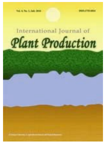

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Implications of organic management on yield, tuber quality and soil health in yams in the humid tropics

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Abstract

Global consciousness of food safety, health and environmental issues has stimulated interest in alternative agricultural systems like organic farming. Since information on organic farming of tuber crops is meagre, a field experiment was conducted in split plot design over a five-year period at Central Tuber Crops Research Institute, India. The aims were to evaluate the impact of organic, conventional and traditional production systems on yield, proximate composition and mineral content of tubers and soil physico-chemical and biological properties in three species of *Dioscorea* (white yam: D. *rotundata*, greater yam: *D. alata* and lesser yam: *D. esculenta*). The production systems were assigned to main plots and species to subplots. Organic farming (20.34 t ha^{-1}) produced significantly higher yield over conventional practice (18.64 t ha^{-1}) by 9%. All the species responded well to organic management, which lowered the bulk density and particle density slightly and improved the water holding capacity (by 15%) of soil. Tuber quality was improved with significantly higher Ca (72.67 mg $100g^{-1}$), slightly higher dry matter, crude protein, K and Mg contents. Organic plots showed significantly higher available K, by 34% and pH, by 0.46 unit and higher soil organic matter by 14%. The dehydrogenase enzyme activity (1.174 µg TPF formed g^{-1} soil h^{-1}), population of bacteria, fungi and P solubilizers were promoted by 14%, 23%, 17% and 22% respectively. Thus organic farming was found to be an eco-friendly management strategy in yams for sustainable yield of quality tubers besides maintaining soil health. Technology involving farmyard manure, green manuring, neem cake, biofertilizers and ash was standardized.

Keywords: Alternative farming; *Dioscorea* spp.; Productivity; Tuber quality; Soil quality.

Introduction

Worldwide concerns regarding food safety, environmental degradation and threats to human health have generated interest in alternative sustainable agricultural systems (Carter et al., 1993). According to the UN millennium ecosystem assessment, "land degradation" is 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 Hindu, 2007). The land quality for food production contributes to future peace. Hence "Organic" is essential for sustainable production, protection of soil health and human health besides conservation of environment. It envisages complete exclusion of synthetic chemicals and minimum use of off-farm generated resources or purchased inputs.

High input conventional agriculture that advocates large scale chemical inputs and few C additions silently result in irrevocable ecological and environmental catastrophes (Susan Andrews et al., 2002; Chhonkar, 2008). The necessity for environmental conservation coupled with the desire for safe foods has made organic farming one of the fastest-growing agricultural enterprises (Katsvairo et al., 2007). Surveys indicate that consumers purchase organic produce because of the belief that they are more nutritious than conventionally grown foods (Rembialkowska, 2007). However, conclusive evidence supporting nutritional or qualitative superiority of the organic production system does not currently exist. Reduced energy use and CO_2 emissions, employment generation, waste recycling and export promotion are the other merits of organic farming (Reganold et al., 2001; Stockdale et al., 2001).

Tropical tuber crops form important staple or subsidiary food for about 500 million of the global population. Yams (*Dioscorea* spp.) are high energy tuberous vegetables with good taste and medicinal values. They are mostly used for their high content of carbohydrate. They also have a higher protein content and better balance of amino acids than many other root and tuber crops. They are food security crops in tropical countries mainly West Africa, the Caribbean, Pacific Islands and South East Asia. 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 gaining popularity among farmers due to its high yield potential

(35-40 t ha^{-1}), wide adaptability in different agro-climatic locations, acceptable tuber quality, novel taste and flavor. The crop has good potential as a vegetable, subsidiary food item and industrial raw material. Yams are also important as sources of pharmaceutical compounds like saponins and sapogenins, which are precursors of cortesone and steroidal hormones.

Tropical tuber crops in general and edible aroids like elephant foot yam, taro and tannia, respond well to organic manures. Hence there is great scope for organic production in these crops (Suja et al., 2009; Suja et al., 2010; Suja et al., 2012). There is a great demand for organically produced tuberous vegetables among affluent Asians and Africans living in Europe, USA and Middle East. Currently research and development on organic farming of tropical tuber crops is less focused. There is not much clear scientific evidence about the effects of organic management on yield, nutritional quality and soil health. The objectives of this study, therefore, were to examine the comparative advantages of organic farming over conventional practice in terms of yield, proximate composition and mineral content of tubers as well as soil physico-chemical and biological properties under yams.

