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Morphophysiology of Eggplant Irrigated With Wastewater and Nitrogen and Phosphorus Doses in the Semi-arid Region of Brazil

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Abstract

Water is a scarce resource in semi-arid regions, therefore, the correct water management is an essential practice. In this research we evaluated the use of nitrogen, phosphorus and treated wastewater on the growth and morphophysiology of eggplants (*Solanum melongena* L.) in the semi-arid region of Brazil. The experiment was conducted in Pombal, Paraíba, Brazil, using a randomized block design, in a 4 × 4 + 1 factorial scheme: wastewater with four nitrogen doses (N_1 = 0.22; N_2 = 0.39; N_3 = 0.56; and N_4 = 0.73 g N dm^{-3}) and four doses of phosphorus (P_1 = 0.96; P_2 = 1.68; P_3 = 2.40; and P_4 = 3.12 g P dm^{-3}), and the controls – distilled water fertilized with 0.56 g of N dm^{-3} and distilled water fertilized with 2.40 g of P dm^{-3}. Each treatment was replicated 4 times. The nitrogen and phosphorous interaction did not influence the growth and physiological aspects of eggplant plants. Excess growing media nitrogen significantly decreased gaseous exchanges of eggplant plants, being found decreased of 4.4 μmol m^{-2} s^{-1} the CO_2 assimilation.

Keywords: fertilization, reuse, *Solanum melongena* L.

1. Introduction

Eggplant (*Solanum melongena* L.) is a vegetable of the Solanaceae family, easily adapted tropical climatic conditions (Lima et al., 2015). The Brazilian semi-arid areas have favorable edaphoclimatic conditions for eggplant cultivation. The semi-arid region of the northeast of Brazil is characterized by an irregular spatial and temporal rainfall distribution (Medeiros et al., 2017) and irrigation is needed to ensure agricultural production in the region (Medeiros et al., 2018a).

To reduce water scarcity in Brazil's semi-arid region, researchers search for viable alternatives, such as the use of "inferior quality" water in irrigated agriculture, mainly saltwater and wastewater (Gonçalves et al., 2013; Oliveira et al., 2014; Lima et al., 2014, 2015; Medeiros et al., 2015, 2018b; Santos et al., 2016).

According to Gonçalves et al. (2013), the planned use of treated wastewater as an alternative water source saves surface water and allows agricultural production in regions with water restrictions. In addition, wastewater provides macro, such as nitrogen and phosphorus, and micronutrients to plants (Medeiros et al., 2017). The reuse of nutrients and reduction of the application of synthetic fertilizers are examples of the benefits of reusing water (Gonçalves et al., 2013; Medeiros et al., 2018b). Nitrogen and phosphorus are essential macronutrients for plant growth and development, and play important roles in the respiration and photosynthesis (Weber et al., 2016).

Despite the benefits of nitrogen and phosphorus for growth, physiological processes and plant production, high concentrations can be harmful during growth and development, causing, among other factors, nutritional imbalance, toxicity and soil salinization (Santos et al., 2016; Weber et al., 2016; Souza et al., 2017). Nitrogen and phosphorus provide higher growth and production in eggplant crops (Souza et al., 2017), but little is known about the optimal concentration levels of these nutrients when using wastewater irrigation. In this research we evaluated the use of nitrogen, phosphorus and treated wastewater on the growth and morphophysiology of eggplants (*Solanum melongena* L.) in the semi-arid region of Brazil.

2. Method

2.1 Localization, Experimental Design, Treatments and Plant Material

The greenhouse experiment was conducted at the Centro de Ciências e Tecnologia Agroalimentar (CCTA) of the Federal University of Campina Grande-UFCG, Pombal, PB. The site is situated at 6º48′16″ S, 37º49′15″ W, with an average altitude of 144 m.

