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Response of upland taro *(Colocasia esculenta)* to varying water regimes under humid tropical conditions of India

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ABSTRACT

The field experiment was conducted on taro (*Colocasia esculenta* L. Schott) during 2017, 2018 and 2019 with three spells of irrigation (irrigation for 2 months and remaining period under stress, irrigation for 4 months and remaining period under stress, irrigation for 6 months) and four levels of drip irrigation, *viz*. 75%, 100%, 125% and 150% of water requirement of the crop (ETc) in factorial design. Pooled analysis of three years data revealed significant difference in growth and yield as well as water-use efficiency under stress and non-stress conditions. Moisture stress two and four months after planting resulted in reduction in leaf area index (-21 and -19%), number of tillers (-27 and -6%), root to shoot ratio (-60 and -43%), cormel to corm ratio (-69 and -53%), cormel yield (-58 and -28%), water-use efficiency (-32 and -36%) and increase in corm yield (+34 and +52%) respectively, compared to no stress. Drip irrigation for six months @ 100% ETc recorded optimum growth, cormel yield (21.08 tonnes/ha) with water-use efficiency (0.4 g/L) in upland condtion.

Key Words: Cormel yield, Drip irrigation, Water stress, Water-use efficiency

Taro or colocasia (*Colocasia esculenta* L. Schott) is mostly cultivated with monsoon rains, quite often needs supplemental irrigation using furrow system. Andhra Pradesh, Odisha, Uttar Pradesh, Madhya Pradesh, Telengana, North-eastern hilly areas are main states growing taro. Most of the varieties and land races are season insensitive and can be grown in any part of the year, provided sufficient soil moisture is assured. The information on its water needs, water-use efficiency and response under different water regimes at various stages of growth is limited. Therefore, an experiment was conducted to evaluate its yield and water-use efficiency under different water regimes under humid tropical conditions of India.

MATERIALS AND METHODS

Field trials were conducted during 2016- 2017, 2017-2018 and 2018-2019 at ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, which lies between 8.54° North latitude and 76.91° East longitude with an altitude of 50 m above mean sea-level. The soil site was sandy clay loam having 62% sand, 10% silt and 28% clay content. The soil was acidic (pH 4.96), medium in available nitrogen (252 kg/ha) and potassium (188 kg/ha) and high in phosphorus (121 kg/ha).

The experiment was laid out as 3 × 4 factorial experiment in randomized block design, with factor 1 as the duration of irrigation and factor 2 as levels of drip irrigation, replicated three times. Three duration of irrigation were irrigation up to 2 months and stress from 3-6 months (D_1), irrigation for 4 months and stress from 5-6 months (D_2) and irrigation for 6 months without any stress (D_3). The four levels of drip irrigation were: 75 (I_1), 100 (I_2), 125 (I_3) and 150% (I_4) of crop water requirement (ETc). Improved variety, "Muktakeshi" having 6-7 months duration was used. Irrigation schedule was fixed based on reference evapotranspiration (ET_0) and the crop factor. Crop water requirement was calculated based on ET_0 and crop coefficient (Allen *et al.*, 1998).

Observations on number of days taken for first sprouting, and 50% sprouting, growth parameters, *viz.* plant height, number of tillers, number of leaves, and leaf area, total biomass production at senescence, yield and yield attributes (corm yield, cormel yield, total yield, average number and weight of cormels, and cormel to corm ratio) were recorded. Water-use efficiency (WUE) was recorded as the ratio of total

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plant dry biomass and total water used per plant, expressed in g/L (Gança *et al.*, 2018).

The data over the seasons were pooled and analysed statistically, following SAS procedure (SAS, 2010) by applying the technique of Analysis of Variance (ANOVA) for Factorial experiment in RBD and multiple comparison of treatment means was done by least significant difference.

RESULTS AND DISCUSSION

During all the seasons, The cormels started sprouting almost uniformly, irrespective of treatment factors. On an average, crop took 23-29 days for initiating sprouting. Under different irrigation levels, irrigation at 75% ETc took 27.2 days for sprouting, though difference was not statistically significant. 50% sprouting was achieved 6-7 weeks after planting in all treatments (Fig. 1). The 125% ETc resulted in better and early sprouting. Drip irrigation ensures smaller percentage of wetted surface to save water (Unlu *et al.*, 2006) which in turn would hasten sprouting with adequate moisture near the plant zone. Rate of emergence may vary with different levels of drip irrigation (Mabhaudhi *et al.*, 2013). It is also reported that under dry land conditions Taro takes about 70 days for emergence (Mare, 2010).