Materials and Methods

Site description

Field experiments were conducted for five consecutive years during May-January from 2006-2011 at Central Tuber Crops Research Institute (CTCRI) (8^o 29' N, 76^o 57' E, 64 m altitude), Thiruvananthapuram, Kerala, India, in an acid Ultisol (pH: 5.33). In the land used for this study two crops of green manure cowpea was raised and incorporated an year prior to the initiation of the present experiment. Thus chemical inputs were not used in this land for an year before taking up the current research. In general, the fertility status of the soil was medium for organic C, low for available N and high for available P and K. The physico-chemical and biological properties of the soil prior to experimentation are furnished in Table 1. The site experiences a typical humid tropical climate. The mean annual rainfall was 1915 mm, maximum and minimum temperatures were 31.66 ^oC and 24.62 ^oC respectively and relative humidity was 75.4%.

Table 1. Soil properties prior to experimentation.

Soil parameter	Before experiment
pH	5.33
Organic C (%)	0.746
Available N (kg ha^{-1})	159.32
Available P (kg ha^{-1})	216.92
Available K (kg ha^{-1})	337.50
Bulk density (g cm^{-3})	1.665
Particle density (g cm^{-3})	2.650
Water holding capacity (%)	9.84
Porosity (%)	28.45
Bacteria (cfu g^{-1})	72×10^3
Fungi (cfu g^{-1})	5×10^2
Actinomycetes (cfu g^{-1})	5×10^2
Dehydrogenase enzyme (mg TPF formed g^{-1} soil h^{-1})	0.065

Experimental design, treatments and test variety

Three species of edible *Dioscorea* (white yam: *D. rotundata* (var. Sree Priya), greater yam: *D. alata* (var. Sree Keerthi) and lesser yam: *D. esculenta* (var. Sree Latha)) were evaluated under conventional, traditional and organic farming systems in split plot design. Species were assigned to main plots and production systems to sub plots and replicated thrice. The gross plot size was 7.2×3.6 m (32 plants of white yam and greater yam and 36 plants of lesser yam) accommodating 12 net plants of white yam and greater yam and 14 plants of lesser yam. In “conventional plots” the package of practices recommendations (farmyard manure (FYM) @ 10 t ha^{-1} + NPK @ 80:60:80 kg ha^{-1}) was advocated. Farmers practice of using FYM @ 15 t ha^{-1} and ash @ 1.5 t ha^{-1} was followed in “traditional plots”. In “organic farming plots”, FYM @ 15 t ha^{-1}, green manure (to yield 15-20 t ha^{-1} of green matter in 45-60 days), ash @ 1.5 t ha^{-1}, neem cake @ 1 t ha^{-1} and biofertilizers (*Azospirillum* @ 3 kg ha^{-1}, mycorrhiza @ 5 kg ha^{-1} and phospho-bacteria @ 3 kg ha^{-1}) were used. The average nutrient contents of the various organic sources used in the experiment are given in Table 2 and the quantity of nutrients applied in the various treatments are provided in Table 3. Released varieties of yams (white yam (var. Sree Priya), greater yam (var. Sree Keerthi) and lesser yam (var. Sree Latha) from CTCRI, Thiruvananthapuram, India, were used for the study.

Table 2. Average nutrient content of organic manures.

Organic manures	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
	(%)					ppm			
Farmyard manure	0.50	0.20	0.28	0.08	0.075	1465.00	70.00	40.00	3.00
Green manure	3.45	0.57	2.02	0.41	0.39	1324.77	509.03	78.10	11.83
Neem cake	1.50	1.00	1.20	1.75	0.65	850.00	40.00	15.00	12.00
Ash	0.6	1.60	7.11	15	1.3	5125.00	2850.00	625.00	122.00

Table 3. Quantity of nutrients applied (kg ha^{-1}).