The experimental design was randomized blocks, with treatments arranged in a 4 × 4 + 1 factorial scheme, with four replications each, totalizing 68 experimental units. The factors consisted of four nitrogen doses (N_1 = 0.22, N_2 = 0.39, N_3 = 0.56 and N_4 = 0.73 g dm^{-3} of soil) and four doses of phosphorus (P_1 = 0.96, P_2 = 1.68, P_3 = 2.40 and, P_4 = 3.12 g dm^{-3} of soil), corresponding respectively to 40, 70, 100 and 130% of the recommended fertilization for eggplant pot production (Malavolta, 2006). In addition to these treatments, the control treatment consisted of 100% of the recommended nitrogen and phosphorus does irrigated with drinking water. The control was compared with the treatments that received the minimum (40%) and recommended (100%) doses of nitrogen and phosphorus fertilization irrigated with wastewater.

We grew eggplant variety Embú in 20 L plastic pots, filled with 20 kg of soil. The soil used in the pots for eggplant cultivation was classified as sandy loam, non-saline and non-sodic. The material came from the municipality of Pombal, Paraíba. The soil chemical and physical characteristics were determined using the methodology recommended by Embrapa (1997) (Table 1).

Table 1. Chemical and physical attributes of the soil used during the experiment

Chemical												
pH_{es}	K^+	Na^+	Ca^{2+}	Mg^{2+}	H+Al	CEC	EC_{se}	N	OC	OM	BS	P_{Ass}
	------------------- cmol$_c$ kg^{-1} -------------------					------ dm^{-1} ------		------- g kg^{-1} --------			cmol$_c$ kg^{-1}	mg 100 g^{-1}
7.7	0.3	0.7	5.2	2.3	0.0	8.6	2.2	0.5	5.4	9.3	8.6	4.6

Physical						
Sand	Silt	Clay	Porosity	DP	BD	Water available
-------------------- g kg^{-1} ---------------------			%	-------------- g cm^{-3} --------------		g kg^{-1}
729	145	126	50	2.8	1.4	73.9

Note. pHse: pH of saturation extract; K^+: Potassium; Na^+: Sodium, Ca^{2+}: Calcium; Mg^{2+}: Magnesium; H+Al: Hydrogen+Aluminium; CEC: Cation Exchange Capacity; ECes: Eletric Conductivity in the saturation extract; N: Nitrogen; OC: Organic Carbon; OM: Organic matter.

We produced the eggplant seedlings in expanded polystyrene trays of 128 cells, using a commercial substrate based on pine bark, hummus, and vermiculite. After twenty-five days of sowing (DAS), two seedlings were transplanted per pot, and at 17 days after transplanting (DAT), we performed the thinning leaving the more vigorous seedlings. During the experiment, the soil of the pots were maintained near the field capacity approach described by Medeiros et al. (2017) using wastewater and water supply, according to the treatments.

We used urea as nitrogen source (45% N). To avoid possible losses due to volatilization and/or leaching, nitrogen fertilization was divided in seven applications, every 7 DAT.

The source of phosphorus was superphosphate (18% of P_2O_5), added as a basal fertilization five days before transplanting. Potassium fertilization was also carried out with potassium chloride in the amount of 0.31 g dm^{-3}, fertilized in the same period of nitrogen fertilizations.

The wastewater used in the experiment came from showers, sinks and urinals of the bathrooms of the UFCG, Campus de Pombal, collected by pipes and deposited in a septic tank. The tank was connected by a tube inserted at the lower end to a plastic container with 500 L capacity, functioning as effluent distribution tank. The distribution occurred connecting three different intermittent aerobic filters (each filter receiving 50 L of wastewater every 6, 8 and 12 hours). The effluent produced was stored in a plastic container with a 500 L capacity.

The filters were constructed adapting plastic containers with a capacity of 250 L each. The containers have three layers: a bottom layer of 10 cm of gravel, a layer in the middle composed by 50 cm of sand and in the upper part another layer of 5 cm of gravel, to standardize the flow.

The physical-chemical characterization of the wastewater (mean values) before and after the treatment with sand filter (Sousa, 2015) is shown in Table 2.

