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Paclobutrazol and ethylene on growth and nutrient accumulation in potted ornamental pineapple[1]

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ABSTRACT: With the decrease in residences, the demand for the production of plants with a landscape effect in reduced size and more compact has grown. The objective of this work was to evaluate the growth and accumulation of nutrients in a potted ornamental pineapple hybrid, treated with paclobutrazol and subjected to early floral induction. The experimental design used was a randomized block, factorial arrangement (2 × 5), with 4 replications and 4 plants per plot. The primary treatments were the presence and absence of the plant growth regulator paclobutrazol (PBZ). The secondary treatments were five times of floral induction with ethylene: 90, 120, 150, 180, and 210 days after transplanting (DAT) of the seedlings. At 130, 160, 190, 220, and 250 DAT, the following variables were evaluated: leaf area; fresh and dry mass of leaves; stems and roots; sodium; macro and micronutrient contents in the plant. The use of paclobutrazol reduces vegetative growth and the accumulation of fresh and dry mass of the aerial and root parts. The order of accumulation was K > N > Ca > Mg > P > S > Mn > Na > Fe > Zn > B > Cu, in plants not treated with PBZ, and K > N > Ca > Mg = P > S > Mn > Na > Fe > B > Zn > Cu, in plants treated with PBZ, showing that the use of paclobutrazol increases boron accumulation.

Key words: *Ananas comosus*; growth inhibitor; plant regulator

Paclobutrazol e etileno no crescimento e acúmulo de nutrientes em abacaxi ornamental em vaso

RESUMO: Com a diminuição da área das residências, cresceu a demanda pela produção de plantas com efeito paisagístico em tamanho reduzido e mais compactas. O objetivo deste trabalho foi avaliar o crescimento e acúmulo de nutrientes em um híbrido de abacaxi ornamental em vaso, tratado com paclobutrazol e submetido à indução floral precoce. O delineamento experimental utilizado foi o de blocos casualizados, arranjo fatorial (2 × 5), com 4 repetições e 4 plantas por parcela. Os tratamentos primários foram a presença e ausência do regulador de crescimento vegetal paclobutrazol (PBZ). Os tratamentos secundários foram cinco vezes de indução floral com etileno: 90, 120, 150, 180 e 210 dias após o transplante (DAT) das mudas. Aos 130, 160, 190, 220 e 250 DAT foram avaliadas as seguintes variáveis: área foliar; massa fresca e seca de folhas, caules e raízes; teores de sódio, macro e micronutrientes na planta. O uso de paclobutrazol reduz o crescimento vegetativo e o acúmulo de massa fresca e seca das partes aérea e radicular. A ordem de acúmulo foi: K > N > Ca > Mg > P > S > Mn > Na > Fe > Zn > B > Cu, nas plantas não tratadas com PBZ, e K > N > Ca > Mg = P > S > Mn > Na > Fe > B > Zn > Cu, em plantas tratadas com PBZ, mostrando que o uso do paclobutrazol aumenta o acúmulo de boro.

Palavras-chave: *Ananas comosus*; inibidor de crescimento; regulador de plantas

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Introduction

The Brazil geographic position facilitates access to the international market and generates opportunities for enterprises in the flower and ornamental plant production sector (Costa Junior et al., 2016). An ornamental plant with a landscape effect and of great importance for the aforementioned sector is the ornamental pineapple. This plant, as it is exotic origin and has high durability, can be marketed as a flower, foliage, cut or potted minifruit (Lima et al., 2017a; Pereira et al., 2018).

This market for flowers and ornamental plants accounted for more than 210 thousand jobs created for the year 2020, thus ratifying its social and economic impact. The main ornamental pineapple varieties produced and marketed today are *Ananas comosus* var. *erectifolius*, *A. comosus* var. *bracteatus* and *A. comosus* var. *ananassoides* (Costa Junior et al., 2016).

The most marketed products recently are rhizomes and foliage for floral arrangements and green potted plants (Souza et al., 2014; Lima et al., 2017b). Events such as the COVID-19 pandemic have boosted the use of ornamental plants resistant to adverse conditions in the interiors of family homes as therapy for psychological problems (Reis et al., 2020).

