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Cropping system and irrigation effects on Nutrient use efficiency and quality of elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson]

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ABSTRACT

A field experiment was conducted during 2012 and 2013 at the Regional Centre of ICAR-Central Tuber Crops Research Institute, Dumuduma, Bhubaneswar, Odisha to study the effects of cropping system and irrigation on nutrient use efficiency and quality of elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson]. The experiment was laid out in split plot design with elephant foot yam + green gram (*Vigna radiata* L.) and elephant foot yam sole crop in 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 sub-plots. The treatments were replicated five times. Elephant foot yam + green gram resulted in greater corm yield compared to other treatments. The drip irrigation at 100, 80 and 60% CPE resulted in 16.7 and 14.9%, 16.4 and 14.6%, 12.3 and 11.5% higher yield over surface irrigation during 2012 and 2013, respectively. The greater nitrogen, phosphorus and potassium uptake as well as nutrient use efficiency were noticed in elephant foot yam + green gram intercropping with drip irrigation at 100% CPE followed by at 80% CPE. The elephant foot yam + green gram resulted in greater protein and sugar content in corms than sole cropping. But, starch and oxalate content was higher in sole elephant foot yam corms. The minerals, i.e. P, K, Ca, Mg and Zn content in the corms of sole elephant foot yam crop and surface irrigation were higher than other treatments. However, optimum elephant foot yam corm yield and nutrient use efficiency with mineral nutrition can be obtained under elephant foot yam + green gram intercropping with the application of drip irrigation at 80% CPE.

Key words: Corm yield, drip irrigation, elephant foot yam, nutrient uptake

INTRODUCTION

Elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson] is a tuberous vegetable crop and has wide range of adaptability and high yield potential. It is cultivated throughout India, particularly in Andhra Pradesh, West Bengal, Bihar, Uttar Pradesh, Tamil Nadu, Kerala, Maharashtra, Odisha and Karnataka (Nedunchezhiyan, 2017). Earlier, cultivation of elephant foot yam was at subsistence level limited to household consumption, but presently the crop is gaining its popularity among the farmers as a large scale commercial crop due to its increasing market demand. 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 circular shaped lamina on a long pseudostem (petiole) and is

planted at wider spacing. Depending upon the location it produces 3-4 pseudostem during crop growth period. It takes nearly three months to fully cover the ground. The long pseudostem coupled with wider spacing allows intercrop to grow. 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* L.) 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. The commercial crop is grown under protective irrigation. In Andhra Pradesh the crop is irrigated at weekly interval thereby providing 22-25 irrigation during crop growth period of 8 months. The corm yield of elephant foot yam 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 requirements and checks unwanted weed growth. Drip irrigation is high frequency irrigation method with an efficiency of about 98-99 % (Ertek et al., 2007). The higher crop yields and water productivity in vegetables was reported in drip irrigation system (Tiwari et al., 2003). Higher nutrient use efficiency under drip irrigation was reported in potato (Phene et al., 1979; Chawla and Narda, 2002). The information on nutrient use efficiency and quality of elephant foot yam under cropping systems and irrigation was negligible. Keeping the above in view, a study was carried out to find the effects of intercropping in elephant foot yam under irrigation on nutrient use efficiency and quality characters of elephant foot yam.

MATERIALS AND METHODS

A field experiment was conducted during 2012 and 2013 at the Regional Centre of ICAR-Central Tuber Crops Research Institute (20°14' N and 85°47' E at 33 m above mean sea level), Dumuduma, Bhubaneswar, Odisha. The climate condition of the location is warm and moist with hot and humid summer and mild winter. The average annual rainfall of the experimental site is 1554.5 mm out of which nearly 80% is received during June to September. The soil of the experimental site was sandy clay loam in texture with water holding at field capacity was 110 mm m^{-1}. The soil was low in organic carbon (0.41%), available nitrogen (92.6 kg ha^{-1}) and available potassium (87.2 kg ha^{-1}) and medium in available phosphorus (12.2 kg ha^{-1}) with normal soil reaction (pH 6.9). The experiment was laid out in split-plot design with five replications having elephant foot yam + green gram and elephant foot yam sole crop in 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 sub-plots. The elephant foot yam (var. Gajendra) seed weighing 400-500 g was planted at the spacing of 90 × 90 cm on the ridges below 5 to 10 cm depth of the soil with the help of spade. The green gram (var. Dhauli) seeds were sown (10 kg ha^{-1}) 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 N, P_2O_5, and K_2O @100:80:100 kg ha^{-1}. During the final land preparation total amount of phosphorous as single super phosphate (SSP) was applied along with FYM 10 t ha^{-1}, borax 10 kg ha^{-1} and zinc sulphate 10 kg ha^{-1}. The nutrient N as urea and K as muriate of potash (MOP) were applied in three 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.

