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Response of varieties of elephant foot yam (*Amorphophallus paeoniifolius*) to organic management

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ABSTRACT

Consumer awareness regarding the impacts of high-input chemical intensive conventional agriculture on the soil, environment and human health has spurred the growth of organic agriculture systems. Organic agriculture ensures sustainable production, safe food and environmental conservation. It is estimated that more than 95% of organic production is based on crop varieties that were bred for the conventional high-input sector. Such varieties lack important traits required under organic and low-input production conditions. There is dearth of information on the response of varieties to organic management. Field experiments were conducted for two years during 2010 and 2011 at the Central Tuber Crops Research Institute, Thiruvananthapuram, to compare the growth, yield and quality performance of five elephant foot yam [*Amorphallus paeoniifolius* (Dennst.) Nicolson] varieties (Peerumade local, Gajendra, Sree Padma, Vegetable and Fruit Promotion Council Keralam (VFPCK) local and Sree Athira) and soil physicochemical and biological properties under organic vs conventional systems in split plot design. Varieties × production systems interaction was not significant for most of the variables. The elite as well as the local varieties responded equally well to both the systems with average corm yields of 27.72 tonnes/ha under organic and 28.55 tonnes/ha under conventional practice. The var. Gajendra responded well to organic management producing higher yield (+10%). The other varieties had lower yield losses (-2.5-15.0%) under the organic system. The corms of the varieties had slightly higher dry matter, sugar, P, K and Fe contents under organic system. The varieties also exerted similar effects on soil physicochemical and biological properties, when tested under organic and conventional management. However, Gajendra and Sree Padma effected significantly higher organic C status under organic management due to greater biomass addition on account of their innate robust plant type. In general, there was significant improvement in soil pH and bacterial count, slight lowering of bulk density and particle density, improvement in water holding capacity, secondary and micronutrient status, N fixers and dehydrogenase enzyme activity in the organic system.

Key words: Adaptation, Elephant foot yam, Organic agriculture, Quality, Varieties, Yield

Elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson) is an important tropical tuber crop popular as a food security crop and a remunerative cash crop. Its corms are rich in starch, which is used as a vegetable having high nutritive value, good taste and cooking quality besides having medicinal values. The corms also contain moderate amounts of protein, Ca and vitamin C. The crop has a high production potential. It has great scope for commercial exploitation as a medicinal crop in pharmacological industry due to the presence of various nutraceuticals and the corms find wider use in traditional ayurvedic preparations for the treatment of inflammation, piles and gastrointestinal disorders (Regu *et al*. 1999).

Organic farming was found to be an eco-friendly management strategy in elephant foot yam for sustainable yield of quality tubers and higher profit besides maintaining soil health. Technologies for organic production of elephant foot yam was standardized (Suja *et al*. 2010, 2010a, 2012b, Suja 2013).

One of the biggest challenges that organic farmers face is identification of locally adapted crop varieties that can thrive under organic management conditions in the absence of chemical supports (Maddox 2015). It is estimated that more than 95% of organic production is based on crop varieties that were bred for the conventional high-input sector (van Bueren *et al*. 2011), which lack important traits required under organic and low-input production conditions (van Bueren *et al*. 2002, Murphy *et al*. 2007, Wolfe *et al*. 2008). Hence, the conventional varieties are not ideal for the diverse growing conditions found on organic farms (Maddox 2015). Experimental evidences on the adaptation of varieties developed for chemical intensive system to organic management is also lacking (Fagnano *et al*. 2012).

Presently in elephant foot yam, we have both improved

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(Gajendra, Sree Padma, Sree Athira) and local varieties suitable for cultivation in the different agro-ecological regions of India. However, little had been documented about the response of varieties to organic farming. Hence, the objectives of the present study were to compare the growth, yield and quality performance of elephant foot yam varieties and soil physico-chemical and biological properties under organic vs conventional management.

