Original Research Article

Growth and Quality of Papaya 'Tainung 01' Seedlings Submitted to Different Irrigation Depths

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ABSTRACT

Performing an adequate irrigation management for the production of papaya seedlings is essential to obtain plants that express all their genetic potential. For this reason, this work aimed to evaluate the effect of different irrigation depths on the growth and quality of papaya type 'Tainung 01' seedlings. The study took place at the Federal Institute of Espírito Santo, Campus Itapina, located in the in Colatina, in the Northwest region of the State of Espírito Santo, Brazil. The experimental design was completely randomized with 25 repetitions for each treatment. The treatments consisted on the application of six irrigation depths: 4, 6, 8, 10, 12 and 14 mm d^{-1}. The seedlings were evaluated at 65 days after planting for the following morphological characteristics: plant height, stem diameter, number of leaves, leaf area, dry mass of the aerial part, dry mass of the root system, total dry mass and Dickson quality index. The irrigation depth of 9.16 mm d^{-1} had a higher Dickson quality index attesting a higher quality of seedlings, being the most suitable for the production of papaya 'Tainung 01' seedlings.

Keywords: Carica papaya L., quality seedlings, irrigation management, Dickson index, vegetative development, water replenishment.

1. INTRODUCTION

The papaya (*Carica papaya* L.) is one of the most appreciated fruit trees in the tropical and subtropical regions of the world. In Brazil, the cultivar 'Tainung 01' is the main hybrid of papaya of the ‘Formosa’ group produced. It presents fruits with an average weight from 900 to 1100 g, peel with light green coloration, reddish-orange pulp and resistance to transport, being destined mainly for the national market [1;2].

In the papaya crop, the production of seedlings is a fundamental stage to obtain plants that express all their genotypic potential [3]. Irrigation plays a major role in the seedling production process because it is directly related to its quality. In most cases, the application of water to the plants is done erroneously, without evaluation criteria, limiting the potential of agricultural crops. Evaluating the water requirement for seedling production is very important, once both lack and excess of water generate limitations on the growth and development of plants [4].

The morphological characteristics of the seedlings, and consequently their quality, are affected when under conditions of hydric deficit. Such responses have already been observed in several crops as in *Eucalyptus grandis* W. (Hill ex. Maiden) seedlings [5], in *Schinus terebinthifolius* seedlings [4] and *Passiflora edulis* Sims Seedlings [6].

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Water excess is favorable to the emergence of disease because it is directly linked to the leaching of nutrients and it causes environmental questions related to excessive water consumption. The lack of water induces water stress and it limits nutrient absorption and cell expansion, reducing leaf area, increasing leaf abscission and reducing the process of photosynthesis [5;7].

Good irrigation management can provide the plants with an adequate water humidity, therefore, knowledge of soil, climate, culture and irrigation method must be taken into account. Thus, studies are necessary to quantify the water demand in the development of papaya seedlings. In this context, this work aimed to evaluate the effect of different irrigation depths on the growth and quality of papaya 'Tainung 01' seedlings.

2. MATERIAL AND METHODS

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

The experiment started on May 16 and ended on July 19, 2018. Its development occurred in a greenhouse of 125 m^2 and a height of 3 m. Within the greenhouse, six individualized environments (Box), with 2.42 m^2 each, were created, surrounded on the sides by translucent plastic canvas. Each box consisted on six GREEN MIST (NaanDanJain®) anti-mist nebulizers located one meter above the seedlings and spaced 0.8 m apart.

The experimental design was completely randomized, with 25 repetitions for each treatment. The treatments consisted in the application of six daily irrigation depths: 4, 6, 8, 10, 12 and 14 mm, uniformly distributed in ten hours a day (7 a.m. to 5 p.m.), individually controlled by electronic controllers and centrifugal pumps of 0.5 hp independently installed, operating at a service pressure of 2 kgf cm^{-2}.

The papaya 'Tainung 01' seedlings were produced in tubes, with a volumetric capacity of 280 cm^3. All tubes were pre-sanitized with 2% sodium hypochlorite solution and filled with Tropstrato HT® Vegetable substrate plus Osmocote Plus® 15-9-12 (3M) at the dosage of 3g $tube^{-1}$, which presents the following chemical composition: N = 15% (7% ammoniacal 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%. The tubes were arranged in holders with a capacity of 54 cells, being positioned alternately, in order not to prevent the arrival of light, avoiding the wadding.

