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Scientific Article

Zucchini cultivation under salt stress and exogenous application of paclobutrazol

Cultivo de abobrinha sob estresse salino e aplicação exógena de paclobutrazol

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ABSTRACT - Salinity is considered an obstacle to the production system that limits the growth and yield of crops around the world. Therefore, it is essential to develop strategies to minimize the effects of salinity and increase yield, especially in the semi-arid region of the Northeast, which has limited water resources of good quality for irrigation. The objective was to evaluate the effects of applying paclobutrazol on zucchini crop under salt stress. The experiment was conducted in a greenhouse, in a randomized block experimental design, in a 2 × 5 factorial scheme, with two salinity levels of irrigation water (0.6 and 4.0 dS m^{-1}) and five concentrations of paclobutrazol - PBZ (0; 2; 4; 6 and 8 g L^{-1}), and with four repetitions. Application of 8 mg L^{-1} PBZ increases stem diameter in zucchini under irrigation of 4.0 dS m^{-1}. Chlorophyll *b* and total chlorophyll contents increase with PBZ concentration of 4 mg L^{-1} and irrigation of 0.6 dS m^{-1}. PBZ concentration of 4 mg L^{-1} increases the relative water content while reducing electrolyte leakage in zucchini under salinities of 4.0 and 0.6 dS m^{-1} respectively. Root, stem and leaf dry mass of zucchini increases when plants are irrigated with water of 0.6 dS m^{-1} and subjected to PBZ concentration of 8 mg L^{-1}. PBZ concentrations do not attenuate the effects of salinity on leaf area, crown volume and diameter, vegetative vigor index, chlorophyll *a* and carotenoids.

Keywords: *Cucurbita pepo* L.. Growth regulators. Abiotic stress.

RESUMO - A salinidade é considerada um obstáculo ao sistema de produção que limita o crescimento e a produtividade das culturas em todo o mundo. Dessa forma, é essencial desenvolver estratégias para minimizar os efeitos da salinidade e aumentar a produtividade, especialmente na região semiárida do Nordeste, que possui recursos hídrico limitados de boa qualidade para a irrigação. Objetivou-se avaliar os efeitos da aplicação de paclobutrazol no cultivo de abobrinha sob estresse salino. O experimento foi conduzido em casa de vegetação, no delineamento experimental de blocos casualizados, em esquema fatorial 2 × 5, sendo dois níveis de salinidade da água de irrigação (0,6 e 4,0 dS m^{-1}) e cinco concentrações de PBZ (0; 2; 4; 6 e 8 g L^{-1}), e com quatro repetições. A aplicação de paclobutrazol de 8 mg L^{-1} aumenta o diâmetro do caule em abobrinha sob irrigação de 4,0 dS m^{-1}. Os teores de clorofila b e total aumenta com concentração 4 mg L^{-1} de paclobutrazol e irrigação de 0,6 dS m^{-1}. As concentração de PBZ de 4 mg L^{-1} eleva o teor relativo de água enquanto reduz o extravasamento de eletrólitos sob salinidade de 4,0 e 0,6 dS m^{-1} respectivamente. A fitomassa seca da raiz, caule e folha da abobrinha aumenta quando irrigada com água de 0,6 dS m^{-1} e concentração de 8 mg L^{-1} de paclobutrazol. As concentrações de PBZ não atenuam os efeitos da salinidade sob as variáveis área foliar, volume e diâmetro de copa, índice de vigor vegetativo, clorofila *a* e carotenoides.

Palavras-chave: *Cucurbita pepo* L.. Reguladores de crescimento. Estresse abiótico.

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INTRODUCTION

Belonging to the Cucurbitaceae family and the *Cucurbita* genus, zucchini (*Cucurbita pepo* L.) is one of the main vegetables grown in Brazil, standing out among the ten most valuable vegetables in the country in economic and yield terms (GRANGEIRO et al., 2020). Zucchini is valued not only for its nutritional properties, but also for its high acceptance by the consumer market (FILGUEIRA, 2012).

