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INTERCROP AND IRRIGATION EFFECTS ON DRY MATTER PRODUCTION AND PARTITIONING IN ELEPHANT FOOT YAM (*Amorphophallus paeoniifolius* (Dennst.) NICOLSON)

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ABSTRACT

The 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 intercrop and drip irrigation on dry matter production and partitioning in elephant foot yam [Amorphophallus paeoniifolius (Dennst.) Nicolson]. The experiment was laid out in split plot design with five replications. The treatments consisted of C1-elephant foot yam + green gram and C2-elephant foot yam sole crop in main plots and I1-surface irrigation, I2-drip irrigation at 100% cumulative pan evaporation (CPE), I3-drip irrigation at 80% CPE and I4-drip irrigation at 60% CPE in sub-plots. Under intercropping the elephant foot yam corm sprouted earlier than sole cropping. The pseudostem and corm dry matter production, and corm bulking rate was higher for elephant foot yam + green gram intercropping which led to greater corm yield than sole cropping. Drip irrigation at 100% CPE and 80% CPE resulted in earlier sprouting of elephant foot yam which led to greater pseudo stem and corm dry matter production, corm bulking rate and corm yield. Considering the corm yield of elephant foot yam as well as importance and availability of water, green gram can be grown as intercrop in elephant foot yam with the application of drip irrigation at 80% CPE.

INTRODUCTION

Elephant foot yam [Amorphophallus paeoniifolius (Dennst.) Nicolson] is an important tuber crop in India. In India, it is commercially large scale cultivated in Andhra Pradesh, West Bengal, Bihar, Uttar Pradesh, Tamil Nadu, Kerala, Maharashtra, Odisha and Karnataka (Nedunchezhiyan, 2017). Elephant foot yam grows well in fertile soil and is grown in alluvial soils in Andhra Pradesh, Bihar, West Bengal and Uttar Pradesh, and vertisols in Chhattisgarh, Gujarat, Karnataka, Maharashtra and Tamil Nadu. It is also grown in alfisols in Kerala, Odisha and northeastern states (Nedunchezhiyan *et al*., 2011). 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.

The elephant foot yam plant looks like an unfolded umbrella because of its round lamina on a long pseudo stem (petiole). The above-ground part is a solitary leaf. The elephant foot yam corms takes long time to initiate sprout and the solitary leaf takes three months to fully cover the ground. This plant feature allows intercrop to grow when elephant foot yam is planted 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* 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 corm yield of elephant foot yam reduced by 30-40% under water stress conditions (Das *et al*., 1995). Surface irrigation is the most common method adopted in elephant foot yam. Frequent irrigation immediately after planting is initiating early sprouting in elephant foot yam. However it augment weed growth and development which later affect the elephant foot yam growth and development. 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). The information on dry matter production and partitioning characteristic 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 dry matter production and partitioning characteristic 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. The soil was 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 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 bellow 5 to 10 cm depth of the soil 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 N, P2O5, and K2O 100:80:100 kg/ha. During the final land preparation total amount 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 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 exceeds 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, 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 (m2). 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 the green gram were left in the field and trampled them to act as mulch. The elephant foot yam crop was harvested at 240 DAP. The elephant foot yam days to sprouting, dry matter production and partitioning in to pseudostem and corm at 60, 90, 120, 150 DAP and at harvest (240 DAP) were recorded. The corm yield was recorded at harvest.

The corm bulking rate (CBR) was recorded during different phases of growth from 1-90, 90-150 and 150-240 DAP and expressed in g day-1 which was calculated as follows

$$\text{CBR (g plant}^{-1}) = \frac{W2 - W1}{t2 - t1}$$

W1 and W2 are the initial and final fresh weight of corms in g per heap at time t1 and t2 respectively.

The statistical analyses of the data were 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 5% probability level.

RESULTS AND DISCUSSION

Days to sprouting

The data on days to sprouting (100%) of elephant foot yam presented in the Table 1 revealed that during 2013 recorded early sprouting than 2012. The elephant foot yam sprouted significantly earlier under intercropping with green gram than sole cropping in both the years. As the green gram crop covered the soil surface, it might have maintained better soil moisture regime and micro climatic condition favouring early sprouting of elephant foot yam. This may be due to the some competition for growth resources for earlier initiation of physiological processes of elephant foot yam (Ravi *et al*., 2011). The findings of present investigation corroborates well with the findings of Singh *et al*. (2013) and Sahoo *et al*. (2015).The elephant foot

Table 1: Effect of cropping system and irrigation on days to sprouting and pseudo stem dry matter production at different growth periods of elephant foot yam

