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Salicylic acid in young 'BRS Vitória' vines under water stress

Ácido salicílico em mudas de videira cultivar 'BRS Vitória' sob estresse hídrico

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Highlights

An irrigation depth of 60% promoted leaf development.
A salicylic acid concentration of 1.5 mM increased catalase activity.
Lower fresh mass values were obtained at 120% irrigation.

Abstract

The economic importance of grapevines in Vale do São Francisco, Brazil, requires the production of young vines with good agronomic and physiological importance. Although environmental limitations such as water stress can reduce yields, salicylic acid (SA) can mitigate its harmful effects and minimize the water volume applied, since it is a signaling molecule that activates growth and vine defense responses, thereby ensuring the satisfactory development of young vines. The present study aimed to assess the agronomic, physiological, and biochemical characteristics of young 'BRS Vitória' vines under water stress and submitted to different salicylic acid doses. The experiment was conducted in a greenhouse, in a completely randomized two-factor design (five SA doses: 0; 0.5; 1.0; 1.5; 2.0 mM and four water regimes: 60, 80, 100 (control) and 120% of crop evapotranspiration), with eight repetitions. The variables assessed were total number of leaves, shoot fresh and dry mass, main stem length, average main stem diameter, number of nodes on the main stem, main stem internode length, activity of the antioxidant enzymes catalase (CAT) and peroxidase (POD), and lipid peroxidation. The results indicated that the irrigation depths and SA doses studied improved the development of young grapevines. Salicylic acid increased the number of leaves, fresh and dry mass, and number of nodes under 60% irrigation. In summary, SA attenuated the effects of water stress in young vines.

Key words: Plant Growth Regulator. *Vitis* spp. Water stress. Irrigation.

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Resumo

A importância econômica da videira no Vale do São Francisco, Brasil, implica na produção de mudas de videira com bom desempenho agronômico e fisiológico. As restrições ambientais, como o estresse hídrico, podem ocasionar na redução da produtividade, porém, a aplicação de ácido salicílico pode mitigar os efeitos deletérios do estresse hídrico e minimizar o volume de água aplicado, visto que é uma molécula sinalizadora para a ativação do crescimento e respostas de defesa da planta, mantendo o desenvolvimento satisfatório de mudas de videira. O objetivo do presente trabalho foi avaliar as características agronômicas, fisiológicas e bioquímicas em mudas de videira cv. BRS Vitória sob restrição hídrica, com aplicações de ácido salicílico. O experimento foi conduzido em casa de vegetação, utilizando delineamento inteiramente casualizado, em esquema fatorial duplo (cinco doses de ácido salicílico: 0; 0,5; 1,0; 1,5; 2,0 mM e quatro condições hídricas: 60, 80, 100 (controle) e 120% da evapotranspiração da cultura), com oito repetições. Determinou-se o número de folhas total, massa fresca e seca da parte aérea, comprimento do ramo principal, diâmetro médio do ramo principal, número de nós no ramo principal, comprimento do entrenó no ramo principal, atividade das enzimas antioxidantes catalase (CAT) e peroxidase (POD) e peroxidação de lipídios. Os resultados mostraram que as lâminas de água e as doses de ácido salicílico beneficiaram o desenvolvimento das mudas de videira. Para o número de folhas, massa da matéria fresca e seca e número de nós, o ácido salicílico promoveu maior desempenho quando aplicada a lâmina 60%. Em suma, o ácido salicílico apresentou-se como atenuador dos efeitos das restrições hídricas nas mudas de videira.
Palavras-chave: Regulador Vegetal. *Vitis* spp. Estresse hídrico. Irrigação.

Introduction

Agricultural production and its productive feasibility are directly linked to climate factors (Marengo et al., 2017) and subject to environmental limitations such as abiotic stresses, which influence vine development and can reduce yields (Ochieng et al., 2016). Among abiotic stresses, drought stress caused by water deficit is the most limiting factor, reducing photosynthesis by damaging chloroplasts and deactivating electron transfer (Sharma et al., 2012).

The harmful effects of water stress depend on its intensity and duration, as well as the intrinsic stress tolerance and phenological stage of the crop. On the other hand, over- irrigation contributes to increasing the water table which, in turn, can increase soil salinity, reduce the area explored by the root system, heighten nutrient loss through leaching and raise production costs. As a result, crop profitability may decline significantly (Soares & Costa, 1998). Thus, applying a smaller volume of water combined with products that exhibit physiological or growth-regulating effects, such as salicylic acid (SA), may mitigate the harmful effects of water stress by improving vine water use efficiency (WUE) (Dutra, 2015).

Evidence suggests that SA, a vine phenolic acid, acts as a signaling molecule for the activation of vine growth and defense responses, such as systemic acquired resistance and counterattacking pathogen infection (Klessig & Malamy, 1994), influencing a variety of vine physiological and biochemical processes, with significant effects on biotic and abiotic stress resistance (Szalai et al., 2000; Prabha & Negi, 2014).

Thus, given the economic importance of grapevines, especially in the Vale do São Francisco region of Brazil, it is important to use high quality young vines with good agronomic and physiological performance. However, soil and climate factors can influence the growth and development of young vines, particularly abiotic stresses such as water deficit (Affonso et al., 2015).

SA application combined with reduced irrigation can help maintain satisfactory crop yields and, in the case of young grapevines, improve photosynthesis and biomass production, thereby shortening the time to transplanting.

As such, the hypothesis of this study is based on the water stress attenuating effect of SA in young vines, and the aim was to assess the agronomic, physiological and biochemical characteristics of young 'BRS Vitória' vines under water deficit, submitted to different salicylic acid doses.

Material and Methods

The experiment was conducted between November and December 2019, in a greenhouse belonging to the Department of Technology and Social Sciences (DTCS) of Bahia State University, Campus III (9°25′14″ S and 40°29′08″ W; 360 m above sea level), in Juazeiro city, Bahia state (BA).

Minimum and maximum temperatures during the study period ranged from 18 to 25 and 26 to 39°C, with 39-85% relative humidity.