Treatments	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
2006									
Conventional	130	80	108	8	7.5	14.65	0.7	0.4	0.03
Traditional	84	54	148.65	237	30.75	98.85	43.8	9.975	1.875
Organic	238.73	87.09	242.46	271.11	53.05	161.00	64.82	13.29	2.47
2007									
Conventional	130	80	108	8	7.5	14.65	0.7	0.4	0.03
Traditional	84	54	148.65	237	30.75	98.85	43.8	9.975	1.875
Organic	322.82	100.98	291.70	281.10	62.55	193.29	77.22	15.19	2.76
2008									
Conventional	130	80	108	8	7.5	14.65	0.7	0.4	0.03
Traditional	84	54	148.65	237	30.75	98.85	43.8	9.975	1.875
Organic	190.22	79.07	214.06	265.34	47.56	142.38	57.66	12.19	2.31
2009									
Conventional	130	80	108	8	7.5	14.65	0.7	0.4	0.03
Traditional	84	54	148.65	237	30.75	98.85	43.8	9.975	1.875
Organic	215.68	83.28	228.97	268.37	50.44	152.15	61.42	12.77	2.40
2010									
Conventional	130	80	108	8	7.5	14.65	0.7	0.4	0.03
Traditional	84	54	148.65	237	30.75	98.85	43.8	9.975	1.875
Organic	212.85	82.81	227.31	268.03	50.12	151.07	61.00	12.70	2.39

Field management

White yam and greater yam setts (tuber pieces) of 250-300 g were planted in pits (45 cm^3) dug at 90 cm spacing. These pits were later reformed into mounds. Whole tubers of lesser yam of 100-150 g were planted in mounds at a spacing of 75 cm. The plants were trailed 15 days after sprouting using coir ropes tied to casuarina poles. Field culture was done in accordance with KAU (2002). The crop was planted during May in each year, mainly rain-fed and harvested after nine months. In organic farming plots, green manure cowpea was sown in between the pits immediately after planting yams. The green matter was incorporated at 50% flowering stage of cowpea. The quantity of green matter obtained was 20.25, 25.95, 13.22, 16.91 and 16.50 t ha^{-1} in 2006, 2007, 2008, 2009 and 2010 respectively.

Plant and soil measurements

Yield: Tubers from the net plot were harvested and fresh weights were recorded and tuber yield was expressed in t ha^{-1}.

Quality: Proximate analyses of tubers for dry matter, starch, total sugar, reducing sugar, crude protein and total phenols were done using standard procedures. Dry matter and crude protein were determined by the method of AOAC (1980). The starch content was determined by conversion to sugars by acid hydrolysis and then by the method of Dubois et al. (1956). Total sugars were also determined by the same method. Reducing sugars was estimated by the method of Nelson (1944) and total phenols by the method of Swain and Hillis (1955). Mineral composition of corms viz., P, K, Ca, Mg, Cu, Zn, Mn and Fe contents were also determined by standard methods (Piper, 1970). The P content of corms was determined by the method of colorimetry, K and Ca by flame photometry, Mg, Fe, Mn, Zn and Cu by direct reading in atomic absorption spectrophotometer.

Soil properties: The pH, organic C, available N, P, K, Ca, Mg, Cu, Zn, Mn and Fe 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). Microbial plate count of bacteria, fungi and actinomycetes were also determined by standard procedures described by Timonin (1940). Activity of the enzymes, dehydrogenase, acid phosphatase, urease and nitrate reductase were determined by standard procedures (Klein et al., 1971; Tabatabai and Bremner, 1969; Bremner and Douglas, 1971; Reddy and Chhonkar, 1990).

Statistical analysis

The analysis of variance of data was done using SAS (2008) by applying analysis of variance technique (ANOVA) for split plot design and pooled analysis of data of five years was also done.

Results

Tuber yield

During the first and third years, species × production systems interaction was significant. In the first year, white yam produced higher yield in conventional practice (19.21 t ha^{-1}), which was on par with organic farming (17.81 t ha^{-1}). In the case of greater yam all the production systems were on par; traditional practice (20.65 t ha^{-1}) resulted in slightly higher yield than organic (19.47 t ha^{-1}) and conventional practices (19.04 t ha^{-1}). In lesser yam, organic farming proved superior (8.59 t ha^{-1}). In the third year, white yam and lesser yam responded well to organic farming producing significantly higher yield (28.34 and 23.57 t ha^{-1}). The tuber yield of greater yam remained on a par in the various systems (16-17 t ha^{-1}). In the second and third years, production systems varied significantly and organic farming produced significantly higher yield (26.14 and 23.07 t ha^{-1}) over conventional practice (20.77 and 17.17 t ha^{-1}). During the fourth and fifth years, the main and interaction effects were not significant.

Analysis of yield trend over the years indicated that in general, for yams, yield under organic farming showed an upper hand over conventional practice up to the third year. Thereafter it was on par with conventional practice or even slightly declined. This trend holds good specifically in the case of white yam and lesser yam. However, in the case of greater yam, different trends were observed during different years. During the second and fifth years, organic farming produced higher yield over conventional practice. During the remaining years response to organic farming was almost equivalent or slightly lower than conventional practice (Figure 1).

