GAS EXCHANGE RESPONSE OF *Annona emarginata* (SCHLTDL.) H. RAINER UNDER WATER DEFICIT

RESPOSTAS DAS TROCAS GASOSAS DE *Annona emarginata* (SCHLTDL.) H. RAINER SOB DÉFICE HÍDRICO

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ABSTRACT

Widely used as rootstocks for economical Anonaceae, the araticum-de-terra-fria (*Annona emarginata*)shows tolerance to drought. However, studies on the physiological responses of this species to adverse environmental conditions are scarce. The aim of this study was to evaluate the gas exchange in *A. emarginata* plants submitted to water deficit. Therefore, plants were submitted to two treatments: control and water stress. Gas exchange measures were evaluated 12 days after the suspension of the irrigation. Water stress in araticum-de-terra-fria plants promoted reductions in all gas exchange variables, except for internal carbon values that was increased. When stomatal conductance decreases, but the internal carbon increases or appears constant, the decrease in CO_2 assimilation can be attributed to non-stomatal factors. Although the decreased stomatal conductance may also contribute to the photosynthesis reduction, the decreased CO_2 assimilation in araticum-de-terra-fria stressed plantsoccurred mainly because of carboxylation efficiency reductions.

Keywords: Water deficit. Annonaceae. A_{net}. Produtivity. g_s.

RESUMO

Amplamente utilizado como porta enxertos para Anonáceas de importância econômica, o araticum-de-terra-fria (*Annona emarginata*) apresenta tolerância à seca. No entanto, estudos sobre as respostas fisiológicas dessa espécie a condições ambientais adversas são escassos. O objetivo deste estudo foi avaliar as trocas gasosas em plantas de *A. emarginata* submetidas ao défice hídrico. Portanto, plantas foram submetidas a dois tratamentos: controle e estresse hídrico. Mediu-se as trocas gasosas 12 dias após a suspensão da irrigação. O estresse hídrico promoveu reduções em todas variáveis analisadas, com exceção da concentração de carbono interno (Ci) que aumentou. Quando condutância estomática (g_s) diminui e Ci aumenta ou permanece constante, a diminuição na assimilação de carbono pode ser atribuída a fatores não-estomáticos. Embora a redução da $g_s$também possa colaborar para esse decréscimo, a diminuição das taxas fotossintéticas em plantas estressadas de araticum-de-terra-fria é resultante da diminuição da eficiência de carboxilação.

Palavras-chaves: Défice hídrico. Anonaceae. A_{net}. Produtividade. g_s.

Drought is one of the most important abiotic stresses. It can influence the distribution of tree species, and limit the productivity of ecosystems (LARCHER, 2000). The photosynthetic assimilation is one of the physiological processes that can be affected by drought. Variations in the rate of CO_2 assimilation occur because of changes in stomatal conductance and photosynthetic capacity, in both photochemical and biochemical stages (DITMAROVÁ et al., 2010).

Species-specific differences in the ability to survive stress periods, may be an important factor influencing the distribution of the species (ENGELBRECHT; KURSAR; TYREE, 2005). Most species of Annonaceae naturally exhibit less photosynthetic capacity and greater capacity of conservation strategies of water use (FU et al., 2012). With the intention of obtaining Annonaceae orchards with high productivity, rootstock have been used (BRAGA, 2008). *Annona emarginata* (Schltdl.) H. Rainer (araticum-de-terra-fria) has been used as a rootstock for *Annona cherimola* x

Annona squamosal (atemoya) because higher survival, branch length and number of leaves were observed (ALMEIDA, 2009). According to Bonaventure (1999) and Tokunaga (2005), is tolerance specie to soils with water shortage. Therefore, this species may be an adequate alternative of rootstock for atemoya in soil under these conditions. In this way, we hypothesize that *A. emarginata* presents high water use efficiency even with a lower CO_2 input due to the stomatal closure in response to water stress, and may become the solution to increase productivity in environments where there is a lack of water. Therefore, the aim of this study was to evaluate the gas exchange in plants of *A. emarginata* submitted to the water deficit.

To achieve our objective, the seeds were sown in tubes (50mL) with substrate of expanded vermiculite in nursery at 50% shading. With average of 10cm of height, the plants were transplanted to polyethylene bags (4.5L) filled with expanded vermiculite of medium texture. Were irrigated daily with water and once a week with nutrient solution of Hoagland and Arnon (1950) diluted to 50% ionic strength (BARON et al., 2013) until the beginning of the experiment (524 days after sowing).