Temperature and humidity variations were monitored and recorded internally in the agricultural greenhouse by a Model 200 Data Logger (WatchDog®), with a maximum temperature ranging from 25.2 to 45.4ºC (average of 38.84 ºC), the average temperature from 20.9 to 27.5 ºC (average of 24.66 ºC) and the minimum temperature from 14.1 to 21.3 ºC (average of 17.68 ºC) (Fig. 1). The average relative humidity ranged from 60.8 to 80.4% (average of 65.76%) (Fig. 2). These conditions mentioned above are considered as ideal for the development of papaya plants [9].

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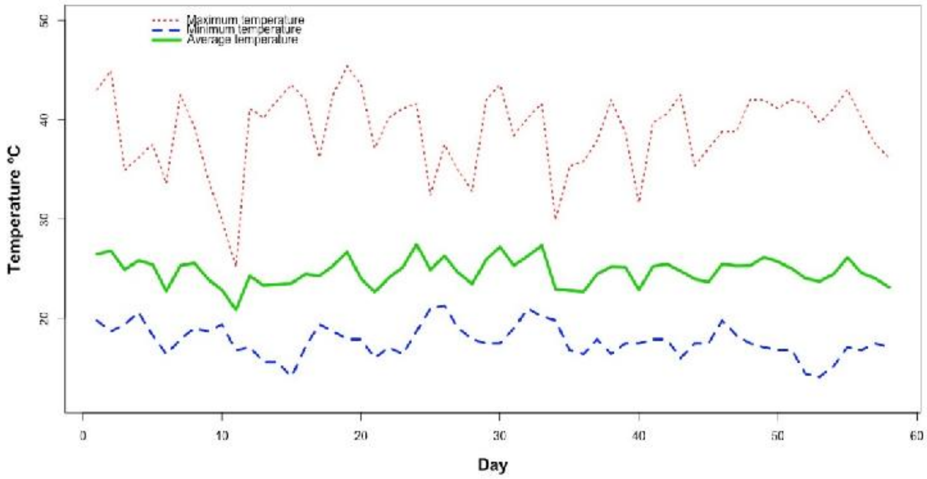

Fig. 1. Maximum, minimum and average temperatures within the greenhouse during the experimental period in Colatina, Espírito Santo.

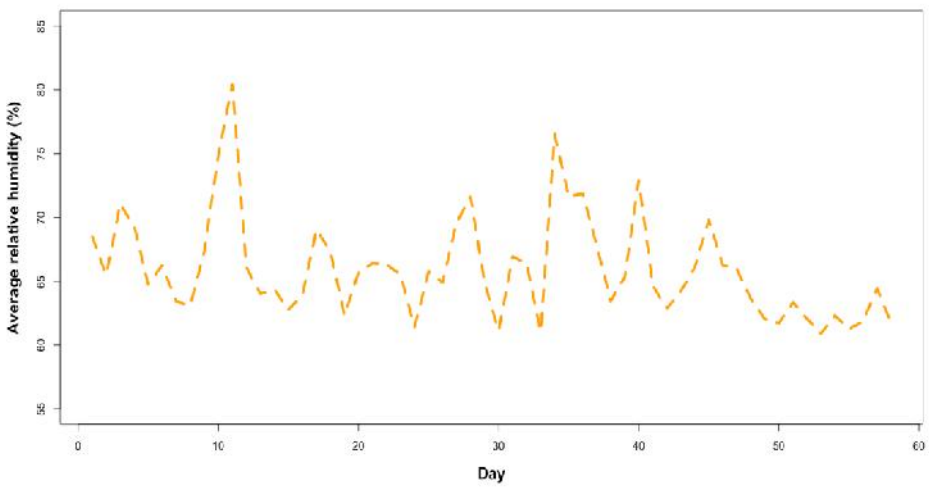

Fig. 2. Average relative humidity within the greenhouse during the experimental period in Colatina, Espírito Santo.

Externally climatic variables were recorded by an ONSET® weather station, installed next to the experiment, with maximum temperatures ranging from 22.0 to 34.2 ºC (average of 29.78 ºC), average temperatures 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. 3). The average relative humidity varied from 76.9 to 94.1% with average marking of 82.78% (Fig. 4).

The reference evapotranspiration (ETo) was estimated externally by the FAO-56 Penman-Monteith method [10] by the equation:

$$ETo = \frac{0.408\Delta(Rn - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34\, u_2)}$$

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}).

The average reference evapotranspiration (ETo) during the evaluation period was 2.15 mm d^{-1}, with maximum temperature of 2.97 mm d^{-1} and a minimum of 1.06 mm d^{-1} (Fig. 5).

