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Short Research Article

STRATEGIES FOR TARO (*Colocasia esculenta*) IRRIGATION

ABSTRACT

This study aimed to evaluate the taro (*Colocasia esculenta*), var. São Bento, in response to different irrigation strategies. The experiment was carried out at Ifes *campus* Santa Teresa, Brazil, at an altitude of 130 meters above sea level, using a randomized block design (RBD) with five treatments for the water availability factor of culture (f factor) equivalent to 0.1; 0.2; 0.3; 0.4 and 0.5, and four replications. Meteorological data were used to estimate the crop water demand, performing daily water balance using spreadsheets. We evaluated the applied water depth, the yield of commercial cormels and the water use efficiency by taro, due to the f factor. The results were submitted to analysis of variance and regressions. Increasing the f factor provided a reduction of applied irrigation depths. Lighter and frequent irrigations improved the development and yield of taro and can be recommended for its management.

Keywords: f factor, taro, cocoyam, yield, efficiency.

1. INTRODUCTION

The taro (*Colocasia esculenta*), also known as cocoyam, is of great economic and social importance in many tropical and subtropical regions of the world, occupying a prominent place in the diet of many people in these regions [1]. In Brazil, it is grown mainly in the states of the Mid-South region. It is present in almost all the municipalities of Minas Gerais State, which is the state's largest producer of the country and it is explored in family farming. Taro presents fleshy cormels, with similar nutritional value of potato tubers [2].

World production of taro in 2013 reached 9.976 million tons grown on 1.299 million hectares, and Nigeria was responsible for about 3.450 million tons, followed by China with 1.845 million tons and Cameroon with 1.551 million tons [3]. However, the FAO estimates that only 145,000 tons are sold and the remainder is used in the food base of these people. Recent data are not found on the production of taro corms on the national scene of Brazil, but it is estimated that this is around 200,000 tons.

Despite the potential that culture has to develop in excess moisture environments, excessive shading and other climatic stress [4], there is still a lack of information about it. Even the need for water for the crop is not consolidated, and most often is not linked to technical criteria, resulting in unnecessary expenditure of energy for irrigation and waste of water or under-utilization of irrigation system.

The expansion of irrigated areas, currently held, this tied to concerns about the availability of water for agriculture and energy costs associated with practice. Consequently, the adoption of strategies aimed to reduce the water wastes, without incurring losses in productivity [5], become essential to the efficient use of these water and energy resources.

According to [6], the productivity of a culture is a function of complex biological, physiological, physical and chemical processes, which are determined by environmental conditions and genetic factors of crop itself. Thus, the realization of irrigation tends to raise the productivity of crops. However, only irrigation without an efficient management to consider the crop and physiological aspects of the species, physical, chemical and physicochemical soil and particularities of the adopted irrigation system [7], just not provide a significant increase in productivity, but an expressive reduction of the costs associated with the cultivation.

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Proper and strategic water management can be done using the water use efficiency (WUE) index for planning and irrigation decision-making, increasing the crop yield [8]. Thus, a good management strategy of irrigation is essential to save water without, however, endangering the crop yield [9-10].
In the case of taro, there is a shortage of technical information of Brazilian soils and climate conditions, and most of the work reported in researches comes from other countries [11-12]. As regards, the water requirement for this crop is lack of clear information and it is not being known about water requirements in their phenological phases to conditions of Brazilian agricultural ecosystems. Therefore, the present study was due to evaluate the response of taro to different strategies of irrigation (f factors).

2. METHODOLOGY

The experiment was conducted in the Vegetable Crops sector of the Instituto Federal do Espírito Santo, campus Santa Teresa, Espírito Santo state, Brazil, as shown in Figure 1. The area is located in the coordinates latitude 19º48'36" south and longitude 40º40'48" west, has an altitude of 130 m above sea level, with soil classified predominantly as Latosol Yellow Eutrophic clayey, containing 63% of clay in its composition. In the area where the experiment was carried out, the field capacity (FC) is 32%; the permanent wilting point (PMP) is 20.6%; the bulk density is 1.16 g cm^{-3} and the crop root depth was 40 cm.