The experiment was conducted in a greenhouse (22°53 'S, 48°26 'W) with controlled system: relative air humidity of 50-70%, temperature of 25-29°C and photosynthetic photon flux density (PPFD) up to 1000 µmol $m^{-2}s^{-}1$. The experimental design was designed in randomized blocks of two treatments (Control - plants constantly irrigated; and Stress - total suspension of the irrigation for 12 days) with two replicates of four plants per pot for a total of 8 plants. Monitoring of water loss from the substrate was performed according to Thameur et al. (2012).

On the last day of irrigation suspension, the gas exchange variables were evaluated in the plants of both treatments at 8h, 9h, 10h, 11h, 12h, 14h and 16h (IRGA, LI-6400, LI-COR). Were analyzed: CO_2 assimilation rate (A_{net}, µmol CO_2 m^{-2} s^{-1}), stomatal conductance (g_s, mol m^{-2} s^{-1}), transpiration rate (E, mmol H_2O m^{-2} s^{-1}), internal carbon concentration (Ci, µmol CO_2 mol^{-1}air), carboxylation efficiency (A/Ci) (CAEMMERER; FARQUHAR, 1981) and water use efficiency

(A/E) (μmol CO_2 mmol H_2O^{-1}) (SINCLAIR et al., 1984). The measurements were performed on two leaves per individual and four individuals per treatment, on fully expanded 2nd and 3rd leaves. The results obtained were compared among the treatments by T test with 5% of probability.

After twelve days of irrigation suspension, the loss of water in the substrate dropped from 97% to 65%. In general, A_{net}, g_s, *E,* A/E and A/Ci of the plants under stress decreased, while Ci increased when compared to control. The first hour of evaluation (8h) showed that plants under stress had reduced values of A_{net}, A/E and A/Ci and higher Ci (Fig. 1). At 9h, the same pattern was observed, except for *E* values, which also had decrease in plants under stress (Fig. 1C). In the period from 10 to 12h, a pattern was observed, in which A_{net}, g_s, *E* and A/Ci were smaller in plants under stress (Fig. 1A, 1B, 1C and 1E). At 14h, the plants under stress only maintained the lower A_{net} and A/Ci (Fig. 1D and 1E). On the other hand, at the end of the afternoon (at 16h) only g_s and *E* were lower in relation to control group (Fig. 1B and 1C).

