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Growth, Dry Matter Production and Nutrient Uptake of Elephant Foot Yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson) as Influenced by Drip Irrigation and Fertigation Levels

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Abstract

A field experiment was conducted for consecutive three years (2009-2011) at the Regional Centre of ICAR-Central Tuber Crops Research Institute, Dumuduma, Bhubaneswar, Odisha to study the effect of drip irrigation and fertigation levels on growth, dry matter production and nutrient uptake pattern in elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson). The experiment was laid out in split plot design with drip irrigation levels in main plots (I_1 - 60% CPE, I_2 - 80% CPE and I_3 - 100% CPE) and fertigation levels in sub plots (F_1 - N:K_2O 80:80 kg ha^{-1}, F_2 - N:K_2O 100:100 kg ha^{-1} and F_3 - N:K_2O 120:120 kg ha^{-1}). A control treatment (surface irrigation; soil application of N-P_2O_5-K_2O 100-60-100 kg ha^{-1}) was included in this experiment. The treatments were replicated three times. Farmyard manure 10 t ha^{-1} and 60 kg ha^{-1} P_2O_5 were incorporated into the soil in all the treatments during the last plough. The result revealed that drip fertigation treatment I_3F_3 resulted in maximum growth attributes and corm yield. However, it was at par with I_3F_2 and I_2F_3. The dry matter accumulation in corm was greater than in shoot at 3, 5 and 8 MAP. The consumptive use of 1258.1 mm water was observed with drip irrigation, whereas in surface irrigation it was 1721.4 mm. At 3 MAP, nutrient uptake by shoot was greater than in corm. At 5 and 8 MAP, nutrient uptake by corm was greater than in shoot. The total K uptake of elephant foot yam was greater than N and P. The total N, P and K uptake was maximum at 8 MAP (at harvest) in all the treatments. The treatment I_3F_3 resulted in maximum total N, P and K uptake at all the stages. The water requirement of elephant foot yam reduced from 6.1 to 4.4 litres day^{-1} plant^{-1} and saved water 58.0-66.4% through drip irrigation. Drip fertigation (three splits) saved fertilizer N:K_2O 20:20 kg ha^{-1} (20%) and increased corm yield up to 15.1%.

Key words: Elephant foot yam, corm yield, dry matter partitioning, nutrient uptake

Introduction

Elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson) is grown for its starchy corm. It is considered as a famine food in the Pacific Islands (Thaman, 1984). In India, elephant foot yam is commercially cultivated due to its high productivity and popularity as a vegetable in various cuisines (Misra et al., 2002). It has great scope for exploitation as a medicinal crop in pharmacological industry (Misra et al., 2005). The corms are used in the traditional ayurvedic preparation for treatment of inflammation, piles and digestive disorders (Raghu et al., 1999). The leaves are used as a vegetable by local tribes in India as they contain high concentration of vitamin A (Ravi et al., 2011). Presently the area under elephant foot yam cultivation is expanding in Tamil Nadu, Odisha, Gujarat and Maharashtra (Nedunchezhiyan, 2014). Elephant foot yam, though adapts to drought conditions

(Ravi et al., 2015), watering during dry period increases its productivity (Sugiyama and Santosa, 2008). Venkatesan et al. (2014) reported 30-40% reduction in crop yield due to climate change and water scarcity. Generally, farmers follow surface method of irrigation to cope up with the deficiency of rains. During early stage, surface irrigation causes heavy weed infestation apart from un-utilization of most of the applied water by the elephant foot yam.

Judicious but optimum use of water and nutrients are highly critical for sustaining crop production. Water is a scarce resource which needs to be preserved and the ultimate goal should be to ensure more crop per drop. Drip irrigation is an efficient method of providing water directly in to the root zone of plants. 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 and water use efficiency with considerable saving of water was reported in vegetables due to drip irrigation system (Manjunath et al., 2001; Tiwari et al., 2003). Pan evaporation is most widely used method to schedule the irrigation because it is easy and inexpensive (Ertek et al., 2007). The method of nutrient application is also important in improving the nutrients use efficiency. In traditional methods, fertilizers applied are generally not utilized efficiently by the crop. In fertigation, nutrients are applied through drip emitters directly into the zone of maximum root activity and to meet the crop demand so as to get maximum yield (Patel and Rajput, 2000; Chawla and Narda, 2002).

Drip fertigation is considered to be the most efficient in improving the yield (Behera et al., 2013). However, lack of scientific studies on drip irrigation and fertigation hinders further expansion of elephant foot yam crop cultivation in water scarce area. The present study reports the effects of drip irrigation and fertigation on elephant foot yam growth, dry matter production and nutrient uptake pattern.

