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Research Paper

Intercrop and drip irrigation effects on growth, yield, water-use efficiency and economics of elephant foot yam (*Amorphophallus paeoniifolius*)

S.K. JATA[1], M. NEDUNCHEZHIYAN[2], S.K. MAITY[3] AND M. MALLIKARJUN[4]

Institute of Agriculture, Visva-Bharati, Sriniketan, Birbhum, West Bengal 731 236

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ABSTRACT

A field experiment was conducted during 2012–13 and 2013–14 at Bhubaneswar, Odisha to study the effects of intercrop and drip irrigation on growth, corm yield, water-use efficiency as well as economics of production of elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson]. The experiment was laid out in split plot design with 5 replications, keeping elephant foot yam + green gram and elephant foot yam sole crop in the main plots and surface irrigation, drip irrigation at 100% cumulative pan evaporation (CPE), drip irrigation at 80% CPE and drip irrigation at 60% CPE in the sub-plots. The results revealed that, drip irrigation at 60–80% CPE resulted in higher green gram seed yield (630 kg/ha). Elephant foot yam + green gram intercropping system recorded better growth, yield attributes and yield than sole elephant foot yam. Drip irrigation at 100% and 80% CPE realized better growth, yield attributes and yield compared to other treatments. Surface irrigation resulted in higher consumptive use of water (204 cm) than drip irrigation (50, 41 and 30 cm at 100, 80 and 60 CPE respectively). The highest water-use efficiency was noticed in elephant foot yam + green gram intercropping with drip irrigation at 60% CPE (1080 kg/ha-cm). The highest net returns was recorded with elephant foot yam + green gram intercropping with drip irrigation at 100% CPE (309 × 10^3₹/ha), which was statistically at par with elephant foot yam + green gram intercropping with drip irrigation at 80% CPE (307 × 10^3₹/ha). Thus, elephant foot yam and green gram can be grown as an intercrop profitably with application of drip irrigation at 80% CPE to harvest greater yield and realize more returns.

Key words **:** Corm equivalent yield, Drip irrigation, Elephant foot yam, Green gram

Elephant foot yam is considered as the king of tuber crops due to its wide adaptability, high yield potential and profitability. Earlier, cultivation of elephant foot yam was at subsistence level limited to household consumption, but presently the crop is gaining popularity among the farmers as a large-scale commercial crop due to its increasing market demand. In India, it is commercially cultivated in Andhra Pradesh, West Bengal, Bihar, Uttar Pradesh, Tamil Nadu, Kerala, Maharashtra, Odisha and Karnataka (Nedunchezhiyan, 2017). It is a good source of vitamin A, rich in dietary fibre and has several medicinal and therapeutic values, and also recommended in case of piles, dysentery, asthma, swelling of lungs, vomiting, abdominal pain and as blood purifier.

Elephant foot yam has a long umbrella shaped canopy and is planted at wider spacing. It takes 3 months to fully cover the ground and that allows intercrop to grow in wider spaces. Intercropping with the short duration pulses may be advantageous, as the elephant foot yam takes 50-60 days to cover the ground (Nedunchezhiyan and Byju, 2005). Short duration pulses like green gram (*Vigna radiata*) can be grown as intercrop with elephant foot yam crop as it improves soil fertility by fixing atmospheric nitrogen symbiotically and enrich the soil organic matter content through their leaf litter, and the haulms can be used as mulching material (Nedunchezhiyan and Byju, 2005). Presence of legumes in the mixtures benefit the associated non-legumes as the legumes provide a portion of biologically fixed nitrogen to non-legume components (Kavamahanga *et al*., 1995). Elephant foot yam is known for its relatively high water requirement. In Andhra

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[3]**Corresponding author's Email**: swapankumar.maity@gmail.com
[1]Junior Farm Superintendent, [2]Principal Scientist (Agronomy), Regional Centre of ICAR-Central Tuber Crops Research Institute, Bhubaneswar, Odisha 751 019; [3]Assistant Professor, Department of Agronomy, Institute of Agriculture, Visva-Bharati, Sriniketan, Birbhum, West Bengal 731 236; [4]Research Associate (Crop Production), Krishi Vigyan Kendra, Kalikiri, Chittoor, Andhra Pradesh 517 234

Pradesh, the crop is irrigated at weekly intervals thereby providing 22-25 irrigations during the crop growth period of 8 months. The corm yield of elephant foot yam is reduced by 30-40% under water stress conditions (Das *et al.,* 1995). Drip irrigation is an efficient method of providing water directly into the root zone of the plants. It reduces water requirement and checks unwanted weed growth. Drip irrigation is a high frequency irrigation method with an efficiency of about 98-99% (Ertek *et al.,* 2007). Tiwari *et al*., (2003) reported higher crop yields and water productivity under drip irrigation system in vegetables. Thus, intercropping in elephant foot yam and drip irrigation provides ample scope to increase farm productivity and water-use efficiency. Limited information is available on drip irrigation in elephant foot yam. Hence, it is imperative to study the effect of green gram intercropping in elephant foot yam under drip irrigation in terms of growth, productivity, water-use efficiency and economics.

