ENRICHMENT OF ATMOSPHERIC CO_2 IN THE GROWTH AND QUALITY OF MINI WATERMELON FRUIT CV. SMILE IRRIGATED WITH SALINE WATER

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ABSTRACT: The goal of this study was to evaluate the performance of the mini watermelon plant under salinity and different levels of atmospheric CO_2 concentration. The experiment was carried out at the National Center of Agricultural Informatics Research (CNPTIA - *Centro Nacional de Pesquisa de Informática Agropecuária*) in two different growth chambers. In the first growth chamber, the mini watermelon plants were irrigated with saline water at two different levels of electrical conductivity (ECw = 1 and 5 dS.m-1) and with an increase in the atmospheric CO_2 concentration to 800ppm. In the second growth chamber, the mini watermelon plants were irrigated with saline water as previously described and with the atmospheric CO_2 concentration at 400ppm.The increase of CO_2 concentration provided an increase of both size and mass of the fruits, even in plants under salt stress. Thus, the results demonstrate that the increase of the atmospheric CO_2 concentration provides a greater development of fruits of the mini watermelon and it can be used to improve the production even under salt stress caused by irrigation water.

KEYWORDS: Cucurbitaceae; Salt stress; Greenhouse gas

ENRIQUECIMENTO DE CO_2 ATMOSFÉRICO NO CRESCIMENTO E NA QUALIDADE DE FRUTOS DA MINI MELANCIA CV. SMILE IRRIGADA COM ÁGUA SALINA

RESUMO: Estudou-se, se a tolerância da planta e a qualidade dos frutos da mini melancia à salinidade, ocasionada pela água de irrigação, poderia ser afetada pelo incremento do CO_2 atmosférico. O experimento foi realizado no Centro Nacional de Pesquisa de Informática Agropecuária (CNPTIA) em duas câmaras de crescimento. Na primeira câmara de crescimento, cultivaram-se plantas da mini melancia irrigadas com água diferentes condutividades elétricas (CEa=1 e 5 $dS{\cdot}m^{-1}$), com aumento da concentração atmosférica de CO_2 para 800ppm. Na

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segunda câmara de crescimento cultivaram-se plantas da mini melancia irrigadas com água diferentes condutividades elétricas (CEa=1 e 5 $dS \cdot m^{-1}$) com a concentração de CO_2 atmosférico de 400ppm. O aumento de CO_2 favoreceu maiores dimensões e massa nos frutos, mesmo em plantas sob estresse salino. Dessa forma, conclui-se que o aumento da concentração de CO_2 atmosférico favorece o desenvolvimento de frutos da mini melancia e pode servir para melhorar a produção mesmo sob estresse salino ocasionado pela água de irrigação.

PALAVRAS-CHAVE: Cucurbitaceae; Estresse salino; Gás do efeito estufa

INTRODUCTION

Data from the Intergovernmental Panel on Climate Change (IPCC, 2014) show that with the continued increase in greenhouse gas emissions, global warming levels can already be seen. These effects, related to climate change, already have impacts on human health, food production, ecosystems and water supply. This scenario demonstrates the vulnerability of societies and ecosystems present on the planet. According to the Intergovernmental Panel on Climate Change (2014), an alternative to reduce these problems would be an adaptation to the impacts caused by climate changes.

The increase in temperature of the planet was approximately 0.2 °C per decade, within a historical series from 1976 to 2006 (HANSEN et al., 2006). The greenhouse effect, caused mainly by the emission of CO_2, N_2O and CH_4 gases, boosted global warming in the last century (NAJAFI; ZWIERS; GILLETT, 2015). If the level of CO_2 in the atmosphere does not stabilize or decay, there may be an irreversible increase in the Earth's average temperature of 1ºC (HANSEN; SATO, 2004). In the scenarios studied, if there is an increase in the concentration of atmospheric CO_2 from 580 to 1000 ppm, it is probable that the temperature of the planet increases by 4ºC until the year 2100 (IPCC, 2014).

In addition to warming, changes in climate are also related to the distribution of precipitation that tends to be more scarce in regions that already have a low water supply. Thus, changes in precipitation and temperature patterns threaten agricultural production and increase the vulnerability of people who depend on agriculture and may become more severe in subsistence agriculture regions (LIPPER et al., 2014).

Within the problem related to the low water availability, there is still the question about the quantity of fresh water destined for agriculture. It is estimated that of the 90% of fresh water available for human consumption, 70% is destined for agriculture and 22% for industry (JOHN;

MARCONDES, 2010). Thus, the use of low quality or residual water would be a good option in times of water scarcity, as well as being of great importance for regions with low availability.

