

Citrullus lanatus morphophysiological responses to the combination of salicylic acid and salinity stress

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ABSTRACT: The salinity of irrigation water is one of modern agriculture's major obstacles, as it can damage the plants metabolism and, consequently, its development. Currently there is a great demand for substances that may mitigate such effects, such as salicylic acid. Thus, this study aimed to evaluate the effects of salicylic acid application on watermelon plants (*Citrullus lanatus* L.) under salinity stress. The experimental design was a randomized block design, in an incomplete factorial scheme, with four replications and two plants per replicate. The treatments resulted from the combination of five concentrations of salicylic acid (0.00, 0.15, 0.50, 0.85 and 1.00 mM) and five electrical conductivities of the irrigation water (0.50, 1.01, 2.25, 3.49 and 4.00 dS m⁻¹). The development, gas exchange, chlorophyll index and fluorescence were evaluated 30 days after transplanting. This data was submitted to analysis of variance and then confidence bands (confbands) and Pearson correlation were produced. The application of salicylic acid (up to 0.85 mM) promotes beneficial effects for the watermelon plants morphophysiology, while the increase in electrical conductivity of the irrigation water is harmful.

Key words: development; gas exchanges; photosynthesis; salinity; watermelon

Respostas morfofisiológicas da combinação de ácido salicílico e estresse salino em *Citrullus lanatus*

RESUMO: A salinidade da água de irrigação é um dos grandes entraves da agricultura moderna, podendo causar danos ao metabolismo e, conseqüentemente, ao desenvolvimento das plantas. Atualmente há uma grande demanda por substâncias que possam atenuar tais efeitos, dentre elas destaca-se o ácido salicílico. Com isso, objetivou-se avaliar os efeitos da aplicação de ácido salicílico na cultura da melancia (*Citrullus lanatus* L.) sob estresse salino. O delineamento experimental foi em blocos casualizados, em esquema fatorial incompleto, com quatro repetições e duas plantas por repetição. Os tratamentos resultaram da combinação de cinco concentrações de ácido salicílico (0,00; 0,15; 0,50; 0,85 e 1,00 mM) e cinco condutividades elétricas da água de irrigação (0,50; 1,01; 2,25; 3,49 e 4,00 dS m⁻¹). Aos 30 dias após transplantio foram avaliados o desenvolvimento, trocas gasosas, índices e fluorescências de clorofila. Os dados foram submetidos a análise de variância e em seguida foram produzidas bandas de confiança (confbands) e correlação de Pearson. A aplicação de ácido salicílico (até 0,85 mM) apresenta efeitos benéficos para a morfofisiologia da melancia, enquanto o aumento da condutividade elétrica da água de irrigação pode apresentar efeitos deletérios.

Palavras-chave: desenvolvimento; trocas gasosas; fotossíntese; salinidade; melancia

Introduction

The practice of agriculture depends on several factors related to climate, soil and the plant, among which water is a key factor (Delgado et al., 2010). Arid and semi-arid regions are characterized low precipitation rates, high mean temperatures and high evaporation rates, making irrigation indispensable tool agricultural production (Lucena et al., 2018). In addition to the amount of water, another fundamental condition for agriculture cultivation in the semiarid regions is the quality of the irrigation water. The irrigation is often performed with water of marginal quality, usually obtained from underground wells containing high amounts of salts (Medeiros et al., 2008).

Water salinity causes disturbances in plant metabolism and growth, as well as in its biochemical and physiological processes. Thus, the plant needs to adjust to survive this adverse condition, being able to perform processes of adaptation in the absorption, transport and distribution of ions in its cells. Such changes may be seen in its development and physiology (El-Esawi et al., 2018).

Watermelon (*Citrullus lanatus* L.) is a plant species in the family Cucurbitaceae and one of the most cultivated vegetable crops in Brazil (Nunes et al., 2017). Watermelon is considered moderately tolerant to irrigation water salinity, i.e., it supports irrigation with electrical conductivity (ECw) of up to 2.0 dS m⁻¹, without losses in yield (Ayers & Westcot, 1999).

There is a diversity of literary works contemplating the effects of salinity on the cultivation of watermelon (Cheng et al., 2015; Sousa et al., 2016; Silva Júnior et al., 2017). These authors reported that salinity stress significantly affects the following variables: main branch length, stem diameter, leaf number, leaf area, root length, shoot dry mass, root dry mass, net CO₂ assimilation, transpiration rates, stomatal conductance and water use efficiency.

Numerous researches have been carried out to attenuate the salinity harmful effects on cultivated species, especially regarding the use of salicylic acid, which is implicated in plant salinity-stress responses (Ayyub et al., 2015; Silva et al., 2018). This acid acts as a regulator of plant development, taking part in several physiological processes, including defense responses to biotic and abiotic stresses (Miura & Tada, 2014). This hormone has a defensive function against various types of stress, mainly due to its properties as an oxidizing agent in cell membrane cytoplasm, as well as its chemical structure

(Tonel et al., 2013). Salicylic acid potentially generates a wide range of metabolic responses and measures photosynthetic parameters and plant water relations, depending on the applied concentration (Hayat et al., 2010). Pre-treatment with salicylic acid alleviated the adverse effects of saline stress on basil (*Ocimum basilicum* L.) based on Na⁺ and K⁺ contents (Parizi et al., 2011). Thus, the aim of this study was to evaluate the effects of salicylic acid application on watermelon (*Citrullus lanatus* L.) plants under salinity stress.

Materials and Methods

The experiment was carried out from January to March 2018, at a greenhouse in the Department of Plant Science and Environmental Sciences of the Federal University of Paraíba - UFPB, located in Areia, Paraíba, Brazil. The 'Crimson Sweet' watermelon cultivar seeds were soaked in salicylic acid solutions with different concentrations for a period of 12 hours. Seeds were then sown in 200 cells plastic trays, one per cell. A mixture of soil and organic compost, in a 1:1 ratio, was used to fill the trays, and its chemical characteristics are presented in Table 1.

At 15 days after sowing, when the seedlings presented 2 definitive leaves, the transplanting was done. The experimental units were composed of plastic tubes with 0.3 dm³ capacity, containing one plant each. The soil used to fill the tubes is classified as Oxisoil (Soil Taxonomy - USDA, 1999) (Latosoil in Brazilian classification - Embrapa, 2013), and the results of its chemical analysis are presented in Table 2.

The experimental design was a randomized block design in a 5 x 5 incomplete factorial scheme, with four replications and two plants per replicate. The treatments resulted from the combination of five concentrations of salicylic acid (SA - 0.00, 0.15, 0.50, 0.85 and 1.00 mM) and five electrical conductivities of the irrigation water (ECw - 0.50; 1.01, 2.25, 3.49 and 4.00 dS m⁻¹), generated from the Box Central Composite experimental matrix.

