GAS EXCHANGE DYNAMICS IN GRAFTED PASSION FRUIT UNDER SALINE AND WATER STRESS

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ABSTRACT: The Brazilian northeast stands out in the production of passion fruit (*Passiflora edulis* f. flavicarpa Degener) and a large part of this production is impacted by abiotic stress. In this sense, the objective of this research was to evaluate the impact of water and saline stress on the physiology of cv. SCS437 Catarina (*P. edulis*) grafted on cv. UFERSA.BRS RM 153 (*Passiflora foetida* L.). An experiment was conducted under field conditions under four irrigation depths (L) (L1 = 40%, L2 = 60%, L3 = 80% and L4 = 100% of field capacity) and four levels of electrical conductivity (EC) of irrigation water (S) (S1 = 1.5, S2 = 3.0, S3 = 4.5 and S4 = 6.0 dS m^{-1}), constituting seven treatments, T1 (L1S1), T2 (L2S1), T3 (L3S1), T4 (L4S1), T5 (L4S2), T6 (L4S3) and T7 (L4S4), and four replications in randomized blocks. The CO_2 assimilation rate (A), transpiration rate (E), stomatal conductance (gs) and water use efficiency (WUE) were evaluated. Grafting increased the productive performance of cv. SCS437 Catarina under abiotic stress. The plants showed significant gains in total yield, commercial yield and pulp yield under salt stress of up to 4.5 dS m^{-1}. The transpiration rate decreased linearly with increasing water deficit, whereas water use efficiency and intrinsic water use efficiency decreased with increasing EC.

KEYWORDS: *Passiflora foetida* L.; abiotic stress; salinity. UFERSA BRS RM 153; SCS437 Catarina.

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DINAMICA DAS TROCAS GASOSAS EM MARACUJÁ ENXERTADO SOB ESTRESSE SALINO E HÍDICO

RESUMO: O nordeste brasileiro se destaca na produção de maracujazeiro-azedo (*Passiflora edulis* f. flavicarpa Degener) e grande parte dessa produção é impactada por estresse abiótico. Nesse sentido, o objetivo desta pesquisa foi avaliar o impacto do estresse hídrico e salino na fisiologia da cv. SCS437 Catarina (*P. edulis*) enxertada na cv. UFERSA.BRS RM 153 (*Passiflora foetida* L.). Um experimento foi conduzido em condições de campo sob quatro lâminas (L) de irrigação (L1= 40%, L2= 60%, L3= 80% e L4= 100% da capacidade de campo) e quatro níveis de condutividade elétrica (CE) da água de irrigação (S) da água (S1= 1,5, S2= 3,0, S3= 4,5 e S4= 6,0 dS m^{-1}), constituindo-se sete tratamentos, T1 (L1S1), T2 (L2S1), T3 (L3S1), T4 (L4S1), T5 (L4S2), T6 (L4S3) e T7 (L4S4), e quatro repetições em blocos casualizados. Avaliou-se taxa de assimilação de CO_2 (A), taxa de transpiração (E), condutância estomática (gs) e eficiência do uso da água (EUA). A enxertia aumentou o desempenho produtivo da cv. SCS437 Catarina sob estresse abiótico. As plantas apresentaram ganhos significativos de rendimento total, comercial e rendimento de polpa sob estresse salino de até 4,5 dS m^{-1}. A taxa de transpiração reduziu linearmente com o aumento do déficit hídrico, ao passo que a eficiência no uso da água e eficiência intrínseca no uso da água diminuíram com o aumento da CE.
PALAVRAS-CHAVE: *Passiflora foetida* L.; estresse abiótico; salinidade. UFERSA BRS RM 153; SCS437 Catarina.

INTRODUCTION

The cultivation of passion fruit faces several challenges. In northeastern Brazil, the main ones are saline and water stress. As highlighted by Gull, Lone et Wan (2019), plants subjected to these adverse conditions present a series of physiological and morphological responses, including reduced photosynthetic rate, stomatal closure, and decreased carbohydrate synthesis. These negative effects compromise plant growth, development, and productivity.

Salt and water stress profoundly affect the morphophysiological and biochemical aspects of passion fruit. According to Gheyi et al. (2016), plants subjected to high salt concentrations modify their lipid metabolism, reduce the photosynthetic rate, and adjust stomatal conductance to minimize water loss through transpiration. These morphological and physiological changes are essential for the plant's survival under adverse conditions, but they can compromise its productivity in the long term.