A completely randomized two-way (5 x 4) design was used, consisting of five SA doses and four water regimes, with eight repetitions. The young vines used were of the 'BRS Vitória' grape cultivar, obtained at RKF Mudas certified seedling nursery in Juazeiro (BA). The SA doses used in each treatment were 0, 0.5, 1.0, 1.5 and 2.0 mM, prepared by dissolving SA in 5 mL of absolute ethanol, topped up with distilled water and applied in conjunction with the irrigation depths. The water regimes analyzed were 60, 80, 100 (control) and 120% of crop evapotranspiration.

The young vines were planted in 5 L pots (one per pot) spaced 25 cm apart, filled with 1.5 kg of gravel at the bottom and 5 kg of soil collected on the university campus and classified as Fluvic Neosol, with the characteristics described in Table 1. The soil was fertilized in line with crop requirements, using 3 g of urea (45% N), 1 g of single superphosphate (18% P_2O_5, 16% Ca^{2+} and 10% S) and 1.5 g of potassium chloride (60% K_2O) per pot, in accordance with the recommendations for grapevine growing in the Brazilian semiarid (Soares & Leão, 2009).

Table 1

Physical and chemical characteristics of soil collected at 0-20 cm. UNEB, Juazeiro-BA, 2019

Checmical Attributes								Physical Attributes			
pH	OM	P	K^+	Ca^{2+}	Mg^{2+}	Na^+	H+Al	Sand	Silt	Clay	Textural Class
1:2.5	g/Kg	mg/dm³	$cmol_c/dm^3$					%			Sand
6.6	6.3	5.63	0.16	2.3	0.6	0.01	0.99	86	12	2	
BS($cmol_c/dm^3$): 3.06								V(%): 75			

Organic matter (OM); Sum of bases (SB); Base saturation (V).

The water depth for irrigation management and treatment application was established by measuring the capacity of the pots via a weighing lysimeter, with watering performed daily to maintain this capacity and vines submitted to full irrigation (100% of ETc) as baseline, considered the control treatment. The treatments with different irrigation depths began after seedling acclimation, two weeks after transplanting them to the pots.

The different SA doses were applied weekly for a total of five applications, the first performed two days after the irrigation treatments and the last 35 days after the first SA application. SA was applied using a backpack sprayer equipped with a JD 12 nozzle, working pressure of 45 psi and 2 L of spray solution per treatment, placing a plastic curtain between pots to prevent the spray from drifting.

The effects of the treatments were evaluated 20 days after the final SA application, based on the following biometric variables: total number of leaves, shoot fresh and dry mass (leaves and branches) (g), main stem length (cm), average main stem diameter (mm), number of nodes on the main stem and main stem internode length (cm).

For biochemical analyses, the leaves were collected, immediately frozen in liquid nitrogen and stored in a freezer at -18ºC until analysis. Three collections were performed, at 7, 21 and 35 days of water stress (DWS). The vine extract was obtained from 80 mg of vine material ground in liquid nitrogen for enzyme extraction, using a benchtop centrifuge (Thoth TH9300) and 2 ml Eppendorf microtubes, adapted from Kar and Mishra (1976), and 200 mg in 15 ml Falcon tubes for lipid peroxidation analysis.

For enzyme extraction, 2 ml of a solution containing 50 mM phosphate buffer (pH 6.7) and 1% (m/v) polyvinylpolypyrrolidone was added. The homogenate was centrifuged at 10,000 rpm for 25 min in a refrigerated centrifuge at 4°C and the supernatant collected for enzyme assays (Kar & Mishra, 1976). The specific activity of the antioxidant enzymes was determined by previously quantifying the soluble proteins of each enzyme extract according to Bradford (1976).

Catalase (CAT) activity was determined in line with Kar and Mishra (1976), reducing absorbance to 240 nm every 10 seconds for one minute and monitoring hydrogen peroxide consumption via spectrophotometry (Azzota® Advanced Uv-Vis Spectrophotometer, SM 1600). One unit of CAT activity was defined as the degradation of 1 μmol of H_2O_2 min^{-1} mg^{-1} protein and the molar extinction coefficient (ε) was calculated as 39.4 mM cm^{-1}.

Peroxidase (POD) activity was determined in accordance with the method described by Teisseire and Guy (2000), with readings performed in a spectrophotometer at 430 nm (Azzota® Advanced Uv-Vis Spectrophotometer, SM 1600). POD activity was calculated using a molar extinction coefficient of 2.5 mmol L^{-1} cm^{-1} and expressed in μmol min^{-1} mg^{-1} protein.

Lipid peroxidation was established in line with Devi and Prasad (1998). Samples of fresh ground leaves (200 mg) were homogenized in 5 ml of extraction buffer containing 0.25% thiobarbituric acid (TBA) and 10% trichloroacetic acid (TCA) and incubated at 90°C for 60 min. The homogenate was cooled using ice and then centrifuged at 10,000 g for 15 min. Absorbance was measured at wavelengths of 560 and 600 nm and the results expressed in nmol of MDA (malondialdehyde) per gram of fresh mass, using the molar extinction coefficient of MDA (155 mmol L^{-1} cm^{-1}).

The results were submitted to analyses of variance (F test) and regression, with means compared by Tukey's test at 5% probability. The Shapiro Wilk test was applied to the variables and the data for total number of leaves and shoot fresh and dry mass were transformed using the square root √(x+0.5). The statistical software used was Sisvar v. 38 (Ferreira, 2014).

Results and Discussion

There was significant interaction between SA doses and irrigation depths for the variables number of leaves, fresh and dry mass and number of nodes, but no significant difference in branch and internode length for the individual factors.

Vines treated with 1.5 mM of AS at 60% irrigation showed greater leaf development, producing a larger number of leaves (Figure 1a). The total number of leaves showed an increasing linear effect at an irrigation depth of 80% (Figure 1b).

Foliar SA spraying in young vines was efficient in reducing the harmful effects of water deficit or overwatering. SA acted as an elicitor by activating antioxidant enzymes and reducing lipid peroxidation in the vines studied. With the decline in oxidative stress, the vines grew and developed more efficiently, even when exposed to less-than-ideal conditions.

SA treatment is efficient at increasing vine growth, as observed in the present study, whereby SA promoted greater leaf development regardless of the dose used, guaranteeing photosynthetic activity and, consequently, growth. Salicylic acid is a phenolic vine growth regulator, classified as a protective agent under biotic and abiotic stress (Hayat et al., 2010).

