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Evaluation of West Indian cherry (*Malpighia emarginata*) rootstock under saline water irrigation and nitrogen fertilization

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Abstract

This study aimed to evaluate the growth and quality of CMF 102 West Indian cherry rootstock subjected to irrigation with different salinity levels and nitrogen (N) doses. The experiment was carried out under protected environment, using a randomized block design in a 5 × 4 factorial scheme, with four replicates. Treatments consisted of five levels of electrical conductivity of water – ECw (0.3 – Control; 1.3; 2.3; 3.3 and 4.3 dS m^{-1}) and four nitrogen doses (70, 100, 130 and 160% of N recommendation). CMI 102 West Indian cherry rootstock growth was evaluated through plant height, stem diameter, number of leaves, leaf area, shoot and total dry phytomass and Dickson quality index of seedlings 165 days after emergence. Additionally, the absolute growth rate of plant height was evaluated from 45 to 165 days after emergence. The results indicated that irrigation with ECw up to 2.22 dS m^{-1} leads to a maximum reduction of 10% in growth and in the quality of CMF 102 rootstock. Highest growth of CMF 102 West Indian cherry rootstock is obtained with fertilization of 70% of N. The plants of West Indian cherry irrigated with 4.3 dS m^{-1} of saline water showed an acceptable Dickson quality index; therefore, seedlings with IQD higher than 0.2 considered as good quality. In general, West Indian cherry plants can be classified as sensitive to irrigation with saline waters higher than 0.3 dSm^{-1}. No significant effect was found for the interaction between water salinity and N doses.

Keywords: *Malpighia emarginata*, water quality, fertilization.
Abbreviations: Days after emergence_DAE; plant height_PH; stem diameter_SD; number of leaves_NL; leaf area_LA; shoot dry phytomass_SDP; total dry phytomass_TDP; Dickson quality index_DQI; absolute growth rate of plant height_AGR_{PH}.

Introduction

West Indian cherry (*Malpighia emarginata*) is a rustic plant. Its cultivation expanded in the semi-arid regions of Northeast Brazil due to the favorable climatic conditions, making the crop important for the Northeastern economy (Almeida et al., 2014). The Brazilian Northeast region has irregular rainfalls associated with high temperatures and evaporation rates, making the use of irrigation for rational exploitation of agriculture essential. However, the available waters normally have salt contents that may compromise crop growth and yield. Thus, it is very important to conduct studies and develop techniques that allow for the efficient use of saline water to meet the different demands and adequate form of water use (Ferreira et al., 2016). According to Oliveira et al. (2015), studies have been conducted to find adequate management and/or techniques that allow the use of lower-quality waters, without compromising crop development and yield. Nitrogen performs an important function in the production of amino acids, proteins, nucleic acids and chlorophylls, which may favor such tolerance (Lima et al., 2014). Additionally, the accumulation of these organic solutes inside the cell may increase plant's capacity for osmotic adjustment, helping and favoring the increase of tolerance to certain levels of water and salt stresses (Alves et al., 2012; Nascimento et al., 2015). According to Lima et al. (2015), when the plant is subjected to irrigation with saline water there is a competition in the absorption of nitrate and chloride. When the nitrate concentration is higher in the root zone, chloride assimilation is inhibited. It reduces the effects of the salts and consequently contributes to better plant development. Some researches with other crops, such as banana (Maia et al., 2003), 'caramboleira' (Leal et al., 2007), guava (Amorim et al., 2015), sunflower (Nobre et al., 2010), the cowpea (Furtado et al., 2014) and castor bean (Lima et al., 2015) have reported the beneficial effects of nitrogen application on the growth and development of the plants. Thus, it is necessary to carry out new studies to provide information on the supplied nitrogen doses to meet the nutritional needs of the cultivar and to mitigate the deleterious effects caused by irrigation with saline water. In this context, this study aimed to evaluate the growth and quality of CMF 102 West Indian cherry rootstocks subjected to irrigation with different salinity levels and nitrogen (N) doses.