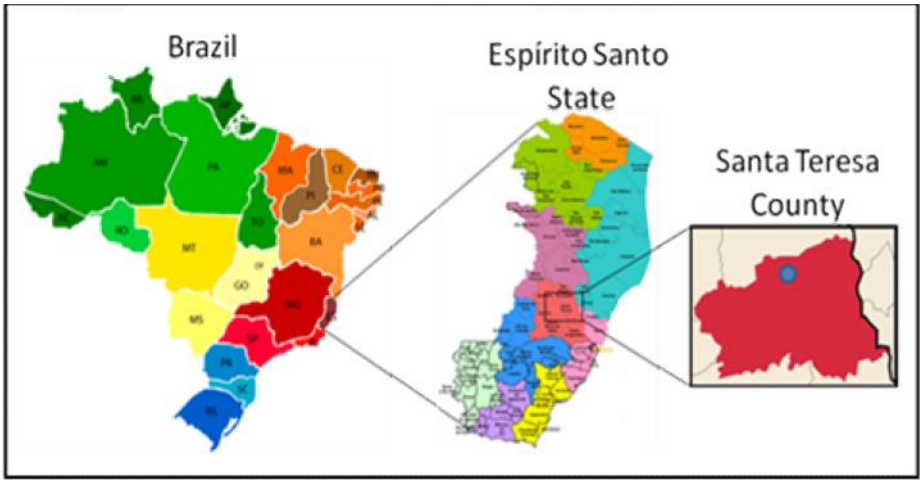

Figure 1: Localization of experimental area in Santa Teresa County, Espírito Santo State, Brazil [13-15].

It was installed a drip irrigation system, divided in sectors, to irrigate the plots individually, according to the treatments. The irrigation periods were determined according to the water availability for the crop (f factor), established for each treatment, as shown in Table 1. Thus, irrigation was performed when the water in the soil was depleted equivalent to 10; 20; 30; 40 and 50% of the total water available, respectively, for the treatments T1, T2, T3, T4 and T5, in a randomized block design, with four replications. Figure 2 shows a part of the experimental area.

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Figure 2: Taro cultivated in the experimental area, localized in the Instituto Federal do Espírito Santo, Santa Teresa campus.

The treatments were irrigated at different times, so when the irrigations occurred, the amount of water in the soil was different, which gave different soil water deficits for each treatment, as shown in Table 1.

Table 1: Treatments and their respective f factors and water deficits, in mm, at the time of irrigation

Treatment	T1	T2	T3	T4	T5
f factor	0.1	0.2	0.3	0.4	0.5
Water deficit (mm)	7.3	14.6	21.9	29.2	36.5

The irrigation levels were determined, individually for each treatment, using spreadsheets, that calculated the water balance with climate measurements (maximum and minimum temperatures and the rain) and sporadic determination of soil water content with the stove method. The calculation of crop evapotranspiration is given by Equation 1 [16-17]. The reference evapotranspiration was determined by Hargreaves and Samani method [18]. The single crop coefficient (Kc) used for taro was proposed by [19], which suggests the following values: Kc initial: 1.05 in the first two months after planting; Kc mid: 1.15, the second to the sixth month after planting and Kc final: 1.1, the sixth month until harvest.

$$ETc = ET_0 \, K_C \, K_S \, K_L \qquad (1)$$

Where:
ET_C - crop evapotranspiration, mm d^{-1};
ET_0 - reference evapotranspiration, mm d^{-1};
K_C – single crop coefficient, dimensionless;
K_S – water stress coefficient, dimensionless;
K_L - correction factor due to the drip irrigation, based on the wetted and shaded area, dimensionless.

The irrigation system was assessed following the method proposed by [20] and determined the Distribution Uniformity (DU) coefficient of the irrigation system. These authors suggest collecting flow rates at 4 points (emitters) along the lateral line, i.e., the first dripper, the drippers located at 1/3 and 2/3 of the length of the line and the last dripper. The lines selected within the sector should be: first, those located at 1/3 and 2/3 of the length and the last lateral line, assessing 16 values as a whole.
It was cultivated taro var. São Bento. Before the crop implementation, the experimental area was prepared and fertilized. Taro corms were used for the experiment implementation and they were

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distributed in the planting furrows so that the yolks placed face up. Then the corms were covered with soil until about two centimeters above the yolks apex.