The Northeast region has a high climatic variability, characterized by scarcity and irregularities in the distribution of rainfall and high rates of evapotranspiration, which restricts the practice of agriculture during the dry season and contributes to water deficit (DANTAS et al., 2022a; SILVA et al., 2023). In the region, the sources of water available for irrigation are predominantly from surface reservoirs and contain high levels of dissolved salts (OLIVEIRA et al., 2015), which vary from 0.75 to 3.0 dS m^{-1} and can cause negative effects on the physical and chemical attributes of the soil, as well as altering the physiological and biochemical processes of plants, impacting their growth, development and yield (LIMA et al., 2016; MUHAMMAD et al., 2021).

High concentration of salts in irrigation water is considered one of the abiotic stresses that most limit the growth and yield of crops worldwide, because under conditions of salt stress there is a reduction in the osmotic potential of the soil solution, resulting in a reduction in water availability and/or excessive accumulation of sodium and chloride ions in plant tissues (LIMA et al., 2019), where they cause osmotic, toxic, and nutritional effects on plants (FURTADO et al., 2012). Under conditions of salt stress, plants have a delay in leaf production, necrosis of the aerial part and roots, and reductions in leaf area and photosynthetic activity, which affect their growth (VELOSO et al., 2021). Several studies have been carried out to evaluate the effects of salinity on zucchini crop, such as Putti et al. (2018) and Dantas et al. (2022b).

In this context, in order to achieve success in the use of saline water for agricultural production, several cultivation alternatives have been used to minimize the deleterious effects of salinity on plants. The use of paclobutrazol (PBZ) has stood out as a promising alternative. PBZ belongs to the family of plant growth-regulating triazoles and its exogenous application can help reduce some of the harmful effects of salt stress by maintaining endogenous cytokinin concentration, stabilizing leaf water potential, and increasing levels of antioxidant enzyme activities and chlorophyll content (TESFAHUN, 2018).

Guimarães et al. (2021) studied the effects of different methods of applying PBZ (foliar application, via soil and a control - without PBZ) on ornamental sunflower irrigated with brackish waters (0.4, 1.9, 3.4, 4.9 and 6.4 dS m^{-1}) and concluded that this application, mainly via soil, attenuates the effects of salt stress by promoting increments in stomatal conductance, transpiration and photosynthesis of the plants.

Although the use of PBZ in other crops has been reported, its effects on zucchini under salt stress conditions are not yet known. Therefore, the objective of this study was to evaluate the effects of PBZ application on zucchini crop under salt stress.

MATERIAL AND METHODS

The experiment was carried out at the Center for Technology and Natural Resources of the Federal University of Campina Grande, Paraíba, Brazil, at local coordinates 07° 15’ 18” S latitude, 35° 52’ 28” W longitude and average altitude of 550 m from October to December 2022 under greenhouse conditions. The region has a tropical climate with a dry season, As type, according to the Köppen-Geiger climate classification (ALVARES et al, 2013), with moderate temperatures.

The experimental design was randomized blocks, in a 2 × 5 factorial arrangement, whose treatments resulted from the combination of two factors: two levels of water salinity - SL (0.6 and 4.0 dS m^{-1}) and five concentrations of PBZ (0, 2, 4, 6, and 8 mg L^{-1}), and these combinations were referred to as SL1P0, SL2P0, SL1P2, SL2P2, SL1P4, SL2P4, SL1P6, SL2P6, SL1P8 and SL2P8, with four repetitions. The highest level of salinity was established based on studies conducted by Amorim (2015). PBZ concentrations were determined according to a study conducted by Oliveira et al. (2012).

Planting was carried out in containers with capacity for 25 L, equipped with drainage lysimeters, and a 16-mm diameter drain was installed at the base of each lysimeter. This drain was connected to a container for collecting drained water, which was later used to determine the water consumption by the plants. To prevent clogging of the drain by soil material, the end of the drain inside the pot was wrapped with a non-woven geotextile (Bidim OP 30).