Materials and Methods

A field experiment was conducted for consecutive three years (2009-2011) at the ICAR-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. The soil at the experimental 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^{-1} depth. Other physico-chemical features of the soil was as follows: Bulk density 1.54 g cc^{-1}, pH 6.2, organic carbon 0.34%, available N 172 kg ha^{-1}, available P 21.4 kg ha^{-1} and available K 226 kg ha^{-1}. The experiment was laid out in split plot design with three replications. The experiment consisted of three drip irrigation treatments viz., I_1 - 60% CPE, I_2 - 80% CPE and I_3 - 100% CPE in main plots and three fertigation treatments viz., F_1 - N:K_2O 80:80 kg ha^{-1}, F_2 - N:K_2O 100:100 kg ha^{-1} and F_3 - N:K_2O 120:120 kg ha^{-1} in sub plots. A control treatment (surface irrigation IW/CPE:1, where pan evaporation is directly cumulated; soil application of N-P_2O_5-K_2O 100-60-100 kg ha^{-1}) was included in this experiment for comparison. P_2O_5 60 kg ha^{-1} through single super phosphate was applied to soil in all the fertigation treatments and 10 t ha^{-1} farmyard manure was incorporated into the soil in all the treatments during last plough. N and K_2O were supplied through urea and white muriate of potash, respectively. N and K_2O were applied in 3 splits at 1st (40%), 2nd (30%) and 3rd (30%) month after planting (MAP). In control treatment, N and K_2O were applied in soil in 2 splits (50% 1 MAP and the remaining 50% 2 MAP). Healthy, whole corms of 400 g weight treated with cow-dung slurry (10 kg of fresh cow-dung dissolved in 10 litre of water and mixed with 50 g *Trichoderma*) one day before were planted at 90 cm spacing on the ridges formed at 90 cm spacing. For drip irrigation, drip lateral was laid out at 90 cm spacing between rows. Along the lateral line, a dripper at 90 cm distance was placed with a discharge capacity of 4 litres per hour. The depth of water in drip irrigation treatments was worked out based on daily pan evaporation (for e.g. drip irrigation at 100% = 1.0 x 0.6 (pan factor) x 0.7 (elephant foot yam crop coefficient (Nedunchezhiyan et al., 2010) x pan evaporation in mm). The volume of drip irrigation water per ha required was calculated by multiplying depth of water (mm) x 10000 litres. (for e.g. 3 mm of water = 3 x 10000 = 30000 litres). Water meter fixed at the delivery end of the pump quantifies the volume of water delivered to the field. Drip irrigation was given in alternate days throughout crop growth. In control treatment, 4 cm water was given as surface irrigation. The irrigation was withheld 10 days before harvesting. Hand weeding was done at 1st, 2nd and 3rd MAP. The crop was planted on 11.05.2009, 03.05.2010 and 17.04.2011 and harvested on 06.01.2010, 29.12.2010 and 13.12.2011, respectively (at 8 MAP).

Rainfall and weather data during the crop period was recorded for three seasons. The mean monthly maximum temperature ranged between 29.0 and 37.8°C and minimum temperature ranged between 15.4 and 26.6°C. The mean monthly relative humidity varied between 59.3 and 89.2%. The mean total rainfall during the crop growing period was 1411.2 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 1093.3, 1038.4 and 983.5 mm at 60, 80 and 100% CPE, respectively. The mean amount of water applied through drip irrigation in each treatment was 164.8, 219.7 and 274.6 mm at 60, 80 and 100% CPE, respectively. In control treatment 653.8 mm of water was applied through surface irrigation.

Biometrical observations on crop growth were recorded at 3rd and 5th MAP. Dry matter production and partitioning was recorded at 3rd, 5th and 8th MAP (harvest). N, P and K content in shoot, corm and root were estimated at 3rd, 5th and 8th MAP (harvest). Nutrient uptake was calculated by multiplying nutrient content with dry matter production. The data was analysed statistically according to Panse and Sukhatme (1967). The significant differences between the treatments were compared with the critical difference (CD) at a 0.05 level of probability.

Results and Discussion

Growth and yield

Increasing the level of drip irrigation and fertigation increased the elephant foot yam growth attributes markedly (Table 1). Drip irrigation at I_3 resulted in maximum pseudostem length and girth, and canopy spread (Table 1) compared to other treatments. However, it was statistically at par with drip irrigation at I_2 both at 3rd and 5th MAP. Similarly, drip fertigation at F_3 resulted in maximum

Table 1. Growth attributes of elephant foot yam as influenced by drip irrigation and fertigation (Pooled data of 3 years)

