Original Research Article

Growth and Quality of Papaya ‘Golden THB’ Seedlings Cultivated Under Different Irrigation Depths

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ABSTRACT

The obtainment of seedlings is one of the main stages of the papaya crop and good irrigation management provides proper water status, contributing to higher quality seedlings. Thus, this work had as objective to evaluate the growth and quality of Papaya 'Golden THB' seedlings submitted to different irrigation depths. The study was carried out at the Federal Institute of Espírito Santo, Campus Itapina, located in Colatina, Northwest region of the State of Espírito Santo, Brazil . The experimental design was completely randomized with six treatments composed of 25 plants each, totaling 150 seedlings in the experiment. The treatments consisted in the application of six daily irrigation depths, corresponding to 4, 6, 8, 10, 12 and 14 mm. At 65 days after planting, the seedlings were evaluated for morphological characteristics: leaf area, root system length, plant height, stem diameter, dry mass of the aerial part, dry mass of the root system, total dry mass and Dickson quality index. The recommended irrigation depth for the production of papaya 'Golden THB' seedlings is 8.15 mm d^{-1}, which had the highest Dickson quality index and the best values for the morphological characteristics studied.

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Keywords: Carica papaya L., efficiency of water use, irrigation management, Dickson index, vegetative development, water replenishment.

1. INTRODUCTION

The papaya (*Carica papaya* L.) is one of the most cultivated and consumed fruit trees in tropical and subtropical regions, and its production is widespread in almost all tropical America countries. The cultivar 'Golden THB' belongs to the ‘Solo’ group, being characterized by high productivity, uniformity and vigor in the plantations, being destined mainly for the export market [1].

One of the main stages to reach the maximum genetic potential of papaya growth is to obtain seedlings [2]. The correct management of irrigation of the seedlings maintains an adequate water status contributing to get plants with a higher quality standard [3]. In many cases, the application of water to the plants is done empirically, without technical knowledge, leading to a reduction of the productive potential of the crops [4].

The amount of water is a limiting factor in the development of plants and lack or excess affects plant health, growth and production [5]. The lack of water creates water stress and a decrease in the absorption of nutrients. The excess is conducive to disease development, causes leaching of nutrients and excessive water consumption, causing socioenvironmental problems [6]. So, the knowledge of the set of techniques for the production of seedlings favors the elaboration of more efficient protocols for making seedlings with higher quality [7].

Thus, studies are necessary to evaluate the efficiency of water use in the development of papaya seedlings. The objective of this work was to evaluate the growth and quality of papaya 'Golden THB' seedlings submitted to different irrigation depths.

2. MATERIAL AND METHODS

The study took place at the Federal Institute of Espírito Santo, Campus Itapina, located in Colatina, Northwest region of the State of Espírito Santo, Brazil, located at 19°29 'South, 40°45' West and altitude of 62 meters, from May 16 to July 19, 2018. The climate of the region, according to Köppen's classification, is Tropical Aw [8]. The zone is characterized by the irregularity of the rain and the occurrence of high temperatures.

The experiment was conducted in an agricultural greenhouse covered with transparent plastic film and black polypropylene screen with 50% shading, linear dimensions of 25 mx 5 m and height of 3 m, in six individual environments (BOX) with dimensions of 2.20 m long by 1.10 m wide each, isolated by transparent plastic canvas on the sides. Each BOX consisted of six GREEN MIST anti-mist nebulizers from NaanDanJain®, located 1 m above the seedlings and spaced 0.8 m apart, with a daily watering frequency of 10 hours (from 07:00 am 05:00 pm), operating at a service pressure of 2 kgf cm^{-2}, individually controlled by electronic controllers and centrifugal pumps of 0.5 hp independently installed.

The treatments consisted in the application of six daily irrigation depths, corresponding to 4, 6, 8, 10, 12 and 14 mm d^{-1}, for the production of papaya seedlings. The experimental design was completely randomized, with each treatment consisting of 25 plants, totaling 150 seedlings in the experiment.