In addition, grafting becomes a promising strategy to mitigate the effects of saline and water stress in passion fruit cultivation. As discussed by Souza et al. (2023), grafting offers resistance to diseases and pests, as well as greater tolerance to adverse soil conditions. This technique allows the selection of rootstocks adapted to saline environments and with greater efficiency in water absorption, contributing to the maintenance of productivity under challenging conditions. Thus, the objective of this research was to evaluate the impact of water and saline stress on the physiology of cv. SCS437 Catarina grafted on cv. UFERSA.BRS RM 153.

MATERIAL AND METHODS

The experiment was conducted in the field, installed in February 2021 at Sítio Cumaru, Upanema/RN, located at the geographic coordinates of 5° 33' 34.66" south latitude, 37° 11' 56.11" west longitude. The climate of the region is BSwh' (semiarid, hot and dry), according to the Köppen classification. The data for this study were collected in the second year of cultivation, between January and August 2022, except for the physiology data, obtained in August and October 2021. The seedlings were produced at the "Seedling Production Unit" of UFERSA/Mossoró. The UFERSA BRS RM-153 cv. was used as rootstock and the SCS437 Catarina cv. was used as graft. The grafting method used was full cleft grafting. During the seedling production process and after grafting, the seedlings remained in a greenhouse under 50% shade and were irrigated daily.

Sixty days after grafting, they were transplanted into the field. Before planting, soil collection and analysis were carried out to determine the fertilization of the foundation and covering; the values are shown in Table 1. The plants were trained in vertical espaliers. The holes were prepared with soil material from the first 10 cm and mixed with 2.0 L of sheep manure with a C/N ratio of 19:1, plus 200 g of monoammonium phosphate (MAP – 10-52-00).

Table 1: Physical-chemical characterization of soil (0 – 20 cm)

Chemical characterization								
P	K	Ca	Mg	Na	SB	EC	OM	pH
dm^{-3}	.... $cmol_c\ dm^{-3}$				....	$dS\ m^{-1}$	$g\ kg^{-1}$	(H_2O)
8.6	0.51	7.7	0,6	0,1	8,91	0,07	6,9	8,1
Physical characterization								
Sand			Silt			Clay		
....%..								
78.0			6.0			16.0		

Sum of bases (SB); Electrical conductivity: EC; Organic matter: OM.

The experiment was conducted in a completely randomized block design (CRD) with four replications. Eight plots were arranged per block, one border and seven treatments, each with six plants, five useful and one border, totaling 192 plants in a spacing of 3 m between rows x 4 m between plants (830 plants/hectare). The treatments were formed by combining different irrigation depths (L) and salinity levels (S). Seven treatments were constituted, being: T1 (L1S1), T2 (L2S1), T3 (L3S1), T4 (L4S1), T5 (L4S2), T6 (L4S3) and T7 (L4S4) where "L" represents the irrigation depths (L1 = 40%, L2 = 60%, L3 = 80% and L4 = 100% of crop evapotranspiration) and "S" the electrical conductivity (EC) of the irrigation water (S1 = 1.5, S2 = 3.0, S3 = 4.5 and S4 = 6.0 $dS\ m^{-1}$).

The salinity levels of the irrigation water were obtained from tubular well water with the addition of NaCl, $CaCl_2.2H_2O$ and $MgCl_2.6H_2O$ salts, in the equivalent proportion of 7:2:1 (Table 2) and the chemical characterization of irrigation water according to electrical conductivity (EC) is in the table 3.

Table 2: Sodium (NaCl), calcium (CaCl) and magnesium chloride ($MgSO_4$) in grams per m3.

EC	**NaCl**	**CaCl**	**$MgSO_4$**
$dS.m^{-1}$	.... g/m^3		
1.5	0	0	0
3.0	818	0	123
4.5	1373	294	308
6.0	1929	588	492

Electrical conductivity: EC.