Treatments	Pseudostem length (cm)		Pseudostem girth at collar region (cm)		Canopy spread (cm)	
	3rd MAP	5th MAP	3rd MAP	5th MAP	3rd MAP	5th MAP
Drip irrigation treatments						
I_1	59	102	12.6	17.3	76	112
I_2	63	107	13.8	18	83	117
I_3	65	110	14.1	18.4	84	120
CD (0.05)	3	7	0.8	0.7	8	10
Fertigation treatments						
F_1	58	101	12.6	17.1	77	110
F_2	63	107	13.6	18.1	81	118
F_3	66	111	14.3	18.5	85	121
CD (0.05)	2	6	0.7	0.6	7	8
Interaction						
I_1F_1	57	96	12.2	16.1	72	105
I_1F_2	58	102	12.6	17.6	76	112
I_1F_3	61	107	13.1	18.1	80	118
I_2F_1	58	100	12.7	17.3	78	109
I_2F_2	64	108	13.8	18.2	83	120
I_2F_3	67	112	14.8	18.6	87	122
I_3F_1	60	106	12.9	18	80	116
I_3F_2	66	110	14.4	18.5	85	121
I_3F_3	70	114	15.2	18.9	88	123
Control	62	107	13.2	18	82	119
CD (0.05)	3	10	1.2	1	12	13

pseudostem length and girth, and canopy spread. However, it was statistically at par with F_2 both at 3rd and 5th MAP. Sahoo et al. (2014) also observed higher growth attributes at higher level of nutrient application.

Drip fertigation at I_3F_3 resulted in maximum growth attributes. However, it was statistically at par with drip fertigation at I_3F_2 and I_2F_3 and I_2F_2 as well as control. This indicates that drip fertigation at I_2F_2 is sufficient for optimum development of growth attributes. Although in control treatment the quantity of water applied through surface irrigation was higher and recommended dose of fertilizer applied in soil, growth attributes were lesser. This was because of loss of water and nutrients apart from heavy weed infestation which removed considerable amount of water and nutrients from the soil.

Total dry matter production and partitioning into shoot, corm and root followed trends similar to growth attributes (Table 2). The dry matter accumulation in corm was greater than in shoot at 3rd, 5th and 8th MAP. The total dry matter production and partitioning in shoot, corm and root was maximum at I_3, it was on par with I_2. Fertigation at F_3 was resulted in maximum dry matter production and partitioning in shoot, corm and root. However it was statistically at par with fertigation at F_2.

Drip fertigation at I_3F_3 resulted in maximum dry matter production and partitioning in shoot, corm and root and it was statistically at par with drip fertigation at I_3F_2 and I_2F_3. Also, corm dry matter accumulation was statistically at par with I_2F_2 at 8 MAP. In control treatment, shoot dry matter accumulation was statistically at par with I_1F_3, I_2F_2, I_2F_3, I_3F_1 and I_3F_2, whereas corm dry matter accumulation was statistically at par with I_1F_3 and I_2F_2. This indicates that in control treatment, the production and translocation of photosynthates to developing corm was less owing to non-availability of sufficient water and nutrients at later stages. The drip fertigation at I_2F_3 was sufficient for efficient production and partitioning of dry matter.

Marked variation in corm yield was noticed with respect to drip irrigation and fertigation levels (Fig. 1). Maximum corm yield was recorded at the maximum irrigation level I_3 (100% CPE) (Fig 1). However, it was statistically at par with I_2. Higher growth attributes (Table 1) and efficient dry matter partitioning (Table 2) in I_3 and I_2 treatments contributed for higher corm yields (Table 1). Increasing the fertigation levels increased the corm yield. Higher corm yield was obtained in the treatment F_3 (Fig. 1). The next best treatment was the fertigation of F_2. Venkatesan et al. (2014) reported that the increased application of major nutrients from 50 to 100% of recommended dose of fertilizer (RDF) under fertigation increased the elephant foot yam corm yield from 20.1 to 39.1 t ha^{-1}. Similar report in cassava was reported by Odubanjo et al. (2011) and in elephant foot yam by Nedunchezhiyan et al. (2010). In elephant foot yam, corm yield increased with increase of fertilizer level up to N:P:K 100:60:100 kg ha^{-1} (Sahoo et al., 2014). In the present study, interaction effect between drip irrigation and fertigation levels was found significant (Fig. 2). The maximum corm yield was recorded with drip fertigation at I_3F_3. However, it was statistically at par with the application of drip fertigation at I_2F_3 and I_3F_2. Corm yield increased by 21.3, 17.0 and 15.1% with drip fertigation

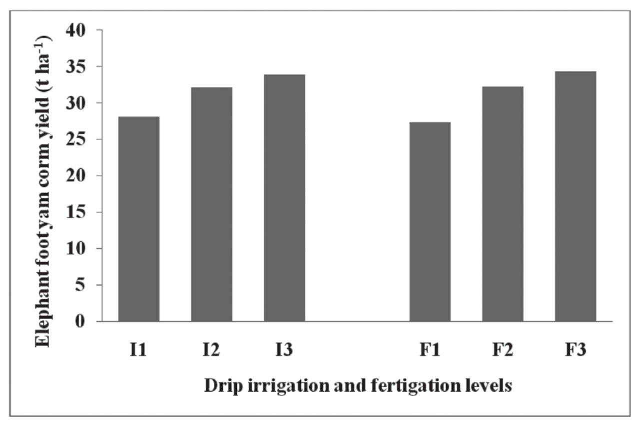

Fig.1. Effects of drip irrigation and fertigation levels on corm yield in elephant foot yam