For the production of the seedlings were used seeds of the papaya 'Golden THB' obtained from the company NorteFrut® located in Linhares-ES. The seedlings were produced in tubes with a top diameter of 53 mm, 190 mm in height and 280 ml of volumetric capacity. The tubes were arranged in holders with 54 cells, distributed alternately for not limiting the light in the seedlings, which could lead to them to a stretching. All tubes were previously sanitized and sterilized with 2% sodium hypochlorite diluted in water and filled with Tropstrato HT® Vegetable substrate plus Osmocote Plus® 15-9-12 (3M), at a dosage of 3g tube^{-1}, which had the following chemical composition: N = 15%, (7% ammonia and 8% nitrate), P_2O_5 = 9%, K_2O = 12%, Mg = 1.3%, S = 5.9%, Cu = 0.05%, Fe = 0.46%, Mn = 0.06% and Mo = 0.02%. No additional fertilization was done.

During the execution of the experiment, variations in temperature and relative humidity within the greenhouse were monitored by a WatchDog® Model 200 Data Logger. Externally climatic variables were recorded by an ONSET® weather station, reference evapotranspiration (ETo) was estimated by the Penman-Monteith method FAO-56 Standard [9] by the equation:

$$\boldsymbol{ETo} = \frac{\mathbf{0.408}\Delta(\boldsymbol{Rn} - \boldsymbol{G}) + \boldsymbol{\gamma}\,\frac{\mathbf{900}}{\boldsymbol{T} + \mathbf{273}}\,\boldsymbol{u}_2(\boldsymbol{e}_s - \boldsymbol{e}_a)}{\Delta + \boldsymbol{\gamma}(\mathbf{1} + \mathbf{0.34}\,\boldsymbol{u}_2)}$$

in which ETo is the daily reference evapotranspiration (mm.d^{-1}); Rn is the daily radiation balance (MJ.m^{-2}.d^{-1}); G is the daily flow of heat in the soil (MJ.m^{-2}.d^{-1}); T is the daily average air temperature (ºC); u_2 is the daily average wind speed at 2 m in height ($m.s^{-1}$); e_s is the saturation pressure of the daily average water vapor (kPa); e_a is the daily average water vapor pressure (kPa); Δ is the slope of the vapor pressure curve at the point of T ($kPa.ºC^{-1}$) and γ is the psychrometric coefficient ($kPa.ºC^{-1}$).

At 65 days after planting, the seedlings were evaluated for the following morphological characteristics: a) leaf area (LA), expressed in cm^2, estimated with LI-COR leaf area measurer model LI-3100C; b) length of the root system (LRS), measured from the base of the stem to the largest root length, in cm, with graduated ruler; c) plant height (PH), measured in cm, with the use of a graduated ruler, from the stem to the apical bud; d) stem diameter (SD), measured 2 cm above the edge of the tube, in mm, with a digital caliper from Metrotools, model MPD-150; e) dry mass of the aerial part (DMAP), dry mass of the root system (DMRS) and total dry mass (TDM), expressed in grams, through an electronic scale with an accuracy of 0.001g; f) Dickson quality index (DQI) according to Dickson et al. [10], given by:

$$\text{DQI} = \frac{\text{TDM}}{\frac{PH}{\text{SD}} + \frac{DMAP}{\text{DMRS}}}$$

To obtain the DMAP and DMRS, the plants were subjected to drying process in greenhouse with forced circulation of air at 65 ºC for 72 hours and weighed on electronic scale with precision of 0.001 g. The TDM was obtained by the sum of DMAP and DMRS.

The data were subjected to analysis of variance by the F test, at 5% probability, when significant, regression models were adjusted to better explain the effect of the irrigation depths on the characteristics analyzed by the R software [11]. The maximum points were determined by the first derivative of the regression equations.

3. RESULTS AND DISCUSSION

During the experimental period, the external meteorological variations of the agricultural greenhouse presented a maximum temperature of 22.0 to 34.2 ºC (average of 29.78 ºC), average of 19.7 to 24.8 ºC (average of 22.18 ºC) and minimum of 13.1 to 20.6 ºC (average of 16.98 ºC) (Fig. 1). The average relative humidity varied from 76.9 to 94.1% (average of 82.78%) (Fig. 2). The maximum reference evapotranspiration observed was 2.97, minimum of 1.06 and average of 2.15 mm d^{-1} (Fig. 3).

