Indian Journal of Agricultural Sciences **87** (8): 1018–23, August 2017/Article
https://doi.org/10.56093/ijas.v87i8.73076

Organic source of nutrients effect on growth, yield and quality of elephant foot yam (*Amorphophallus paeoniifolius*)

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Received: 17 October 2016; Accepted: 11 January 2017

ABSTRACT

A field experiment was conducted at the Regional Centre of ICAR-Central Tuber Crops Research Institute, Bhubaneswar, India during 2008-09 and 2009-10 to find out the effect of organic source of nutrients on growth, yield and quality of elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson). The experiment consisted of nine treatments (T_1 to T_9) involving different combinations of vermicompost, farmyard manure, poultry manure, vesicular arbuscular mycorrhizae, phosphorous solubilising bacteria, *Azospirillum* and ash and recommended N-P_2O_5-K_2O 80-60-100 kg/ha (T_{10}). Application of 10 t FYM along with 5 t ash, 5 kg *Azospirillum* and 5 kg PSB /ha (T_7) resulted in significantly taller pseudostem, more girth of pseudostem at collar region, wider canopy, more leaflets/hill and leaf area at 3 and 5 MAP. Plants under the same treatment had maximum dry matter in pseudostem, leaf canopy and corm, and corm yield. Application of PSB resulted in greater dry matter production and corm yield than VAM. FYM based organic source of nutrients significantly reduced calcium oxalate in corms.

Key words: Biofertilizers, Corm yield, Elephant foot yam, Organic manures

Nitrogen, phosphorus and potassium are the most important elements for realizing potential yield of crops. In intensified cropping system, which has high turnover of nutrients, poor recycling of organic sources and application of chemical fertilizers containing these major nutrients caused deficiency of several micronutrients in soil and also lead to environmental pollution (Kumar 2008). Khambalkar *et al*. (2012) reported that the long term application of chemical fertilizers alone under intensive cropping may deplete the reserve pool of non-applied nutrients and carbon, which if not properly managed, leads to deterioration of soil productivity and fertility. The negative effect of chemical fertilizers can be reduced by suitable substitution of organic source to sustain the crop productivity. Furthermore, continuing world energy crisis and spiraling price of chemical fertilizer, the use of organic manure as a renewable source of plant nutrients is assuming importance (Devi *et al*. 2011). Addition of organic sources can increase the growth and yield through improving soil productivity (Santhi and Selvakumari 2000). Organic source permits the recycling of organic wastes, the disposal of which could be difficult and expensive. Vermicomposting is the better way of utilizing organic wastes and supplementing biofertilizers enriches soil fertility (Paikray *et al*. 2002).

Elephant foot yam [*Amorphophallus paeniifolicus* (Dennst.) Nicolson] growth and corm yield is influenced by the size of planting material (corms/cormels/corm pieces), plant spacing, nutrient management and water availability (Ravi *et al*. 2011). The market for organically produced food is on the rise despite a dialogue on organic vs modern agriculture. Elephant foot yam yields are very high and removes correspondingly high amount of nutrients. An elephant foot yam corm yield of 43 tonnes/ha removed 124.8 kg N, 26.1 kg P and 222.4 kg K (Kabeerathumma *et al*. 1987). As the economic part of elephant foot yam is underground, organic manures have direct effect on the yield and quality of corms. Keeping this in view, a field experiment was conducted to evaluate locally available organic manures as source of nutrients on the growth, yield and quality of corm in elephant foot yam.

MATERIALS AND METHODS

A field experiment was conducted at the Regional Centre of ICAR-Central Tuber Crops Research Institute (20º 14' 50" N and 85º 47' 06" E), Bhubaneswar, India during 2008-09 and 2009-10. The soil of the experiment field is Typic Rhedustalfs with pH 5.4, organic carbon 0.35%, available N 168 kg/ha, available P_2O_5 19.6 kg/ha and available K_2O 152 kg/ha. The experiment was conducted in randomized block design with three replications. The experiment consisted of