MATERIALS AND METHODS

A field experiment was conducted during 2012 and 2013 at the Regional Centre of ICAR-Central Tuber Crops Research Institute, Dumuduma (20°14' N and 85°47' E at 33 m above mean-sea level), Bhubaneswar, Odisha. The soil of the experimental site was sandy clay loam, low in organic carbon (0.41%), available nitrogen (92.6 kg/ha) and available potassium (87.2 kg/ha) and medium in available phosphorus (12.2 kg/ha) with neutral soil reaction (*p*H 6.9). The climate of the area is warm and moist with hot and humid summer and mild winter. The average annual rainfall received during the experimental period was 1,554.5 mm, out of which nearly 80% was received during June to September. The experiment was laid out in split-plot design with 5 replications keeping elephant foot yam + green gram and elephant foot yam sole crop in main plots and surface irrigation, drip irrigation at 100%, 80% and 60% cumulative pan evaporation (CPE), in subplots. The elephant foot yam (var. Gajendra) corm pieces weighing 400–500 g were planted at a spacing of 90 cm × 90 cm on ridges at 5 to 10 cm depth with the help of spade. The green gram (var. Dauli) seeds were sown (10 kg/ha) continuously on single row on the top of the ridges immediately after planting of elephant foot yam. After 15 days of sowing, green gram plants were thinned 15 cm apart. The recommended fertilizer dose for the elephant foot yam crop was 100:80:100; N: P_2O_5: K_2O kg/ha. During the final land preparation, full dose of phosphorous as single super phosphate (SSP) was applied along with FYM @ 10 t/ha, borax @ 10 kg/ha and zinc sulphate @ 10 kg/ha. The nutrient, N as urea and K as muriate of potash (MOP) were applied in 3 equal splits at 45, 75 and 105 days after planting (DAP) by band placement just after weeding followed by earthing up. No separate fertilizer was applied for green gram.

Surface irrigation was followed on furrows at IW/CPE = 1. Whenever the pan evaporation exceeded 40 mm, surface irrigation was provided 40 mm depth of irrigation. Irrigation water for was conveyed through pipelines. Drip irrigation at 60%, 80% and 100% CPE was applied at 3 days interval. The depth of irrigation required for each time was estimated as follows:

Irrigation water (mm) = [% CPE to be applied × Pan factor (0.6) × Crop factor (0.7)] - Effective rainfall. The water holding capacity of the soil was 110 mm/m and excess water beyond the water holding capacity is considered as loss of water. Volume of water applied each time was calculated as follows:

Volume (l) = Irrigation water (mm) × area (m^2). The fully matured green gram pods were harvested at 60 and 75 days after sowing (DAS). The haulms of the green gram were left in the field and trampled together to act as mulch. The elephant foot yam crop was harvested at 240 DAP. Growth observations of green gram were recorded at 75 DAS and yield attributes and yield at harvest. The growth characters of elephant foot yam were recorded at 150 DAP and yield attributes and yield at 240 DAP. The Corm equivalent yield (CEY), consumptive use of water (CUW) and water-use efficiency (WUE) were calculated as follows:

$$\text{CEY (t/ha)} = \text{Corm yield of elephant foot yam (t/ha)} + \frac{\text{Seed yield of green gram (t/ha)} \times \text{price of green gram seed (₹/t)}}{\text{Price of elephant foot yam corm (₹/t)}}$$

$$\text{CUW (cm)} = \text{Effective rainfall (cm)} + \text{irrigation water applied (cm)} + \text{soil moisture contribution from root zone (cm)}$$

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

The statistical analysis of the data was performed using Microsoft Excel and MSTAT-C software. The homogeneity of error variance was tested using Bartlett's χ^2-test. As the error variance was homogeneous, pooled analysis was done. Statistical significance between mean differences among treatments for various parameters was analyzed using critical differences (CD) at 0.05 probability level.