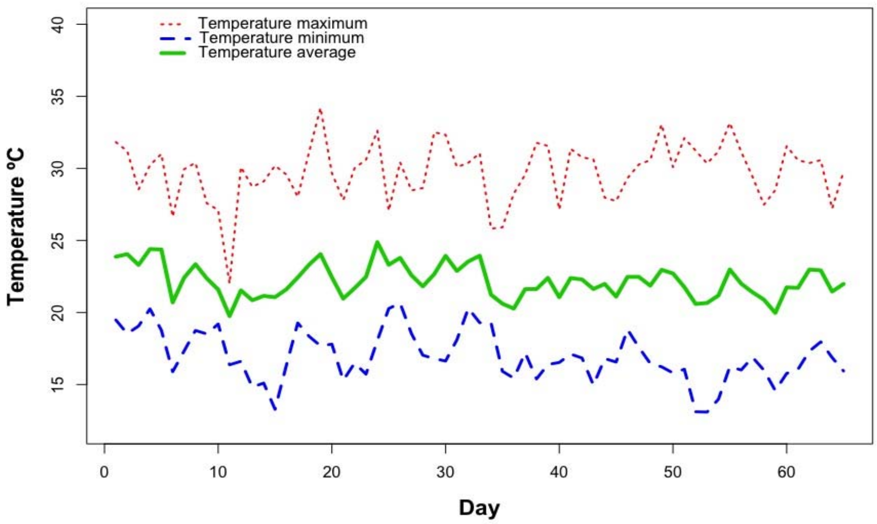

Fig. 1. Maximum, minimum and average external temperatures during the experimental period in Colatina, Espírito Santo.

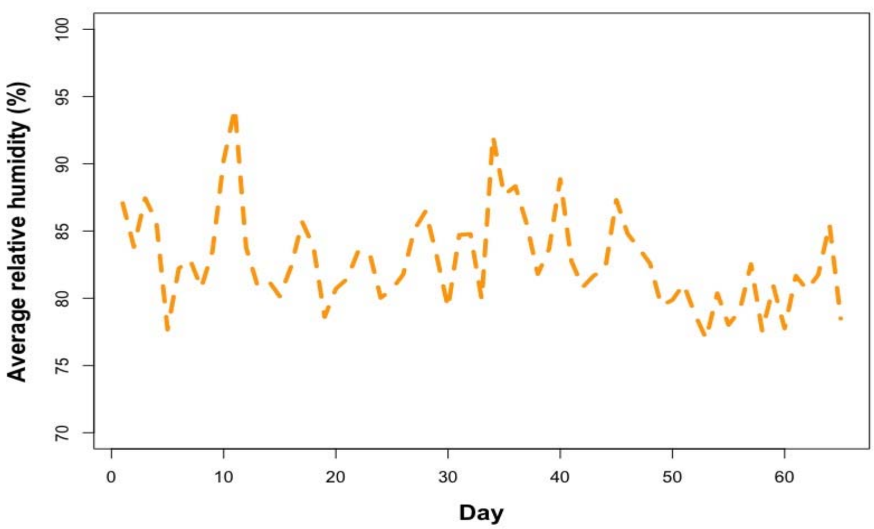

Fig. 2. External average relative humidity during the experimental period in Colatina, Espírito Santo.