Table 2. Physical-chemical characteristics of the wastewater (WW) of the septic tank and after the sand filters

Wastewater before filter												
pH	EC_a	DO	Ca	Mg	Cl^-	P	N	Na	K	COD	BOD	SAR
	dS m^{-1}	----------	----------	----------	----------	----------	mg L^{-1}	----------	----------	----------	----------	mmol L^{-1}
8.3	0.82	0.4	34.4	25.4	102.5	0.8	0.01	0.02	0.09	89.8	15.6	3.6
Wastewater after the sand filters[1]												
pH	EC_a	DO	Ca	Mg	Cl^-	P	N	Na	K	COD	BOD	SAR
	dS m^{-1}	----------	----------	----------	----------	----------	mg L^{-1}	----------	----------	----------	----------	mmol L^{-1}
6.2	0.56	6.4	58.4	44.0	86.2	0.7	0.01	0.01	0.0	127.3	25.4	1.3

Note. pH: Hydrogenionic potential; EC: Eletric Conductivity; DO: Dissolved Oxygen; Ca: Calcium; Mg: Magnesium, Cl^-: Cloretum; P: Fosforum; N: Nitrogen; Na: Sodium; K: Potassium; COD: Chemical Oxygen Demand; BOD: Biochemical Oxygen Demand; SAR: Sodium Adsorption Ratio. [1]These values were compatible with those recommended for agricultural use, according to CONAMA resolution (Brazil, 2005).

2.2 Data Sampling

Physiological and growth assessments were performed at the beginning of flowering, 40 days after transplanting (DAT). Eggplant plants growth was evaluated by plant height (PH), stem diameter (SC), leaf number (LN) and leaf area (LA). Plant height (mm) was the distance between the plant collar and the apex of the main stem. Stem diameter (mm) was determined at 3 cm of the plant collar using a digital caliper. For number of leaves, were only the leaves with at least 50% of photosynthetic active area and 1cm minimum width. Leaf area (cm²) was obtained according to the methodology provided by Maldaner et al. (2009).

The physiological variables were measured using an infrared gas analyzer (IRGA) LCpro (Analytical Development, Kings Lynn, UK) with a constant light source of 1,200 μmol of m^{-2} s^{-1} photons. The readings were performed on the fifth leaf of the main stem of each plant, determining the photosynthetic rate (P) in μmol CO_2 m^{-2} s^{-1}, transpiration (T) in mmol of H_2O m^{-2} s^{-1}, stomatal conductance (Sc) in mol H_2O m^{-2} s^{-1}, and intracellular concentration of CO_2 (Ic) in μmol m^{-2} s^{-1}. These data were used to estimate the instantaneous water use efficiency (WUE = P/T) [(μmol of CO_2 m^{-2} s^{-1}) (mmol of H_2O m^{-2} $s^{-1})^{-1}$] and the instantaneous efficiency of carboxylation (IEC = P/Ic) [(μmol m^{-2} s^{-1}) (μmol $mol^{-1})^{-1}$] (Silva et al., 2015).

We used an analysis of variance by the F test ($p < 0.05$) to determine the effects of phosphorous and nitrogen doses, and their interaction on the growth and physiological aspects of eggplant. When signicant, a polynomial regression analysis was performed. A Tukey test was performed to compare the averages of the control treatment (drinking water + 100% of nitrogen and phosphorus dose) with the treatments that used wastewater for irrigation with 40% (N_1P_1) and 100% (N_3P_3) of nitrogen and phosphorus. The analyses were performed at the statistical software SISVAR (Ferreira, 2014).

3. Results

The results of the analysis of variance for the growth of eggplant plants show that nitrogen doses significantly influenced plant height (PH) and leaf area (LA) ($p < 0.01$). Phosphorus doses and interaction between nitrogen and phosphorus did not affect the plant growth variables. The different types of water used for irrigating the plants (wastewater and drinking water) did not significantly influence the studied variables (Table 3).