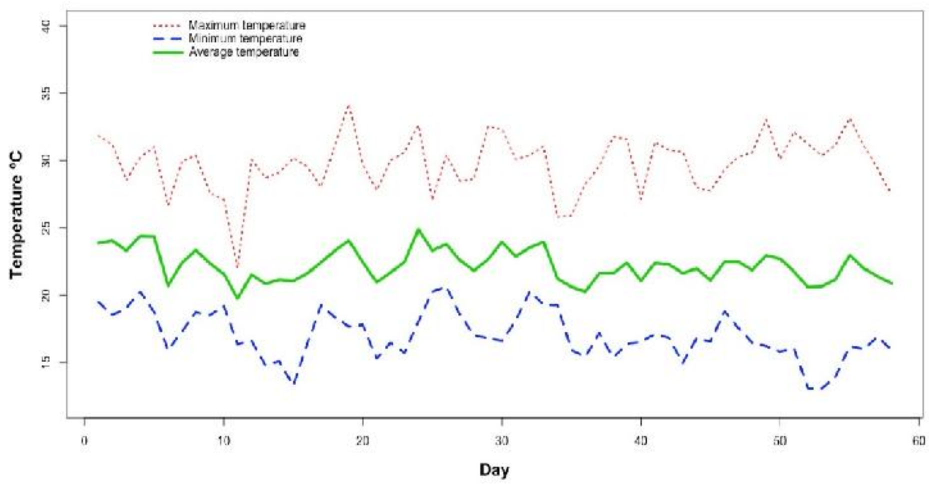

Fig. 3. Maximum, minimum and average external temperatures during the experimental period in Colatina, Espírito Santo.

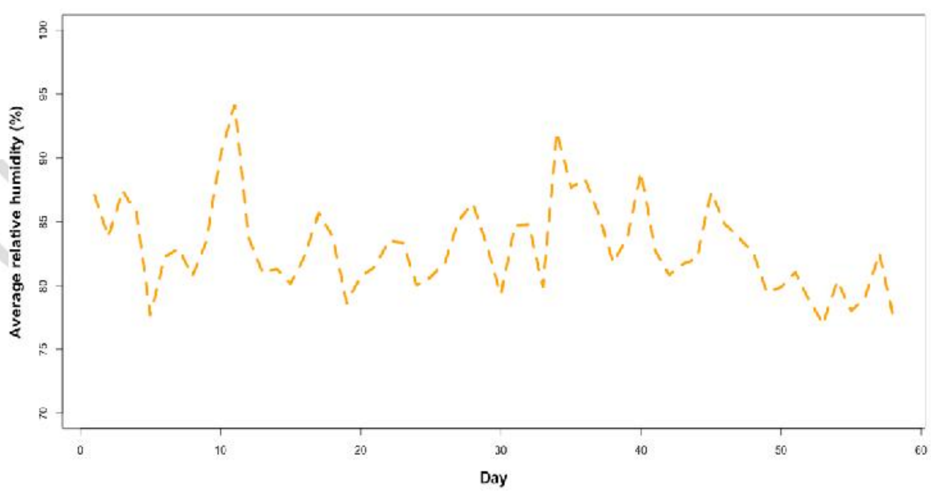

Fig. 4. Average external relative humidity during the experimental period in Colatina, Espírito Santo.

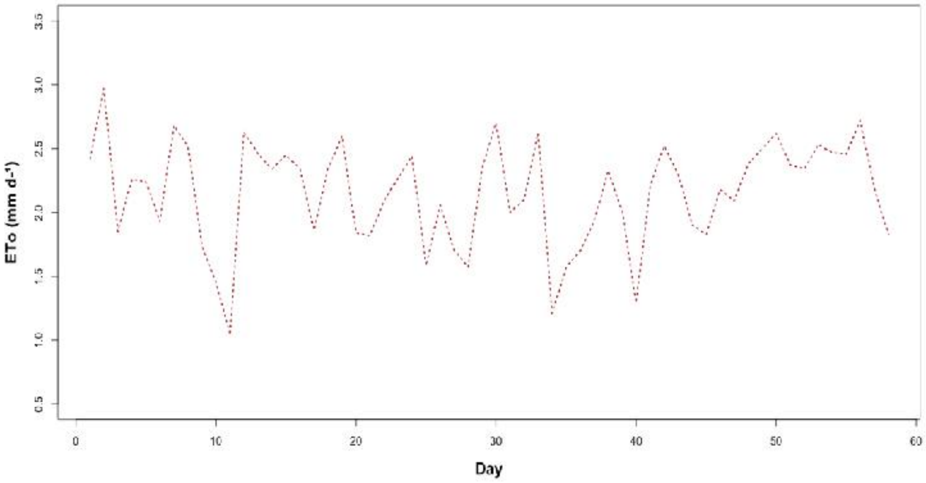

Fig. 5. Reference evapotranspiration during the experimental period in Colatina, Espírito Santo.