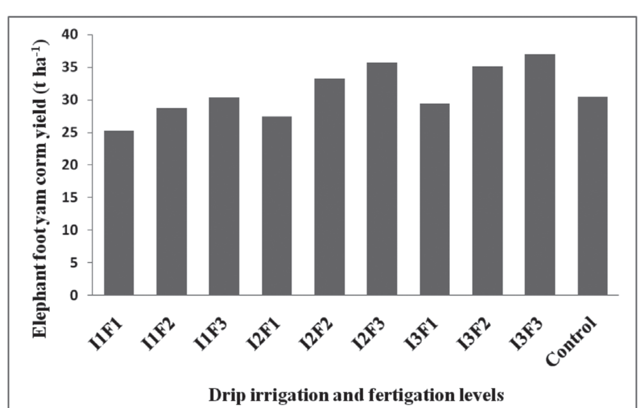

Fig.2. Interaction effects of drip irrigation and fertigation on corm yield in elephant foot yam

Table 2. Dry matter production and partitioning of elephant foot yam as influenced by drip irrigation and fertigation (Pooled data of 3 years)

Treatments	Dry matter production (g plant^{-1}) at 3rd MAP				Dry matter production (g plant^{-1}) at 5th MAP				Dry matter production (g plant^{-1}) at 8th MAP (Harvest)			
	Shoot	Corm	Root	Total	Shoot	Corm	Root	Total	Shoot	Corm	Root	Total
Drip irrigation treatments												
I_1	20.3	54.3	3.9	78.6	70.3	317	4.9	392.2	77.6	503.5	6	737.9
I_2	20.9	59.1	4.3	84.3	72.2	355.4	5.4	433	79.6	592.9	6.8	799.3
I_3	22.3	62.7	4.5	89.6	77.3	383.1	5.6	466	85.6	624.8	6.9	848.4
CD (0.05)	1.6	4.8	0.3	7.4	6.2	28.3	0.3	38.6	6.3	51.2	0.5	72.3
Fertigation treatments												
F_1	19.7	50.7	3.7	74.1	68.3	289.4	4.7	362.3	75.4	513.1	5.1	692
F_2	21	61	4.5	86.5	72.5	370.3	5.5	448.2	80	588.3	7.1	823
F_3	22.8	64.4	4.6	91.8	79.1	395.9	5.7	480.7	87.4	619.8	7.5	870.4
CD (0.05)	1.3	4	0.2	6.1	5.1	23.5	0.2	32	5.2	42.4	0.4	60
Interaction												
I_1F_1	18.3	49.4	3.2	70.9	63.7	276.3	4.1	344.1	70.3	459.6	4.2	666.1
I_1F_2	19.8	55.9	4.3	80	68.2	330.1	5.2	403.5	75.2	504.8	6.8	756.8
I_1F_3	22.9	57.7	4.3	84.9	79.1	344.6	5.4	429.1	87.4	546.2	7.1	790.7
I_2F_1	19.8	50.8	3.7	74.3	68.3	291.4	4.9	364.6	75.6	526.2	5.4	695.2
I_2F_2	20.7	60.4	4.6	85.7	71.9	365.9	5.6	443.4	79.2	610.8	7.2	815.2
I_2F_3	22.1	66	4.7	92.8	76.4	408.9	5.8	491.1	84.1	641.6	7.7	887.4
I_3F_1	21.1	52	4.1	77.2	72.8	300.4	5.1	378.3	80.4	553.6	5.8	714.8
I_3F_2	22.4	66.8	4.6	93.8	77.3	414.8	5.7	497.8	85.5	649.2	7.4	897.1
I_3F_3	23.5	69.4	4.8	97.7	81.9	434.2	5.9	522	90.8	671.7	7.7	933.2
Control	20.2	52.2	3.8	76.2	71.6	296.4	5	373	80.3	530.2	6.6	717.1
CD (0.05)	2.1	6.6	0.3	10.1	8.4	38.8	0.3	52.8	8.6	70	0.7	99

at I_3F_3, I_2F_3 and I_3F_2 respectively, as compared to control. At same level of fertilizer dose, I_3F_2 resulted in 15.1% higher yield and saving of 58.0% (37,92,000 litres ha^{-1}) water over control. The corm yield of control was statistically at par with I_3F_1. It indicates that saving of $N:K_2O$ 20:20 kg ha^{-1} (20%) and water 58.0% (37,92,000 litres ha^{-1}) over control under drip fertigation. Drip fertigation provides water and nutrients directly in to the root zone of plants with lesser loses compared to application through surface irrigation. Therefore, plants efficiently utilized the available water and nutrients and produced higher yields in drip fertigation treatments.