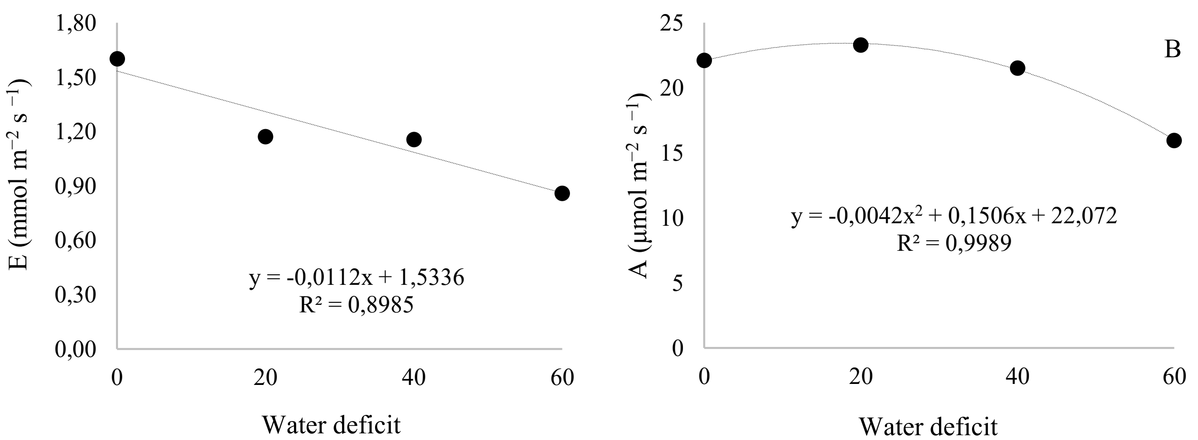
Table 3: Chemical characterization of irrigation water according to electrical conductivity (EC).

EC	Na	Ca	Mg	K	Cl	S04	HCO3
dS m^{-1}	.... cmol$_c$ dm^{-3}						
1.50	5.0	8.0	2.0	0.12	8.1	0.3	7.0
3.00	19.0	8.0	3.0	0.12	22.1	1.3	6.9
4.50	28.5	12.0	4.5	0.12	35.6	2.8	6.9
6.00	38.0	16.0	6.0	0.12	49.1	4.3	6.8

The CO_2 assimilation rate (A – µmol CO_2 m^{-2} s^{-1}), transpiration rate (E – mmol H_2O m^{-2} s^{-1}), stomatal conductance (gs – mmol H_2O m^{-2} s^{-1}) and water use efficiency (WUE – µmol CO_2 m^{-2} s^{-1}/mmol H_2O m^{-2} s^{-1}) were evaluated with a portable infrared gas analyzer (IRGA). The collected data were subjected to analysis of variance using the F test ($p<0.05$) and regression analysis was performed for the contrasts of slides within S1 (CEa=1.5 dS m^{-1}) and salinity within slide L4 (100% of ETc), using Excel applying the linearized model ($Y = a + b Xn$, where n = 1, 1.2, 2, 2.5 and 3) in the transformation of the data with variation of n from 1.5 to 3.0, for better adjustment of the curve and the quadratic polynomial model.

RESULTS AND DISCUSSION

Different results were found for the variables evaluated according to the analysis of variance, except for gs, a significant difference ($p<0.05$) was observed for E and A when the different water deficits were evaluated within the EC 1.5 dS m^{-1} and for E and EUA when different electrical conductivities were evaluated within the 100% layer. Figure 1 presents the regressions for these variables.



