Journal of Root Crops
Indian Society for Root Crops
ISSN 0378-2409, ISSN 2454-9053 (online)
Journal homepage: https://journal.isrc.in

Water productivity and crop water production function of Taro (*Colocasia esculenta* L. Schott) under different irrigation regimes

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Abstract

Field studies were conducted to assess the performance of upland taro (*Colocasia esculenta* L. Schott) to varying levels of drip irrigation, furrow irrigation and rainfed conditions in terms of yield, water productivity and to work out the crop water production function, during 2016-2019. Pooled analysis of data collected for three seasons indicated that, drip irrigation at ETc 100% was optimum for achieving maximum cormel yield (21.08 t ha^{-1}) and was the most viable option compared to other unstressed conditions for optimum water productivity (3.5 kg m^{-3}). The field experimental data showed a quadratic relation between crop water requirement and yield ($R^2 = 0.666$). The derived crop water production function (CWPF), Yield = -2.382 + 0.00652WR - 0.000047WR^2 estimated the yield of 20.33 t ha^{-1} in taro, corresponding to the simulated gross irrigation requirement of 695 mm under the humid tropical conditions of Kerala, India. The information will support the farmers to develop irrigation plans in advance during summer season, and for ensuring effective usage of irrigation water in water scarce areas.

Keywords: Cormel yield, Crop water production function, Drip irrigation, Taro, Water productivity

Introduction

Taro or colocasia (*Colocasia esculenta* L. Schott) is one of the important root crops of the world fromolden times. It is one among the oldest crops, dating back to more than 10,000 years, known to man (Rao et al., 2010). Taro is adapted to tropical lowlands with evenly distributed annual rainfall of 2000 mm, high temperatures of 20-35ºC and shaded conditions. There are two main production systems used in taro cultivation: flooded or low land taro production, where water is available throughout, and dry land taro or upland taro, which is rain-fed and supplemented with irrigation to realise the expected yield.

In India, taro is cultivated in most of the states including the Northeastern hilly areas, as sole crop or on a limited scale as intercrop or homestead crop, however the cormels are consumed by all sections of people as a routine vegetable. The crop is mostly cultivated with monsoon rains, quite often needs supplemental irrigation, using furrow system. Though most of the states in India receives good rainfall from South-West and Northeast monsoons, water shortages are experienced during summer and post-monsoon seasons and a major share of rainfall is utilized in agriculture sector (Surendran et al., 2015). The aim of the present study is to derive crop water production function of taro, based on data collected from field experiments conducted for three

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Received: 02 February 2023; Revised: 23 February 2023; Accepted: 26 February 2023

seasons and to work out the water use efficiency under tropical conditions of India.

Materials and Methods

The experimental trials were carried out during the three consecutive summer seasons of 2016-2017, 2017-2018 and 2018-2019 at ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. 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. In all the seasons, the crop was planted in November and harvested in May to avoid the rainy period. The experiment was conducted in Randomized Block Design, with five levels of drip irrigation [50% (T_1), 75% (T_2), 100% (T_3), 125% (T_4) and 150 % (T_5) of crop water requirement (*ETc*)], furrow irrigation (T_6) and a rainfed crop (T_7) replicated three times. Improved variety of taro, 'Muktakeshi' was used as the planting material for the experiment. As per the package of practices recommended by ICAR-CTCRI, 12 t FYM and 80 kg N, 25 kg P and 100 kg K were applied. Drip irrigation was given every day based on pan evaporation values, furrow irrigation twice a week @ 5 mm per day. For rainfed crop, only lifesaving irrigation was given, whenever no rain was there continuously for a week.

At harvest, yield data were recorded. Based on the yield data from net plots, per hectare yield was estimated in t ha^{-1}. Water productivity was worked out based on cormel yield and total water used by the crop (Heydari, 2014).

$$WP\ (kg\ m^{-3}) = \text{Cormel yield}\ (kg\ ha^{-1}) / \text{Total water used}\ (m) \quad \ldots \text{Eqn. (1)}$$

Crop water requirement (CWR) was calculated by multiplying the reference crop evapotranspiration (ET_0, which is equal to open pan evaporation (*Ep*) × Pan coefficient, (*Kp*) (taken as 0.7) and the crop coefficient (*Kc*). Crop coefficient (K_c) values for taro as described by Fares (2008) were taken at different growth stages of the crop. K_c (initial) = 1.05 (2 months), K_c (med) = 1.15 (3 months) and K_c (late) = 1.1 (1 month). It is assumed that the crop water requirement is fully met so that the actual crop evapotranspiration (*ETc*) would be equal to the crop water requirement.

$$i.e., CWR = ET_c \quad \ldots \text{Eqn. (2)}$$

Hence, the relation between applied water and crop yield corresponds to the CWPF for taro under humid tropical conditions of Kerala. The data from each season and over the years were pooled and analysed statistically following Indian NARS Statistical computing portal (SSCNARS) by applying the technique of Analysis of Variance (ANOVA) for RBD and multiple comparison of treatment means was done by least significant difference.