The irrigation was measured by means of drainage lisimetry (Alves et al., 2017). The water with the lowest salt concentration (0.5 dS m⁻¹) came from the UFPB supply system. To prepare the waters with higher electrical conductivities a mixture of salts containing NaCl, CaCl₂·2H₂O and MgCl₂·6H₂O, in a 7:2:1 ratio. The conductivity of the waters was measured using Instrutherm® portable conductivity meter (model CD-860).

Table 1. Chemical characteristics of the substrate used for the seedlings formation in the experiment.

pH (H ₂ O)	O.M. (%)	P (mg dm ⁻³)	K ⁺	Na ⁺	Ca ²⁺	Mg ²⁺	Al ³⁺	H ⁺ + Al ³⁺	BS	CEC	V (%)
7.4	4.08	46.57	50.85	0.22	5.57	3.92	0	1.12	9.84	10.96	89.77

O.M.= organic matter; BS= base sum; CEC= cation exchange capacity; V= base saturation.

Table 2. Chemical characteristics of the soil used in the experiment.

pH (H ₂ O)	O.M. (%)	P (mg dm ⁻³)	K ⁺	Na ⁺	Ca ²⁺	Mg ²⁺	Al ³⁺	H ⁺ + Al ³⁺	BS	CEC	V (%)
6.2	2.48	24.85	78.42	0.07	3.9	1.9	0	2.43	6.07	8.5	71.46

O.M.= organic matter; BS= base sum; CEC= cation exchange capacity; V= base saturation.

At 30 days after transplanting, the development variables (stem diameter, main stem length, leaf number and leaf area); gas exchange variables (stomatal conductance – g_s , net CO_2 assimilation rate – A , transpiration rate – E , internal CO_2 concentration – C_i , water-use efficiency – WUE (A/E), instantaneous carboxylation efficiency – EiC (A/C_i), instantaneous water-use efficiency – iWUE (A/g_s) and leaf temperature – T_{leaf}); chlorophyll fluorescence parameters (initial fluorescence – F_o , maximum fluorescence – F_m , variable fluorescence – $F_v = F_m - F_o$), potential quantum yield of photosystem II – F_v/F_m and effective quantum yield of photosystem II – F_v/F_o); and chlorophyll contents (chlorophyll a, chlorophyll b, total chlorophyll and chlorophyll a/b ratio).

The variables were analyzed as follows:

a) stem diameter: determined at 2 cm from the soil, using a digital caliper graduated in mm;

b) main stem length: measured from the lap of the plant to the last leaf insertion, using a ruler graduated in cm;

c) leaf number: determined from the first basal leaf, with yellow and dry leaves being disregarded;

d) leaf area: measured with a graduated ruler, using the formula $LA = C * L * f$, where LA = leaf area; C = leaf length; L = leaf width; and f = correction factor for cucurbitaceae plants = 0.70, according to Almeida (2013);

e) gas exchanges: determined using an infrared gas analyzer (IRGA, portable model LI-6400, Li-color, Lincoln, Nebraska, USA). The readings were performed between 9 and 10 am. The CO_2 contents were set at $400 \mu\text{mol m}^{-2} \text{s}^{-1}$ and the luminous intensity at $1200 \mu\text{mol of photons m}^{-2} \text{s}^{-1}$. Young, recently expanded and well illuminated leaves, were evaluated.

f) chlorophyll fluorescence: measured with the modulated fluorometer Plant Efficiency Analyzer - PEA II® (Hansatech Instruments Co., UK). Foliar tweezers were placed 30 minutes before the readings for dark adaptation.

g) chlorophyll content: measured with a portable electronic chlorophyllmeter (model CFL 1030, ClorofiLog®), one reading per plant in recently expanded leaves. The content was expressed as Falker Chlorophyll Index (FCI).

The data were submitted to analysis of variance and then confbands were produced, from which is possible to observe the confidence intervals with 95% probability. In addition, the Pearson correlation and the graph produced using the Corplot statistical package (Wei & Simko, 2017) were performed using the R (R Core Team, 2018) software.

Results and Discussion

Through analysis of variance, it was observed that there was no significant interaction between the factors (using parametric statistical methods), nor any significant effect for the factors alone. Thus, confidence intervals (bands) were used to show the mean effect of each factor isolated for each analyzed variable.

Regarding the stem diameter, there were mean oscillations for the factors studied. The plants submitted to salicylic acid

(SA) had maximum stem diameters values (4.87 mm) at the dose of 0.15 mM (Figure 1A). While the values observed in response to salinity were higher at the electrical conductivity of 3.49 dS m^{-1} , with 4.93 mm (Figure 1B). However, there was a decrease when the ECw increased above this value. Similar results were obtained by Silva Júnior et al. (2017), who observed reduction in the stem diameter of watermelon plants with the increase of ECw above de 3.76 dS m^{-1} .

As with the stem diameter, for the main stem length the highest values were observed at the SA dose of 0.15 mM, with 25.79 cm (Figure 1C). When under salinity stress, the response decreased as ECw increased, with the highest value (28.60 cm) obtained at 0.5 dS m^{-1} salinity level and the lowest value (13.65 cm) at 4.00 dS m^{-1} , thus representing a 109.5% reduction (Figure 1D). Sousa et al. (2016) obtained similar results to those found in the present study, when working with the mini watermelon 'Smile'.

Regarding the leaf number, the highest mean value (8.19 leaves) was obtained at the lowest SA concentration (0.15 mM), with a decrease at 0.5 mM and subsequent increase in the higher doses (Figure 1E). Similar results were found by Ayyub et al. (2015), who observed increased leaf number in response to increased salicylic acid concentrations. Regarding the salinity treatment, the highest average was found at the ECw of 1.01 dS m^{-1} , with 9.25 leaves, decreasing at subsequent salinity levels, with the lowest average (5.50 leaves) obtained at 4.00 dS m^{-1} , representing a 68.2% decrease (Figure 1F).

For the leaf area, the highest value (22.08 cm^2) was observed at the SA dose of 0.50 mM, and the lowest (17.71 cm^2) at 1.00 mM (Figure 1G). As for the salinity response, it can be verified that the highest value (23.88 cm^2) was obtained at the ECw of 0.50 dS m^{-1} , while the lowest value was recorded at the ECw of 1.01 dS m^{-1} , increasing in the subsequent salinity levels (Figure 1H). The salinity decreased the number of leaves, however, increased the width and length of the leaves, which resulted in greater leaf area. These results differ from those found by Sousa et al. (2016), who obtained a decreasing linear response with the increase of irrigation water salinity.