RESULTS AND DISCUSSION

Growth, yield attributes and yield

Green gram: Plant height was under surface irrigation and drip irrigation at 100% CPE. The number of pods/plant was greater with drip irrigation at 100 and 80% CPE (Table 1). Seed yield/plant varied significantly with different irrigation levels. All the drip irrigation treatments re-

sulted in significantly higher seed yield/plant than surface irrigation. Greater seed yield was recorded under drip irrigation at 60 and 80% CPE resulted in higher productivity. This indicate that crop green gram could perform better as an intercrop with less water application. The lowest seed yield was observed with surface irrigation. All the drip irrigation treatments resulted in significantly higher haulm yield over surface irrigation. Greater haulm yield was recorded at 80% CPE and the lowest haulm yield was observed with surface irrigation.

Elephant foot yam: Intercropping green gram with elephant foot yam showed increase in growth attributes of elephant foot yam (Table 2). The number of pseudostems/hill was significantly higher in intercropped elephant foot yam than its sole crop. This might be due to inter-plant competition for the growth factors such as light and space. Singh *et al*. (2013) also reported similar findings under intercropping of elephant foot yam. The pseudostem height was greater under elephant foot yam + green gram intercropping than sole elephant foot yam (Table 2). The intercropping of green gram had no significant effect on the pseudostem collar girth of elephant foot yam, but relatively higher values were noticed under sole crop than intercropped elephant foot yam. The greater pseudostem height and lower pseudostem collar girth of elephant foot yam under intercropping was due to longitudinal elongation of cells to trap sunlight for photosynthesis. Chattopadhyay *et al.* (2008) and Nedunchezhiyan (2014) also reported similar findings in elephant foot yam under intercropping. The canopy spread and number of leaflets/hill in elephant foot yam under intercropping was greater compared to sole elephant foot yam. The green gram canopy covered the ground quickly and allowed minimum sunlight to pass, hence elephant foot yam canopy expanded horizontally to trap more sunlight. The irrigation levels did not influence the number of pseudostems/hill, pseudostem height, collar girth, canopy spread and number of leaflets per plant (Table 2). However, greater number of pseudostems/hill was recorded with drip irrigation at 60% CPE. The pseudostem height and collar girth was

Table 1. Effect of drip irrigation on plant height, dry-matter accumulation, yield attributes and yield of green gram at harvest as intercrop in elephant foot yam (pooled data of 2 years)

Treatment	Plant height (cm)	Pods/plant	Seed yield (g/plant)	Seed yield (kg/ha)	Haulm yield (kg/ha)
Surface	35.0	19	5.7	238	1,057
Drip at 100% CPE	34.5	26	7.1	312	1,384
Drip at 80% CPE	33.3	26	7.5	330	1,466
Drip at 60% CPE	32.8	24	7.5	330	1,462
SEm±	1.2	0.8	0.3	15	64
CD (P=0.05)	NS	3	0.9	45	197

CPE, Cumulative pan evaporation; NS, non-significant

Table 2. Effect of green gram intercropping and drip irrigation on growth of elephant foot yam at 150 days after planting (pooled data of 2 years)

Treatment	Pseudo stems/hill	Height of pseudostem (cm)	Collar girth of pseudo stem (cm)	Canopy spread (cm)	Leaflets/hill
Cropping system					
EFY + GG intercropping	2.9	75.3	20.7	85.8	244
EFY sole	2.6	65.8	20.8	78.6	224
SEm±	0.06	2.1	0.5	2.3	10
CD (P=0.05)	0.2	8.3	NS	NS	NS
Irrigation					
Surface	2.6	71.8	20.5	84.0	197
Drip at 100% CPE	2.7	73.0	21.6	86.7	227
Drip at 80% CPE	2.7	69.3	20.6	82.9	196
Drip at 60% CPE	2.9	67.8	20.2	80.5	203
SEm±	0.2	2.1	0.5	2.3	10
CD (P=0.05)	NS	NS	NS	NS	NS

EFY, Elephant foot yam; GG, green gram; CPE, cumulative pan evaporation; NS, non-significant

greater with drip irrigation at 100% CPE and least at 60% CPE. The greater canopy spread and number of leaflets/plant of elephant foot yam was recorded with drip irrigation at 100% CPE. Similar findings of earlier workers, results were reported by Shibhila and Balakrishnan (1990), Doyle *et al*. (1994) and Nedunchezhiyan *et al*. (2016).