The surface irrigation was followed on furrows at IW/CPE = 1. Whenever the pan evaporation exceeded 40 mm then the surface irrigation was provided 40 mm depth of irrigation. The irrigation water for surface irrigation was conveyed through pipe lines. The drip irrigation at 60%, 80% and 100% CPE was applied at every three 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.

As the water holding capacity of the soil was 110 mm m^{-1}, the excess of 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).

During 2012, 268, 48, 39 and 29 cm water was applied through surface irrigation, 100, 80 and 60% CPE, respectively. During 2013, 139, 51, 43 and 31 cm water was applied through surface irrigation, 100, 80 and 60% CPE, respectively. The fully matured green gram pods were plucked at 60 and 75 days after sowing (DAS). The haulms of green gram were left in the field and trampled to act as mulch. Elephant foot yam crop was harvested at 240 DAP. The yield, nutrient uptake and quality characters were studied at harvest time. Mineral nutrients content and quality parameters of the corm were analyzed by following AOAC (1980).

The statistical analysis of the data was performed using Microsoft Excel and MSTAT-C softwares. Statistical significance between mean differences among treatments for various parameters was analyzed using critical differences (CD) at 0.05 probability level.

RESULTS AND DISCUSSION

Corm yield

The intercropping of elephant foot yam + green gram recorded increased corm yield of 11 and 9.5% over sole cropping of elephant foot yam during 2012 and 2013 respectively (Table 1). Higher corm yield under intercropping might be due to greater growth and yield attributes. A short-duration grain legume promoting growth and yield of elephant foot yam has been reported by Nedunchezhiyan and Byju (2005). All levels of drip irrigation resulted in significantly higher corm yields than surface irrigation in both the years (Table 1). The drip irrigation at 100, 80 and 60% CPE had 16.7 and 14.9%, 16.4 and 14.6%, 12.3 and 11.5% yield advantage over surface irrigation during 2012 and 2013, respectively. Higher corm yield might be due to greater growth and yield attributes. Venkatesan et al. (2014) reported that the 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 in both the years (Table 2). The drip irrigation at 100% CPE registered an increase in corm yield by 19.3% over surface irrigation under intercropping, but this increase was 11.8% under sole cropping. Similarly, drip irrigation at 80% CPE showed an increase in corm yield by 18.6% over surface irrigation under intercropping, whereas it was 11.6% under sole cropping.

Nutrient use efficiency

Nutrient uptake of elephant foot yam presented in the Table 1 revealed that potassium uptake was higher than nitrogen and phosphorus in both the years. The nitrogen, phosphorus and potassium uptake by elephant foot yam were significantly higher in elephant foot yam + green gram intercropping than sole cropping except potassium uptake during 2013. The greater nutrient uptake of elephant foot yam in elephant foot yam + green gram intercropping might be attributed to higher nutrient content in the pseudo stem and corm and higher dry matter production under intercropping system.