The yield performance was evaluated from the average productivity of cormels obtained in treatments, and quantified the commercial cormels production. The cormels classification was performed according to the [21] recommendation, from the transverse diameter, being large (>47mm), medium (33-46mm), and little cormels (<33mm). For the aggregation of commercial cormels it was considered the sum of large and medium cormels.

The water use efficiency was determined by the ratio of the productivity (t ha^{-1}) values and the respective applied irrigation depth (mm), in each treatment, and the results expressed in kg m^{-3} as cited by [22] and [17].

The data were submitted to analysis of variance and regressions, and the coefficients were analyzed with 1% level of probability by the F test.

3. RESULTS AND DISCUSSION

Figure 3 shows the relationship between the total water depths depending on the soil water depletion. It is observed that the f factor increase has provided a reduction in the total water depth applied to the crop.

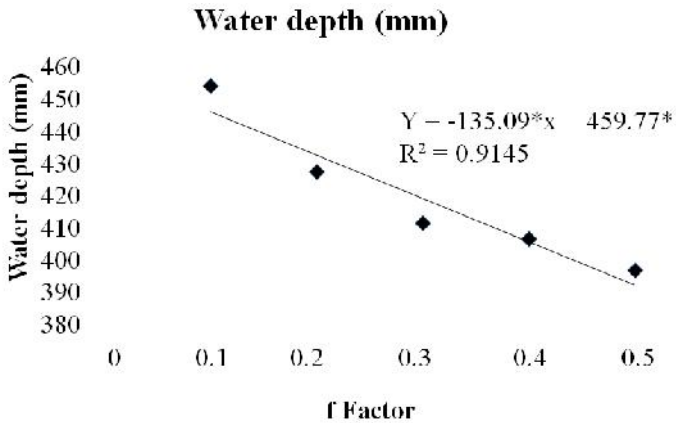

Figure 3: Total water applied in different irrigation frequencies (f factor).
*Significant from F test. *P = .01*

At T1 treatment, with f factor 0.1, the total water depth was 454 mm and at T5 treatment, the largest f factor, 397 mm was demanded by the culture, with approximately 12.6% of difference. This occurs because for higher f factor values, the intervals between irrigations (irrigation frequency) become larger, which promotes greater soil water depletion by reducing its moisture and consequent reduction in evapotranspiration and therefore lower replacement water through irrigation.

In Figure 4 the yield of taro in relation to f factors is showed. It is observed that the increase in the irrigation intervals provided a reduction of yield in commercial cormels.

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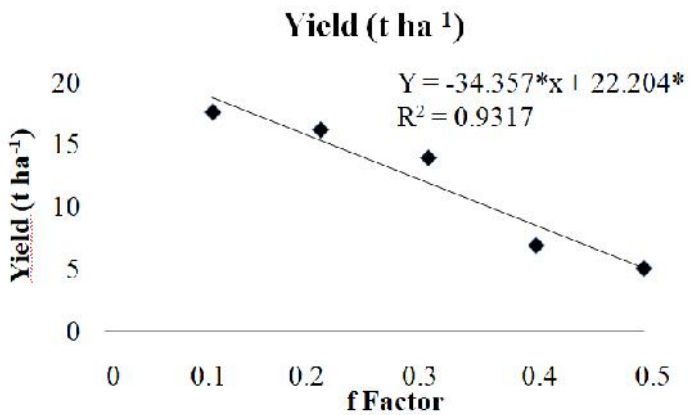

Figure 4: Average yield of taro cultivar "São Bento" under different irrigation frequencies (f factor).

*Significant from F test. *P = .01*

The T1 and T2 treatments had the highest yield among all tested. This occurred because with the high irrigation frequency, the plants were subjected to less or no water stress, unlike the T4 and T5 treatments that received the largest individual irrigation levels, but in more distant periods, which may be caused drought stress and thus reduced plant yield.