Table 3. Summary of analysis of variance for the variables plant height (PH), stem diameter (SD), leaf number (LN) and leaf area (LA) of eggplant under nitrogen and phosphate fertilization, and test of comparison of means between treatments irrigated with wastewater (WW) and drinking water (DW)

Source of variation	DF	Mean Squares			
		PH	SD	LN	LA
Nitrogen (N)	3	104.57**	0.74^{ns}	15.30^{ns}	454305.41**
Linear regression	1	3.50^{ns}	1.30^{ns}	22.57^{ns}	1211961.37**
Quadratic Regression	1	190.78**	0.82^{ns}	17.01^{ns}	126711.08^{ns}
Phosphorous (P)	3	40.32^{ns}	1.54^{ns}	24.30^{ns}	269020.98^{ns}
Linear regression	1	97.35^{ns}	1.61^{ns}	1.65^{ns}	374279.32^{ns}
Quadratic Regression	1	19.69^{ns}	0.30^{ns}	40.64^{ns}	278367.03^{ns}
Interaction (N × P)	9	55.84^{ns}	1.04^{ns}	20.12	162893.48^{ns}
Blocks	3	39.42	0.40	45.93	234645.46
Residue	45	26.67	1.59	25.89	140972.47
C.V. (%)		14.60	12.69	23.79	16.67
Treatments		**Averages**			
Control (DW)		31.00a	9.45a	20.25a	2065.68a
N_3P_3 (WW)		31.75a	9.47a	21.75a	2053.55a
N_1P_1 (WW)		32.25a	9.50a	22.00a	2107.69a

Note. ns: not significant, **, *: significant at 1 and 5% probability by F-test, respectively; Means followed by the same letter in the column do not differ by Tukey's test at 5% probability level ($p < 0.05$). N_1P_1: (0.22 g dm^{-3} of nitrogen + 0.96 g dm^{-3} of phosphorous + wastewater) = treatments with wastewater and 40% of nitrogen and phosphorous recommendation; N_3P_3: (0.56 g dm^{-3} of nitrogen + 2.40 g dm^{-3} of phosphorous + wastewater) = treatments with wastewater and 100% of nitrogen and phosphorous recommendation; Control (0.56 g dm^{-3} of nitrogen + 2.40 g dm^{-3} of phosphorous + drinking water) = plants that received irrigation with drinking water and 100% of the recommended dose of nitrogen and phosphorous.

The relationship between plant height averages and nitrogen doses fit a quadratic function better (Figure 1A). The greatest height (38 cm) occurred at the estimated dose of 0.47 g of N dm^{-3}, 14.6% more than the minimum nitrogen dose (0.22 g of N dm^{-3}). Doses greater than 0.47 g of N dm^{-3} decreased the plant height by 10% compared to the maximum height. Nitrogen doses negatively influenced the leaf area (Figure 1B). There was a linear decrease of leaf area of 0.15% per unit increase in the nitrogen dose, a reduction of 352 cm^2 (0.22 g of N dm^{-3}) in the leaf area of the plants at the maximum nitrogen dose (0.73 g of N dm^{-3}).

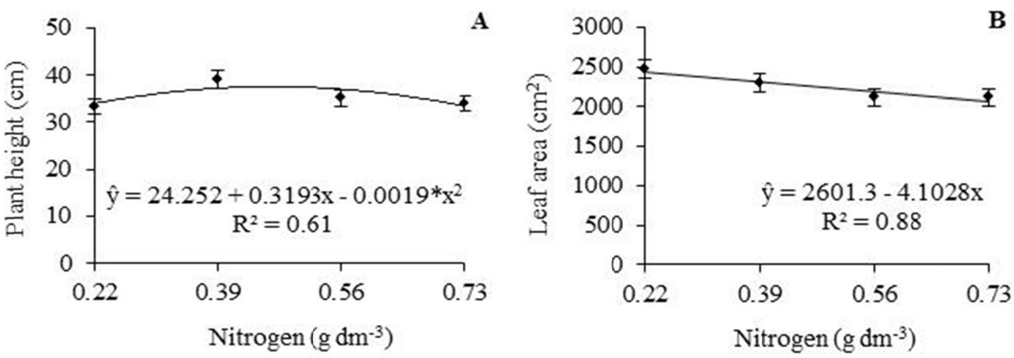

Figure 1. Plant height (PH) and leaf area (LA) of eggplant in function of nitrogen doses, using wastewater, at 40 days after transplanting