Results and discussion

Effect of saline stress and nitrogen doses on growth of the West Indian cherry

According to the analysis of variance (Table 1), irrigation with saline water had significant effect on plant height, stem diameter and number of leaves at 165 days after emergence (DAE). Nitrogen doses had significant effect only on the number of leaves, at 165 DAE. Additionally, there was no significant effect of the interaction (irrigation water salinity and N doses) on the studied variables.

Increased water salinity significantly inhibited the height of CMF 102 West Indian cherry rootstocks at 165 DAE. The regression equation showed a linear reduction in PH (6.39% reduction per unit increase of ECw). Plants irrigated with ECw of 4.3 dS m^{-1} showed reduction of 25.56% in comparison to those subjected to the lowest salt level (0.3 dS m^{-1}). According to Lima et al. (2015), reduction in plant growth under stress conditions induced the closure of leaf stomata and decreased transpiration due to the lower absorption of water and nutrients.

Similarly, as observed for plant height (Fig. 1A), the stem diameter of West Indian cherry rootstocks (Figure 1B) also decreased linearly, when water salinity increased. The reduction of 3.05% at 165 DAE per unit increase in ECw was observed, i.e., plants subjected to the highest ECw level (4.3 dS m^{-1}) showed reduction of 0.79 mm compared to the lowest ECw (0.3 dS m^{-1}). Reduction in SD may have occurred due to the specific effects of the ions associated with the osmotic effect, which delays cell expansion and division, affecting plant growth (Souza et al., 2015). Irrigation with saline water negatively affects plant growth because of the osmotic and specific effects of the ions, postponing cell expansion and division, causing negative effects on the photosynthetic rate and damaging physiological and biochemical processes of plants (Gomes et al., 2011; Nunes et al., 2012).

The different levels of salinity caused a quadratic effect on the number of leaves at 165 DAE (Fig. 2A). According to the regression equations, the maximum value of 34 leaves was found in plants subjected to ECw of 0.9 dS m^{-1}. According to Oliveira et al. (2011), reduction in the number of leaves is associated with anatomic and morphological changes of the plant, which occur to reduce water loss. The accumulation of NaCl in the irrigation water reduces the absorption of water and nutrients by plants, which is an important factor for the reduction in photosynthetic and metabolic processes, leading to reduction in plant growth (Travassos et al., 2012; Oliveira et al., 2013).

Nitrogen doses caused linear reduction in the NL at 165 DAE (Fig. 2B), indicating 5.53% for every 30% increase in N dose, i.e., 16.60% in the NL of plants fertilized with 160% compared with those fertilized with 70% N. A possibly explanation is that, the N in the fertilizer associated with the lowest dose did not meet plant requirement already reported by Souza et al. (2016) in the production of 'Crioula' guava rootstock.

According to the analysis of variance (Table 2), the levels of water salinity had significant effect on the absolute growth rate of plant height in the period from 45 to 165 DAE and on shoot dry phytomass, total dry phytomass and Dickson quality index at 165 DAE. On the other hand, N doses had significant effect only on Dickson quality index. Regarding the interaction between factors (irrigation water salinity × N doses), no significant effect was (Table 2).

The increase in water salinity also significantly reduced AGR_{PH} from 45 to 165 DAE (Fig. 3), which decreased by 8.12% per unit increase of ECw, corresponding to a reduction of 0.116 cm cm^{-1} day^{-1} (32.49%) compared to the plants irrigated with the lowest salt level (4.3 dS m^{-1}). Sousa et al. (2011) reported that this behavior is due to the reduction in water availability and excessive accumulation of Na^+ and Cl^- in plant tissues, altering physiological processes such as quantum yield and gas exchanges.

