Original Research Article

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

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.

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].

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

36 expansion, reducing leaf area, increasing leaf abscission and reducing the process of
37 photosynthesis [5;6].
38
39 Good irrigation management can provide the plants with an adequate water humidity,
40 therefore, knowledge of soil, climate, culture and irrigation method must be taken into
41 account. Thus, studies are necessary to quantify the water demand in the development of
42 papaya seedlings. In this context, this work aimed to evaluate the effect of different irrigation
43 depths on the growth and quality of papaya 'Tainung 01' seedlings.
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46 **2. MATERIAL AND METHODS**
47
48 The experiment took place at the Federal Institute of Espirito Santo, Campus Itapina in
49 Colatina, Northwest region of the State of Espírito Santo, Brazil, located at 19°29' South,
50 40°45' West and 62 meters high. The climate of the region, according to the classification of
51 Köppen, is Tropical Aw [7]. The region is characterized by the irregularity of the rain and the
52 occurrence of high temperatures.
53
54 The experiment started on May 16 and ended on July 19, 2018. Its development occurred in
55 a greenhouse of 125 m^2 and a height of 3 m. Within the greenhouse, six individualized
56 environments (Box), with 2.42 m^2 each, were created, surrounded on the sides by
57 translucent plastic canvas. Each box consisted on six GREEN MIST (NaanDanJain[®]) anti-
58 mist nebulizers located one meter above the seedlings and spaced 0.8 m apart.
59
60 The experimental design was completely randomized, with 25 repetitions for each treatment.
61 The treatments consisted in the application of six daily irrigation depths: 4, 6, 8, 10, 12 and
62 14 mm, uniformly distributed in ten hours a day (7 a.m. to 5 p.m.), individually controlled by
63 electronic controllers and centrifugal pumps of 0.5 hp independently installed, operating at a
64 service pressure of 2 kgf cm^{-2}.
65
66 The seedlings were produced in tubes, with a volumetric capacity of 280 cm^3. All tubes were
67 pre-sanitized with 2% sodium hypochlorite solution and filled with Tropstrato HT® Vegetable
68 substrate plus Osmocote Plus[®] 15-9-12 (3M) at the dosage of 3g $tube^{-1}$, which presents the
69 following chemical composition: N = 15% (7% ammoniacal and 8% nitrate), P_2O_5 = 9%, K_2O
70 = 12%, Mg = 1.3%, S = 5.9%, Cu = 0.05%, Fe = 0.46%, Mn = 0.06% and Mo = 0.02%. The
71 tubes were arranged in holders with a capacity of 54 cells, being positioned alternately, in
72 order not to prevent the arrival of light, avoiding the wadding.
73
74 Temperature and humidity variations were monitored and recorded internally in the
75 agricultural greenhouse by a Model 200 Data Logger (WatchDog[®]), with a maximum
76 temperature ranging from 25.2 to 45.4 ºC (average of 38.84 ºC), the average temperature
77 from 20.9 to 27.5 ºC (average of 24.66 ºC) and the minimum temperature from 14.1 to 21.3
78 ºC (average of 17.68 ºC) (Fig. 1). The average relative humidity ranged from 60.8 to 80.4%
79 (average of 65.76%) (Fig. 2). These conditions mentioned above are considered as ideal for
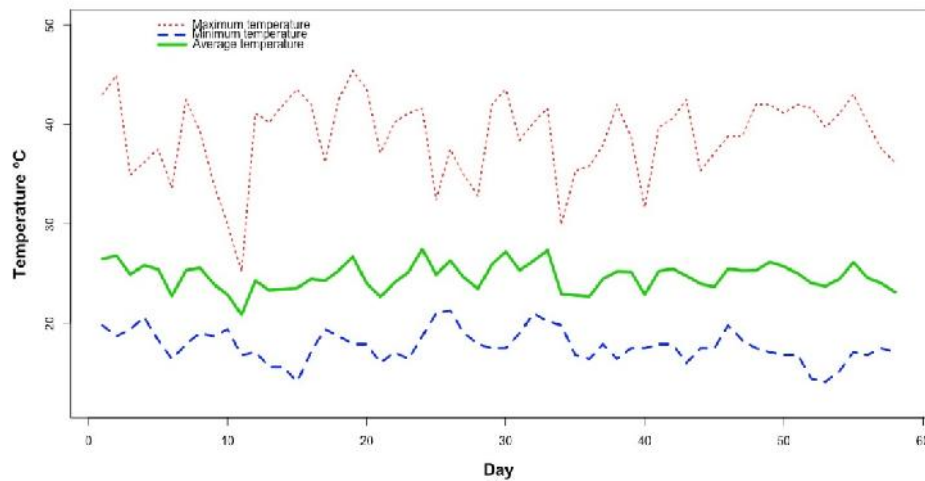80 the development of papaya plants [8].
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Fig. 1. Maximum, minimum and average temperatures within the greenhouse during the experimental period in Colatina, Espírito Santo.
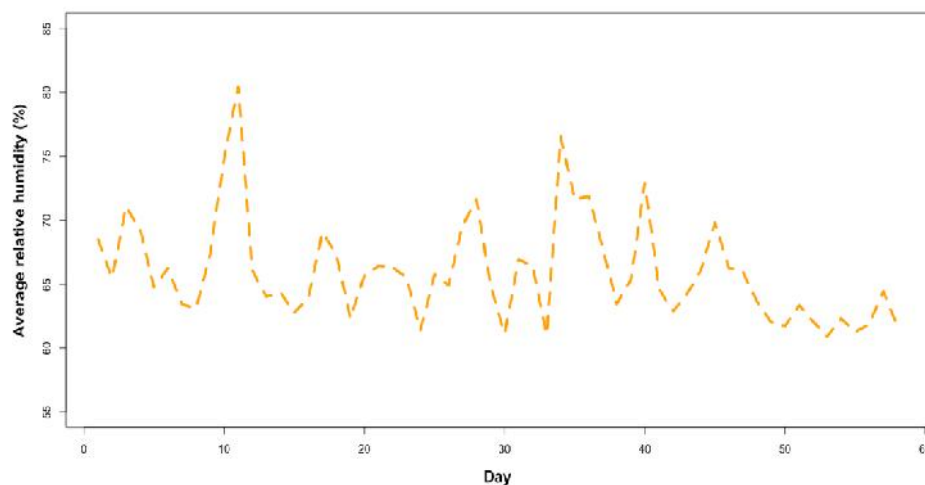