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the following treatments: T_1- Vermicompost 5 tonnes + ash 5 tonnes/ha, T_2- Farmyard manure (FYM) 10 tonnes + ash 5 tonnes/ha, T_3- Poultry manure 5 tonnes + ash 5 tonnes/ha, T_4- Vermicompost 5 tonnes + ash 5 t + *Azospirillum* 5 kg + Vesicular arbuscular mycorrhizae (VAM) 5 kg/ha, T_5- Vermicompost 5 tonnes + ash 5 tonnes + *Azospirillum* 5 kg + Phosphorus solubilising bacteria (PSB) 5 kg/ha, T_6- FYM 10 tonnes + ash 5 tonnes + *Azospirillum* 5 kg + VAM 5 kg/ha, T_7- FYM 10 tonnes + ash 5 tonnes + *Azospirillum* 5 kg + PSB 5 kg/ha, T_8- Poultry manure 5 tonnes + ash 5 tonnes + *Azospirillum* 5 kg + VAM 5 kg/ha, T_9- Poultry manure 5 tonnes + ash 5 tonnes + *Azospirillum* 5 kg + PSB 5 kg/ha and T_{10}- Recommended N-P_2O_5-K_2O 80-60-100 kg/ha. The mean nutrient content of organic manures used in this experiment was as follows: FYM (N-P-K 0.59-0.30-0.46%), Vermicompost (N-P-K 1.52-0.68-1.03%), poultry manure (N-P-K 1.46-0.96-0.92%) and ash (N-P-K 0-0.96-3.14%). Organic manures, ash and phosphorus were applied before last plough. *Azospirillum*, PSB and VAM were applied in the pits just before placing the seed corms. The 'Gajendra' variety of elephant foot yam weighing 400 g was planted at 90 × 90 cm spacing. FYM and total phosphorus were applied during last plough. Half dose of nitrogen and potassium were applied 1 month after planting (MAP) and the remaining half dose was applied 1 month after 1st dose. No pesticide was applied as there were no diseases and insect pests. Weeding followed by earthing up was carried out at 20, 40 and 70 days after planting. The crop was planted 14 June 2006 and 16 June 2007 and harvested 13 February 2007 and 15 February 2008, respectively (8 MAP). The crop was raised under rainfed conditions and received 1399.5 and 1366.7 mm rainfall during growing period of 2006-07 and 2007-08, respectively. However, four supplementary irrigations were given during the post monsoon period (October-January). In each irrigation, 4 cm water was applied.

Measurements on growth parameters (height and girth of pseudostem, number of leaflets per leaf) and dry matter were carried out at 3, 5 and 8 MAP (harvest). Corm yield was recorded at harvest at 8 MAP. Quality characters of corms such as dry matter, starch, total sugars and calcium oxalate were analysed at harvest. Cost of cultivation and returns were calculated as prevailing market rates of inputs and output during the cropping period. Benefit:cost ratio was calculated by dividing gross returns by cost of cultivation. The data were subjected to the analysis of variance (ANOVA) appropriate to the design using GENSTAT programme. The significant differences between the treatments were compared with the critical difference (CD) at a 5% level of probability.

RESULTS AND DISCUSSION

Growth

Significant differences were observed in pseudostem length (94-134 cm), pseudostem girth (16-22 cm), canopy spread (110-140 cm), number of leaflets/hill (615-724), and leaf area index (1.08-1.23) among ten nutrient sources treatments (Table 1). Organic source of nutrients had significant effect on pseudostem length, canopy spread and girth of pseudostem at collar region. Application of 10 tonnes FYM along with 5 tonnes ash, 5 kg *Azospirillum* and 5 kg phosphorus solubilising bacteria per ha (T_7) resulted in significantly taller pseudostem, wider canopy and more girth of pseudostem at collar region at 3 and 5 MAP and it was statistically at par with plants under the treatments T_6-FYM 10 tonnes + ash 5 tonnes + *Azospirillum* 5 kg + VAM 5 kg/ha and T_2-Farmyard manure 10 tonnes + ash 5 tonnes/ha. The pseudostem height, canopy spread and girth of pseudostem at collar region of plants under the treatment T_{10} (recommended N-P_2O_5-K_2O 80-60-100 kg/ha), T_5 (vermicompost 5 tonnes + ash 5 tonnes + *Azospirillum*

Table 1 Growth and leaf area index of elephant foot yam as influenced by organic source of nutrients (Pooled data of two years)

