



Water Smart Technologies for Enhancing Corm Yield, Water and Energy Productivity of Elephant Foot Yam (*Amorphophallus paeoniifolius*) (Dennst.) Nicolson

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Abstract

Field experiments were carried out at ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala during 2017-18 and 2018-19 in *Amorphophallus paeoniifolius* (Dennst.) Nicolson, commonly known as elephant foot yam, *suran* or *jimmikhand* or *ole*, which is an important tropical tuber crop in India, gaining popularity as a food security crop, and cash crop due to its production potential and preference as a starchy vegetable having high nutritive and medicinal values. Drip irrigation at 50% cumulative pan evaporation (CPE) along with six different sets of water saving techniques, i.e., plastic porous ground cover mulching, antitranspirant spray on foliage, soil application of pusa hydrogel, synthetic super absorbent polymer, coir pith and biomulching were experimented. Drip irrigation at 50% CPE, 100% CPE, and a rainfed crop without any water saving measures were kept for comparison. In both the years, the treatment with ground cover mulching resulted in the maximum corm yield (40.1 tha^{-1}), B:C ratio (2.94) and water productivity (3.87 kg m^{-3}), reduced the irrigation water requirement by 50%, enhanced the corm yield by 32% and energy use efficiency by 30% as compared to irrigation at 100% CPE.

Key words: Drip irrigation, elephant foot yam, energy productivity, water productivity, water saving

Introduction

Water is the only source on earth that has no substitution. Globally, there is a constantly increasing pressure on water resources in terms of quantity and quality. Agriculture is by far the largest consumer of freshwater, about 70%. According to a UN report on the state of the world's water (Watts 2018) more than 5 billion people may suffer from water shortages by 2050 due to climate change, increased demand and polluted supplies. The effect of water scarcity will be more pronounced in tropical tuber crops where, these crops have to compete with other high value crops. Elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson), is considered as an important tropical tuber crop in India and is gaining popularity not only as a food security crop, but also as a cash crop due to its production potential

and preference as a starchy vegetable having high nutritive and medicinal values. It is extensively grown throughout North India, North Eastern India, Konkan region of Maharashtra, Gujarat, Andhra Pradesh, Odisha, Kerala and Tamil Nadu. Till recent times, the crop was cultivated under rainfed conditions, like other tuber crops utilizing the monsoon showers. Presently its cultivation is attempted in non traditional areas also due to its perennial demand as well as the attractive price, which quite often necessitates assured irrigation in many places. In states like Andhra Pradesh, Odisha, Bihar and West Bengal where the crop is grown on commercial basis, farmers resort to flood irrigation (Nedunchezhiyan et al., 2008). Recently, micro irrigation is also adopted by commercial farmers, but without any rationale. Studies carried out at ICAR-CTCRI revealed that drip irrigation results in more corm yield than flood irrigation

and irrigation during 13- 24 weeks after planting is more critical than the initial stages of establishment of the crop which coincides with corm development phase (Ravi et al., 2015; Sunitha et al., 2018).

In view of the water scarcity expected in near future, development of suitable climate smart technologies, especially water smart technologies for judicious management of irrigation water is the need of the hour in tropical countries. Hence, an attempt was made to compare the different water smart technologies for reducing the water losses and attaining optimum yield, in elephant foot yam, under micro irrigation.

Materials and Methods

Field experiments were carried out at ICAR-Central Tuber Crops Research Institute, Kerala, India during two growing seasons of elephant foot yam, 2017-18 and 2018-19. The location lies between 8.54° North latitude and 76.91° East longitude and comes under the humid tropical climatic zones of India with an altitude of 50 m above mean sea level. The soil in the experimental area was deep, well drained, sandy clay loam (sand 69%, silt 7% and clay 24%), moderately acidic in reaction (pH 5.2). The soil was medium in organic carbon and available nitrogen, high in available phosphorus and low in available potassium status.

The crop was planted under drip irrigation during March in both the years. Nine treatments were included in the study, drip irrigation at 50% cumulative pan evaporation (CPE) along with six different water saving techniques, i.e., plastic porous ground cover mulching (T1), antitranspirant spray on foliage (kaolinite 0.5% foliar spray at fortnightly intervals after sprouting) (T2), soil application of pusa hydrogel (0.5g/ plant before planting in pit) (T3), synthetic super absorbent polymer (0.25g per plant) (T4), coir pith (one kg per plant) (T5) and biomulching with crop residues (T6). Treatments with drip irrigation at 50% (T7), 100% CPE (T8), and a rainfed crop (T9) without any water saving measures were also kept for comparison. The leading variety of *Amorphophallus* in India, 'Gajendra' was used for the study by planting 500 g each of the seed corms uniformly at a spacing of 90 x 90 cm in RBD with three replications. Drip irrigation was given once in two days upto 6 months. Quantity of irrigation was fixed based on the daily open pan evaporation and pan factor, in mm. Crop factor was

taken into account at different stages of growth as suggested by Allen and Pruitt (1991). The crop received an effective rainfall of 548 mm during the first season and 720 mm during the second season distributed over 48 and 57 days respectively.

