

Growth and quality of potted ornamental peppers treated with paclobutrazol

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Abstract – The objective of this work was to evaluate the action of paclobutrazol (PBZ) on the growth and ornamental value of two pepper accessions and two commercial cultivars of ornamental pepper – Biquinho Vermelha and Bode Amarela. A PBZ aqueous solution (250 mL) was used to soak the substrate at 0, 20, 40, and 60 mg L⁻¹ a.i. concentrations when the plants had 12 cm height. At the end of plant growth, the following parameters were evaluated: plant height, chlorophyll content in leaves, number of fruit and leaves, and canopy compactness at the time the plants reached maturity to be marketed, with 30% of ripe fruit. Irrespective of the applied PBZ concentration, plant height diminished, and chlorophyll content increased. PBZ did not improve the ornamental characteristics of the genotypes 'Biquinho Vermelha' and 2334PB, which resulted in unsuitable plants for market requirements. For the genotypes 2345PB and 'Bode Amarela', the application of 20 mg L⁻¹ of PBZ is the most indicated, and it results in plants with adequate ornamental characteristics required by the national market of flowers and ornamental plants.

Index terms: *Capsicum annuum*, *Capsicum chinense*, chlorophyll, growth regulator.

Crescimento e qualidade de pimentas ornamentais em vaso tratadas com paclobutrazol

Resumo – O objetivo deste trabalho foi avaliar a ação do paclobutrazol (PBZ) sobre o crescimento e valor ornamental de dois acessos e duas cultivares comerciais de pimenta ornamental – Biquinho Vermelha e Bode Amarela. Uma solução aquosa de 250 mL de PBZ foi adicionada aos vasos com 0, 20, 40 e 60 mg L⁻¹ i.a., quando as plantas apresentavam 12 cm de altura. Ao final do crescimento, determinaram-se os seguintes parâmetros: a altura das plantas, o teor de clorofila das folhas, o número de frutos e de folhas, e a compactidade da parte aérea no estágio de maturidade das plantas, com 30% de frutos maduros. Independentemente da concentração de PBZ aplicada, houve redução da altura das plantas e aumento da concentração de clorofila nas folhas. O PBZ não melhorou as características ornamentais dos genótipos 'Biquinho Vermelha' e 2334PB, o que resultou em plantas inadequadas aos requisitos do mercado. Para os genótipos 2345PB e 'Bode Amarela', a aplicação de 20 mg L⁻¹ de PBZ é a mais indicada e resulta em plantas com características ornamentais adequadas requeridas pelo mercado nacional de flores e plantas ornamentais.

Termos para indexação: *Capsicum annuum*, *Capsicum chinense*, clorofila, regulador de crescimento.

Introduction

The market for potted ornamental chilli pepper has increased considerably in Brazil and abroad (Finger et al., 2015). Ornamental peppers should show some important morphological characteristics that provide aesthetic value, which includes vivid foliage, small height, and colourful fruit contrasting with the green foliage (Rêgo et al., 2013).

For decorative purposes, it is necessary to use pepper cultivars adapted to the growth in small pots with a limited amount of substrate. However, there are only few commercial cultivars available in the market, since most plants from the genus *Capsicum* are of large size (Santos et al., 2013).

Paclobutrazol (PBZ) interferes with the first steps of the caurene oxidation pathway, preventing the formation of gibberellins, and acting as a negative

control of the mechanisms related to gibberellins action, mainly by inhibiting the plant growth (Ribeiro et al., 2011). For these aspects, PBZ has been used with the purpose to reduce height in several species of ornamental plants (Rademacher, 2000). In the 'Pitanga' pepper (*C. chinense*), PBZ applied either by spraying on the leaves or put in the substrate was effective in reducing the plant height, plant diameter, and in increasing the leaf-chlorophyll content (Grossi et al., 2005). In the same work, the authors found that the reduction of plant height was proportional to the increase of PBZ concentration; however, no evaluation of the ornamental properties was performed. PBZ was also efficient in reducing the stem growth of sunflower and orchid plants (Wanderley et al., 2014a, 2014b). Potted sunflowers soaked with PBZ reduced the stem extension, which was reversed by spray of GA₃ (Ribeiro et al., 2011).