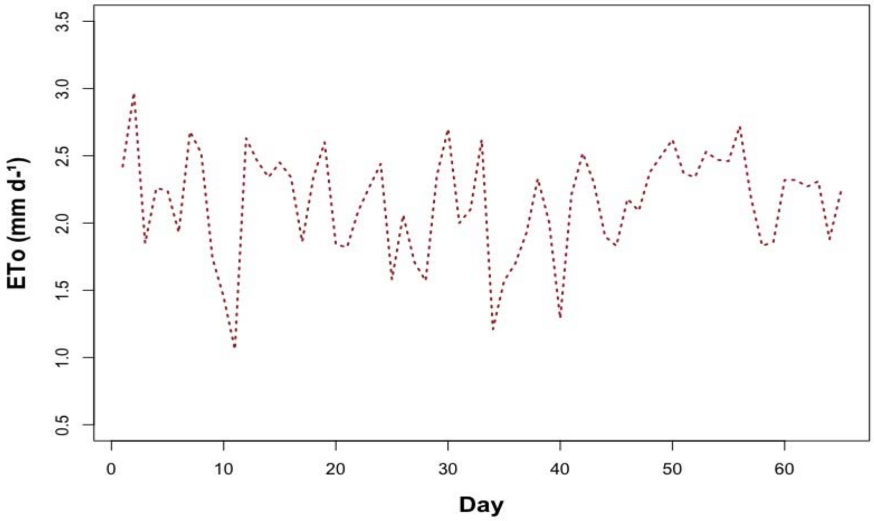

Fig. 3. Reference evapotranspiration during the experimental period in Colatina, Espírito Santo.

Within the agricultural greenhouse, the maximum temperature varied from 25.2 to 45.4 ºC (average of 38.84 ºC), the average temperature had variations from 20.9 to 27.5 ºC (average of 24.66 ºC) and the minimum temperature ranged from 14.1 to 21.3 ºC (average of 17.68 ºC) (Fig. 4). The average relative humidity ranged from 60.8 to 80.4% (average of 65.76%) (Fig. 5). These conditions of average temperature and relative humidity are considered ideal for the development of papaya plants [12]. On average, the maximum, average and minimum temperatures within the agricultural greenhouse were 30.42, 11.18 and 4.12% higher than the external averages, while relative humidity decreased by 20.6%.

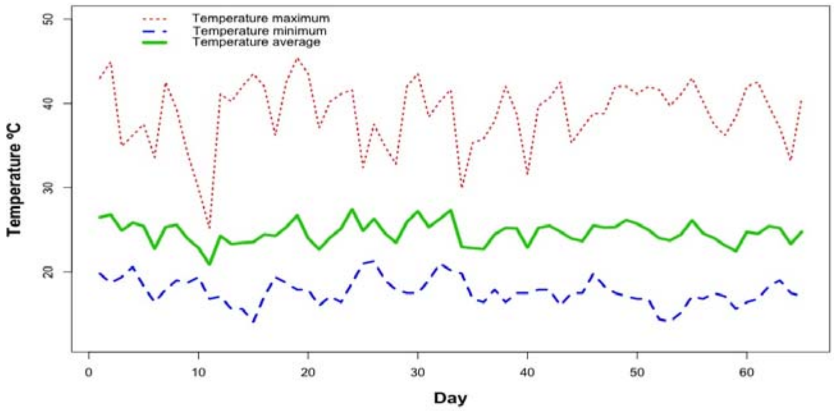

Fig. 4. Maximum, minimum and average temperatures within the agricultural greenhouse during the experimental period in the municipality of Colatina, Espírito Santo.

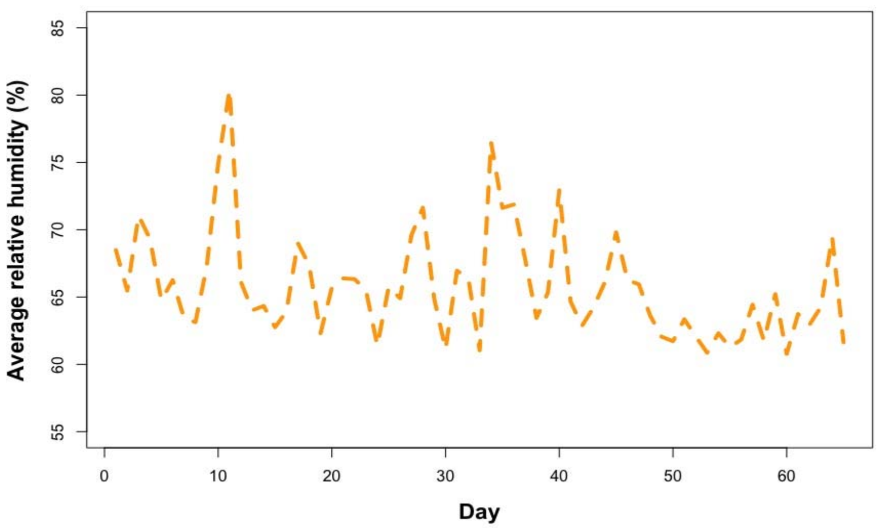

Fig. 5. Average relative humidity within the agricultural greenhouse during the experimental period in Colatina, Espírito Santo.

