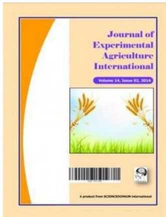

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Effect of Irrigation Depths on the Growth of Papaya Seedlings

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Water is a limiting factor for the production of Papaya tree (*Carica papaya* L.) seedlings. Its lack leads to a reduction in the absorption of nutrients and its excess provides an environment for the development of pathogens, contributing to the leaching of nutrients, besides generating wastes. The present study aimed to evaluate the effects of irrigation depths on the growth of seedlings of 'Rubi INCAPER 511' papaya. The experiment was carried out at the Federal Institute of Espirito Santo, Brazil. The experimental design was completely randomized. Six treatments were used: 4, 6, 8, 10, 12 and 14 mm d^{-1} with 24 seedlings per treatment, totaling 144 in the experimental field. 60 days after sowing, the following morphological characteristics were evaluated: plant height, stem diameter, number of leaves, leaf area, SPAD index, shoot dry mass, dry mass of the root system and Dickson quality index. The depths between 12.5 and 14 mm d^{-1} presented higher Dickson quality index, stem diameter, plant height and leaf number, with the 12.5 mm d^{-1} depth being recommended for economic reasons in the production of seedlings of papaya 'Rubi INCAPER 511'.

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Keywords: Carica papaya L.; seedling quality; nursery.

1. INTRODUCTION

The papaya (*Carica papaya* L.) plays an important role in tropical fruit production, and its cultivation is spread worldwide [1]. India, Brazil, Mexico and Indonesia appear as the main products accounting for about 68% of world production in 2016 [2]. In Brazil, the state with the highest production is Bahia with 753,417 tons followed by Espirito Santo with production of 251,365 tons, the two states accounting for 70% of all Brazilian production in 2016 [3].

The formation of seedlings in the cultivation of papaya is an extremely important stage for the plants to express the maximum productive potential. Among the costs for the implantation of the crop, the irrigation system is highlighted because it is very onerous. Thus, the investment in alternative technologies that are sustainable, reduce production costs and improves the producer's income becomes extremely necessary [4,5].

The amount of water available is of great importance for the papaya crop, and the lack or excess interferes with the growth of the plant, besides reducing the quality and productivity of the fruits [6]. Water is a limiting factor for the production of seedlings, it is fundamental to promote seed germination, the rooting of cuttings and the development of grafted seedlings [7]. The lack of water causes a reduction in the absorption of nutrients that can lead the plant to water stress, while the excess provides a favourable environment for the development of pathogens, contributing to nutrient leaching, besides generating waste which causes social and environmental problems [8].

The application of water in plants is most often done without technical criterion, resulting in the non-expression of maximum genetic potential and decrease of the crop production. Thus, the knowledge of the production system of seedlings, in a general way, allows the elaboration of protocols that optimize the production of seedlings with better quality, decreasing the waste of water resources, energy and nutrients [9,10].

In this context, it is necessary to evaluate the efficiency of water use for the production of papaya seedlings. This study aimed to evaluate the growth of papaya seedlings of the variety 'Rubi INCAPER 511' under different irrigation depths.

2. MATERIALS AND METHODS

The study took place at the Federal Institute of Espírito Santo Campus Itapina, in Colatina, a city located in the north of Espírito Santo state, Brazil, located at 19°32'22" South latitude and 40°37'50" West longitude, from September 9th to November 7th in 2016. The average, maximum and minimum temperatures in the experimental period are shown in Fig.1 and the average relative humidity in Fig. 2.