MATERIALS AND METHODS

Field experiments were conducted for two consecutive years (during March-December during 2010 and 2011) at the Central Tuber Crops Research Institute (CTCRI), Thiruvananthapuram (8°29'N, 76°57'E, 64 m altitude), India in an acid Ultisol (pH: 5.45). Two crops of green manure cowpea was raised and incorporated during 2009-2010 prior to the experimentation. In general, the fertility status of the soil was low for N (166.84 kg/ha) and high for organic C, available P and K (1.39%, 296.07 and 368.43 kg/ha, respectively). The site experiences a typical humid tropical climate. The mean annual rainfall was 1958.70 mm, maximum and minimum temperatures were 32.10 and 25.70°C, respectively, and relative humidity was 76.50%.

Five varieties (Peerumade local, Gajendra, Sree Padma, Vegetable and Fruit Promotion Council Keralam (VFPCK) local and Sree Athira) of elephant foot yam were evaluated under conventional and organic systems in split plot design. A brief description of varieties is given in Table 1. Varieties were assigned to main plots and production systems to sub plots. The treatment combinations were replicated thrice. In the organic practice, the field validated organic production technology, farmyard manure (FYM) (cowdung + neem cake mixture (10:1) inoculated with *Trichoderma harzianum* @ 36 tonnes/ha + green manuring to generate 20-25 tonnes/ha green matter in 45-60 days + neem cake @ 1 tonnes/ ha+ ash @ 3 tonnes/ha) was advocated. In conventional practice, FYM @ 25 tonnes/ha+ NPK @ 100:50:150 kg/ha (Package of Practices (POP) recommendation of Kerala Agricultural University (KAU)) was followed.

Elephant foot yam was planted in plots of size 4.5 × 4.5 m. Corm pieces of 500 g with a portion of terminal bud treated with slurry containing cowdung, neem cake and *Trichoderma harzianam* (5 g/kg seed) were planted in pits of 60 × 60 × 45 cm size. The plant to plant distance was 90 cm. Cultural practices followed were in accordance with the package of practices of KAU (2002). The crop was planted during March in each year, mainly as rain-fed and harvested after nine months. In organic farming plots, green manure cowpea was sown twice viz., prior to experimentation and immediately after planting elephant foot yam in between the pits and green matter was incorporated at 50% flowering stage. The quantity of green matter incorporated was 22.25 tonnes/ha and 21.50 tonnes/ha in 2010 and 2011, respectively.

Growth characters such as plant height, leaf spread and girth of pseudostem were measured from three plants at 3, 6 and 9 months after planting (MAP), mean values computed and expressed in cms. Corms from the net plot were harvested and corm yield was expressed in t/ha. Proximate analyses of tubers for dry matter, starch, crude protein, total sugars, ash and fibre (AOAC 1980) and mineral composition of tubers, viz. P, K, Ca, Mg, Fe, Mn, Zn and Cu contents (Piper 1970), chemical parameters of soil viz., organic C, pH, available N, P, K, Ca, Mg, Fe, Mn, Zn and Cu status (Page *et. al*. 1982), physical characters of the soil such as bulk density, particle density, water holding capacity (WHC) and porosity (Gupta and Dakshinamoorthy 1980), plate count of soil microbes viz. bacteria, fungi, actinomycetes, N fixers and P solubilizers (Timonin 1940) were determined by standard procedures. 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 yield data of two years was also done.

RESULTS AND DISCUSSION

Growth, yield and quality

Varietal effect was significant for plant height at all stages and pseudostem girth at 9 MAP. Production systems imparted significant effect on canopy spread at all stages and pseudostem girth at 3 and 9 MAP. Gajendra and Sree