According to Taiz et al. (2017), plants may present defense mechanisms when subjected to salinity stress, such as reduced leaf growth in order to reduce water loss through transpiration. However, Lima et al. (2017) states that the effects of salt stress depend on several factors such as the plant species and its development stage. With the application of SA, stomatal conductance (g_s) values tended to increase with increasing doses, starting from the 0.15 mM treatment (Figure 2A). The g_s values decreased as the ECw increased, emphasizing the salinity influence on stomata opening. The values ranged from 0.0323 to $0.0543 \text{ mol H}_2\text{O m}^{-2} \text{s}^{-1}$, at salinity levels of 0.5 and 4.0 dS m^{-1} , reducing 40.5% between the highest and lowest level (Figure 2B).

For the net CO_2 assimilation rate (A), in the absence of SA treatment, the highest values ($4.39 \mu\text{mol CO}_2 \text{ m}^{-2} \text{s}^{-1}$) were verified. The lowest A values were observed at 0.15 mM of SA, with an average of $3.12 \mu\text{mol CO}_2 \text{ m}^{-2} \text{s}^{-1}$ (Figure 2C). A decrease in A was observed as the ECw increased, except at

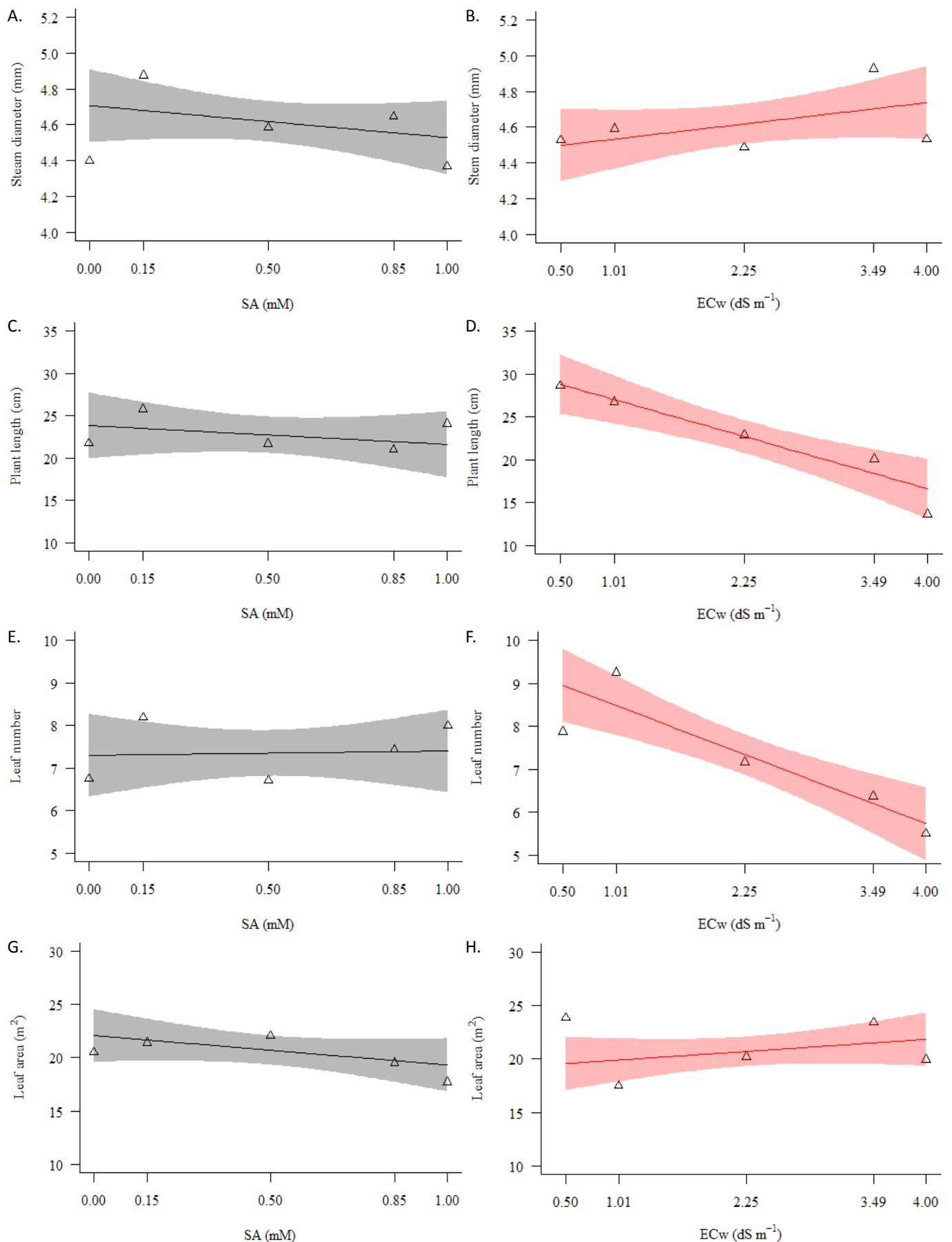


Figure 1. Stem diameter (A and B), main stem length (C and D), leaf number (E and F) and leaf area (G and H) of watermelon (*Citrullus lanatus* L.) plants submitted to salicylic acid (SA) and salinity stress (ECw).