The haulms of the green gram were left in the field and trampled after plucking the pods and it act as mulch. The haulms decompose and releases nutrients into the soil. Further green gram also fixes atmospheric nitrogen in the soil. All these nutrients were efficiently utilized by the long duration elephant foot yam crop and led to higher uptake of nutrients. Nedunchezhiyan et al. (2008) also reported higher nutrients uptake when elephant foot yam crop was mulched. The nitrogen, phosphorus and potassium uptake was higher with drip irrigation at 100% CPE followed by drip irrigation at 80% CPE compared to other treatments. The interaction effect for nitrogen, phosphorus and potassium uptake between cropping systems

and irrigation was significant for nitrogen uptake during 2013, phosphorus uptake during 2012 and potassium uptake in both the years (Table 2). Greater nitrogen, phosphorus and potassium uptake were noticed in elephant foot yam + green gram intercropping with drip irrigation at 100% CPE. This might be due to higher dry matter production in this treatment. Goenaga (1994) and Nedunchezhiyan et al. (2016) reported that nutrient uptake increased parallel to yield increase.

The nutrient use efficiency of N, P and K was significantly higher in elephant foot yam + green gram intercropping than sole elephant foot yam (Table 1). Application of drip irrigation at 100% CPE resulted in greater nutrient use efficiency and it was at par with drip irrigation at 80% CPE. This was due to efficient utilization of applied fertilizers in this treatment as indicated by higher corm yield. Nedunchezhiyan (2017) also reported similar findings in elephant foot yam. Significantly lower nutrient use efficiency was observed with surface irrigation. It was 14.2 and 13.3% lower during 2012 and 2013, respectively than both drip irrigation at 100 and 80% CPE. In both the years, greater nutrient use efficiency was noticed in elephant foot yam + green gram intercropping with drip irrigation at 100% CPE followed by 80% CPE (Table 2). This might be due to greater corm yield in this treatment.

Table 1. Effect of green gram intercropping and drip irrigation on nutrient uptake and nutrient use efficiency of elephant foot yam

Treatments	Corm yield (t ha^{-1})		Nitrogen uptake (kg ha^{-1})		Phosphorous uptake (kg ha^{-1})		Potassium uptake (kg ha^{-1})		Nutrient use efficiency (kg kg^{-1})	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Cropping system										
EFY+GG intercropping	31.4	33.2	34.6	35.0	7.7	7.7	66.9	62.3	115	122
EFY sole	28.3	30.3	33.5	33.4	7.3	7.4	60.8	59.0	101	108
SEm±	0.2	0.3	0.2	0.3	0.1	0.03	1.2	0.9	0.77	1.0
CD (P=0.05)	1.0	1.2	0.8	1.3	0.3	0.1	4.6	NS	3.04	3.7
Irrigation										
Surface	26.8	28.8	33.6	34.0	7.1	7.3	60.2	58.8	97	104
Drip at 100% CPE	31.3	33.1	35.0	34.8	8.1	8.0	68.6	61.6	113	120
Drip at 80% CPE	31.2	33.0	34.2	34.5	7.7	7.7	64.3	62.1	113	120
Drip at 60% CPE	30.1	32.1	33.4	33.4	7.2	7.2	62.4	60.1	109	116
SEm±	0.3	0.3	0.3	0.3	0.1	0.1	1.3	0.9	1.0	0.9
CD (P=0.05)	1.0	0.8	0.9	0.9	0.3	0.4	3.8	NS	3.0	2.7
Interaction	*	*	NS	*	*	NS	*	*	*	*

EFY: Elephant foot yam, GG: Green gram, CPE: Cumulative pan evaporation
*Significant at 0.05 probability

Table 2. Interaction effect of cropping system and drip irrigation on nutrient uptake and nutrient use efficiency of elephant foot yam

