



Irrigation schedule for maximum corm yield and water productivity in elephant foot yam (*Amorphophallus paeoniifolius*)

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Received: 03 January 2017; Accepted: 18 April 2018

ABSTRACT

Field experiments were carried out on elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson] during 2013-2014 and 2014-2015 to study the effect of different irrigation schedules in order to arrive at an optimum schedule for attaining maximum corm yield and water productivity. Two methods (Drip and Flood methods) and two levels of irrigation (75% and 100% pan evaporation) were applied at different stages of growth as first 12 weeks, 13-24 weeks, 1-24 weeks, 75% during first 12 weeks and 100% during 13-24 weeks after planting and vice versa. Whole corm size of 500 g each of the variety 'Gajendra' was uniformly used as the planting material. Pooled analysis of the data showed superiority of drip irrigation over flood irrigation. Among the treatment combinations, drip irrigation at 100% pan evaporation during 13-24 weeks after planting resulted in the maximum corm yield (40.59 t/ha). However, this was at par with drip or flood irrigation given during the entire period of 1-24 weeks at 75% and 100% levels. Drip irrigation at 100% pan evaporation during 13-24 weeks resulted in maximum water productivity (4.57 kg/m³). Under flood irrigation, maximum water productivity recorded was 3.87 kg/m³. Irrigation during 13-24 weeks after planting coinciding with corm development stage was found to be more critical than irrigation given during the initial stages of planting. The study revealed that drip irrigation at 100% pan evaporation during 13-24 weeks after planting is the most ideal for attaining maximum corm yield and water productivity in elephant foot yam.

Key words: Corm yield, Elephant foot yam, Irrigation schedule, Water productivity

Elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson], one of the tropical tuber crops, is gaining popularity not only as a food security crop but also as a cash crop due to its production potential and popularity as a starchy vegetable having high nutritive and medicinal values. Its cultivation is mainly confined to India, Philippines, Indonesia, Sri Lanka and South East Asia. Till recent times, the crop was cultivated under rainfed conditions, like other tuber crops in areas with annual rainfall varying between 1000 mm and 3000 mm. Presently, its cultivation is attempted in non traditional areas also due to its perennial demand as well as the attractive prices. Commercial growers plant the crop by the end of March or beginning of April with protective irrigation in Odisha and Andhra Pradesh (Nedunchezhiyan *et al.* 2008). Farmers give more than 20 irrigations apart from rainfall. Generally they follow flood irrigation providing 4-5cm water, thereby lot of water is wasted by runoff and percolation. Recently, commercial farmers started using micro irrigation, but

without any rationale. They even keep the drippers open for 8 or more hours to completely wet the field, thereby a major portion of irrigation water is lost by evaporation and deep percolation resulting in lower efficiencies. Availability of irrigation water will be a major constraint in future for agricultural production in India (Amarasinghe *et al.* 2007) and especially for tuber crops production due to climate change and more demand for other high value crops. This warrants an efficient irrigation schedule for increasing the water use efficiency of tuber crops through suitable water saving techniques.

Drip irrigation is capable of applying precise amounts of water in soil around the root zone, with a high degree of uniformity and frequency. These features make it potentially much more efficient than other irrigation methods (El-Hendawy *et al.* 2008). Similarly, the requirement of water may not be uniform throughout the growing season of a crop. In elephant foot yam, six phenological phases are identified as sprouting and initial establishment, rapid root and shoot growth with tuber initiation, maximum root and shoot growth with corm bulking, dry matter accumulation in aerial parts, senescence with continued corm bulking and maturity, and a dormancy period (Lebot 2009). Adequate moisture during the critical period of growth is vital to realise maximum corm yield. The present study was conducted to optimise the irrigation schedule in elephant foot yam for attaining

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Table 1 Physical and chemical properties of the soil (top 30 cm) in experimental plot

Physical						Chemical					
Sand (%)	Silt (%)	Clay (%)	FC (%)	WP (%)	BD (g/cc)	pH	EC (ds/m)	OC (%)	Available nutrients (kg/ha)		
									N	P	K
69	7	24	24.5	7.8	1.30	5.2	0.08	0.57	380	59	169

FC–field capacity, WP - wilting point, BD-bulk density, EC-electrical conductivity, OC-organic carbon, N-nitrogen, P- phosphorous, K-potassium.

maximum corm yield and water productivity.