Countries such as the United States and Canada have a high demand for products derived from ornamental pineapple (Junqueira & Peetz, 2017). Considering that consumer markets are always looking for new genotypes of ornamental plants with exotic characteristics, the ornamental pineapple has potential (Santos et al., 2021).

Souza et al. (2014) reports that for pot cultivation requires plant height ≥ 65 cm; the rosette diameter ≥ 80 cm; leaf length “D” ≥ 60 cm; the peduncle length ≥ 30 cm; syncarpium and crown length ≥ 5 cm; syncarpial diameter ≥ 3 cm; and the crown/syncarpion ratio close to 1. Plants without thorns and a ratio of 1/3 of the height of the pot to the plant.

The Embrapa developed the hybrid “D”, a product of the crossing of the *Ananas comosus* var. *bracteatus* × *A. comosus* var. *erectifolius*, which has potential for pot cultivation (Costa Junior et al., 2016).

The process of obtaining smaller plants with size adjusted to commercial standards, the use of plant regulators can be of great value (Petri et al., 2016; Lima et al., 2017b), due to their effects on growth dynamics (Taiz et al., 2017). Regulators such as paclobutrazol, for growth reduction, and ethylene, for artificial floral induction, are successfully used in several crops such as *Capsicum annuum*, *C. chinense*, *Helianthus annuus*, and *Physalis angulata* (Bosch et al., 2016; Mortate et al., 2018), in addition to pineapple (Mendes et al., 2011; Tellez et al., 2023).

The ornamental pineapple important characteristics such as intense green color and absence of thorns in the leaves, generally responds to flowering induction 10 months after field planting and 13.5 months after potted planting (Taniguchi et al., 2015; Costa Junior et al., 2016). In edible cultivars, the plants response to induction is largely determined by the age or size of the plant (Mendes et al., 2011; Fernandes et al., 2018; Tellez et al., 2023).

The use of spaces in increasingly smaller apartments boosts the preference for simple management plants and increases the demand for smaller ornamental plants (Junqueira & Peetz, 2017). In this sense, the use of paclobutrazol and the early application of ethylene can reduce the size of plants and/or make them more attractive, due to possible morphological changes in their plant parts.

Larger plants generally have higher demands for macro and micronutrients (Fernandes et al., 2018). Plants with reduced size as a result of the application of growth regulators may have a different need for nutrients compared to plants not treated with regulators and may need different fertilization plans.

The information on growth and nutrient accumulation of new ornamental pineapple hybrids treated with paclobutrazol and, at the same time, with early floral induction with ethylene, are lacking. Therefore, considering the lack of research and the potential for commercialization of potted culture, the objective of this work was to evaluate the growth and accumulation of nutrients in a hybrid of ornamental pineapple in pots, treated with paclobutrazol and subjected to early floral induction.

Materials and Methods

The experiment was carried out in the experimental area of Embrapa Agroindústria Tropical, located in Fortaleza, Ceará, Brazil (3° 45’ 05’’ S; 38° 34’ 35’’ W, and 30 m of altitude). The regions climate, according to the Köppen climate classification, is of the Aw’ type, characterized as tropical rainy, very hot, with rainfall predominant in the summer and autumn seasons, and an average temperature above 18 °C.

The micropropagated seedlings of ornamental pineapple, hybrid “D”, (*Ananas comosus* var. *bracteatus* × *A. comosus* var. *erectifolius*), with a height between 5 to 8 cm and 12 to 16 leaves, acclimatized for four months in a greenhouse with 70% shading. During this period, the plants were cultivated in plastic trays, fertilized by applying one liter per week of macro and micronutrient solution at 50% of the culture medium and irrigated by microsprinkler.

The after acclimatization, the seedlings were transplanted to a screen with 50% shading, equipped with transparent plastic on the upper structure, to eliminate rainfall interference under the experiment. Fertilization was carried out with Osmocote© NPK 15-09-12 slow-release fertilizer, as recommended by Santos et al. (2021). The recommended total dose, 13.2 g plant^{-1}, was divided into three quarterly applications, after transplanting.

The irrigation was carried out in an automated manner, by a surface drip irrigation system. The main features of this system include timer; solenoid valve; water reservoir; motor pump set; disk filter; main and branch lines (φ = 32 mm) of PVC and side lines of LDPE (φ = 16 mm); sphere records; manometer with glycerin; and self-compensating drippers with a flow of 2 L h^{-1}. The water depth used was between 1.4 to 5 mm depending on the developmental stage. The irrigation system presented a water distribution uniformity coefficient above 90%.