Treatments	Days to 100% sprouting		Pseudo stem dry matter (g heap-1)									
			60 DAP		90 DAP		120 DAP		150 DAP		At harvest	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Cropping system												
EFY + GG intercropping	47	46	13.2	13.7	17.2	16.5	34.8	42.2	40.5	49.7	49.5	61.4
EFY sole	48	48	13.2	13.7	16.1	16.2	35.6	42.1	41.7	49.4	47.7	57.9
SEm±	0.2	0.3	0.6	0.3	0.2	0	0.3	0.4	0.7	0.7	0.5	0.9
CD (P = 0.05)	0.8	1.4	NS	NS	0.8	0.2	NS	NS	NS	NS	1.8	3.5
Irrigation												
Surface	53	51	14	13.1	17.5	15.3	32.2	40.9	37.6	49.3	55.4	57.2
Drip 100% CPE	44	43	14	14.6	18.9	17.9	36.6	44.1	45.9	52	49.9	61.7
Drip 80% CPE	46	46	12.6	13.7	15.7	16.6	37.4	42.2	42.5	48.4	45.7	61.2
Drip 60% CPE	48	48	12.2	13.4	14.5	15.7	34.6	41.3	38.3	48.5	43.5	58.5
SEm ±	0.5	0.5	0.6	0.5	0.2	0.3	0.4	0.8	1.15	1	0.6	1.2
CD (5%)	1.4	1.4	NS	NS	0.7	0.8	1.3	2.3	3.37	2.8	1.8	3.5

Table 2: Effect of cropping system and irrigation on corm dry matter production at different growth periods of elephant foot yam

Treatments	Corm dry matter (g heap-1)									
	60 DAP		90 DAP		120 DAP		150 DAP		At harvest	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Cropping system										
EFY+GG intercropping	36.9	33	50.7	56.1	139	151.9	216.7	219.4	500	532
EFY sole	36.8	34	49.6	55.8	139.3	151.8	217.4	219.1	453	483
SEm±	0.5	0.9	0.8	0.1	1	0.4	3	1	6.5	6.4
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	25.5	24.9
Irrigation										
Surface	37.8	34	51.2	54.9	135.6	150.6	208.1	219	429	461
Drip 100% CPE	37.5	32.5	52.5	57.5	139.8	153.8	225.7	221.7	498	528
Drip 80% CPE	36.3	32.8	49	56.2	140.8	151.9	219.1	218.1	495	525
Drip 60% CPE	35.8	34.5	47.9	55.3	140.3	151	215.1	218.2	483	516
SEm ±	0.7	0.7	1.1	0.7	1.4	1	4.2	1.5	5.9	5.3
CD (5%)	NS	NS	3.2	1.9	4.1	NS	12.1	NS	17.1	15.6

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

Table 3: Effect of cropping system and irrigation on corm bulking rate at different growth periods of elephant foot yam

Treatments	Corm bulking rate (g day-1)						Corm yield (t ha-1)	
	1-90 DAP		90-150 DAP		150-240 DAP			
	2012	2013	2012	2013	2012	2013	2012	2013
Cropping system								
EFY+GG IC	7.5	6.5	8.3	7	8.5	8.5	31.4	33.2
EFY sole	4.9	4.7	6.2	5.6	6.3	7.2	28.3	30.3
SEm±	0.04	0.3	0.1	0.3	0.1	0.3	0.2	0.3
CD (P=0.05)	0.2	1.3	0.3	1.4	0.5	1.2	1	1.2
Irrigation								
Surface	5.2	5.3	7.5	6.4	7.4	7	27.1	29.1
Drip 100% CPE	6.5	6.3	7.8	7	7.6	8.5	31.7	33.5
Drip 80% CPE	6.5	5.7	6.7	5.9	7.6	8.1	31.6	33.5
Drip 60% CPE	6.5	5.2	7	5.8	7	7.8	30.5	32.6
SEm ±	0.1	0.2	0.1	0.2	0.2	0.1	0.4	0.3
CD (5%)	0.4	0.5	0.2	0.7	NS	0.4	0.8	0.7

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

yam corms took significantly longer duration for sprouting under surface irrigation in comparison with drip irrigation. Among the levels of drip irrigation, earliest sprouting was observed at 100% CPE in both the years.

Dry matter production and partitioning

The data on pseudo stem dry matter production of elephant foot yam was recorded at 60, 90, 120, 150 DAP and at harvest during 2012 and 2013 (Table 1). The dry matter accumulation in pseudo stems increased progressively from 60 DAP to till harvest. Greater dry matter production was recorded during 2013 than 2012 at all the growth stages of crop growth except 90 DAP. The cropping system significantly influenced the dry matter production of pseudo stem of elephant foot yam at 90 DAP and at harvest during both the years. The dry matter production was higher for elephant foot yam + green gram intercropping than sole cropping in all the crop growth stages. This might be due to sprouting earlier (Table 1) which led to higher growth attributes. The irrigation significant influenced pseudo stem dry matter production at all the growth stages except at 60 DAP in both the years. Greater dry matter production of pseudo stem was recorded with the drip irrigation at 100% CPE. But during 2012, at 120 DAP drip irrigation at 80% CPE and at harvest surface irrigation were recorded higher dry matter production. Higher pseudo stem dry matter production might be due to higher growth attributes. Elephant foot yam continuously grows and accumulates dry matter as long as there is adequate moisture in the soil (Mukhopadhayay and Sen, 1986; Nair and Mohankumar, 1991). Ravi *et al*. (2011) and Suja *et al*. (2012) reported that elephant foot yam has high dry matter production capability per unit area than most of the other vegetables.