We found a significant difference of gas exchange, photosynthetic rate (P), transpiration (T), stomatal conductance (Sc) and intracellular concentration of CO_2 (Ic) among nitrogen doses ($p < 0.01$). Phosphorus doses and interaction between nitrogen and phosphorus did not affect eggplant gas exchange, P, T, Sc, and Ic. The test of means reveals that the type of water (drinking water and wastewater) used for irrigation significantly influenced the transpiration and stomatal conductance (Table 4).

Table 4. Intracellular CO_2 concentration (Ic), transpiration (T), stomatal conductance (Sc), photosynthetic rate (P), water use efficiency (WUE = P/T) and instantaneous efficiency of carboxylation (IEC = P/Ic) of eggplant (*Solanum melongena* L.) plants fertilized with doses of nitrogen and phosphorus and test of means between treatments irrigated with wastewater (WW) and drinking water (DW)

Source of variation	DF	Mean Squares					
		P	**T**	**Sc**	**Ic**	**P/Ic**	**IEC**
Nitrogen (N)	3	38.61**	7.29**	0.114**	4147.30**	0.54^{ns}	$2.4E\text{-}04^{ns}$
Linear regression	1	41.49^{ns}	0.88^{ns}	0.001^{ns}	10939.50**	0.01^{ns}	$2.4E\text{-}04^{ns}$
Quadratic regression	1	52.65**	17.27**	0.294**	1296.00^{ns}	0.99^{ns}	$2.4E\text{-}04^{ns}$
Phosphorous (P)	3	0.09^{ns}	0.23^{ns}	0.003^{ns}	99.66^{ns}	0.18^{ns}	$2.4E\text{-}04^{ns}$
Linear regression	1	0.02^{ns}	0.08^{ns}	0.011^{ns}	273.80^{ns}	0.47^{ns}	$2.4E\text{-}04^{ns}$
Quadratic regression	1	0.08^{ns}	0.12^{ns}	0.001^{ns}	25.00^{ns}	0.05^{ns}	$2.4E\text{-}04^{ns}$
Interaction (N × P)	9	7.15^{ns}	0.35^{ns}	0.002^{ns}	236.36^{ns}	0.21^{ns}	$2.4E\text{-}04^{ns}$
Blocks	3	4.62	0.81	0.005	264.54	0.57	2.4E-04
Residue	45	131.11	0.65	0.006	318.36	0.23	2.4E-04
C.V. (%)		10.83	18.89	18.52	7.99	14.30	15.13
Treataments		**Averages**					
Control (DW)		14.61a	3.62b	0.34b	212.12a	2.89a	0.06a
N_3P_3 (WW)		17.02a	5.15a	0.52a	228.00a	3.90a	0.07a
N_1P_1 (WW)		16.48a	3.97b	0.34b	235.87a	3.02a	0.07a

Note. ^{ns}: not significant, **, *: significant at 1 and 5% probability by F-test, respectively; Means followed by the same letter in the column do not differ by Tukey's test at 5% probability level ($p < 0.05$). N_1P_1: (0.22 g dm^{-3} of nitrogen + 0.96 g dm^{-3} of phosphorous + wastewater) = treatments with wastewater and 40% of nitrogen and phosphorous recommendation; N_3P_3: (0.56 g dm^{-3} of nitrogen + 2.40 g dm^{-3} of phosphorous + wastewater) = treatments with wastewater and 100% of nitrogen and phosphorous recommendation; Control (0.56 g dm^{-3} of nitrogen + 2.40 g dm^{-3} of phosphorous + drinking water) = plants that received irrigation with drinking water and 100% of the recommended dose of nitrogen and phosphorous.