The effectiveness of PBZ to reduce the plant growth varies according to plant stage of development, product concentration, species, cultivar, and time and mode of application (Rademacher, 2000; Mabvongwe et al., 2016). As PBZ is better absorbed by the root system, a direct application to the soil or pot substrate provides an increased efficacy at low concentrations (Currey & Lopez, 2009).

Only few studies (Grossi et al., 2005; Ribeiro, 2016; Sipioni et al., 2016) have reported the effects of PBZ in controlling the growth on peppers species from the genus *Capsicum* (*C. annuum*; *C. baccatum*; *C. chinense*, and *C. frutescens*) with ornamental potential. Nevertheless, the results showed a great response variability in the four tested species. The demand for ornamental peppers in Brazil is increasing year by year. However, only few commercial cultivars are available, considering the wide genetic variability in the genus *Capsicum*. The knowledge on the responses of a range of genotypes will increase the number of species with ornamental characteristics.

The objective of this work was to evaluate the effect of PBZ on the growth and ornamental value of two accessions and two commercial cultivars of pepper – Biquinho Vermelha and Bode Amarela.

Materials and Methods

Four pepper genotypes with ornamental potential were used, two of them are the commercial cultivars

Bode Amarela and Biquinho Vermelha, both from the species *C. chinense*, and two are the accessions 2334PB and 2345PB of the species *C. annuum* and *C. chinense*, respectively, from the germplasm bank of Universidade Federal da Paraíba.

Seed were sown in polystyrene trays filled with the commercial substrate Bioplant (Bioplant Agrícola Ltda., Nova Ponte, MG, Brazil) in January 2013. The seedlings were transplanted into 900 mL pots no. 13 (11 cm height, 9.5 cm basal diameter, 13.5 cm top diameter), which contained the same substrate used for sowing. The plantlets were transplanted when showing two to three pairs of true leaves. The plants were grown in a greenhouse under natural conditions of light, in Viçosa, MG, Brazil (20°45'S, 42°51'W, 648 m altitude). During the transplanting, the substrate was fertilized with 2.5 g of formulated N-P₂O₅-K₂O 0-10-10. During the experiment, fertilization was performed every 20 days with 10 g of N-P₂O₅-K₂O 10-0-10 formula. The irrigation was made once or twice a day as needed.

At 15 days after the transplantation, when plants reached an average height of 12 cm, 250 mL paclobutrazol were directly applied to the growth substrate of each pot, at 20, 40, and 60 mg L⁻¹ PBZ (Cultar 250 SC, Syngenta, Brazil), corresponding to 5, 10, and 15 mg of the active ingredient, respectively. Control plants were watered with 250 mL of tap water. Plant height, chlorophyll-leaf content, number of fruit and leaves, and canopy compactness were evaluated when the plants reached the maturity to be marketed (30% of ripe fruit).

The criteria used to establish the ornamental value of pepper plants in this research followed the standard by the Brazilian cooperative Veiling Holambra, São Paulo (Oliveira et al., 2007). Its quality standards take into account the following measurable characteristics: height (12–38.5 cm, in pots no. 13–15), canopy compactness, number of fruit per plant, maturation point; and quality (yellow and dry leaves, nutritional deficiencies, toxicity caused by chemicals). In order to meet the requirements of Veiling Holambra, the lot should show 90% uniformity in relation to the above mentioned characteristics.

Plant height was measured from the substrate level to the last fully expanded leaf. The chlorophyll content was indirectly estimated by the SPAD 502 chlorophyll-meter (Spectrum Technologies, Inc., Aurora, IL, USA), using the average of nine leaves, three at the basal part,

three in the middle part, and three of the upper part of each plant. The canopy compactness was determined by taking two measures with 90° angle between them, and dividing the smallest value by the largest one. The closest ratio indicate a complete round canopy (Ribeiro et al., 2011). The total numbers of fruit and leaves were counted in each plant, when plants had a minimum of 30% of ripe fruit (Segatto et al., 2013).