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Fig. 2. Average relative humidity within the greenhouse during the experimental period in Colatina, Espírito Santo.

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 [9] by the equation:

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

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).
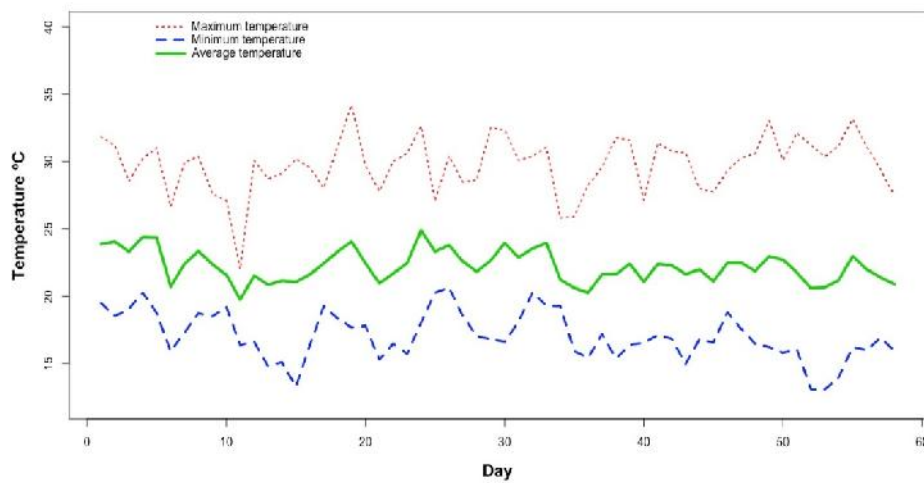
Fig. 3. Maximum, minimum and average external temperatures during the experimental period in Colatina, Espírito Santo.
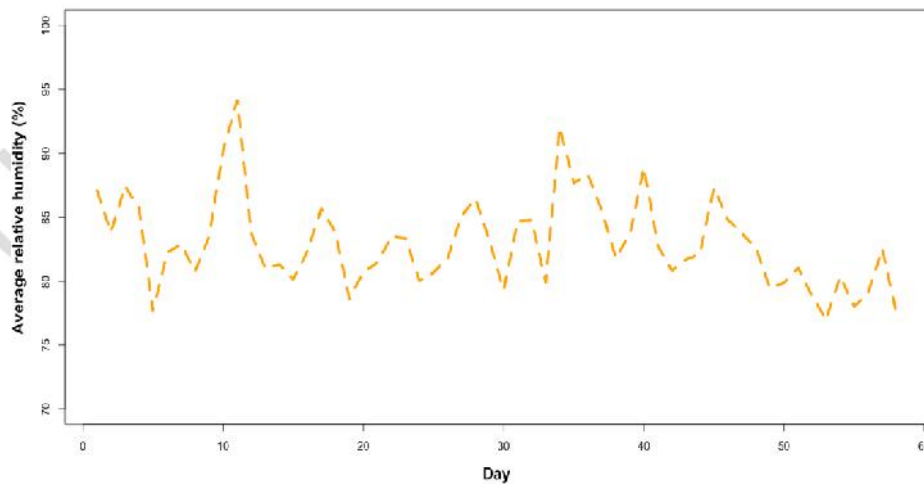
Fig. 4. Average external relative humidity during the experimental period in Colatina, Espírito Santo.
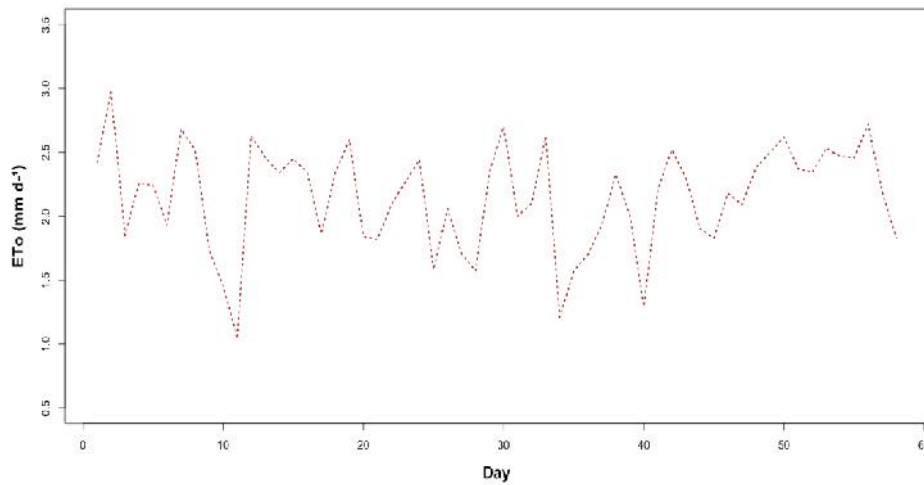
Fig. 5. Reference evapotranspiration during the experimental period in Colatina, Espírito Santo.

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 cm2, 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. [10], given by:

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

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 [11]. 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