After analysis of variance, a significant difference ($P < 0.05$) was observed for all the evaluated characteristics, noting that the application of the different irrigation depths interfered in the growth and quality of the papaya 'Golden THB' seedlings.

The length of the root system (LRS) showed a quadratic effect, with determination coefficient (R^2) of 0.745 and maximum point with 27.78 cm in the irrigation depth of 9.44 mm d^{-1} (Fig. 6A). Leaf area (LA) presented a quadratic adjustment, with its maximum point in the irrigation depth of 7.28 mm d^{-1}, with an area of 116.65 cm^2 and R^2 of 0.9401 (Fig. 6B). Measure LA is very important because the leaves are responsible for capturing the highest amount of solar energy required for photosynthesis, producing photosimilates used for maintenance and growth of the plant [13; 14]. So, higher AF indicates more suitable seedlings the field conditions because they possess larger photosynthetically active area [15].

Under stress conditions, plants change their morphological characteristics [16]. The water deficit caused by the lack of water in the smaller irrigation depths decreases the swelling pressure of the plant cells, reflecting in turgidity dependent processes, as the expansion of the leaf area and the extension of the root system. The expansion of the leaf area is early affected when the amount of water is reduced, this morphological change leads the plants to transpire less, supporting for a longer time the availability of water in the substrate [17].

On the other hand, the excess of irrigation affected the length of the root system and the leaf area of the seedlings. Under such conditions plants are exposed to an oxygen-depleted environment (anoxia). Virtually all plants need oxygen to perform their metabolic activities, thus under anoxic conditions their development is limited. The root respiration rate is diminished in anaerobic environments, causing damage to its growth. In addition, the roots cannot supply the energy demand required to sustain the physiological processes of the aerial part of the plants, limiting their development [17].

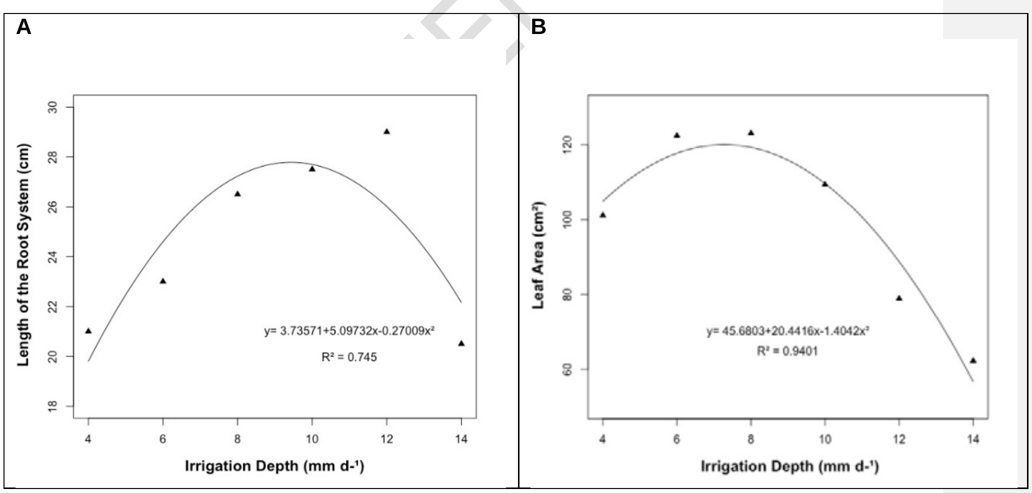

Fig. 6. Length of root system (A) and leaf area (B) of papaya 'Golden THB' seedlings submitted to different irrigation depths.

The plant height (PH) presented quadratic adjustment, with R^2 of 0.7697. The maximum height of 16.01 cm was observed in the irrigation depth of 8.84 mm d^{-1} (Fig. 7A). The lowest heights were observed in the largest and the shortest irrigation depth. According to Delgado *et al.* [7], the excess water provides greater leaching of nutrients present in the substrate, limiting the size of the plants. On the other hand, lack of water prevents the expansion of the cell wall due to altered hormonal balance and cellular turgidity impairing plant growth [18].