Consumptive use

The consumptive use of water was computed and presented in Fig.3. The mean consumptive use of 1258.1 mm water (1019 litres $plant^{-1}$; 4.4 litres day^{-1} $plant^{-1}$) over the three seasons was observed with drip irrigation, whereas in flood irrigation it was 1721.4 mm water (1394 litres $plant^{-1}$; 6.1 litres day^{-1} $plant^{-1}$). The higher consumptive use of water in surface irrigation was due to various means of loss of water. The difference in effective rainfall in this study was negligible, because the crop received more than 1200 mm of rainfall between July and September (South West monsoon). Drip and surface irrigation was given during pre and post monsoon period as well as during dry spell of monsoon period of the crop growing season. The mean amount of water applied through drip irrigation at 60% CPE was 164.8 mm (1648000 litres; 133 litres $plant^{-1}$), at 80% CPE was 219.7 mm (2197000 litres; 178 litres $plant^{-1}$) and at 100% CPE was 274.6 mm (2746000 litres; 222 litres $plant^{-1}$). In control treatment 653.8 mm (6538000 litres; 530 litres $plant^{-1}$) of water was applied through surface irrigation.

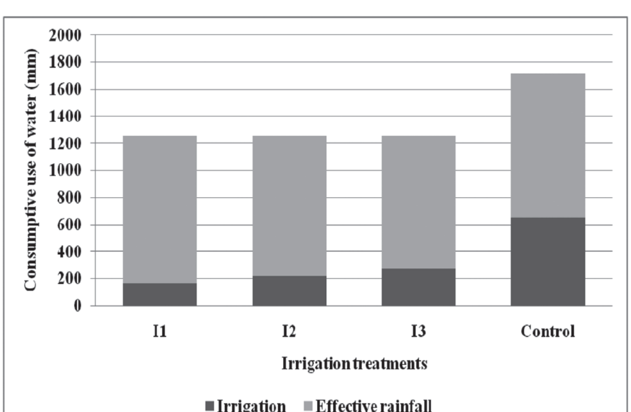

Fig.3. Consumptive use of water by elephant foot yam

Nutrient uptake

Discernable difference in N, P and K nutrients uptake was observed with respect to levels of drip irrigation and fertigation (Table 3, 4 and 5). The uptake of N, P and K nutrients increased with the increase of age of the crop. This was mainly due to accumulation of more dry matter. At 3rd MAP, nutrient uptake by the shoot was more than the corm. At 5th and 8th MAP, nutrients uptake by the corm was more than the shoot. There was not much variation in uptake of nutrients by the root across all the crop growth. Nutrient uptake was linearly related to dry matter accumulation. The difference in nutrients uptake between 5th and 8th MAP in shoot was negligible as there was no increase in the shoot and root dry matter. At 5 MAP, only corm dry matter increased.

The total N uptake was maximum at 8th MAP in all the treatments (Table 3). The treatment I_3 resulted in significantly maximum total N uptake at 3rd, 5th and 8th MAP. The N uptake by shoot in I_3 and I_2 was at par at 5th and 8th MAP. The N uptake by the corm in I_3 was greater than other treatments at all the crop growth stages. The N uptake by the roots was not significant in all the crop growth stages. Increasing fertigation level increased the N uptake. Significantly, maximum total N uptake was observed in F_3 at all the crop growth stages. This was due to the increase in available N to the plants and increase in dry matter accumulation. In elephant foot yam, utilization of N increased with increase in N application (Sahoo et al., 2015). Nitrogen uptake by the shoot and corm in F_3 was superior to other treatments.

The treatment I_3F_3 resulted in maximum total N uptake at all the crop growth stages. However, it was statistically at par with I_3F_2 and I_2F_3 at 5th and 8th MAP. The total N uptake in control treatment was lower than I_3F_3, I_3F_2 and I_2F_3, but statistically at par with I_1F_2, I_2F_1 and I_3F_1 at 3 MAP, I_1F_1, I_1F_2, I_2F_1 and I_1F_3 at 5th MAP, and I_1F_2, I_1F_3, I_2F_1 and I_3F_1 at 8th MAP. Nitrogen uptake by the shoot was significantly greater in I_3F_3 at all the crop growth stages, but it was statistically at par with I_3F_2, I_2F_3 and I_1F_3 at all the crop growth stages. Nitrogen uptake by the corm was greater in I_3F_3 at all the crop growth stages. However it was statistically at par with I_3F_2 and I_2F_3 at 5th and 8th MAP.

