



Effects of Organic and Inorganic Fertilizers on Yield of Elephant Foot Yam and Soil Enzymes Activity

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Abstract

A field experiment was carried out for two consecutive years during 2011 and 2012, to study the effects of organic and inorganic fertilizers on leaf area and yield of elephant foot yam and soil enzyme activities. The experiment was conducted at the Regional Centre of Central Tuber Crops Research Institute, Bhubaneswar using randomized block design (RBD) with three replications. The experiment comprised of eight treatments involving organic and inorganic fertilizers. Highest leaf area per plant was recorded with the application of FYM 25 t ha⁻¹ and the application of FYM 10 t ha⁻¹ with NPK@ 100-60-100 kg ha⁻¹. These treatments also resulted in higher light interception and offered lower soil resistance. The application of FYM 10 t ha⁻¹ + NPK@ 100-60-100 kg ha⁻¹ and FYM 25 t ha⁻¹ has produced 105.7% and 97.1% higher corm yield respectively, over control. These treatments maintained higher soil enzyme activities despite poor post harvest soil nutrient status. In alfisols, medium duration elephant foot yam can be cultivated profitably under protective irrigation with the application of FYM 10 t ha⁻¹ + NPK@ 100-60-100 kg ha⁻¹ or FYM 25 t ha⁻¹ with enhanced soil enzyme activity.

Key words: Elephant foot yam, nutrient management, soil enzyme, soil resistance, yield

Introduction

Elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson (Aracea)], is regarded as king of tuber crops due to its high yield potential and profitability. In India, it is cultivated under large area in Andhra Pradesh, Bihar, Chhattisgarh, Jharkhand, Gujarat, Kerala, Maharashtra, Tamil Nadu, Uttar Pradesh, West Bengal and North Eastern States (Nedunchezhiyan and Byju, 2005). Elephant foot yam is regarded as a commercial crop due to its high productivity and popularity as vegetable in various Indian cuisines. It is rich in carbohydrates and is a good source of proteins and vitamins (Bradbury and Holloway, 1988). It is also a good source of Vitamin A, rich in dietary fibre and has several valuable medicinal and therapeutic values (Chattopadhyay and Nath, 2007).

Providing adequate nutrition is essential for higher growth and tuber yield of elephant foot yam. Studies indicated that elephant foot yam is a fertilizer-responsive crop that produced profitable yields under adequate fertilizing. In the sandy loam soils of West Bengal, elephant foot yam produced high tuber yield with the application of NPK @ 150:60:50 kg ha⁻¹ in six months (Mukhopadhyay and Sen, 1986). Nair and Mohankumar (1991) reported that under Kerala conditions ten months duration elephant foot yam required a fertilizer dose of 100:50:150 kg N, P₂O₅ and K₂O ha⁻¹ for optimum yield. Applying organic source of nutrients is one of the viable approaches to maximize the elephant foot yam productivity and quality while maintaining soil fertility (Suja et al., 2006; Suja and Sundaresan, 2008). Organic source of fertilisers

enhanced soil structure and reduced the soil resistance for tuberous crops. Several studies conducted on potato indicated that soil resistance against to tubers growth was reduced by compost application (Tu et al., 2006; Taheri et al., 2012). Patel and Mehta (1987) reported higher corm yield with the application of FYM 30 t ha⁻¹ in Gujarat. Another experiment conducted in Kerala reported that elephant foot yam yield increased three times when N, P₂O₅ and K₂O 80:80:120 kg ha⁻¹ was applied along with FYM 25 t ha⁻¹ (Mandal and Saraswat, 1968).

The total leaf area of a plant or the size of a canopy is an important determinant of its light interception, growth, water use efficiency, energy and gas exchange related to photosynthesis. It determines the unit-level dry matter production in elephant foot yam (Ravi et al., 2010). The leaf area index (LAI) increased with time and reached maximum (6.1) at 120 days after planting (DAP) at a planting density of 14,420 plants per ha (Das et al., 1997). Studies indicated that the leaf spread of organically grown and conventionally raised elephant foot yam plants were comparable till six month after planting (MAP) (Suja et al., 2012).