Observations on sprouting of corms was recorded in different treatments. Biometric observations such as height of plants, height of pseudostem, girth of pseudostem, number of leaves, number, length and breadth of leaflets and canopy spread were recorded at 3 and 5 months after planting (MAP). The crop was harvested after 10 months during December and corm yield per plant was recorded and per ha was estimated. Based on the corm yield and the total irrigation water used, water productivity was worked out (Heydari 2014). Energy equivalents of various inputs and outputs were computed (Singh and Mittal 1992; Devasenapathy et al., 2006) and energy efficiency indices were worked out as per Dazhong and Pimental (1984). Economics was worked out based on various inputs and labour costs at the end of two seasons. 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 RBD and multiple comparison of treatment means was done by least significant difference.

Results and Discussion

Sprouting of corms

There was variation in the pattern of sprouting of planted corms under different treatments. The corms took 18-35 days for initiating sprouting during first season while it took 37-45 days during second season. Fifty per cent sprouting was achieved within 32-39 days and 100% sprouting within 48-60 days for the first crop. Second crop took 50-55 days for 50% sprouting and 55-75 days for 100% sprouting. Full sprouting was achieved early under irrigation at 50% CPE along with porous ground cover mulching (T1) (48 days and 55 days respectively) during the two seasons. The rainfed control (T9) took 56 days and 65 days for first sprouting during the two seasons respectively and 79 days and 90 days respectively for completing sprouting. In elephant foot yam, sprouting is highly influenced by the soil moisture availability. Early sprouting was observed under drip irrigation along with suitable conservation of moisture, which is mainly

because of the availability of enough moisture exactly in the planting zone. Moreover 50% irrigation with ground cover mulching (T1), which acted as a physical barrier against evaporation loss from soil surface, retained more soil moisture than under full irrigation at 100% CPE (T8), which enhanced the sprouting percentage to more than 50% within 32-50 days. Early sprouting and establishment of the crop with micro irrigation compared to surface irrigation is reported in *Amorphophallus* (Sunitha et al., 2018).

Corm yield

The corm yield was the highest when the crop was irrigated at the rate of 50% CPE along with porous plastic ground cover mulching (T1) in both the years (48.81 and 38.46 t ha⁻¹ respectively). However, this was on par with other water smart techniques such as soil application of Pusa Hydrogel (T3) synthetic gel (T4) and coir pith (T5) during the first year. Anti-transpirant spray (T2) and biomulching (T6) did not perform good in terms of corm yield and recorded the minimum (Table 1). During

Table 1. Corm yield of elephant foot yam under different water saving techniques

Treatment	Corm yield (t ha ⁻¹)		
	2017-18	2018-19	Pooled yield
T ₁ : Irrigation at 50 % + Ground cover mulching	41.81	38.46	40.1
T ₂ : Irrigation at 50 % + Kaolinite spray	28.84	30.26	29.6
T ₃ : Irrigation at 50% + Pusa hydrogel	33.35	35.72	34.5
T ₄ : Irrigation at 50% + Synthetic SAP	32.94	33.56	33.3
T ₅ : Irrigation at 50% + Coir pith	30.72	29.19	30.0
T ₆ : Irrigation at 50% + Biomulching	29.81	30.36	30.1
T ₇ : Irrigation at 50 %	23.50	28.04	25.8
T ₈ : Irrigation at 100%	28.52	32.03	30.3
T ₉ : Rainfed control	16.93	17.42	17.20
CD(0.05)	11.963	8.42	9.91

second year also, ground cover mulching (T1), and application of hydrogels (T3 and T4) were found promising for soil moisture conservation resulting in more corm yield. Pooled data analysis also showed the same trend in terms of corm yield and ground cover mulching (T1) resulted in maximum corm yield (40.1 t ha⁻¹). In all water saving techniques, though the level of irrigation was reduced to 50%, the soil moisture was retained for a longer period in the exact root zone, thereby reducing the consumptive usage and assured effective use of soil available water. Maximum corm yield was recorded with 50% irrigation and porous ground cover mulching (T1), closely followed by application of Pusa Hydrogel (T3) and synthetic gel (T4). SAPs are functional macromolecules with the ability to absorb water (Esposito et al., 1996) and act as miniature water reservoirs releasing water into the soil maintaining moisture balance (Zohuriaan Mehr and Kabiri 2008). In *Amorphophallus*, the hydrogel retained more soil moisture throughout the growth period and enhanced the corm yield with saving of irrigation water.