The lysimeters were filled by placing a layer of crushed stone Nº 0, followed by 25 kg of *Neossolo Regolítico* (Entisol) with sandy clay loam texture (0-20 cm depth), taken from the rural area of the municipality of Lagoa Seca, PB. This soil was properly pounded to break up clods, and its chemical and physical characteristics (Table 1) were obtained according to the methodology proposed by Teixeira et al. (2017).

Table 1. Chemical and physical characteristics of the soil used in the experiment.

Chemical characteristics							
pH H_2O	OM	P	K^+	Na^+	Ca^{2+}	Mg^{2+}	$Al^{3+} + H^+$
1:2.5	g dm^{-3}	mg dm^{-3}	cmol$_c$ kg^{-1}				
6.5	8.1	79	0.24	0.51	14.90	5.40	0.90

Chemical characteristics						Physical characteristics				
EC_{se}	CEC	SAR_{se}	ESP	SB	V	Particle-size fraction (g kg^{-1})			Moisture content (dag kg^{-1})	
dS m^{-1}	cmol$_c$ kg^{-1}	(mmol$_c$ L^{-1})$^{0.5}$	%	cmol$_c$ kg^{-1}	%	Sand	Silt	Clay	33.42 kPa^1	1519.5 kPa^2
2.15	21.95	0.16	3.08	21.05	95.89	572.7	100.7	326.6	25.91	12.96

pH - Hydrogen Potential; OM - Organic Matter: Walkley-Black Wet Digestion; Ca^{2+} and Mg^{2+} - extracted with 1 M KCl at pH 7.0; Na^+ and K^+ - extracted with 1 M NH_4OAC at pH 7.0; Al^{3+} + H^+ - extracted with 0.5 M CaOAc at pH 7.0; EC_{se} - electrical conductivity of saturation extract; CEC - cation exchange capacity; SAR_{se} - sodium adsorption ratio of saturation extract; ESP - exchangeable sodium percentage; SB - sum of bases (K^+ + Ca^{2+} + Mg^{2+} + Na^+); V - base saturation ([SB/CEC] × 100); ^{1,2} - correspond to field capacity and permanent wilting point, respectively.

The lowest electrical conductivity (0.6 dS m^{-1}) used in the experiment was obtained with water from the water supply system of Campina Grande, PB. On the other hand, the highest ECw level (4.0 dS m^{-1}) was prepared by the dissolution of the salts NaCl, $CaCl_2.2H_2O$ and $MgCl_2.6H_2O$, in the equivalent proportion of 7:2:1, respectively, in public-supply water of Campina Grande, PB, considering the relationship between ECw and salt concentration as suggested by Richards (1954) and presented in Equation 1:

$$Q \approx 10 \times ECw \tag{1}$$

Where:

Q = quantity of salts to be dissolved ($mmol_c L^{-1}$); and,
ECw = electrical conductivity of water ($dS m^{-1}$).

Sowing was carried out in disposable 300 ml cups, by planting two seeds per cup before transplanting. After fifteen days, the seedlings were transferred to holes with a depth that could accommodate the volume of soil contained in the 300 ml cup. Prior to transplanting, rootbound plants were observed. After transplanting, they were acclimatized for fifteen days and irrigated using water with an electrical conductivity of 0.6 $dS m^{-1}$. At the end of this acclimatization period, the irrigation of the treatments began. The attenuator (paclobutrazol) was applied fifteen days after the onset of salt stress, via irrigation. The quantities corresponding to 0, 2, 4, 6 and 8 $mg L^{-1}$ of PBZ were weighed on an analytical scale, diluted in one liter of water and applied to each plant individually, following the methodology described by Oliveira et al. (2012).

Nitrogen, potassium and phosphorus fertilization was carried out according to the recommendation of Novais, Neves and Barros (1991), by applying 100, 150 and 300 $mg kg^{-1}$ of soil of N, P_2O_5 and K_2O. Urea (45% N), potassium chloride (60% K_2O) and monoammonium phosphate (50% P_2O_5 and 11% N) were used as sources of these nutrients.