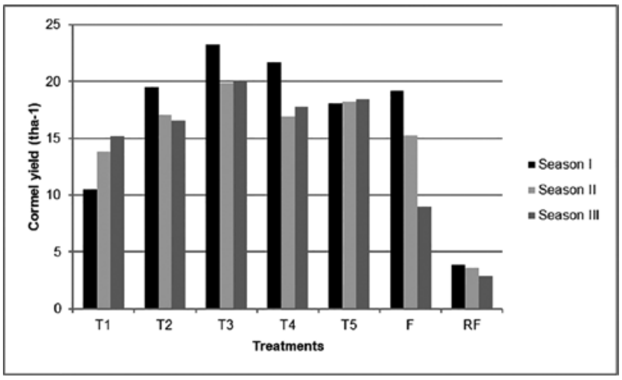


Fig. 1. Taro cormel yield during the three seasons

Results and Discussion

Taro cormel yield

Cormel yield of taro varied significantly with different treatments and seasons (Fig.1). During the first season, the highest cormel yield (23.3 t ha^{-1}) was recorded by 100% *ETc*, which was not statistically different from other irrigation levels except 50% ETc and 75% *ETc*. During second and third seasons also, cormel yield was the highest under 100% *Etc* (19.91 t ha^{-1} and 20.02 t ha^{-1}) respectively. However, the values were not statistically different among 75%, 100%, 125% and 150% *ETc*. Furrow irrigation also performed equally good with respect to cormel yield in all the seasons, except second season. Rainfed crop with onlyminimum life saving irrigation recorded an average cormel yield of 3.47 t ha^{-1}.

Pooled analysis of three seasons data showed statistical difference in cormel yield only with treatments, not among the seasons. The yield varied from 13.18 to 21.08 under drip irrigation and the rainfed crop recorded 3.47 t ha^{-1} cormel yield. *Etc* at 100% recorded the highest cormel yield, followed by *ETc* at 125%. There was 45% increase in cormel yield under drip irrigation at *ETc* 100% compared to the furrow irrigation. In field experiment in taro with different irrigation water levels of 50, 75 and 100% *ETc*, *ETc* at 50% recorded the highest reduction in terms of vegetative growth, yield characteristics, yield and bio constituents compared to 75% of *ETc* level and unstressed plant (100% of *ETc*) (El Al et al., 2019). In yet another study, *in situ* moisture conservation methods influenced soil water availability and subsequent vegetative growth and yield of taro under upland conditions (Manyatsi et al., 2011). Of the five levels of crop evapotranspiration (*ETc*) studied, 100% *ETc* was found optimum, as there was no corresponding increase in taro cormel yield with higher levels of irrigation. Hence the water requirement was estimated as 619, 628 and 608 mm during the season I, II, and III (Sunitha et al., 2022).

Water productivity and Crop water production function

Water productivity of taro varied from 1.9 to 4.2 kg m^{-3} during the first season, under different *ETc.* During the second season, the values ranged from 1.9 to 4.4 kg m^{-3}, and during the third season, the values ranged from 2 to 4 kg m^{-3}, with the highest value in 50% *ETc* in all the seasons. Based on the pooled means also, irrigation at 50% *ETc* recorded the highest value (3.9 kg m^{-3}). Furrow irrigation recorded 1.8 and rainfed crop recorded 1.5 kg m^{-3} of water productivity respectively.

