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Research Paper

Drip irrigation and fertigation effects on corm yield, water- and fertilizer-use efficiency and economics in elephant foot yam (*Amorphophallus paeoniifolius*)

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ABSTRACT

A field experiment was conducted during 3 consecutive years (2009–11) at Dumuduma, Bhubaneshwar, Odisha, to study the effect of drip irrigation and fertigation levels on corm yield, water-and fertilizer-use efficiency as well as economics in elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson]. The experiment laid out in a split-plot design with 3 replications, consisted of 3 drip irrigation levels, viz. I_1, 60% cumulative pan evaporation (CPE); I_2, 80% CPE and I_3, 100% CPE, in main plots and 3 fertigation levels, viz. F_1, N-K_2O @ 80-80 kg/ha; F_2, N-K_2O @ 100-100 kg/ha and F_3, N-K_2O @ 120-120 kg/ha in subplots. A control treatment (flood irrigation and soil application of N-P_2O_5-K_2O @ 100-60-100 kg/ha) was also included for comparison. Soil application of P_2O_5 @ 60 kg/ha was done in all the fertigation treatments and farmyard manure @ 10 t/ha was applied to all the treatments during the last ploughing and incorporated into the soil. Higher corm length, diameter and yield/plant were recorded with drip irrigation at 100% CPE with fertigation of N-K_2O @ 120-120 kg/ha. The highest corm yield (37.0 t/ha) was obtained due to drip irrigation at 100% CPE and fertigation of N-K_2O @ 120–120 kg/ha. However, the maximum water-use efficiency (WUE) was recorded with drip irrigation at 80% CPE and fertigation of N-K_2O @ 120-120 kg/ha. This treatment resulted in optimum corm yield (35.7 t/ha) with net saving of 4,341,000 litres (434.1 mm) of water/ha of land/season, net income of 154 × 10^3 ₹/ha and net profit ₹701/mm of water applied.

Key words **:** Consumptive use, Corm yield, Elephant foot yam, Water-use efficiency

Elephant foot yam is a tuberous vegetable crop cultivated throughout India, in particular in Andhra Pradesh, West Bengal, Bihar, Uttar Pradesh, Tamil Nadu, Kerala, Maharashtra, Odisha and Karnataka (Nedunchezhiyan and Byju, 2005). Commercially the crop is grown under protective irrigation. Irrigation through drip saves lot of water (scarce commodity). Drip irrigation is an efficient method of providing water directly into the root zone of plants. It checks unwanted weed growth and reduces water requirements. Irrigation efficiency in drip irrigation is as high as 90% compared to 30–50% in surface irrigation, besides substantial saving of water to the extent of 40–80%. The higher crop yields with considerable saving of water and higher water production efficiency in vegetables was reported in drip irrigation system (Manjunath *et al*., 2001; Tiwari *et al*., 2003). Pan evaporation is most widely used method to schedule the irrigation because of its easy and inexpensive use (Ertek *et al*., 2007).

Elephant foot yam is a nutrient exhaustive crop. It is a shallow-rooted crop and its feeding roots are in the top only hence it exhausts nutrients from the topsoil. A crop yielding 33 tonnes of corm removed 128.8 kg N, 23.6 kg P and 239.6 kg K/ha (Kabeerathumma *et al*., 1987). The method of nutrient application is important in improving the use efficiency of nutrients. Fertigation is a method of application of fertilizers through irrigation. Fertigation enables adequate supply of water and nutrients with precise timing and uniform distribution to meet the crop requirement to get maximum yield (Patel and Rajput, 2000; Chawla and Narda, 2002). Phene *et al*. (1979) reported 25–50% reduction in fertilizer use using drip system compared to surface broadcasting with no yield reduction. Drip fertigation is considered to be the most efficient in improving the yield and saving of water (Behera *et al*., 2013). Thus, drip irrigation and fertigation provides ample scope to increase water and fertilizer-use efficiency along with higher yield. Research work on drip-irrigation scheduling and fertigation to elephant foot yam is not available. Hence expansion of the crop in water-limited areas is hindering. Keeping the above in view, it is imperative to study the effect of drip irrigation and fertigation levels on corm yield, water and fertilizer-use efficiency and economics in

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elephant foot yam.