For shoot dry phytomass (SDP), a decreasing linear response was observed (Figure 4), with reduction of 6.36% per unit increase in ECw. Highest SDP (5.3 g/plant) was found in plants subjected to salinity of 0.3 dS m^{-1}. Increment of salts in the irrigation water eventually caused nutritional imbalance and such imbalance may lead to losses in the production of vital photoassimilates, such as sugars, carbohydrates and proteins; thus, compromising growth and phytomass production (Silva et al., 2008; Torres et al., 2014). Total dry phytomass (TDP) also decreased with the increment in the levels of irrigation water salinity (Fig. 5). The best results were found at salinity of 0.3 dS m^{-1}, TDP of 7.77 g per plant, with reduction of 10.35% per unit increase in ECw, corresponding to 44.53% between the highest and lowest salinity levels.

Effect of saline stress and nitrogen doses on Dickson quality index of the West Indian cherry

Dickson quality index (DQI) showed linear reduction when salinity of irrigation water increased. According to the regression equation, there was a reduction of 8.73% per unit increase of ECw (Fig. 6A). West Indian cherry rootstocks subjected to irrigation with the highest salinity level (4.3 dS m^{-1}) exhibited DQI of 0.31, with reduction of 0.21 (37.56%) compared to those irrigated with ECw of 0.3 dS m^{-1}. The higher the DQI, the better the final quality of the seedling, a fact confirmed in the present study.

According to the regression equation, increasing N doses significantly influenced the DQI of West Indian cherry rootstocks (Fig. 6B). In other words, for every 30% increase in N dose there was a linear increase of 9% (Fig. 6B), and West Indian cherry rootstocks subjected to fertilization with 160% N showed an increment (15.53%) equivalent to 0.48 in the DQI. The higher the DQI, the better the quality of the seedling produced, because it relates robustness and biomass distribution balance (Oliveira et al., 2013; Souza et al., 2017).

Materials and methods

Localization, experimental procedure and treatments

The study was conducted from March to August 2016 under greenhouse conditions, at the Center of Sciences and Agri-Food Technology (CCTA) of the Federal University of Campina

Table 1. Summary of the analysis of variance for plant height (PH), stem diameter (SD), number of leaves (NL) and leaf area (LA) of CMI 102 West Indian cherry rootstocks under saline water irrigation and nitrogen fertilization at 165 days after emergence – DAE.

Source of variation	DF	Mean squares			
		PH	SD	NL	LA
Saline levels (SL)	4	324.29^{**}	2.07^{**}	473.93^{**}	7232.9^{ns}
Linear regression	1	899.65^{**}	6.41^{**}	1357.2^{**}	3737.8^{ns}
Quadratic regression	1	94.38	0.09^{ns}	236.16^{*}	20688.7^{*}
N doses (ND)	3	52.13^{ns}	0.06^{ns}	160.07^{*}	9763.1^{ns}
Linear regression	1	142.92^{*}	0.06^{ns}	472.06^{**}	7917.2^{ns}
Quadratic regression	1	1.12^{ns}	0.03^{ns}	2.11^{ns}	812.4^{ns}
Interaction (SL x ND)	12	34.95^{ns}	0.67^{ns}	65.03^{ns}	6645.2^{ns}
Blocks	3	826.43^{**}	5.23^{**}	1004.3^{**}	46826.3^{**}
CV (%)		14.19	11.05	25.25	17.24

ns, **, * respectively not significant, significant at p < 0.01 and p < 0.05.