At 65 days after planting, the seedlings were evaluated about the following morphological characteristics: plant height (PH), measured in cm, using a graded ruler, from the stem to the apical bud; stem diameter (SD), measured 2 cm above the edge of the tube, in mm, with a digital caliper ruler from Metrotools company, model MPD-150; number of leaves (NL), defined by the total leaf count of the seedling; leaf area (LA), expressed in cm^2, estimated with a LI-COR leaf area meter model LI-3100C; dry mass of the aerial part (DMAP), dry mass of the root system (DMRS) and total dry mass (TDM), expressed in grams; Dickson quality index (DQI) according to Dickson et al. [11], given by:

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

The DMAP and DMRS were obtained after the seedlings were dried in a greenhouse with forced air circulation for 72 hours at 65 ºC and weighed in an electronic scale with an accuracy of 0.001 g. The TDM was obtained by the sum of DMAP and DMRS.

The data were submitted to analysis of variance by the F test at 5% probability through the software R [12]. When significant, they were adjusted to regression models that better explained the effect of the irrigation depths on the analyzed variables. The maximum points were obtained through the primary derivative of the regression equations.

3. RESULTS AND DISCUSSION

After analysis of variance, significant differences were observed for the stem diameter, leaf area, dry mass of the aerial part, dry mass of the root system, total dry mass and Dickson quality index by the F test ($P<0.05$) attesting that the applied irrigation depth interfered on these characteristics, however, the results found for plant height and number of leaves were not significant.

Plant height (PH) had an average of 21 cm in all applied irrigation depths (Fig. 6). Considering that the ideal plant height for transplanting papaya seedlings to the field varies

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from 15 to 20 cm [13], all irrigation depths produced seedlings with satisfactory size at 65 days after planting. According to Carneiro [14], this is a non-destructive and easily measured feature standing as a parameter for transplanting seedlings into the field. However, for Costa *et al.* [15] and Posse *et al.* [6], PH cannot be used alone to determine seedling quality and should be used join stem diameter and aerial part biomass to do that.

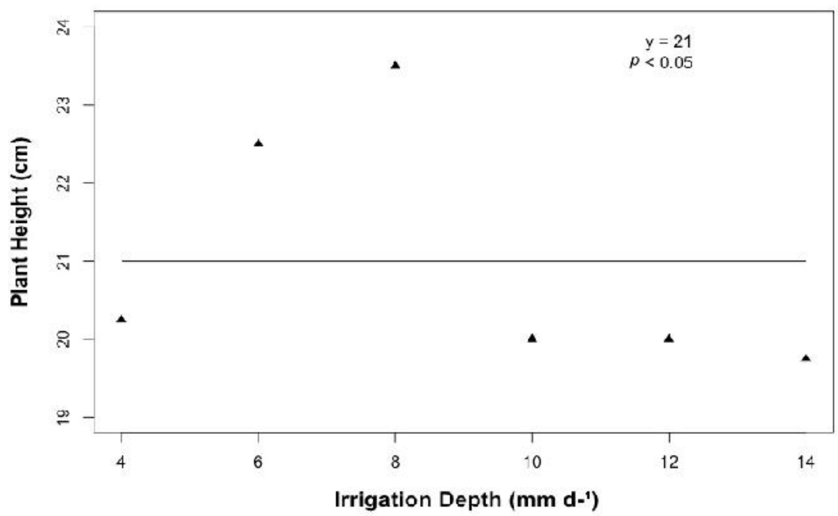

Fig. 6. Plant height of papaya "Tainung 01" seedlings under the different irrigation depths

The number of leaves (NL) had an average of 9.6 leaves in all applied treatments (Fig. 7). Although the number of leaves did not differ significantly in relation to the applied irrigation depth, these results are superior to those found by Oliveira *et al.* [16], who observed a maximum number of 7 leaves for the 'Rubi INCAPER 511' variety in the 13.08 mm d^{-1} irrigation depth at 60 days after planting.