MATERIALS AND METHODS

A field experiment was conducted for 3 consecutive years (2009–11) at the Regional Centre of ICAR-Central Tuber Crops Research Institute, Dumuduma, (20°14' 53.25" N, 85°47' 25.85" E and 33 m above mean sea-level), Bhubaneswar, Odisha. The soil of the experiment site was sandy loam, with field capacity of 14.6% and permanent wilting point 8.6%. The soil water-holding capacity was 60 mm/m depth. Other physico-chemical features of the soil were: bulk density 1.54 g/cc, *p*H 6.2, organic carbon 0.34%, available N 172 kg/ha, available P 21.4 kg/ha and available K 226 kg/ha. The experiment was laid out in a split-plot design with 3 replications. The experiment consisted of 3 drip irrigation levels, viz. I_1 60% cumulative pan evaporation (CPE); I_2, 80% CPE and I_3, 100% CPE, in main plots and 3 fertigation levels, viz. F_1, N-K_2O @ 80-80 kg/ha; F_2, N-K_2O @ 100-100 kg/ha and F_3, N-K_2O @ 120-120 kg/ha, in subplots. A control treatment (flood irrigation and soil application of N-P_2O_5-K_2O @ 100-60-100 kg/ha) was included for comparison. Soil application of P_2O_5 @ 60 kg/ha through single super phosphate was applied in all the fertigation treatments and farmyard manure @ 10 t/ha was applied to all the treatments at the time of last ploughing and incorporated into the soil. The N and K_2O were supplied through urea and muriate of potash respectively. The N and K_2O were applied in 3 splits at 1 (40%), 2 (30%) and 3 (30%) months after planting (MAP). In the control treatment, N and K_2O were applied in soil in 2 splits (50% at 1 MAP and the remaining 50% at 2 MAP). Healthy whole corms of 400–500 g weight treated with cowdung slurry (10 kg fresh cowdung dissolved in 10 litres water and mixed with 50 g *Trichoderma*) 1 day before were planted at 90 cm spacing on the ridges formed at 90 cm spacing. Drip irrigation was given on alternate days throughout the crop growth as per treatments based on pan evaporation, considering pan factor 0.6 and elephant foot yam crop coefficient 0.7. Flood irrigation of 4 cm was given at 7 days interval. The irrigation was withheld 10 days before harvesting. Hand-weeding was carried out at 1, 2 and 3 MAP. The crop was planted on 11 May 2009, 3 May 2010 and 17 April 2011 and harvested on 6 January 2010, 29 December 2010 and 13 December 2011 (8 MAP) during the 3 seasons.

Mean of weather data of 3 years during the crop-growth period are presented here. The mean monthly maximum temperature ranged between 29.0 and 37.8°C, and minimum temperature between 15.4 and 26.6°C. The mean monthly relative humidity varied between 59.3 and 89.2%. The total rainfall during the crop-growing period was 1,411.2 mm in 92 rainy days. The effective rainfall is a part of rainfall available for consumptive use of the crop. The effective rainfall was calculated by soil-moisture balance method (Reddy and Reddi, 2010). The mean effective rainfall was 1,093.3, 1,090.5 and 1,087.6 mm at 60, 80 and 100% CPE respectively. The amount of water applied through drip irrigation in each treatment was computed (mean of three years). It was 164.8, 219.7 and 274.6 mm at 60, 80 and 100% CPE respectively. In the control treatment, 653.8 mm water was applied through flood irrigation.

Corm-yield data was recorded at harvesting. Consumptive use (CU), water-use efficiency (WUE) and fertilizer use efficiency (FUE) were calculated as:

CU (mm) = Irrigation water (mm) + effective rainfall (mm) + soil profile moisture contribution

$$\text{WUE (kg/mm-ha)} = \frac{\text{Corm yield (kg)}}{\text{Consumptive use of water (mm-ha)}}$$

$$\text{FUE (kg/kg)} = \frac{\text{Corm yield (kg)}}{\text{Quantity of fertilizers applied (kg)}}$$

The data were analysed statistically as per to Panse and Sukhatme (1967). The homogeneity of error variance was tested using Bartlett's χ^2-test. As the error variance was homogeneous, pooled analysis of 3 years data was done. The significant differences between the treatments were compared with the critical difference (CD) at a 0.05 level of probability.