Pooled analysis of yield data indicated that production systems varied significantly. Organic farming (20.34 t ha^{-1}) was superior to conventional practice (18.64 t ha^{-1}) and produced 9.12% higher yield. Species × production systems interaction was absent. However, in all the species organic farming produced slightly higher yield than conventional practice (Table 4). Averaging over the years, the yield increase observed under organic farming in white yam, greater yam and lesser yam was 9.35, 10.51 and 6.85% respectively over conventional practice.

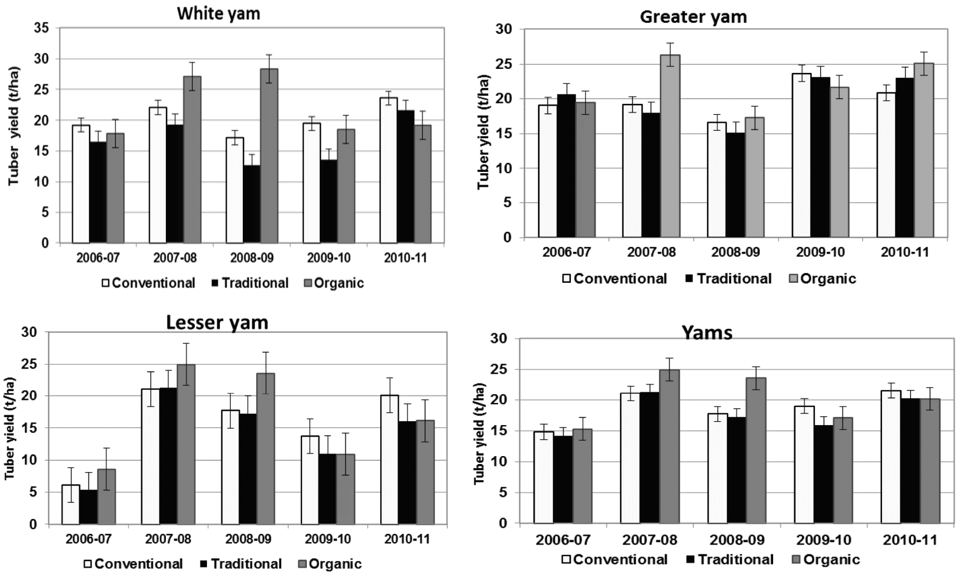

Figure 1. Yield trend over the years as affected by production systems in yams.

Table 4. Yield (t ha^{-1}) response of *Dioscorea* species to production systems combined over years.

Species/ Production systems	Conventional	Traditional	Organic	Mean of *Dioscorea* species
Dioscorea rotundata	20.31	16.76	22.21	19.76^{a}
Dioscorea alata	19.87	19.97	21.96	20.61^{a}
Dioscorea esculenta	15.75	14.18	16.83	15.58^{b}
Mean of production systems	18.64^{b}	16.97^{c}	20.34^{a}	

For each factor, means followed by different letters are significantly different at P<0.05.

Tuber quality

Proximate composition

There was no profound difference in the cooking quality of tubers from the different production systems and the tubers tasted equally good. Pooled analyses of biochemical constituents of corms viz., dry matter, starch, crude protein, total sugar, reducing sugar and total phenols revealed that production systems did not vary significantly (Table 5). However, organically produced tubers had 7% higher dry matter and 6% higher crude protein contents. Traditional practice, which was also strictly organic in nature, produced tubers with 10% higher starch content over conventional practice. Synthetic fertilizers enhanced the contents of total and reducing sugars and total phenols.

Table 5. Effect of production systems on bio-chemical constituents of tuber combined over years.

Production systems	Dry matter (%)	Starch (% Fw basis)	Crude protein (% FW basis)	Total sugars (% FW basis)	Reducing sugars (% FW basis)	Total phenols (mg $100g^{-1}$)
Conventional	31.36[a]	26.77[a]	1.92[a]	2.52[a]	0.13[a]	61.56[a]
Traditional	32.62[a]	29.44[a]	2.04[a]	1.96[a]	0.11[a]	31.78[a]
Organic	33.56[a]	26.40[a]	2.04[a]	1.88[a]	0.12[a]	37.22[a]

For each factor, means followed by same letters are not significantly different at P<0.05. FW: fresh weight basis.