The net photosynthetic rate of the eggplant plants showed a quadratic relationship with nitrogen dose, observing a maximum value of 17.5 µmol m^{-2} s^{-1} at the estimated dose of 0.45 g of N dm^{-3} (Table 2, Figure 2A). At the maximum applied dose of nitrogen, the net photosynthetic rate decreased by 25% (13.1 µmol m^{-2} s^{-1}) compared the dose at which we found the maximum net photosynthetic rate (Figure 2A). Transpiration rate also had a quadratic polynomial adjustment with the increasing nitrogen doses (Figure 2B). There was an increase transpiration rate up to 0.44 g of N dm^{-3} and a decrease at the greatest doses. At 0.44 g of N dm^{-3}, the transpiration rate was 33% greater (4.78 mmol of H_2O m^{-2} s^{-1}) than the maximum dose of 0.73 g of N dm^{-3} (3.21 mmol of H_2O m^{-2} s^{-1}) (Figure 2B).

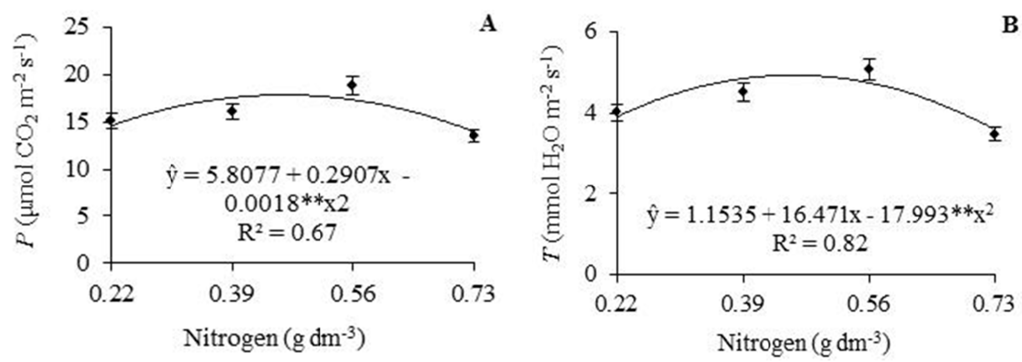

Figure 2. Photosynthetic rate (A) and transpiration (B) of eggplant plants cv. Embú, at 40 days after transplanting, irrigated with wastewater and submitted to different doses of nitrogen

Intracellular CO_2 concentration decreased linearly with the increase in the nitrogen dose, with a 0.14% per unit increase in the nitrogen dose (Figure 3A). We observed the greatest intracellular CO_2 concentration (241.22 µmol

mol m^{-2} s^{-1}) in plants that received the dose of 0.22 g of N dm^{-3}, that was statistically higher than the lowest value found (206.94 μmol mol^{-1}) at the highest dose (0.73 g of N dm^{-3}). The increase of the nitrogen doses affected the eggplants' stomatal conductance (Figure 3B). The regression between nitrogen and stomatal conductance showed a quadratic relationshipr, with a high predictive capacity ($R^2 = 0.84^{**}$). The estimated dose of 0.50 g of N dm^{-3} resulted in a stomatal conductance 22% greater (0.60 mol m^{-2} s^{-1}) than the lowest nitrogen doses applied, 0.73 g dm^{-3} (0.47 mol m^{-2} s^{-1}, a reduction of 0.13 mol m^{-2} s^{-1}).