Table 1 Description of the test varieties of elephant foot yam

Varieties	Pedigree and source	Description
Peerumade local	Local variety procured from Peerumade Development Society, Peerumade, Pothupara, Idukki	Matures in 8-9 months and produces 40-45 t/ha
Gajendra	Selection from local collections of Kovvur, West Godavari district, Andhra Pradesh, released from Vegetable Research Station, Rajendra Nagar, under the aegis of All India Co-ordinated Research Project (AICRP) on Tuber Crops	Average yield of 42.00 t/ha, potential yield of 55.00 t/ha, matures by 180-210 days
Sree Padma	Selection from indigenous germplasm collection from Wyanad, Kerala, released by ICAR-CTCRI, Thiruvananthapuram	Average yield of 42.00 t/ha, potential yield of 80.20 t/ha , matures within 8-9 months
VFPCK local	Local variety obtained from Vegetable and Fruit Promotion Council Keralam	Matures in 8 months and produces 35-40 t/ha
Sree Athira	Hybrid selection released from ICAR-CTCRI, Thiruvananthapuram	Matures in 9-10 months and yields 40.50 t/ha

Source: (AICRP 2012; CTCRI, 2006).

Padma were significantly taller. Conventional practice resulted in significantly greater canopy spread and pseudostem girth (Table 2). The effect of varieties × production systems interaction was not significant.

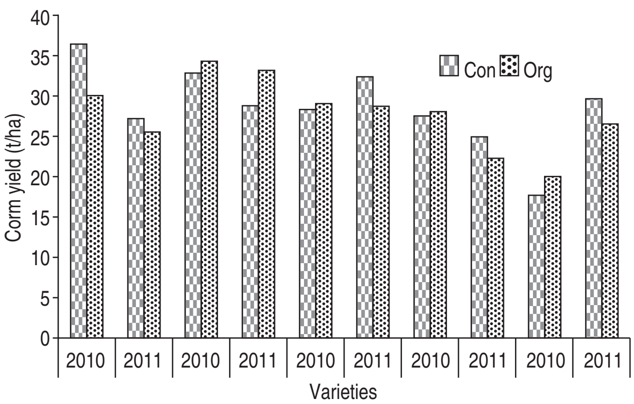
During both the years, the varietal effect was significant. The effects of production systems and varieties × production systems interaction were not significant. In the first year, all the varieties, except Sree Athira, performed well and were on par (28-34 tonnes/ha). During second year, the elite varieties, Gajendra, Sree Padma and Sree Athira performed well (28-30 tonnes/ha) and the locals (Peerumade and VFPCK locals) proved inferior. In both the years of experimentation, yield under organic farming (28.23, 27.21 tonnes/ha respectively, during the years) was on a par with that of conventional practice (28.55, 28.56 tonnes/ha respectively). Corm yield in the individual years as well as the mean showed that the elite as well as the local varieties responded equally well to both the practices with average corm yields of 27.72 tonnes/ha under organic and 28.55 tonnes/ha under conventional practice (Fig 1 and Table 3). This indicates that both elite and local varieties exhibited similar abilities to source nutrients and put down roots, contrary to the hypothesis that chemicals were easy to access.

Though the interaction, varieties × production systems was not significant according to ANOVA, a different behavior of the varieties was identifiable with either higher yield, for Gajendra (+10%) or lower yield losses (–15 % for VFPCK local, 2.5-5.0 % for others) under the organic system, as compared to the conventional one. This suggests that elite varieties, especially Gajendra, may be more suitable for organic farming and confirms the importance of genotype selection for adaptability to organic farming. The effect of varieties, production systems and varieties × production systems was not significant for most of the tuber quality traits. The corms of Sree Athira had significantly higher crude protein contents and the locals had appreciably higher crude fibre contents (Table 4). The biochemical and mineral contents of organic corms were on par with that of conventional corms. However, the conventional corms had significantly higher Mn content. Organic corms had slightly higher dry matter, sugar, P, K and Fe contents (Table 5). Similar results of higher levels of K were observed in organic tomatoes (Pieper and Barrett 2008), organic elephant foot yam and yams (Suja *et al*. 2012a, 2012b, Suja 2013, Suja and Sreekumar 2014) and inorganic fertilizer treatment was found to significantly enhance the content of Mn in strawberry fruits (Hargreaves *et. al*. 2008) and elephant foot yam (Suja *et al*. 2012a, 2012b, Suja 2013).