However, it is common to find high saline concentrations in the waters of those regions. Thus, the use of low quality water for irrigation may become a limiting factor for plant production, since salinity may inhibit plant growth due to osmotic and toxic effects (MUNNS, 2008). The physiological and biochemical functions can be influenced by the excess of salts (DIAS; BLANCO, 2010). However, these responses will depend on the tolerance of each culture to salt stress.

Therefore, it is considered important the studies which evaluate the limitations of the crops caused by the gases that cause the greenhouse effect and the quality of the irrigation water.

Thus, the objective of this work was to study the combined effect of salinity with the increase of atmospheric CO_2 in the production of the mini watermelon. We also sought to verify if the tolerance of mini watermelon to salinity caused by irrigation water can be affected by the increase of atmospheric CO_2.

MATERIAL AND METHODS

The experiment was carried out in two growing chambers belonging to the National Agricultural Research Center (CNPTIA), located in the city of Campinas, São Paulo state.

The seeds of the mini watermelon cv. Smile were sown in plastic trays with coconut fiber and covered with vermiculite substrate. The transplanting was carried out 35 days after sowing, to polyethylene pots containing 8 liters of commercial substrate and kept in a greenhouse (dimension of 1 m x 0.45 m), with vertical conduction (CAMPAGNOL, 2009).

The experiment was set up in two growth chambers with a useful area of 11 m² each. It was used 440 lux artificial lighting, 12-hour photoperiod, average temperature of 27 ° C and average relative humidity of 50%. Localized irrigation was used, by drip irrigation, estimating the water demand with the aid of tensiometers.

The experiment consisted of two treatments, referring to the saline concentration of the irrigation water: S1 = nutrient solution (ECw = 1 dS.m-1) and S5 = nutrient solution plus saline water (ECw = 5 dS.m-1). Both of them were installed in two growth chambers, the first with 800 (C1) and the second with 400ppm (C2) of CO2 injected inside each chamber and controlled by electronic system.

In order to obtain saline concentrations in the irrigation water, the salts from fertilizers recommended for fertigation of this crop were used, according to Campagnol (2009). In addition to the fertilizers, the sodium chloride and calcium chloride salts were also used in a ratio of 2: 1, in order to obtain the saline concentration of the treatments.

In each chamber, treatments were arranged in randomized blocks, with four replicates (each replicate = three pots, with one plant per pot). Above each experimental block, at a height of 2.2 m, there was an iron structure and from that structure a narrow ribbon plastic was attached to each vessel. As the plant grew, the main branch was wrapped in narrow ribbon plastic. The plants were driven vertically until they reached 2.2 m, then the apical meristem of the main branch was cut.

Daily, all female flowers on the main branch were pollinated manually up to 1.5 m from the base of the plant. When the fruits had a diameter of approximately 0.10 m, they were bagged in nylon nets and hang up. Only one fruit per plant was left.

Plant height (PH), stem diameter (SD), number of leaves (NL) and number of secondary branches (NB) were measured in the main branch of the mini watermelon plant.

To quantify the stomatal conductance (SC), a SC-1 model leaf particle was used, measuring the first mature leaf located at 1.5m from the substrate, during flowering and during fructification.

The leaf area (LA) was obtained by means of the electronic meter CI-203CA (CID Bio-Science), measuring the leaves of the main branch of each plant. From these leaves, the fresh leaf mass (FLM) was also measured by means of a scale. After drying in an electric oven (60 ° C), the dry leaf mass (DLM) was obtained after weighing. With the MSF and MFF data it was possible to estimate leaf water content (LWC).

At the end of the experiment, five fruits of each treatment were collected, totaling 20 fruits. In the fruits, the physical variables were analyzed: fruit mass (FM), fruit diameter (FD), pulp diameter (PD), shell thickness (ST) and pulp firmness (PF).

The results obtained in the experiments were submitted to analysis of variance, using t test analysis and unfolding based on the tukey test at a 5% probability level.

RESULTS AND DISCUSSION

Plant height (PH) and number of secondary branches in the main branch (NB) were affected by salinity (Table 1); however, stem diameter (SD) and number of leaves (NL) variables were not affected by Salinity (Table 1).

The increase of atmospheric CO_2 affected positively the stem diameter (SD), giving a higher average for the plants grown in a growth chamber with 800ppm of atmospheric CO_2.

The other variables: PH, NL and NB did not differ statistically at a 5% probability level by the Tukey test (Table 1).

There was no statistical difference, although the height of the plant presented higher values for growth chamber with CO_2 concentration of 800 ppm. Pritchard and Amthor (2005) report that changes in plant metabolism, growth and physiological processes may undergo changes as a function of increasing CO_2 concentration in the atmosphere. That response was also observed in soybean growth in open-top greenhouses with CO_2 gas injection (LESSIN; GHINI, 2009). In the present study, the fact that there was no interaction between the increase in atmospheric CO_2 and the height of the plant was possibly due to the management used in the experiment, which, after reaching 2.2 m, had the apical meristem removed.

