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Inhibitor of gibberellin biosynthesis in ornamental peppers

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ABSTRACT

The objective of this study was to evaluate whether the inhibition of gibberellin biosynthesis affects the morphophysiological traits of potted ornamental *Capsicum baccatum* and *Capsicum annuum* growing under shade house conditions. Plants maintained in 2.7 L pots were arranged in a completely randomized design in a 2x4 factorial consisting of two pepper cultivars Chapéu-de-frade (*C. baccatum*) and Vulcão (*C. annuum)* and four paclobutrazol (PBZ) concentrations (0, 25, 50, and 75 mg L^{-1}) with four replicates. At 30, 45, and 60 days after treatment, the plants were analyzed, and data were submitted to the analysis of general and regression variance. Gibberellin biosynthesis inhibition affected the morphophysiological and biochemical evaluations. For most evaluated traits, no interaction between factors was observed, suggesting that both pepper cultivars had a similar response to the growth regulator. PBZ-induced inhibition of gibberellin biosynthesis improved plant water status, which enhanced the vigor of potted pepper plants. The dramatic reduction of upper leaves promoted by plant growth regulators compared to basal ones negatively impacted the visual ornamental aspect of Chapéu-de-frade peppers.

Keywords: *Capsicum annuum*, *C. baccatum* v. *pendulum*, paclobutrazol, plant growth regulator, ornamental value.

RESUMO

Inibidor da biossíntese de giberelinas em pimenteiras ornamentais

O objetivo deste estudo foi avaliar se a inibição da biossíntese de giberelinas afeta as características morfofisiológicas das espécies *Capsicum baccatum* e *Capsicum annuum* destinadas ao uso ornamental, cultivadas em vasos em casa de vegetação. As plantas foram conduzidas em vaso de 2,7 L em casa de vegetação, organizadas em delineamento inteiramente casualizado, com esquema fatorial 2x4 constituído por duas variedades de pimenteiras "Chapéu-de-frade" (*C. baccatum*) e "Vulcão" (*C. annuum)* e 4 concentrações de paclobutrazol (PBZ) (0; 25; 50 e 75 mg L^{-1}) e quatro repetições. Aos 30, 45 e 60 dias após a aplicação do inibidor foram realizadas avaliações. A restrição da biossíntese de giberelinas promove alterações morfológicas que elevam a longevidade e vigor de folhas, e induz um status hídrico que favorece o vigor das pimenteiras envasadas. Para a cv. Chapéu-de-frade, a drástica redução do limbo foliar na parte superior resultante da ação do regulador vegetal em relação a base da copa, resultou em uma copa com menor atributo ornamental.

Palavras-chave: *Capsicum annuum*, *C. baccatum* v. *pendulum*, paclobutrazol, regulador de crescimento, valor ornamental.

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Ornamental pepper plants are commercialized as cuttings, gardens or potted plants. Potted plants are usually grown for retail, mainly during the fall and winter festivals in Europe and the United States (Stommel *et al.*, 2018), during which decorative pepper shrubs are popular.

Many small or semi-dwarf pepper cultivars are grown for the ornamental market (Coon *et al.*, 2017). Although a wide range of information on plant height exists, little is known about the actual expression of dwarfism or other factors related to canopy structure. This information is important for breeding investigations on fixed canopy traits because the phenotypic plasticity of *Capsicum* is regulated by factors, including light availability, pot type, amount and type of growing media, and treatment of the growing environment, all of which greatly affect product quality (Parladore *et al.*, 2019; Gallegos *et al.*, 2020). Two important factors that modulate the quality of ornamental potted plants are light intensity and water supply. The absence of light in transport vehicles, markets, and customer homes may accelerate leaf senescence and abscission. These conditions stimulate senescence and abscission of leaves, flowers, and fruits (Ribeiro *et al.*, 2019).

Potted pepper plants are destined for the urban environment, usually indoors, where lighting is typically limited, and plant management, such as watering frequency, is often neglected in everyday life. Growth regulators that restrict the biosynthesis of gibberellins, such as paclobutrazol (PBZ), may minimize etiolation in plants under intense shading conditions and lead to a more suitable canopy architecture for plants in pots. An interaction between shading levels and the biosynthesis of gibberellins in plants treated with PBZ has been observed for several pot-grown ornamental species (Ahmad *et al.*, 2015). Growth regulators may also improve the response of plants to water deficits by activating mechanisms of drought escape and tolerance without other external stimuli. Furthermore, studies have shown that this activation increases eco-physiological performance and ornamental quality in potted pepper Hot Pepper Octopus (Soares *et al.*, 2020).

