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Growth and Yield of Elephant Foot Yam under Integrated Nutrient Management (INM) in Alfisols

Elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson) is regarded as the king of tuber crops, and it belongs to Araceae family. Tropical tuber crops are the primary staple food of the wet tropics and in India these crops are cultivated as a secondary staple as well as for many commercial applications such as production of starch and sago. With ever-increasing population pressure and fast depletion of natural resources, it has become extremely important to diversify the present day agriculture in order to meet various human needs (Janardhanan et al., 2003). Presently, the status of elephant foot yam is elevated from a small scale subsistence crop to a large scale commercial crop as it is widely used for culinary purpose, pickle making and is a good remedy for patients suffering from piles, asthma, dysentery and abdominal pain (Misra *et al.*, 2002). The corms are usually eaten boiled, mashed or sometimes pounded, frequently mixed with other staples, such as sour vegetables. Even the stem and flowers are used as food (Raghu et al., 1999). It also contains vitamins, minerals, and energy (Bradbury and Hammer, 1990; Chowdhury and Hussain, 1979; Parkinson, 1984) and has medicinal and therapeutic value (Chattopadhyay and Nath, 2007). The elephant foot yam is important among the aroids and responds well to application of manures and fertilizers. External application of major nutrients is essential for better growth and yield of elephant foot yam in alfisols. Alfisols are low in organic matter content. Hence, application of organic manures enhances the fertilizer use efficiency. Keeping the above in view, an investigation was carried out to find the effect of varied inorganic and organic fertilizers on productivity potential of elephant foot yam in alfisols.

A field experiment was carried out for two consecutive years (2011 and 2012) at the Regional Centre of Central Tuber Crops Research Institute (20 °14'53.25'' N and 85°47'25.85'' E and 33 m above mean sea level), Dumuduma, Bhubaneswar, Odisha, India. Texturally the soil is sandy loam with pH 6.7. The soil type on experimental site is alfisols and falls under the family on Typic Rhodustalfs. The initial soil fertility status of the experimental site was 0.3% organic carbon, 91.5 kg ha^{-1} available nitrogen, 14.9 kg ha^{-1} available phosphorus and 235.7 kg ha^{-1} available potassium. The experiment was laid out in randomized block design (RBD) with three replications. The experiment comprised eight treatments viz. Control, N-P_2O_5-K_2O 60-60-60 kg ha^{-1}, N-P_2O_5-K_2O 80-60-80 kg ha^{-1}, N-P_2O_5-K_2O 100-60-100 kg ha^{-1}, FYM 10 t ha^{-1} + N-P_2O_5-K_2O 60-60-60 kg ha^{-1}, FYM 10 t ha^{-1} + N-P_2O_5-K_2O 80-60-80 kg ha^{-1}, FYM 10 t ha^{-1} + N-P_2O_5-K_2O 100-60-100 kg ha^{-1} and FYM 25 t ha^{-1}. The variety Gajendra, 400 g weight whole corm was planted at a spacing of 75 cm on the ridges formed at spacing of 75 cm. The fertilizers and manures were applied as per treatments. Full P was applied as basal dose during the final ploughing and 1/3rd of N and K were applied as basal dose. The remaining N and K were applied in two equal splits at one and two months after planting. The FYM used in this experiment contained 0.54 % N, 0.32 % P and 0.48 % K. During the year 2011 and 2012, the mean monthly maximum temperature ranged from 29.0-37.3 °C and 29.7-39.3 °C and minimum temperature ranged from 15.5-26.1 °C and 15.3-27.2 °C, respectively. The mean monthly relative humidity varied between 59.5 % and 89.0 % during 2011 and between 68.5 % and 88.0 % during 2012. The total rainfall during the crop growing period of 2011 and 2012 was 1450.5 and 1097.3 mm, respectively. A total of 95 rainy days was recorded during 2011 and a total of 85 rainy days was recorded during 2012.

The growth attributes viz.; pseudostem height, canopy spread, and pseudostem diameter were measured up to 5 months after planting (MAP) because plant showed senescence (yellowing) afterwards. Yield attributes and yield were recorded at harvest. The data were subjected to analysis of variance for randomized block design (Panse and Sukhatme, 1976).