Corm yield from plants sprayed with kaolinite at 0.5% (T2), was 35% less than the maximum corm yield, based on pooled data analysis. Since the spray was given on the under surface of leaves, the plants continue to had the normal photosynthetic rate. However, soil moisture retention was not as good as a physical ground cover in other techniques. Under irrigation at the rate of 50% CPE alone (T7), the corm yield was less by 55% compared to porous ground cover mulching (T1). Ground cover mulching (T1) also resulted in 32% higher corm yield compared to irrigation at the rate of 100% CPE (T8).

Trials carried out through All India Coordinated Research Project on Tuber Crops across the country indicated that *Amorphophallus* under drip irrigation at 100% CPE resulted in maximum corm yield in different agro climatic conditions in India (James George et al., 2013) compared to lower irrigation levels. In the present study, assuring enough soil moisture by way of suitable water conservation measures could give corm yield on par with 100% irrigation which indicates the significance of water saving technologies with 50% water economy (Fig.1).

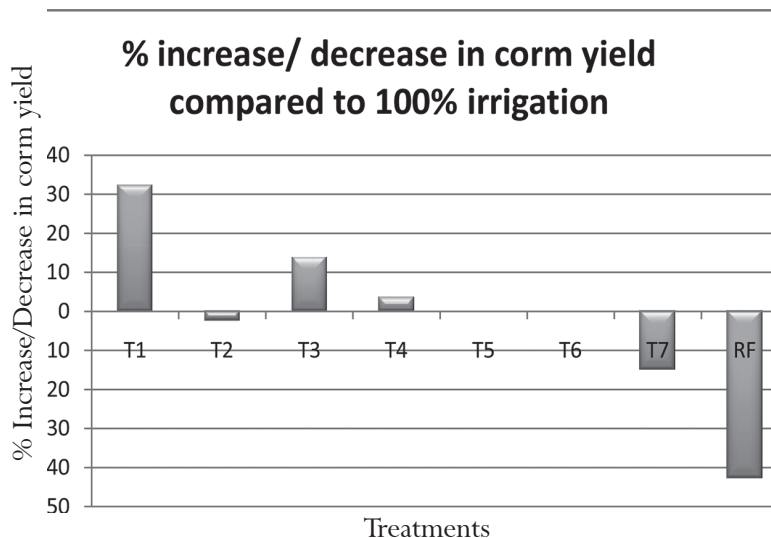


Fig. 1. Corm yield as affected by water saving techniques compared to 100% irrigation

Water productivity

Water productivity is the ratio of crop output and the water input. 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 based on means of two years. The crop received 270 mm during the first season and 290 mm during the second season under water saving treatments. The ratio ranged from 2.8 to 4.4 kg m⁻³ in water saving treatments. The productivity was maximum when porous ground cover mulch (T1) was used for moisture retention (Fig. 2). Irrigation at the rate of 100% CPE without any moisture saving technique (T8) resulted in a water productivity of 2.5 kg m⁻³. In general, water productivity was more when suitable water conserving measures were undertaken, either by porous ground cover or application of Super Absorbent

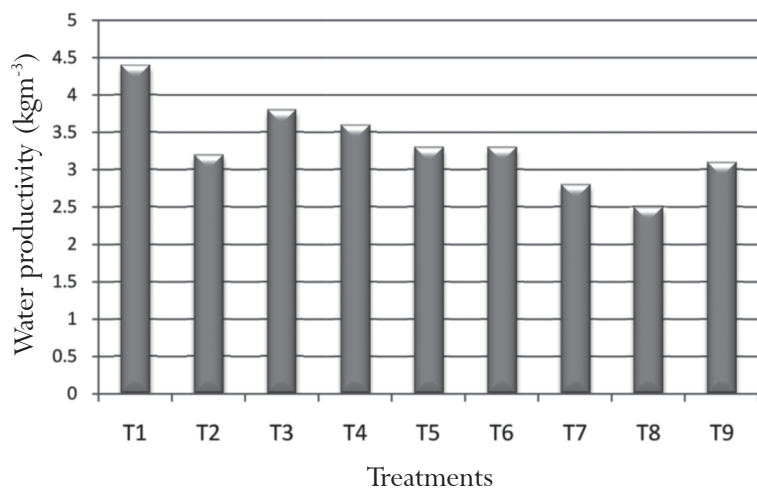


Fig. 2. Water productivity under different water saving techniques

Polymer (SAP) in soil. Irrigation at 100% CPE could not result in a corresponding increase in water productivity. This indicates the wastage of water for non-productive uses when the root zone is exposed, compared to the effective use of water under other techniques. The reduced unproductive loss of water along with ideal agronomic conditions resulted in more water productivity under drip system as established in many other crops (Chouhan et al., 2014; Jha et al., 2017). Higher water productivity is an important indicator in improved water management system which shows the efficiency of irrigation, that too with effective utilization of soil moisture for a prolonged time interval of crop growth in the present study.

