca (by 30.86%) and Mg (by 25.94%) contents under organic management over conventional practice. However, the Fe, Zn and Cu contents were slightly favoured under organic practice. Lowering of soil acidity might have enabled the availability of major and secondary nutrients to some extent as reported by Prakash *et al*. (2002).

Microbial count

The population of bacteria, fungi and actinomycetes were not significantly influenced by the production systems (Table 6). However, the counts were appreciably higher in all the production systems other than conventional system, where chemicals were not used or minimally used. The higher microbial population may be due to higher decomposition of organic matter due to the addition of large quantities of organic manures. Suja *et al*. (2012a and 2012b) reported that the population of bacteria, fungi and N fixers were higher in organic plots than in conventional plots in elephant foot yam.

CONCLUSIONS

Organic farming is an eco-friendly approach in cassava for sustainable yield of quality tubers and maintaining soil fertility. Generation of sufficient biomass in and around the farms, development of biogas plants and agro-forestry, addition of crop residues, green manuring, recycling of on-farm and off-farm wastes, enhancing nutrient value of manures through proper composting, adoption of crop rotations involving legumes etc., are the strategies that will help to promote organic farming in cassava in rainfed and tribal areas, where these are popular as high energy staple food.

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