Paclobutrazol (PBZ) is a plant growth regulator belonging to the triazole group that inhibits gibberellin biosynthesis and amplifies the action of DELLA proteins (a family of nuclear proteins that stunt growth) (Zhou & Underhill, 2020). The effects of PBZ on ornamental pepper plants include reducing plant height, delaying leaf and fruit senescence and abscission, and increasing drought tolerance (França *et al.*, 2018). However, our knowledge has many gaps regarding how pepper genotypes and PBZ concentrations interact, especially for commercial cultivars, such as Vulcão (*Capsicum annuum*). Another species of the Baccatum clade, *Capsicum baccatum* var. *pendulum*, known as Chapéu-de-frade, is a good prospect for the ornamental market. However, some canopy characteristics, such as major height and a small number of leaves and fruits compared to Vulcão could be modulated by gibberellin biosynthesis inhibition. Melo *et al.* (2014) reported that *C. baccatum* var. *pendulum* accessions showed highly persistent fruits and a long flower pedicel, desirable ornamental traits.

This study evaluated whether the inhibition of gibberellin biosynthesis affects the morphology and physiology of the ornamental peppers Chapéu-de-frade (*Capsicum baccatum*) and Vulcão (*Capsicum annuum*) and whether there are differences between the two pepper types grown in pots under shade conditions.

MATERIAL AND METHODS

An experiment was conducted from December 2018 to April 2019 in a 50% shade house located at the State University of Southwestern Bahia (UESB), Vitória da Conquista, Bahia state, Brazil (14°53′08″S, 40°48′02″W). According to the Köppen-Geiger climatic classification, the climate is Cwa (tropical altitude), with an annual average temperature of 20.2°C.

Certified, locally acquired seeds of the two *Capsicum* pepper cultivars, Chapéu-de-frade (*C. baccatum* v. *pendulum*) and Vulcão (*C. annuum*) were sown in 2.7 L polyethylene pots filled with Vivatto Slim Plus® growing medium, biostabilized pine bark, charcoal mill, water, and phenolic foam, at a density of 260 kg m^{-3} dry basis, 200% water retention capacity, 1.5% fertilizer, and 0.20% corrective, based on Neres (2016). Three seeds were sown per pot. After seed emergence, seedlings were thinned to leave one seedling per pot. Each pot received 3 g of 10-10-10 NPK diluted in 150 mL water every 15 days. Irrigation was performed daily to maintain pot capacity.

A completely randomized design was organized with treatments arranged in a 2x4 factorial, consisting of two pepper cultivars (Chapéu-de-frade and Vulcão) and four concentrations of an inhibitor of gibberellin biosynthesis (PBZ; 0, 25, 50, and 75 mg L^{-1}). Treatments were replicated four times, totaling 32 experimental units. The inhibitor of gibberellin biosynthesis, PBZ, was applied to the growing substrate when the plants were 15 cm tall, using 200 mL of Cultar 250 SC® (250 g a.i. L^{-1} PBZ).

The following measurements were assessed at 30, 45, and 60 d after applying PBZ: plant height, measured from the substrate level to apex using a ruler (cm); mean stem diameter, measured at substrate level using a digital caliper (mm); leaf greenness index, measured using a portable chlorophyll meter (SPAD 502, MINOLTA, Japan) and the SPAD index was the mean of three readings taken on the topmost fully expanded leaf; and the number of leaves, branches, and fruits, counted on each plant.

At 60 days after PBZ application, the following measurements were evaluated: leaf gas exchange, relative leaf water content, water potential, photosynthetic pigments, shoot dry weight, shoot fresh weight, root dry weight, root fresh weight, total plant dry weight, total plant fresh weight, total leaf area, and specific and individual leaf area.

Foliar gas exchange was determined at 7:00 a.m. and 12:00 p.m. using an infrared gas analyzer (IRGA – LCPro, ADC, UK) coupled to an actinic light source emitting 1,000 µmol photons m^{-2} s^{-1} of photosynthetically active radiation. IRGA measured the CO_2 assimilation rate (A, µmol CO_2 m^{-2} s^{-1}), transpiration rate (E, mmol water vapor m^{-2} s^{-1}), stomatal conductance (gs, mol m^{-2} s^{-1}), and internal CO_2 concentration in the leaf (Ci, µmol CO_2 mol^{-1} air). Water use efficiency (A/E) is the ratio of CO_2 assimilation rate to transpiration rate, and carboxylation efficiency (A/Ci) is the ratio of the CO_2 assimilation rate to the internal CO_2 concentration in the leaf.