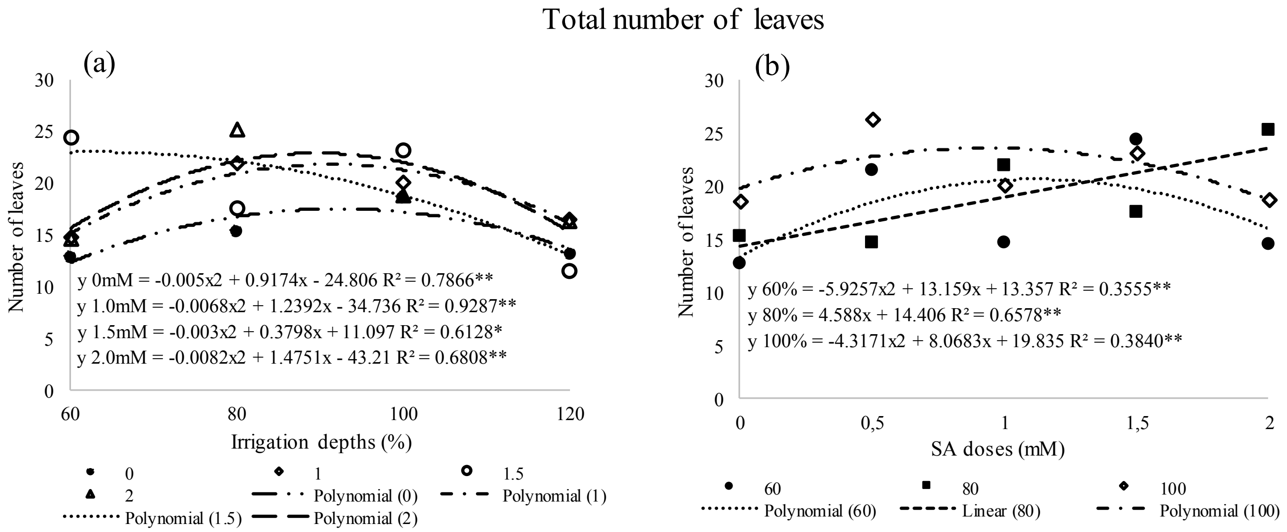

Figure 1. Number of leaves on the main stem of young 'BRS Vitória' vines under decomposition of different irrigation depths within different SA doses (a), and different SA doses within irrigation depths (b). UNEB, Juazeiro-BA, 2019. **Significant according to Tukey's test (p< 0.01) and *(p<0.05).

In regard to shoot fresh mass, 1.5 mM of SA promoted greater accumulation at 60% irrigation and a linear effect for SA doses at water depths greater than 60% (Figure 2a). Lower fresh mass values were recorded at the highest irrigation depth (120%) with and without SA treatment, indicating that excess water was also harmful to the vines (Figure 2b).

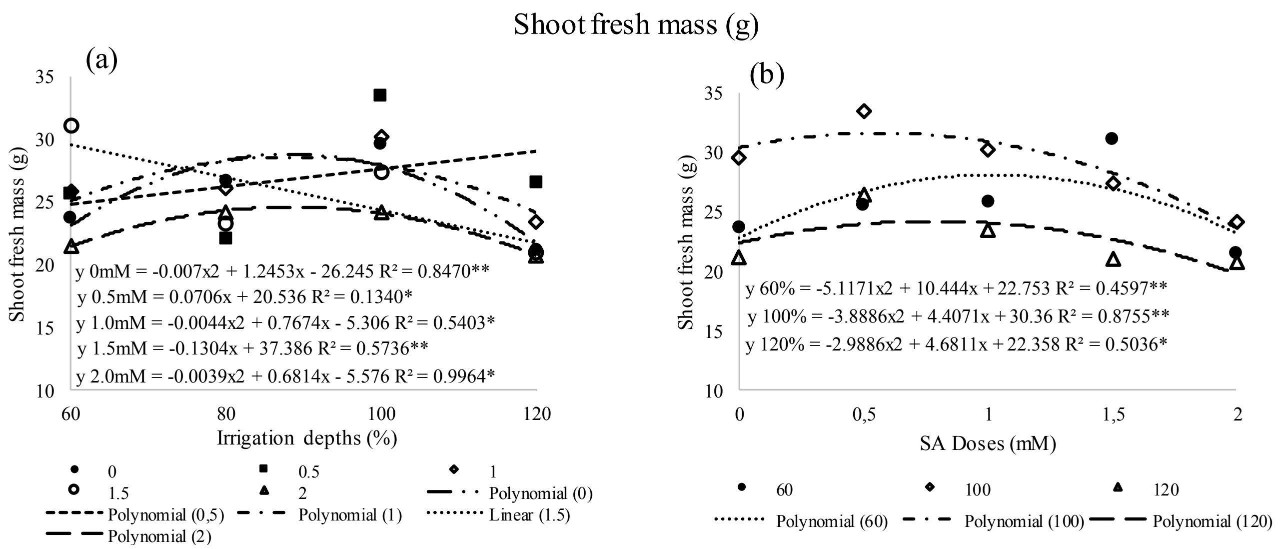

Figure 2. Shoot fresh mass (g) in young 'BRS Vitória' vines under decomposition of different irrigation depths within different SA doses (a), and different SA doses within irrigation depths (b). UNEB, Juazeiro-BA, 2019. **Significant according to Tukey's test (p< 0.01) and *(p<0.05).

It was effective at promoting fresh and dry mass accumulation and can be used to regulate resistance responses in crops, since variations in biomass allocation to different organs can be key to successful seedling adaptation to a stressful environment (Tang et al., 2015). This is because the accumulation of organic solutes contributes to water retention in cells during water stress and to vine performance under excess soil water content, since oxygen diffusion is 10,000 times slower, causing hypoxia and interfering in vine respiration and oxygen demand (Abaspour et al., 2019).

For shoot dry mass, young vines treated with 1.0 mM of SA at 60, 80 and 100% irrigation exhibited greater accumulation (Figure 3a). Dry mass values were higher at 100% irrigation regardless of SA application (Figure 3b).