Table 2 Growth performance of elephant foot yam varieties under organic vs conventional management (mean of two years)

Varieties/Production systems	Plant height (cm)			Canopy spread (cm)			Pseudostem girth (cm)		
	3 MAP	6 MAP	9 MAP	3 MAP	6 MAP	9 MAP	3 MAP	6 MAP	9 MAP
Varieties									
Peerumade local	34.16	33.94	55.00	86.70	93.30	79.90	12.64	14.39	10.28
Gajendra	49.16	49.33	66.20	86.90	94.40	87.60	12.69	15.61	12.44
Sree Padma	44.27	40.89	65.60	90.20	100.40	91.70	13.39	15.03	12.17
VFPCK local	32.89	32.83	50.60	85.70	92.70	75.70	12.30	13.50	8.22
Sree Athira	39.05	37.06	52.70	88.80	93.60	78.70	13.39	14.50	9.28
CD (P=0.05)	7.548	8.385	11.14	NS	NS	NS	NS	NS	2.701
Production systems									
Conventional	39.51	38.47	59.50	92.00	98.40	86.50	13.45	14.98	11.16
Organic	40.31	39.16	56.60	83.30	91.40	78.90	12.31	14.23	9.80
CD (P=0.05)	NS	NS	NS	6.02	5.55	6.84	0.636	NS	1.25

MAP- Months after planting.



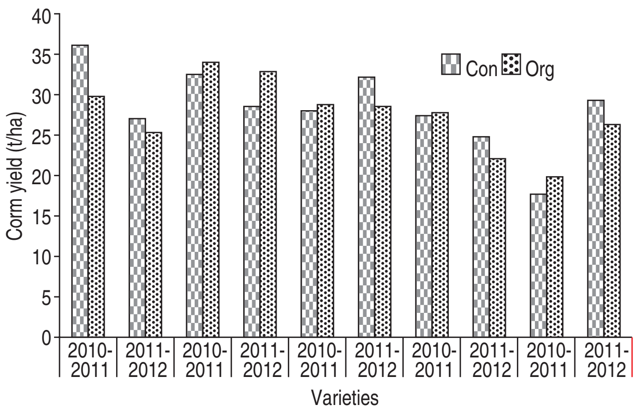


Fig 1 Response of varieties of elephant foot yam to organic vs conventional management during the period of study

Soil properties

Physical properties of the soil

The varietal effect on the physical properties of the soil was on par. The varieties × production systems effect was also not significant. Though there was slight reduction of bulk density and particle density and improvement in water holding capacity of the soil under organic management in all the varieties, the effect of production systems was also not significant (Table 6). This is similar to the earlier reports in elephant foot yam, yams and taro (Suja *et al*. 2012a, 2012b, Suja 2013, 2015, Suja and Sreekumar 2014).

Table 3 Yield response (tonnes/ha) of elephant foot yam varieties to organic farming (Mean of two years)

Varieties/Production systems	Conventional	Organic	Mean of varieties
Peerumade local	27.42	26.71	27.07
Gajendra	30.75	33.69	32.22
Sree Padma	30.31	28.85	29.59
VFPCK local	30.69	26.09	28.39
Sree Athira	23.61	23.26	23.43
Mean of production systems	28.55	27.72	
CD (P=0.05)	Varieties: 2.826; Production systems: NS; Varieties × production systems: NS		

Table 4 Effect of varieties and production systems on biochemical constituents of corms

Varieties/ Production systems	Dry matter (%)	Starch (% FW basis)	Crude protein (% FW basis)	Total sugars (% FW basis)	Ash (% DW basis)	Fibre (% DW basis)
Varieties						
Peerumade local	20.88	13.63	2.13	2.08	3.98	1.45
Gajendra	21.03	13.64	1.94	2.05	4.43	1.20
Sree Padma	23.24	15.48	1.99	2.16	4.07	1.07
VFPCK local	19.84	12.55	2.26	1.91	4.72	1.50
Sree Athira	24.75	16.19	2.87	2.117	3.97	1.10
CD (P=0.05)	NS	NS	0.469	NS	NS	0.224
Production systems						
Conventional	21.87	14.33	2.27	1.98	4.47	1.26
Organic	22.03	14.26	2.21	2.14	3.99	1.26
CD (P=0.05)	NS	NS	NS	NS	1.100	NS