The corm dry matter production of elephant foot yam was presented in Table 2 revealed that the dry matter accumulation in corm increased progressively from 60 DAP to till harvest. The corm dry matter production was slow up to 90 DAP then increased steadily up to 150 DAP. The corms dry matter production was rapid between 150 DAP and at harvest (240 DAP). This was because up to 90 DAP the plant put forth more vegetative growth (divert more photosynthates for pseudo stem growth) thereby corm growth was less. Between 90 and 150 DAP, both vegetative and corm grows parallel (divert photosynthates equally to pseudostem and corm). After 150 days, the growth of pseudo stem was negligible thereby the photosynthates is translocated to developing corm. Nedunchezhiyan *et al*. (2017) also reported pseudo stem dry matter accumulation was very less compared to corm at 5 months after planting. It indicated partitioning efficiency of dry matter towards corm was very high. Increasing rate of corm dry matter accumulation between 5 and 8 months after planting was reported by Nedunchezhiyan (2014). This was in agreement with Das et al. (1997). The year 2013 recorded higher dry matter production than the 2012 at all growth stages except at initial stage *i.e.* at 60 DAP. The intercropping of green gram had no significant effect on elephant foot yam corm dry matter production at different growth stages except at the harvest. However, greater dry matter production of elephant foot yam was noticed under intercropping than sole crop of elephant foot yam.

The surface irrigation resulted in greater corm dry matter production at early stage *i.e.* at 60 DAPS. But subsequent stages drip irrigation recorded higher corm dry matter production than surface irrigation. It indicated the production and partitioning of photosynthates was lesser in surface irrigation owing to non availability of sufficient nutrients to the elephant foot yam crop as it loss through leaching and weeds uptake under surface irrigation. Nedunchezhiyan *et al*. (2016) also reported similar view. Corm dry matter production recorded at harvest revealed that drip irrigation at 100% CPE resulted in greater dry matter production than other levels. It was closely followed by drip irrigation at 80% CPE.

Corm bulking rate

The data on corm bulking rate for different growth periods 1-90, 90-150 and 150-240 DAP of elephant foot yam are presented in the Table 3. The corm bulking rate increased from the initial period to till harvest. The cropping system significantly influenced the corm bulking rate of elephant foot yam in both the years. The corm bulking rate was higher in elephant foot yam + green gram intercropping than sole cropping in all the stages. The highest corm bulking rate recorded with intercropping was 8.5 g day-1 during last phase of crop growth period during both the years. Whereas the sole elephant foot yam cropping recorded corm bulking rate of 6.3 and 7.2 g day-1 during 2012 and 2013, respectively at last phase. Sahoo *et al*. (2015) also reported greater corm bulking rate at last phase in elephant foot yam. The irrigation significantly influenced the corm bulking rate of elephant foot yam at different growth stages of the crop except in 150-240 DAP during 2012. The corm bulking rate was greater with drip irrigation at 100% CPE than other treatments in all the stages.

Corm yield

The cropping system significantly influenced the elephant foot yam corm yield in both the years (Table 3). The intercropping of elephant foot yam + green gram resulted in 11 and 9.5% increase in corm yield over sole cropping of elephant foot yam during 2012 and 2013 respectively. Greater corm yield under intercropping was due to greater pseudostem dry matter (Table 1), corm dry matter (Table 2) and corm bulking rate (Table 3). Cultivation of close growing pulses in elephant foot yam increases corm yield of elephant foot yam (Nedunchezhiyan and Byju, 2005). In this experiment, green gram apart from fixing atmospheric nitrogen in the soil, it acted as mulching after harvesting of the pods. Marked variation in corm yield was noticed with respect to irrigation treatments (Table 3). All levels of drip irrigation recorded significantly higher corm yields than surface irrigation in both the years (Table 3). 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. Greater corm yield was due to greater pseudostem dry matter (Table 1), corm dry matter (Table 2) and corm bulking rate (Table 3) in these treatments. Under moisture stress free conditions, weeds compete with crop for nutrients than water. Under surface irrigation, weeds remove more nutrients and deprived of elephant foot yam thereby reduces corm yield (Nedunchezhiyan, 2017). 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 (Fig. 1). 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. Nitrogen fixed by the green gram was efficiently utilized by elephant foot yam under drip irrigation than surface irrigation wherein weeds competed with the crop. Nedunchezhiyan *et al*. (2008) reported greater corm yield of elephant foot yam when conserving soil moisture by mulching in elephant foot yam + green gram intercropping system. Mulching also suppresses weed growth.

It can be concluded that green gram intercropping in elephant foot yam under drip irrigation has increased dry matter production and partitioning into corm of elephant foot yam. Considering the corm yield of elephant foot yam as well as importance and availability of water, green gram can be grown as intercrop in elephant foot yam with the application of drip irrigation at 80% CPE.

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