MATERIALS AND METHODS

Field experiments were conducted at ICAR-Central Tuber Crops Research Institute, Kerala (8.5° N, 76.95° E, 50 m above MSL) with elephant foot yam for two years (2013-2014 and 2014-15). The soil in the experimental area was deep, well drained, sandy clay loam comprising 69% sand, 7% silt and 24% clay (Table 1). The soil was moderately acidic in reaction having a field capacity of 24.5 %. The location received an average rainfall of 862 mm during the growing season. Maximum temperature varied between 30-34°C and minimum temperature, 22-25°C having a relative humidity of 64 to 81% .

The experiment was laid out in split plot design with two methods of irrigation as main plots (M1: Drip irrigation and M2: Flood irrigation) and two levels of irrigation at four different stages of growth as sub plots (S1: Irrigation at 75% of pan evaporation (PE) during 1-12 weeks after planting (WAP), S2: Irrigation at 75% PE during 13-24 WAP, S3: Irrigation at 75% PE during 1-24 WAP, S4: Irrigation at 100% PE during 1-12 WAP, S5: Irrigation at 100% PE during 13-24 WAP, S6: Irrigation at 100% PE during 1-24 WAP, S7: Irrigation at 75% PE during 1-12 and 100% during 13-24 WAP and S8: Irrigation at 100% PE during 1-12 and 75% during 13-24 WAP). The leading variety of elephant foot yam in India, 'Gajendra' was used for the study by planting 500 g each of the whole seed corm at a spacing of 90 ×90 cm with a gross plot size of 25 plants, during February in both the years (Fig 1). Standard nutrient dose of 25 t/ha of FYM and 100-50-150 kg/ha of N, P₂O₅ and K₂O were applied uniformly in all the treatments.

Quantity of irrigation was fixed based on the daily open pan evaporation and the pan factor. Reference crop evapotranspiration (ET₀) was estimated from pan evaporation (E_p) and pan factor (K_p), as $ET_0 = E_p \times K_p$ where K_p is 0.7 (Allen *et al.* 1998a). The actual crop evapotranspiration (ET_c) was estimated by multiplying reference crop evapotranspiration with crop coefficient (ET_c= ET₀ × K_c) (Doorenbos and Pruitt 1992) where, K_c is the crop coefficient. The crop coefficient values of 0.5, 1.1 and 0.95 at initial, middle and maturity stages respectively, were used for calculating crop evapotranspiration (Allen *et al.* 1998b). Drip irrigation was given once in alternate days and the drippers were placed at the rate of one dripper per plant (Fig 1). For flood irrigation, the field was irrigated once in a week. The flow of water to the irrigation treatment was controlled by water meters with control valves.

Net irrigation water requirement was determined based on the difference between ET_c and the effective rainfall. The effective rainfall was estimated using dependable rainfall method as suggested in FAO CROPWAT model. Based on the corm yield and the total water used, water productivity was worked out (Heydari 2014).

Observations on sprouting was recorded from each plot. Soil moisture status was assessed under each treatment by gravimetric method, by collecting soil samples from two depths, viz. 0-15 cm and 15-30 cm from basin at monthly intervals. Three plants each from the net plot were tagged and biometric observations such as height of plants, height of pseudo stem, girth of pseudo stem, number of leaves, number, length and breadth of leaflets to calculate leaf area and canopy spread were recorded at monthly intervals, after full sprouting. Leaf area per plant was calculated according to Ravi *et al.* (2010). Destructive sampling was done at 5 months after planting and weight of fresh roots, corm, pseudo stem and leaves per plant were recorded in three plants under each treatment. Representative plant samples were collected and oven dried to assess the biomass production under each treatment. The crop was harvested after 10 months during December and corm yield from net plot was recorded and corm yield per ha was estimated. Corm bulking efficiency was also worked out based on the increase in corm yield compared to the initial corm size of 500 g planted. All the data pertaining to two years were pooled and analysed using Indian NARS Statistical Computing Portal, IASRI by applying the technique of Analysis of variance (ANOVA) for split plot design and multiple comparison of treatment means was done by least significant difference.