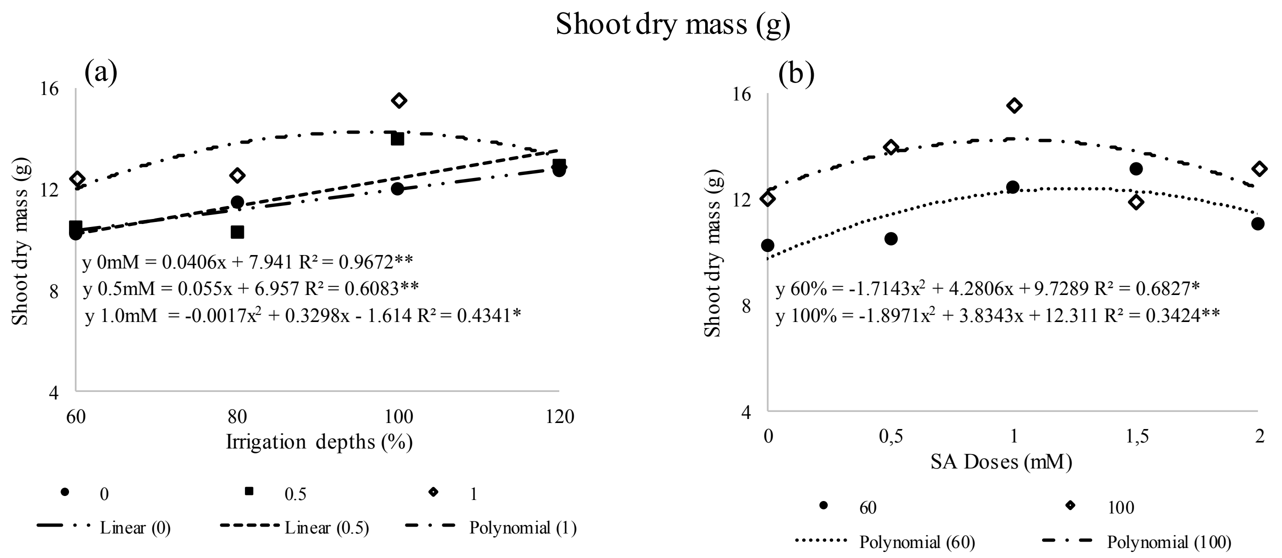

Figure 3. Shoot dry mass (g) in young 'BRS Vitória' vines under decomposition of different irrigation depths within different SA doses (a), and different SA doses within irrigation depths (b). UNEB, Juazeiro-BA, 2019. **Significant according to Tukey's test ($p < 0.01$) and *($p<0.05$).

SA application increased dry mass, an effect associated with a rise in stomatal conductance, thus ensuring a higher rate of net CO_2 assimilation. Abbasi et al. (2020) observed satisfactory responses to 0.01 mM of SA for the morphological traits of cucumber, observing increases in stem length, stem fresh and dry mass, and number of leaves and branches. Habibi (2012) found that SA affected drought tolerance in barley, linking this vine growth regulator to greater antioxidant defense capacities and the maintenance of photosynthesis under water deficit.

Young vines irrigated at 60% displayed a larger number of nodes on the main stem when sprayed with 1.5 mM of SA (Figure 4a). However, the number of nodes declined at the same SA dose and an irrigation depth of 120%. At an SA dose of 2.0 mM, the number of nodes was higher at 80% irrigation when compared to 120% (Figure 4b).

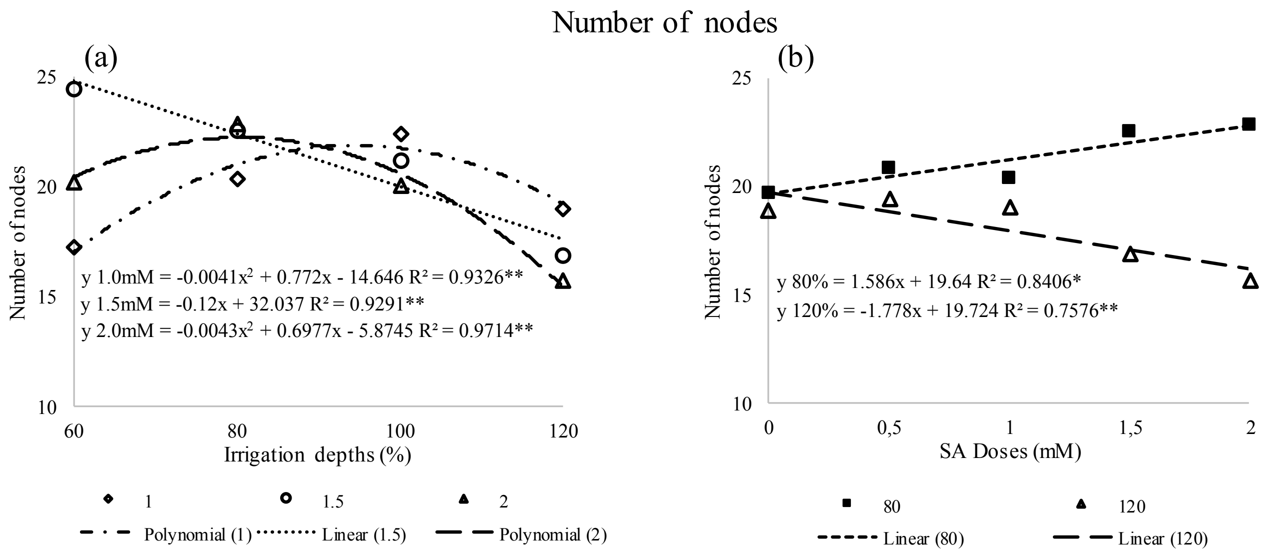

Figure 4. Number of nodes on the main stem of young 'BRS Vitória' vines under decomposition of different irrigation depths within SA doses (a), and different SA doses within irrigation depths (b). UNEB, Juazeiro-BA, 2019. **Significant according to Tukey's test (p< 0.01) and *(p<0.05).

In the present study, SA increased the number of nodes on the main stem and, consequently, its growth. SA produced a significant effect in grapevines by inducing resistance to water loss and increasing leaf water content, directly influencing photosynthesis and, as such, improving vine growth under water stress (Roustakhiz & Saboki, 2017).