Fresh leaf mass (FLM), dry leaf mass (DLM), leaf water content (LWC) and leaf area (LA) were affected by salinity (Table 1). It was verified that the increase of atmospheric CO_2 also affected the leaf area (Table 1).

Akbariet al. (2015) also observed a negative effect of salinity on dry mass and plant height in maize plants. Salinity also affected the leaf area and dry mass of eggplant leaves (LIMA et al., 2015), as well as water content, fresh and dry mass of the basil shoot (BIONE et al., 2014).

The decrease of the leaf area due to the stress caused by the salinity is related to the difficulty of the plant in absorbing soil water (osmotic stress). Consequently, the decrease of the leaf area causes reduction of the area for transpiration of the plant, reducing the release of water by the leaves and it keeps the soil more humid (MUNNS; TESTER, 2008).

The treatment with higher concentration of CO2 (800ppm) and lower electrical conductivity in irrigation water (EC = 1dS / m) presented the highest average for the leaf area, a result different from that obtained by Rezende et al. (2002). These authors observed that well-irrigated pepper plants had a lower leaf area when cultivated in an environment with higher CO2 concentration. It is therefore evident that each culture has a distinct response to the increase in atmospheric CO2 and different types of stress.

The lower mean observed for leaf water content (LWC) verified for the saline treatment (CEa = 5 dS/m), shows that there were no mechanisms to increase the water content in the plant tissue in order to reduce the concentration of ions in this tissue, as observed by Sousa (2011).

Stomatal conductance (SC) was affected by salinity (Table 1). The stomatal response is undoubtedly induced by the osmotic stress of the salt around the root. Transpiration as well as leaf water potential are important mechanisms for plant tolerance to salinity (MUNNS; TESTER, 2008).

The growth chamber with 400ppm of CO_2 had higher mean values compared to the growth chamber with 800 ppm of CO_2 for stomatal conductance. The non-saline treatment, within the 400 ppm growth chamber, presented a higher mean, differing from saline treatment within the 800 ppm chamber (Figure 1A).

In vines treated with and without water stress and with and without increasing CO_2 concentration (700ppm), the plants under stress had lower values for SC, while plants without water stress and without increase in CO_2 concentration showed the highest values (LEIBAR et al., 2015). The results were similar to those obtained in the present study.

The variables related to the physical characteristics of the fruits of the mini watermelon, fruit mass (FM) and pulp diameter (PD) were affected by salinity. However, for the variables, shell thickness (ST) and fruit pulp firmness (PF), no significant effect of salinity was observed (Table 2).

Medeiros et al. (2008) working with two hybrids of melon, also observed that the increase of salinity resulted in the reduction of fruit mass. Teodoro et al. (2004) working with different irrigation blades in the watermelon crop (*Citrullus lanatus*), observed that productivity is affected by the lack of water in the soil, with a positive linear response from the lowest irrigation blade (118.6mm) to the highest irrigation blade (442,0mm). Comparing these results to those reported by Munns and Tester (2008), who found that salt ions around the roots tend to cause osmotic stress, making it difficult to absorb water by the roots of the plants, it can be said that the same Behavior was observed in the present study, affecting the variables related to the production of mini watermelon (FM and FDDP).

The results for the firmness of the mini watermelon pulp corroborated with the work of Gurgel et al. (2010). Those authors worked with two varieties of melon, in which no effect of salinity of the irrigation water on the firmness of the fruit pulp was observed.

For fruit mass and fruit pulp diameter, the saline treatment from the growth chamber with 800 ppm of CO_2 did not differ from the non-saline treatment of the growth chamber with 400 ppm of CO_2. It can thus be inferred that the increase of the atmospheric CO_2 favored the response to salinity for FM and PD. For the fruit mass (FM), such a response becomes more evident, since the saline treatment from the growth chamber with 800 ppm of CO_2 and the non-saline treatment of the 400 ppm of CO_2 differed from the non-saline treatment of the growth chamber with 400 ppm of CO_2 (Figure 1B).

Due to the increase of fruit production in some vegetables, the enrichment of CO_2 in a protected environment becomes attractive, although it is an expensive practice. However, CO_2 enrichment in irrigation water may be a more attractive alternative (CANIZARES et al., 2004).

An example of this is the result of mass and diameter of chili fruits irrigated with CO_2 enriched water, which provided higher values when compared to plants that did not receive irrigation water enriched with CO_2 (FURLAN et al., 2002).

CONCLUSIONS

The increase of CO_2 in the atmosphere of growth chambers affected fruit mass and diameter of the mini watermelon fruit in salt stress.

The enrichment of atmospheric CO_2 can be used to increase fruit production of the mini watermelon, with or without saline water in irrigation.