Incorporation of organic manures in soil increases soil enzymatic activity due to alteration in the soil structure that favour microbial growth, and beneficial effects of added minerals from organic manure into the soil. (Goyal et al., 1993). Enzyme activities play key role in the biochemical functioning of soils by catalyzing soil organic matter formation, degradation and nutrient cycling. Soil enzymatic activity is responsible for the formation of stable organic molecules that contribute to the permanence of the soil ecosystem as well as facilitate nitrogen (urease) and phosphorus (phosphatase) cycles (Pascual et al., 2002). These processes together help in maximising leaf area or size of canopy and enhancing tuber yield (Suja, 2013). Keeping the above in view, an investigation was carried out to study the effects of organic and inorganic fertilizers on leaf area, yield and soil enzyme activities of the elephant foot yam grown in alfisols.

Materials and Methods

A field experiment on elephant foot yam cv. *Gajendra* was carried out for consecutive two years during 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 33m above mean sea level), Dumuduma, Bhubaneswar, Odisha, India. The soil type of experimental site was alfisols with sandy loam texture with a p^H of 6.7. A Randomized Block Design (RBD) was used with three replications. The experiment comprised eight treatments viz. Control, T₁ - NPK @ 60:60:60 kg ha⁻¹, T₂ - NPK @ 80:60:80 kg ha⁻¹, T₃ - NPK @ 100:60:100 kg ha⁻¹, T₄ - FYM 10 t ha⁻¹ + NPK @ 60:60:60 kg ha⁻¹, T₅ - FYM 10 t ha⁻¹ + NPK @ 80:60:80 kg ha⁻¹, T₆ - FYM 10 t ha⁻¹ + NPK @ 100:60:100 kg ha⁻¹ and T₇ - FYM 25 t ha⁻¹. The elephant foot yam cv. *Gajendra* was planted at a spacing of 75 cm on the ridges formed at a spacing of 75 cm. The fertilizers and manures were applied as per dosage prescribed in the treatments. Single super phosphate (SSP) along with 1/3rd of N and K were applied as basal dose during the final ploughing while rest of N and K were applied in two equal splits at one and two months after planting. Protective irrigation was given as per requirement. During the year 2011 and 2012, the crop was planted in May and harvested during December after eight months.

During 2011 and 2012, the mean monthly maximum temperature ranged between 29.0-37.3°C and 29.7-39.3°C while minimum temperature dropped between 15.5-26.1°C and 15.3-27.2°C range 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 in 2011 and 2012 was 1450.5 and 1097.3 mm, respectively. A total of 95 rainy days was recorded during 2011 while 85 rainy days were observed during 2012.

Leaf area per plant was measured at 3 and 5 months after planting (MAP) by dissecting leaflets from the plants and fed into leaf area meter (Biovis). The leaf area is expressed in cm² plant⁻¹. Leaf area index (LAI) was calculated at 3 and 5 MAP by dividing total leaf area of a plant by plant spacing. Light interception (%) at canopy was computed at 3 and 5 MAP. Light measurements above and below canopy were measured with digital light meter (LX-101A; Lutron Electronic Enterprise Co., Ltd). The difference of light measurement above and below canopy was multiplied with 100 and expressed in percentage of light interception. Soil resistance was measured with penetrometer (Eijkelkamp, The Netherlands) at 3 and 5 MAP and expressed in MPa.

Yield attributes and yield was recorded at harvest (8 MAP). Corm bulking rate (CBR) was recorded between 0-3, 3-5 and 5-8 MAP and expressed in g day^{-1} which was calculated as follows:

$$\text{CBR (g plant}^{-1}\text{)} = \frac{W_2 - W_1}{t_1 - t_2}$$

Where, W_2 and W_1 are the final and initial weight in gram (g) per plant at time t_1 and t_2 respectively.

Corm bulking efficiency (CBE) was computed between 0-3, 3-5 and 5-8 MAP and was worked out by using the following equation:

$$\text{CBE (\%)} = \frac{C_o - C_s}{S_c} \times 100$$

where, C_o and C_s are the corm weight at the time of observation and weight of seed corm (S_c) planted, respectively. Urease and acid phosphatase enzyme content in soil were analyzed following Tabatabai (1994). Soil available nitrogen, phosphorus and potassium were analysed by following the methods suggested by Subbiah and Asija (1956), Bray and Kurtz (1945) and Jackson (1967). The data were analyzed using descriptive statistics and Analysis of Variance (ANOVA) as suggested by Panse and Sukhatme (1967). All the statistical analyses were performed using GenStat Discovery (edition 3; VSN International).