The total P uptake of elephant foot yam was lesser than N and K. The total P uptake was maximum at 8th MAP in all the treatments (Table 4). The treatment I_3 resulted

Table 3. N uptake of elephant foot yam as influenced by drip irrigation and fertigation (Pooled data of 3 years)

Treatments	N uptake (kg ha^{-1}) at 3rd MAP				N uptake (kg ha^{-1}) at 5th MAP				N uptake (kg ha^{-1}) at 8th MAP (Harvest)			
	Shoot	Corm	Root	Total	Shoot	Corm	Root	Total	Shoot	Corm	Root	Total
Drip irrigation treatments												
I_1	8.2	4.1	0.2	12.5	37.8	48.6	0.3	86.7	40.7	74.6	0.3	115.6
I_2	8.7	5.3	0.3	14.3	40.1	57.2	0.4	97.7	42.7	91.7	0.4	134.8
I_3	9.5	6.2	0.3	16	43.7	63.2	0.4	107.3	46.7	100.1	0.4	147.2
CD (0.05)	0.6	0.4	0.2	0.8	3.8	5.1	0.3	8.2	4.1	7.8	0.3	9.4
Fertigation treatments												
F_1	7.8	3.2	0.2	11.2	35.6	43.8	0.3	79.7	37.7	77.1	0.3	115.1
F_2	8.8	5.5	0.3	14.6	40.5	59.9	0.4	100.8	43.5	91.4	0.4	135.3
F_3	9.8	6.9	0.3	17	45.5	65.3	0.4	111.2	48.9	97.9	0.4	147.2
CD (0.05)	0.5	0.3	0.2	0.7	3.2	4.2	0.2	6.8	3.4	6.5	0.2	7.8
Interaction												
I_1F_1	7	2.7	0.1	9.8	32.4	40.5	0.2	73.1	34.9	66.2	0.2	101.3
I_1F_2	8.1	4.2	0.2	12.5	37	51.1	0.3	88.4	40.3	75.1	0.4	115.8
I_1F_3	9.6	5.4	0.3	15.3	44	54.2	0.3	98.5	46.9	82.6	0.4	129.9
I_2F_1	7.8	3.2	0.2	11.2	35.7	44.1	0.3	80.1	37.5	78.9	0.3	116.7
I_2F_2	8.7	5.5	0.3	14.5	40.4	59.7	0.4	100.5	42.3	94.6	0.4	137.3
I_2F_3	9.5	7.3	0.3	17.1	44.2	67.7	0.4	112.3	48.2	101.6	0.4	150.2
I_3F_1	8.5	3.8	0.2	12.5	38.8	46.8	0.4	86	40.8	86.4	0.3	127.5
I_3F_2	9.7	6.7	0.3	16.7	44.2	68.7	0.4	113.3	47.9	104.4	0.4	152.7
I_3F_3	10.3	8.2	0.4	18.9	48.2	74	0.5	122.7	51.5	109.6	0.5	161.6
Control	8	3.6	0.2	11.8	37.9	45.9	0.3	84.1	40.3	81.4	0.4	122.1
CD (0.05)	0.8	0.5	0.3	1.1	5.3	6.9	0.3	11.2	5.6	10.7	0.3	12.9

Table 4. P uptake of elephant foot yam as influenced by drip irrigation and fertigation (Pooled data of 3 years)

Treatments	P uptake (kg ha^{-1}) at 3rd MAP				P uptake (kg ha^{-1}) at 5th MAP				P uptake (kg ha^{-1}) at 8th MAP (Harvest)			
	Shoot	Corm	Root	Total	Shoot	Corm	Root	Total	Shoot	Corm	Root	Total
Drip irrigation treatments												
I_1	2	1.8	0.1	3.9	7.2	12.3	0.1	19.6	6.8	18.3	0.1	25.2
I_2	2.2	2.1	0.1	4.4	7.5	15	0.2	22.7	7.1	24.4	0.1	31.6
I_3	2.3	2.4	0.1	4.8	8.1	16.6	0.2	24.9	7.6	27	0.1	34.7
CD (0.05)	0.2	0.2	NS	0.3	0.4	1.3	0.02	1.4	0.5	2.2	NS	2.2
Fertigation treatments												
F_1	2	1.5	0.1	3.6	6.8	10.6	0.1	17.5	6.5	18	0.1	24.6
F_2	2.2	2.3	0.1	4.6	7.6	16	0.2	23.8	7.1	24.7	0.1	31.9
F_3	2.3	2.5	0.1	4.9	8.4	17.3	0.2	25.9	7.9	27	0.1	35
CD (0.05)	0.2	0.2	NS	0.2	0.3	1.1	0.02	1.2	0.4	1.8	NS	1.8
Interaction												
I_1F_1	1.8	1.3	0.1	3.2	6.3	9.5	0.1	15.9	6	14.7	0.1	20.8
I_1F_2	2	2	0.1	4.1	7.1	13.2	0.1	20.4	6.7	18.9	0.1	25.7
I_1F_3	2.3	2.1	0.1	4.5	8.2	14.2	0.2	22.6	7.7	21.4	0.1	29.2
I_2F_1	2	1.5	0.1	3.6	6.8	10.6	0.1	17.5	6.5	18.2	0.1	24.8
I_2F_2	2.2	2.3	0.1	4.6	7.6	16	0.2	23.8	7	26	0.1	33.1
I_2F_3	2.2	2.6	0.1	4.9	8.1	18.3	0.2	26.6	7.7	29	0.1	36.8
I_3F_1	2.1	1.8	0.1	4	7.4	11.6	0.1	19.1	7	21.1	0.1	28.2
I_3F_2	2.3	2.6	0.1	5	8.2	18.8	0.2	27.2	7.7	29.2	0.1	37
I_3F_3	2.4	2.7	0.1	5.2	8.8	19.3	0.2	28.3	8.3	30.8	0.1	39.2
Control	2	1.8	0.1	3.9	7.2	11.4	0.1	18.7	7	19.9	0.1	27
CD (0.05)	0.3	0.3	NS	0.4	0.5	1.8	0.03	1.9	0.7	3	NS	3