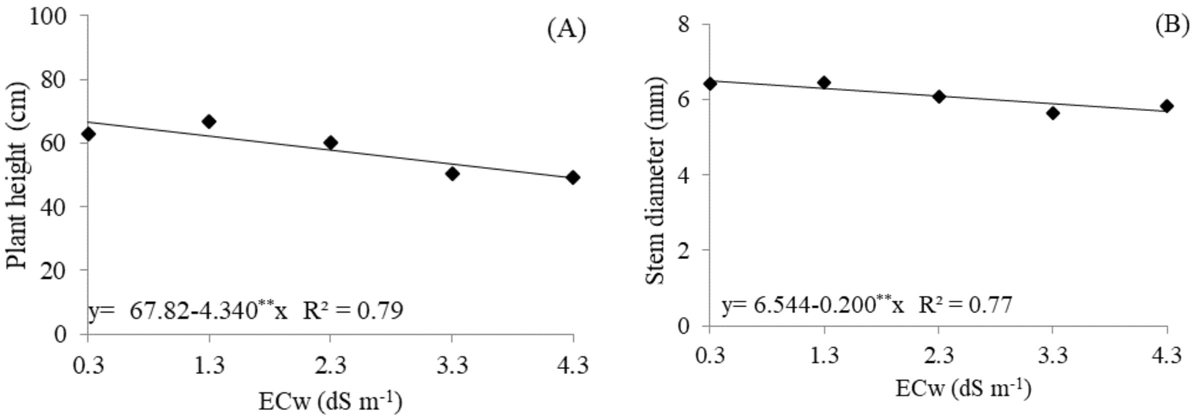

Fig 1. Plant height (A) and stem diameter (B) of a West Indian cherry rootstocks as a function of irrigation water salinity – ECw at 165 days after emergence.

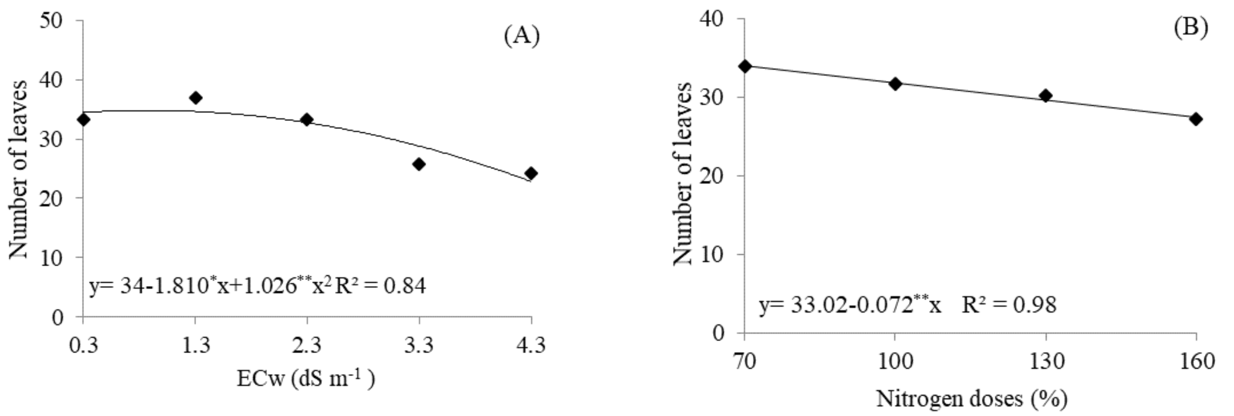

Fig 2. Number of leaves of West Indian cherry rootstock as a function of irrigation water salinity – ECw (A) and nitrogen doses (B) at 165 days after emergence.

Table 2. Summary of the analysis of variance for absolute growth rate of plant height (AGR_{PH}) from 45 to 165 days after emergence (DAE), shoot dry phytomass (SDP), total dry phytomass (TDP) and Dickson quality index (DQI) of CMI 102 West Indian cherry rootstock at 165 DAE.

Source of variation	DF	Mean squares			
		AGR_{PH}	SDP	TDP	DQI
Saline levels (SL)	4	0.04^{**}	6.00^{*}	28.58^{**}	0.12^{*}
Linear regression	1	0.13^{**}	18.62^{**}	103.70^{**}	0.36^{**}
Quadratic regression	1	0.006^{ns}	0.008^{ns}	0.30^{ns}	0.10^{**}
N doses (ND)	3	0.01^{ns}	2.18^{ns}	0.47^{ns}	0.04^{*}
Linear regression	1	0.02^{*}	1.18^{ns}	0.03^{ns}	0.09^{**}
Quadratic regression	1	0.01^{ns}	4.19^{ns}	1.28^{ns}	$0,02^{ns}$
Interaction (SL x ND)	12	0.007^{ns}	2.46^{ns}	1.62^{ns}	0.02^{ns}
Blocks	3	0.03^{*}	1.45^{ns}	15.64^{**}	0.25^{ns}
CV (%)		18.25	30.16	18.01	29.58

ns, **, * respectively not significant, significant at p < 0.01 and p < 0.05.