Results and Discussion

Leaf area

In elephant foot yam, leaf area development continued up to 5 MAP and then the plants started senescence. Thus, the leaf area per plant was recorded in 3 and 5 MAP. Data presented in the Table 1 indicated that at 3 MAP, higher leaf area per plant was noticed for the treatments T_7 : FYM 25 t ha^{-1} and T_6 : FYM 10 t ha^{-1} + NPK @ 100:60:100 kg ha^{-1} , indicating their superiority over other treatments (Table 1). At 5 MAP, maximum leaf area per plant was observed with the application of T_7 : FYM 25 t ha^{-1} followed by T_6 : FYM 10 t ha^{-1} + NPK @ 100:60:100 kg ha^{-1} . In general, leaf area per plant was found significantly higher with the application of graded level of inorganic fertilizers along with FYM 10 t ha^{-1} than the application of only graded level of inorganic

fertilizers both at 3 and 5 MAP. LAI had a positive linear relationship with total leaf area per plant (Table 1). The treatments having higher leaf area per plant recorded correspondingly higher LAI. Higher LAI helps to intercept more light for photosynthesis leading to high dry matter production (Ravi et al., 2011).

Light interception

Light interception through the canopy system was significantly influenced by varied organic and inorganic fertilizer levels in elephant foot yam as evidenced in Table 1. At 3 and 5 MAP, the highest light interception was recorded in T_7 : FYM 25 t ha^{-1} and the application of T_6 : FYM 10 t ha^{-1} + NPK @ 100:60:100 kg ha^{-1} . These treatments were significantly superior to other treatments in enhancing light interception, due to larger LAI which might have intercepted more light in the canopy column. Higher light interception led to higher photosynthesis, which led to higher vegetative growth and corm yield. The next higher level of light interception was recorded in the plants which received graded levels of fertilizers (NPK @ 100:60:100, 80:60:80 and 60:60:60 kg ha^{-1}) along with FYM 10 t ha^{-1} . The lowest light interception was noticed in control, which had lower leaf area per plant than other treatments (Table 1).

Soil resistance

Tuberous crops like elephant foot yam require lesser soil resistance for favourable corm growth and development. Organic and inorganic fertilizer levels had significant impact on soil resistance (Table 1). At 3 and 5 MAP, significantly lower soil resistance was observed in T_7 : FYM 25 t ha^{-1} . Application of graded levels of fertilizers (NPK @ 100:60:100, 80:60:80 and 60:60:60 kg ha^{-1}) along with FYM 10 t ha^{-1} recorded lower level of soil resistance than application of only graded levels of inorganic fertilizers at 3 and 5 MAP. Nedunchezhiyan et al. (2013) reported that lower soil resistance in FYM and paddy straw applied sweet potato fields. Lower soil resistance in the rhizosphere facilitates rapid bulking of the corms. The control or no fertilizer treatment recorded lower soil resistance than only inorganic fertilizer applied treatments at 3 and 5 MAP (Table 1).

Yield

Significant differences in the corm diameter due to effects of organic and inorganic fertilizer levels were noticed

Table 1. Effect of organic, inorganic fertilizers on light interception and soil resistance of elephant foot yam (Pooled data of 2011-2012)

Treatments	Leaf area (cm ²) plant ⁻¹		LAI		Light interception(%)		Soil resistance(MPa)	
	3 MAP	5 MAP	3 MAP	5 MAP	3 MAP	5 MAP	3 MAP	5 MAP
Control (No fertilizer)	5525	9126	0.98	1.62	29.9	46.2	0.399	0.385
T ₁	5595	10175	0.99	1.80	33.6	60.3	0.421	0.405
T ₂	6252	10864	1.11	1.93	36.9	60.2	0.426	0.438
T ₃	6525	11628	1.16	2.06	37.9	65.4	0.438	0.446
T ₄	7335	11658	1.30	2.07	38.2	65.4	0.351	0.308
T ₅	7695	12744	1.36	2.26	45.6	65.4	0.338	0.306
T ₆	8418	14700	1.49	2.61	50.6	66.8	0.331	0.285
T ₇	8740	16020	1.55	2.84	54.1	71.2	0.288	0.231
CD (0.05)	342	1248	0.12	0.16	4.1	5.8	0.023	0.031