The height is used as a base parameter for the transplanting of seedlings to the field, taking advantage of larger seedlings, since seedlings of smaller stature can be constantly damaged, impairing their development and production [5].

The stem diameter (SD) presented quadratic behavior, with a maximum point of 6.04 mm in the irrigation depth of 6.29 mm d^{-1} and R^2 of 0.9225 (Fig. 7B). The behavior of SD was similar to that presented by LA. This fact can be explained, according to Melo *et al.* [15], because of the high predictive correlation, thus, plants with larger leaf area produce more photosimilates and, consequently, larger stem diameter, the opposite is observed in plants with smaller leaf area that has reduced stem diameter.

Stem diameter and plant height are very important characteristics, since they are related to possible tipping of seedlings in the field and they are easily evaluated, expressing quality in every stage of the seedling development [19].

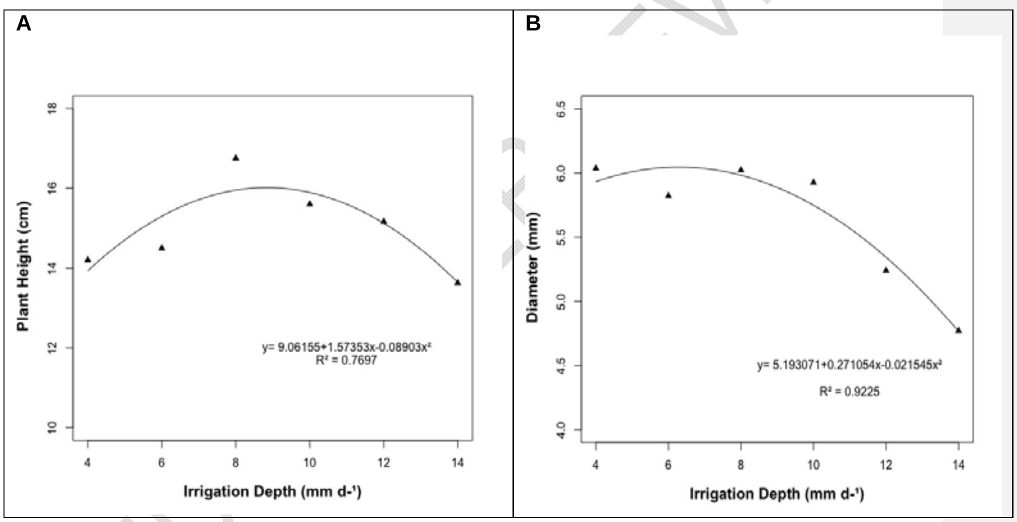

Fig. 7. Plant height (A) and stem diameter (B) of papaya 'Golden THB' seedlings submitted to different irrigation depths.

The dry mass of the aerial part (DMAP), dry mass of the root system (DMRS) and total dry mass (TDM) showed a quadratic effect, with a maximum point of 0.95 g, 0.44 g and 1.39 g irrigation depths of 8.36, 8.52, 8.42 mm d^{-1} and R^2 of 0.9607, 0.8607 and 0.9581, respectively (Fig. 8A, 8B and 8C). There is similarity in the adjustments of LA, DMAP, DMRS and TDM, so it can be observed that the increase in foliated area allowed greater light uptake for the practice of photosynthesis, providing better growth and accumulation of dry mass by plants [15]. It is clear that both the excess and the lack of water caused a decrease in the accumulation of DMAP, DMRS and TDM by plants.

The excess water creates anaerobic conditions in the roots, reducing the transport of electrons, damaging the photosynthetic apparatus and the accumulation of carbohydrates by the roots, limiting the growth of the plants, so under these conditions there is a decrease in the total dry mass production of the plant [20; 21; 22; 23]. Like the excess, the water deficit caused by the lack of water generates inhibition of the photosynthesis by the plants inducing the accumulation of abcisic acid (ABA) promoting the closure of the stomata and limiting the gas exchanges reducing the production of photosimilates and consequently the total dry mass of the plant [17].