The T5 treatment plants had few or no large cormels, predominantly medium and small cormels, in addition to the mother cormel, occurring cormels damaged by rot, which are not viable to trade. The T1 and T2 treatments presented a number of large and medium-sized cormels in a satisfactory amount for each class, with low number of small and damaged cormels.

It is observed a tendency to increase yield by reducing the irrigation interval. The highest yield of commercial cormels was achieved with the T1 treatment, and the observed mean of 17.55 t ha^{-1}. For the T5 treatment the average yield achieved was 5.01 t ha^{-1}, that is 71.4% lower than the first one. As cited by [23], stress conditions such as lack of water led to slow growth and retarded development of cormels, as in this experiment.

In Figure 5, the water use efficiencies, in relation to f factors, are showed. The greater efficiencies can be seen at T1 and T2, with values of 3.87 and 3.77 kg m^{-3}, respectively. In these treatments the soil remained wetted between irrigation intervals, which provided better conditions for the crop development and to achieve high yield.

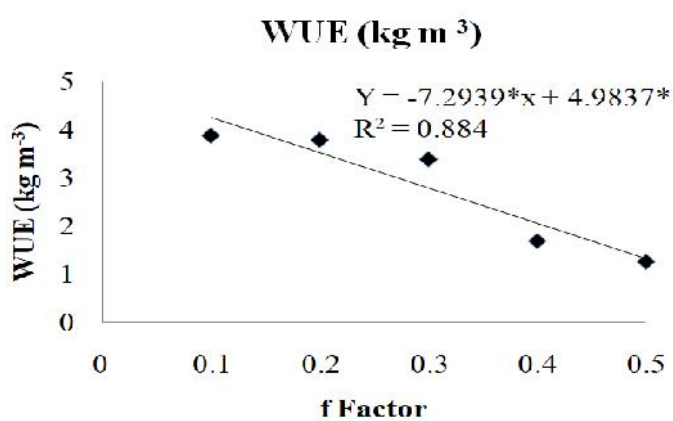

Figure 5: Water Use Efficiency (kg m^{-3}) of taro cultivar "São Bento" under different irrigation frequencies (f factor).

*Significant from F test. *P = .01*

According to [24], when the irrigation interval is too long, the friability of the soil immediately obtained after irrigation undergoes a progressive alteration and, depending on the texture, can at the end of the period, present hard consistency, hindering the penetration of roots of cultivated plants. The local soil used has high clay content, with greater consistency at lower humidity levels. In this case it is

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important to increase the irrigation frequency, establishing temporarily lower irrigation frequency, a condition that will keep the moist topsoil for a longer period of time. Even applying greater total water depths, it is recommended to apply lighter and frequent irrigations for taro cultivation.

4. CONCLUSION

Increasing the f factor provided a reduction of applied irrigation depths. Lighter and frequent irrigations favor the development and yield of taro and can be recommended for their management.

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REFERENCES

1. Huang CC, Chen WC, Wang CCR. Comparison of Taiwan paddy and upland cultivated taro (*Colocasia esculenta* L.) cultivars for nutritive values. Food Chemistry. 2007; 102 (1): 250–256.

2. Brasil Manual de hortaliças não-convencionais. Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Desenvolvimento Agropecuário e Cooperativismo. - Brasília: Mapa / ACS, 2010; 92 p. Portuguese.

3. FAO. Food and Agriculture Organization of the United Nations. Statistics Division: Production of Taro. 2014. Accessed 15 August 2016. Available: http://faostat3.fao.org/download/Q/QC/E .

4. Heredia Zárate NA Produce the clones of inhame cultivation of no pantanal sud matogrossense. Horticultura Brasileira 1995; 13 (1): 38-40. Portuguese.

5. Coelho EF, Coelho Filho MA, Oliveira SL Agricultura irrigated: the use of irrigation in the country. Eunápolis: Bahia Agrícola, 2005; 7 (1). Portuguese.