The experimental design was randomized blocks, factorial arrangement (2 × 5), with 4 replications and 4 plants per plot. The primary treatments were the presence and absence of the plant regulator paclobutrazol (PBZ). The secondary treatments were five times of floral induction with ethylene: at 90, 120, 150, 180, and 210 days after transplanting (DAT) the seedlings in the pots.

The 50 mL of paclobutrazol (purity of 90 mg i.a. L^{-1}) were applied on the rosette of the plants, as recommended by Bosch et al. (2016). The application was carried out 150 days after planting (DAP), as this is the period of greatest vegetative growth for ornamental pineapple with 15-20 leaves (Carvalho et al., 2019).

The moment of floral induction, a volume of 40 mL $plant^{-1}$ of the solution prepared with 0.5 mL of 24% Ethrel©, 0.35 g of calcium hydroxide and 20 g of urea in 1 L of water was used with final pH between 7 and 8. The solution was manually applied on the rosette of the plants for each treatment, according to Mendes et al. (2011).

The measurements at 130, 160, 190, 220, and 250 DAT of the leaf area and plant fresh and dry matter production of the aerial (leaves, stem) and root parts, by collecting one plant per plot. The plants were washed and divided into leaves, stems and roots and placed in paper bags. Four "D" leaves were selected per plant, separated and placed in paper bags after measuring the leaf area. Fresh mass was weighed on a precision scale (0.01 g) and leaf area was estimated using an area integrator (LI-COR, model LI-3100 C). The dry mass was weighed on a precision scale, after the plant, material was placed in a forced air circulation oven (65 °C) and reached a constant weight.

The macro and micronutrient and sodium contents were evaluated 40 days after exposure to ethylene. The material was treated and taken to the forced air circulation oven for drying. When dry, the material was ground and the nutrient concentration was estimated by the method of analysis of plant tissues used by Embrapa (Miyazawa et al., 2009). Nutrient accumulation was calculated by multiplying nutrient concentration by dry mass.

The statistical analysis was performed using the SISVAR software. For data distributed over time, regression analysis of variance was performed, testing the linear and quadratic models. All analyzes were performed considering the 5% probability level ($p < 0.05$).

Results and Discussion

The leaf fresh and dry mass, leaf area and stem dry mass responded to the interaction between paclobutrazol factors and evaluation days. Stem fresh mass responded individually to both factors and root fresh and dry mass responded separately to paclobutrazol (Table 1).

The root, stem and leaf fresh masses of plants treated with PBZ were lower than those not treated at all evaluation times. The estimated reduction at 130, 160, 190, 220, and 250 DAT was 73 to 80% (Figure 1).

The leaf area and dry mass of leaves and stem of plants treated with PBZ were also lower than those not treated, in all evaluation periods. The estimated reduction at 130, 160, 190, 220, and 250 DAT was 70 to 85%.

The based on these results, it is verified that the use of paclobutrazol in ornamental pineapple both reduced the accumulation of fresh and dry mass and decreased the leaf area. According to Ribeiro et al. (2019), the effect of PBZ is proportional to its dosage. Bosch et al. (2016) reports phytotoxicity effects with sprays above 120 mg L^{-1} on *Physalis angulata* plants. França et al. (2018) the application of 20 mg L^{-1} of paclobutrazol is the