Table 6 Physical properties of soil under organic vs conventional management after the experimentation

Production systems	Dry bulk density (g/cm^3)	Wet bulk density (g/cm^3)	Particle density (g/cm^3)	Water holding capacity (%)	Porosity (%)
Conventional	1.771	1.640	2.435	12.55	32.65
Organic	1.744	1.615	2.401	13.33	32.47
CD (P=0.05)	NS	NS	NS	NS	NS

Chemical properties of the soil

The effect of varieties, production systems and varieties × production systems was not significant during the first year. The pH, organic C, available N, P and K status of organic and conventional plots was almost the same. Chemical analysis of soil samples at the termination of the experiment indicated that varieties × production systems interaction was not significant, except, organic C and available K status. However, between the systems, organic management resulted in significant improvement in pH (Table 7). Organic C status was significantly higher under organic practice for Gajendra and Sree Padma. This may be mainly due to greater biomass addition on account of their inherent robust plant type (Table 2). Available K status was significantly highest in conventional practice and lowest in organic practice under Sree Athira. Elephant foot yam is a heavy K consuming crop and responds well to easily available nutrient sources of K.

The status of secondary and micronutrients, Ca, Mg, Fe, Mn and Zn was also not significantly influenced by the

Table 5 Effect of varieties and production systems on mineral content (mg/100g) of corms

Varieties/Production systems	P	K	Ca	Mg	Fe	Mn	Zn	Cu
Varieties								
Peerumade local	230.60	1623	160.20	65.08	60.80	4.90	8.62	0.93
Gajendra	215.80	1581	149.00	63.67	56.60	4.91	7.82	0.91
Sree Padma	197.20	1416	149.80	64.67	71.00	4.97	6.87	0.72
VFPCK local	212.30	1777	159.60	65.08	72.20	5.01	7.07	0.85
Sree Athira	225.50	1741	164.90	63.42	71.20	4.12	7.50	0.80
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Production systems								
Conventional	207.40	1587	157.00	64.13	64.40	5.33	7.39	0.88
Organic	225.20	1669	156.40	64.63	68.40	4.23	7.76	0.81
CD (P=0.05)	NS	NS	NS	NS	NS	0.584	NS	NS

varieties, production systems and varieties × production systems interaction (Table 8). Available Cu content was significantly influenced by varieties × production systems interaction. Though no definite trend was observed, Cu content was higher in conventional practice for most of the varieties especially, Gajendra and Sree Padma. However, exchangeable Ca, Mg, Fe and Zn contents were slightly higher in organic plots. Similar results have been reported earlier under organic management of yams and aroids (Suja *et al*. 2012a, Suja 2013, 2015, Suja and Sreekumar 2014).

Table 7 Effect of production systems and varieties × production systems interaction on major soil chemical properties in elephant foot yam at the end of experimentation

Varieties × Production systems	pH	Organic C (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Laxities					
Peerumade local Conv	4.591	1.522	83.10	74.10	418
Peerumade local Org	4.536	1.135	80.60	70.40	374
Gajendra Conv	4.587	1.099	78.30	70.50	428
Gajendra Org	4.757	1.597	77.70	88.00	408
Sree Padma Conv	4.481	1.008	80.10	74.10	400
Sree Padma Org	4.896	1.549	79.50	74.10	440
VFPCK Conv	4.505	0.946	81.80	63.00	462
VFPCK Org	4.718	1.006	70.80	90.00	457
Sree Athira Conv	4.732	1.454	77.20	90.20	556
Sree Athira Org	4.689	1.151	93.40	82.90	328
CD (P=0.05)	NS	0.439	NS	NS	193.1
Production systems					
Conventional	4.58	1.21	80.10	74.40	453
Organic	4.72	1.29	80.40	81.10	401
CD (P=0.05)	0.134	NS	NS	NS	NS