The leaf relative water content (RWC) was determined using the equation: $RWC = [(FW - DW)/(TW - DW)] \times 100$, where FW, DW, and TW are leaf fresh, dry, and total weight, respectively, measured at dawn. Water potential was also measured at dawn, using the second fully expanded leaf counting from the apex of each plant (Scholander *et al.*, 1964).

Photosynthetic pigments were determined on the first bottom-up fully expanded leaf following the methodology described by Barbieri Júnior *et al.* (2010). Absorbance was measured at wavelengths of 663, 646, and 470 nm using a spectrophotometer (700 Plus, Femto, Brazil). Readings were converted to mg g^{-1} of leaf fresh matter, according to the sample weight, volume of acetone, and chlorophyll content.

Shoot, root, and total dry weights were obtained by drying in a hot air oven at 65°C until a constant weight was attained. Root and shoot percentages were determined via the ratio of dry weight to fresh weight of roots and shoots, respectively, whereas the shoot to root ratio was the ratio of shoot dry weight to root dry weight. The yield ratio was calculated as the ratio of fruit dry weight to total plant dry weight.

An area meter was used to determine the total leaf area (LI 3100, LI-COR, USA), with readings expressed in cm^2. Individual leaf area was defined as the ratio between total leaf area and the number of leaves, whereas specific leaf area was the ratio between total leaf area and total leaf dry weight.

Data were tested for normality (Lilliefors) and homogeneity of variances (Cochran). Regression models were submitted to an F-test at 5% and 1% significance levels, and the coefficients of regression models and the linear coefficient of determination (r^2) were analyzed by t-tests (at 10%, 5%, and 1% significance levels). After these procedures, the regression models that complied with the requirements previously described were further defined by adjustment to the biological response of each trait. Statistical analyses were performed using SAEG software (System of Statistical and Genetic Analyses, version 9.1).

RESULTS AND DISCUSSION

Gibberellin biosynthesis inhibitors affected plant height, plant dry matter content and related ratios, total leaf area, specific leaf area, number of fruits, SPAD index, and photosynthetic pigments. Pepper types differed in plant height, stem diameter, number of fruits, leaf area and related ratios, dry weight and related ratios, and physiological measurements (transpiration, stomatal conductance, internal CO_2 concentration, SPAD index, and total carotenoid content).

Although the effect of gibberellin biosynthesis inhibition and pepper type on response traits has been well characterized, the effect of the interaction between these factors was not observed for most response traits, except for total plant and root dry weights, individual leaf area, leaf pigments, water potential at predawn, and internal CO_2 concentration. The uniform effect of PBZ concentrations on both pepper types, shown by the absence of interaction, suggests a similar response when submitted to the growth regulator. Plant height of both pepper types remained below 25 cm, including PBZ-untreated plants; thus, they were classified as semi-dwarf plants (Coon *et al.*, 2017).

Inhibition of gibberellin biosynthesis resulted in shorter plants between 30 and 60 days. At 60 days after PBZ application, the number of fruits and leaf area and related ratios decreased because of the inhibition of gibberellin biosynthesis. However, the number of branches, number of leaves, and stem diameter increased with increasing PBZ concentration (Figure 1).

Shorter plants with more branches induced by the inhibition of gibberellin biosynthesis lead to a more symmetric, compact canopy, which is a desirable trait for the ornamental quality of plants marketed in pots (França *et al.*, 2018). According to Coon *et al.* (2017), ornamental peppers have a more compact canopy because of their polychotomous branching growth pattern, whereas standard pepper cultivars have a dichotomous growth pattern. However, in the present study, the inhibition of gibberellin biosynthesis resulted in the elevation of branch number only during the initial development of pepper plants.

Although the number and dry weight of fruits decreased at 60 d after applying PBZ, the ratio of fruit dry weight to total plant dry weight was high because of the increase in the concentration of the gibberellin inhibitor (Figure 1). Despite the reduction in the number of fruits per plant as the concentration of the inhibitor increased, the ornamental quality of the plants was not affected because plants were taller and had thicker stems, a higher numbers of branches and leaves, larger individual leaf areas, and thicker leaves (Ribeiro *et al.*, 2019). PBZ-induced vigorous leaves are directly associated with plant esthetics owing to an evenly dense canopy, which results in the suitable cover of the pot.

The more favorable ornamental pattern was verified for cultivar Vulcão characterized by shorter plants, a higher number of fruits, greater individual leaf area, and higher SPAD index and chlorophyll content compared to Chapéu-de-frade. Despite the lower number of fruits in Chapéu-de-frade plants, their fruits were heavier, a different morphological characteristic from Vulcão (Table 1).