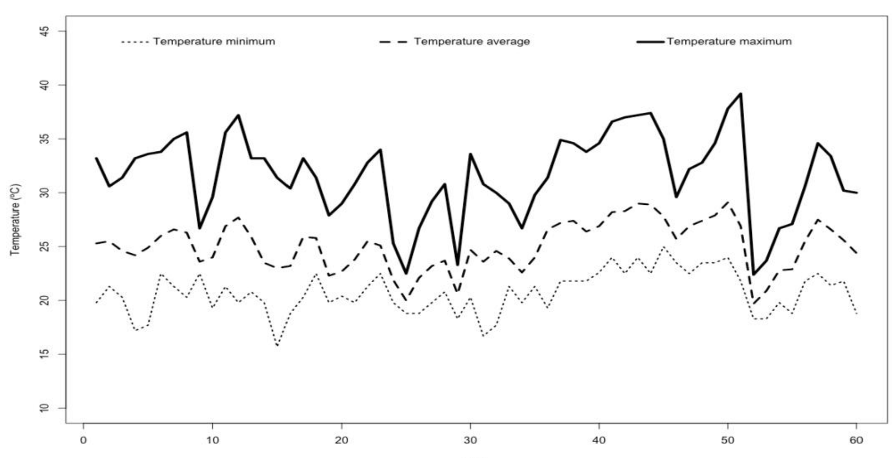

Fig. 1. Average, maximum and minimum temperatures during the experiment period in Colatina, Espírito Santo

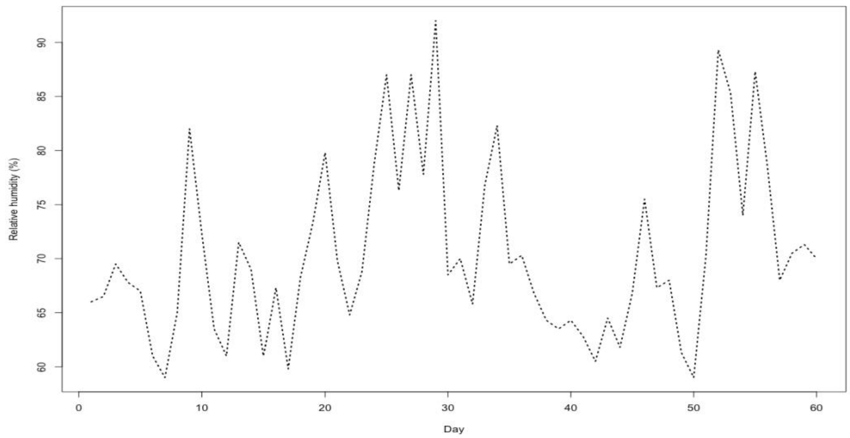

Fig. 2. Average relative humidity during the experiment period in Colatina, Espírito Santo

The experiment took place in an agricultural greenhouse, with linear dimensions of 25 m x 5 m with height of 3 m, covered by transparent plastic film and black polypropylene screen with 50% shading. In the interior of the greenhouse were made six individualized environments (BOX), with 2.20 m long for 1.10 m wide, isolated by transparent plastic canvas on the sides. Each BOX contained six nebulizers of the GREEN MIST model of the NaanDanJain® company spaced by 0.8 m each other and located 1 m from the seedlings, with individualized irrigation maintained by centrifugal pumps of 0.5 CV and electronically controlled, operating by pulses of 10 hours per day, with a service pressure of 2 kgf cm^{-2}.

The treatments consisted on the application of six irrigation depths: 4, 6, 8, 10, 12 and 14 mm d^{-1}. The experimental design was completely randomized with 24 seedlings per treatment, totaling 144 in the experimental field.

For the preparation of the seedlings were used tubes with a volume of 280 cm^3, arranged alternately in trays containing 54 cells to avoid shading which could lead to seeding. All tubes were pre-sanitized with 2% sodium hypochlorite solution. The tubes were filled with commercial substrate Tropstrato HT Vegetables plus Osmocote Plus 15-9-12 (3M), at the dosage of 3 g $tube^{-1}$, with 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 papaya seeds used were of the 'Rubi INCAPER 511' variety, which has desirable agronomic characteristics and good market acceptance. It produces fruits with dark green skin, average weight of 1.47 kg, orange-reddish flesh and soluble solids of 10.2 °brix [11]. Two seeds were sown per tube and, at 10 days after sowing, thinning was carried out, with only one seedling per tube.