Irrigation	2012				2013			
	EFY+GG intercropping	EFY sole	SEM±	CD (P=0.05)	EFY+GG intercropping	EFY sole	SEm±	CD (P=0.05)
Corm yield (t ha^{-1})								
Surface	27.5	26.2	0.5	1.4	29.6	28.1	0.4	1.2
Drip at 100% CPE	33.3	29.4			34.8	31.3		
Drip at 80% CPE	33.0	29.3			34.7	31.3		
Drip at 60% CPE	31.7	28.4			33.9	30.4		
N uptake (kg ha^{-1})								
Surface	34.0	33.2	0.44	NS	33.9	34.1	0.4	1.2
Drip at 100% CPE	35.9	34.1			36.0	33.6		
Drip at 80% CPE	34.3	34.2			35.3	33.7		
Drip at 60% CPE	34.1	32.6			34.8	32.1		
P uptake (kg ha^{-1})								
Surface	7.0	7.2	0.2	0.5	7.3	7.3	0.2	NS
Drip at 100% CPE	8.3	7.9			8.1	8.0		
Drip at 80% CPE	7.8	7.5			7.7	7.7		
Drip at 60% CPE	7.6	6.8			7.5	6.8		
K uptake (kg ha^{-1})								
Surface	58.1	62.3	1.8	2.0	58.0	59.7	1.3	1.5
Drip at 100% CPE	74.8	62.3			65.6	57.5		
Drip at 80% CPE	68.2	60.4			63.0	61.2		
Drip at 60% CPE	66.6	58.2			62.5	57.7		
Nutrient use efficiency (kg kg^{-1})								
Surface	100.4	93.4	1.4	4.2	108	100	1.3	3.8
Drip at 100% CPE	121.6	104.9			128	112		
Drip at 80% CPE	120.8	104.6			127	112		
Drip at 60% CPE	116.3	101.4			124	109		

EFY: Elephant foot yam, GG: Green gram, CPE: Cumulative pan evaporation

Quality attributes

The protein content was higher in the corm harvested in the year 2012 as compared to corms harvested in 2013 (Table 3). The elephant foot yam + green gram resulted in greater protein and sugar content in corms than sole cropping (Table 3). Though starch and oxalate content was not significant, higher amount was observed in sole elephant foot yam corms. The lower starch and oxalate content in the corms of elephant foot yam grown under intercropping might be due to dilution

effect, as the corm yield in elephant foot yam + green gram intercropping was higher (Table 1). The irrigation treatments significantly influenced the protein and sugar content of corm of elephant foot yam in both the years (Table 3). The protein and sugar content in the corm was significantly higher with surface irrigation than all drip irrigation levels. Increasing drip irrigation level decreased the protein and sugar content. Irrigation treatments did not influence starch and oxalate content significantly. But greater in quantity was noticed in surface irrigation. The interaction effect of cropping systems and irrigation for protein and sugar content of elephant foot yam was noticed (Table 4). Sole elephant foot yam crop with surface irrigation recorded significantly higher protein and sugar content in corms. Interaction effect was not significant for starch and oxalate.

The mineral nutrients content in elephant foot yam corms was not significantly influenced by cropping system (Table 5). The minerals, i.e. P, K, Ca, Mg and Zn content in the corms of sole elephant foot yam crop were greater than corms produced under elephant foot yam + green gram intercropping. Lower mineral nutrients content in corms of elephant foot yam grown under intercropping might be due to dilution effect. Irrigation treatment significantly influenced P content in the corm. The surface irrigation resulted in significantly higher P content in corms of elephant foot yam. It is followed by drip irrigation at 80 and 100% CPE. The K content of elephant foot yam corms was greater when surface irrigated. Irrigation treatment did not influence Ca and Mg content in corms (Table 5). Zn content in corms of drip irrigation was greater than surface irrigation. Dilution effect on quality characters and mineral nutrition was reported earlier in elephant foot yam (Nedunchezhiyan et al., 2017; Suja, 2013). Interaction effect of cropping system and irrigation for Zn content was noticed during 2012 (Table 4). The elephant foot yam sole cropping with drip irrigation at 60% CPE recorded greater Zn content in corms.

The present investigation revealed that optimum elephant foot yam corm yield and nutrient use efficiency with mineral nutrition can be obtained under elephant foot yam + green gram intercropping with the application of drip irrigation at 80% CPE.