The dry weight ratios of Chapéu-de-frade were higher than those for Vulcão. Although the accumulation of dry matter is not directly related to the ornamental aspect of plants, the greater buildup of photoassimilates in Vulcão roots compared to Chapéu-de-frade was associated with longer shelf life (Table 1). Bizuayehu & Getachew (2021) pointed out that the inhibition of gibberellin biosynthesis may increase the hydraulic conductivity of the xylem, improve plant water status, maintain cell membrane stability, and create greener leaves, all of which indicate delayed senescence and abscission.

The increase in leaf greenness (higher SPAD index) was associated with higher chlorophyll biosynthesis. The small difference between the concentrations that resulted in the highest SPAD index and chlorophyll content was related to SPAD readings considering the analyzed area. In contrast, pigment contents were estimated based on the weight of the sample. The increased chlorophyll content in PBZ-treated plants as carotenoid content declined was associated with the attenuation of leaf senescence (Figure 1).

Gibberellins are associated with decreased leaf senescence because of negative interactions with abscisic acid (Akhtar *et al.*, 2020). Despite the drop in gibberellin levels (mainly GA4 and GA7) during the process of leaf senescence, inhibitors of gibberellin biosynthesis, such as PBZ, delayed leaf senescence in *Arabidopsis* and cassava (Davenport & Reese, 2019).

Chapéu-de-frade was more responsive to PBZ application and exhibited an earlier increase in total chlorophyll and chlorophyll b contents, reaching higher values and lower carotenoid content in the leaves (18, 17, and 31 mg L^{-1}, respectively) compared to Vulcão (37, 39, and

44 mg L-1, respectively) (Figure 1). An uneven phenotypic response of *Capsicum* accessions to PBZ applied for ornamental purposes has been reported (Ribeiro *et al.*, 2019). Potted *C. annum* and *C. chinensis* accessions responded differently to PBZ with respect to the greenness of leaves (França *et al.*, 2018).

The relationship between the shoot to root ratio and PBZ concentration was fitted to a decreasing quadratic model. The model revealed increased root dry weight and decreased shoot dry weight as gibberellin biosynthesis restriction increased. Despite the increase in