Phytosanitary control to prevent the emergence of pests such as silverleaf whiteflies (*Bemisia tabaci*), passionvine bug (*Leptoglossus gonagra*) and Florida wax scale (*Ceroplastes floridensis*) was carried out by means of selective chemicals based on Imidacloprid and Thiamethoxam, using 1 g to 10 L for both in the preparation of the solution.

The evaluation for data collection was carried out at 40 days after transplantation (DAT), when electrolyte leakage (% EL) and relative water content (RWC) were measured. Contents of chlorophyll *a*, chlorophyll *b*, total chlorophyll and carotenoids were determined by the method of Arnon (1949), using a spectrophotometer at the absorbance wavelength (A) of 470, 646, and 663 nm, according to Equations 2, 3, 4 and 5. The values obtained for the contents of chlorophyll *a*, chlorophyll *b* and carotenoids in the leaves were expressed in $mg g^{-1}$ of fresh matter ($mg g^{-1}$ FM).

$$\text{Chl } a = 12.21A663 - 2.81A646 \tag{2}$$

$$\text{Chl } b = 20.13A646 - 5.03A663 \tag{3}$$

$$\text{Chl } t = \text{Chl } a + \text{Chl } b \tag{4}$$

$$\text{Car} = \frac{\text{Car} = (1000A470 - 1.82 \text{ Chl } a - 85.02 \text{ Chl } b)}{198} \tag{5}$$

Where:

Chl *a* - chlorophyll *a*;
Chl *b* - chlorophyll *b*;
Chl *t* - chlorophyll *t*; and,
Car - carotenoids.

Electrolyte leakage in the leaf blade was obtained according to Scotti-Campos et al. (2013), as shown in Equation 6:

$$\% EL = \frac{Ci}{Cf} x100 \tag{6}$$

Where:

% EL - electrolyte leakage in the leaf blade;
Ci - initial electrical conductivity ($dS m^{-1}$); and,
Cf - final electrical conductivity ($dS m^{-1}$).

Relative water content in the leaf blade (RWC) was determined according to the methodology of Weatherley (1950), using Equation 7:

$$RWC = \frac{(FM-DM)}{(TM-DM)} x 100 \tag{7}$$

Where:

RWC- relative water content (%);
FM - leaf fresh mass (g);
TM - leaf turgid mass (g); and
DM - leaf dry mass (g).

At 40 DAT, stem diameter (SD) was determined using a digital caliper and leaf area was determined by collecting a leaf disk with a known area (4 cm^2) and then drying it in an oven at 80 °C; from the total leaf dry mass, it was possible to make the relationship and obtain the leaf area of the plant. Root dry mass, stem dry mass and leaf dry mass were determined after the material was dried in an oven at 80 °C and then weighed on a semi-analytical balance. Crown diameter (DCrown) was obtained by the mean crown diameter observed in the row direction (DR) and interrow direction (DIR); crown volume (VCrown) was calculated from plant height (H), DR and DIR, using Equation 8; and the vegetative vigor index (VVI), determined according to Portella et al. (2016), using Equation 9:

$$VCrown = \left(\frac{\pi}{6}\right) x H x DR x DIR \tag{8}$$

Where:

VCrown – crown volume (m3);
H – plant height (m);
DR – crown diameter in the row direction (m); and
DIR – crown diameter in the interrow direction (m).

$$VVI = \frac{[H + DCrown + (SD x 10)]}{100} \tag{9}$$

Where:

VVI – vegetative vigor index;
H – plant height (m);
DCrown – crown diameter (m); and
SD – stem diameter (m).

The multivariate structure of the results was evaluated by principal component analysis (PCA), synthesizing the amount of relevant information contained in the original data set in a smaller number of dimensions, resulting from linear combinations of the original variables generated from the eigenvalues ($\lambda \geq 1.0$) in the correlation matrix, explaining a percentage greater than 10% of the total variance (GOVAERTS et al., 2007).