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Table 1. Averages of plant height (PH), stem diameter (SD), number of leaves (NL), number of secondary branches (NB), fresh leaf mass (FLM), dry leaf mass (DLM), leaf water content (LWC), leaf area (LA) and stomatal conductance (SC) of mini watermelon cv. Smile irrigated with water from different salt concentrations (ECw 1 and 5 dS.m-1) and grown in growth chambers with different CO_2 concentrations (400 and 800 ppm)

Treatment	PH (m)	SD (mm)	NL	NB	FLM (g)	DLM (g)	LWC (%)	LA (cm²)	SC mmol.m^{-2}.s^{-1}
ECw= 1dS/m	2,17 a	5,26 a	61,54 a	6,70 a	89,52 a	14,51 a	83,81 a	2179786 a	288,36 a
ECw= 5dS/m	1,91 b	5,04 a	62,34 a	3,86 b	61,21 b	11,25 b	82,05 b	1515656 b	213,92 b
CO_2 400 ppm	1,98 A	4,83 B	60,87 A	5,21 A	73,07 A	12,17 A	83,44 A	1711095 B	263,54 A
CO_2= 800 ppm	2,10 A	5,45 A	62,95 A	5,41 A	78,18 A	13,56 A	82,60 A	1981106 A	238,74 A
C.V.	16,0	14,9	15,7	44,6	23,1	30,9	2,5	27,9	24,0

Means followed by the same letter do not differ statistically from each other in the columns by the Tukey test at a 5% of probability, being the lower case between the treatments (CEa = 1dS / m and CEa = 5dS / m); and the upper case between treatments (CO_2 = 400 ppm and CO_2 = 800 ppm).

Table 2. Means of fruit mass (FM), pulp firmness (PF), shell thickness (ST) and pulp diameter (PD) of fruits of mini watermelon cv. Smile irrigated with water from different salt concentrations (ECw 1 and 5 dS.m-1) and grown in growth chambers with different CO_2 concentrations (400 and 800 ppm)

Treatment	FM (g)	PF (Kgf)	ST (mm)	PD (mm)
ECw= 1dS/m	1619,9 a	1,01 a	4,1 a	130,8 a
ECw= 5dS/m	1106,2 b	1,19 a	3,1 a	117,3 b
CO_2=400 ppm	1151,01 B	1,197 A	3,3 A	119,6 B
CO_2=800 ppm	1575,26 A	1,054 A	3,9 A	128,5 A
C.V.	10,2	22,8	30,8	4,5

Means followed by the same letter do not differ statistically from each other in the columns by the Tukey test at a 5% of probability, being the lower case between the treatments (CEa = 1dS / m and CEa = 5dS / m); and the upper case between treatments (CO_2 = 400 ppm and CO_2 = 800 ppm).

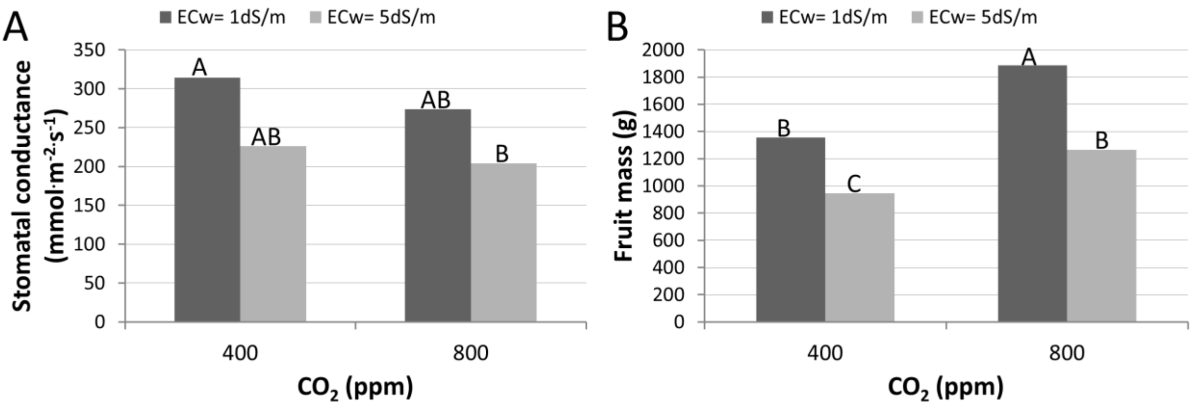

Figure 1. Stomatal conductance of plants (A) and Fruit mass (B) of mini watermelon cv. Smile irrigated with water from different salt concentrations (ECw of 1 and 5 dS.m-1) and grown in growth chambers with different concentrations of CO_2 (400 and 800 ppm). Means followed by the same letter do not differ statistically from each other by the Tukey test at a 5% of probability.