(Table 2). The pooled mean data for two experimental years of investigation revealed that T₆: FYM 10 t ha⁻¹ + NPK @ 100:60:100 kg ha⁻¹ resulted in highest corm diameter and it was on par with T₇: FYM @ 25 t ha⁻¹, T₅: FYM @ 10 t ha⁻¹ + NPK @ 80:60:80 kg ha⁻¹. Significantly higher corm yield per plant was observed with T₆: FYM 10 t ha⁻¹ + NPK @ 100:60:100 kg ha⁻¹ and T₇: FYM 25 t ha⁻¹. This was due to higher leaf area development in these treatments (Table 1) intercepted more light and produced more photosynthates, and in turn which translocated to bulking corms. Lesser soil resistance favoured smooth bulking of corms in these treatments (Table 1), which can be evidenced by higher corm diameter (Table 2). Marked variation in CBR was observed due to organic and inorganic fertilizer levels (Table 2). At 0-3 and 3-5 MAP, higher CBR was noticed with T₆: FYM 10 t ha⁻¹ + NPK @ 100:60:100 kg ha⁻¹ and T₇: FYM 25 t ha⁻¹. At 5-8 MAP, higher CBR was registered with T₆:

FYM 10 t ha⁻¹ + NPK @ 100:60:100 kg ha⁻¹, T₇: FYM 25 t ha⁻¹ and T₅: FYM @ 10 t ha⁻¹ + NPK @ 80:60:80 kg ha⁻¹. Higher photosynthesis and favourable rhizosphere nutrients led to higher CBR in these treatments. The application of T₆: FYM 10 t ha⁻¹ + NPK @ 100:60:100 kg ha⁻¹ was resulted in higher CBE through out the crop growth period. However, it was on par with the application of T₇: FYM 25 t ha⁻¹ at later stages (3-5 and 5-8 MAP).

The corm yield increased gradually with addition of FYM as well as due to increase in soil fertility level (Table 2). The application of T₆: FYM 10 t ha⁻¹ + NPK @ 100:60:100 kg ha⁻¹ and T₇: FYM 25 t ha⁻¹ enhanced the corm yield as compared to other treatments. The yield increase was about 105.7% in T₆: FYM 10 t ha⁻¹ + NPK @ 100:60:100 kg ha⁻¹ and 97.1 % in T₇: FYM 25 t ha⁻¹ over control. The higher corm yield in these treatments was due to higher photosynthates production from higher leaf

Table 2. Effect of organic, inorganic fertilizers on yield attributes and corm yield of elephant foot yam (Pooled data of 2011-2012)

Treatments	Corm diameter (cm)	Corm yield (g plant ⁻¹)	CBR(g day ⁻¹)			CBE(%)			Corm yield (t ha ⁻¹)
			0-3 MAP	3-5 MAP	5-8 MAP	0-3 MAP	3-5 MAP	5-8 MAP	
Control	19.6	1045	3.6	5.0	5.6	9.0	54.5	161.3	18.3
T ₁	20.6	1390	4.8	5.9	6.2	20.9	98.1	247.5	24.3
T ₂	21.6	1555	5.0	6.9	7.1	26.4	129.8	288.8	27.2
T ₃	23.0	1695	5.9	7.5	7.9	31.8	141.1	323.8	29.6
T ₄	23.4	1845	6.6	7.9	8.8	48.1	166.5	361.3	32.3
T ₅	24.5	2020	7.8	8.5	9.0	75.8	202.9	405.0	35.4
T ₆	25.6	2150	8.3	9.1	9.5	87.3	224.0	437.5	37.6
T ₇	24.7	2060	7.9	9.0	9.0	78.9	212.4	415.0	36.1
CD (0.05)	1.9	124	0.3	0.5	0.5	5.2	14.1	32.1	2.1

area, higher corm diameter, adequate availability of essential nutrients in the rhizosphere and lesser soil resistance. Incremental increase of inorganic fertilizers with or without FYM correspondingly enhanced the corm yield demonstrating the need for adequate nutrition for realizing higher yield. Similar fertilizer response was reported in yam (Nwinyi, 1984), taro (Ramaswamy et al., 1982) and elephant foot yam (Mukhopadhyay and Sen, 1986). The corm yield in control treatment was significantly lower due to inadequate photosynthetic area (Table 1), poor corm bulking (Table 2) and higher soil resistance (Table 1).