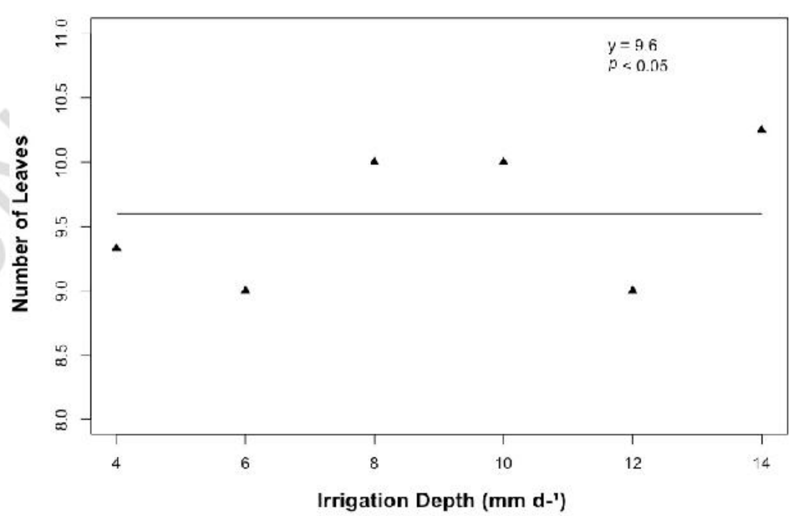

Fig. 7. Number of leaves of papaya "Tainung 01" seedlings under the different irrigationdepths

The stem diameter (DC) showed quadratic adjustment, with a maximum point of 6.49 mm in the 9.62 mm d^{-1} depth and coefficient of determination (R^2) of 0.757 (Fig. 8). Plants with larger stem diameter have higher resistance and quality when transplanted to field conditions, thus, being the most desirable [17]. According to Trindade [9], papaya plants are very sensitive to lack of water, delaying their growth and reducing the rate of stem development which leads to a reduction in stem diameter, corroborating with the results of this work, presented for the depths smaller than 9.62 mm.

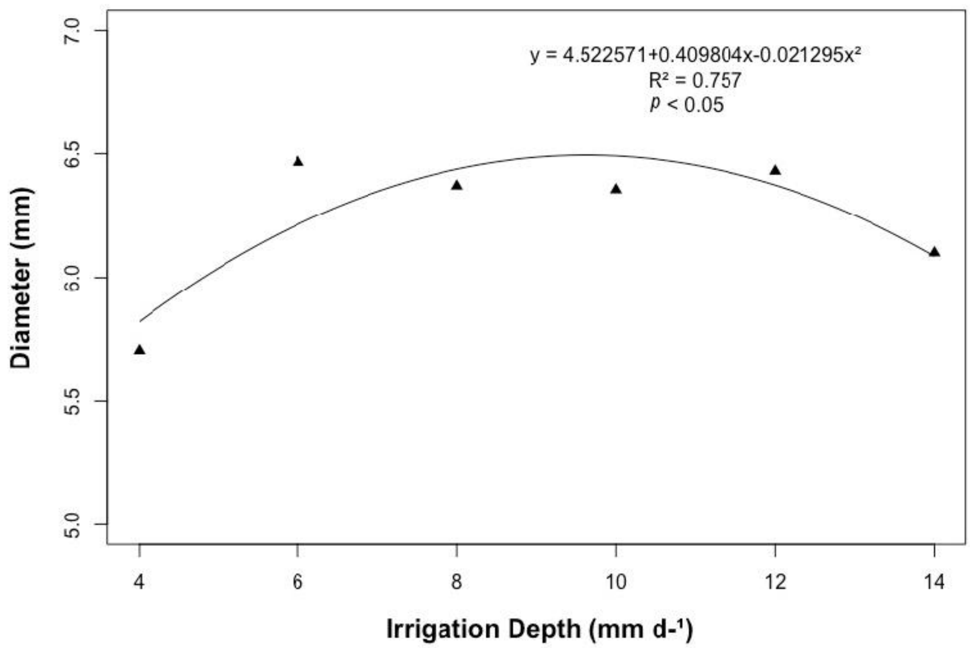

Fig. 8. Stem diameter of papaya "Tainung 01" seedlings under different irrigation depths

Leaf area (LA) presented a quadratic effect, with R^2 of 0.916 and maximum point of 192.25 cm^2 in the 6.73 mm d^{-1} irrigation depth (Fig. 9). Although there was no difference in the number of leaves of the seedlings in relation to the water depth applied, the leaf area was affected by the amount of water available to the seedlings, attesting that the leaves varied in size. According to Sá *et al.* [18], the leaf area is the most important characteristic to be studied in papaya plants, since this variable allows the identification of plants with greater tolerance to stress.