The number of corms/hill and corm diameter was not influenced by cropping system (Table 3). However, greater average corm weight was noticed in elephant foot yam + green gram intercropping than sole cropping of elephant foot yam. The higher number of corms/hill of elephant foot yam was recorded with surface irrigation as compared to drip irrigation (Table 3). The drip irrigation at 100% CPE resulted in greater corm diameter compared to other treatments. Surface irrigation resulted in lower corm diameter. Average corm weight at all the levels of drip irrigation was higher than surface irrigation. The interaction effect of cropping systems and irrigation on average corm weight was significant (Table 4). Under intercropping, the average corm weight of elephant foot yam was highest with drip irrigation at 100% CPE and 80% CPE. This might be due to greater growth attributes in these treatments.

The corm yield recorded under elephant foot yam + green gram intercropping was significantly higher than sole cropping (Table 3) and intercropping resulted in 10.2% increase in corm yield over sole cropping. Higher corm yield under intercropping might be attributed to greater corm diameter and average weight of corm. Nedunchezhiyan and Byju (2005) also reported that short-duration grain legumes promote growth and yield of elephant foot yam. All levels of drip irrigation resulted in significantly higher corm yield than surface irrigation (Table 3). The drip irrigation at 100, 80 and 60% CPE had 15.8, 15.5 and 11.9% yield advantage over surface irrigation, respectively. Higher corm yield might be due to greater corm diameter and average corm weight in these treatments. Venkatesan *et al*. (2014) reported that highest corm yield of elephant foot yam was observed with the application of drip irrigation at 100% CPE. The interaction effect between cropping systems and irrigation on corm yield was significant (Table 4). Drip irrigation at 100% CPE increased the corm yield by 19.2% in intercropping over surface irrigation but this increase was 11.8% under sole cropping. Similarly, drip irrigation at 80% CPE showed an increase in corm yield by 18.5% over surface irrigation under intercropping, whereas it was 11.4% under sole cropping.

System productivity

Corm equivalent yield of the elephant foot yam + green gram intercropping system was significantly higher than sole elephant foot yam (Table 3). The increase in corm equivalent yield under intercropping was 13.0% over the sole crop. Nedunchezhiyan *et al*. (2008) also reported higher corm equivalent yield in elephant foot yam + green gram intercropping system. All the levels of drip irrigation resulted in significantly higher corm equivalent yield than surface irrigation. The highest yield was noted with the drip irrigation at 100% CPE being on a par with drip irrigation at 80% CPE. The interaction effect of cropping systems and irrigation on corm equivalent yield of elephant foot yam was significant (Table 4). The highest corm equivalent yield was obtained with elephant foot yam + green gram intercropping with drip irrigation at 100% CPE, which was on a par with elephant foot yam + green gram intercropping with drip irrigation at 80% CPE.

Table 3. Effect of green gram intercropping and drip irrigation on yield attributes and yield of elephant foot yam (pooled data of 2 years)

Treatment	Corms/hill	Corm diameter (cm)	Average corm weight (kg)	Corm yield (t/ha)	Corm equivalent yield (t/ha)
Cropping system					
EFY + GG intercropping	1.10	17.3	2.5	32.3	33.1
EFY sole	1.11	16.9	2.3	29.3	29.3
SEm±	0.01	0.13	0.03	0.3	0.3
CD (P=0.05)	NS	NS	0.1	1.2	1.3
Irrigation					
Surface	1.15	16.8	2.1	27.8	28.1
Drip at 100% CPE	1.10	17.6	2.5	32.2	32.6
Drip at 80% CPE	1.09	17.1	2.5	32.1	32.6
Drip at 60% CPE	1.07	16.9	2.4	31.1	31.6
SEm±	0.01	0.2	0.04	0.3	0.4
CD (P=0.05)	0.04	0.6	0.1	1.0	1.2

EFY, Elephant foot yam; GG, green gram; CPE, cumulative pan evaporation

Consumptive use

The consumptive use of water in both elephant foot yam + green gram intercropping and sole elephant foot yam cropping was 81 cm (Table 5). Under surface irrigation, the consumptive use of water was very high (204 cm). The consumptive use of water with drip irrigation was lower than surface irrigation. Nedunchezhiyan (2017) also reported lower consumptive use of water in elephant foot yam under drip irrigation than surface irrigation. The consumptive use of water with drip irrigation at 100, 80 and 60% CPE was 50, 41 and 30 cm, respectively (Table 5).