The experiment was carried out in a completely randomized design, with a 4x4 factorial arrangement (four pepper genotypes and four PBZ doses), and five replicates. Data were subjected to the analysis of variance and to the regression analysis. The models were chosen based on the significance of the regression coefficients, using t-test at 1% probability, for the coefficient of determination and the biological phenomenon. The Dunnett's test was used to compare means to the control, at 5% probability.

Results and Discussion

Irrespective of the genotype used, drenching the pot substrate with PBZ reduced the plant height with a similar adjusted regression model (Figure 1 A). A significant reduction of plant height was reached with 20 mg L⁻¹ PBZ treatment, and no further height reduction occurred by increasing the dose of PBZ up to 60 mg L⁻¹. The highest height reduction (92.3%) – from 92.04 cm to 7.07 cm – was observed in the 2334PB accession, with 40 mg L⁻¹ PBZ, according to the estimated curve (Figure 1 A and Figure 2). The least effect of PBZ was found for 'Bode Amarela', with 61% reduction of plant height, and 20 mg L⁻¹ PBZ application. The reduction of plant height with PBZ occurs due to the inhibition of the gibberellin synthesis, which is responsible for the expansion and elongation meristem cells that will form the internode region (Rademacher, 2000). The variation of height reduction, observed in the tested genotypes, occurred because the effectiveness of PBZ varies according to the species, and also among varieties of the same species (Rademacher, 2000). Ribeiro (2016) worked with eight ornamental pepper genotypes from *C. chinense* and *C. annuum*, and found different PBZ responses between and within species. This suggests different levels and intensities of responses, involving alterations in the expression of specific genes, and in the activation of signaling pathways. In general, these genes act on several physiological phenomena;

however, genus or species, associated to other factors, can determine the specific effect on the response (Brandão, 2010).

Veiling standards for plant height between 12-38.5 cm were adopted in the present work, in addition to others characteristics (canopy compactness, number of fruit per plant, yellowish and brittle leaves). The application of 40 and 60 mg L⁻¹ PBZ to 'Biquinho Vermelha' and the accession 2334PB were not able to fit them on this pattern. These doses caused a high degree of crinkled leaves, leaving them brittle and with an intensely stunted growth, and reduced their commercial and ornamental values. For those genotypes, the PBZ dose of 20 mg L⁻¹ caused only mild symptoms of phytotoxicity, but they did not show satisfactory characteristics to be used as ornamental plants because they had an excessively low height of 9.8 and 13.6 cm for 'Biquinho Vermelha' and 2334PB, respectively (Figure 2). According to Brum et al. (2007), the height of ornamental plants should be 1.5 to 2 times that of the pot height; in this case, it should be between 16.5 and 22 cm for pots of 11 cm height. Thus, lower doses of PBZ, applied by drench or spray, may result in less phytotoxicity and smaller reduction of plant height. Grossi et al. (2005) applied PBZ on pepper 'Pitanga' (*C. chinense*), and found no toxicity effect when PBZ was applied on leaves; however, some plant characteristics were affected by the application, as branch length, which was reduced, consequently reducing the plant height. This behavior shows a great variability among genotypes and species of peppers in response to PBZ.

The same symptoms of phytotoxicity were observed in all doses of PBZ for the accession 2334PB. In addition, the plants did not show a proper height for ornamental purposes, with an average height of 12 cm (Figure 1 A and Figure 2). In 'Bode Amarela' pepper, only the lowest dose of 20 mg L⁻¹ of PBZ did not cause any symptom of phytotoxicity, and the plants had an adequate height of 18.5 cm for its use in ornamentation (Figure 1 A and Figure 2). For this cultivar, the doses of 40 and 60 mg L⁻¹ promoted an excessive reduction of height and phytotoxic effects on the plants. Grossi et al. (2005) observed a linear reduction of plant height in 'Pitanga' ornamental pepper, which was proportional to the increasing doses of PBZ (5, 10, 15, 30, and 60 mg a.i. L⁻¹ PBZ). The phytotoxic symptoms reported by these authors are corroborated by the present work for the doses of 30 and 60 mg a.i. L⁻¹.

The plants of the 2345PB accession responded better to the plant growth regulator PBZ. They did not show any symptom of phytotoxicity for all applied doses, and had an appropriate average height of 19.3 cm for ornamentation (Figure 1 A and Figure 2).