After reduction of the dimensions, the original data of the variables of each component were subjected to multivariate analysis of variance (MANOVA) by the Hotelling (1947) test at 0.05 probability level for salinity levels and PBZ concentrations, as well as for their interaction. Only variables with a correlation coefficient greater than or equal to 0.65 were maintained for each principal component (PC) (HAIR JUNIOR et al., 2009). Statistical analyses were performed using Statistica v. 7.0 software (STATSOFT, 2004).

RESULTS AND DISCUSSION

The multidimensional space of the original variables was reduced to two principal components (PC1 and PC2) with eigenvalues greater than $\lambda \geq 1.0$, as highlighted by Kaiser (1960). The eigenvalues and percentage of explained variance for each component (Table 1) together represented 71% of the total variation. PC1 explained 45.97% of the total variance, representing most of the variables analyzed, while PC2 represented 25.03% of the remaining variance.

There was a significant effect ($p \leq 0.01$) of the interaction between water salinity levels (SL) and PBZ concentrations (P) for PC1 and PC2 (Table 1). In addition, when analyzed separately, salinity levels and PBZ concentrations also showed significant effect ($p \leq 0.01$).

Figures 1A and 1B show the effects of the treatments and the variables for the principal components (PC1 and PC2). In PC 1, a possible interaction between water salinity levels and PBZ concentrations is observed, with a correlation coefficient greater than 0.61 for the variables SD, LA, VCrown, DCrown, VVI, %EL, RWC, RDM, SDM and LDM. On the other hand, for PC2, a possible interaction between the variables Chl *a*, Chl *b*, Chl *t* and CAR was observed, with a correlation coefficient greater than 0.68.

When analyzing principal component 1, it was observed that plants irrigated with the highest salinity level (ECw= 4.0 dS m^{-1}) and subjected to PBZ concentration of 8 mg L^{-1} obtained the highest value for stem diameter, 14.37 mm; when compared with plants that had the lowest value, in the SL2P2 treatment, a 2.9 mm increase was observed. The increase in this variable when a higher PBZ concentration was used can be explained by the fact that triazole compounds such as PBZ reduce gibberellin biosynthesis and contribute to increments in abscisic acid and cytokinin contents, which favor the maintenance of water balance in plants under salt stress (HU et al., 2017).

Maintenance of water in the cells is indispensable, since it is responsible for turgor pressure and, consequently, for cell division and expansion. Amorim et al. (2015), in studies with zucchini under different levels of water salinity (ECw= 0, 1.0, 2.0, 3.0 and 4.0 dS m^{-1}), also found a reduction in stem diameter at the highest level of salinity, corroborating the results found in this study.

The highest values observed for leaf area occurred in the SL1P0 treatment, in contrast to the lowest mean values found in plants under irrigation of 4.0 dS m^{-1} and 2 mg L^{-1} of PBZ (SL2P2), a reduction of 3601.26 cm². For this variable, PBZ concentrations had no influence, since the highest values were observed in the control treatment. This can be explained by the action of the osmotic and toxic effects of ions, especially Na^+ and Cl^-, which accumulate near the root system of plants, causing a reduction in osmotic potential and hindering water absorption, consequently causing decreases in plant growth (ALVARENGA et al., 2019).

Lima et al. (2020), in a study carried out with mini watermelon under salt stress conditions (ECw= 0.3, 1.3, 2.3, 3.3 and 4.3 dS m^{-1}), observed that salinity above 0.3 dS m^{-1} causes reduction in growth variables, especially in the number of leaves, which is directly associated with leaf area.

Table 2 shows that the crown volume, crown diameter and vegetative vigor index were reduced as salinity increased. The highest mean values found for these variables were observed in the SL1P0 treatment (0.065 m^3, 1.321 m^2 and 2.74, respectively). The SL2P2 treatment had the lowest means for these variables; compared to the control treatment, the reductions were around 12.3, 37.9% and 64.6%, respectively.