Water-use efficiency

The water-use efficiency was significantly influenced by the cropping system and drip irrigation levels (Table 5). Higher water-use efficiency was noticed with elephant foot yam + green gram intercropping than the sole elephant foot yam. The drip irrigation resulted in greater water-use efficiency than surface irrigation. This might be due to higher corm yield with moderate amount of water application. Nedunchezhiyan (2017) also reported similar findings in elephant foot yam. The water-use efficiency increased significantly with successive lower rate of water application under drip irrigation. The interaction effect of cropping system and irrigation on water-use efficiency was found significant. The elephant foot yam + green gram intercropping system resulted in higher water-use efficiency than sole elephant foot yam with different irrigation levels. The highest water-use efficiency was noticed in elephant foot yam + green gram intercropping with drip irrigation at 60% CPE.

Economics

The cost of cultivation in elephant foot yam + green gram intercropping was 4% higher than sole elephant foot yam (Table 5). The increase in net return under intercropping was 16.9% over sole elephant foot yam. Intercropping elephant foot yam with green gram resulted in significantly higher B: C ratio than sole elephant foot yam. The cost of cultivation was lower in surface irrigation than drip irrigation (Table 5). Under different levels of drip irriga-

Table 4. Interaction effect of cropping system and drip irrigation on average corm weight, corm yield, corm equivalent yield, water-use efficiency and net return (pooled data of 2 years)

Irrigation	EFY + GG intercropping	EFY sole	SEm±	CD (P=0.05)
Average corm weight (kg)				
Surface	2.2	2.0	0.05	0.2
Drip at 100% CPE	2.7	2.4		
Drip at 80% CPE	2.7	2.4		
Drip at 60% CPE	2.5	2.3		
Corm yield (t/ha)				
Surface	28.6	27.2	0.5	1.4
Drip at 100% CPE	34.1	30.4		
Drip at 80% CPE	33.9	30.3		
Drip at 60% CPE	32.8	29.4		
Corm equivalent yield (t/ha)				
Surface	29.2	27.2	0.5	1.5
Drip at 100% CPE	34.9	30.4		
Drip at 80% CPE	34.8	30.3		
Drip at 60% CPE	33.7	29.4		
Water-use efficiency (kg/ha-cm)				
Surface	109	102	9.5	28
Drip at 100% CPE	782	681		
Drip at 80% CPE	889	775		
Drip at 60% CPE	1154	1007		
Net returns (× 10^3₹/ha)				
Surface	260	237	6	19
Drip at 100% CPE	338	280		
Drip at 80% CPE	336	278		
Drip at 60% CPE	322	267		

EFY, Elephant foot yam; GG, green gram; CPE, cumulative pan evaporation

Table 5. Effect of cropping system and drip irrigation on consumptive use, water-use efficiency and economics (pooled data of 2 years)

Treatment	Consumptive use (cm)	Water-use efficiency (kg/ha-cm)	Total cost (× 10^3₹/ha)	Net returns (× 10^3₹/ha)	B: C ratio
Cropping system					
EFY + GG intercropping	81	733	181	311	1.8
EFY sole	81	641	174	266	1.5
SEm±	–	6.8	0.2	4	0.02
CD (P=0.05)	–	27	1	16	0.1
Irrigation					
Surface	204	105	173	249	1.4
Drip 100% CPE	50	731	180	309	1.7
Drip 80% CPE	41	832	180	307	1.7
Drip 60% CPE	30	1,080	177	295	1.7
SEm±	–	6.8	0.2	5	0.02
CD (P=0.05)	–	20	0.6	13	0.1

EFY, Elephant foot yam; GG, green gram; CPE, cumulative pan evaporation

tion, the cost of cultivation decreased with the lower level of water application. All the levels of drip irrigation resulted in significantly higher net return than surface irrigation. The highest net return was noted with drip irrigation at 100% CPE being on a par with the drip irrigation at 80% CPE. The B: C ratio under surface irrigation was significantly lower than all the levels of drip irrigation. Nedunchezhiyan (2017) also reported higher economic returns with drip irrigation at 80-100% CPE in elephant foot yam. Venkatesan *et al*. (2014) reported that judicious and optimal use of water is prerequisite to maximize the productivity and return in elephant foot yam crop.

The interaction effect of cropping system and irrigation on cost of cultivation was not significant (Table 4) but it was significant for net return. The highest net returns was obtained from elephant foot yam + green gram intercropping with drip irrigation at 100% CPE which was on a par with elephant foot yam + green gram intercropping under drip irrigation at 80% CPE. The interaction effect of cropping system and irrigation on B: C ratio was not significant.

It can be concluded that green gram can be grown as intercrop in elephant foot yam, as it increases system productivity and economic returns. Considering the importance of the scarce commodity water, application of drip irrigation at 80% CPE was optimum for elephant foot yam + green gram intercropping system to harvest higher yield and returns.

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