At 60 days after planting, the seedlings were evaluated for the following morphological characteristics: a) plant height (PH), measured with a graduated ruler, in cm; b) stem diameter (SD), measured 2 cm above the collection of the seedling, with pachymeter, in mm; c) length of the root system (LRS), measured from the base of the collection to the largest root length, in cm, with graduated ruler; d) number of leaves (NL), defined by the total leaf count of the seedling; e) leaf area (LA), as measured by the LI-3100 equipment, in cm^2; f) SPAD index, measured with SPAD 502 Plus equipment; g) dry mass of the aerial part (DMAP) and dry mass of the root system (DMRS), measured in g; h) Dickson Quality Index (DQI) according to Dickson et al. [12] given by:

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

In order to obtain dry mass of the aerial part (DMAP) and dry mass of the root system (DMRS) the plants were dried in a ventilated oven at 65°C for 72 hours and weighed in a semi-analytical balance.

The results were submitted to analysis of variance and the effects of treatments were evaluated by the F test at 5% probability. When significant, regression models were fitted that best applied to the effects of the irrigation blade on the characteristics evaluated. The maximum points were obtained through the primary derivative of the regression equations.

3. RESULTS AND DISCUSSION

After analysis of variance, a significant difference (p <0.05) was observed for all the morphological characteristics evaluated in relation to the applied irrigation depths, attesting that they affected the growth of papaya seedlings of the variety 'Rubi INCAPER 511'.

Plant height (PH) increased linearly in relation to applied irrigation depths, with coefficient of determination (R^2) of 0.8383 (Fig. 3A) showing that 83% of the height of the plant was explained by the irrigation depths. According to Klar and Jadoski [13], the water deficit causes a reduction in the growth of the seedlings. Higher plant height is more desirable because it offers more resistance to mechanical damage. Melo et al. [14], suggest that this characteristic is an important factor for the transportation of the seedlings, being those that have low stature are constantly damaged, affecting their development and, consequently, the final production.

The stem diameter (SD) showed quadratic adjustment, with maximum point in the irrigation depth of 13.92 mm d^{-1} with a diameter of 6.42 mm and R^2 of 0.9181 (Fig. 3B). Carneiro [15] cites that a larger diameter contributes to a smaller tipping of seedlings in the field. In this way, higher diameters are more desired for papaya seedlings. According to Melo *et al.* [14], the increase in diameter has a correlation with the amount of photoassimilates produced by the plant, being highlighted in the field, due to its higher vigor. Carneiro [15] and Dassie et al. [16] reported that plant height and stem diameter are easy to evaluate morphological characteristics used as the basis for the transplanting of seedlings to the field, the ones with the highest values of these characteristics being the most desirable.

The length of the root system (LRS) presented an increasing linear adjustment in relation to the increase of the irrigation depths, with R^2 of 0.9566 (Fig. 4). According to Scalon et al. [17], under water deficit conditions, the water concentrates only on the surface of the substrate, so some plant species have adaptation mechanisms to tolerate the available water quality. In this work, smaller values for the LRS were found in less water availability. This fact can be explained by the abscisic acid hormone, which is synthesized under conditions of water stress, stimulating the growth and lateral formation of the roots, optimising the water absorption by the plants [18].