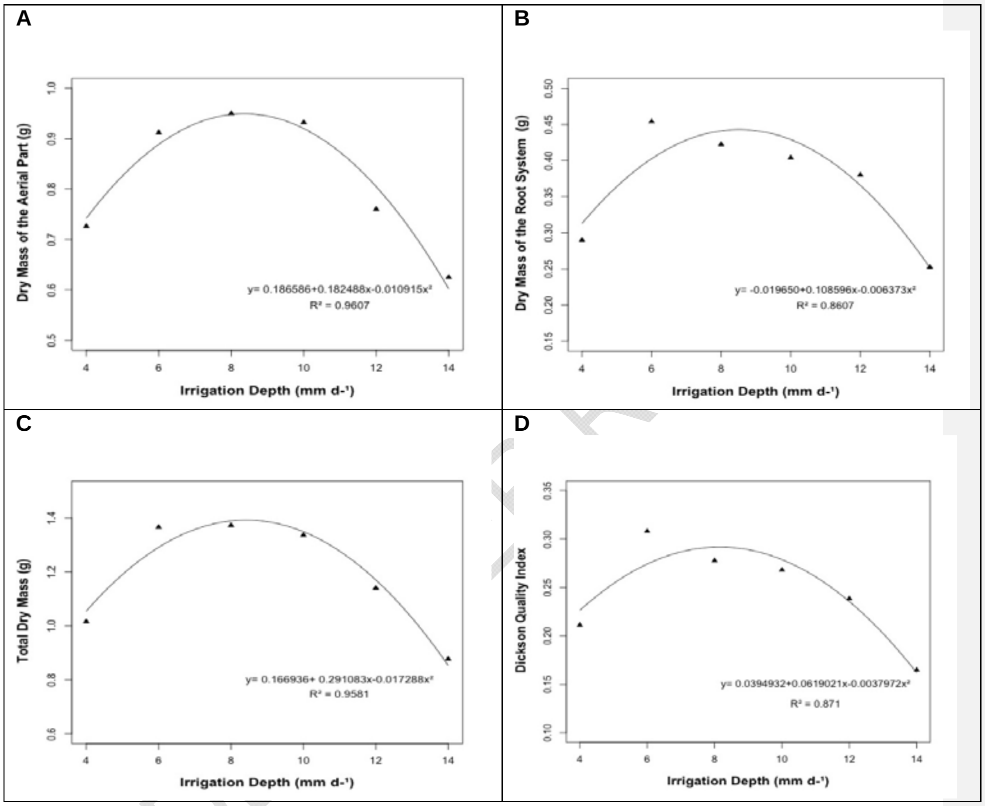

Fig. 8. Dry mass of aerial part (A), dry mass of the root system (B), total dry mass (C) and Dickson quality index (D) of papaya 'Golden THB ' seedlings submitted to different irrigation depths.

The Dickson quality index (DQI) presented quadratic adjustment, with a higher index of 0.29 in the irrigation depth of 8.15 mm d^{-1} and R^2 of 0.871 (Fig. 8D). Posse *et al.* [24], found that the 8 mm d^{-1} depth is the most adequate for the formation of yellow passion fruit seedlings. Posse *et al.* [25], also observed that, no matter the climatic conditions, the 8 mm daily depth was the one that provided the best formation of cacao seedlings TSH1188 genotype, with quality and economic use of water and energy.

The DQI is an indicative of quality of seedlings considering in its formula growth characteristics of all parts of the plant. Hunt [26], establishes a minimum DQI value of 0.20 to obtain a quality seedling. Considered also by Johnson and Cline [27], as a promising morphological measure, the DQI reflects the quality of the seedlings considering in its calculation the robustness (TDM) and the balance of the phytomass distribution. The

Dickson quality index proved to be a good indicator of quality for the papaya 'Golden THB' seedlings.

In addition, low-DQI seedlings reflect higher mortality rates when they are taken to the field, because they present lower lignification, which would imply a lower survival capacity, thus, seedlings with higher indexes are more likely to survive [28; 29].

4. CONCLUSION

The irrigation depth indicated for production of papaya 'Golden THB' seedlings with high quality is 8.15 mm d^{-1} because it presented the highest Dickson quality index and the best values for the morphological characteristics studied.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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