Fig 1 Elephant foot yam under drip irrigation

RESULTS AND DISCUSSION

Sprouting of corms

There was variation in the pattern of sprouting of corms with method as well as stages of irrigation. Under drip irrigation, the corms took 22 days for initiating sprouting while 50% sprouting was achieved within 36-52 days and 100% sprouting within 52-64 days. Under flood irrigation, the corms took 36 days for initiating sprouting. Fifty percent and full sprouting were achieved within 42-52 days and 60-68 days respectively. Traditionally farmers plant the corms during February end to March second week so that setts would sprout with the pre-monsoon showers (Mohankumar *et al.* 2000). In elephant foot yam, sprouting is highly influenced by the soil moisture availability. Though the normal planting season is February to March, the crop starts sprouting with premonsoon showers during April-May or with the commencement of SW monsoon in June under rainfed conditions. About 75-80% of the sprouting of planted corms and development of first leaf occurs during 2-3 months and this crop growth period requires adequate soil moisture through irrigation or rainfall (Ravi *et al.* 2010). Early sprouting observed in the present study under drip irrigation, is mainly because of the availability of enough moisture exactly in the planting zone. Under flood irrigation, irrigation water was more confined to the interspaces, rather than planting zone and hence took more time for achieving full sprouting. Under both the methods, S2 and S5, where irrigation was not given during the initial period, resulted in late sprouting with the monsoon showers.

Crop growth

Pooled data analysis of the morphological observations recorded at monthly intervals revealed that, crop growth was not significantly affected by either the method or levels of irrigation at any interval of growth, except canopy spread and number of leaves. There was no significant difference in canopy spread between drip and flood irrigation. However, under sub plot treatments, irrigation during initial period especially drip irrigation resulted in more canopy spread at 2 MAP (97.8 cm) and 3 MAP (108.3 cm). However, towards later stages of growth, i.e., after 3 months, canopy spread was more or less same for all the irrigation treatments suggesting that once the canopy is established, the crop retains its rate of growth for a further period upto 5-6 months, until senescence starts. Once the sprout is initiated, further development of leaf is completed within 30 days provided sufficient soil moisture is available (Ravi *et al.* 2011). Hence early sprouting with drip irrigation resulted in more canopy spread during initial months.

Similarly, number of leaves was uniform under different irrigation treatments except at 4 MAP, where flood irrigation resulted in more number of leaves (2.03) compared to drip method (1.67). At 3 MAP also flood irrigation resulted in more number of leaves (2.49), though the difference was insignificant compared to drip (2.16). The number and size of leaves which develop during the growing season

is dependent on quantity of planting material used, soil fertility, soil moisture and developing corm age (Das *et al.* 1997). In the present study, 500 g corms were used as planting material with uniform nutrition except irrigation. Irrigation during initial stages either through drip or flood produced more number of leaves by triggering the cormal buds. Similarly, under flood irrigation, more area of wetted zone was created which have activated the cormal buds to produce more leaves, but with less vigour. But a significant difference was not observed accordingly in the leaf area or leaf area index in any stages of growth among the irrigation treatments, since the canopy spread and number of leaflets were almost uniform.

Biomass production and partitioning

Biomass yield per plant was estimated based on the below ground root and corm dry matter, and the above ground dry matter, which is mainly the leaf and petiole. There was no significant difference in biomass production of plants among the method of irrigation or stages of irrigation. However, their interaction effects on total dry matter yield per plant was significant. Drip irrigation at 100% PE during 13-24 weeks resulted in maximum dry matter production per plant (807.6 g) followed by drip irrigation at 75% PE during 1- 24 weeks (725.4 g) and few other treatment combinations (Fig 2).

Similar to total biomass production, the interaction effect of method and stages of irrigation on biomass partitioning was significant. However, a corresponding increase in dry matter partitioning to corms was not observed in all the treatments. Dry matter partitioning efficiency was greater where irrigation was given during the second half, i.e., during 13-24 weeks after planting. When irrigation was given only during the first 12 weeks, biomass contribution for tuber bulking was 70.8 to 80.6%, whereas ensuring moisture during tuber bulking phase during later stages contributed 73.5 to 82.3% towards corm development. Similarly, drip irrigation resulted in more dry matter partitioning (80%) compared to flood system (77%). Corm yield was significantly reduced due to water deficit stress (WDS) during 4-5 MAP as well as 5-6 MAP in elephant foot yam (Ravi *et al.* 2015) which indicates that soil moisture plays an important role in tuber bulking. In general, it was found that 77- 82% of the total biomass was partitioned to