Treatment	Pseudostem length (cm)		Canopy width (cm)		Pseudostem girth at collar region (cm)		No. of leaflets/ hill		Leaf area index	
	3 MAP	5 MAP	3 MAP	5 MAP	3 MAP	5 MAP	3 MAP	5 MAP	3 MAP	5 MAP
T_{1-} VC + ash	60	98	72	115	12	17	320	650	0.56	1.10
T_{2-} FYM + ash	65	126	82	134	14	20	328	690	0.57	1.17
T_{3-} PM + ash	57	94	70	110	12	16	310	615	0.55	1.08
T_{4-}VC + ash + Az + VAM	63	114	78	124	12	18	318	658	0.55	1.11
T_{5-}VC + ash + Az + PSB	65	120	80	126	13	19	320	662	0.56	1.12
T_{6-}FYM + ash + Az + VAM	72	130	84	136	16	20	334	706	0.59	1.20
T_{7-}FYM + ash + Az + PSB	75	134	88	140	17	22	342	724	0.60	1.23
T_{8-} PM + ash + Az + VAM	58	96	70	115	12	16	317	642	0.55	1.09
T_{9-} PM + ash + Az + PSB	62	105	73	120	13	18	322	648	0.56	1.10
T_{10-} Recommended POP	68	120	78	130	14	18	330	690	0.57	1.17
CD (P=0.05)	6	10	7	12	2	2	NS	NS	NS	NS

FYM- Farmyard manure; VC-Vermicompost; VAM-Vescicular arbuscular mycorrhizae; PM-Poultry manure; PSB-Phosphorus solubilizing bacteria; Az-*Azospirillum.*

5 kg + phosphorus solubilising bacteria 5 kg/ha) and T_4 (vermicompost 5 tonnes + ash 5 tonnes + *Azospirillum* 5 kg + vesicular arbuscular mycorrhizae 5 kg/ha) were statistically at par at 3 and 5 MAP. Significantly shorter pseudostem length, lower canopy spread and girth of pseudostem at collar region were observed in plants under the treatment T_3 (poultry manure 5 tonnes + ash 5 tonnes/ha at 3 and 5 MAP). However, it was statistically at par with plants under the treatment T_1 (vermicompost 5 tonnes + ash 5 tonnes/ha, T_8-poultry manure 5 tonnes + ash 5 tonnes + *Azospirillum* 5 kg + VAM 5 kg/ha) and T_9 (poultry manure 5 tonnes + ash 5 tonnes + *Azospirillum* 5 kg + PSB 5 kg/ha). No marked variation in number of leaflets/hill and leaf area index was observed with regard to source of nutrients. Although maximum number of leaflets/hill (724) and leaf area index (1.23) were observed in plants under the treatment T_7, it was not statistically significant from other treatments. It indicated that quantity of nutrients supplied through inorganic source and various types of organic sources was sufficient for crop growth up to five months.

Dry matter production and partitioning

Dry matter partitioning in to pseudostem, leaf canopy and corm indicated that dry matter accumulation in pseudostem and leaf canopy was up to 5 MAP after that the accumulation was very less as compared to corm. The dry matter accumulation in corm continued till the harvest at 8 MAP (Table 2). This is in agreement with Das *et al*. (1997). The dry matter accumulation in leaf canopy was greater than in pseudostem. The dry matter accumulation in corm was greater than combined dry matter accumulation of pseudostem and leaves at all the stages. It indicated that the partitioning efficiency of dry matter towards corm was very high. The total dry matter production rate was very high between 3 and 5 MAP (Table 2). The dry matter produced between 5 and 8 MAP was partitioned mainly to the corm.

Significantly maximum dry matter accumulated in pseudostem, leaf canopy and corms of plants under T_7 at 3, 5 and 8 MAP and it was statistically on par with T_6 and T_2. The total dry matter production (TDM) per plant varied between 502.6 and 700.7 g/plant the maximum being in plants under the treatment T_7 and this was on par with the TDM produced in plants under T_6 (678.3 g/plant) and T_2 (657.8 g/plant) (Table 2). It indicated that FYM was the better source of nutrients among organic sources as well as inorganic source. The inorganic source of nutrients was subjected to various losses after application. When inorganic fertilizers are applied at an early growth period, long duration crops like elephant foot yam is unable to get sufficient nutrients at later period. This was amply indicated by greater growth parameters at early period of crop growth due to inorganic fertilizer application (Table 1) and lower dry matter accumulation rate at later period (Table 2 and 3). Application of biofertilizers had additional advantage of increasing the dry matter accumulation, though not at significant level (Table 2). Application of PSB resulted in greater dry matter production and corm yield than VAM.