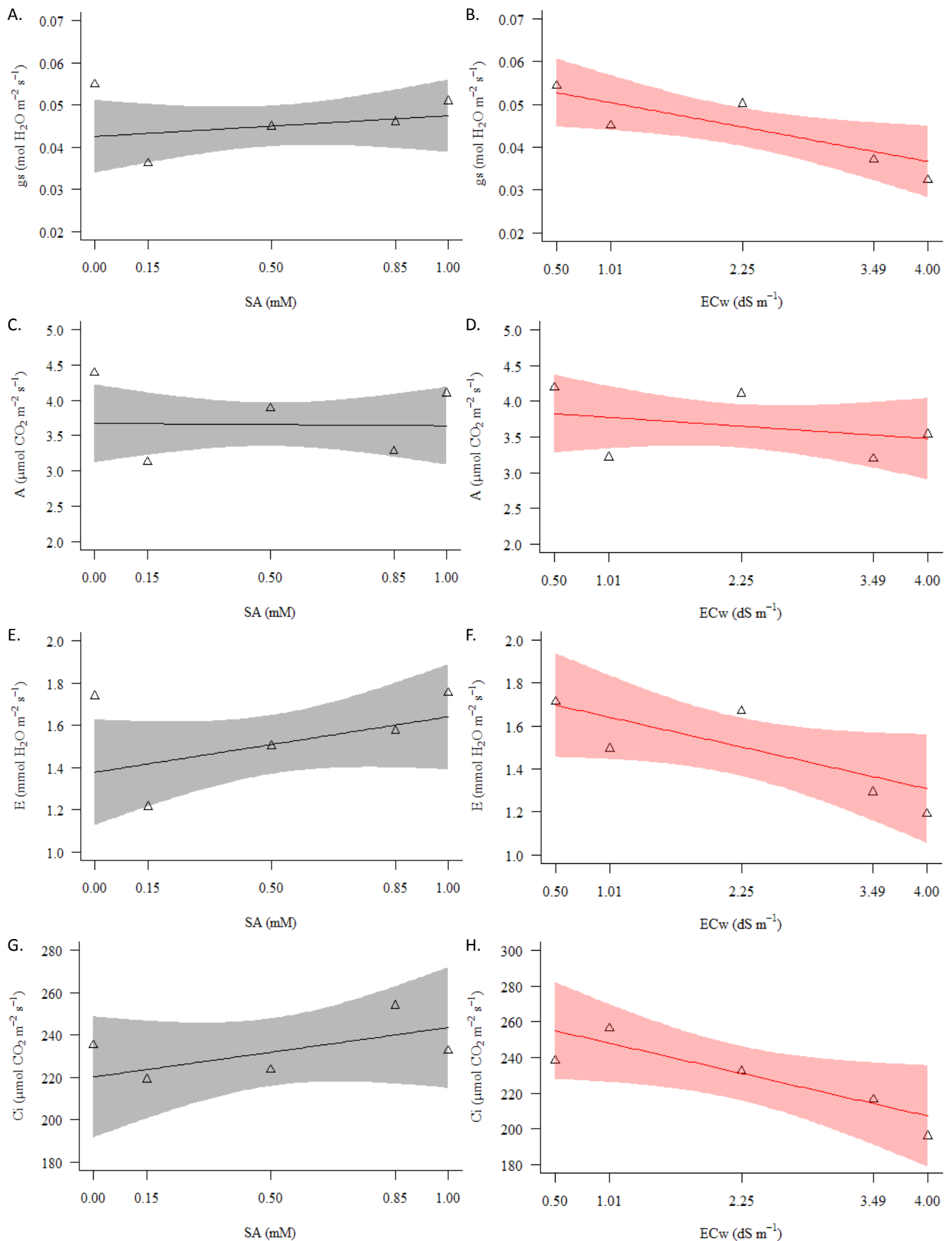


Figure 2. Stomatal conductance (gs - A and B), net CO₂ assimilation rate (A - C and D), transpiration rate (E - E and F) and internal CO₂ concentration (Ci - G and H) of watermelon (*Citrullus lanatus* L.) plants submitted to salicylic acid (SA) and salinity stress (ECw).

2.25 dS m⁻¹ in which a higher average (4.11 µmol CO₂ m⁻² s⁻¹) was verified (Figure 2D). The values ranged from 4.19 µmol CO₂ m⁻² s⁻¹ to 3.19 µmol CO₂ m⁻² s⁻¹, at 0.50 dS m⁻¹ and 3.49 dS m⁻¹ salinity levels, respectively, with a 23.8% decrease. When working with *Ficus carica* L., Silva et al. (2010) found that the photosynthetic rate (A) and stomatal conductance (gs) values were similar, emphasizing that the decrease in CO₂ assimilation is related to the partial closure of stomata.

The reduction in photosynthetic rates with the increase of the electrical conductivities may have occurred due to stomatal limitation, decreasing CO₂ entry in the leaves and thus influencing the net CO₂ assimilation (Taiz et al., 2017). According to some authors, salinity stress impairs the photosynthetic rate due to CO₂ diffusion resistance through stomata and changes in the photosynthetic metabolism (Munns & Tester, 2008; Mancarella et al., 2016).

Regarding the SA treatment, it was observed that the mean values of transpiration rate (E) increased with increasing doses. The highest (1.75 mmol H₂O m⁻² s⁻¹) and lowest (1.21 mmol H₂O m⁻² s⁻¹) mean values were obtained at 1.01 mM and 0.15 mM of SA, respectively (Figure 2E). According to the mean values of transpiration rate, it was verified that E decreased as ECw levels increased, ranging from 1.19 to 1.71 mmol H₂O m⁻² s⁻¹, at 4.00 and 0.50 dS m⁻¹ salinity levels, respectively, with a 30.41% decrease between the highest and lowest values (Figure 2F). The increasing magnitude of salinity stress (ECw) may have caused stomata closure, limiting the plants transpiration and reducing the photosynthetic rate (Silva et al., 2010). The excess salts in higher electrical conductivities levels may have affected nutrients uptake and concentration within the plant (Nobre et al., 2013).

Regarding the SA treatment, the highest values of internal CO₂ concentration (Ci) were found at the dose of 0.85 mM, with 253.86 µmol CO₂ mol⁻¹, and the lowest values were recorded at the dose of 0.15 mM (219.01 µmol CO₂ mol⁻¹) (Figure 2G). The high internal CO₂ concentration verified at the higher ECw level, can be explained by the fact that there is no flow during the photosynthetic process, not occurring the reduction of carbon to organic compounds (Taiz et al., 2017). Regarding the salinity treatment, the mean values for Ci decreased with the increase of ECw, except at 1.01 dS m⁻¹, where the highest values (256.28 µmol CO₂ mol⁻¹) were observed. The lowest Ci values (195.99 µmol CO₂ mol⁻¹) were verified at 4.0 dS m⁻¹ salinity level, representing a 23.5% reduction (Figure 2H).

Regarding the water use efficiency (WUE), it can be observed that the plants submitted to different doses of salicylic acid had a better response in the concentration of 0.15 mM, with an average of 2.763 µmol CO₂ mol H₂O⁻¹, then reducing with higher SA concentrations (Figure 3A). However, it is possible to observe an inverse effect in relation to the salinity stress treatment, that is, with the increase in salt stress, there was also an increase in water use efficiency (Figure 3B).

This behavior observed for the SA treatment responses may be related to increased transpiration rates in the plants submitted to larger doses of the growth regulator. On the other hand, the reduced transpiration produced by increasing

salinity levels prevents water loss in the form of vapor, since the efficiency in water usage is given by the relation between the photosynthesis and transpiration rates, in which the values obtained show the amount of carbon that the plant fixes for each unit of water it loses (Taiz et al., 2017).