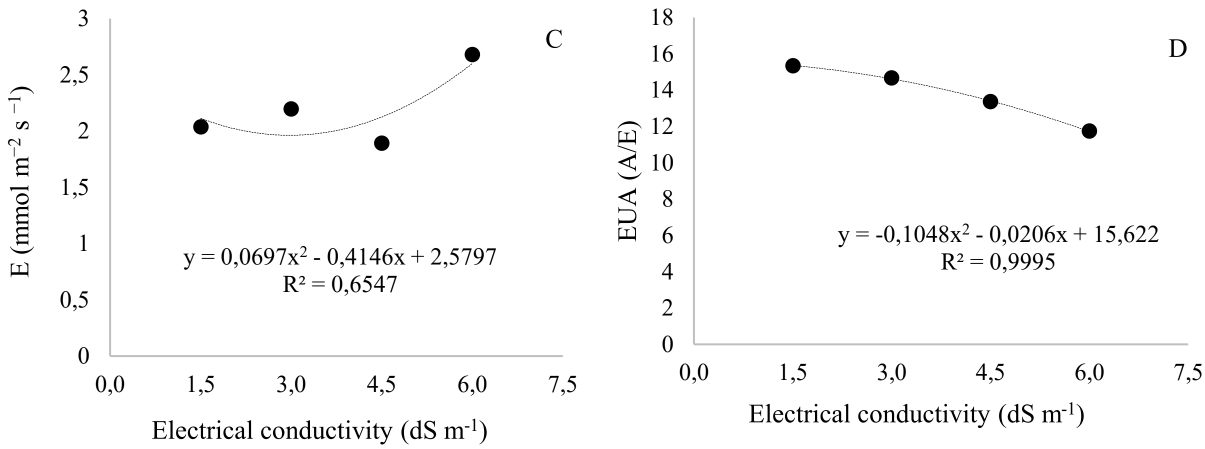


Figure 1. Regression for transpiration rate (E), CO_2 assimilation rate (A), water use efficiency (EUA) in passion fruit cv. SCS437 Catarina grafted on cv. UFERSA BRS RM-153 grown under different electrical conductivities (EC) and different water deficits. Source: Author.

The transpiration rate (E) under water deficit conditions under irrigation with water of 1.5 dS m^{-1} (Figure 1A) showed a linear decrease of 26.8, 27.8 and 46.3%, respectively, for deficits of 20, 40 and 60% of water requirement. The CO_2 assimilation rate (A) (Figure 1B) showed a decreasing quadratic behavior, increasing by 5.4% for the 20% deficit and then decreasing in the other deficits. The "E" under different electrical conductivities (EC) in the absence of water deficit (Figure 1C) showed an increasing quadratic behavior of 31.5% for the EC of 6.0 dS m^{-1} compared to the EC of 1.5 dS m^{-1}. Water use efficiency (EUA) was significantly reduced and its data showed a decreasing quadratic behavior (Figures 1D. For WUE, the reduction between the extremes of EC was 23.5%.

Investigating plant responses to increasing water deficit, focusing on the underlying physiological mechanisms and correlating them with relevant scientific research, we observed a significant reduction in transpiration rate with increasing water deficit. The main mechanism responsible for the reduction in transpiration under water deficit is stomatal closure (VADEZ et al., 2024).

The reduction in transpiration rate can also be explained by the reduction in leaf area, resulting from the abscission of old leaves and/or the production of smaller leaves, reducing the transpiration surface (CAMPOS et al., 2023), in addition to the accumulation of solutes in the cytoplasm, such as proline and betaine, maintaining turgidity and cellular function under water stress (SHARMA et al., 2024). However, since these variables were not measured, this is only one possible explanation for this response. The additional observation of a reduction in the CO_2 assimilation rate (Figure 3B), coupled with a decrease in the transpiration rate, adds a significant layer to our understanding of the passion fruit's response to water stress. CO_2 assimilation in the stomata is essential for the production of carbohydrates and other organic compounds. However, a reduction in the transpiration rate, coupled with water deficit, directly influences stomatal movement, resulting in reduced CO_2 entry into the leaf, negatively affecting the assimilation rate (GHEYI et al., 2016).

The reduced transpiration rate suggests that the plant may be prioritizing water conservation over CO_2 assimilation under higher levels of water stress. This conservative strategy may be an adaptive response to ensure plant survival under adverse conditions, even if it leads to a reduction in photoassimilate production, as suggested by Sabir et al. (2020) when evaluating the physiological response of Z. jujuba under water deficit.

Regarding the transpiration rate evaluated under different EC, an increase was observed with increasing EC, as found by Souto et al. (2022) when evaluating the application of plastic film mulching and irrigation with saline water on the gas exchange, photosynthetic efficiency, and productivity of yellow passion fruit grafted onto P. cincinnata. This result may be associated with the rootstock species, which, because it tolerates salinity of 4.0 dS m^{-1}, may have positively influenced the transpiration rate, acting as a "protector" for the graft, allowing it to maintain higher transpiration rates under saline conditions, possibly due to better water management (SOUZA et al., 2023).

The variables presented above are directly correlated with water use efficiency, which refers to the plant's efficiency in converting absorbed water into biomass or production based on the relationship between CO_2 assimilation rate (A) and transpiration rate (E). The higher the ratio, the higher the EUA, as EUA is proportional to A and inversely proportional to E. The significant 23.5% reduction in EUA under EC 6.0 dS m^{-1} conditions can be explained by the 31.5% increase in transpiration rate without a corresponding increase in CO_2 assimilation rate (5.8%), indicating greater water loss without a proportional benefit in terms of carbon fixation (SILVA et al., 2022).

CONCLUSIONS

Under normal water regime, the rootstock provided higher transpiration rates in saline conditions, due to better water management. Increasing salinity reduced water use efficiency and a water deficit of up to 20% increased the CO_2 assimilation rate.

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