Mineral composition

Pooled analysis of mineral content of tubers indicated that except for P and Ca, there was no significant variation in the mineral composition of corms due to the various practices (Table 6). In this study the P content of traditionally produced tubers and Ca content of organically produced tubers were significantly higher. There was slight improvement in K and Mg contents of tubers under organic management when compared to conventional practice.

Table 6. Effect of production systems on mineral composition of corms (mg $100g^{-1}$ DW basis) (Mean of 5 years).

Production systems	P	K	Ca	Mg	Cu	Zn	Mn	Fe
Conventional	472.35[a]	1026.67[a]	57.67[b]	161.74[a]	0.292[a]	4.45[a]	0.318[a]	5.129[a]
Traditional	495.11[a]	1066.82[a]	68.09[ab]	159.87[a]	0.250[a]	4.41[a]	0.386[a]	5.280[a]
Organic	411.81[b]	1051.33[a]	72.67[a]	180.85[a]	0.243[a]	4.49[a]	0.349[a]	5.027[a]

For each factor, means followed by different letters are significantly different at P<0.05. DW: dry weight basis.

Soil chemical properties

The trend in the status of the major soil properties over the years was almost the same in all the production systems (Figure 2). There was a slight improvement in pH in all the plots from the initial status of 5.326 after first year, which dropped slightly after second crop and thereafter increased steadily. Organic C showed increment till the second year, which declined after three years and then remained steady. Available N and K showed increase and decrease in alternate years. The available P status increased progressively up to the fourth year and then declined. In general in all the years the status of these parameters was higher under organic management.

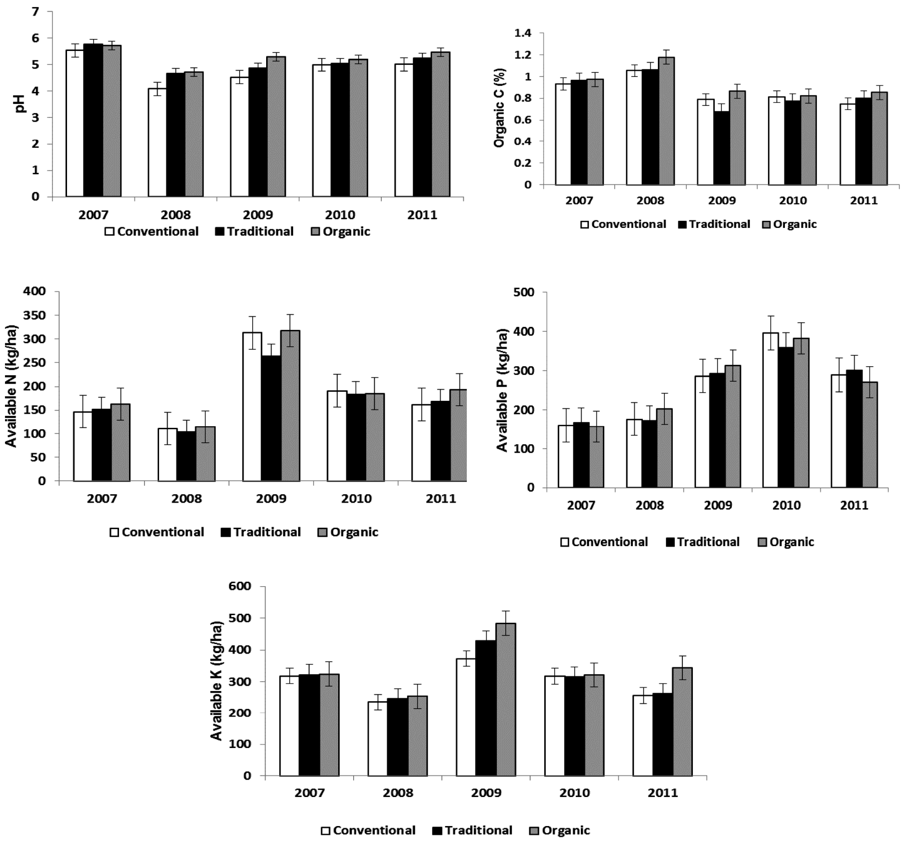

Figure 2. Pattern of pH, organic C and major nutrients as affected by production systems in yams over the years.