Yield attributes and yield

Organic source of nutrients had significant effect on yield attributes of elephant foot yam. Plants under the treatment T_7 had maximum corm length, corm diameter and corm yield/plant and it was statistically on par with plants under the treatments T_6 and T_2 (Table 3). Organic source of nutrients supplied through vermicompost was the next best. It was followed by nutrients supplied through poultry manure. Organic matter maintains regular supply of macro and micro nutrients in optimal congruence with the crop demand which might have improved its yield attributes (Patra *et al*. 2016). The lowest corm length and corm diameter and corm yield/plant was observed in plants under the treatment T_{10}. The variation in yield attributes

Table 2 Dry matter production and partitioning of elephant foot yam as influenced by organic source of nutrients (Pooled data of two years)

Treatment	Dry matter production at 3 MAP (g/plant)				Dry matter production at 5 MAP (g/plant)				Dry matter production at 8 MAP (g/plant)			
	Pseudostem	Leaf	Corm	Total	Pseudostem	Leaf	Corm	Total	Pseudostem	Leaf	Corm	Total
T_{1-} VC + ash	11.5	17.4	45.4	74.3	24.5	37.2	317.7	379.3	25.8	39.2	488.8	553.8
T_{2-} FYM + ash	12.1	17.9	49.1	79.1	28.2	41.7	377.6	447.4	31.0	45.8	581.0	657.8
T_{3-} PM + ash	10.4	15.5	41.4	67.3	24.3	36.1	318.8	379.1	26.7	39.7	490.4	556.8
T_{4-}VC + ash + Az + VAM	12.3	18.0	46.9	77.3	26.3	38.4	322.7	387.4	28.3	41.3	496.4	566.1
T_{5-}VC + ash + Az + PSB	12.9	18.8	47.3	79.1	27.6	40.1	331.9	399.6	29.7	42.7	510.7	583.0
T_{6-}FYM + ash + Az + VAM	12.3	18.8	50.6	81.7	28.8	43.6	389.2	461.5	31.7	47.9	598.7	678.3
T_{7-}FYM + ash + Az + PSB	12.8	19.3	52.3	84.3	29.7	44.9	402.1	476.7	32.7	49.3	618.7	700.7
T_{8-} PM + ash + Az + VAM	9.9	15.1	41.3	66.3	23.1	35.2	317.7	375.9	25.3	38.7	488.7	552.7
T_{9-} PM + ash + Az + PSB	10.7	15.8	41.8	68.3	24.8	37.0	321.8	383.7	27.3	40.7	495.2	563.2
T_{10-} Recommended POP	11.6	17.9	47.5	77.0	23.8	36.5	317.1	377.3	24.5	37.7	440.4	502.6
CD (P=0.05)	0.8	1.6	4.8	7.4	2.3	3.6	30.1	31.2	2.4	3.8	42.8	52.2

FYM- Farmyard manure; VC-Vermicompost; VAM-Vescicular arbuscular mycorrhizae; PM-Poultry manure; PSB-Phosphorus solubilizing bacteria; Az-*Azospirillum*.

Table 3 Dry matter production rate, yield and economics of elephant foot yam as influenced by organic source of nutrients (Pooled data of two years)