in significantly high total P uptake at 3rd, 5th and 8th MAP. Phosphorus uptake by shoot was maximum at 5th MAP irrespective of the treatment, and it decreased towards 8th MAP. This may be due to the translocation of P from mature leaves to growing corms. The shoot P uptake was significantly greater in I_3. But it was statistically at par with I_2 at 3rd and 8th MAP. Phosphorus uptake by the corm increased progressively up to 8th MAP. Phosphorus uptake by the corm in I_3 was greater than other treatments at all the crop growth stages. Phosphorus uptake by the roots was not significant at all the crop growth stages. Increasing fertigation level increased the P uptake. Significantly maximum total P uptake was observed in F_3 at all the stages of crop growth. This may be due to high P and dry matter accumulation (Table 2). Phosphorus uptake by the shoot and corm in F_3 was superior to other treatments at 5th and 8th MAP.

The treatment I_3F_3 resulted in maximum total P uptake at all the crop growth stages. However, it was statistically at par with I_3F_2 and I_2F_3 at 3rd, 5th and 8th MAP. The total P uptake in control was lower than I_3F_3, I_3F_2 and I_2F_3, but statistically at par with I_1F_2, I_2F_1 and I_3F_1 at 3rd, 5th and 8th MAP and also with I_1F_3 at 8th MAP. Phosphorus uptake by the shoot was significantly greater in I_3F_3 at all the crop growth stages, but it was statistically at par with I_3F_2, I_2F_3 and I_1F_3 at 3rd and 8th MAP. Phosphorus uptake by the corm was maximum in I_3F_3 at all the crop growth stages. However it was statistically at par with I_3F_2 and I_2F_3 at 3rd, 5th and 8th MAP.

The total K uptake of elephant foot yam was greater than N and P. The total K uptake was maximum at 8th MAP in all the treatments (Table 5). The treatment I_3 resulted in significantly maximum total K uptake at 3rd, 5th and 8th MAP. Potassium accumulation in the shoot was maximum at 5th MAP in all the treatments. It decreased towards 8th MAP. This may be due to translocation of K from mature leaves to growing corms. The K accumulation in the shoot was significantly maximum in I_3, but it was statistically at par with I_2 at 8th MAP. Potassium accumulation in the corm increased progressively up to 8th MAP. Potassium accumulation by the corm in I_3 was significantly superior to all the treatments at all the crop growth stages. Potassium accumulation by the roots was not significant at all the crop growth stages. Increasing fertigation level increased the K uptake. Significantly maximum total K uptake was observed in F_3 at all the crop growth stages. This was due to the total dry matter production. Potassium accumulation by the shoot and corm in F_3 was superior to other treatments at 3rd, 5th and 8th MAP.

The treatment I_3F_3 resulted in maximum total K uptake at all the crop growth stages. However, it was statistically at par with I_3F_2 and I_2F_3 at 3rd MAP, I_3F_2 at 5th and 8th MAP. The total K uptake in control treatment was lower than I_3F_3, I_3F_2, I_3F_1, I_2F_3, I_2F_2 and I_1F_3 at 3rd MAP, I_3F_3, I_3F_2, I_3F_1, I_2F_3, I_2F_2, I_1F_3 and I_1F_2 at 5th MAP, and I_3F_3, I_3F_2, I_3F_1, I_2F_3, I_2F_2 and I_1F_3 at 8th MAP. Potassium accumulation in the shoot was significantly greater in I_3F_3 at all the crop growth stages, but it was statistically at par with I_3F_2 and I_2F_3 at all the crop growth stages. Potassium accumulation in the corm was maximum in I_3F_3 at all the crop growth stages. However it was statistically at par with I_3F_2 at 3rd, 5th and 8th MAP.