For main stem length, there was no significant interaction between the factors, irrigation depths and SA doses, and as such, the factors were analyzed separately. Analysis of irrigation depths with quadratic adjustment (Figure 5a) shows an increase in branch growth with irrigation depth, peaking at 91.07% irrigation and then declining. As shown in Figure 5b, young vines treated with different SA doses exhibited less stem growth than that of controls.

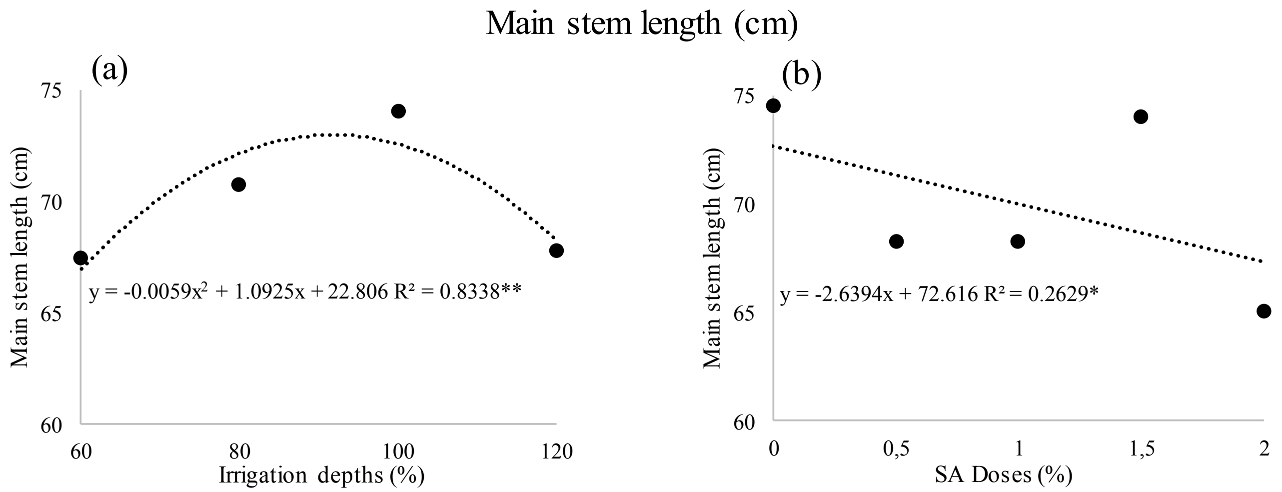

Figure 5. Main stem length (cm) of young 'BRS Vitória' vines in response to the irrigation depths applied (a), and different salicylic acid doses (SA) (b). UNEB, Juazeiro-BA, 2019. **Significant according to Tukey's test ($p< 0.01$) and *($p<0.05$).

Mazzuchelli et al. (2014) reported that irrigation regimes and SA treatment showed isolated effects on the growth of eucalyptus, with greater height at 100% irrigation. This is similar to our findings, although SA application promoted greater vine growth. Silva et al. (2017) found that water deficit reduced stem length in sesame and limited their development due to the decline in physiological and biochemical processes. However, SA application induces growth and biochemical changes, such as in the antioxidant system by stimulating the action of antioxidant enzymes and not only vines' immediate defense response, with a long-term effect on growth and metabolism, preparing vines for future exposure to stress (Karalija & Parić, 2017).

Main stem internode length showed no significant difference only for irrigation depth. Internode growth tended to increase with greater water availability (Figure 6).

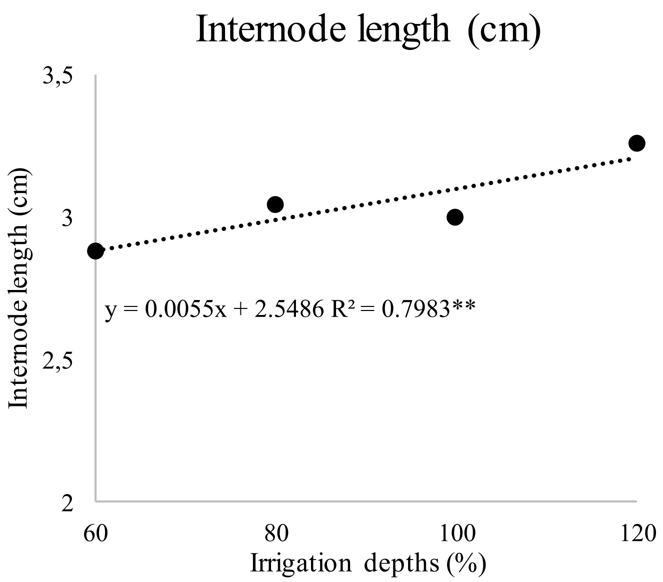

Figure 6. Main stem internode length (cm) in young 'BRS Vitória' vines for the irrigation depths applied. UNEB, Juazeiro-BA, 2019. **Significant according to Tukey's test ($p < 0.01$).

In the present study, SA treatment contributed to main stem internode growth. Similarly, El-kenawy (2017) reported that SA was effective at promoting vine growth through stem elongation due to its important physiological functions, such as photosynthesis, carbohydrate metabolism, stress and defense, energy production, signal transduction and toxin metabolism (Kang et al., 2013).

There was a significant effect for lipid peroxidation at 7 and 35 DWS (Figure 7) and a significant difference in CAT and POD activity at all three assessment times (7, 21 and 35 DWS).

For lipid peroxidation, MDA increased with water stress and no SA spraying, whereas vines treated with 0.5 mM of SA obtained lower MDA values under 80% irrigation (Figure 7a) at 7 DWS. A similar effect was observed for MDA content in decomposition of the 80 and 100% irrigation depths in interaction with 0.5 mM of SA (Figure 7b). Application of 0.5 mM of SA was efficient at decreasing lipid peroxidation in vines under water stress. At 35 DWS, MDA content peaked at 1.0 mM of SA and 120% irrigation, unlike what occurred at 2.0 mM. It is important to note that vines in the control treatment showed greater lipid peroxidation at irrigation depths of 80 and 100%, in relation to the remaining SA doses (Figure 7a), whereas 0.5, 1.0 and 1.5 mM of SA at 80% irrigation produced the lowest MDA values (Figure 7b).