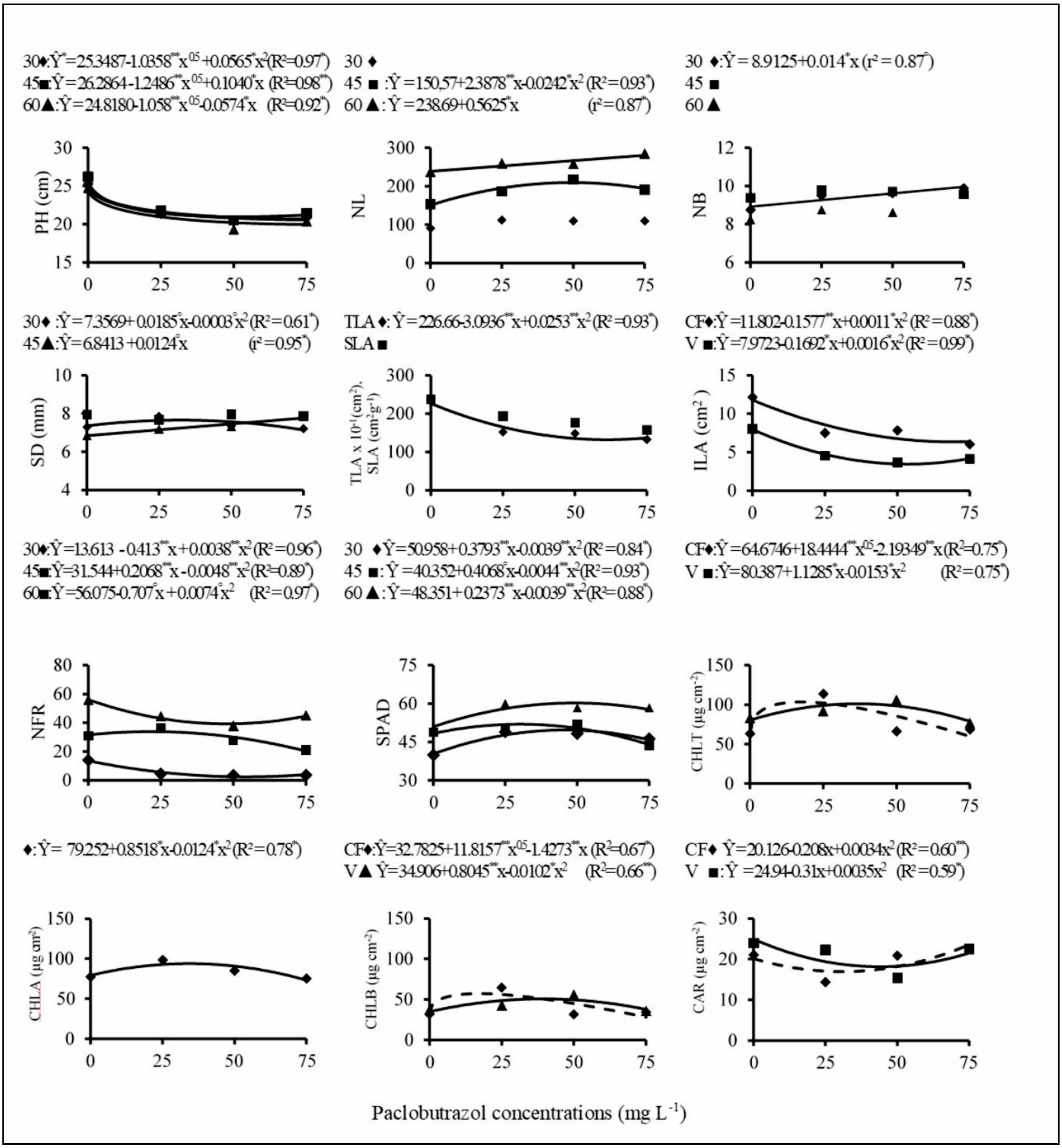

Figure 1. Plant height (PH), number of leaves (NL), number of branches (NB), mean stem diameter (SD), total leaf area (TLA), individual leaf area (ILA), number of fruits (NFR), SPAD index (SPAD), total chlorophyll (CHLT), chlorophyll a (CHLA), chlorophyll b (CHLB), and carotenoids (CAR) in Chapéu-de-frade (CF) and Vulcão (V) peppers treated with paclobutrazol concentrations at 30, 45, and 60 days after applying the regulator. º, *, ** and ns represent significance at the 10%, 5% and 1% probability level and non-significant, respectively, based on the analysis of variance of the regression model and t-test of coefficients of regression model and linear coefficient of determination. Vitória da Conquista, UESB, 2018-2019.

root dry weight with increasing PBZ concentrations, dry matter percentage (dry weight/fresh weight ratio on a whole plant basis) decreased by 9% up to 75 mg L^{-1}, indicating that water content contributes more to the root volume (Figure 2). Kamran *et al.* (2018) verified that PBZ-treated corn plants had thicker roots and greater root pressure.

For the ornamental purposes of potted peppers, roots as a preferential sink is a characteristic of interest because they are associated with a drought escape mechanism. Vigorous roots increase the water uptake capacity, which in turn lengthens the life cycle of pepper plants. Plant water status improves when this greater water uptake capacity is associated with water storage in the roots and decreased transpiration resulting from the reduction in photoassimilate partitioning to aerial parts (decreased leaf area). Storing water in roots is considered an important drought escape mechanism (Kamram *et al.*, 2018).

There was a decrease in total plant dry weight for both cultivars. This decrease was more homogenous and intense with decreasing PBZ application in Chapéu-de-frade (27% less than the control) compared to Vulcão (21% less than the control). Total dry weight in Chapéu-de-frade remained higher than in Vulcão up to 50 mg L^{-1}, and then, the values became equal at 75 mg L^{-1} (Figure 2).

The reduction in dry matter accumulation in *Capsicum* plants

Table 1. Plant height (PH), number of leaves (NL), number of branches (NB), mean stem diameter (SD), number of fruits (NFR), SPAD index (SPAD), at 30, 45, and 60 days after applying the growth regulator, paclobutrazol (PBZ); total leaf area (TLA), specific leaf area (SLA), chlorophyll a (CHLA), yield ratio (YR), shoot to root ratio (SRR), shoot weight percentage (SWP), root weight percentage (RWP), stem dry weight (STDW), leaf dry weight (LDW), fruit dry weight (FDW), shoot dry weight (SDW), plant relative water content (RWC), CO_2 assimilation rate (A), transpiration rate (E), stomatal conductance (gs), carboxylation efficiency [A/Ci (internal CO_2 concentration in the leaf)], and water use efficiency (WUE) evaluated at 60 days after applying PBZ to two ornamental pepper cultivars, Chapéu-de-frade (CF) and Vulcão (V) under different PBZ concentrations. Vitória da Conquista, UESB, 2018-2019.