Table 3. The physical and chemical characteristics of the substrate used in the experiment.

Textural classification	Apparently density kg dm^{-3}	Total porosity %	Organic matter g kg^{-1}	P mg dm^{-3}	Exchange complex Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
					--------- cmol$_c$ dm^{-3} --------			
Sandy loam	1.38	47.00	32	17	5.4	4.1	2.21	0.28

Saturation extract

pH$_{se}$	EC$_{se}$ dS m^{-1}	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	Cl^{-}	SO_4^{2-}	CO_3^{2-}	HCO_3^{-}	Saturation %
		--------------------------- mmol$_c$ dm^{-3} --------------------------								
7.41	1.21	2.50	3.75	4.74	3.02	7.50	3.10	0.00	5.63	27.00

pH$_{se}$ = pH of the saturation extract of substrate; EC$_{se}$ = Electrical conductivity of saturation extract of substrate at 25 °C.

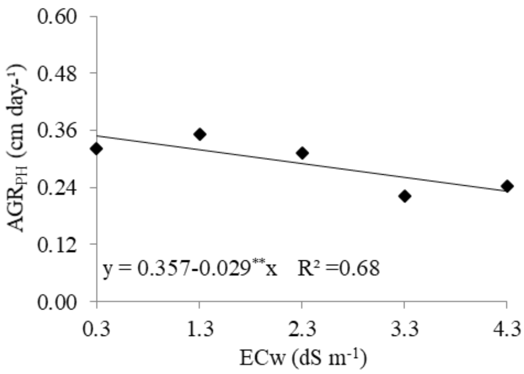

Fig 3. Absolute growth rate of plant height (AGR$_{PH}$) of West Indian cherry rootstocks as a function of irrigation water salinity – ECw at 45-165 days after emergence.

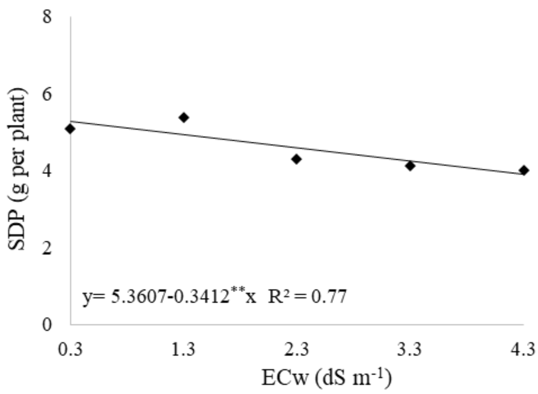

Fig 4. Shoot dry phytomass (SDP) of West Indian cherry rootstocks as a function of irrigation water salinity at 165 days after emergence.

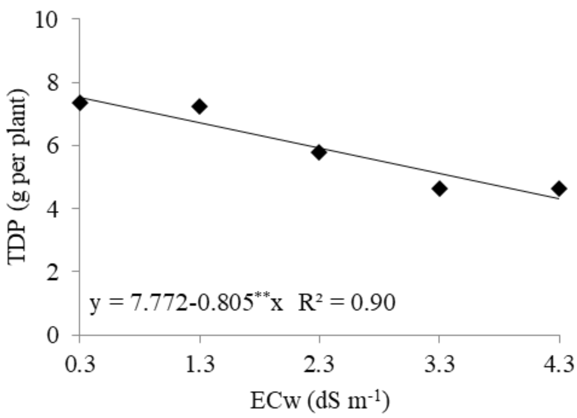

Fig 5. Total dry phytomass (TDP) of West Indian cherry rootstocks as a function of irrigation water salinity at 165 days after emergence.