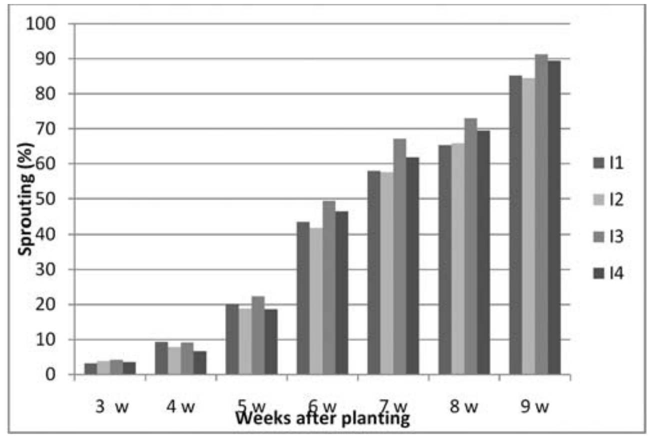

Fig. 1: Sprouting of taro cormels under different irrigation levels

The height, number of leaves and leaf area were more under higher levels of irrigation, but were statistically insignificant with lower levels. However, growth significantly reduced due to stress after two and four months. There was no significant difference in height, number of leaves or leaf area indices among irrigation levels in any of the season. Number of tillers were statistically higher in 150% ETc 4 and 5 months after planting, however, 6 months, number was high in 75% ETc, as the plants started senescence. The LAI