As observed for leaf area, there were reductions in the variables VCrown, DCrown and VVI, which may be associated with the defense mechanism of plants that, under conditions of salt stress, reduces the transpiring surface to avoid water loss to the environment (OLIVEIRA et al., 2017). According to studies carried out by Lacerda et al. (2022) with guava crop, reductions in VCrown, DCrown and VVI were found as salinity increased, reinforcing the results found here.

Regarding the membrane integrity status, the zucchini plants in the SL2P6 treatment showed electrolyte leakage values more than twice as high as those in the SL1P4, thus indicating more severe damage to the membranes of plants irrigated with higher salinity levels, probably due to lipid peroxidation caused by reactive oxygen species (ROS), which can affect the photosynthetic process and, consequently, contribute to lower plant growth under this irrigation condition (DEMIDCHIK et al., 2014). These results are in agreement with those reported by Fernandes et al. (2022) in a study with the cultivation of Italian zucchini grown in a hydroponic system under salt stress.

It was observed that SL2P4 plants had higher values for the relative water content, while the lowest values were observed in SL1P0 plants. The increase in relative water content may have been due to the increase in the levels of cytokinin and abscisic acid, promoted by the action of paclobutrazol. Nivedithadevi, Somasundaram and Pannerselvam (2012) found that plants treated with PBZ synthesized more cytokinins, helping to stabilize the leaf water potential.

For principal component 2 (PC2), chlorophyll *a* contents ranged from 66.82 to 1132.30 μg mL^{-1}, and the lowest mean value was found in SL1P2 plants, while the highest mean was obtained in plants subjected to irrigation with 0.6 dS m^{-1} water and without PBZ application (SL1P0). The absence of paclobutrazol led to a higher chlorophyll *a* content, indicating that PBZ concentrations did not exert a significant influence on this variable. Indeed, the highest value was obtained in the control treatment.

Table 2. Eigenvalues, percentage of total explained variance in multivariate analysis of variance (MANOVA) and the correlation coefficients (r) between original variables and principal components.

	Principal components (PCs)	
	PC1	PC2
Eigenvalues (λ)	6.43	3.51
Percentage of total variance (S^2%)	45.97	25.03
Hotelling test (T^2) for water salinity (SL)	0.01	0.01
Hotelling test (T^2) for PBZ concentrations (P)	0.01	0.01
Hotelling test (T^2) for the interaction (SL × P)	0.01	0.01

PCs	Correlation coefficient						
	SD	LA	VCrown	DCrown	VVI	%EL	RWC
PC1	-0.65	-0.89	-0.70	-0.87	-0.96	0.61	0.81
PC2	0.51	0.44	-0.61	-0.40	-0.21	-0.22	-0.19
	Mean values						
	SD	LA	VCrown	DCrown	VVI	%EL	RWC
SL1P0	12.72	5154.86	0.065	1.321	2.74	31.37	77.70
SL2P0	13.97	4379.72	0.026	0.911	2.44	23.00	75.07
SL1P2	12.55	3990.39	0.023	0.938	2.31	18.24	78.76
SL2P2	11.47	1553.60	0.008	0.501	1.77	30.45	83.51
SL1P4	12.97	4218.54	0.017	0.812	2.23	14.54	81.91
SL2P4	12.25	2235.34	0.012	0.591	1.94	27.15	88.43
SL1P6	12.77	3226.27	0.024	0.882	2.29	22.94	79.90
SL2P6	12.66	2711.69	0.010	0.577	1.96	41.03	80.92
SL1P8	14.12	3871.81	0.022	0.875	2.40	24.28	78.71
SL2P8	14.37	2716.22	0.012	0.671	2.22	22.13	79.82
PCs	Correlation coefficient						
	Chl *a*	Chl *b*	Chl *t*	CAR	RDM	SDM	LDM
PC1	0.06	-0.14	-0.03	0.05	-0.66	-0.94	-0.88
PC2	-0.98	-0.68	-0.84	-0.71	-0.46	0.01	0.04
	Mean values						
	Chl *a*	Chl *b*	Chl *t*	CAR	RDM	SDM	LDM
SL1P0	1132.30	358.64	1490.94	328.07	2.42	15.66	21.79
SL2P0	730.79	240.77	971.57	223.32	2.51	13.52	22.22
SL1P2	666.82	231.54	898.37	180.36	2.31	12.52	23.16
SL2P2	939.48	251.41	1190.90	242.06	1.68	5.76	8.32
SL1P4	929.95	609.40	1539.36	173.05	2.01	11.19	23.37
SL2P4	851.70	272.15	1123.85	293.17	2.27	6.45	11.43
SL1P6	798.77	283.17	1081.95	183.44	2.59	11.98	19.05
SL2P6	788.36	264.77	1053.14	208.06	2.37	6.04	13.98
SL1P8	691.77	233.07	924.85	213.09	2.67	15.95	24.11
SL2P8	721.91	399.60	1121.52	143.62	2.62	11.94	15.58