Conclusion

Water and nutrients are the major input components which determine crop productivity. Judicious and proper application of water and nutrients is necessary to achieve optimum productivity. Drip irrigation and fertigation saves water and nutrients and improve their utilization. At same level of fertilizer dose, I_3F_2 resulted in 15.1% higher yield apart from saving of 58.0% water over control. The corm yield in control and I_3F_1 was statistically at par, which indicated saving of fertilizer $N:K_2O$ 20:20 kg ha^{-1} (20%) and water 58.0% under drip fertigation. Although higher level of drip irrigation (100% CPE) and fertigation ($N:K_2O$ 120:120 kg ha^{-1}) (I_3F_3) resulted in maximum growth and yield as well as greater uptake of N, P and K, for sustainable environment, optimum growth and yield as well as better utilization of N, P and K can be achieved either at drip irrigation at 100% CPE with fertigation $N:K_2O$ 100:100 kg ha^{-1} (I_3F_2) or 80% CPE with fertigation $N:K_2O$ 120:120 kg ha^{-1} (I_2F_3) along with soil application of P_2O_5 60 kg ha^{-1}. In former case, 58.0% (37,92,000 litres ha^{-1}) water was saved over control. In latter case, 66.4% (43,41,000 litres ha^{-1}) water was saved, but utilized additional $N:K_2O$ 20:20 kg ha^{-1} over control. Depending up on the availability of water/ fertilizer, either one of the treatments can be opted. The water requirement of elephant foot yam reduced from 6.1 to 4.4 litres day^{-1} $plant^{-1}$ and saved water upto 58.0-66.4% through drip irrigation. Drip fertigation saved fertilizer $N:K_2O$ 20:20 kg ha^{-1} (20%) and increased corm yield up to 15.1%.

Table 5. K uptake of elephant foot yam as influenced by drip irrigation and fertigation (Pooled data of 3 years)

Treatments	K uptake ($kg\ ha^{-1}$) at 3[rd] MAP				K uptake ($kg\ ha^{-1}$) at 5[th] MAP				K uptake ($kg\ ha^{-1}$) at 8[th] MAP (Harvest)			
	Shoot	Corm	Root	Total	Shoot	Corm	Root	Total	Shoot	Corm	Root	Total
Drip irrigation treatments												
I_1	7.9	8.3	0.1	16.3	32.8	64.6	0.5	97.9	31.5	98.3	0.6	130.4
I_2	9.1	9.5	0.2	18.8	36.8	76.1	0.6	113.5	36	121.7	0.7	158.4
I_3	10	11.2	0.2	21.4	40.3	89.2	0.7	130.2	38.5	139.6	0.7	178.8
CD (0.05)	0.8	1	0.02	1.8	3.4	6.6	0.06	10.2	3.4	10.7	0.07	12.6
Fertigation treatments												
F_1	8.1	7.6	0.1	15.8	33.6	58.3	0.5	92.4	31.6	96.9	0.5	129
F_2	9	10	0.2	19.2	36.3	81	0.6	117.9	35.1	124.7	0.7	160.5
F_3	9.9	11.4	0.2	21.5	40	90.6	0.7	131.3	39.3	138	0.8	178.1
CD (0.05)	0.7	0.8	0.02	1.5	2.8	5.5	0.05	8.5	2.8	8.9	0.06	10.5
Interaction												
I_1F_1	6.9	7	0.1	14	29.5	51.3	0.4	81.2	27.6	77.8	0.4	105.8
I_1F_2	7.8	8.3	0.1	16.2	31.8	68.1	0.5	100.4	31	101.8	0.7	133.5
I_1F_3	9.1	9.6	0.1	18.8	37.2	74.4	0.6	112.2	35.8	115.3	0.7	151.8
I_2F_1	8.3	7.4	0.1	15.8	34.1	58.7	0.5	93.3	33.3	98.5	0.5	132.3
I_2F_2	9	9.6	0.2	18.8	36.8	77.3	0.6	114.7	35.4	125.9	0.7	162
I_2F_3	10	11.6	0.2	21.8	39.4	92.2	0.7	132.3	39.3	140.8	0.8	180.9
I_3F_1	9	8.5	0.1	17.6	37.4	64.9	0.6	102.9	33.8	114.3	0.6	148.7
I_3F_2	10.2	12	0.2	22.4	40.2	97.6	0.7	138.5	39	146.5	0.8	186.3
I_3F_3	10.8	13.2	0.3	24.3	43.4	105.2	0.7	149.3	42.9	158	0.8	201.7
Control	8.6	8.3	0.1	17	36.3	62.6	0.6	99.5	36.6	105	0.7	142.3
CD (0.05)	1.2	1.3	0.03	2.5	4.6	9.1	0.08	13.9	4.6	14.7	0.1	17.3

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