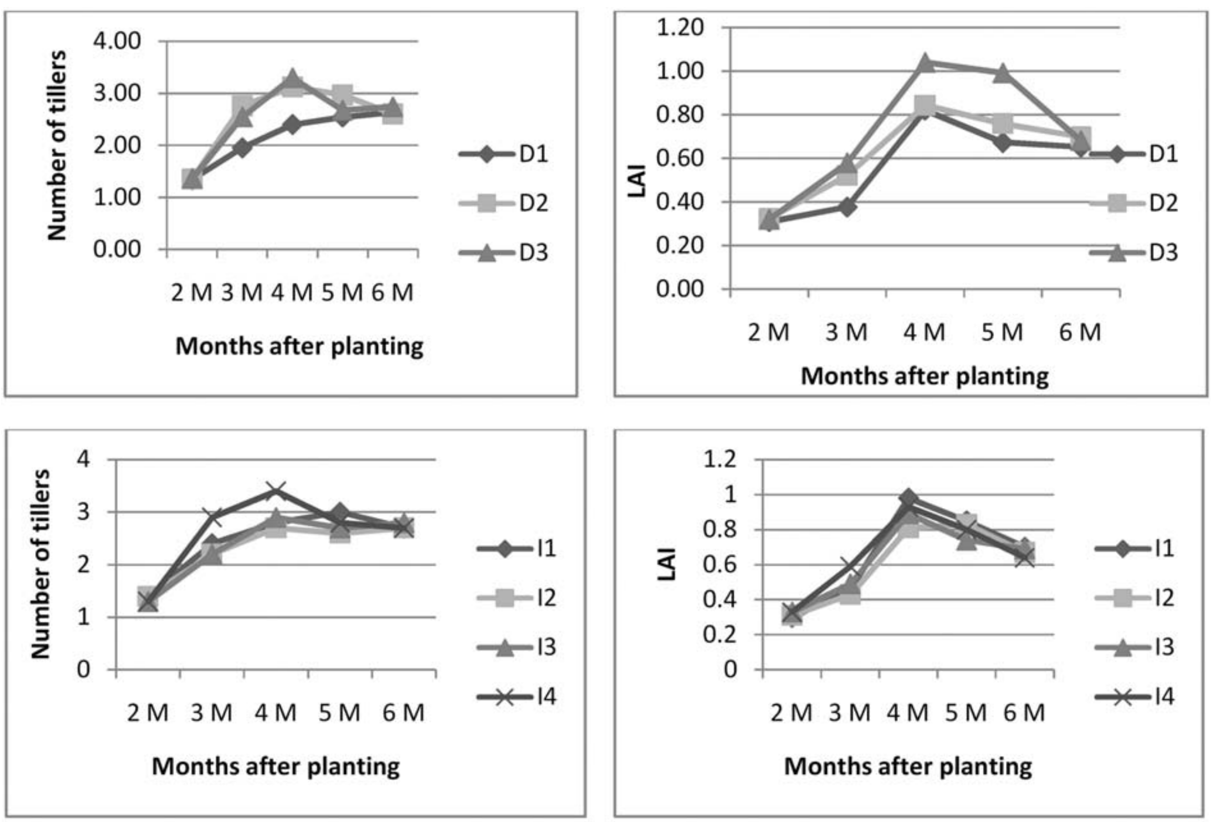

Fig. 2: Number of tillers and leaf area index under different duration and levels of irrigation

was maximum with D_3 and I_4 2, 3 and 4 months after planting. At 5 and 6 months, maximum LAI was recorded by D_3 at I_1 level of irrigation, but was on a par with other irrigation levels (Fig. 2).

Reduced growth in taro with limited water availability was reported by earlier workers (Mabhaudhi *et al.*, 2013). As the initial leaves started drying towards physiological maturity, decrease in plant height was noted in all the treatments. Water stress also resulted in reduced number of leaves subsequently as a result of premature senescence as reported by Mabhaudhi *et al.* (2013). Under drought, reduced growth and biomass production in taro as a mechanism for drought avoidance is reported (Gouveia, *et al.*, 2020). Under unstress conditions, leaf number and LAI increased gradually and reached the peak at 5 months after planting depicting the importance of moisture almost throughout the life-cycle. Similarly increase in LAI values with sufficient soil moisture is reported in taro by Manyatsi *et al.* (2011). In potato, the most sensitive stages of water stress is reported as vegetative and tuberization stage (Cameron *et al.*, 2021), having negative impact on crop.

Biomass partitioning at senescence indicated clear difference among duration of irrigation, not with irrigation levels. Cormel yield ranged from 11.5 to 69.9 g from D_1 to D_3 on dry weight basis. There was an increase of 1.4 and 5 times the dry matter yield of cormels under no stress compared to stress for two and four months (Fig. 3). Cormel yield constituted 47, 62 and 74% of total biomass under D_1, D_2 and D_3 respectively.

Root: shoot ratio increased from 7.9 to 20 from D_1 to D_3. Among the irrigation levels, there was no statistical variation (10-12.7). Root-shoot ratio depicts the plant's ability to maintain dynamic balance between functionally interdependent organs such as corm + cormel and the shoot. A lower ratio indicates an increase investment in shoot development due to stress. Adequate soil moisture assured decrease in shoot growth, efficient translocation of starch to corms and cormels, in detriment to underground parts. Such a decrease in root-shoot ratio in taro accessions under drought has been reported (Gouveia, *et al.*, 2020).

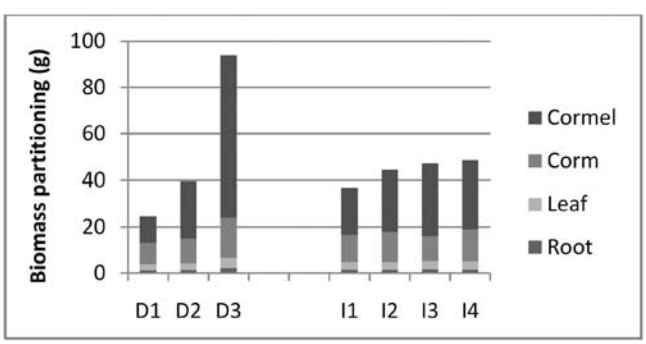

Fig. 3: Biomass partitioning under different treatments

Number of cormels increased by 65% and 94% as the crop was irrigated up to 4 months (D_2) and 6 months (D_3) respectively, compared to 2 months (D_1). However, a corresponding increase was not noted with increasing levels of irrigation, I_1 to I_4. Drip irrigation at 75% ETc produced maximum number of cormels per plant (22.11) and irrigation at 150% ETc resulted in minimum number of cormels (14.44).

Average cormel weight per plant ranged from 5-26.5 g among the treatment combinations which showed significant difference among duration of irrigation as well as levels of irrigation. Plants without any stress after two and four months resulted in significantly more average cormel weight per plant and were 31 and 35% superior compared to irrigation up to 2 months, which has undergone stress after two months growth. Average cormel weight was maximum with irrigation at 150% ETc (18.13 g) and minimum with 100% ETc (13.43 g). Similar production of larger tubers with fully irrigated crop and water shortage leading to more number of smaller tubers and less tuber yield is common in potato also (Mattar *et al.*, 2021).