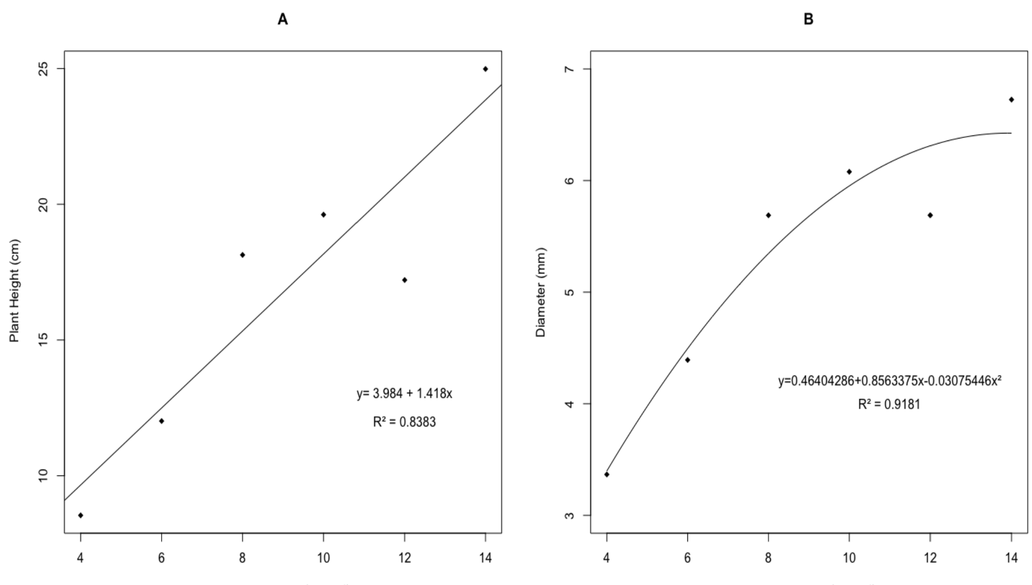

Fig. 3. Variation of plant height (A) and stem diameter (B), under different irrigation depths in papaya seedlings

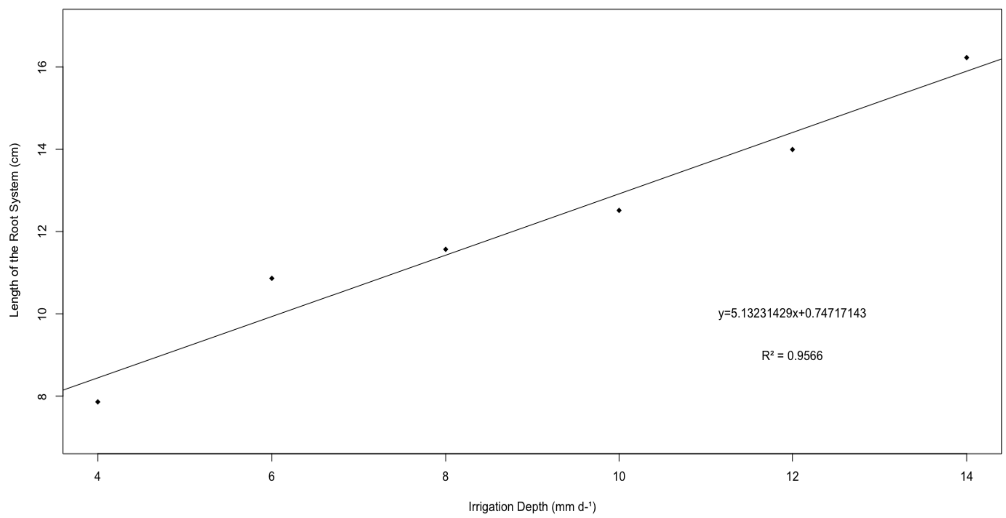

Fig. 4. Variation of root system length under different irrigation depths in papaya seedlings

The number of leaves (NL) presented quadratic effect, with determination coefficient of 0.7495 (Fig. 5A). The maximum number of leaves (around 7) was observed in the irrigation depth of 13.08 mm d^{-1} (Fig. 5A). So important for the development of plants, the number of leaves indicates seedlings with more aptitude for the field conditions, because they present a larger photosynthetically active area [14]. Klar and Jadoski [9] and Diniz et al. [19] suggest that the stress state affects the metabolism of the plants, translocating the photoassimilates to the osmotic adjustment, reducing the number of leaves.