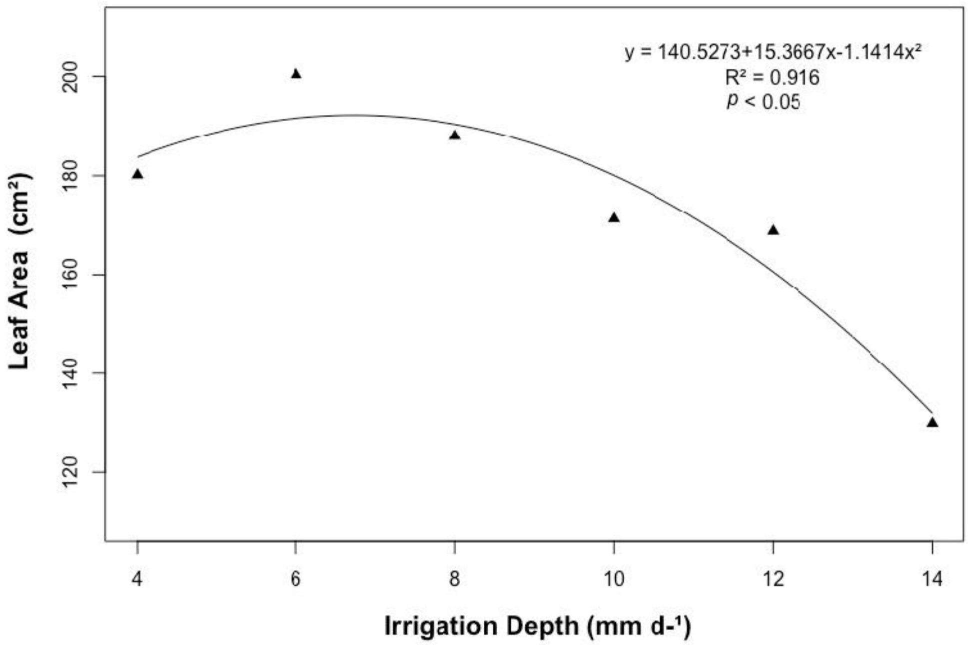

Fig. 9. Leaf area of papaya "Tainung 01" seedlings under the different irrigation depths

It is verified that LA is directly affected by the lack or excess of water available to the plants. The reduction of leaf area is a defense mechanism of plants, under water shortage, the decrease of leaf area is related to gas exchange, reducing water loss through transpiration [18]. In the other hand, papaya seedlings are susceptible to flooding [19]. Under conditions of excess water, the plants are submitted to an environment with lack of oxygen, limiting the metabolic activity and, consequently, their development [7].

The dry mass of the aerial part (DMAP), the dry mass of the root system (DMRS) and the total dry mass (TDM) presented quadratic behavior with a maximum point of 1.85 g, 0.94 g and 2.78 g in the 9.67 mm d^{-1}, 8.88 mm d^{-1} and 9.32 mm d^{-1} irrigation depths and R^2 0.826, 0.946 and 0.903, respectively (Fig.10, Fig. 11 and Fig. 12). Reducing the amount of water available to the plants interfered negatively in the accumulation of dry mass of the plants. This reduction in environments with water deficit is generated by the inhibition of photosynthesis caused by the induction of abscisic acid accumulation, causing stomatal closure, limiting gas exchange, and reducing the consumption of photoassimilates by the expanding leaves [20;7].

The papaya tree is extremely sensitive to lack of aeration in the soil caused by water excess, reducing its physiological activities significantly 24 hours after being under such conditions, and exposure for two to four days in these environments may cause death of the plants [9]. In case of flooding, there is a lack of oxygen to the roots, causing tissue death, leading to limited absorption of nutrients and water due to the lack of energy, leading to a decrease in the plant biomass [7].