6. Doorenbos J, Kassam AH. Yield response to water. Rome: FAO, 1979; 306p.

7. Mantovani EC, Souza JAR, Souza DO. Irrigação do tomateiro In: Silva DJH, Vale FXR. (Ed.) Tomate - Production of tecnologia Viçosa: Suprema Gráfica e Editora. 2007; 117-157 Portuguese.

8. Karatas BS, Akkuzu E, Uma HB, Asik S, Avci M. Using Satellite remote sensing to asses irrigation performance in water user Associations in the Lower Gediz Basin, Turkey. Agricultural Water Management. 2009; 96 (1): 982-990.

9. Jalota SK, Sood AGBS, Chahal BU. Crop water productivity of cotton (*Gossypium hirsutum* L.) – wheat (*Triticum aestivum* L.) system as influenced by deficit irrigation, soil texture and precipitation. Agricultural Water Management. 2006; 84 (1): 137-146.

10. Pereira LS, Paredes P, Eholpankulov ED, Inchenkova OP, Teodoro PR, Horst MG. Irrigation scheduling strategies for cotton to cope with water scarcity in the Fergana Valley, Central Asia. Agricultural Water Management. 2009; 96 (1): 723-735.

11. Gondim ARO, Puiatti M, Cecon PR, Finger FL. Crescimento, producer and producer of artificial as part of the production of the sombreamento. Horticultura Brasileira, 2007; 25 (3): 418-428. Portuguese.

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12. Mabhaudhi T, Modia AT, Beletseb YG, Response of taro (*Colocasia esculenta* L. Schott) landraces to varying water regimes under a rainshelter. Agricultural Water Management. 2013; 121 (1): 102–112.

13. Camaravni Espírito Santo State map. Accessed: 10 October 2017. Available: http://www.camaravni.es.gov.br/mapa_estado.asp. Portuguese.

14. Theinglink Brazil map. Accessed: October 10 to 17. Action: Hotspot: //www.ingtonink.com/syn/725367519031853057. Portuguese.

15. Wikipedia Santa Teresa map. Accessed: 10 October 2017. Available: https://upload.wikimedia.org/wikipedia/commons/3/3b/EspiritoSanto_Municip_SantaTeresa.svg Portuguese.

16. Mantovani EC, Bernardo S, Palaretti LF. Irrigação: princípios e métodos. 2. ed. Viçosa, MG: UFV, 2009; 355 p. Portuguese.

17. Vieira GHS, Mantovani EC, Sediyama GC, Lo Monaco PAV. Lâminas de irrigação em cana-de-açaucar for the discovery of the condoções of the disciplines. Irriga, Ed. Esp. 2015; 137-148 Portuguese.

18. Allen RG, Pereira LS, Raes D, Smith M. Crop evapotranspiration: Guidelines for computing crop water requirements. Rome: FAO. 1998; 300 p. (FAO irrigation and drainage paper 56).

19. Fares A. Water management software to estimate crop irrigation requirements for consumptive use permitting in Hawaii. Final Report, University of Hawai'i at Mãnoa. 2008. Accessed: 06 April 2014. Available: http://files.hawaii.gov/dlnr/cwrm/publishedreports/PR200808.pdf.

20. Keller J, Karmeli D. Trickle irrigation design. Rain Bird Sprinkler Manufacturing Corporation, 1975; 133 p.

21. Puiatti M, Campos JP, Casali VWD, Cardoso AA, Cruz R. Sistemas de colocação do cana-de-açuca and do capim gordura, the cultivar of inhame 'Chineseês'. Horticultura Brasileira, Brasília. 1990; 8 (1): 14-16. Portuguese.

22. Sammis TW. Comparison of sprinkler, trickle, subsurface, and furrow irrigation methods for row crops. Agronomy Journal. 1980; 72 (5): 701-704.

23. Caesar K. Growth and development of *Xanthosoma* and *Colocasia* under different light and water supply conditions. Field Crops Research. 1980; 3(1): 235-244.

24. Vicente ASC, Vicente SEI Prophets para Manejo da Irrigação Belém 2004; 30p Portuguese.