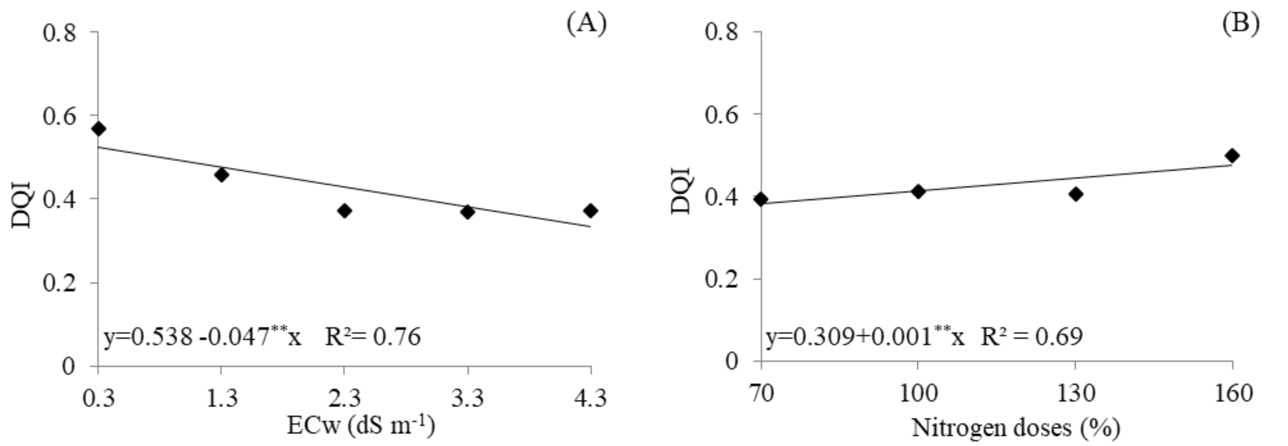

Fig 6. Dickson quality index (DQI) of West Indian cherry as a function of water salinity (A) and nitrogen doses (B) at 165 days after emergence.

Grande (UFCG), Campus of Pombal – PB, Brazil (6º48'16" S; 37º49'15" W; ~144 m).

The experiment was set up in a randomized blocks, in 5 x 4 factorial scheme, with four replicates and two plants per plot. Treatments consisted of different levels of irrigation water electrical conductivity – ECw (0.3– Control, 1.3, 2.3, 3.3 and 4.3 dS m^{-1}) associated with nitrogen doses (70, 100, 130 and 160% of N recommendation), and the 100% dose corresponded to 600 mg of N dm^{-3} (Ferreira, 2014). Solutions of different salinity levels were obtained by mixing public-supply water (ECw=0.3 dS m^{-1}) and sodium chloride (NaCl), calcium chloride ($CaCl_2.2H_2O$) and magnesium chloride ($MgCl_2.6H_2O$), in equivalent proportion of 7:2:1, which is the predominant ratio in the main water sources available for irrigation in Northeast Brazil (Medeiros, 1992), following the relationship between ECw and concentration of salts ($mmol_c$ L^{-1} = EC x 10) (Rhoades et al., 1992).

Plant materials

The genetic material was CMF102 West Indian cherry. The West Indian cherry plant is a shrub (hairless), medium-sized, 2 to 3 m tall, dense with scattered branches, opposite leaves, short petiole, oval and elliptic-petiolate, measuring between 2.5 and 7.5 cm. The base and especially the apex of the leaves are acute, dark green in color on the upper surface and pale green on the lower surface (Calgaro and Braga, 2012).

Establishment and management of the experiment

West Indian cherry rootstocks were produced in plastic bags with capacity for 1150 mL, perforated at the bottom to allow free water drainage. The bags were filled using a substrate composed of Fluvic Neosol + Bovine manure + Sand (82, 3 and 15%, respectively). Five seeds were equidistantly planted at 1.5 cm depth. The bags were placed on metal benches, at height of 0.8 m from the soil

The physical and chemical characteristics of the soil in the study (Table 3) were determined according to Claessen (1997) at the Soil and Plant Laboratory of the CCTA/UFCG.