149 from 15 to 20 cm [12], all irrigation depths produced seedlings with satisfactory size at 65
150 days after planting. seeding. According to Carneiro [13], this is a non-destructive and easily
151 measured feature standing as a parameter for transplanting seedlings into the field.
152 However, for Costa *et al.* [14] and Posse *et al.* [15], PH cannot be used alone to determine
153 seedling quality and should be used join stem diameter and aerial part biomass to do that.
154
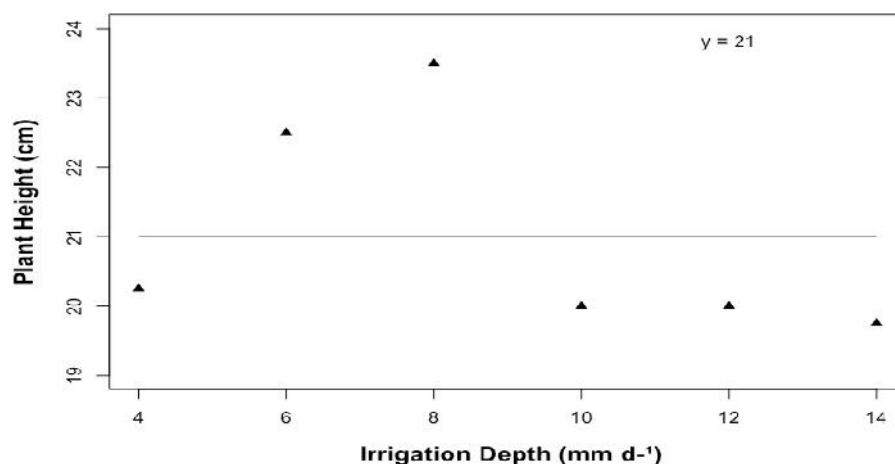
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156 **Fig. 6. Plant height of papaya "Tainung 01" seedlings under the different irrigation**
157 **depths**
158
159 The number of leaves (NL) had an average of 9.6 leaves in all applied treatments (Fig. 7).
160 Although the number of leaves did not differ significantly in relation to the applied irrigation
161 depth, these results are superior to those found by Oliveira *et al.* [16], who observed a
162 maximum number of 7 leaves for the 'Rubi INCAPER 511' variety in the 13.08 mm d^{-1}
163 irrigation depth at 60 days after planting.
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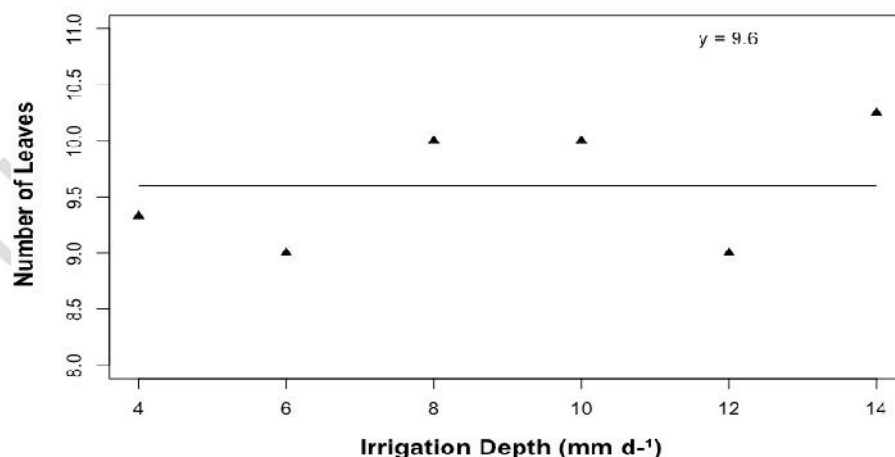
165
166 **Fig. 7. Number of leaves of papaya "Tainung 01" seedlings under the different**
167 **irrigation depths.**
168

169 The stem diameter (DC) showed quadratic adjustment, with a maximum point of 6.49 mm in