Biological properties of the soil

Microbial count of the soil and soil enzyme activity

Production systems imparted significant effect on bacterial count. Varieties × production systems interaction effect was not significant for biological properties of the soil. Bacterial count in the soil was significantly higher in organic plots. The population of fungi, actinomycetes, P solubilizers, N fixers and dehydrogenase enzyme activity was almost same in both the production systems (Tables 9 and 10). However, the dehydrogenase enzyme activity and the count of N fixers were slightly higher in organic plots. Dehydrogenase, the respiratory enzyme and integral part of all soil organisms, is the most commonly used indicator of biological activity in soils. The higher dehydrogenase activity in organic plots might be due to higher oxidation or decomposition of organic matter due to addition of large quantities of organic sources of nutrients (FYM, green manure, neem cake etc.) to supplement the nutrient requirement. Suja and Sreekumar (2014) also observed similar results in yams. The conventional practice favored the acid phosphatase activities slightly (Table 9), which may be due to addition of synthetic fertilizers.

It can be concluded that both the improved and local

Table 9 Effect of production systems on soil microbial activityat the end of experimentation

Production systems	Bacteria ($\times 10^7$cfu/ g soil)	Fungi ($\times 10^6$cfu/ g soil)	Actino-mycetes ($\times 10^5$cfu/ g soil)	P solubi-lizers ($\times 10^6$cfu/ g soil)	N fixers ($\times 10^5$ cfu/g soil)
Conventional	22	5	24	5	165
Organic	31	6	22	5	182
CD (P=0.05)	8.35	NS	NS	NS	NS

Table 8 Effect of production systems and varieties × production systems interaction on secondary and micronutrient status of soil at the end of experimentation

Varieties × Production systems	Exchangeable Ca (meq/100g)	Exchangeable Mg (meq/100g)	Available Fe (ppm)	Available Mn (ppm)	Available Zn (ppm)	Available Cu (ppm)
Laxities						
Peerumade local Conv	0.712	0.332	32.22	7.04	5.55	0.41
Peerumade local Org	1.119	0.415	35.99	8.29	6.10	0.59
Gajendra Conv	0.779	0.397	32.73	8.02	5.80	0.54
Gajendra Org	0.815	0.386	31.98	7.54	5.53	0.33
Sree Padma Conv	0.959	0.401	34.73	9.99	6.04	0.75
Sree Padma Org	0.823	0.417	32.42	8.99	5.84	0.33
VFPCK Conv	0.944	0.406	34.95	8.67	5.82	0.44
VFPCK Org	0.839	0.375	33.42	7.20	5.84	0.35
Sree Athira Conv	0.843	0.429	32.40	8.59	5.86	0.37
Sree Athira Org	0.903	0.384	34.63	7.07	5.98	0.63
CD (P=0.05)	NS	NS	NS	NS	NS	0.255
Production systems						
Conventional	0.85	0.39	33.41	8.46	5.82	0.50
Organic	0.90	0.40	33.69	8.02	5.86	0.45
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table 10 Effect of production systems on soil enzyme activity at the end of experimentation

Production systems	Dehydrogenase enzyme (mg TPF formed/g soil/h)	Acid phosphatase (µg para nitro phenol released/ g soil/h)	Urease (mg urea formed/g soil/h)
Conventional	1.323	1.42	1.99
Organic	1.625	1.23	1.99
CD (P=0.05)	NS	NS	NS

varieties of elephant foot yam were equally suitable for conventional and organic agriculture owing to their almost similar yields, corm quality and impact on soil physico-chemical-biological properties.

There should be greater attention for research on breeding in organic agricultre as there is increasing consumer demand and subsequent growth of organic products at approximately 20%/year. Breeding programs in organic agriculture should focus on traits including improved nitrogen and nutrient-use eficiency, adaptation to soil microbes, improved competitiveness against weeds and resistance to insects and diseases currently controlled with chemical pesticides. With the incorporation of these traits into high yielding cultivars, organic agriculture will be better equipped to realize its full potential as a viable alternative to conventional agriculture.

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