The data on pseudostem height and canopy spread under different growth stages were presented in Table 1 and 2. Application of FYM 25 t ha^{-1} and FYM 10 t ha^{-1} + N-P_2O_5-K_2O 100-60-100 kg ha^{-1} resulted in taller pseudostem and higher canopy spread at all stages of crop growth compared to other treatments. Though application of FYM 25 t ha^{-1} resulted in slow growth at 2 MAP compared to FYM 10 t ha^{-1} + N-P_2O_5-K_2O 100-60-100 kg ha^{-1} later it picked up the growth. This was due to the addition of more inorganic nutrients in the treatment FYM 10 t ha^{-1} + N-P_2O_5-K_2O 100-60-100 kg ha^{-1}, which was immediately available to the plants for uptake. Similar results of increase in plant growth for higher levels of inorganic fertilizers (N, P and K) in taro have been realized by Bhuyan and Quasem (1983), Hossain and Rashid (1982) and Rahman and Rashid (1983). Availability of more nutrients after mineralization apart from growth hormones, better moisture retention and improved soil properties with the application of FYM 25 t ha^{-1} might helped the plants to produce higher pseudostem height and canopy spread at later stages. The control treatment

Table 1. Effect of fertility levels on pseudostem height (cm) of elephant foot yam

Treatments	2 MAP			3 MAP			4 MAP			5 MAP		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
Control(No fertilizer)	13.9	13.2	13.5	56.8	54.6	55.7	72.1	68.2	70.1	89.3	87.3	88.3
N-P_2O_5-K_2O 60-60-60 kg ha^{-1}	20.6	13.5	17.0	58.5	55.9	57.2	73.3	72.8	91.4	91.4	89.5	90.4
N-P_2O_5-K_2O 80-60-80 kg ha^{-1}	20.0	13.3	16.6	60.6	56.8	58.7	77.2	75.0	76.1	93.9	84.0	92.9
N-P_2O_5-K_2O 100-60-100 kg ha^{-1}	20.3	14.2	17.3	61.5	58.1	59.8	78.9	76.1	77.5	96.7	93.4	95.1
FYM 10 t ha^{-1} + N-P_2O_5-K_2O 60-60-60 kg ha^{-1}	20.5	15.3	17.9	63.1	59.9	61.5	82.1	80.5	81.3	101.9	100	100.9
FYM 10 t ha^{-1} + N-P_2O_5-K_2O 80-60-80 kg ha^{-1}	20.8	14.9	17.8	63.8	61.45	62.6	83.8	82	82.9	106.8	100.7	103.7
FYM 10 t ha^{-1} + N-P_2O_5-K_2O 100-60-100 kg ha^{-1}	25.1	15.2	20.1	65.2	63.4	64.3	86.4	85.4	85.9	109.9	104.6	107.2
FYM 25 t ha^{-1}	15.6	14.5	15.1	64.5	62.5	63.5	88.6	86.2	87.4	114.3	106.8	110.5
LSD (0.05)	1.6	2.2	1.9	3.0	2.8	3.6	4.1	4.3	4.4	7.6	6.3	9.7

Table 2. Effect of fertility levels on canopy spread (cm) of elephant foot yam

Treatments	2 MAP			3 MAP			4 MAP			5 MAP		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
Control(No fertilizer)	19.7	23.1	21.4	53.2	52.5	52.8	70.2	69.0	69.6	87.4	85.0	86.2
N-P_2O_5-K_2O 60-60-60 kg ha^{-1}	21.1	22.3	21.7	54.1	53.3	53.7	71.8	71.0	71.4	89.7	86.9	88.3
N-P_2O_5-K_2O 80-60-80 kg ha^{-1}	23.4	25.9	24.6	55.4	54.3	54.8	74.2	72.6	73.4	94.1	89.9	92.0
N-P_2O_5-K_2O 100-60-100 kg ha^{-1}	26.4	25.5	25.9	58.6	56.5	57.5	75.8	73.5	74.6	93.8	90.5	92.1
FYM 10 t ha^{-1} + N-P_2O_5-K_2O 60-60-60 kg ha^{-1}	26.8	26.4	26.6	59.3	57.1	58.2	78.3	76.7	77.5	97.7	95.6	96.6
FYM 10 t ha^{-1} + N-P_2O_5-K_2O 80-60-80 kg ha^{-1}	29.1	28.3	28.7	60.2	57.9	59.1	80.2	79.0	79.6	99.9	99.4	99.6
FYM 10 t ha^{-1} + N-P_2O_5-K_2O 100-60-100 kg ha^{-1}	30.3	28.8	29.6	62.3	61.3	60.9	83.4	82.3	82.8	103.7	100.3	102.0
FYM 25 t ha^{-1}	27.8	26.8	27.3	60.4	57.1	58.7	86.9	83.3	85.1	107.8	105.1	106.4
LSD (0.05)	3.7	4.4	4.3	3.2	3.6	3.4	7.0	5.8	7.2	8.7	6.3	8.1