The leaf area (LA) presented a simple linear effect in relation to the applied irrigation depths, with R^2 of 0.9014 (Fig. 5B). Similar results were found by Lopes et al. [8] that studied the effect of the irrigation depth on the development of *Eucalyptus grandis* W. (HILL ex. MAIDEN) seedlings, showing that the leaves had reduced size under water deficit conditions. According to Figueirôa *et al.* [20], the increase in water availability has a direct influence on leaf area growth.

Mott et al. [21] reported that the environment directly interferes with leaf size and so, an environment with high humidity implies larger leaves, whereas in water scarce environments it infers into smaller leaves, reducing warming and leaf transpiration on warmer days. Larger leaves produce more photosynthesis, but they present a larger surface, which implies higher evaporation, causing exhaustion of the water present in the soil, besides having excessive absorption of solar energy which causes damage, so the plants reduce their leaf area when in stress due to lack of water [18].

The chlorophyll content index SPAD presented linear decreasing behavior in relation to the increase of the irrigation depths, with R^2 of 0.8541 (Fig. 6). According to Zuffo et al. [22], the SPAD index determines the amount of green present in the leaves of the plant, being a very efficient way of determining the leaf nitrogen content, since the chlorophyll (green pigmentation) of the plants composition presents the nitrogen molecule. Its use allows the generation of important information for decision making, as well as being a low-cost, non-destructive measure.

It was observed that as the irrigation depths increased, there was a significant reduction in the SPAD index. Lopes et al. [8] say that the excessive application of water in the production of seedlings implies leaching of the nutrients. Possibly, this fact explains the decrease in the green content of the plants influenced by the leaching of the nitrogen present in the substrate. The nutrient leaching caused by the constant use of irrigation is very common, prolonging the development time of the seedlings as a result of the lower use of fertilization [23].

The dry mass of the aerial part (DMAP) presented linear regression in relation to applied irrigation depths, with R^2 of 0.9079 (Fig. 7A). Plants under smaller irrigation depths have reduced DMAP. Similar results were obtained by

Santiago et al. [24], that studied the growth of young plants of Mimosa caesalpiniifolia BENTH cultivated under water stress, showing a decrease of the dry mass of the aerial part in plants submitted to water restriction.

The dry mass of the root system (DMRS) showed a quadratic effect with a maximum point on the irrigation depth of 12.65 mm d^{-1} with weight of 0.72 g and R^2 of 0.9354 (Fig. 7B). Under the condition of lack or excess water in the root system, plants have limitations, increasing the amount of water in the roots contributes to an environment with low oxygen concentrations, reducing the photosynthetic rate of the plant, impairing the transport of photo assimilates to the root system and, consequently, the reduction in the dry mass of the root system [25,26].