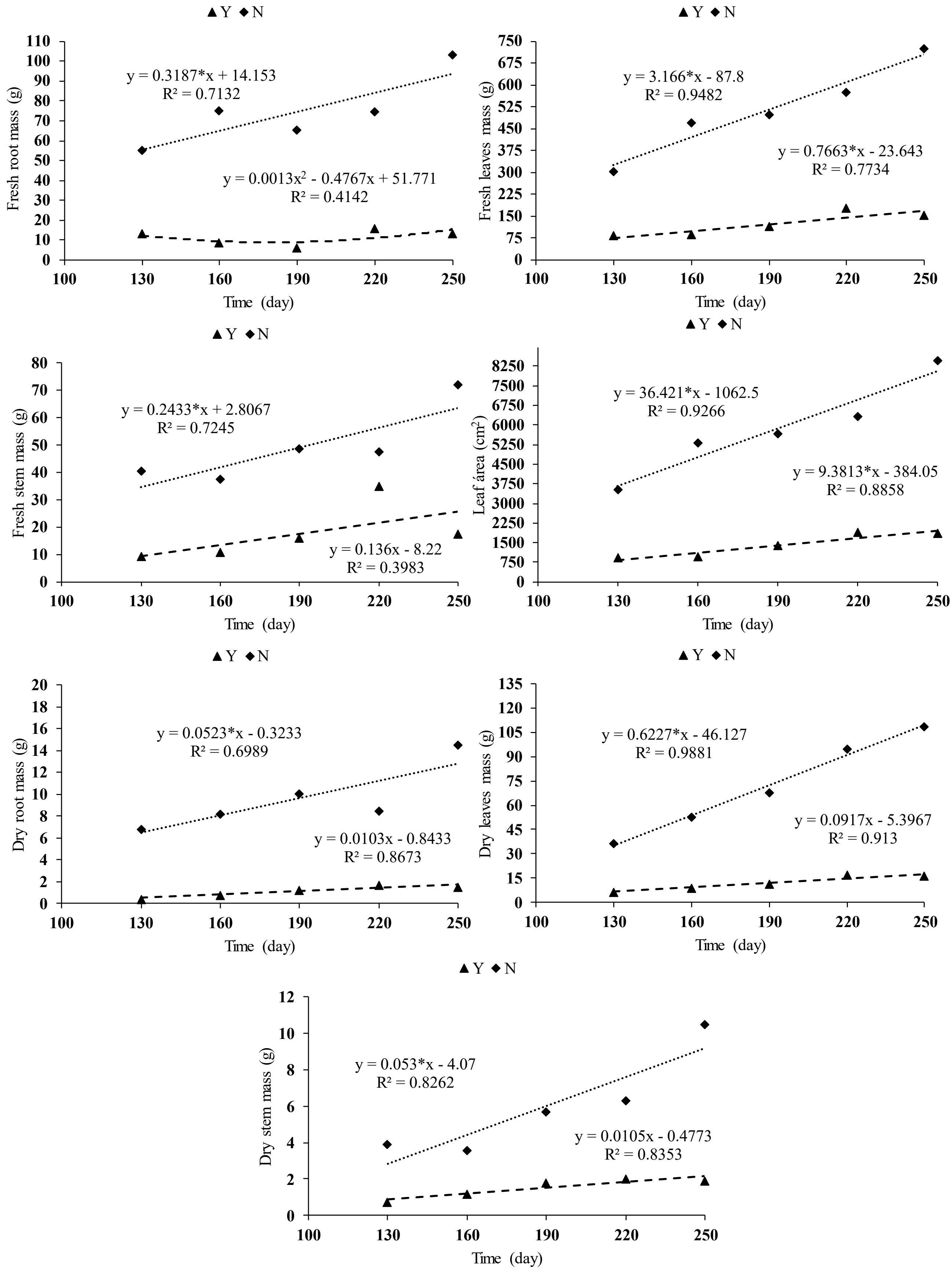
most indicated one, and results in plants with adequate ornamental characteristics.

The results obtained in the present work can be explained by the fact that paclobutrazol acts to inhibit the biosynthesis of gibberellins, generating a reduction in plant size (Bosch et al., 2016). Petri et al. (2016) found in temperate climate plants the greatest effect of PBZ applied in the root zone and

Table 1. Summary of the analysis of variance for the variables of fresh and dry mass of leaves, stem and roots and leaf area, in plants of hybrid "D" (*Ananas comosus* var. *bracteatus* × *A. comosus* var. *erectifolius*) of ornamental pineapple grown in pots, under greenhouse conditions, Fortaleza, Ceará, Brazil. 2018/2019.