Energy efficiency indices

Energy value of various inputs including human labour (men and women) for field preparation, planting, intercultural operations and harvesting and FYM and fertilizers applied was uniform for all the treatments and computed as 22,186 MJ/ha. Additional energy required for drip irrigation and imposing water saving technologies differed among the treatments and hence the total input energy was calculated separately. Total input energy ranged from 24,637.5 to 26,850.5 MJ/ha and was compared with the rainfed cultivation which was 22,186 MJ/ha. The total output energy computed from corm yield ranged from 92,880 to 1,44,360 MJ and the output energy was 61,920 MJ under rainfed cultivation.

The average of two years data showed that porous ground cover mulching (T1) was superior in terms of energy efficiency indices (Table 2) which resulted in maximum energy use efficiency (5.85) and energy productivity (1.63 kg/ MJ). Ground cover mulching resulted in 44% and 109% higher energy use efficiency than 100% irrigation (T8) and rainfed crop (T9) respectively.

Table 2. Energy efficiency indices of elephant foot yam under different water saving techniques

Treatment	EUE	Energy productivity (kg MJ ⁻¹)
T ₁ : Irrigation at 50 % + Ground cover mulching	5.85	1.63
T ₂ : Irrigation at 50 % + Kaolinite spray	4.33	1.20
T ₃ : Irrigation at 50% + Pusa Hydrogel	5.04	1.40
T ₄ : Irrigation at 50% + Synthetic SAP	4.87	1.35
T ₅ :Irrigation at 50% + Coir pith	4.38	1.22
T ₆ :Irrigation at 50% + Biomulching	4.40	1.22
T ₇ : Irrigation at 50 %	3.79	1.05
T ₈ : Irrigation at 100%	4.06	1.13
T ₉ : Rainfed control	2.79	0.78

Water conservation using porous ground cover sheets resulted in significantly higher corm yield and hence total output energy was higher. Consequently high energy use efficiency and energy productivity were recorded in T1, followed by Pusa hydrogel (T3). All the energy efficiency values were low under rainfed crop and supplemental irrigation resulted in an increase in energy efficiency indices though the energy input was less under rainfed cultivation. This shows the superiority of drip irrigation in *Amorphophallus* along with water conserving technologies wherein sufficient soil moisture is ensured in the active root zone of the crop, especially during the critical growth stages of the crop.

Economics

Gross income and net income varied among the treatments and were maximum under the water saving treatment with ground cover mulching (T1) followed by the application of Pusa Hydrogel (T3). Though ground cover sheets cost more compared to other water saving treatments, reuse of the sheets for 4-5 seasons make it economic. B:C ratio also followed the same trend (Fig. 3).

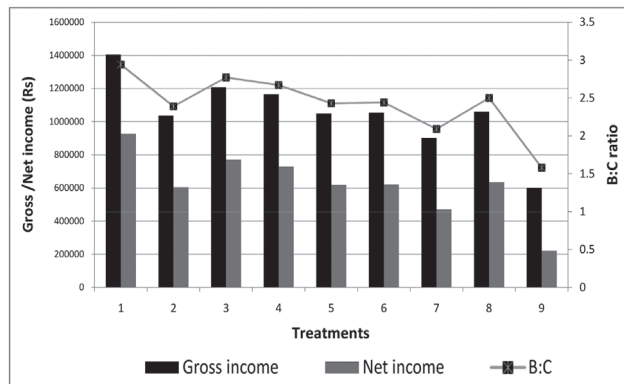


Fig. 3. Economics of elephant foot yam cultivation under water saving techniques

B:C ratio was the highest with ground cover mulching (2.94) and the lowest under rainfed cultivation (1.58).

Conclusion

The study suggests the possibility of reducing water requirement of elephant foot yam and enhancing water productivity and farmers income by adopting suitable water smart practices. In both the years, the treatment with porous ground cover mulching resulted in the maximum corm yield (40.1 tha⁻¹), B:C ratio (2.94) and water productivity (3.87 kg m⁻³), and reduced the irrigation water requirement by 50% and enhanced the corm yield by 32% and energy use efficiency by 44% as compared to 100% irrigation.

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