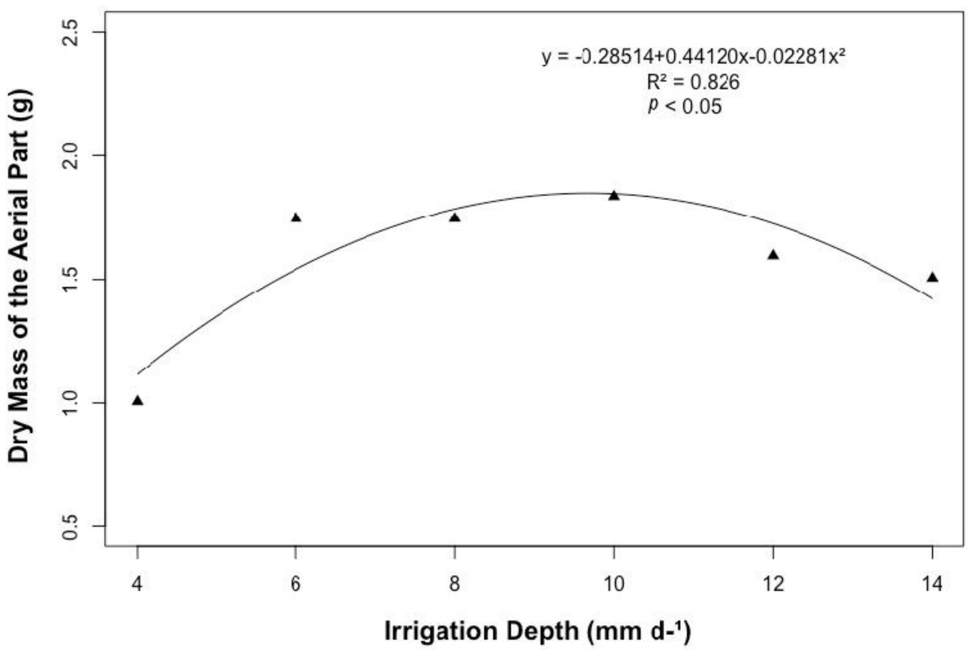

Fig. 10. Dry mass of the aerial part of papaya "Tainung 01" seedlings under the different irrigation depths

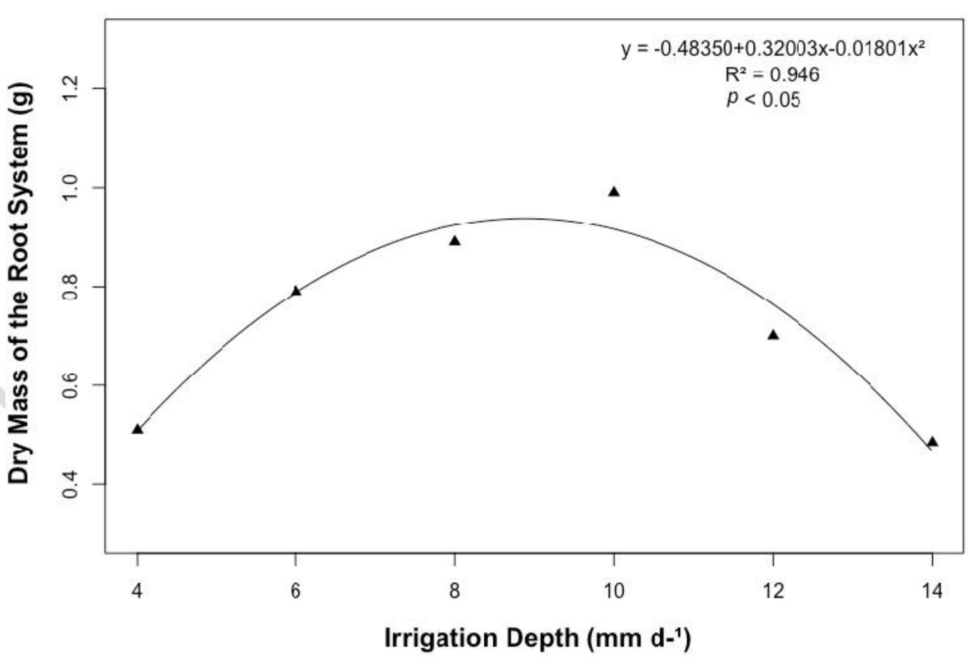

Fig. 11. Dry mass of the root system of papaya "Tainung 01" seedlings under different irrigation depths