SL – Water salinity, SL1 (0.6 dS m^{-1}); SL2 (4.0 dS m^{-1}); P – paclobutrazol – P0 (0 mg L^{-1}); P2 (2 mg L^{-1}); P4 (4 mg L^{-1}); P6 (6 mg L^{-1}); P8 (8 mg L^{-1}); SD (Stem diameter - mm); LA (Leaf area - cm^2); VCrown (crown volume – m^3); (Crown diameter – m^2); VVI (Vegetative Vigor Index); %EL (Electrolyte leakage - %); RWC (Relative Water Content - %) Chl *a* (Chlorophyll *a* - mg g^{-1} FM); Chl *b* (Chlorophyll *b* - mg g^{-1} FM); Chl *t* (Total chlorophyll - mg g^{-1} FM); CAR (Carotenoids - mg g^{-1} FM); RDM (Root dry mass - g); SDM (Stem dry mass - g); LDM (Leaf dry mass - g).

In the literature, it is common to find evidence that the increase in salinity usually results in a reduction in chlorophyll contents. However, some authors have already reported an increase in this variable in response to salt stress, so it can adapt to the environment. According to Mendes et al. (2011), the increase in chlorophyll contents under adverse conditions is related to the activation of a protective mechanism for the photosynthetic apparatus and seems to be a direct implication of the very development of chloroplasts, through the increase in the number of thylakoids or even the increase in the number of chloroplasts.

SL1P4 plants obtained the highest mean values for chlorophyll *b* and total chlorophyll, 609.40 and 1539.36 µg mL^{-1}, respectively. On the other hand, the SL1P2 treatment had lower mean values compared to SL1P4, on the order of 37.9 and 58.36% for these variables, respectively (0.6 dS m^{-1} and 2 mg L^{-1} of PBZ).

Application of PBZ at a concentration of 4 mg L^{-1} resulted in a significant increase in chlorophyll *b* and total chlorophyll contents, thus mitigating the deleterious effects of salinity on these variables. Treatment with PBZ may result in increased cytokinin contents (BURONDKAR et al., 2016). This may be associated with the ability of triazoles to raise cytokinin levels and thus increase chloroplast differentiation, chlorophyll biosynthesis, and maintenance of the integrity of this molecule (SANTOS FILHO et al., 2022).

The highest mean value observed for the carotenoid content (328.07 mg g^{-1} FM) was observed in the treatment SL1P0 (143.62 mg g^{-1} FM) in zucchini plants irrigated with water of 4.0 dS m^{-1} and subjected to PBZ concentration of 8 mg L^{-1}, a reduction of 56.2%. These results corroborate those found by Dantas et al. (2022a), who evaluated the negative effects of salt stress on Italian zucchini plants and observed a 41.96% reduction in carotenoid content when comparing plants subjected to the highest salt concentration (6.6 dS m^{-1}) with those that received the lowest salt concentration (2.1 dS m^{-1}).