Evaluated parameters	Days after treatment											
	30				45				60			
	Cultivars											
	CF		V		CF		V		CF		V	
PH	24.78	A	19.42	B	25.66	A	20.31	B	24.34	A	18.53	B
NL	78.93	B	132.06	A	175.19	A	199.37	A	249.25	A	270.31	A
NB	8.75	A	10.13	A	8.69	A	9.39	B	8.25	A	9.39	A
SD	8.06	A	6.80	B	8.53	A	7.01	B	8.60	A	7.12	B
TLA	-		-		-		-		2011.58	A	1310.85	B
SLA	-		-		-		-		204.57	A	175.57	B
NFR	2.31	B	10.56	A	14.50	B	43.31	A	16.44	B	75.06	A
SPAD	31.96	B	23.84	A	49.47	A	47.79	A	48.55	B	64.91	A
CHLA	-		-		-		-		37,51	B	46,50	A
SRR	-		-		-		-		4.1073	A	3.11	B
YR	-		-		-		-		0.2367	A	0.23	A
SWP(%)	-		-		-		-		14.686	A	12.91	B
RWP(%)%)	-		-		-		-		12.606	A	13.21	A
SDW	-		-		-		-		8.3898	A	5.06	B
LDW	-		-		-		-		9.61	A	7.46	B
FDW	-		-		-		-		98.54	A	50.17	B
STDW	-		-		-		-		32.943	A	24.20	B
RWC	-		-		-		-		92.225	A	92.21	A
gs	-		-		-		-		0.5306	B	1.27	A
A	-		-		-		-		17.148	B	20.74	A
E	-		-		-		-		5.6143	B	6.70	A
WUE	-		-		-		-		3.0726	A	3.08	A
A/Ci	-		-		-		-		0.0690	A	0.08	A

Means followed by the same uppercase letter in the row do not differ based on the F-test at a 5% probability. CF = Chapéu-de-frade cultivar; V = Vulcão cultivar.

under the restriction of gibberellin biosynthesis has been reported (Mutlu & Agan, 2015). It is associated with an increase in the action of growth inhibitors, such as abscisic acid, and a decrease in growth promoters, such as auxins, gibberellins, and cytokinins (Opio *et al.*, 2020).

The Chapéu-de-frade cultivar had a noticeable reduction in leaf water potential with increased inhibition of gibberellin biosynthesis compared to Vulcão. The water potential usually decreases because of decreased osmotic potential and pressure potential.