Regardless of the dose and genotypes used, PBZ-treated plants exhibited greener leaves, in comparison to the control. However, the pattern of increase of chlorophyll content varied among the genotypes (Figure 1 B). PBZ had a similar effect on chlorophyll content of *Arabidopsis thaliana* (Ribeiro et al., 2012a, 2012b) and 'Pitanga' pepper (Grossi et al., 2005). There are still doubts on whether the application of PBZ causes the increase of chlorophyll synthesis, or simply generates a "hub effect" due to the reduced leaf expansion (Davis et al., 1988).

In comparison to the control, the number of leaves was significantly reduced in all doses of PBZ, except for the 20 mg L⁻¹ in 'Bode Amarela' (Table 1). Sankhla et al. (1986) have stated that the effect of PBZ on the production of new leaves depends on its

applied concentration. At high PBZ concentrations, the production of leaves is reduced, whereas at low concentrations, the number of leaves is hardly changed. The density of leaves in an ornamental plant should be proportional to plant height, which results in a good canopy formation. In addition to the photosynthetic surface appropriate to the demands of the plant, the plant canopy should project to the sides of the pot, thus taking a circular shape and covering the substrate. However, the characteristics of each variety should be taken into account, as there are some of them that will not present this pattern for the canopy.

For the accessions 2345PB and 2334PB, and for 'Bode Amarela', the number of fruit was not affected by the PBZ doses. However, plants of 'Biquinho Vermelha' had the number of fruit significantly reduced by the use of PBZ (Table 1). This result suggests the existence of a varietal effect not only for the plant height reduction, but also for the fruiting pattern. The inhibition of gibberellic acid biosynthesis promoted by PBZ may