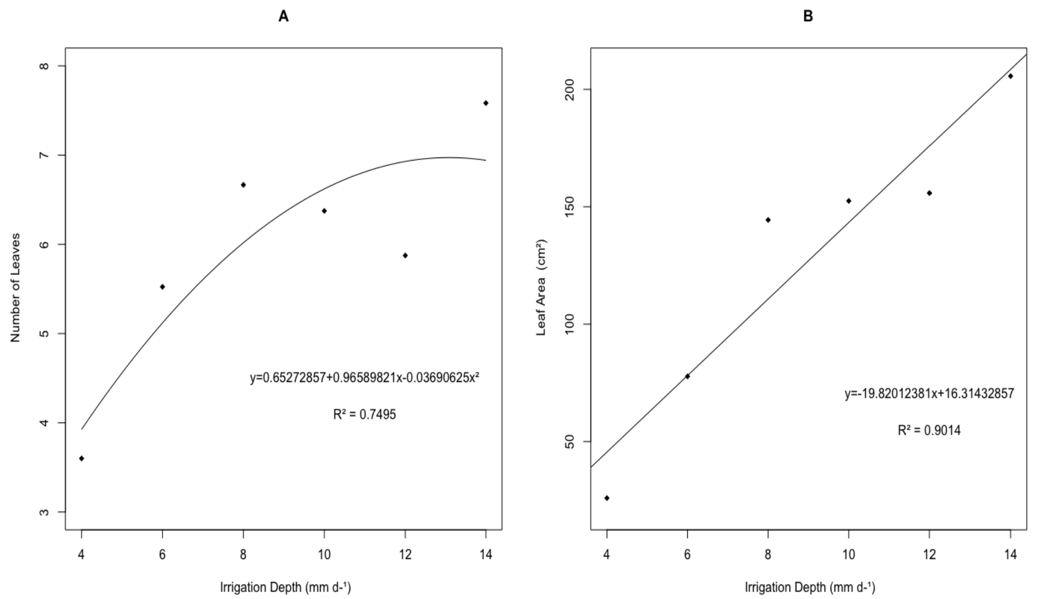

Fig. 5. Variation of number of leaves (A) and leaf area (B), under different irrigation depths in papaya seedlings

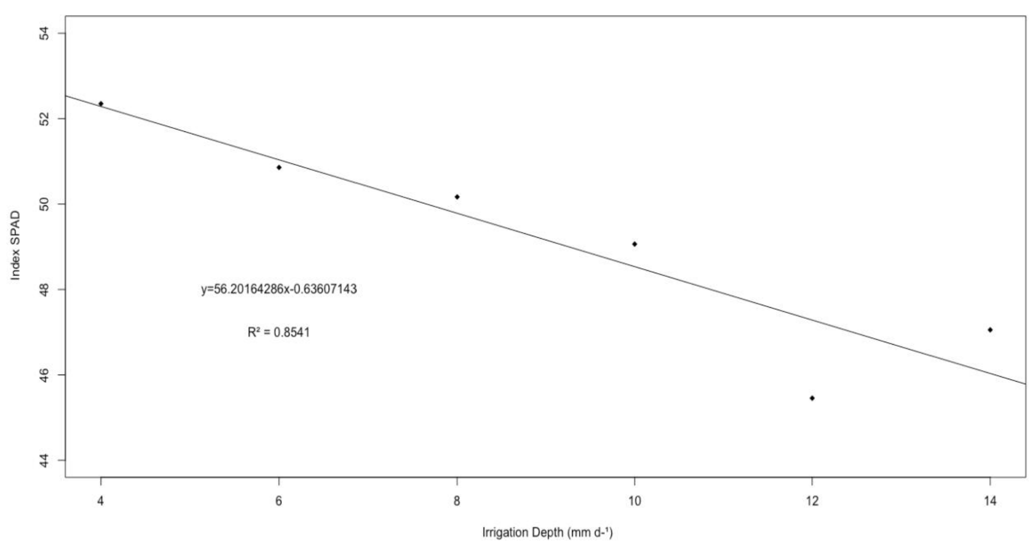

Fig. 6. Variation of the SPAD index, under different irrigation depths in papaya seedlings