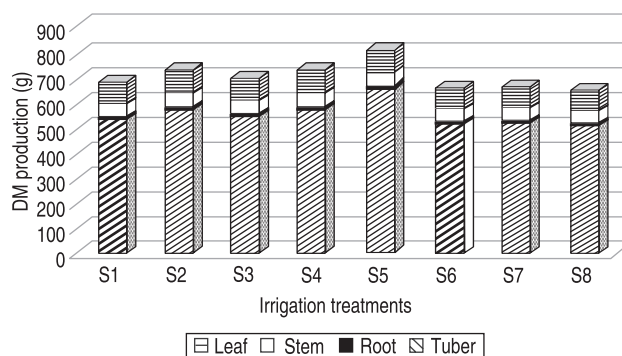


Fig 2 Biomass partitioning under different irrigation treatments

corm yield under different irrigation treatments.

Corm yield

Pooled analysis of the corm yield data showed superiority of drip irrigation over flood irrigation. During both the years, drip irrigation resulted in significantly higher corm yield (32.78 t/ha) than flood irrigation (29.64 t/ha). Among the sub plot treatments, 100% irrigation given during 13-24 WAP was on par with all other treatments except 75% irrigation given either during the first 12 weeks or the 12 weeks thereafter. Among the treatment combinations, drip irrigation at 100% PE during 13-24 WAP resulted in maximum corm yield (40.59 t/ha). However, this was on par with drip or flood irrigation given during the entire period of 1-24 weeks at 75% and 100% PE (Table 2).

Fertigation experiment conducted at CTCRI, RC, Bhubaneswar indicated that drip irrigation at 100% PE and 100% fertigation resulted in maximum corm yield (CTCRI 2011). Based on fertigation trials conducted under AICRP on tuber crops, James George *et al.* (2013) concluded that corm yield was significantly reduced when irrigation was lesser than 100% PE. Maximum corm yield was recorded under drip irrigation at 100% CPE and fertigation at 100% level in Tamil Nadu (Venketasan *et al.* 2014). In these studies, irrigation was given throughout the growth period. The results of the present study clearly indicated that water requirement of elephant foot yam is critical during 13-24 weeks after planting, which coincides with tuber development phase. This was in agreement with Ravi *et al.* (2015). Drip irrigation at 100% PE during this

phase is as good as irrigation given throughout the growth cycle. Soil moisture during the initial stages of growth is mainly utilized for sprouting, tuber initiation and initial establishment of canopy, tuber bulking also starts during this phase in elephant foot yam (Ravi *et al.* 2015). Translocation of starch from vegetative parts to the corm is faster during 3-6 months, which results in more tuber bulking. Once the corm development is over, senescence starts, normally during 6 to 7 months after planting. Corm maturity occurs at this stage. In elephant foot yam, rate of corm bulking increased steadily between one and 5-6 months after planting and the rate was maximum during fifth or sixth month after planting (Ravi *et al.* 2011).

Corm bulking efficiency

Corm bulking efficiency (corm yield per plant / weight of corm planted) followed the same trend of total corm yield. Maximum corm bulking was recorded under drip irrigation given at 100% PE during 13-24 WAP (6.57 times) followed by drip irrigation at 100% during the entire crop growth period of 24 weeks. Under flood irrigation, maximum corm bulking was observed when irrigation was given at 75% PE for the entire 24 weeks (5.28 times) (Fig 3). Corm bulking efficiency mainly depends upon the size and nature of planting material (cut/ whole corm), crop spacing and the management conditions (Ravi *et al.* 2011). In the present study, whole corms of 500g were planted uniformly, so the difference observed in bulking across irrigation treatments could be attributed to the irrigation management and soil moisture availability during tuber bulking stage.