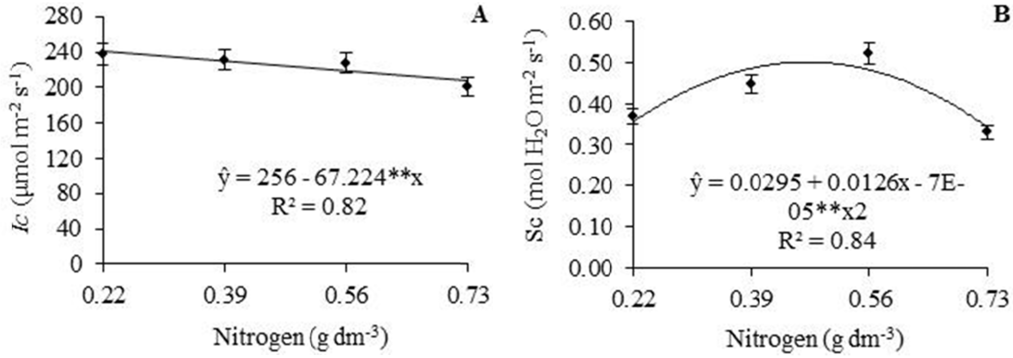

Figure 3. Intracellular CO_2 concentration (A) and stomatal conductance (B) of eggplant plants cv. Embú, at 40 days after transplanting, irrigated with wastewater and submitted to different doses of nitrogen

4. Discussion

The absence of a significant effect on stem diameter (SD) and leaves number (LN) indicates that the lowest nitrogen dose (0.22 g N dm^{-3}) was enough to guarantee the development of the stem and the larger number of leaves of the eggplant plant. The estimated dose of 0.47 g of N dm^{-3} promoted greater plant growth, which was the accumulated dry matter over time and represents the net photosynthesis. Increases up to the optimum nitrogen dose may be related to a greater leaf area development, root system growth, and the leaf area/photosynthesis ratio (Santos et al., 2016; Vieira et al., 2016; Medeiros et al., 2018a). Our results show that nitrogen, when supplied in adequate quantities, significantly increases the plant growth and development, since it is a part of plant metabolism through enzymes, amino acids, proteins, pigments and nucleic acids, fundamental constituents of protoplasm and chlorophyll, essential for photosynthesis (Carneiro et al., 2015; Santos et al., 2016; Souza et al., 2017; Medeiros et al., 2018b).

The reductions of eggplant growth as result of nitrogen doses above the inflection point probably occurred due to the acidification, since the fertilizer supplied to the plants was urea that releases H^+ after urease reaction (Ramos et al., 2016). Thus, resulting in excess nitrogen in the plant growing media with the use of wastewater, damaging the plants, mainly due to the imbalance concerning other nutrients (Lima et al., 2014; Vieira et al., 2016). The acidification may also be a result of macronutrient concentrations and salt content in the wastewater in which dissolved nitrogen and phosphorus are abundant (Gonçalves et al., 2013; Medeiros et al., 2015, 2018b). Other studies also observed reductions in plant height of several crops as a result of nitrogen excess during fertilization (Araújo et al., 2012; Abrantes, 2014; Medeiros et al., 2015; Ramos et al., 2016).

The decrease in leaf area observed in this study is probably related to the excess of nitrogen in the growing media if in pots. Araújo et al. (2012) also found that excessive doses of nitrogen reduced plant growth and development, possibly due to the toxic and saline effect, especially when applied in the form of urea. According to Oliveira et al. (2014), eggplant is a moderately salinity-sensitive crop, and the limit of salinity is 1.5 dS m^{-1}, reducing 4.4% of yield by salinity increase. The application of wastewater during crop cycle associated with the release of hydrogen ions during the nitrification process of the urea promoted soil salinization (Souza et al., 2016).

Ramos et al. (2016) reported similar results evaluating nitrogen rates on cotton leaf area. Lima et al. (2015) observed a linear reduction of leaf area in eggplant plants of 525.5 cm^2 per unit increase of water salinity. However, Abrantes (2014) found a quadratic effect in the leaf area of eggplant, increasing up to the dose 0.26 g of N dm^{-3} and decreasing at the doses above this value. In our experiment, the minimum nitrogen dose (0.22 g of N dm^{-3}) with wastewater was enough to guarantee a greater leaf expansion of eggplant plants, showing an adequate supply of nitrogen to the plants when irrigated with wastewater.