In the present study, SA attenuate lipid peroxidation, similar to the findings of Abbaspour and Babaee (2017), who demonstrated that interaction between SA and water stress influenced MDA content in grapevines, whereby vines treated with

2 mM of SA obtained lower MDA values. Habibi (2017) also observed reduced lipid peroxidation in grapevines and concluded that damage caused by MDA accumulation is mitigated by SA.

High lipid degradation and MDA production under stress causes the formation of reactive oxygen species (ROS), leading to cell damage and death (Aazami et al., 2023). In stressful environment, SA application prompts gene expression in vines, which produce stress-related proteins that activate to signaling pathways, increasing nitrate reductase activity and abscisic acid content (Shakirova et al., 2003), which protect vines from water stress.

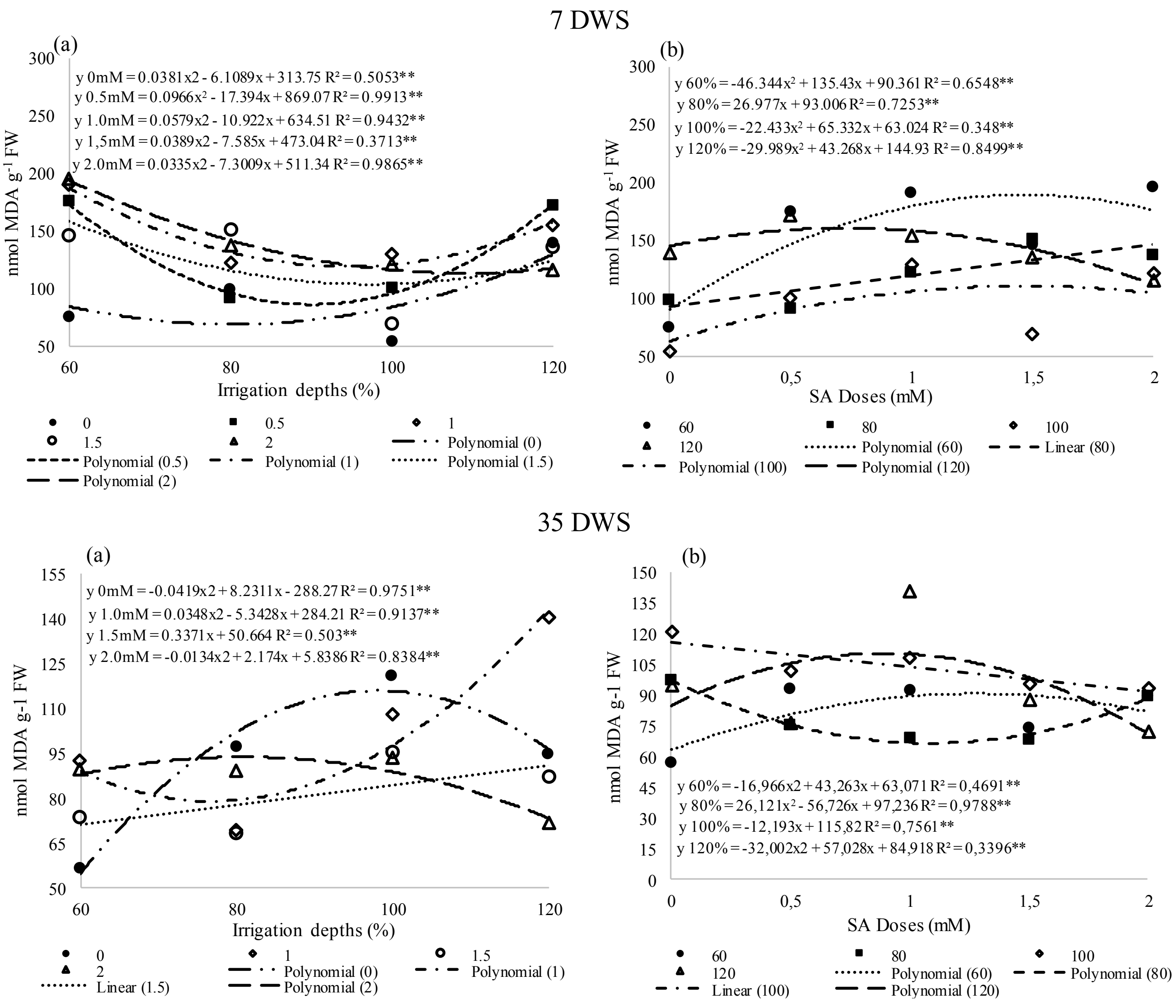

Figure 7. Lipid peroxidation in young 'BRS Vitória' vines under decomposition of different irrigation depths within SA doses (a), and different SA doses within irrigation depths (b), at 7 and 35 days of water stress (DWS). UNEB, Juazeiro-BA, 2019. **Significant according to Tukey's test (p< 0.01).

Treatment with SA increased antioxidant activity in vines and reduced lipid peroxidation, protecting the cell membrane and photosynthetic system. However, the action of SA, which varies between species, developmental stages, doses, and environmental conditions, has yet to be fully understood, since high doses can cause oxidative stress and reduce stress tolerance (Aires et al., 2022).

At 7 DWS and 60% irrigation, the young vines exhibited greater CAT activity at an SA dose of 1.5 mM (Figure 8a), while those treated with 1.0, 1.5 and 2.0 mM displayed increased activity at 120% irrigation. Figure 8b (7 DWS) indicates that CAT activity peaked (243.34 and 266.06 μmol H_2O_2 min^{-1} mg^{-1} of protein) at SA doses of 0.94 and 1.69 mM for irrigation depths of 100 and 120%, respectively.

Greater CAT activity was observed at 21 DWS and 2.0 mM of SA under 60% irrigation, whereas an SA dose of 1.0 mM increased activity to 116.96 μmol H_2O_2 min^{-1} mg^{-1} of protein at 120% irrigation (Figure 8a). A similar effect was observed at 2.0 mM and 60% irrigation (Figure 5 b), while CAT activity peaked at 0.89 mM of SA under 120% irrigation (Figure 8b).