Table 3. Effect of green gram intercropping and drip irrigation on quality of elephant foot yam corm

Treatments	Protein (%)		Sugar (%)		Starch (%)		Oxalate (mg 100 g^{-1})	
	2012	2013	2012	2013	2012	2013	2012	2013
Cropping system								
EFY+GG IC	1.91	1.91	0.85	0.86	15.5	15.3	83.0	83.1
EFY sole	2.18	2.00	0.93	0.94	15.6	15.6	84.7	84.7
SEm±	0.02	0.03	0.01	0.01	0.05	0.1	0.7	0.7
CD (P=0.05)	0.09	NS	0.04	0.03	NS	NS	NS	NS
Irrigation								
Surface	2.35	2.19	1.01	1.00	16.4	16.9	84.4	84.3
Drip at 100% CPE	1.92	1.87	0.77	0.78	14.6	14.6	84.2	84.2
Drip at 80% CPE	1.93	1.88	0.84	0.85	15.3	15.1	82.9	83.0
Drip at 60% CPE	1.97	1.87	0.95	0.96	16.0	15.9	83.8	83.9
SEm±	0.03	0.05	0.01	0.02	0.2	0.2	1.0	1.0
CD (P=0.05)	0.10	0.13	0.04	0.05	0.5	0.5	NS	NS
Interaction	*	NS	*	*	NS	NS	NS	NS

EFY: Elephant foot yam, GG: Green gram, CPE: Cumulative pan evaporation, IC: Intercropping

*Significant at 0.05 probability

Table 4. Interaction effect of cropping system and drip irrigation on quality of elephant foot yam corm

Irrigation	2012				2013			
	EFY+GG intercropping	EFY sole	SEM±	CD (P=0.05)	EFY+GG intercropping	EFY sole	SEM±	CD (P=0.05)
Protein (%)								
Surface	2.32	2.38	0.05	0.14	2.20	2.18	0.07	NS
Drip at 100% CPE	1.81	2.03			1.80	1.95		
Drip at 80% CPE	1.67	2.20			1.78	1.98		
Drip at 60% CPE	1.85	2.09			1.86	1.87		
Sugar (%)								
Surface	0.93	1.06	0.020	0.059	0.93	1.07	0.023	0.068
Drip at 100% CPE	0.77	0.77			0.78	0.79		
Drip at 80% CPE	0.83	0.85			0.85	0.85		
Drip at 60% CPE	0.87	1.04			0.88	1.04		
Zn (mg per 100 g)								
Surface	0.95	1.00	0.006	0.019	0.93	1.00	0.029	NS
Drip at 100% CPE	0.97	1.08			0.97	1.08		
Drip at 80% CPE	0.95	0.99			0.95	0.99		
Drip at 60% CPE	1.04	1.08			1.10	1.08		

EFY: Elephant foot yam, GG: Green gram, CPE: Cumulative pan evaporation

Table 5. Effect of green gram intercropping and drip irrigation on mineral content of elephant foot yam corm

Treatments	P (%)		K (%)		Ca (mg 100 g^{-1})		Mg (mg 100 g^{-1})		Zn (mg 100 g^{-1})	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Cropping system										
EFY+GG IC	0.081	0.077	0.91	1.08	95.3	95.5	45.3	45.4	0.98	0.99
EFY sole	0.085	0.082	0.97	1.13	96.3	96.4	46.4	46.5	1.04	1.04
SEm±	0.001	0.001	0.02	0.02	0.8	0.9	0.6	0.6	0.003	0.01
CD (P=0.05)	NS	0.005	NS	NS	NS	NS	NS	NS	0.01	NS
Irrigation										
Surface	0.088	0.086	1.02	1.16	95.3	95.3	45.8	45.9	0.97	0.96
Drip at 100% CPE	0.082	0.078	0.94	1.07	95.9	95.9	45.7	45.7	1.03	1.03
Drip at 80% CPE	0.082	0.079	0.90	1.09	96.2	96.5	45.9	46.0	0.97	0.97
Drip at 60% CPE	0.079	0.074	0.90	1.11	96.0	96.1	46.0	46.1	1.06	1.09
SEm±	0.002	0.002	0.03	0.03	1.1	1.1	1.0	1.0	0.005	0.02
CD (P=0.05)	0.006	0.005	0.08	NS	NS	NS	NS	NS	0.013	0.06
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	*	NS

EFY: Elephant foot yam, GG: Greengram, CPE: Cumulative pan evaporation, IC: Intercropping
*Significant at 0.05 probability

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