The year wise pattern of the impact of treatments indicates that at the end of first year, organic C, pH, available N, P and K were not significantly influenced by the different production systems. However, organic plots showed slightly higher pH, organic C, available N and K status. After two years, pH and available P status of the soil were significantly higher in organic plots. After three years, organic plots showed significantly higher pH. At the end of four years all these parameters remained unaffected. However, organic plots showed slightly higher pH, organic C and available K status. The post experiment nutrient status after five years indicated that organic plots showed significantly higher available K (by 34%) and pH (by 0.46 unit). Moreover organic plots had 14% higher soil organic C over conventional plots.

The secondary and micronutrient status were not affected by the various production systems (Table 7). However, the exchangeable Ca, available Cu and Mn were higher by 12.39, 5.59 and 2.7% under organic management. The per cent increase or decrease in chemical properties after five years of organic farming is illustrated in Figure 3.

Soil physical properties

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 when examined after three years. However, bulk density was slightly lower and water holding capacity and porosity slightly higher in organic plots. The same trend was observed after four years. At the end of five years, the water holding capacity was significantly higher in organic plots (14.21%) than in conventional plots (12.38%) (Table 8). Thus the water holding capacity of organic plots was 15% higher over conventional plots.

Table 7. Impact of production systems on secondary and micronutrients in soil at the end of five years.

Production systems	Exchangeable Ca (meq 100g^{-1})	Exchangeable Mg (meq 100g^{-1})	Available Cu (ppm)	Available Zn (ppm)	Available Mn (ppm)	Available Fe (ppm)
Conventional	1.694^a	0.501^a	0.768^a	6.812^a	23.64^a	44.7^a
Traditional	1.687^a	0.469^a	0.773^a	6.980^a	21.35^a	43.9^a
Organic	1.904^a	0.425^a	0.811^a	6.734^a	24.28^a	41.2^a

For each factor, means followed by same letters are not significantly different at $P<0.05$.

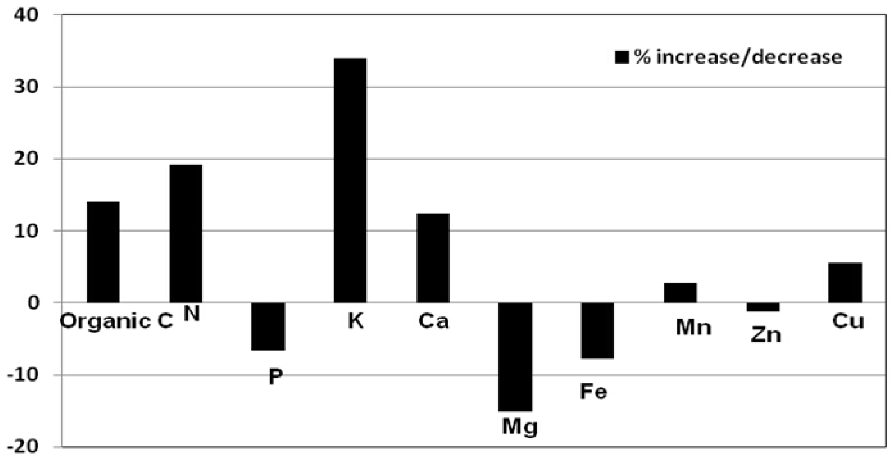

Figure 3. Per cent increase or decrease in chemical properties of soil under organic management in yams.

Table 8. Soil physical properties as influenced by production systems after five years.

Production systems	Bulk density ($g\ cm^{-3}$)	Particle density ($g\ cm^{-3}$)	Water holding capacity (%)	Porosity (%)
Conventional	1.629^{a}	2.400^{ab}	12.38^{b}	32.07^{a}
Traditional	1.704^{a}	2.485^{a}	11.35^{b}	30.95^{a}
Organic	1.614^{a}	2.266^{b}	14.21^{a}	31.30^{a}

For each factor, means followed by different letters are significantly different at P<0.05.

Soil biological properties

Production systems imparted significant effect on actinomycetes count. However, the actinomycetes population under conventional and organic practice was not appreciably different. The population of bacteria, fungi, N fixers and P solubilizers was almost the same in the various production systems. However, the traditional practice favoured the population of bacteria, fungi and N fixers. The population of bacteria and fungi under organic practice was higher by 23 and 17% over that of conventional practice. Organic practice promoted the population of P solubilizers by 22% (Table 9). There was no appreciable difference in the activity of the enzymes viz., dehydrogenase, acid phosphatase, nitrate reductase and urease among the various practices. However, organic farming resulted in slightly higher dehydrogenase activity compared to the other practices and it was 14% higher than that in conventional practice. Traditional practice favoured slightly the phosphatase, nitrate reductase and urease activity when compared to the other treatments (Table 10).