At 35 DWS, CAT activity increased with irrigation depth at control doses and 1.0 mM of SA, with a quadratic effect for irrigation depths at the remaining doses. Applying 1.5 mM of SA increased CAT activity to 43.29 μmol H_2O_2 min^{-1} mg^{-1} of protein at 93.78% irrigation, with a dose of 0.5 mM also producing greater activity at an irrigation depth of 60% (Figure 8a). Only for full irrigation (100%) was there a significant effect between SA doses, with peak CAT activity 1.6 mM of SA (Figure 8b).

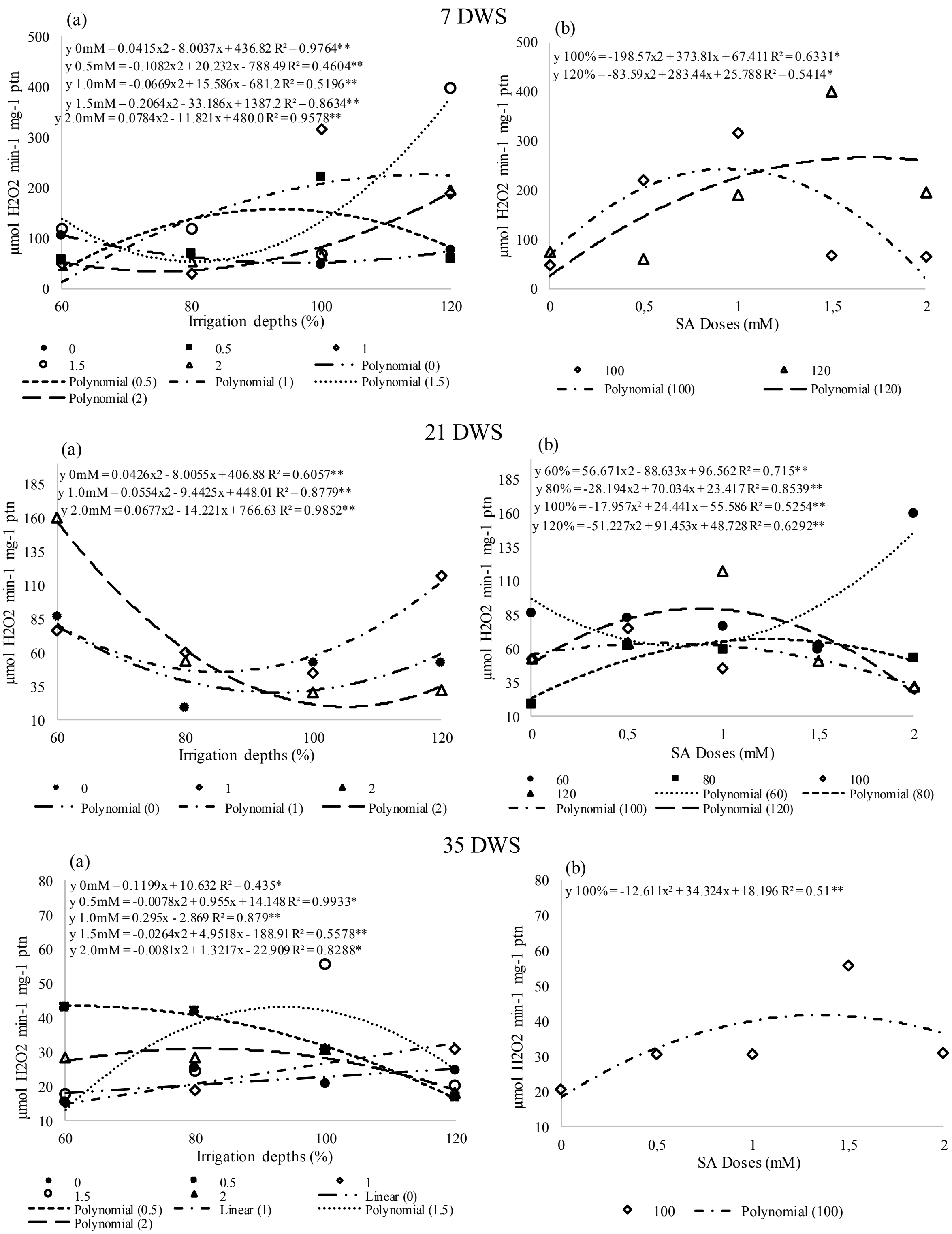

Figure 8. Catalase (CAT) activity in young 'BRS Vitória' vines under decomposition of different irrigation depths within SA doses (a), and different SA doses within irrigation depths (b), at 7, 21 and 35 days of water stress (DWS). UNEB, Juazeiro-BA, 2019. **Significant according to Tukey's test (p< 0.01) and *(p<0.05).

In our study, SA was effective at activating the vine antioxidant system through increased CAT and POD, which may be related to the stress resistance induced by this acid. Similar results were reported by Akbulut et al. (2015), whereby POD activity increased in corn after treatment with a plant growth regulator.

According to Abdelaal et al. (2020a, b) and Abdelaal et al. (2020b), exogenous SA application triggers CAT activity in barley and pepper at doses of 0.5 and 1.0 mM, respectively.

An SA dose of 1.5 mM at 7 DWS influenced POD activity at 60 and 120% irrigation, with no significant effect for the remaining doses and depths (Figure 9a). The effect of SA doses within the 60% irrigation depth demonstrated that POD activity peaked at 1.52 mM of SA (Figure 9b).

At 21 DWS, POD activity was greater in vines treated with 2.0 mM of SA under 60% irrigation but declined as depth increased to 120% (Figure 9a). A decreasing linear effect was observed for POD activity at 120% irrigation as the SA doses increased (Figure 9b) at 21 DWS. However, POD activity was also higher for interaction between 60% irrigation and 2.0 mM of SA.

There was an increasing linear effect for POD activity at 35 DWS in vines treated with 1.5 mM of SA (Figure 9a), the same behavior observed for this dose at 21 DWS. POD activity increased in vines submitted to 0.5 and 2.0 mM of SA and 120% irrigation, with respective values of 0.159 and 0.180 μmol min^{-1} mg^{-1} protein. As shown in Figure 9b, an increasing linear effect was observed for 80% irrigation, and greater POD activity at an SA dose of 2.0 mM with 120% irrigation at 35 DWS.