Source of variation	Medium square ($p < 0.05$)						
	FRM	FLM	FSM	LA	DRM	DLM	DSM
Block	117.9^{ns}	2812.1^{ns}	181.3^{ns}	333688.1^{ns}	6.2^{ns}	159.5^{ns}	4.6^{ns}
PBZ (P)	40024^{*}	1535064.6^{*}	9864.3^{*}	198831269^{*}	725.7^{*}	36159.2^{*}	199.1^{*}
Error 1	91.8	1830	289.6	109656.4	2.6	108	2.7
Day (D)	742.8^{ns}	70772.7^{*}	702.6^{*}	9662036.9^{*}	21.9^{ns}	2329.1^{*}	19.8^{*}
P × D	602.1^{ns}	31182.2^{*}	450.4^{ns}	4116809.6^{*}	14.8^{ns}	1278.1^{*}	11.3^{*}
Error 2	584.1	2576.1	167.6	329082.8	16.2	136.1	1.3
CV_1 (%)	22.2	13.5	51.1	9.1	29.9	24.7	43.4
CV_2 (%)	56.1	16	38.8	15.8	74.8	27.7	30.6

* Significant; ^{ns} Not significant; CV - Coefficient of variation; FRM - Fresh root mass; FLM - Fresh leaves mass; FSM - Fresh stem mass; LA - Leaf area; DRM - Dry root mass; DLM - Dry leaves mass; DSM - Dry stem mass.



Source: The author. * Significant by t test; Absence * not significant by t test; Y - PBZ treated plants; N - plants not treated with PBZ.

Figure 1. Pattern of variation of root (A) leaves (B) and stem (C) leaf area (D) and root (E) leaves (F) and stem (G) dry mass variation, in plants of hybrid "D" (*Ananas comosus* var. *bracteatus* × *A. comosus* var. *erectifolius*) of ornamental pineapple grown in pots, under greenhouse conditions, at 130, 160, 190, 220, and 250 days of transplanting (DAT).

states that paclobutrazol has a different effect in application via spray or soil.

When PBZ is absorbed via the root, it is transported by the xylem to the apical meristems, inhibiting cell elongation (Taiz et al., 2017). The decrease in leaf fresh mass, leaf area, leaf and stem dry mass can be attributed to inhibition of gibberellin biosynthesis. Root fresh and dry mass response can be attributed to the hormone application mechanism, which generated leaching and limited movement via phloem (Taiz et al., 2017).

The root (Figure 1A) and stem (Figure 1C) fresh masses of plants treated without PBZ showed the pattern of linear variation. Whereas, in untreated plants, the models tested were not significant. According to the graph (Figures 1A, 1B, 1C, 1E, 1F, and 1G), the difference in masses between plants with and without PBZ increased with time, demonstrating the persistent effect of this growth regulator.

The fresh mass of leaves, leaf area and dry mass of the root, leaves and stem (Figures 1B, 1D, 1E, 1F, and 1G, respectively) of plants treated with and without PBZ showed the pattern of linear variation. The difference between these variables increased over time, due to the prolonged effect of PBZ.

The fresh and dry mass and leaf area the 130 DAT (Figure 1) showed significant differences between plants with and without PBZ, like what was observed in vegetative growth. The reduction in leaf diameter is related to the reduction in cell elongation because of the effect of PBZ dosage (Taiz et al., 2017; Tellez et al., 2020; 2023).

The similar results, in relation to the reduction in the size of ornamental plants treated with plant regulators, were reported by Bosch et al. (2016), in *Physalis angulata* and in *Zinnia elegans* cv. Lilliput, *Helianthus annuus* cv. Elf. The difference in stem dry mass was affected by the redistribution of photoassimilates in the generation of lateral shoots (Tellez, et al., 2020). The reduction in root elongation was promoted by the leaching of PBZ into the substrate (Bosch et al., 2016; França et al., 2018).

The reduction in the development of plants not treated with PBZ correlated with the size of the pot used was not found in this study as reported by Taniguchi et al., (2015).

The accumulation of nutrients N, P, K, Mg, Cu and Zn and the beneficial element Na, responded to the interaction between PBZ and evaluation days. The nutrients Ca, S, Mn and B responded individually to both factors and Fe responded only to the application of PBZ (Table 2).

The plants that received PBZ accumulated a lower amount of macro and micronutrients and sodium in the aerial part of the plant, varying from 60 to 89% compared to untreated plants (Figure 2).