Treatment	Rate of total dry matter production per plant (g)		Corm length (cm)	Corm diameter (cm)	Corm yield (kg/ plant)	Corm yield (t/ ha)	Cost of cultivation (₹/ ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C ratio
	3-5 MAP	5-8 MAP								
T_{1-} VC + ash	4.10	0.46	19	18	2.15	25.84	130000	258440	128440	1.99
T_{2-} FYM + ash	4.66	0.47	22	23	2.60	30.72	115000	307160	192160	2.67
T_{3-} PM + ash	4.63	0.47	20	19	2.16	25.92	110000	259240	149240	2.36
T_{4-}VC + ash + Az + VAM	4.01	0.46	20	19	2.18	26.13	132000	261270	129270	1.98
T_5 -VC + ash + Az + PSB	4.05	0.46	21	20	2.23	26.76	132000	267600	135600	2.03
T_{6-}FYM + ash + Az + VAM	4.65	0.47	23	24	2.61	31.23	117000	312340	195340	2.67
T_{7-}FYM + ash + Az + PSB	4.65	0.47	24	25	2.67	32.00	117000	320020	203020	2.74
T_{8-} PM + ash + Az + VAM	4.67	0.47	19	18	2.14	25..21	112000	257210	145210	2.30
T_{9-} PM + ash + Az + PSB	4.62	0.47	19	19	2.17	26.06	112000	260640	148640	2.33
T_{10-} Recommended POP	3.90	0.33	17	15	1.94	23.39	110000	233870	123870	2.13
CD (P=0.05)	0.06	0.01	2	2	1.86	2.52				

FYM- Farmyard manure; VC-Vermicompost; VAM-Vescicular arbuscular mycorrhizae; PM-Poultry manure; PSB-Phosphorus solubilizing bacteria; Az-*Azospirillum.* Sale price of elephant foot yam corm Rs 10/kg.

was due to variation in growth, dry matter production and partitioning.

Corm yields significantly varied between 23.39 and 32.00 tonnes/ha among ten treatments. This is in agreement with several reports reviewed in Ravi *et al*. (2011). Marked variation in corm yield was noticed with respect to organic source of nutrients (Table 3). The maximum corm yield (32.00 tonnes/ha) was recorded in plants due to the treatment T_7 and it was statistically on par with the corm yield of plants under the treatments T_6 (31.23 tonnes/ha) and T_2 (30.72 tonnes/ha). The treatments T_7, T_6 and T_2 resulted in 36.8, 33.6 and 31.3% greater corm yield respectively than T_{10}. This was due to higher growth attributes, dry matter production and partitioning, and yield attributes (Table 1 and 2). Corm yields between 39.6 and 98.9 tonnes/ha were obtained due to application of 100-200 kg N and 100-150 kg K_2O_5 each per ha (Ravi *et al.* 2011). Application of farmyard manure at a rate of 30 tonnes/ha increased the fresh mass or corms by 15%, while application of N at 150 kg/ha increased yield by 6.5% (Patel and Mehta 1984). Organic source of nutrients presumably increased growth and yield attributes by increasing availability of plant nutrients. Organic source of nutrients are more positive for crop yields (Bennett and Franzel 2013). In a long term fertilizer trial for ten years, steady increase in rice productivity was achieved by use of combined application of one-third each of cow dung manure + neem cake + composted crop residue for 100% N requirement supplemented with *Azospirillum* + PSB (Chitale *et al*. 2015). Suja *et al*. (2012) also reported significantly superior performance of elephant foot yam under organic source of nutrients. Corm yield with the biofertilizers and FYM + ash application under the treatments T_7 and T_6 was greater than FYM + ash application under the treatment T_2. The corm yield of T_7 and T_6 was 4.2 and 1.7% respectively, greater than T_2. As *Azospirillum* fixes atmospheric nitrogen in the rhizosphere, a long duration crop like elephant foot yam crop could utilize this nutrient over a long period. Similarly, PSB solubilizes unavailable phosphorus and releases in to the soil solution and VAM helping the roots for foraging phosphorus in the rhizosphere. Mycorrhizal symbiosis has been shown to improve soil productivity and are important for increasing the uptake of slowly diffusing ions such as PO_4^{3-} and immobile nutrients such as P, Zn and Cu and thereby improve crop yield by increasing the capacity of plants to obtain nutrients that are relatively immobile in the soil (António Quilambo 2003 and Monreal *et al*. 2011). In the present study, between PSB and VAM, the corm yield due to PSB application was greater but not at a significant level. The use of phosphate solubilizing, plant growth promoting bacteria as live microbial biofertilizers provides a promising alternative to chemical fertilizers (Oteino *et al*. 2015 and Sreedevi 2016). These bacteria release organic acids into the soil which solubilize the phosphate complexes converting them into ortho-phosphate which is available for plant uptake and utilization. The application of PSB promoted growth, dry matter accumulation, biomass and yield in rice, maize, mungbean, pea, tomato (Vahed *et al*. 2012, Walpola *et al*. 2013, Viruel *et al*. 2014, Oteino *et al*. 2015 and Sreedevi 2016).