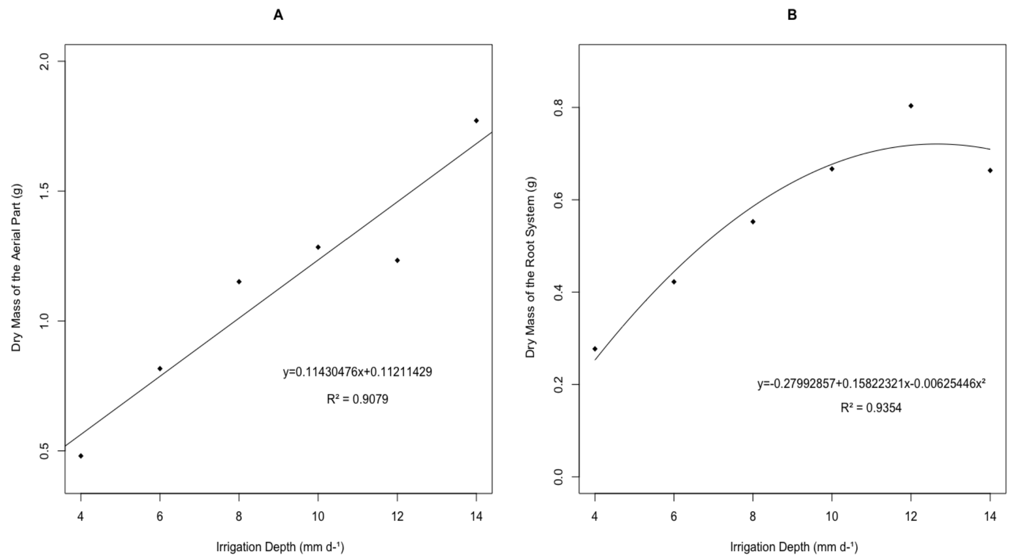

Fig. 7. Variation of the dry mass of the aerial part (A) and the dry mass of the root system (B) of papaya seedlings, under different irrigation depths

The Dickson quality index (DQI) is a balanced formula that relates morphological characteristics, with plant height, stem diameter and dry biomass [27]. The DQI showed a quadratic effect with a higher index of 0.43 in the irrigation depth 12.66 mm d^{-1} and a coefficient of determination of 0.9524 (Fig. 8). Posse et al. [28], evaluating seedlings of yellow passion fruit under different irrigation depths, detected DQI between 0.15 and 0.27, showing that values below 0.20 are not desirable. According to Binotto et al. [29], the DQI can be used to identify which seedlings have greater adaptability and development, conferring greater chances of survival in the field, and as higher this index as greater the robustness and vigor of the seedlings.

Posse et al. [28] reported that DQI should not be analyzed in isolation to determine the quality of a seedling. Characteristics such as plant height, number of leaves and stem diameter, besides being non-destructive methods, should be taken into account to ensure greater survival of the seedlings in the field.

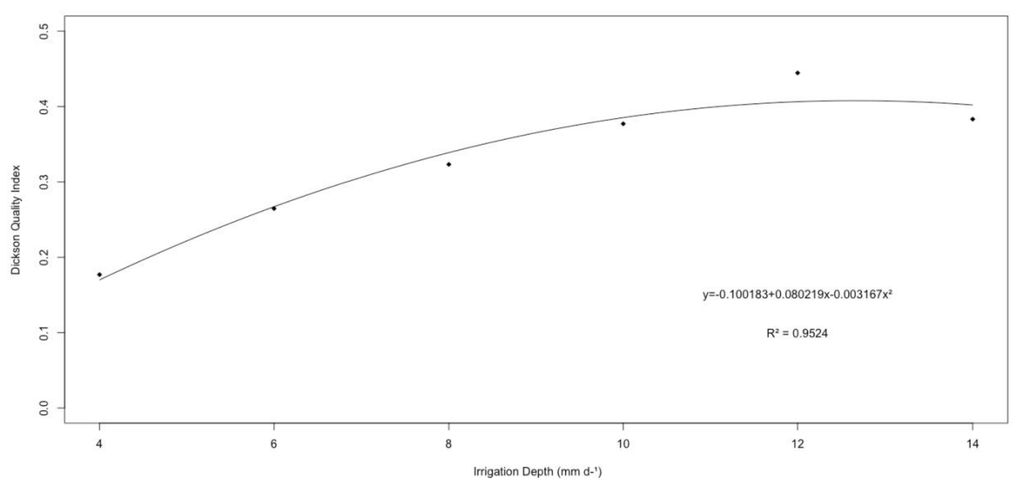

Fig. 8. Variation of the Dickson quality index under different irrigation depths in papaya seedlings

4. CONCLUSION

Irrigation depths interfered with the growth of papaya seedlings, and the depths between 12.5 and 14 mm d^{-1} presented higher Dickson quality index, stem diameter, plant height and number of leaves, which were used to identify better quality seedlings. For reasons of energy conservation and water resources the 12.5 mm d^{-1} depth is the most recommended for the production of seedlings of the variety 'Rubi INCAPER 511'.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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