Soil enzymes

Enzyme activity was an index of soil productivity and plays a key role in soil nutrient cycling (Badiane et al., 2001). Sole application of organic manure (FYM) or combining it with inorganic fertilizers, have significantly increased the urease enzyme activity in the soil than application of inorganic fertilizer alone (Table 3). In this work, higher urease enzyme activity was observed in treatments T₇: FYM 25 t ha⁻¹ and T₆: FYM 10 t ha⁻¹ + NPK @ 100:60:100 kg ha⁻¹. Application of inorganic fertilizers alone at different doses could not significantly increase the soil urease activity over control, though incremental increase was observed across the treatments (Table 3). Organic manures coupled with inorganic fertilizers induced higher urease activity in the soil which might be due to increased levels of soil organic matter coupled with rise in micro flora and micro fauna. Nedunchezhiyan et al. (2010) reported higher urease activity in the sweet potato grown soil when various types of organic manures applied. The similar results were also

reported by Pancholy and Rice (1973). Palma and Conti (1990) who reported that increased urease activity related to type of vegetation and the quality of added organic materials into the soil. Data pertaining to acid phosphatase activity (Table 3) revealed that the treatments T₇: FYM 25 t ha⁻¹ and T₆: FYM 10 t ha⁻¹ + NPK @ 100:60:100 kg ha⁻¹ exhibited higher acid phosphatase activity in the soil. The higher acid phosphatase activity in these treatments might be due to presence of higher substrate availability i.e. available phosphorous, moisture, organic carbon, nitrogen and potassium. Enzymes present in the organic manures may also directly increase enzyme activities (Dick and Tabatabai, 1984). Singh (2002) also reported similar observations in the degraded forests soils of Arunachal Pradesh. Higher urease and acid phosphatase activity indicated higher amount of mineralization of N and P, which are available to the crop for growth and development (He et al., 2010). This was evidenced by higher leaf area development and corm yield in these treatments.

Post harvest soil nutrient status

The post-harvest soil nutrient status revealed that maximum soil available nitrogen was found in T₃: NPK @ 100-60-100 kg ha⁻¹ which is at par with T₂: NPK @ 80:60:80 kg ha⁻¹ (Table 3). In these treatments, the crop didn't utilize the applied nitrogen, as evidenced by lower leaf area development and corm yield in these plants (Table 1 and 2). The maximum soil available phosphorous was observed in the treatment T₄: FYM 10 t ha⁻¹ + NPK @ 60:60:60 kg ha⁻¹ (Table 3) and it was statistically on par with T₅: NPK @ 80-60-80 kg ha⁻¹ and T₃: NPK @ 100-60-100 kg ha⁻¹. In this case too, the crop didn't fully

Table 3. Effect of organic, inorganic fertilizers on soil enzyme activity and post harvest soil nutrient status of elephant foot yam (Pooled data of 2011-2012)

Treatments	Urease (mg NH ₄ g soil ⁻¹ h ⁻¹)	Acid phosphatase (mg pNP g soil ⁻¹ h ⁻¹)	Post harvest soil nutrient status (kg ha ⁻¹)		
			AvailableN	AvailableP ₂ O ₅	AvailableK ₂ O
Control	40.815	69.965	69.01	10.80	177.20
T ₁	41.115	71.750	73.50	14.17	190.73
T ₂	44.135	70.980	82.76	14.88	230.18
T ₃	44.185	73.345	86.45	15.77	226.98
T ₄	57.785	72.035	75.43	16.86	210.20
T ₅	63.965	73.050	70.51	16.33	224.73
T ₆	65.765	74.810	72.21	15.03	222.95
T ₇	69.515	75.100	74.03	13.39	216.32
CD (0.05)	4.947	2.848	7.49	1.69	20.06

utilize the applied phosphorus.. Sole application of inorganic fertilizers T₂: NPK @ 80:60:80 kg ha⁻¹ and T₃: NPK @ 100-60-100 kg ha⁻¹ recorded with higher post harvest soil available potassium content. This might be due to the crop not utilizing the applied potassium. The application of T₇: FYM 25 t ha⁻¹ and T₆: FYM 10 t ha⁻¹ + NPK @ 100:60:100 kg ha⁻¹ recorded lower post harvest soil nutrients status due to utilization of applied nutrients by the crop indicated in the higher corm yields (Table 2). The lowest soil available nitrogen, phosphorus and potassium were observed with control treatment. This might be due to mining of the crop and no external application of nutrients.

Conclusion

This field experiment conducted with elephant foot yam cv. *Gajendra* in Odisha state of India revealed that the application of FYM 10 t ha⁻¹ + NPK @ 100:60:100 kg ha⁻¹ or FYM 25 t ha⁻¹ is required for profuse vegetative growth (leaf area), better light interception and higher corm yield in alfisols under protective irrigated condition. Higher urease and acid phosphatase activity observed in these treatments due to higher substrate availability, led to high mineralization of N and P. Higher availability of soil N and P enabled the elephant foot yam crop to utilize these nutrients for profuse growth and corm bulking.

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