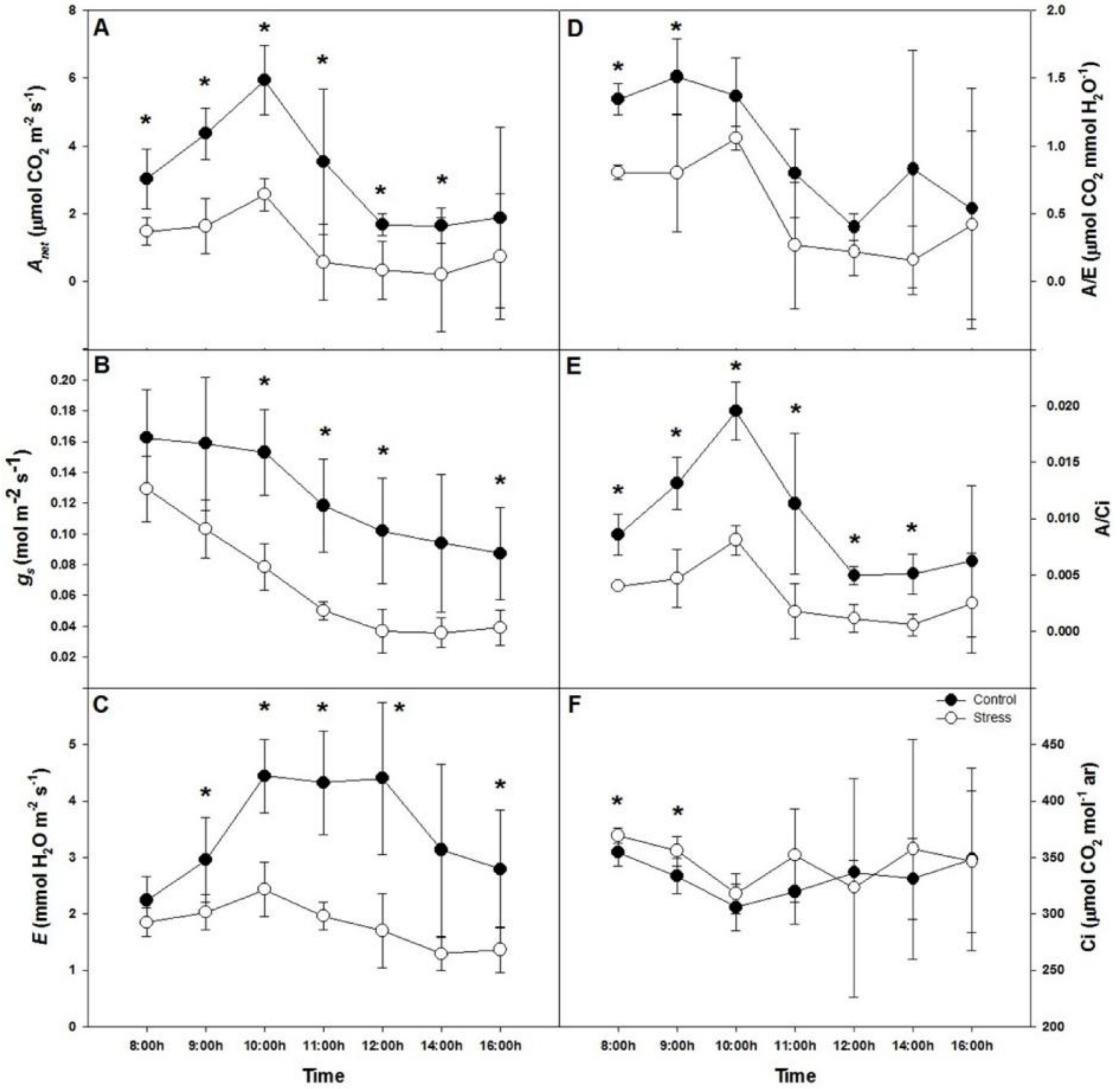
In general, the rate of A_{net} and other variables related to gas exchange is reduced at the end of the stress period, as a consequence of the decrease in soil water potential (SANTOS et al., 2006). The water deficit in the *A. emarginata* promoted reductions in the gas exchange, mainly in A_{net} and A/Ci, which had lower values than the control group during the whole day of evaluation (last day of stress) (Fig.1A and 1E). While A/E reduced and Ci increased in plants under stress only at the beginning of the day (Fig.1D and 1F). Moreover, in the case of g_s and *E,* the reductions were observed between 10h and 12h (Fig. 1B and 1C). According to Herrera et al. (2008), the reduction of A_{net} during stress can occur due to stomatal factors (resistance to CO_2 entry) and non-stomatal factors (low enzymatic activity in CO_2 assimilation), reflecting changes in g_s patterns and Ci. If the g_s decreases, the Ci increases or appears constant, the decrease in A_{net} can be attributed to non-stomatal factors (YAN et al., 2010). Non-stomatal factors are characterized by damage to the metabolism of photosynthesis, which may occur in the photochemical and/ or biochemical stages (FLEXAS, 2004). In addition, the evaluation of the A/Ci ratio allows inferring the damages caused in the biochemical stage (ENNAHLI; EARL, 2005). Thus, *A. emarginata* presents A_{net} reduction at the end of the stress period, mainly due to non-stomatal factors.

Between 9h and 12h, the pattern found in the concomitant reductions of A_{net}, g_s, *E* and A/Ci (Fig. 1) in stress plants due to the response of the hottest and driest period of the day. Many plant species, including other species of the *Anonna*, has a decrease in g_s in response to the high vapor pressure deficit found at midday, thus reduces water loss, presenting lower *E* values (ENDRES, 2007). This response is observed in the plants of the control group, since at midday period there is a decrease of g_s, and consequently decreases of *E* and A_{net}. All these changes probably contribute to reduce A/E values in control group from the 10h until the end of the day (Fig. 1D). The plants submitted to stress had the same pattern of response (Fig 1D). However, we cannot say that A/E at the control level is a mechanism of tolerance of the species.

The stomatal closure (observed in the reduction of g_s values) is the mainly responsible for the decrease of CO_2 diffusion (FLEXAS et al., 2006). However, when there is drastic reduction of g_s, the photosynthetic reduction occurs not only due to stomatal limitation, but also due to losses in the metabolism of photosynthesis (FLEXAS, 2004). Therefore, our g_s and A/Ci data (Fig. 1B and 1D) in stress plants further highlight the effect of A/Ci reduction on A_{net} reduction.

In view of the above, the g_s is a limiting factor, but not the main one, for A_{net} of *A. emarginata* plants under water stress. Finally, we suggest studies about the molecular responses involved in the control of non-stomatal factors. Such studies may help in possible genetic modifications in the species in order to increase their tolerance and productivity under stress.

Figure 1. Gas exchange of *Annona emarginata*plants in control and stress treatments in the last day of experiment. **A**) CO_2 assimilation (A_{net}). **B**) Stomatal conductance (g_s). **C**) Transpiration rate (*E*). **D**) Water use efficiency (A/E). **E**) Carboxylation efficiency (A/Ci) **F**) Internal carbon concentration (Ci). * represents statistical difference between treatments ($p<0,05$).



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