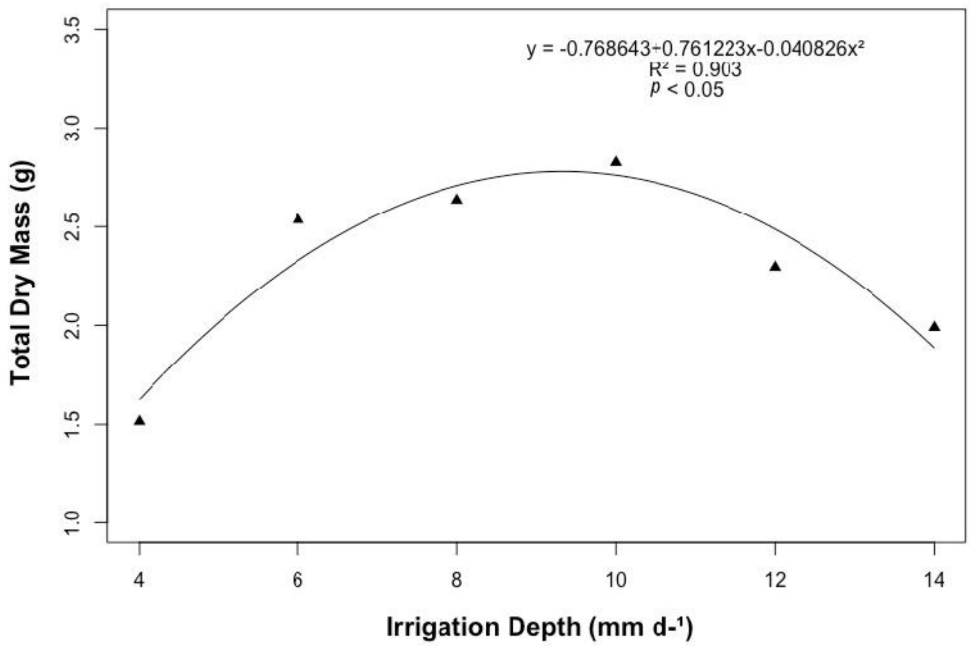

Fig. 12. Total dry mass of papaya "Tainung 01" seedlings under different irrigation depths

The Dickson quality index (DQI) showed a quadratic behavior with a maximum point of 0.51 in the 9.2 mm d^{-1} irrigation depth and R^2 of 0.92 (Fig. 13). The DQI is an indicative of quality of seedlings considering in its formula growth characteristics of all parts of the plant, and, so, the higher the DQI the better the quality of the seedlings is.

Hunt [21] establishes a minimum DQI value of 0.20 to obtain a quality seedling. Considered also by Johnson *et al.* [22], 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 found in this work proved to be a good indicator of quality for the papaya “Tainung 01” seedlings.

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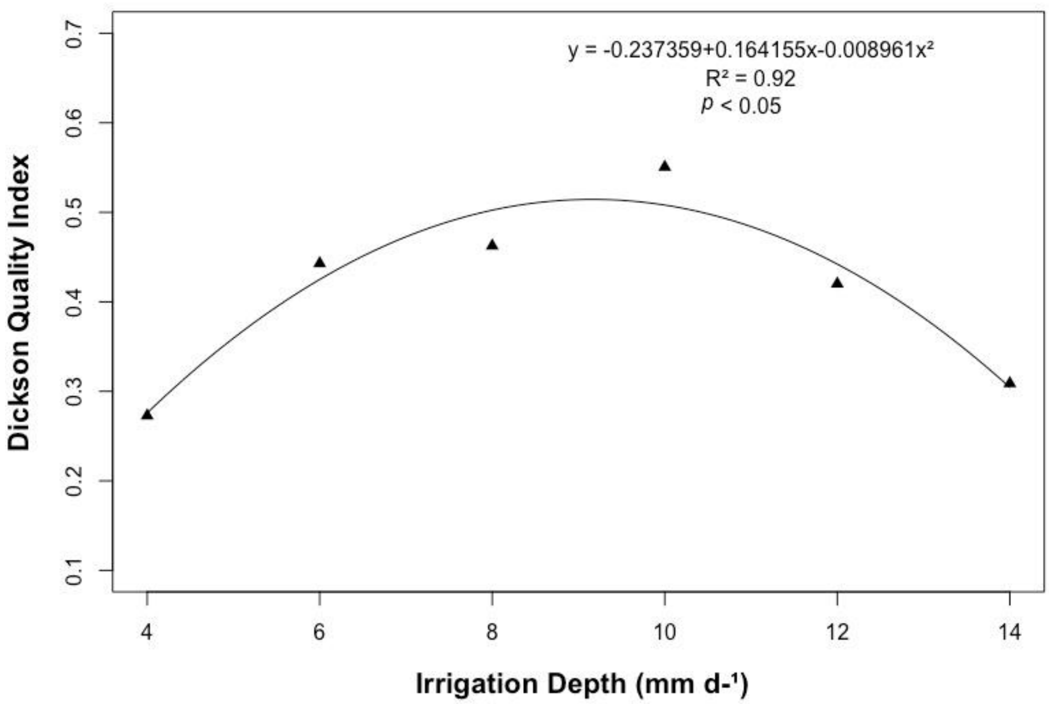

Fig. 13. Dickson quality index of papaya "Tainung 01" seedlings under different irrigation depths

Oliveira *et al.* [16], found for papaya 'Rubi INCAPER 511', also belonging to the 'Formosa' group, a DQI maximum value of 0.43, using a daily 12.66 mm irrigation depth. Seedlings that present higher DQI are more likely to survive when taken to the field due to their greater capacity of acclimation, favoring their development [23;24].

4. CONCLUSION

The irrigation depth of 9.2 mm d^{-1} had a higher Dickson quality index attesting higher quality of seedlings, as well as good answers in the majority of quality characteristics evaluated, being the most suitable for the production of papaya 'Tainung 01' seedlings.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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