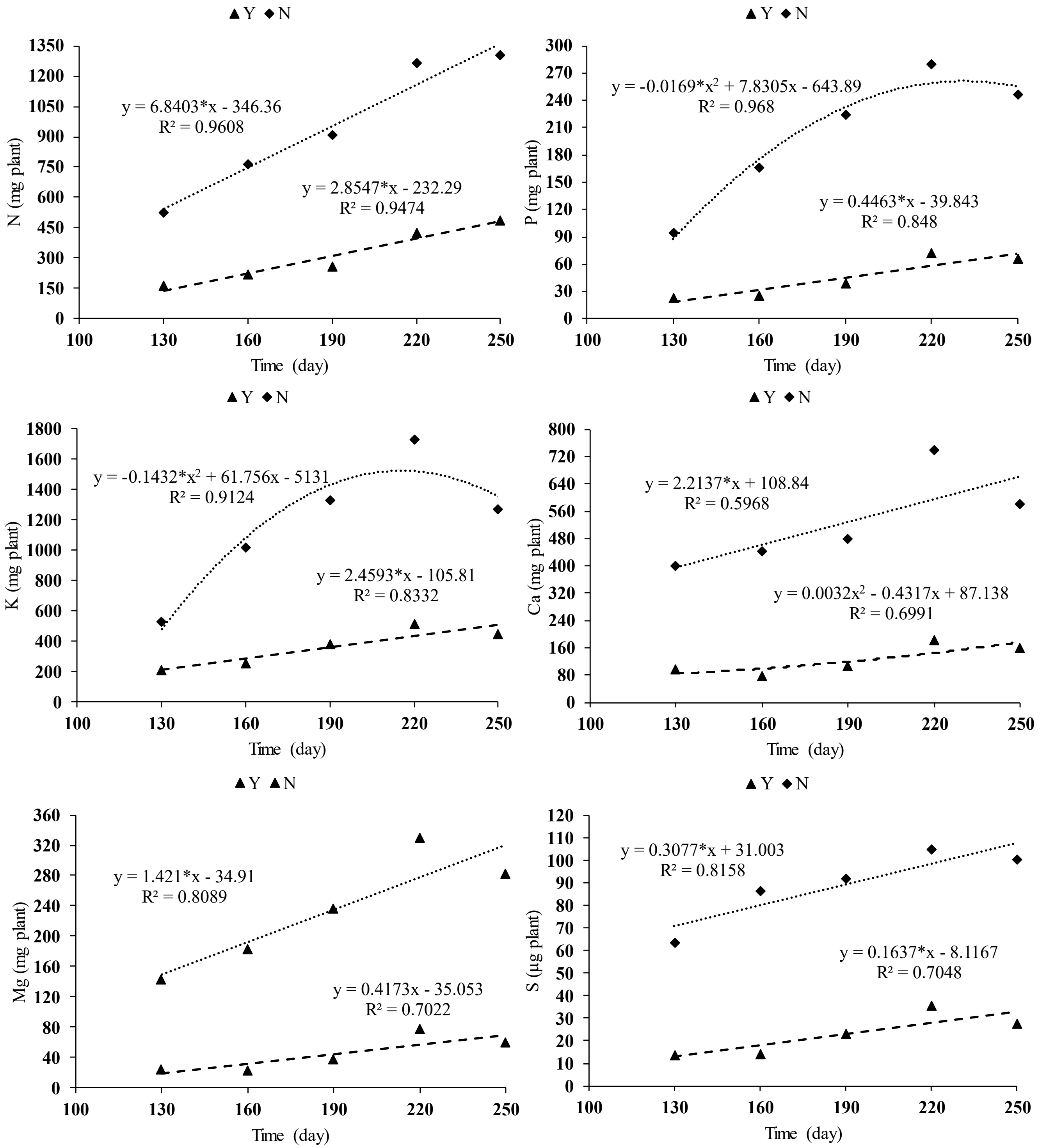
The accumulation of macro and micronutrients in plants treated with PBZ was lower than that reported by Taniguchi et al. (2015), on ornamental pineapple plants not treated with this product, although cultivated under similar conditions. It is noteworthy that the concentration of nutrients was higher in plants treated with PBZ, compared to those not treated. However, when calculating nutrient accumulation, untreated plants had higher values, because they had greater accumulation of dry matter.

The results obtained indicate that PBZ indirectly influenced the reduction of macronutrient accumulation by potentiating the dilution effect. Nouriyani et al. (2012) state that PBZ increases the uptake and transport of nitrogen and other nutrients by the plant. Iuchi et al., (2008) observed in

Table 2. Summary of the analysis of variance for nutrient and sodium accumulation variables, in plants of hybrid "D" (*Ananas comosus* var. *bracteatus* × *A. comosus* var. *erectifolius*) of ornamental pineapple grown in pots, under greenhouse conditions, Fortaleza, Ceará, Brazil, 2018/2019.