Table 9. Influence of production systems on soil microbial load at the end of five years.

Production systems	Bacteria (*10^3cfu g^{-1})	Fungi (*10^2cfu g^{-1})	Actinomycetes (*10^2cfu g^{-1})	N fixers (*10^3cfu g^{-1})	P solubilizers (*10^3cfu g^{-1})
Conventional	96[a]	6[a]	12[a]	11[a]	9[a]
Traditional	158[a]	8[a]	6[b]	16[a]	9[a]
Organic	118[a]	7[a]	11[a]	7[a]	11[a]

For each factor, means followed by different letters are significantly different at $P<0.05$. cfu: colony forming unit.

Table 10. Effect of production systems on soil enzymes after five years of farming.

Production systems	Dehydrogenase enzyme (mg TPF formed g^{-1} soil h^{-1})	Acid phosphatase (µg para nitro phenol released g^{-1} soil h^{-1})	N reductase (µg No_2 N formed g^{-1} soil h^{-1})	Urease (mg urea formed g^{-1} soil h^{-1})
Conventional	0.079[a]	0.741[a]	0.0519[a]	1.998918[a]
Traditional	1.049[a]	1.029[a]	0.0536[a]	1.998943[a]
Organic	1.174[a]	0.689[a]	0.0500[a]	1.998938[a]

For each factor, means followed by same letters are not significantly different at $P<0.05$.

Discussion

Yield

The study has added new information that organic management enhanced yield by 9% in yams. The yield increase observed in this study based on five years' experimentation is contrary to the majority of reports that crop yields under organic management are 20-40% lower than for comparable conventional systems (Stockdale et al., 2001; Gopinath et al., 2008; Ponti et al., 2012). It is reported that yields were directly related to the intensity of farming in the prevailing conventional system (Ramesh et al., 2005; Ramesh et al., 2010). This means that in areas of intensive farming system, shifting to organic agriculture decreases yield depending on the intensity of external input use before conversion (Stanhill, 1990; Offerman and Nieberg, 1999).

Since yams are traditionally grown with low external inputs using organic wastes and manures available in the homesteads, organic management in the present study has shown a potential to increase yields over conventional practice.

Up to the third year, yams, especially, white yam and lesser yam responded well to organic management. The higher yield may be due to the greater uptake of nutrients 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). The various high quality organic resources tried in the organic treatment contributed substantially to major, secondary and micronutrients (Table 3). In general there was a decline in yield by the fourth year, which got slightly enhanced by the fifth year. This might be attributed to unknown inhibitory effects due to continuous cultivation of yams. However the slight increase in yield by the fifth year was more pronounced in the conventional treatment, which may be due to the priming effect of chemical fertilizers on organic manure (FYM) and the subsequent faster release of nutrients. There was no definite trend in the case of greater yam, though greater yam showed a preference to the use of traditional organic manures by virtue of its ethnic nature.

Yams are nutrient exhausting crops. The nutrient removal by a crop of white yam yielding 28.99 tonnes of tuber was 116.52 kg N, 17.3 kg P and 122.68 kg K per ha (Kabeerathumma et al., 1987). To exploit the yield potential of yams proper replenishment of soil with adequate amounts of nutrients is required. Hence the results indicate that higher yield can be obtained even without chemical fertilizers by proper supplementation of nutrients based on soil testing through cheaper and easily available organic sources.

Tuber quality

There was no significant difference in the biochemical composition and mineral content of tubers in the various production systems. This is similar to the finding of Radhakrishnan et al. (2006) that quality parameters of tea manufactured from different farming systems, including organic system, did not vary significantly. This may be due to the fact that regardless of whether the nutrients are from organic or inorganic source, plants absorb the same as inorganic ions and once absorbed the nutrients are re-synthesized into compounds that determine the quality of the produce, which is predominantly the function of genetic make up of the plants (Chhonkar, 2008). But the tuber quality was improved with significantly higher Ca, slightly higher dry matter, crude protein, K and Mg contents. Rembialkowska (2007) stated that organic crops contain more dry matter, minerals, especially Fe, Mg and P by 21%, 29% and 14% over conventionally produced ones. Pieper and Barrett (2008) also found higher levels of K in organic tomatoes. The higher mineral content in organic crops may be due to the higher abundance of micro-organisms in organically managed soil. These micro-organisms produce many compounds that help plants to combine with soil minerals and make them more available to plant roots (Worthington, 2001).