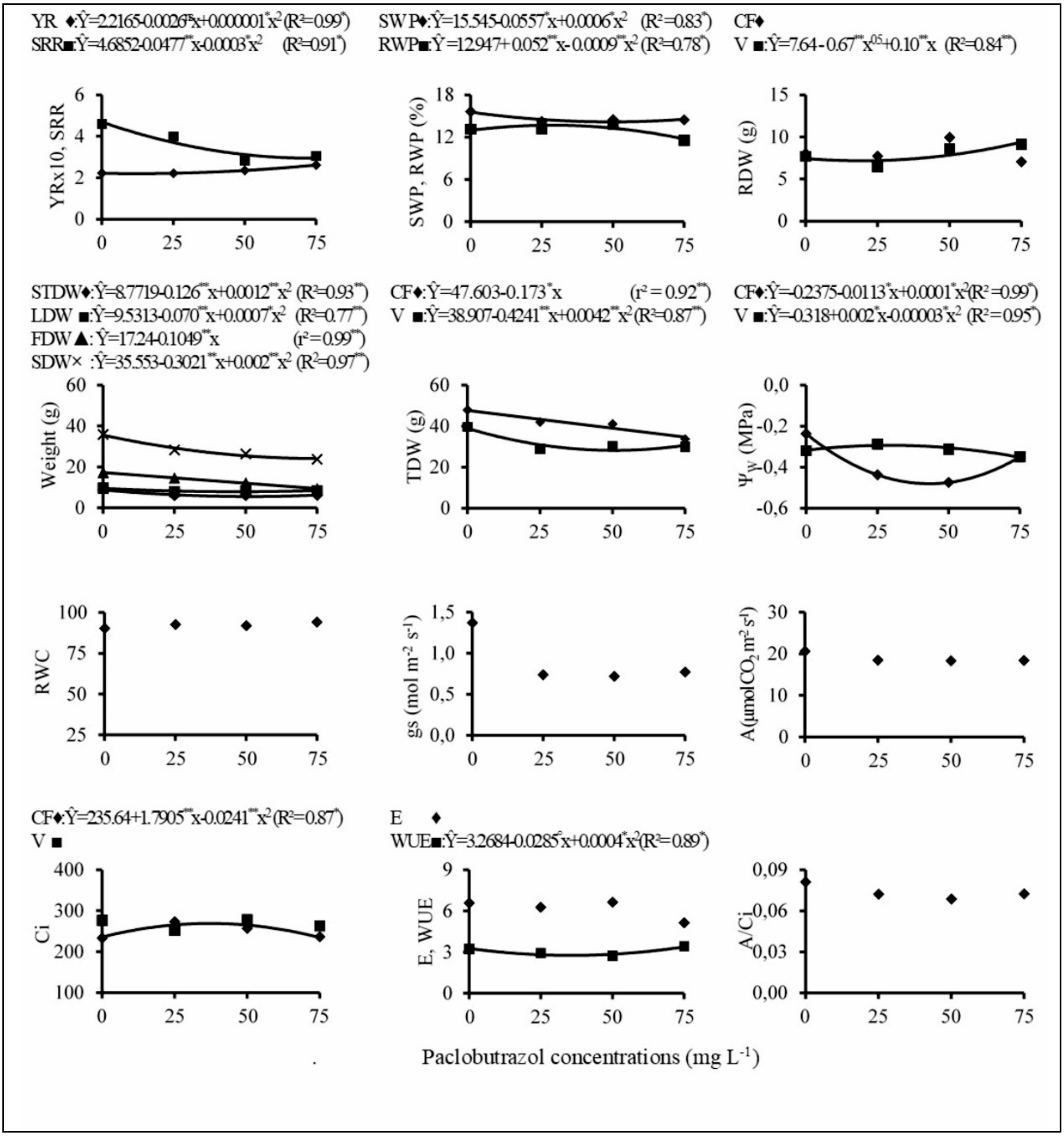

Figure 2. Yield ratio (YR), shoot to root ratio (SRR), shoot weight percentage (SWP), root weight percentage (RWP), root dry weight (RDW), stem dry weight (STDW), leaf dry weight (LDW), fruit dry weight (FDW), shoot dry weight (SDW), total plant dry weight (TDW), water potential (Ψ_w), leaf relative water content (RWC), stomatal conductance (gs), CO_2 assimilation rate (A), transpiration rate (E), water use efficiency (WUE), internal CO_2 concentration in the leaf (Ci), and carboxylation efficiency (A/Ci) of the peppers Chapéu-de-frade (CF) and Vulcão (V) as affected by PBZ application at 60 d after applying the growth regulator. º, *, ** and ns represent significance at the 10%, 5% and 1% probability level and non-significant, respectively, based on the analysis of variance of regression model and t-test of coefficients of regression model and linear coefficient of determination. Vitória da Conquista, UESB, 2018-2019.

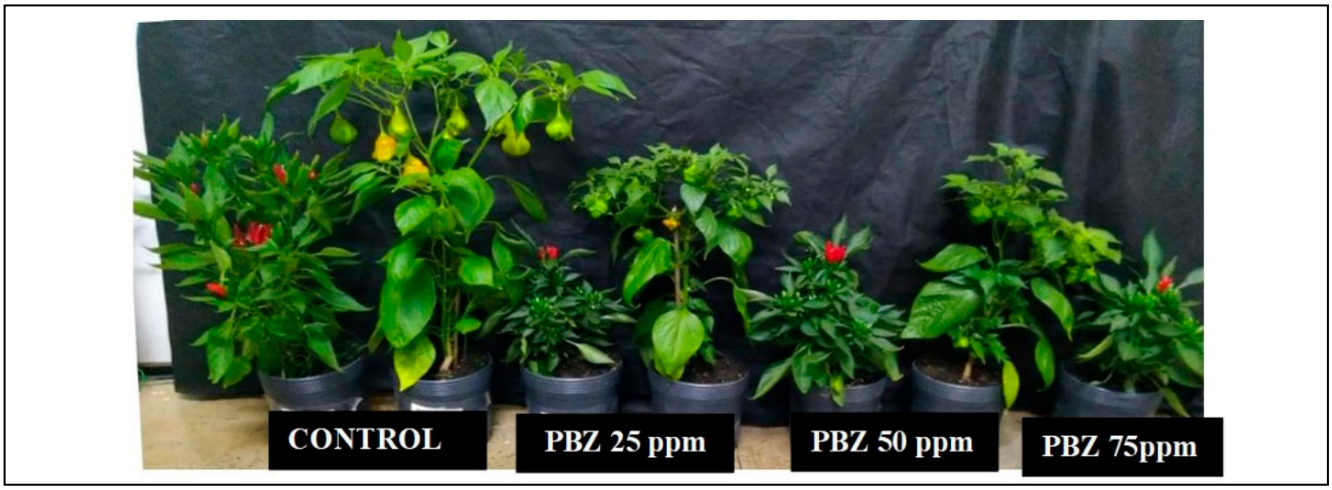

Figure 3. Visual aspect of the ornamental peppers Vulcão and Chapéu-de-frade submitted to gibberellin biosynthesis restriction by paclobutrazol treatment. Vitória da Conquista, UESB, 2018-2019.