RESULTS AND DISCUSSION

Corm yield

Drip irrigation and fertigation levels significantly influenced yield attributes of elephant foot yam (Tables 1, 2). Drip irrigation at 100% CPE resulted in higher corm length, corm diameter and corm yield/plant and it was on par with drip irrigation at 80% CPE (Table 1). Increasing the fertigation levels increased the corm length, corm diameter and corm yield/plant. Significantly higher corm length was noticed with the application of N-K_2O @ 120-120 kg/ha and it was followed by the application of N-K_2O @ 100-100 kg/ha. Corm diameter and corm yield/plant were higher with N-K_2O @ 120-120 kg/ha, but was comparable with N-K_2O @ 100-100 kg/ha, and both the treatments were significantly superior to N-K_2O @ 80-80 kg/ha. Higher levels of nutrients favoured development of larger-size yield attributes. Interaction effect of drip irrigation and fertigation was noticed in corm length, diameter and yield/plant. Drip irrigation at 100% CPE with fertigation of N-K_2O @ 120-120 kg/ha resulted in the

maximum corm length, diameter and yield/plant and it was on par with drip irrigation at 80% CPE with fertigation of N-K_2O @ 120-120 kg/ha and drip irrigation at 100% CPE with fertigation of N-K_2O @ 100-100 kg/ha (Table 2). Corm length, diameter and yield/plant increased by 15.2, 13.0 and 21.4% with drip irrigation at 100% CPE and fertigation of N-K_2O @ 120-120 kg/ha; 11.3, 10.2 and 16.9% with drip irrigation at 80% CPE and fertigation of N-K_2O @ 120-120 kg/ha; and 8.3, 7.3 and 14.9% with drip irrigation at 100% CPE with fertigation of N-K_2O @ 100-100 kg/ha over the control respectively. The higher yield attributes in these treatments was due to stress free moisture and nutrient conditions.

Marked variation in corm yield (t/ha) was noticed with respect to drip irrigation and fertigation levels (Table 1). The maximum corm yield was noticed at the highest irrigation level (100% CPE) (Table 1). However, it was comparable with 80% CPE. Higher corm yield in these treatments was owing to higher yield attributes (Table 1). Increasing the fertigation levels increased the corm yield. Higher corm yield was obtained with the application of N-K_2O @ 120-120 kg/ha (Table 1). The next best treatment was the fertigation of N-K_2O @ 100-100 kg/ha. Venkatesan *et al*. (2014) also reported that the increased application of major nutrients under fertigation increased the corm yield of elephant foot yam. A similar report in cassava was reported by Odubanjo *et al*. (2011). Interaction effect between drip irrigation and fertigation levels was significant (Table 2). The highest corm yield was obtained with drip irrigation at 100% CPE with fertigation of N-K_2O @ 120-120 kg/ha. However, it was on par with the application of drip irrigation at 80% CPE along with N-K_2O @ 120-120 kg/ha and drip irrigation at 100% CPE along with fertigation of N-K_2O @ 100-100 kg/ha. There was an increase in corm yield of 21.3, 17.0 and 15.1% with drip irrigation at 100% CPE along with fertigation of N-K_2O @ 120-120 kg/ha, drip irrigation at 80% CPE with fertigation of N-K_2O @ 120-120 kg/ha and drip irrigation at 100% CPE with fertigation of N-K_2O @ 100:100 kg/ha over the control (flood irrigation and soil application of N-P_2O_5-K_2O @ 100-60-100 kg/ha) respectively. Drip irrigation and fertigation provides water and nutrients directly into the root zone of plants with lesser loses compared to soil application. Plants efficiently utilized the available water and nutrients and give higher yields in drip irrigation and fertigation treatments.

Consumptive use

The consumptive use of water was computed and presented in Fig. 1. The consumptive use of 1,258.1 mm, 1,310.2 mm and 1,362.2 mm was observed with drip irrigation at 60%, 80% and 100% CPE respectively. The higher consumptive use of water at 100% CPE was due to higher amount of water applied through drip irrigation. In control, the consumptive use of water was 1,721.4 mm and it was 36.8, 31.4 and 26.4% higher than drip irrigation at 60%, 80% and 100% CPE respectively.