Table 2 Corm yield of elephant foot yam under different irrigation treatments (Pooled mean of 2 years)

Irrigation treatment	Corm yield (t/ha)		
	Drip irrigation	Flood irrigation	Mean
S1: Irrigation @ 75% PE 1-12 wks	20.12	27.01	23.56
S2: Irrigation @ 75% PE 13-24 wks	24.58	29.19	26.88
S3: Irrigation @ 75% PE 1-24 wks	34.71	32.61	33.66
S4: Irrigation @ 100% PE 1-12 wks	28.95	31.28	30.11
S5: Irrigation @ 100% PE 13-24 wks	40.59	26.86	33.72
S6: Irrigation @ 100% PE 1-24 wks	39.65	30.17	34.91
S7: Irrigation @ 75% PE 1-12 and 100% PE 13-24 wks	36.36	32.03	34.19
S8: Irrigation @ 100% PE 1-12 and 75 % PE 13-24 wks	37.31	27.99	32.65
Mean	32.78	29.64	

CD(Mainplots): 1.54; CD(Subplots): 6.24; CD(Interaction):12.26

Water productivity

Water productivity is the ratio of crop output and the input water. In the present study, water productivity was worked out based on the corm yield obtained and water used under different treatments through irrigation as well as effective rainfall. The ratio ranged from 2.65 to 4.57 kg/m³. Drip irrigation at 100% PE during 13-24 weeks resulted in the maximum water productivity (4.57 kg/m³) (Fig 4). Under flood irrigation, maximum water productivity recorded was 3.87 kg/m³. In general, water productivity was greater under drip irrigation system, whereas under flood irrigation, more irrigation could not result in a corresponding increase in

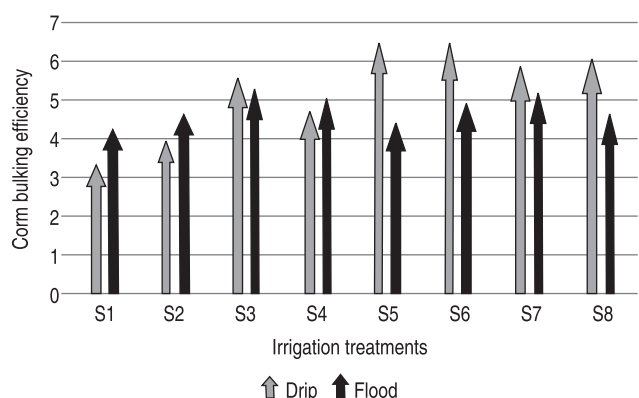


Fig 3 Corm bulking efficiency under different irrigation schedules.

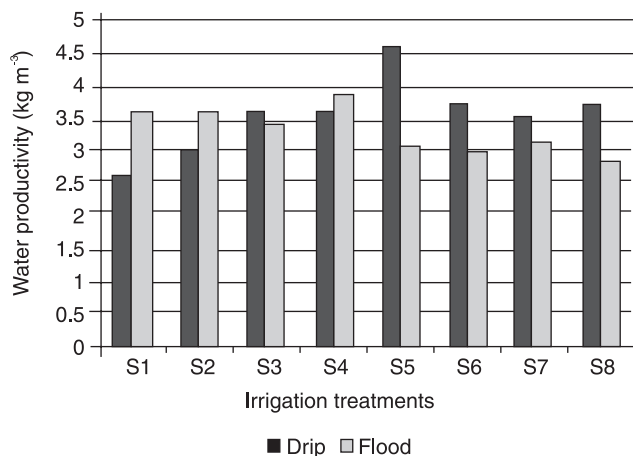


Fig 4 Water productivity of elephant foot yam under different irrigation treatments

water productivity. This indicates the wastage of water for non productive uses under flood irrigation, compared to the effective use of water under drip system. The reduced unproductive water loss along with ideal agronomic conditions resulted in more water productivity under drip system as established in many other crops (Jha *et al.* 2017, Oiganji *et al.* 2016, Chouhan *et al.* 2014). Higher water productivity is an important indicator in improved water management system which shows the efficiency of the drip irrigation, that too during the critical period of crop growth in the present study.

The present study indicated that the drip irrigation resulted in more corm yield in elephant foot yam than flood irrigation. Irrigation during 13-24 weeks after planting coinciding with corm development stage was more critical than irrigation given during the initial stages of 1-12 weeks, coinciding with sprouting and crop establishment stages. Irrigation at 100% pan evaporation applied during corm development stage was as good as irrigation during the entire growth period. The study revealed that drip irrigation at 100% pan evaporation during 13-24 weeks after planting is most ideal for attaining maximum corm yield and water productivity in elephant foot yam.

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