170 the 9.62 mm d^{-1} depth and coefficient of determination (R^2) of 0.757 (Fig. 8). Plants with
171 larger stem diameter have higher resistance and quality when transplanted to field
172 conditions, thus, being the most desirable [17]. According to Trindade [8], papaya plants are
173 very sensitive to lack of water, delaying their growth and reducing the rate of stem
174 development which leads to a reduction in stem diameter, corroborating with the results of
175 this work, presented for the depths smaller than 9.62 mm.
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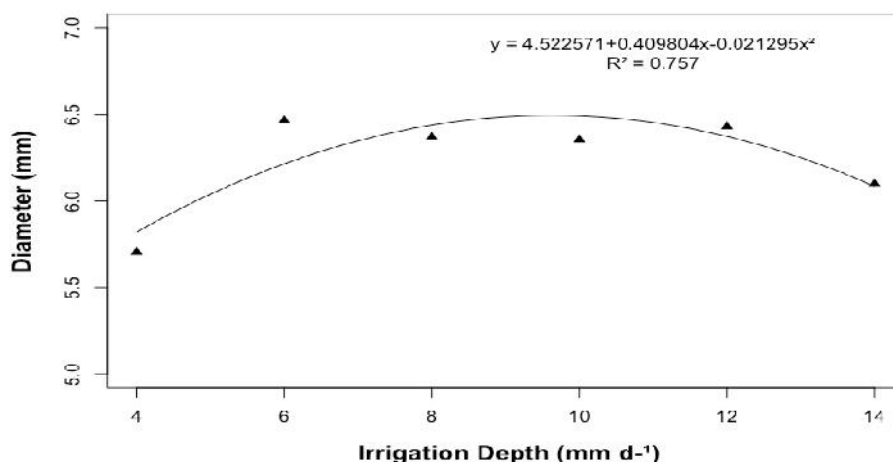
177
178 **Fig. 8. Stem diameter of papaya "Tainung 01" seedlings under different irrigation**
179 **depths.**
180
181 Leaf area (LA) presented a quadratic effect, with R^2 of 0.916 and maximum point of 192.25
182 cm^2 in the 6.73 mm d^{-1} irrigation depth (Fig. 9). Although there was no difference in the
183 number of leaves of the seedlings in relation to the water depth applied, the leaf area was
184 affected by the amount of water available to the seedlings, attesting that the leaves varied in
185 size. According to Sá *et al.* [18], the leaf area is the most important characteristic to be
186 studied in papaya plants, since this variable allows the identification of plants with greater
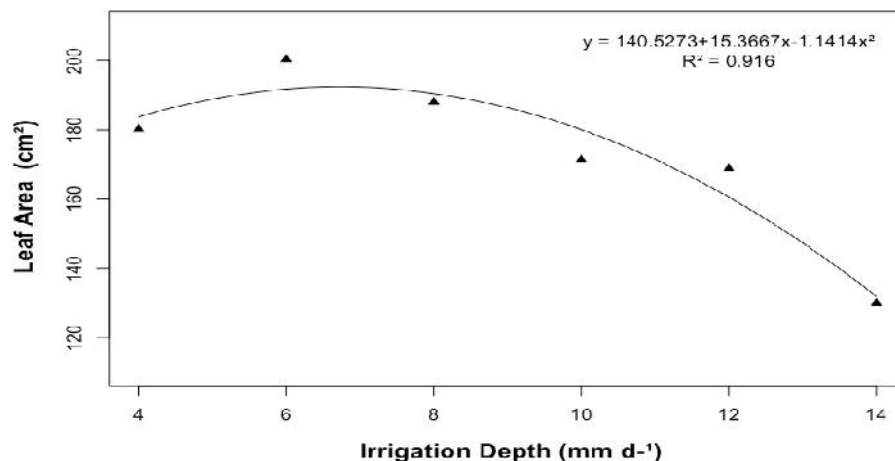187 tolerance to stress.
188