Water-use efficiency

The WUE was the highest with drip irrigation at 100%

Table 1. Drip irrigation and fertigation effects on yield attributes, yield, water-use efficiency (WUE) and fertilizer-use efficiency (FUE) in elephant foot yam (pooled data of 3 years)

Treatment	Corm length (cm)	Corm diameter (cm)	Corm yield/plant (g)	Corm yield (t/ha)	WUE (kg/mm-ha)	FUE (kg/kg)
Drip irrigation						
60% CPE	19.4	20.3	2,280	28.1	22.3	135.7
80% CPE	21.0	22.1	2,610	32.2	24.6	154.9
100% CPE	21.8	22.9	2,750	33.9	24.9	163.3
SEm±	0.28	0.36	50	0.61	0.46	2.89
CD (P=0.05)	1.1	1.4	194	2.4	1.8	11.3
Fertigation (N-K_2O kg/ha)						
80-80	19.2	20.1	2220	27.4	20.9	158.9
100-100	20.9	22.0	2630	32.4	24.7	155.0
120-120	22.1	23.2	2790	34.3	26.2	139.9
SEm±	0.29	0.39	52	0.65	0.49	3.09
CD (P=0.05)	0.9	1.2	160	2.0	1.5	9.5
Control (flood irrigation and soil application of N-P_2O_5-K_2O @ 100-60-100 kg/ha)	20.4	21.6	2480	30.5	17.7	146.1

CPE, Cumulative pan evaporation

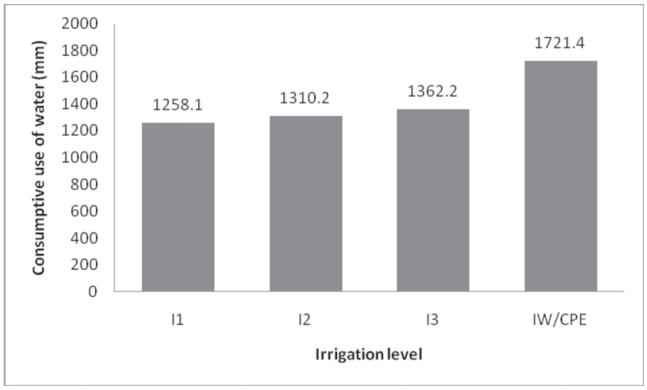

Fig. 1. Consumptive use of water in elephant foot yam (pooled data of 3 years)

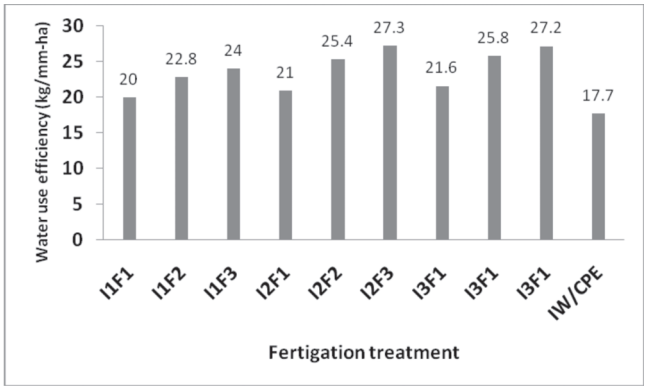

Fig. 2. Water-use efficiency as influenced by drip irrigation and fertigation levels (pooled data of 3 years). Details of treatments are given under materials and methods)

CPE. However, it was on a par with drip irrigation at 80% CPE (Table 1). Higher WUE in these treatments were owing to higher corm yield. In case of fertigation, the highest WUE was observed with N-K_2O @ 120-120 kg/ha and it was comparable with N-K_2O @ 100-100 kg/ha. Drip irrigation and fertigation levels exerted profound influence on WUE. The highest WUE (27.3 kg/mm-ha) was observed with the application of drip irrigation at 80% CPE along with N-K_2O @ 120-120 kg/ha (Fig. 2). This might be due to optimum corm yield with moderate amount of water with higher amount of nutrients. It was followed by drip irrigation at 100% CPE along with N-K_2O @ 120-120 kg/ha (27.2 kg/mm-ha). The water-use efficiency of control (IW: CPE 1.0; soil application of N-P_2O_5-K_2O @ 100-60-100 kg/ha) treatment was 17.7 kg/mm-ha.