Cormel to corm ratio was minimum when the crop was under stress after two months and the highest with irrigation at 125% ETc for 6 months. Corm yield was almost double the cormel yield, when stress was imposed after two months. Corm yield and cormel yield were almost equal when stress was imposed after four months. Unstressed plants resulted in almost double the cormel yield than corm yield. However, there was no significant variation in cormel to corm ratio among the drip irrigation levels.

Moisture stress resulted in the production of more mother corm yield than cormel yield. The highest corm yield was recorded when stress was imposed after 4 months, on par with stress after 2 months. There was 34 and 52 % increase respectively in mother corm yield with stress after two months and four months compared to unstressed plants. Among the irrigation levels, corm yields were more with lower levels of irrigation (ETc 75 and 100%), but the effects were not significant.

There was a corresponding increase in cormel yield when irrigation was given up to six months, followed by irrigation upto four months and two months in all the seasons. Pooled data analysis showed comparable cormel yields under all the irrigation levels. No stress (D_3) produced 140% and stress after four months (D_2) produced 41% more cormel yield, compared to stress after two months of planting (D_1) (Fig. 4). The interaction effect of D_3I_2 recorded the highest cormel yield, at par with other higher irrigation levels.

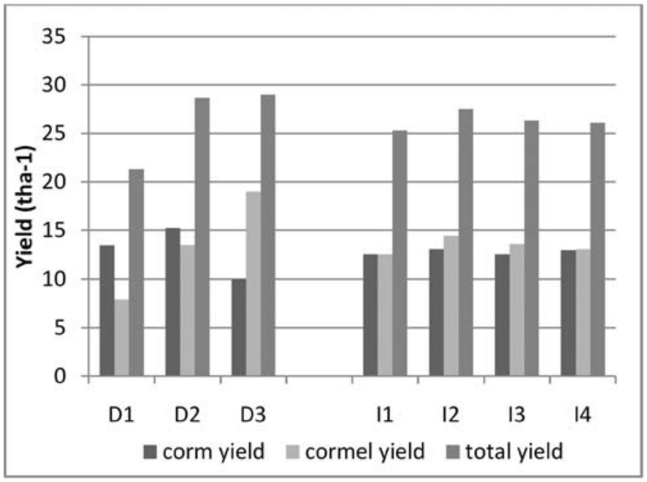

Fig. 4: Yield of taro under different durations and levels of irrigation

Similarly, the total yield per ha (mother corm + cormel yield) also varied with moisture stress, the maximum being recorded for irrigation for six months without any stress, followed by stress after four months and two months.

In all the seasons, the cormel yield was above the word average of 5.39 t / ha and slightly above the Asian average of 16.5 t / ha^{-1}. Low land production systems and the upland production supplemented with irrigation is a must for realising good yield in taro. Irrigation would be beneficial for taro production in drier months as well as low rainfall areas as reported by Bussel and Bonin, (1998). 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) (Abd El Aal *et al.*, 2019). In yet another study, *in-situ* moisture conservation methods tested influenced soil water availability and subsequent vegetative growth and yield of taro under upland conditions (Manyatsi, *et al.*, 2011).

Inducing stress after two months of planting reduced the water use efficiency (0.32 g / L) and there was 47% increase in WUE with no stress. Increasing levels of irrigation resulted in decrease in WUE from 0.36 to 0.28 g / L, as there was no corresponding increment in total plant biomass with the higher level of water used. Lower levels of drip irrigation resulting in higher WUE in taro are reported (Vieira *et al.* 2018). It is also reported that drought tolerant taro accessions can increase or maintain WUE, resulting in a small decrease in total biomass and yield (Ganança *et al.*, 2018; Gouveia *et al.*, 2019).

Taro when cultivated under upland conditions, require continuous soil moisture up to six months. Soil moisture stress after two months of vegetative establishment led to more mother corm yield and stress after two and four months caused 58 and 28 % reduction in cormel yield compared to unstressed conditions. Though different drip irrigation levels did not record much variation in growth and yield, irrigation at 100% ETc was found optimum for highest cormel yield and water use efficiency under upland conditions.

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