Drip irrigation at *ETc* 100% recorded 45% increase in cormel yield and 2.1 times the water productivity than the furrow irrigation. Under limited water availability, water use efficiency (WUE) increases through either increasing yield (biomass) or decreasing water-use through the amount of irrigation applied (Pandey et al., 2000). A similar increase in water use efficiency in potato was reported, with decreasing the amount of irrigation applied (Badr et al., 2012). However, in three land races of taro Mabhaudhi et al., (2013) reported less water use efficiency values of 0.22 to 0.24 kg m^{-3} with irrigation levels of 30, 60 and100% *ETa,* mainly because these land races were adapted to wet land conditions. Muktakeshi variety used in the present study is well adapted to upland conditions, and hence responded well to irrigation and lower level of irrigation led to higher water productivity. Uyeda et al., (2011) reported that upland taro was more efficient in using water than varieties which are more adapted to flooded conditions. Drip irrigation provided with 10, 20, 30, 40, and 50% soil moisture depletion resulted in greater water use efficiency values of 3.87 and 3. 77 kg m^{-3} under 10 and 20% in taro (Vieira et al., 2017).

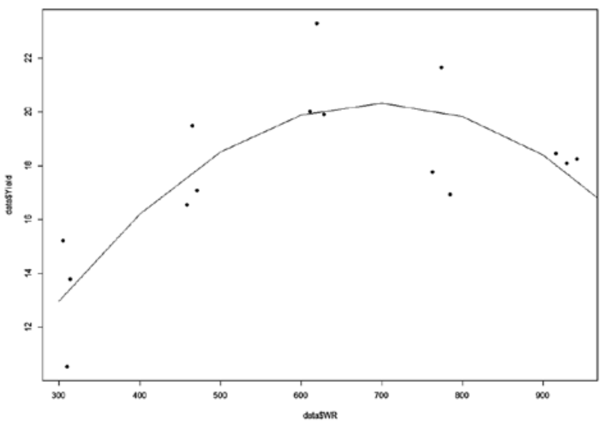
The yield data collected for all seasons under different irrigation levels, *ETc* 50% to 150%, were used to derive the crop water production function for taro. The crop water requirement (*CWR*) was calculated as same as the crop evapotranspiration by assuming no other losses of water. The derived crop water production function Yield $= -2.382 + 0.00652WR - 0.000047WR^2$ and the linear and quadratic parameters were found significant with R^2 value of 0.6657 and p value of 0.00139 for the model (Table 1). The relation depicts a quadratic response for crop yield with the water requirement. From the model, the optimum yield was worked out as 20.327 t ha^{-1} at a CWR of 695 mm for the quadratic equation.

Table 1. Coefficients of crop water production function of the Regression model

Source	Coefficients	t-value	p- value
Intercept	-2.382	-0.534	0.603
WR	0.00652	4.161	0.00137
WR^2	-0.000047	-3.740	0.00282

The CWPF depicted the changes in crop growth and yield parameters with different levels of irrigation water. The crop water production function developed for taro (Fig. 2) followed a quadratic relation with an R^2 value of 0.665. The crop yields increased up to a point (optimum) with irrigation. This relation indicated an increase in the crop yield with water, once it reached an optimum, then it started declining with the application of more water. The application of more irrigation water did not ensure higher yields, as once the crop water requirement was satisfied. Excess water causes more vegetative growth in taro, at the expense of tuber growth. The derived yield based on the quadratic equation is 20.33 t ha^{-1}, almost near to the observed yield of 21.08 t ha^{-1}. Also, the optimum water requirement of 695 mm worked out as per the equation is 12% more than the observed value under field conditions.

The crop water production function was a found to be a useful tool for planning appropriate water management strategies in future to mitigate the impact of climate change and subsequent water shortage problems



Yield = -2.382+ 0.00652 WR -0.000047 WR^2

Fig. 2. Derived crop water production function for taro

expected in agriculture (Letey and Dinar 1986; Kloss *et* al., 2011). This model is also helpful in predicting the crop yield at the field level with respect to the irrigation water, available for use. Accordingly, the choice of crops, area, alternative irrigation schedules etc, to enhance the crop yield can be decided by the farmers.

Conclusion

Studies were conducted to work out the water requirement of upland taro for achieving maximum productivity and water use efficiency under humid tropical conditions of Kerala, India. From the field studies conducted over three seasons, drip irrigation @ *ETc* 100% is found optimum for maximising the cormel yield and water use efficiency. The optimum water requirement of upland taro was observed as 618 mm for a period of six months, assuming that there is no other loss of water, and the crop evapotranspiration (*ETc*) is fully met through irrigation. The derived crop water production function based on the field data collected indicated a quadratic correlation with the crop evapotranspiration. The optimum cormel yield corresponding to the optimum irrigation requirement of 695 mm was observed as 20.33 × 10^3 kg ha^{-1} and beyond this, the yield started declining. This model helps to ensure maximum productive use of irrigation water.

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