During the period of germination and emergence of seedlings, the soil was maintained close to field capacity using water from the local supply system (ECw of 0.3 dS m^{-1}). Solutions with different salt levels began to be applied at 30 days after emergence (DAE), through daily irrigations, manually, using a graduated cylinder, according to the treatment. Irrigations were performed based on plant water requirement, determined by drainage lysimetry (twenty bags were chosen and collectors were installed) by daily application in the late afternoon with the volume to be applied. It was determined by the difference between the applied volume and the volume drained in the previous irrigation (Bernardo et al., 2006). Every 10 days, a leaching fraction of 0.15 was applied based on the volume applied in this period, to reduce salt accumulation in the substrate.

Nitrogen fertilization began 40 DAE and was split into 14 equal parts, applied every week using urea (45% N) as source of N. The fertilizer was applied through fertigation using water with electrical conductivity of 0.3 dS m^{-1} for all treatments.

Traits measured

The growth of West Indian cherry rootstock (CMF 102) was evaluated at 165 DAE. The characteristics such as plant height (PH), stem diameter (SD), number of leaves (NL), leaf area (LA), shoot (SDP) and total dry phytomass (TDP) and Dickson quality index (DQI) were recorded. Additionally, the absolute growth rate of plant height (AGR_{PH}) was evaluated from 45 to 165 DAE.

PH was measured from soil surface to the apical meristem, whereas SD was measured 3 cm above the soil level. The NL was determined by counting the fully expanded leaf blades. LA was determined as recommended by Medeiros et al. (2010), using Eq. 1:

$$LA = 0.7097 \times L \times W. \qquad (1)$$

Where; LA = leaf area (cm^2), L = leaf length and W = leaf width.

The absolute growth rate (AGR) was determined using the methodology proposed by Benincasa (2003), as described in Eq. 2:

$$AGR = \frac{(A_2 - A_1)}{(t_2 - t_1)} \qquad (2)$$

Where; AGR_{PH}= absolute growth rate, A_2 = plant growth at time t_2, A_1 = plant growth at time t_1, and $t_2 - t_1$ = time difference between measurements.

To determine dry phytomass accumulation, the stem of each plant was cut close to the soil and the aboveground material was separated into different parts (stem and leaves). The material was dried in a forced-air oven at 65 ºC until constant weight to determine shoot (SDP) and total dry phytomass (TDP), based on the sum of leaves and stem.

Rootstock quality was determined by the Dickson quality index (DQI) for seedlings, using the formula of Dickson et al. (1960), described by Eq. 3.

$$\mathrm{DQI} = \frac{(\mathrm{TDP})}{(\mathrm{PH/SD}) + (\mathrm{SDP/RDP})} \qquad (3)$$

Where; DQI = Dickson quality index, PH = plant height (cm), SD = stem diameter (mm), TDP = total dry phytomass (g), SDP = shoot dry phytomass (g) and RDP = root dry phytomass (g).

Statistical analysis

The data were subjected to analysis of variance by F-test at 0.05 and 0.01 probability levels. In cases of significance, linear and quadratic polynomial regressions were applied using the statistical program SISVAR (Ferreira, 2011). The choice of regression was made by better adjustment on the basis of coefficient of determination (R^2) and taking into account a probable biological explanation (Lima et al, 2014).

Conclusion

Irrigation with ECw up to 2.22 dS m^{-1} led to a maximum reduction of 10% in growth and in the quality of CMF 102 rootstock. Highest growth of CMF 102 West Indian cherry rootstock was obtained with fertilization equivalent to 70% of recommended N dose. The plants of West Indian cherry irrigated with water of 4.3 dS m^{-1} presented acceptable Dickson quality index; therefore, seedlings with IQD higher than 0.2 are considered of good quality. In general, West Indian cherry plants can be classified as sensitive to the irrigation water salinities higher than 0.3 dS m^{-1}. No significant effect was found for the interaction between water salinity and N doses.

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