The instantaneous carboxylation efficiency values in plants submitted to SA and different saline levels were similar, where the highest averages were obtained in the control treatments, with 0.019 and 0.018 [(µmol m⁻² s⁻¹) (µmol mol⁻¹)⁻¹] (Figure 3C and D). The carboxylation efficiency is obtained by relating the net CO₂ assimilation with the intracellular CO₂ concentration, making clear a close relationship between both (Machado et al., 2005). Based on the previous assertion, the behavior observed in the present work is mainly due to a similarity both to the intracellular CO₂ concentration and to the net CO₂ assimilation.

Studies on the effects of salicylic acid on watermelon gas exchanges are still scarce, however, Silva et al. (2014) reported that SA used in watermelon seeds imbibition has a positive effect on germination, germination speed, germination speed index and mean germination time, attributes that can influence both the growth and development of seedlings and consequently of plants. Still, Gastl Filho et al. (2017), working with cucumber (*Cucumis sativus* L.) plants, verified that the SA negatively influenced the germination test, mainly for the dry mass variables.

For the intrinsic water use efficiency, the SA dose of 0.15 mM provided the best response, with a mean value of 97.051 [(µmol m⁻² s⁻¹) (mmol m⁻² s⁻¹)⁻¹], decreasing with increasing doses (Figure 3E). Regarding the salinity, it can be observed that with increasing salinity levels the plants tended to use water more efficiently, obtaining the best results at 3.49 and 4.0 dS m⁻¹ salinity levels, with averages of 98.019 and 95.615 [(µmol m⁻² s⁻¹) (mmol m⁻² s⁻¹)⁻¹], respectively (Figure 3F).

These results may be related to a stomatal limitation, since under these concentrations of both salicylic acid and salts, the plants presented a lower stomatal conductance, resulting in a lower water loss through transpiration. Dalastra et al. (2014) working with melon (*Cucumis melo* L.), verified that plants subjected to some type of stress tend to reduce stomatal conductance and thus transpiration, which will consequently increase its water use efficiency.

The salicylic acid doses tested in the present study induced a small reduction in the leaf temperature, but when the plants were submitted to increasing salinity levels, the highest salt concentration provided an increase in leaf temperature, reaching 36.34 °C at 4.0 dS m⁻¹ salinity level (Figure 3G and H). According to Taiz et al. (2017) the plants cool their leaves through the transpiration process, however, due to drought stress that may occur with increasing salt concentrations, the stomata are closed, causing a rise of 2 to 5 °C in foliar temperature, a fact that can be observed in the present study.

The initial fluorescence (F₀) values obtained from the salicylic acid treated watermelon plants were higher in the plants submitted to the dose of 1 mM (115.0 quantum⁻¹ electrons) (Figure 4A). The observed behavior can be attributed to the SA role, since this compound acts in the regulation of

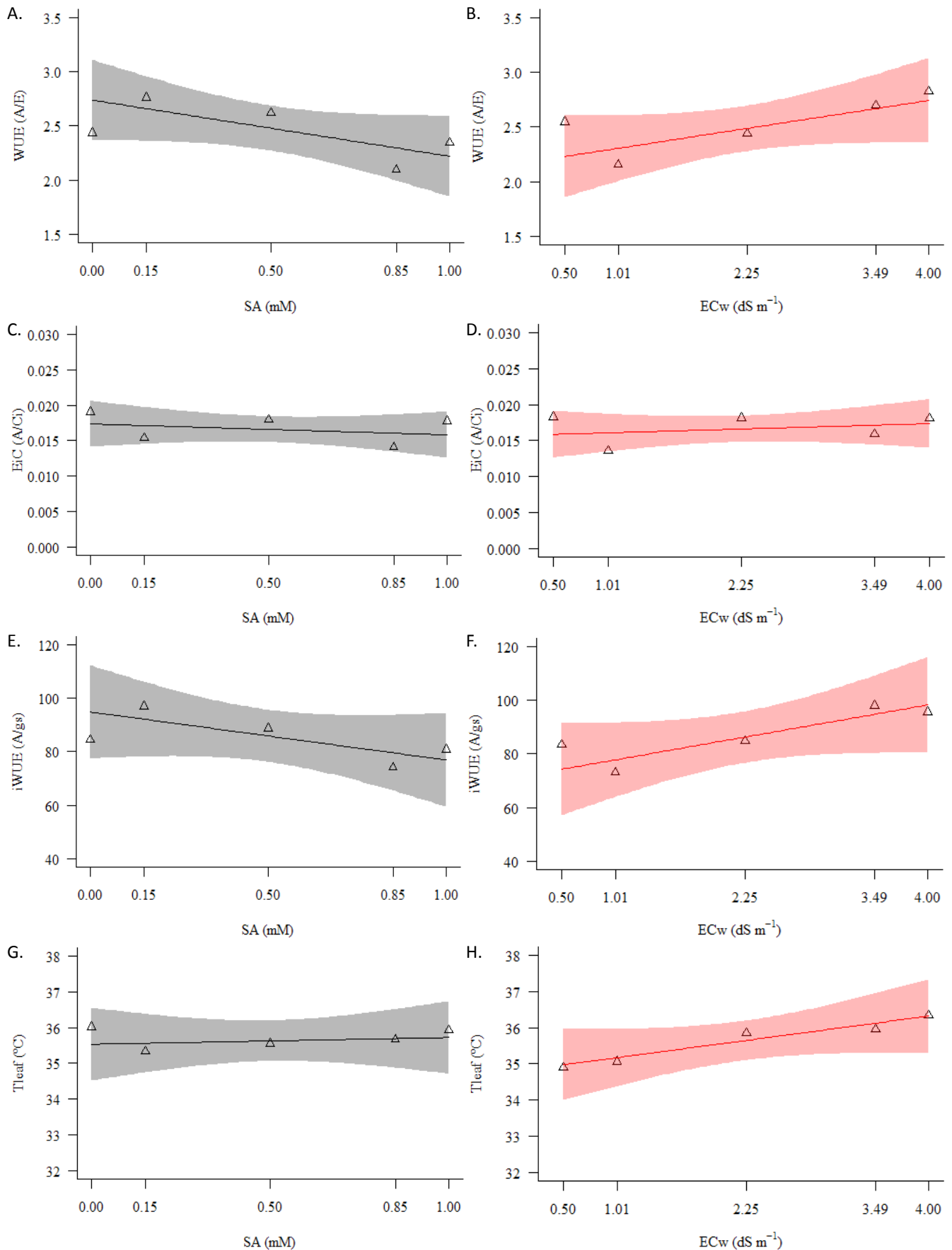


Figure 3. Water-use efficiency (WUE - A and B), instantaneous carboxylation efficiency (Eic - C and D), instantaneous water-use efficiency (iWUE - E and F) and leaf temperature (Tleaf - G and H) of watermelon (*Citrullus lanatus* L.) plants submitted to salicylic acid (SA) and salinity stress (ECw).