SA stimulated POD, mitigating overproduction of ROS, possibly because lipid and protein peroxidation and cell membrane changes improved antioxidant defenses (Zhang & Chen, 2011; Belkadhi et al., 2013).

Thus, research indicates that SA attenuates water stress due to its positive effect on vine antioxidant capacity which, in turn, prevents ROS-related damage to proteins, photosynthetic processes, membranes, thylakoids and pigments, through the positive effect of enzymes such as CAT (Agarwal et al., 2005; Abdelaal et al., 2020a). According to Li and Wang (2021), SA reduces abiotic stress due to the increase in the activity of enzymes such as CAT and POD, since this phenolic acid is a multifunctional regulator that modulates mitochondrial-mediated signaling and programmed cell death (PCD) in vines, thus controlling the metabolism of mitochondrial reactive oxygen species and vine defense responses.

As such, salicylic acid has a number of physiological functions in vines and could potentially mitigate the devastating effects of drought stress (Shakirova, 2007). Depending on its concentration, this plant growth regulator can improve photosynthesis, growth, and several physiological and biochemical characteristics (Rajeshwari & Bhuvaneshwari, 2017).

SA promotes physiological and morphological changes in young grapevines depending on the dose applied and the level of stress, with 1.5 mM efficient under severe water deficit and 1.0 mM for mild or moderate stress. Thus, salicylic acid has a lot physiological functions in vines and could potentially mitigate the devastating effects of drought stress (Shakirova, 2007). This plant growth regulator can improve photosynthesis, growth, and several physiological and biochemical characteristics (Rajeshwari & Bhuvaneshwari, 2017).

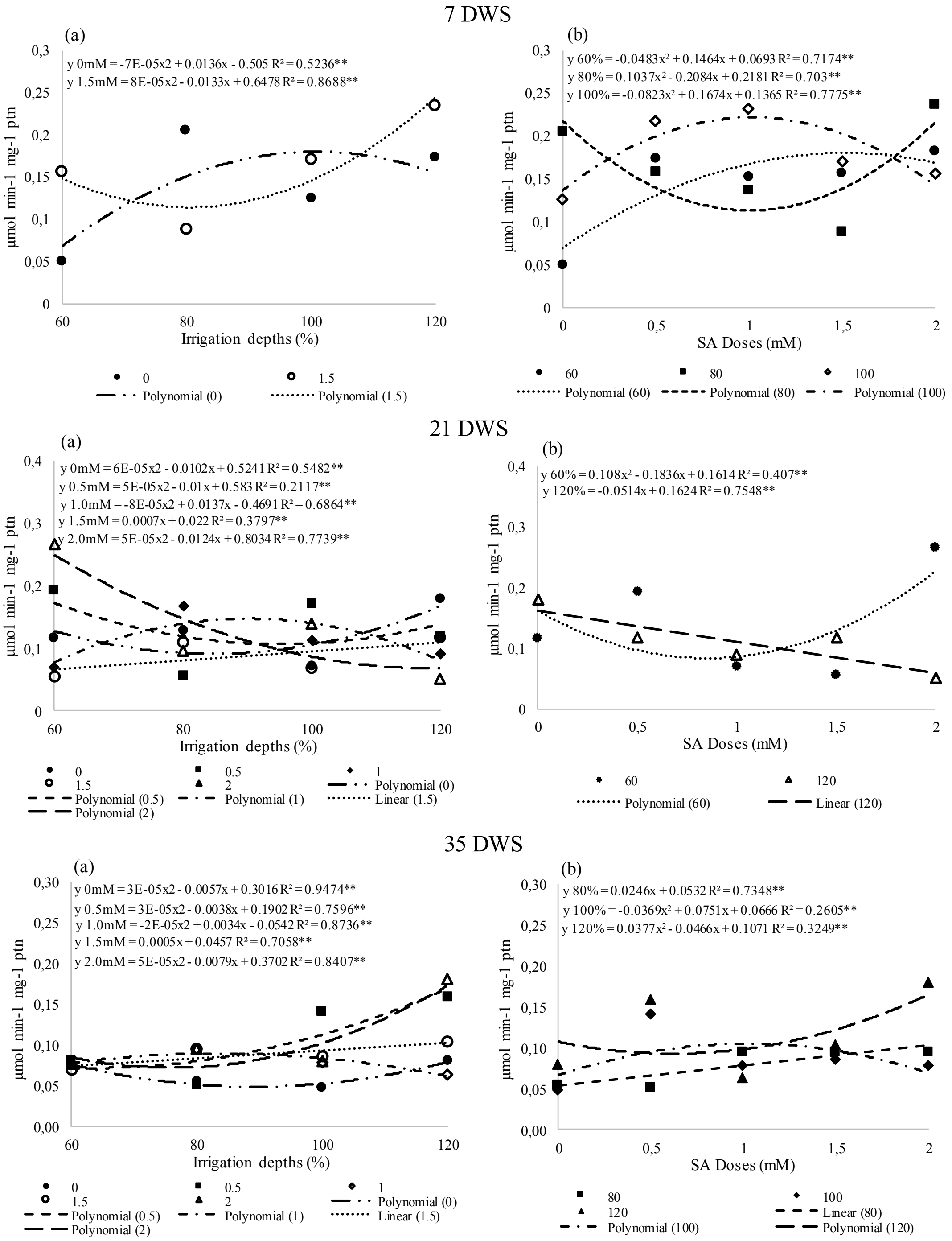

Figure 9. Peroxidase (POD) activity in young 'BRS Vitória' vines under decomposition of different irrigation depths within SA doses (a), and different SA doses within irrigation depths (b), at 7, 21 and 35 days of water stress (DWS). UNEB, Juazeiro-BA, 2019. **Significant according to Tukey's test (p< 0.01).

Conclusion

When applied to young 'BRS Vitória' vines, salicylic acid improved vine morphological and biochemical performance, mitigating the harmful effects of water stress and increasing water savings, especially at a dose of 1.5 mM. This plant growth regulator also attenuated the harmful effect of excess water by improving the antioxidant system through antioxidant enzymes and reducing lipid peroxidation at 2.0 mM.

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