Vermicompost and poultry manure source of nutrients were the next best treatments for corm yield. In low organic carbon soils, addition of more organic matter resulted in greater elephant foot yam yield than higher amount of nutrients. Application of FYM at the rate of 10 tonnes/ha contributed more organic matter to the soil than vermicompost applied at the rate of 5 tonnes/ha and poultry manure at the rate of 5 tonnes/ha (Table 3). The nutrients added to the soil through inorganic fertilizer (N-P_2O_5-K_2O

Table 4 Quality characters of elephant foot yam as influenced by organic source of nutrients (Pooled data of two years)

Treatment	Dry matter (%)	Starch (%)	Total sugars (%)	Calcium oxalate (mg/100 g fresh corm)
T_1- VC + ash	22.7	17.2	0.99	95.0
T_2- FYM + ash	22.7	17.0	0.98	91.9
T_3- PM + ash	22.7	17.2	0.97	95.8
T_4-VC + ash + Az + VAM	22.8	17.3	1.00	94.9
T_5 -VC + ash + Az + PSB	22.9	17.5	0.99	94.2
T_6-FYM + ash + Az + VAM	23.0	17.3	1.00	92.0
T_7-FYM + ash + Az + PSB	23.2	17.3	1.01	91.6
T_8- PM + ash + Az + VAM	22.8	17.3	0.98	96.7
T_9- PM + ash + Az + PSB	22.8	17.3	0.98	95.6
T_{10}- Recommended POP	22.7	17.1	0.97	102.8
CD (P=0.05)	NS	NS	NS	7.8

FYM- Farmyard manure; VC-Vermicompost; VAM-Vescicular arbuscular mycorrhizae; PM-Poultry manure; PSB-Phosphorus solubilizing bacteria; Az-*Azospirillum*.

80-60-100 kg/ha), vermicompost and poultry manures were greater than FYM. The lowest corm yield was observed in plants under the treatment T_{10}. The application of vermicompost as organic source of nutrients has several advantages and its growth promoting properties recorded in several plants and crops (Lazcanoa and Domínguez 2012 and Gupta *et al*. 2014).

Quality

Elephant foot yam is a starchy vegetable. High dry matter and starch gives good consistency after cooking. Low sugar is preferred in the corm as a vegetable. Some varieties of elephant foot yam corms may contain calcium oxalate which causes irritation while eating. Quality attributes like dry matter, starch and total sugars content was not influenced by source of nutrients (Table 4). But calcium oxalate content was lower in corms due to organic source of nutrient compared to inorganic fertilizer. The treatment T_7 resulted in the lowest calcium oxalate accumulation in corms. A decrease of 10.9% calcium oxalate content was observed in corms of plants under the treatment T_7 as compared to plants under T_{10}. Suja (2013) also reported that oxalate content in elephant foot yam was lowered by 21% due to organic source of nutrients.

Economics

Higher returns and benefit cost ratio was observed in FYM based organic source of nutrient supply with or without biofertilizers (Table 3). Maximum returns and benefit cost ratio was achieved in the treatment T_7. This was due to greater corm yield in this treatment. Manjunath *et al*. (2016) reported that use of FYM as a source of nutrients is not only productive but also profitable. Between PSB and VAM, returns and benefit cost ratio with PSB was greater due to higher corm yield. Lower returns and benefit cost ratio was noticed in the treatment T_{10} owing to lesser corm yield. In the context of continuous increase of fertilizer cost which will rise the cost of cultivation and decrease net returns (Bennett and Franzel 2013), the organic source of nutrients offers alternative means of supplying crop nutrient requirements.

For elephant foot yam, to achieve maximum crop growth (taller pseudostem, more girth of pseudostem, wider canopy spread, more leaflets/hill and leaf area), dry matter production, corm yield and low calcium oxalate content the combined application of 10 t FYM along with 5 t ash, 5 kg *Azospirillum* and 5 kg PSB per ha is recommended.

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