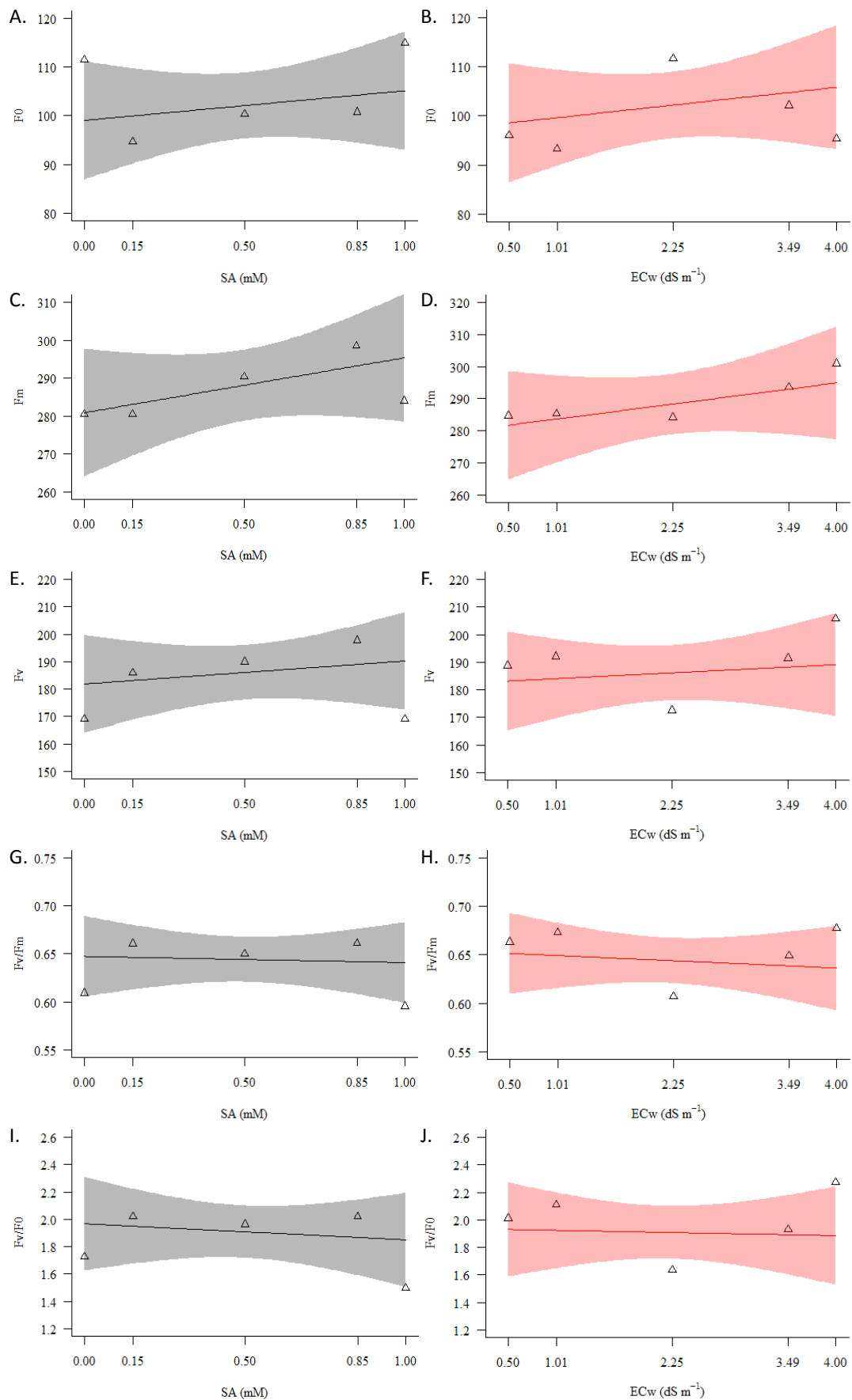


Figure 4. Initial fluorescence (F_0 - A and B), maximum fluorescence (F_m - C and D), variable fluorescence (F_v - E and F), potential quantum yield of photosystem II (F_v/F_m - G and H) and effective quantum yield of photosystem II (F_v/F_0 - I and J) of watermelon (*Citrullus lanatus* L.) plants submitted to salicylic acid (SA) and salinity stress (ECw).

plant defense mechanisms (Miura & Tada, 2014). Regarding the salinity treatment, the maximum F_0 value was verified at 2.25 dS m⁻¹ salinity level, with 111.6 quantum⁻¹ electrons (Figure 4B), decreasing from this ECw on.

The maximum fluorescence (F_m) registered for plants submitted to salicylic acid presented higher results at the dose of 0.85 mM, with 298.5 quantum⁻¹ electrons (Figure 4C). The values obtained as a function of the salinity levels show that the best results were obtained in the plants submitted to the electrical conductivity of 4.00 dS m⁻¹ (301 quantum⁻¹ electrons) (Figure 4D). Thus, these results demonstrate that the watermelon plants are tolerant to the saline levels tested, since the F_m estimates the relationship between the causes and effects that control the mechanisms of water balance and plant growth (Mancarella et al., 2016).

The variable fluorescence (F_v) presented a similar behavior, with the highest averages obtained in the plants submitted to the SA dose of 0.85 mM (197.7 quantum⁻¹ electrons) and at 4.00 dS m⁻¹ salinity level, with 205.6 quantum⁻¹ electrons (Figure 4E and F, respectively). This relationship occurs because F_m directly influences F_v , which is responsible for the potentially active energy of PSII (Sá et al., 2018). Thus, even when submitted to high salt concentrations, the watermelon plants did not present a reduction in the photochemical reactions. These reactions are regulated by the reaction centers that act on the quinone photoreduction and in the electrons transfer between PSI and PSII (Silva et al., 2015).

For the quantum yield of photosystem II (F_v/F_m) it can be observed that the plants submitted to 0.85 mM of SA presented the highest averages (0.661 quantum⁻¹ electrons) (Figure 4G). Regarding the salinity treatment, the highest F_v/F_m values were obtained in the plants submitted to the ECw of 4.00 dS m⁻¹, with 0.68 quantum⁻¹ electrons (Figure 4H). The observed behavior makes it clear that even under stress conditions promoted by the salinity, the PSII efficiency and yield was not affected by the salt levels tested. Tatagiba et al. (2014) state that in many cases high salts concentrations may not directly interfere in the photosynthetic apparatus, but can indirectly affect it through nutritional imbalance and turgor potential loss in the leaves.