For the photosynthesis process, the plant needs to open the stomata and absorb the atmospheric CO_2 necessary to perform the biochemical processes, since the greater stomatal opening favors the entry of CO_2 into the leaf mesophyll, thus increasing the intracellular concentration, and consequently photosynthesis (Silva et al., 2015). In our study, the net CO_2 assimilation rate was reduced when the plants received doses above the estimated level of 0.45 g of N dm^{-3}. Excess growing media nitrogen decreased significantly by 4.4 μmol m^{-2} s^{-1} the CO_2 assimilation.

The positive effects on the net photosynthetic rate observed up to the optimal dose of 0.45 g of N dm^{-3} may be a result of the nitrogen function during plant growth and development, required for the synthesis of several cellular compounds, such as for chlorophyll and ribulose-1,5-biphosphate carboxylase/oxygenase (Rubisco), that act in the photosynthetic process during the photochemical and biochemical phases, respectively (Lima et al., 2014; Souza et al., 2016, 2017). However, plants submitted to excessive doses of nitrogen have a reduction in stomatal opening due to the negative effect of the high doses on the mesophyll conductance (Souza et al., 2016). Abrantes (2014) found the highest value of net photosynthetic rate of 17.2 μmol m^{-2} s^{-1} at the N dose rate of 0.55 g of dm^{-3}, results similar to those found here.

The greater production of foliar biomass raised the transpiration rate as the nitrogen dosed increased to 0.44 g of N dm^{-3}, resulting in increments of the net photosynthetic rate and demand (Silva et al., 2015). Freitas et al. (2012) reported that the stomatal behavior controls the transpiratory water demand determining the loss of water to the environment.The reduction in stomatal conductance probably caused the negative effect on transpiration rate, reducing the water loss by the plants, but also the net photosynthetic rate (Lima et al., 2014; Weber et al., 2016; Souza et al., 2017). The reduction in stomatal conductance can also be a result of the possible reduction of soil water potential due to the increase of solute concentration in the soil solution (Vieira et al., 2016).

The increase in nitrogen fertilization also decreased the intracellular concentration of CO_2 due to two factors. (i) the reduction of CO_2 uptake by foliar tissues, by decrease in the enzymatic activity of Rubisco, a fact evidenced by the decline in photosynthetic rate under high nitrogen concentration. And, (ii) by the increase in oxygenize activity of Rubisco enzyme, instead of the carboxylase (Ramos et al., 2016, Santos et al., 2016). The nitrogen excess probably promoted a phytotoxic effect on plants which possibly caused the partial closure of the stomata due to osmotic effects (Soares et al., 2013, Silva et al., 2015; Vieira et al., 2016). According to Ramos et al. (2016), the reduction in stomatal conductance results in the decline of photosynthesis caused by the decrease in CO_2 pressure within intracellular spaces.

Under optimal nutritional and water availability, plants, in general, have high transpiration rates (Silva et al., 2015, Souza et al., 2016, Ramos et al., 2016). However, under some stress, plants decrease perspiration to minimize water loss (Soares et al., 2013). Therefore, reductions in the photosynthetic and transpiration rates, intracellular CO_2 concentration and stomatal conductance in eggplants submitted to greater nitrogen doses were probably by nutritional excess. Lorenzoni et al. (2018) found similar results of nitrogen on sweet pepper (*Capsicum annuum* L.) plants for the above variables. According to Lorenzoni et al. (2018), an excess of nitrogen or an imbalance with other nutrients trigger detrimental effects on plant performance, which may be a result of the physiological imbalance.

5. Conclusion

Nitrogen and phosphorus doses interaction did not affect the growth and physiological aspects of eggplant.

The increase of the nitrogen doses reduced the leaf area of the eggplant when irrigated with wastewater.

The estimated nitrogen dose of 0.47 g dm^{-3} and irrigation with wastewater resulted in the greatest plant height.

Excess growing media nitrogen significantly decreased gaseous exchanges of eggplant plants, being found decreased of 4.4 μmol m^{-2} s^{-1} the CO_2 assimilation.

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