Soil properties

Organic plots showed significantly higher available K, by 34% and pH, by 0.46 unit and higher soil organic matter, by 14% in this study. Moreover available N and P were also favoured under organic management. Increase in soil organic matter, soil pH, available P and K have been measured in some organic systems (Scow et al., 1994; Clark et al., 1998). Similar results have been reported by Suja et al. (2012) in elephant foot yam, another important tropical tuber crop, under Indian conditions.

Significantly higher pH under organic management in the present study may be due to elimination of NH_4 fertilizers, addition of cations especially via green manure applications, decrease in the activity of exchangeable Al^{3+} ions in soil solution due to chelation by organic molecules and self liming effect of the Ca content in FYM (0.08%), green manure (0.41%), neem cake (1.75%) and ash (15%) (Mei et al., 2002; Prabhakaran and Pitchai, 2002; Prakash et al., 2002).

Higher organic C status of organic plots might be attributed to considerable addition of organic manures particularly green manure cowpea. Higher available N status observed in organic plots may be due to higher N content in the organic manures, especially green manure (Table 2) used in the study. Solubilization of native P by organic acids during decomposition of organic manures and increased mineralization of P from the added organic manures might have led to a higher available P in organic plots. Higher content of K in the organic manures, especially green manure and ash (Table 2), K mining effect from the sub surface layers by the extensive root system of green manure crop of cowpea, organic acid dissolution of the rather inaccessible K minerals in the soil during green manure decomposition all might have contributed to higher content of available K in organic plots.

Thus soil pH is the most important determinant of soil nutrient availability and enhancement of pH to neutral range in the present study might have enabled the availability of major and secondary nutrients to some extent. The study indicates that organic farming involving the use of organic manures offers opportunities to restore and improve soil health, which has seriously deteriorated presently due to chemical based high input farming, by enhancing organic matter levels, neutralising soil acidity, supplying almost all essential nutrients in available form and thereby maintaining soil fertility. A similar trend was observed by Suja et al. (2012) in elephant foot yam.

There was slight lowering of bulk density and particle density and improvement in water holding capacity of the soil under organic management. Radhakrishnan et al. (2006) and Suja et al. (2012) also observed similar results in tea and elephant foot yam respectively under the influence of organic farming. Increased aeration, porosity and water holding capacity of soils have been observed under organic management (Droogers et al., 1996; Gerhardt, 1997; Colla et al., 2000). Moreover changes in organic matter contributes to changes in soil biological and physical properties (Stockdale et al., 2001). The increased organic matter content of soil as evidenced from higher organic C status in organic plots in the present study might have resulted in the formation of stable soil aggregates with the resultant slight decrease in bulk density and increase in water holding capacity.

In this experiment, the organic manures viz., farmyard manure, green manure, neem cake and ash, were used to substitute the chemical fertilizers. Of these, the most important component was green manuring with cowpea (incorporation of 15-20 t ha^{-1} of green matter). The decomposition of these organic manures for release of plant available nutrients involves microbial activity to a greater extent than that in chemical fertilizer applied conventional plots, which might have contributed to higher microbial population and dehydrogenase enzyme activity in the organic plots. This is in accordance to the report of several earlier workers who observed increased microbial population in cultivated organically managed soil (Scow et al., 1994; Stockdale et al., 2001).

Conclusions

In summary, organic farming is an eco-friendly farming strategy in yams for getting higher yield of quality tubers and safe food besides maintaining soil health. This strategy produced 9% higher tuber yield over conventional practice. Organic tubers had significantly higher Ca content, slightly higher dry matter, crude protein, K and Mg contents. The physico-chemical and biological properties of the soil were also favoured under organic farming. The study proves that for a highly nutrient exhausting crop like yam, higher yield can be obtained by using cheaper and on site generated organic manures based on soil testing. Thus green manuring with cowpea is a cost effective practice that could form the main component of any organic farming program. The technology for organic production in yams comprised of application of FYM @ 15 t ha^{-1}, green manure (to yield 15-20 t ha^{-1} of green matter in 45-60 days), ash @ 1.5 t ha^{-1}, neem cake @ 1 t ha^{-1} and biofertilizers (*Azospirillum* @ 3 kg ha^{-1}, mycorrhiza @ 5 kg ha^{-1} and phospho-bacteria @ 3 kg ha^{-1}).

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