resulted in significantly shorter pseudostem and lesser canopy spread at all the growth stages during both the years. This might be due to the non-availability of required nutrients from the soil for the growth and development. The differential effects of inorganic nutrients levels and their combinations with FYM on pseudostem diameter were also observed during the experiment. It was evident from Table 3 that at all stages, application of FYM 10 t ha^{-1} + N-P_2O_5-K_2O 100-60-100 kg ha^{-1} and FYM 25 t ha^{-1} had resulted in larger pseudostem diameter compared to other treatments. Significantly lower pseudostem diameter was observed in control. Number of leaflets per plant was recorded higher with the application of FYM 25 t ha^{-1} and FYM 10 t ha^{-1} + N-P_2O_5-K_2O 100-60-100 kg ha^{-1} compared to other treatments at all the stages except 2 MAP. At 2 MAP, the treatment FYM 10 t ha^{-1} + N-P_2O_5-K_2O 100-60-100 kg ha^{-1} resulted in higher number of leaflets per plant. However, it was on par with FYM 10 t ha^{-1} + N-P_2O_5-K_2O 80-60-80 kg ha^{-1}. This indicated that application of inorganic source of nutrients is essential for immediate availability of nutrients to the crops. Nutrients from FYM were available to the crops at later stages due to slow mineralization. Significantly lowest numbers of leaflets per plant were observed in control.

Table 3. Effect of fertility levels on pseudostem diameter (cm) of elephant foot yam

Treatments	2 MAP			3 MAP			4 MAP			5 MAP		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
Control(No fertilizer)	4.1	4.3	4.2	4.3	4.4	4.3	8.5	8.1	8.3	11.3	10.5	10.9
N-P_2O_5-K_2O 60-60-60 kg ha^{-1}	4.2	4.1	4.1	4.6	4.5	4.5	8.9	8.7	8.8	11.5	10.9	11.2
N-P_2O_5-K_2O 80-60-80 kg ha^{-1}	4.2	4.5	4.3	4.7	4.8	4.7	9.3	9.1	9.2	11.8	11.5	11.6
N-P_2O_5-K_2O 100-60-100 kg ha^{-1}	4.7	4.4	4.5	5.4	5.1	5.2	9.8	9.4	9.6	12.9	12.5	12.7
FYM 10 t ha^{-1} + N-P_2O_5-K_2O 60-60-60 kg ha^{-1}	4.8	4.7	4.7	5.4	5.2	5.3	10.1	9.9	10.0	13.2	12.6	12.9
FYM 10 t ha^{-1} + N-P_2O_5-K_2O 80-60-80 kg ha^{-1}	5.4	4.4	4.9	5.8	5.7	5.7	11.7	11.5	11.6	13.4	12.8	13.1
FYM 10 t ha^{-1} + N-P_2O_5-K_2O 100-60-100 kg ha^{-1}	6.7	5.2	5.9	6.8	6.5	6.6	12.3	11.9	12.1	14.1	13.7	13.9
FYM 25 t ha^{-1}	6.7	5.0	5.8	6.5	6.2	6.3	11.4	11.6	11.5	13.9	13.3	13.6
LSD (0.05)	0.6	0.4	0.6	0.8	1.2	1.1	1.0	0.8	0.8	0.6	0.8	0.8