Fertilizer-use efficiency

Fertilizer-use efficiency was significantly influenced by drip irrigation levels (Table 1). Drip irrigation at 100% CPE resulted in higher FUE than the other treatments. However, it was comparable with 80% CPE. This was due

Table 2. Interaction effect of drip irrigation and fertigation on yield attributes, yield, water-use efficiency (WUE) and fertilizer-use efficiency (FUE) in elephant foot yam (pooled data of 3 years)

Drip irrigation levels	Fertigation levels (N-K_2O) (kg/ha)			SEm±	CD (P=0.05)
	80-80	100-100	120-120		
			Corm length (cm)		
60% CPE	18.6	19.4	20.3	0.49	1.5
80% CPE	19.1	21.2	22.7		
100% CPE	19.8	22.1	23.5		
			Corm diameter (cm)		
60% CPE	18.9	20.5	21.6	0.62	1.9
80% CPE	20.2	22.4	23.8		
100% CPE	21.1	23.3	24.4		
			Corm yield/plant (g)		
60% CPE	2040	2330	2460	86	264
80% CPE	2230	2700	2900		
100% CPE	2390	2850	3010		
			Corm yield (t/ha)		
60% CPE	25.2	28.7	30.3	1.07	3.3
80% CPE	27.5	33.3	35.7		
100% CPE	29.4	35.1	37.0		
			FUE (kg/kg)		
60% CPE	146.3	137.5	123.3	5.11	15.7
80% CPE	159.7	159.3	145.6		
100% CPE	170.7	168.3	150.9		

CPE, Cumulative pan evaporation

to efficient utilization of applied fertilizers in this treatment as indicated by higher corm yields. The FUE decreased with the increase of fertigation levels. This indicated that incremental increase of fertigation level did not increase fertilizer-utilization efficiency linearly in elephant foot yam. The fertigation of N-K_2O @ 80-80 kg/ha resulted in significantly higher FUE. However, it was on par with fertigation of N-K_2O @ 100-100 kg/ha. Application of drip irrigation at 100% CPE along with fertigation of N-K_2O @ 80–80 kg/ha resulted in higher FUE. In this treatment, elephant foot yam crop utilized applied minimum quantity of fertilizer nutrients (N-K_2O @ 80-80 kg/ha) efficiently with the application of drip irrigation at 100% CPE and resulted in moderately higher corm yield. This treatment may be the best treatment in view of utilization of applied nutrients.

Economics

An application of drip irrigation at 100% CPE with fertigation of N-K_2O @ 120-120 kg/ha resulted in greater cost of cultivation, gross return, net return and benefit: cost ratio (Table 3). The next best treatment was application of drip irrigation at 80% CPE with fertigation of N-K_2O @ 120-120 kg/ha. Greater returns and benefit: cost ratio in these treatments was owing to higher corm yield (Table 2). The treatment, application of drip irrigation at 60% CPE with fertigation of N-K_2O @ 80-80 kg/ha resulted in lower cost of cultivation, gross return, net return and benefit: cost ratio (Table 3) owing to lesser quantity of irrigation water and nutrients application and lower corm yield. Economic comparison was worked out for the treatments application of drip irrigation at 80% CPE with N-K_2O @ 120-120 kg/ha, as it recorded the highest WUE of 27.3 kg/mm-ha and control (Table 4). The comparative study was made to elucidate the efficiency of drip irrigation and fertigation system. Application of drip irrigation at 80% CPE with N-K_2O @120–120 kg/ha resulted in 17.0% greater corm yield over the control (IW: CPE 1.0; soil application of N-P_2O_5-K_2O @ 100-60-100 kg/ha) and saved 4,341,000 litres (434.1 mm) of water/ha of land (Table 4). Dingre *et al*. (2012) reported that drip irrigation resulted in 29 to 62% water saving with 4 to 26% increase in onion seed yield. A net income of 154 × 10^3₹/ha was generated through this treatment. With the saved 434.1 mm of water, additional area of 1.98 ha of elephant foot yam can be brought under cultivation. It generates additional net income of 305 × 10^3₹/ha with the total net income of 459 × 10^3₹/ha compared to 129.4 × 10^3₹/ha from the control with the same quantity of irrigation water application. The benefit: cost ratio of drip irrigation at 80% CPE with fertigation of N-K_2O @ 120-120 kg/ha was higher than the control. When computed net profit ₹/mm of water used, the treatment drip irrigation at 80% CPE with fertigation of N-K_2O @ 120-120 kg/ha resulted in ₹701/mm, whereas the control (flood irrigation and soil application of N-P_2O_5-K_2O @ 100-60-100 kg/ha) recorded ₹249/mm.