The ratio between the variable and initial fluorescence (F_v/F_0) presented similar behavior to the quantum yield of PSII, with higher mean values at the SA dose of 0.85 mM (2.02 quantum⁻¹ electrons) and in the plants submitted to the greater ECw level (4.00 dS m⁻¹), with 2.27 quantum⁻¹ electrons (Figures 4I and J). The observed effect evidences that watermelon plants does not suffer reductions in the efficiency of its photosynthetic apparatus, as demonstrated in the effect on the gas exchanges. According to Lima et al. (2017), the intensity of the salinity stress effects on the gas exchanges depend on several factors, such as the plant species, and the sensitivity may be greater at different phenological phases of the plant.

For chlorophyll a, the SA dose of 0.85 mM provided the best response, with an average chlorophyll index (FCI) of 24.53 (Figure 5A). Regarding the salinity treatment, it can be

observed an increasing response with increasing salt levels, obtaining a minimum (20.84) and maximum (25.15) FCI value at 0.5 dS m⁻¹ and 3.49 dS m⁻¹ salinity level, respectively (Figure 5B).

Regarding chlorophyll b, it was observed that the lowest FCI value (4.97) was obtained in the absence of salicylic acid, while the maximum value (5.43) was verified at the SA dose of 0.85 mM (Figure 5C). For the salinity treatment, the lowest and highest mean were registered at the ECw of 0.50 dS m⁻¹ and 3.49 dS m⁻¹, respectively, with a FCI of 4.41 and 5.60 (Figure 5D). Similarly to chlorophyll b, the total chlorophyll best response for the salicylic acid treatment was provided at the dose of 0.85 mM, with a FCI mean of 29.96 (Figure 5E). Regarding the salinity treatment there was an increasing response for total chlorophyll, with the ECw of 4.00 dS m⁻¹ presenting the highest mean, with a FCI of 30.70 (Figure 5F).

For chlorophyll a/b ratio, plants that were not submitted to salicylic acid had the highest mean values, with a mean FCI of 4.67 (Figure 5G). Regarding salinity, the highest chlorophyll a/b ratio values were obtained in the plants submitted to the electrical conductivity of 0.5 dS m⁻¹, with a FCI of 4.85 (Figure 5H). Ram et al. (2014) demonstrated that the application of salicylic acid increases the chlorophyll a, b and total content in watermelon plants, results similar to the ones found in the present work.

Salinity stress causes the destruction of the chlorophyll molecule and promotes instability of the pigment-protein complex, decreasing chlorophyll content in plants (Jaleel et al., 2008). Jamil et al. (2007) claims that chlorophyll content reduces in salinity-sensitive plants and increases in salt-tolerant plants. As watermelon is not a salt-tolerant plant, the explanation for increased chlorophyll indices may be the fact that the evaluation was made 30 days after transplanting and the salinity stress effects may not have reached the chlorophyll content.

The highest positive correlations were observed (Figure 6) between chlorophyll a and b (0.93) and chlorophyll b and total (0.96). The highest negative correlations were observed between Cb and Cab (0.80), Tc and Cab (0.61) and Ca and Cab (0.54). Among chlorophyll fluorescence, the highest positive correlations were observed between F_v/F_m and F_v/F_0 (0.97), F_v and F_v/F_m (0.81), F_v and F_v/F_0 (0.79) and F_v and F_m (0.76); and negatives between F_0 and F_v/F_m (0.85) and F_0 and F_v/F_0 (0.84). Among the gas exchanges, the highest positive correlations were observed between iWUE and WUE (0.94), E and gs (0.91), Ci and EiC (0.90), A and E (0.68), gs and Ci (0.61), gs and A (0.53); and negatives between Ci and iWUE (0.96), WUE and Ci (0.94), WUE and EiC (0.86), iWUE and EiC (0.78), iWUE and gs (0.62), TL and Ci (0.61) and gs and WUE (0.58).

The high correlation (0.91) between gs and E is to be expected, since the greater opening of the stomata favors the greater transpiration by the plants, as well as the internal carbon concentration and, consequently, greater net photosynthesis. When studying *Aleurites fordii* plants, Caron et al. (2017) observed that the transpiration and stomatal conductance are related, evidencing that the transpiration