Table 4. Effect of fertility levels on number of leaflets per plant of elephant foot yam

Treatments	2 MAP			3 MAP			4 MAP			5 MAP		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
Control(No fertilizer)	100	66	83	156	122	139	168	148	158	176	162	169
N-P_2O_5-K_2O 60-60-60 kg ha^{-1}	112	73	93	157	133	145	174	154	164	196	174	185
N-P_2O_5-K_2O 80-60-80 kg ha^{-1}	123	78	101	164	151	158	196	168	182	198	190	194
N-P_2O_5-K_2O 100-60-100 kg ha^{-1}	133	84	108	172	156	164	184	176	180	207	201	204
FYM 10 t ha^{-1} + N-P_2O_5-K_2O 60-60-60 kg ha^{-1}	147	89	118	170	157	163	188	178	183	204	198	201
FYM 10 t ha^{-1} + N-P_2O_5-K_2O 80-60-80 kg ha^{-1}	177	117	147	182	159	171	198	196	197	222	210	216
FYM 10 t ha^{-1} + N-P_2O_5-K_2O 100-60-100 kg ha^{-1}	187	123	155	190	175	183	222	216	219	252	238	245
FYM 25 t ha^{-1}	168	115	142	199	182	190	242	222	232	273	261	267
LSD (0.05)	17	12	12	20	26	22	16	18	24	26	30	38

The effect of differential fertility levels on the yield attributes and yield of elephant foot yam during 2011 and 2012 is presented in Table 5. The pooled mean data for both the years revealed that the treatment FYM 10 t ha^{-1} + N-P_2O_5-K_2O 100-60-100 kg ha^{-1} resulted in highest corm diameter and corm yield per plant closely followed by FYM 25 t ha^{-1}, FYM 10 t ha^{-1} + N-P_2O_5-K_2O 80-60-80 kg ha^{-1} and FYM 10 t ha^{-1} + N-P_2O_5-K_2O 60-60-60 kg ha^{-1}. As expected, the lowest corm yield was recorded with the elephant foot yam plant having no fertility supplements (control treatment). The corm yield increased gradually with increase in fertility levels and similar trend of fertilizer response was reported in yam (Azih, 1976; Gooding, 1971; Kpeglo et al., 1981; Nwinyi, 1984; Shyu and Cheng, 1978) and as well as in taro (Ramaswamy et al., 1982) and in elephant foot yam (Mukhopadhyay and Sen, 1999).

The treatments FYM 10 t ha^{-1} + N-P_2O_5-K_2O 100-60-100 kg ha^{-1} and FYM 25 t ha^{-1} had resulted in higher corm yield per ha and both the treatments were statistically on par (Table 5). Application of FYM 10 t ha^{-1} + N-P_2O_5-K_2O 100-60-100 kg ha^{-1} increased the corm yield by 105 per cent over the control, whereas, FYM 25 t ha^{-1} increased 97.3 per cent corm yield over control. The higher corm yield in these treatments was due to higher growth (Table 1-4) and yield attributes (Table 5). The FYM 10 t ha^{-1} + N-P_2O_5-K_2O 100-60-100 kg ha^{-1} also recorded significantly more corm yield than the N-P_2O_5-K_2O 100-60-100 kg ha^{-1}. This might be due to the additional nutrients available from the FYM along with maintaining higher soil moisture. Thus, indicating the essentiality of integrated use of FYM and fertilizer. However, the corm yield did not increase appreciably at lower dose of N-P_2O_5-K_2O i.e. 60-60-60 kg ha^{-1}.

The data pertaining to N, P and K uptake of elephant foot yam (Table 6) revealed that the application of FYM 10 t ha^{-1} + N-P_2O_5-K_2O 100-60-100 kg ha^{-1} resulted in maximum N, P and K uptake. It was statistically on par with FYM 25 t ha^{-1}. Better utilization of N, P and K was observed in the treatments having integrated nutrient management or higher level of FYM application. This might also be due to higher growth and yield in these treatments. The lowest nitrogen, phosphorus and potassium uptake was observed in control. In this treatment the plant uptake depended on soil native fertility only. The post-harvest soil nutrient status revealed that maximum soil N was available in N-P_2O_5-K_2O 100-60-100 kg ha^{-1} (Table 6). This might be due to un-utilization of applied N in this treatment. The maximum post harvest soil P_2O_5 was observed in FYM 10 t ha^{-1} + N-P_2O_5-K_2O 60-60-60 kg ha^{-1}. This might be due to more application of P and lesser utilization of P by the crop. Elephant foot yam response to P_2O_5 was observed up to 60 kg ha^{-1} (Nair and Mohankumar, 1991; Sethi *et al*., 2002). Higher