Table 3. Economics of drip irrigation and fertigation in elephant foot yam (pooled data of 3 years)

Treatment	Cost of cultivation (× 10^3₹/ha)	Gross returns (× 10^3₹/ha)	Net returns (× 10^3₹/ha)	Benefit: cost ratio
I_1F_1	186.8	252	65.2	1.35
I_1F_2	192.8	287	94.2	1.49
I_1F_3	196.9	303	106.1	1.54
I_2F_1	189.8	275	85.2	1.45
I_2F_2	198.1	333	134.9	1.68
I_2F_3	203.0	357	154.0	1.76
I_3F_1	193.1	294	100.9	1.52
I_3F_2	201.3	351	149.7	1.74
I_3F_3	205.7	370	164.3	1.80
Control	175.6	305	129.4	1.74

Treatment details are given in materials and methods
Selling price elephant foot yam corm ₹10,000/t

It can be concluded that for elephant foot yam, application of drip irrigation at 80% CPE with fertigation of N-K_2O @ 120-120 kg/ha was sufficient for getting optimum yield and maximum WUE. A net saving of 4,341,000 litres (434.1 mm) water/ha of land/season, with net income of 154 × 10^3₹/ha and net profit ₹701/mm of water could be realized with this treatment.

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Table 4. Economic comparison of best drip irrigation and fertigation treatment vs control in elephant foot yam (pooled data of 3 years)

S. No.	Particulars	Best drip irrigation and fertigation treatment (80% CPE and N-K_2O @ 120-120 kg/ha)		Control (IW: CPE: 1.0; soil application of N-P_2O_5-K_2O @ 100-60-100 kg/ha)
		Cost of lateral, drippers, accessories	Cost of valve, pipe, filters	
1	Fixed cost (× 10^3₹/ha)	50.0	50.0	
A	Life year	6	20	
B	Depreciation (× 10^3₹/ha)	8.3	2.5	
C	Interest (12%) (× 10^3₹/ha)	6.0	6.0	
D	Repair and maintenance (2%) (× 10^3₹/ha)	1.0	1.0	
	Total (B, C and D) (× 10^3₹/ha)	15.3	9.5	
	Grand total (× 10^3₹/ha)	24.8		
2	Cost of cultivation (× 10^3₹/ha)	203.0		175.6
3	Irrigation water (mm)	219.7 (80% CPE)		653.8
3a	Irrigation water saving over flood irrigation (mm)	434.1 (4,341,000 litres)		
4	Yield at 80% CPE and N-K_2O @ 120-120 kg/ha (t/ha)	35.7		30.5
4a	Yield increase over flood irrigation (t/ha)	5.2 (17.0%)		
5	Selling price (₹10,000/t) (× 10^3₹/ha)	357.0		305.0
6	Net income (× 10^3₹/ha)	154.0		129.4
7	Addl. area cultivable with 434.1 mm of water	1.98 ha		
8	Addl. expenditure (× 10^3₹/1.98 ha)	402.0		
9	Additional yield (t/1.98 ha)	70.7		
10	Additional income (× 10^3₹/1.98 ha)	707.0		
11	Additional net income (× 10^3₹/1.98 ha)	305.0		
12	Gross cost of cultivation (× 10^3₹/2.98 ha)	605.0		
13	Total net income (× 10^3₹/2.98 ha)	459.0		
14	Benefit: cost ratio	1.76		1.74
15	Net profit ₹/mm of water used	701		198

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