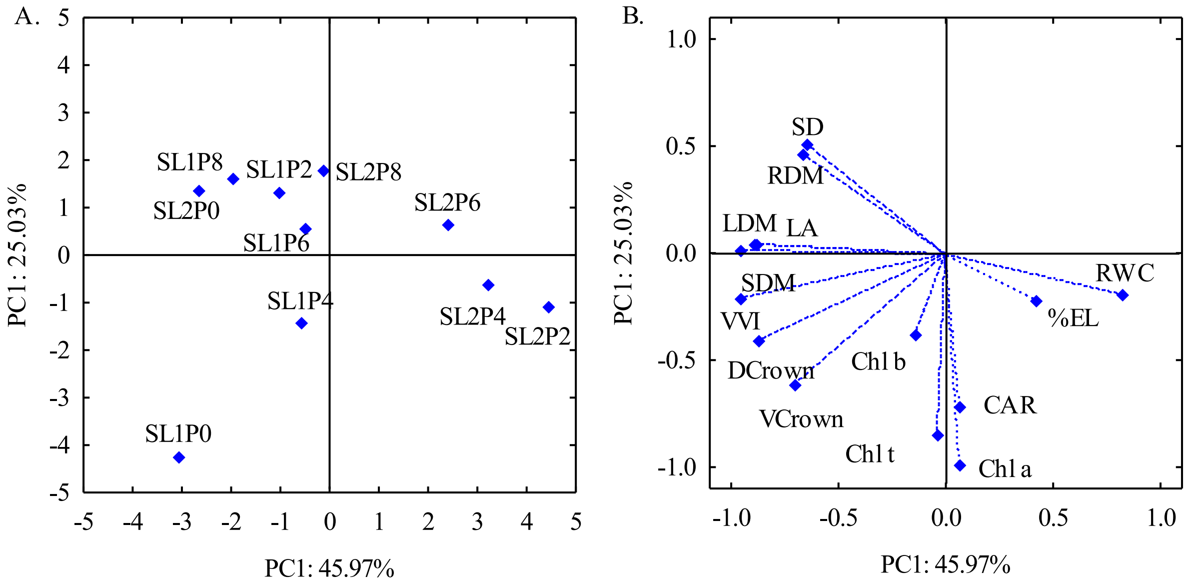

Figure 1. Two-dimensional projection of the scores of the principal components for the factors water salinity levels – SL and concentrations of PBZ – P (A) and of the variables analyzed (B) in the two principal components (PC1 and PC2).

In Figure 1, the two-dimensional projection of the eigenvalues showed that the SL1P8 treatment increased the variables root dry mass (RDM), stem dry mass (SDM) and leaf dry mass (LDM), whose values were 2.67, 15.95 and 24.11 g in the same order; when compared with the lowest mean values observed in the SL2P2 treatment, increments of 37.1, 63.8 and 65.4% were observed, respectively.

Guimarães et al. (2021) studied the effects of different methods of PBZ application in ornamental sunflower irrigated with brackish waters (0.4, 1.9, 3.4, 4.9 and 6.4 dS m^{-1}) and also highlighted that PBZ application, mainly via soil, favored sunflower plants under salt stress, promoting increments in stomatal conductance, transpiration and photosynthesis. This result corroborates those obtained in this study, since the increase in stomatal conductance leads to a higher water consumption by the plant, consequently resulting in an increase in its dry mass.

CONCLUSIONS

Application of paclobutrazol at 8 mg L^{-1} increases stem diameter in zucchini under irrigation of 4.0 dS m^{-1}.

Chlorophyll *b* and total chlorophyll contents increase with paclobutrazol concentration of 4 mg L^{-1} and irrigation of 0.6 dS m^{-1}.

Paclobutrazol concentration of 4 mg L^{-1} increases the relative water content, while reducing electrolyte leakage in zucchini plants under salinity of 4.0 and 0.6 dS m^{-1}, respectively.

Root, stem and leaf dry mass of zucchini increases when plants are irrigated with 0.6 dS m^{-1} water and subjected to paclobutrazol concentration of 8 mg L^{-1}.

Paclobutrazol concentrations do not attenuate the effects of salinity on leaf area, crown volume and diameter, vegetative vigor index, chlorophyll *a* and carotenoids.

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