Table 5. Effect of fertility levels on yield attributes and yield of elephant foot yam

Treatments	Corm diameter (cm)			Corm yield (g plant^{-1})			Corm yield (t ha^{-1})		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
Control (No fertilizer)	23.8	15.3	19.5	1100	990	1045	18.7	17.90	18.3
N-P_2O_5-K_2O 60-60-60 kg ha^{-1}	25.0	16.2	20.6	1500	1280	1390	25.5	23.1	24.3
N-P_2O_5-K_2O 80-60-80 kg ha^{-1}	21.6	21.6	21.6	1650	1460	1555	28.1	26.3	27.2
N-P_2O_5-K_2O 100-60-100 kg ha^{-1}	22.0	24.0	23.0	1710	1680	1695	30.2	29.0	29.6
FYM 10 t ha^{-1} + N-P_2O_5-K_2O 60-60-60 kg ha^{-1}	20.1	26.7	23.4	1970	1720	1845	33.6	31.0	32.3
FYM 10 t ha^{-1} + N-P_2O_5-K_2O 80-60-80 kg ha^{-1}	24.2	24.8	24.5	2140	1900	2020	36.5	34.3	35.4
FYM 10 t ha^{-1} + N-P_2O_5-K_2O 100-60-100 kg ha^{-1}	25.7	25.4	25.5	2240	2060	2150	38.2	37.0	37.6
FYM 25 t ha^{-1}	25.7	23.6	24.6	2130	1990	2060	36.3	35.6	36.1
LSD (0.05)	9.0	8.3	2.5	82	47	124	1.4	2.2	2.1

Table 6. Effect of fertility levels on nutrient uptake by elephant foot yam (Pooled mean of 2 years)

Treatments	Nutrient uptake (kg ha^{-1})			Post harvest soil nutrient status (kg ha^{-1})		
	N	P	K	N	P_2O_5	K_2O
Control (No fertilizer)	42.8	5.3	33.8	69.0	10.8	177.2
$N-P_2O_5-K_2O$ 60-60-60 kg ha^{-1}	54.4	7.3	46.6	73.5	14.2	190.7
$N-P_2O_5-K_2O$ 80-60-80 kg ha^{-1}	59.1	8.6	65.7	82.8	14.9	230.2
$N-P_2O_5-K_2O$ 100-60-100 kg ha^{-1}	67.1	9.6	72.5	86.5	15.8	227.0
FYM 10 t ha^{-1} + $N-P_2O_5-K_2O$ 60-60-60 kg ha^{-1}	74.7	10.2	77.0	75.4	16.9	210.2
FYM 10 t ha^{-1} + $N-P_2O_5-K_2O$ 80-60-80 kg ha^{-1}	91.0	11.4	84.7	70.5	16.3	224.7
FYM 10 t ha^{-1} + $N-P_2O_5-K_2O$ 100-60-100 kg ha^{-1}	100.6	14.8	101.3	72.2	15.0	223.0
FYM 25 t ha^{-1}	94.1	13.7	98.5	74.0	13.4	216.3
LSD (0.05)	7.3	1.7	7.1	7.5	1.7	20.1

post harvest soil K_2O was observed with $N-P_2O_5-K_2O$ 100-60-100 kg ha^{-1} and $N-P_2O_5-K_2O$ 80-60-80 kg ha^{-1}. This was due to non utilization of applied K.

It can be concluded that application of FYM 10 t ha^{-1} + $N-P_2O_5-K_2O$ 100-60-100 kg ha^{-1} or FYM 25 t ha^{-1} is essential for higher growth and corm yield in alfisols under irrigation. These treatments also reduced mining of the soil.

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