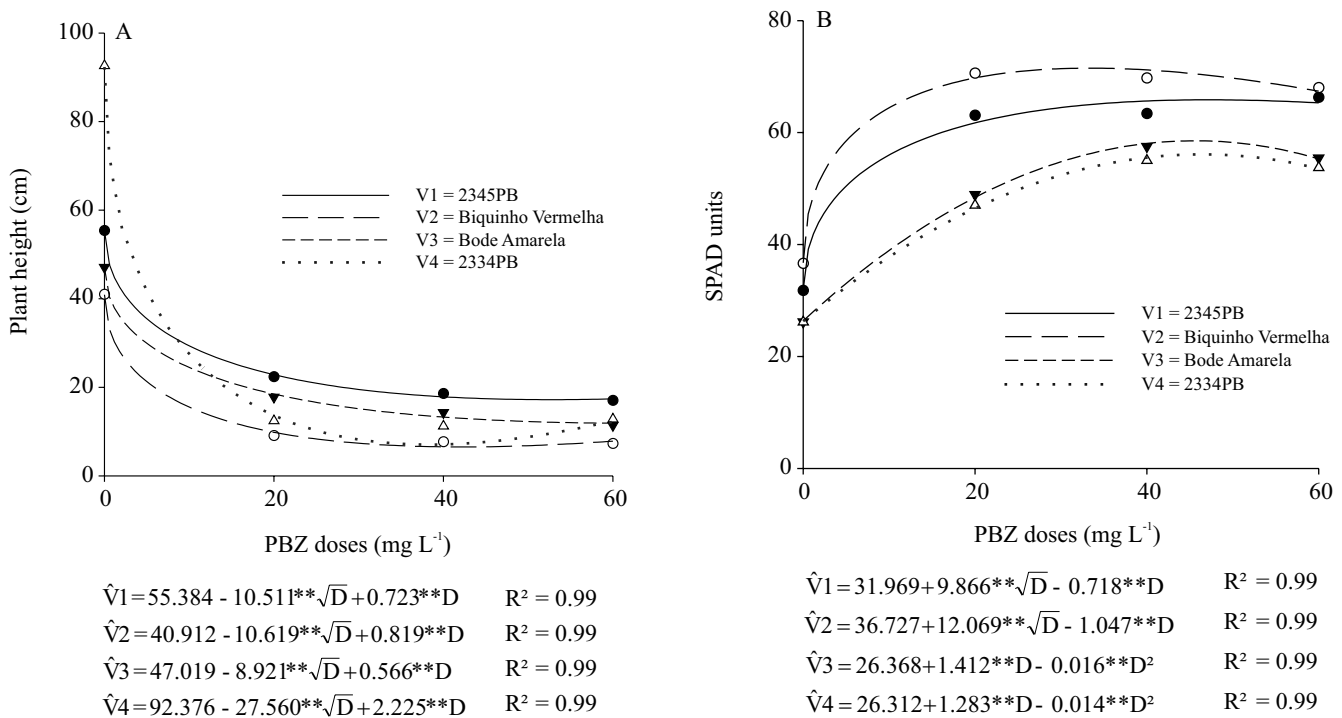


Figure 1. Plant height (A) and SPAD unit (B) according to the increasing levels of paclobutrazol (PBZ) applied to the Biquinho Vermelha and Bode Amarela cultivars and 2345PB and 2334PB accessions of pepper. **Significant by the t-test, at 1% probability.