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 [6].

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;6].

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 [8]. 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 [6].

$$y = -0.28514 + 0.44120x - 0.02281x^2$$
$$R^2 = 0.826$$
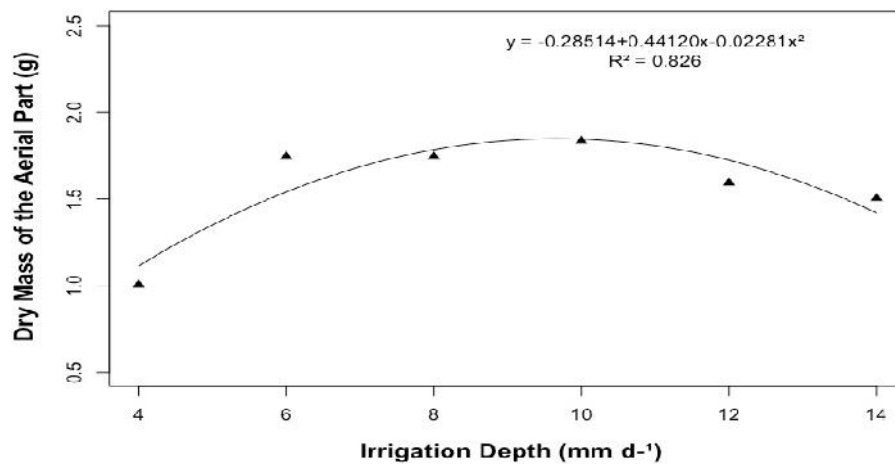
Fig. 10. Dry mass of the aerial part of papaya "Tainung 01" seedlings under the different irrigation depths.

$$y = -0.48350 + 0.32003x - 0.01801x^2$$
$$R^2 = 0.946$$
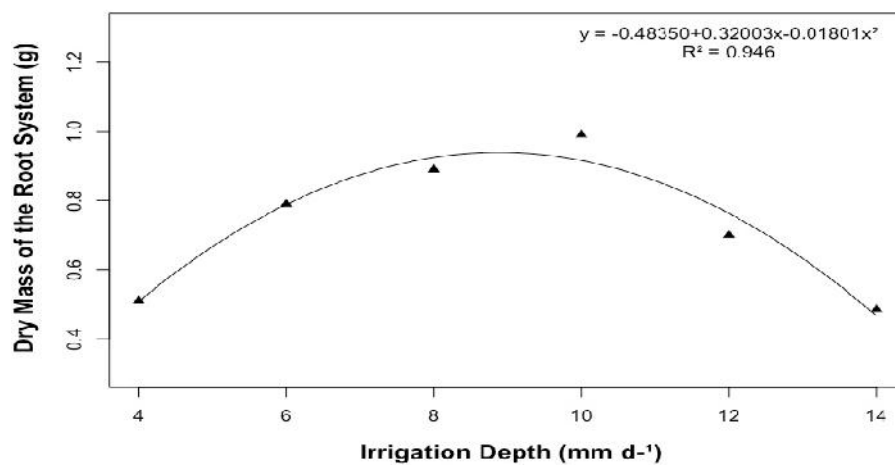
Fig. 11. Dry mass of the root system of papaya "Tainung 01" seedlings under different irrigation depths.