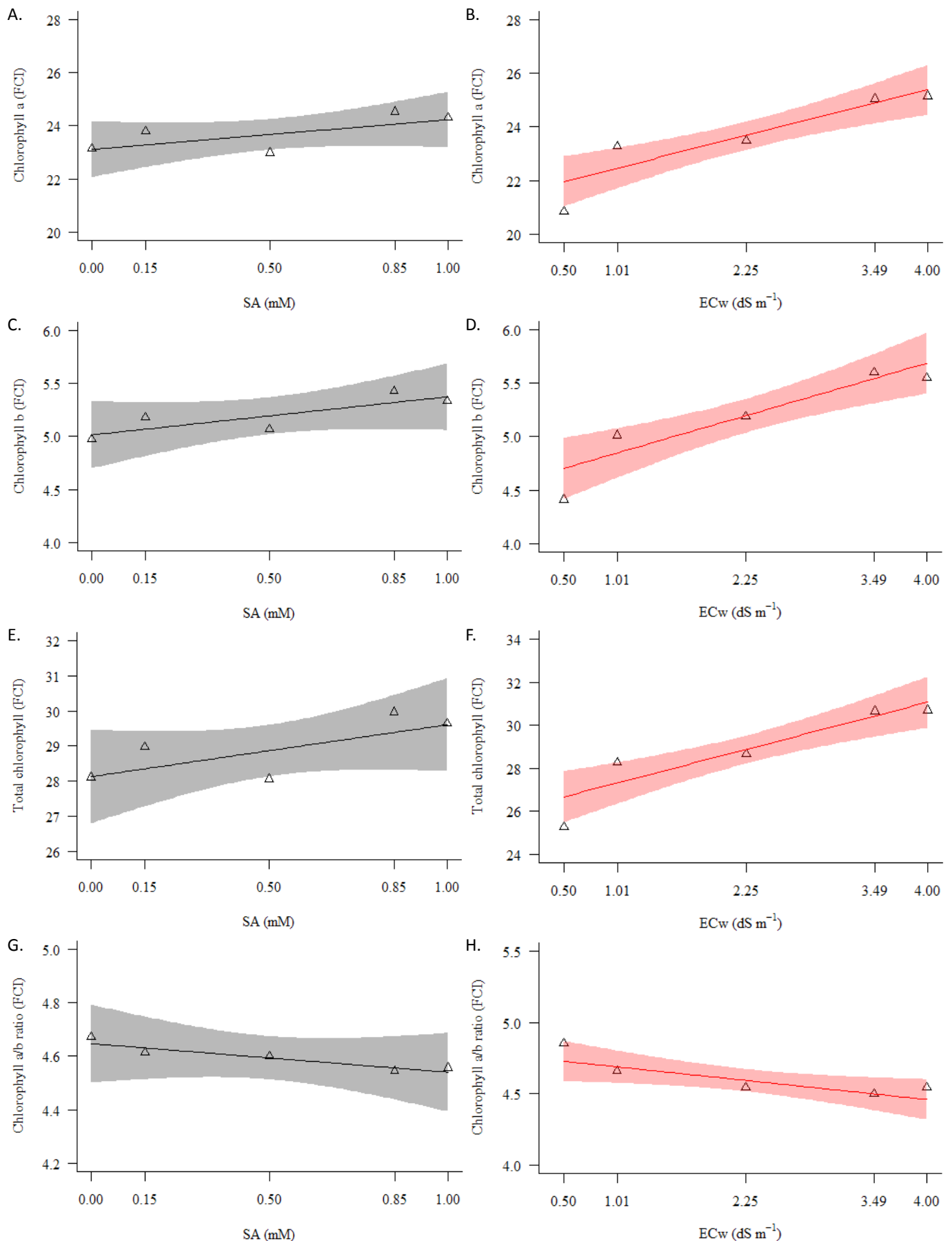


Figure 5. Chlorophyll a (A and B), chlorophyll b (C and D), total chlorophyll (E and F) and chlorophyll a/b ratio (G and H) of watermelon (*Citrullus lanatus* L.) plants submitted to salicylic acid (SA) and salinity stress (ECw).

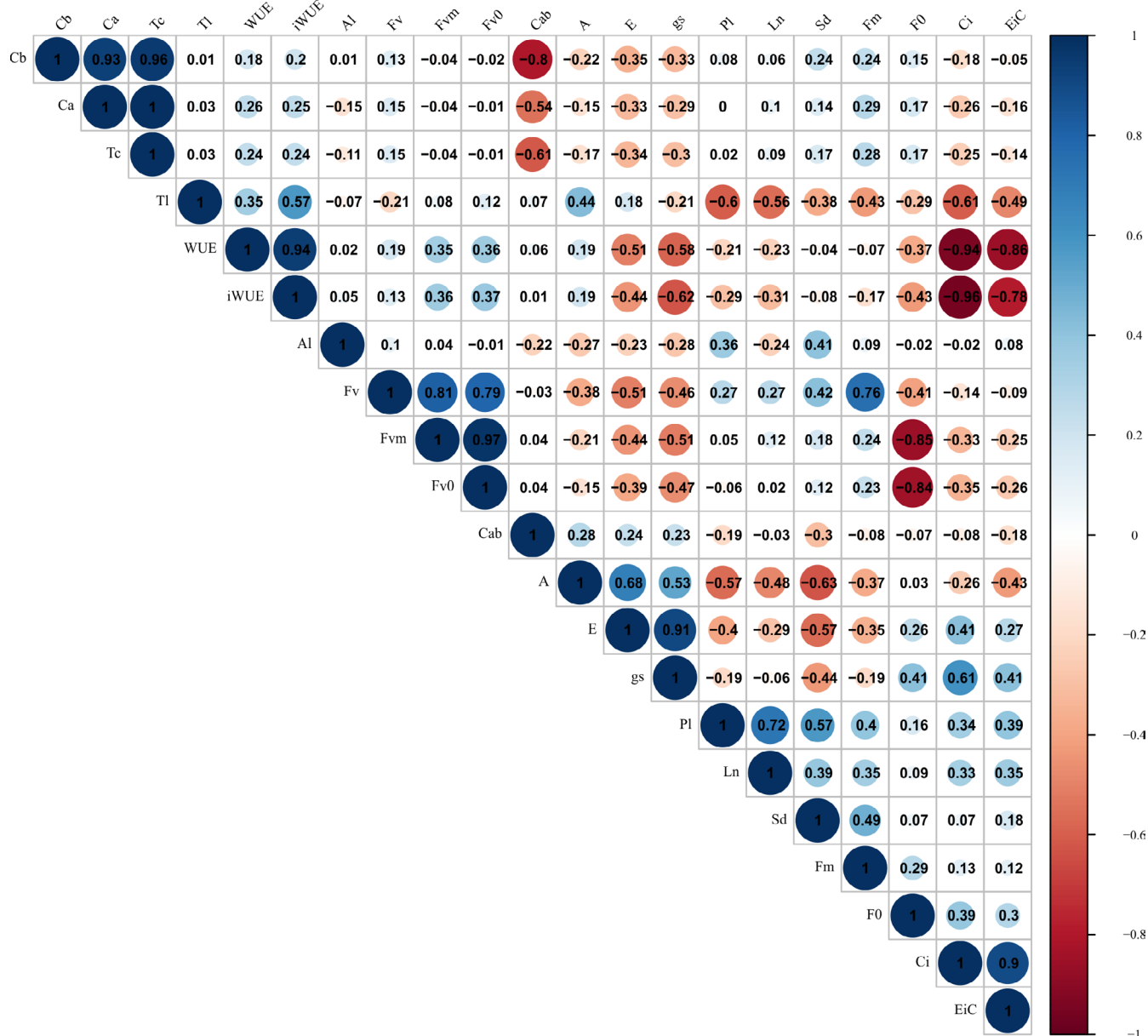


Figure 6. Pearson correlation between growth variables, gas exchanges, chlorophyll index and fluorescence of watermelon (*Citrullus lanatus* L.) plants submitted to salicylic acid and salinity stress.

rate decreases with the closure of the stomata and vice versa. As for the negative correlation between the F_0 and F_v/F_m and F_v/F_0 , it should be noted that the increase in F_0 significantly decreases these variables.

Conclusions

The salicylic acid (SA) has a beneficial effect on the growth of watermelon (*Citrullus lanatus* L.) up to the dose of 0.85 mM, and the electrical conductivity of the irrigation water (ECw) affects it negatively.

The gas exchanges (gs, A, E and Ci) are also positively affected by the increase in the concentration of this acid and negatively by the increase of the ECw.

The WUE, iWUE, EiC and Tleaf are positively affected by the increase in ECw. Chlorophyll fluorescence is positively

affected up to the SA dose of 0.85 mM and positively by the increase of ECw, except for F_0 .

It is noted that the increase in SA doses (up to 0.85 mM) and ECw levels (up to 3.49 dS m⁻¹) have positive effects on the chlorophyll indices. With this, it can be inferred that the application of salicylic acid (up to 0.85 mM) has beneficial effects on the watermelon plants morphophysiology, whereas the increase of ECw levels may cause deleterious effects.

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