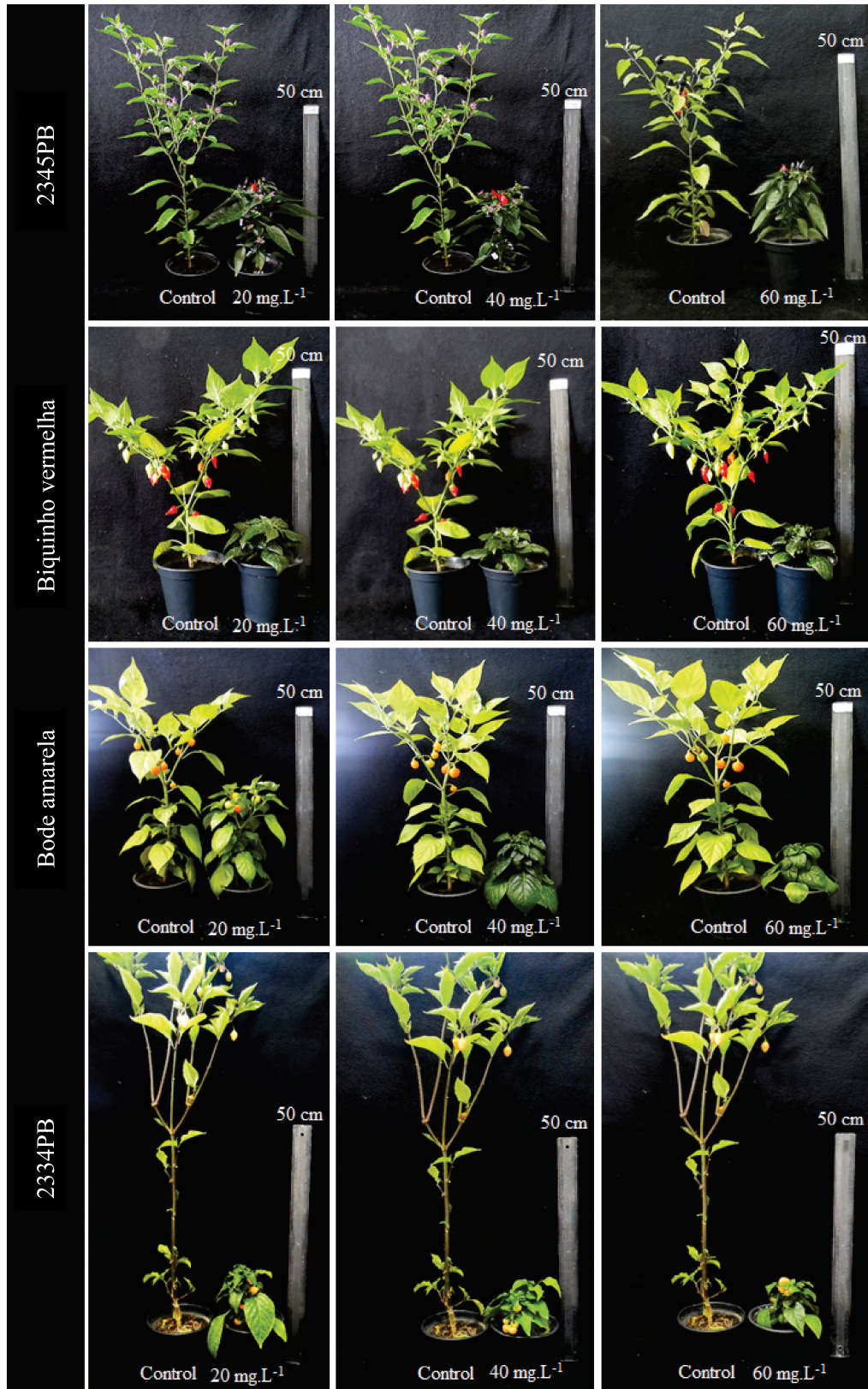


Figure 2. Images of ornamental peppers 2345PB, 'Biquinho Vermelha', 'Bode Amarela', and 2334PB, their controls, and plants treated with paclobutrazol (PBZ).

cause flowering delay and, consequently, less fruit on the plant (Rademacher, 2000).

The canopy compactness was significantly higher than that of the control plants in all the applied PBZ doses just for the accession 2345PB. For the other cultivars, PBZ was not efficient in making the canopy more circular (Table 1). The canopy compactness of the plants was reduced with the application of PBZ, in agreement with Grossi et al. (2005) and Tinoco et al. (2011). This reduction of plant diameters is directly related to the reduction of internode elongation due to the inhibition of gibberellin biosynthesis. The reduction of plant canopy diameter results in a more compact plant. This feature is desirable and serves even as a quality standard for potted ornamental plants, including pots of chrysanthemum, May flower, gerbera and kalanchoe (Noman et al., 2017).

According to the results, the use of 20 mg L⁻¹ PBZ in the commercial cultivar Bode Amarela, and of 20 or 40 mg L⁻¹ PBZ in plants of the accession 2345PB offer to the plants a suitable height for the use in ornamentation, without causing symptoms of phytotoxicity. For the commercial cultivar Biquinho Vermelha and for the

accession 2334PB, new experiments using lower doses PBZ are necessary to determine the optimal dose of this plant growth regulator which could give aesthetic value to these plants for their use as ornamental plants.

Conclusions

1. For the genotypes 2345PB and 'Bode Amarela', the application of 20 mg L⁻¹ of paclobutrazol is the most indicated one, and results in plants with adequate ornamental characteristics, which are required by the national market of flowers and ornamental plants.

2. The application of paclobutrazol does not improve the ornamental characteristics of the genotypes 'Biquinho Vermelha' and 2334PB, which may result in unsuitable plants for the market requirements.

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Table 1. Number of fruit, number of leaves, and canopy compactness of two cultivars and two accessions of pepper treated with paclobutrazol (PBZ)⁽¹⁾.

Genotype	PBZ (mg L ⁻¹)			
	0	20	40	60
	Number of fruit			
2345PB	8.80	10.20 ^{ns}	7.60 ^{ns}	7.60 ^{ns}
Biquinho Vermelha	40.40	6.20*	5.60*	2.00*
Bode Amarela	7.40	14.20 ^{ns}	10.60 ^{ns}	3.60 ^{ns}
2334PB	8.00	9.20 ^{ns}	14.00 ^{ns}	15.80 ^{ns}
	Number of leaves			
2345PB	71.40	44.00*	19.20*	25.80*
Biquinho Vermelha	115.40	37.00*	37.60*	32.80*
Bode Amarela	73.60	68.80 ^{ns}	53.80*	42.20*
2334PB	76.80	64.20*	54.20*	57.40*
	Canopy compactness			
2345PB	0.73	0.90*	0.89*	0.91*
Biquinho Vermelha	0.93	0.88 ^{ns}	0.94 ^{ns}	0.95 ^{ns}
Bode Amarela	0.86	0.91 ^{ns}	0.96 ^{ns}	0.96 ^{ns}
2334PB	0.95	0.84 ^{ns}	0.91 ^{ns}	0.93 ^{ns}

⁽¹⁾Means followed by * differ from the control (0 mg L⁻¹ PBZ) by the Dunnett's test, at 5% probability. ^{ns}Nonsignificant.

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