Inhibition of gibberellins biosynthesis is also related, in a large number of species, to the increase in the levels of proline and sugars, especially in leaves. This is associated with decreased leaf water potential, as observed in Chapéu-de-frade. Thus, once again, the sensitivity of this pepper cultivar to PBZ was greater than that of Vulcão (Figure 2).

The maintenance of high and homogeneous levels of leaf water potential was verified in Vulcão and was greater than in Chapéu-de-frade. This effect was associated with a reduction in specific leaf areas (thicker leaf blades) because the inhibition of gibberellin biosynthesis resulted in an abscisic acid-induced thicker epicuticular wax layer and larger leaf cells (Bizuayehu & Getachew, 2021). In the present study, without restricting water disponibility, the stabilization of the water potential was verified for Vulcão but not for Chapéu-de-frade, indicating that expression of this effect was associated with genotype. For Chapéu-de-frade, a decrease in leaf water potential was verified for all PBZ treatments, with minor values for 33.33 mg L^{-1} of PBZ applied (Figure 2).

The internal CO_2 concentration for Chapéu-de-frade increased because of the effect of PBZ on the elevation of mesophyll resistance (Shevchuk *et al.*, 2019) and the reduction of stomatal conductance (Soumya *et al.*, 2017). The PBZ-induced partial closure of stomata is related to increased abscisic acid levels (Upreti *et al.*, 2013); however, our results showed no effect of PBZ on the stomatal conductance of pepper plants (Figure 2).

A higher mesophyll resistance caused by the inhibition of gibberellin biosynthesis decreases the diffusion capacity of gases in the leaf mesophyll, increasing the internal CO_2 concentration of Chapéu-de-frade. In this study, increased specific leaf area (SLA) was associated with thickening of the palisade and spongy parenchyma, which is the result of stimulating greater elongation of collenchyma cells lengthwise, induced by the growth inhibitor (Shevchuk *et al.*, 2019). This cell elongation reduces the volume of cell spaces and increases mesophyll resistance (Teixeira *et al.*, 2019). Although the inhibition of gibberellin biosynthesis increased chlorophyll content, internal CO_2 concentration, and stomatal resistance, only a slight decrease in net photosynthesis rate was observed because of the increase in PBZ concentrations.

Transpiration reduction induced by PBZ may be related to changes in stomatal mechanisms and leaf anatomy, restricting gibberellin biosynthesis and increasing DELLA proteins (Shohat *et al.*, 2020), leading to decreased catabolism and increased abscisic acid biosynthesis, which improves the mechanism underlying partial stomatal closure, thereby reducing transpiration (Soumya *et al.*, 2017). Although PBZ-induced canopy compaction has been of little significance, it resulted in shorter plants with a greater number of leaves that changed the microclimate, reducing the vapor pressure deficit and transpiration rates, regardless of stomatal conductance (Hütsch & Schubert, 2021).

The leaf anatomy traits of the Chapéu-de-frade were related to lower values of gs, A, and E than in Vulcão. Aworinde *et al.* (2014) reported more pubescent leaves with lower stomatal density on the abaxial and adaxial surfaces of *C. baccatum* than in *C. annuum*. Although it is an important mechanism in reducing transpiration, the presence of hairs increases the reflection of incident solar radiation, which may change photosynthesis rates (Yang *et al.*, 2020). Although leaf anatomical differences may affect gas exchange, the two pepper cultivars maintained a similar tendency when evaluating the carboxylation capacity (A/Ci) and water use efficiency (Table 1).

In addition to the alterations in pepper plant morphophysiology induced by the restriction of gibberellin biosynthesis, the visual ornamental aspect was not contemplated for Chapéu-de-frade. When submitted to PBZ, the basal leaves of the canopy had a greater disproportional size than the upper ones, and because of the length of petiole, fruit shape, and fruit size reduction in Chapéu-de-frade, it made them less visible from the canopy (Figure 3).

The cultivar Chapéu-de-frade has major vegetative vigor, fewer attractive fruits, and minor photosynthetic characteristics compared to Vulcão. Inhibiting gibberellin biosynthesis in the cultivars Chapéu-de-frade and Vulcão improved ornamental traits, including canopy structure, longevity, and leaf vigor, when grown in shaded environments. Morphological changes induced by restriction of gibberellin biosynthesis in the cultivars Chapéu-de-frade and Vulcão (smaller leaves, lower specific and total leaf area, increased number of branches and leaves, and more vigorous root system) improved plant water status.

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