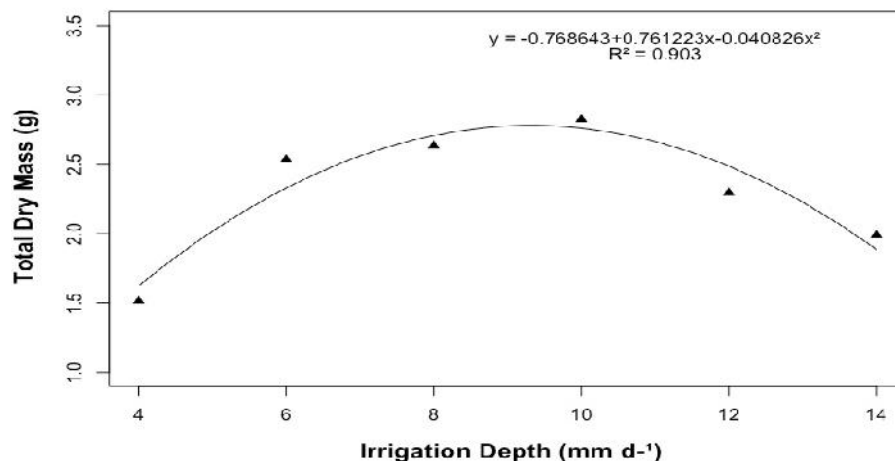$$y = -0.768643 + 0.761223x - 0.040826x^2$$
$$R^2 = 0.903$$

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 & Cline [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.
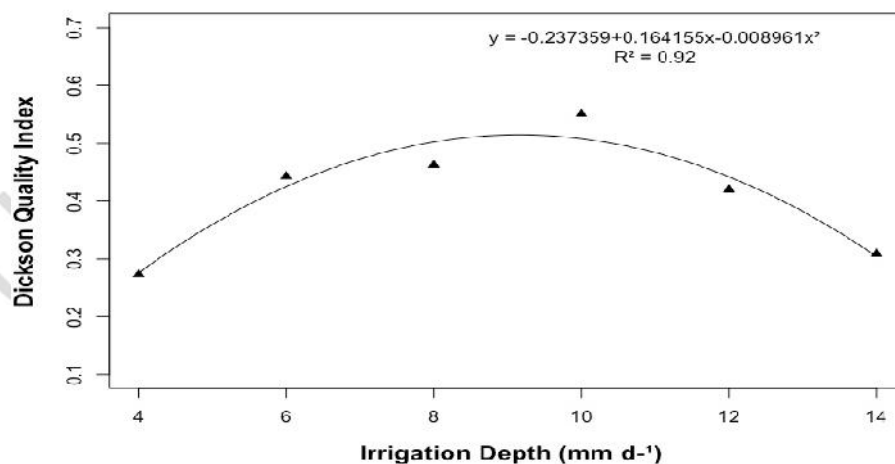

$$y = -0.237359 + 0.164155x - 0.008961x^2$$
$$R^2 = 0.92$$

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

246 Oliveira *et al.* [16], found for papaya 'Rubi INCAPER 511', also belonging to the 'Formosa'
247 group, a DQI maximum value of 0.43, using a daily 12.66 mm irrigation depth. Seedlings that
248 present higher DQI are more likely to survive when taken to the field due to their greater
249 capacity of acclimation, favoring their development [23;24].
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251
252 **4. CONCLUSION**
253
254 The irrigation depth of 9.2 mm d^{-1} had a higher Dickson quality index attesting higher quality
255 of seedlings, as well as good answers in the majority of quality characteristics evaluated,
256 being the most suitable for the production of papaya 'Tainung 01' seedlings.
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259 **COMPETING INTERESTS**
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261 Authors have declared that no competing interests exist.
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