Source of variation	Medium square ($p < 0.05$)					
	N	P	K	Ca	Mg	S
Block	54791.7^{ns}	1111.9^{ns}	30865.1^{ns}	53606.4^{ns}	4155.9^{ns}	215.4^{ns}
PBZ (P)	4136702.2*	246676.9*	6594495.6*	1636922.6*	364330.7*	44226.5*
Error 1	15513	560.3	8707.9	17572	1726.1	42.2
Days (D)	438290.9*	17829.8*	635349.5*	63295.4*	19163.2*	1201.8*
P × D	77411.4*	5742.3*	213947.9*	18393^{ns}	5545.3*	180.3^{ns}
Error 2	25609.1	781.6	20943.3	14822.6	1728.1	168
CV_1 (%)	19.7	19.2	12.2	40.5	29.6	11.6
CV_2 (%)	5.3	22.6	18.9	37.2	29.8	23.1
	Medium square ($p < 0.05$)					
	Na	Cu	Fe	Zn	Mn	B
Block	4.6^{ns}	2330.5^{ns}	2632689.7^{ns}	161767.4^{ns}	15292952.9^{ns}	243051*
PBZ (P)	260.2*	670924*	72716148.2*	226182645*	453552681.6*	3317852.2*
Error 1	2.1	3100.3	3383062	19906.6	8953681	2707.5
Days (D)	31.5*	55800.5*	3925700.8^{ns}	945622.3*	43005800*	338845.2*
P × D	20.4*	26967.8*	4479497.8^{ns}	919350.7*	11855734.6^{ns}	108813^{ns}
Error 2	4.3	7257.2	2831019	87614	7698780	60585.4
CV_1 (%)	40.4	30.8	62.5	13.2	51.9	6.3
CV_2 (%)	57.7	47.1	75.5	27.6	48.1	29.6

* Significant; ^{ns} Not significant; CV - Coefficient of variation; N - Nitrogen; P - Phosphorus; K - Potassium; Mg - Magnesium; Na - Sodium; Cu - Copper; Zn - Zinc; Ca - Calcium; S - Sulfur; Mn - Manganese; B - Boron; Fe - Iron.



Source: The author. * Significant by t; Absence * not significant; Y - PBZ treated plants; N - plants not treated with PBZ.

Figure 2. Pattern of variation of accumulation of: nitrogen (A), phosphorus (B), potassium (C), calcium (D) and magnesium (E), in plants of hybrid "D" (*Ananas comosus* var. *bracteatus* × *A. comosus* var. *erectifolius*) of ornamental pineapple grown in pots, under greenhouse conditions, at 130, 160, 190, 220, and 250 DAT.

Pyrus communis (L.) that paclobutrazol did not significantly affect the contents of N, P, K, Ca, and Mg. However, the response to hormones depends on the species, its development and environmental factors.

The results presented show the influence of PBZ on plant growth and root expansion, as a function of mineral absorption. Almeida et al. (2016) state that PBZ can increase the nitrogen content and stimulate the synthesis of auxins and cytokinins, decreasing its growth inhibitory effect. Cell division and expansion processes, generation of shoots, branches and lateral roots generate greater demand for nutrients (Bosch et al., 2016).

The accumulation of nitrogen, calcium, magnesium and sulfur (Figures 2A, 2D, 2E, and 2F, respectively) of plants treated with and without PBZ showed a pattern of linear variation. The difference in accumulation was smaller in plants treated with PBZ, initially, but increased with time. This again demonstrates the persistent effect of PBZ.

The nitrogen content ranged from 139 to 481 and from 543 to 1,364 mg plant^{-1}, in plants treated with and without PBZ, respectively. These values indicate that N is a highly required element by pineapple, as it is a constituent of amino acids, nucleic acids and the chlorophyll molecule (Taiz et al., 2017; Fernandes et al., 2018). Reis (2015) reported that between 10th and 12th month of planting, the nitrogen absorption rate is higher in edible pineapple cv. Pérola grown in the open.

The accumulation of phosphorus and potassium (Figures 2B and 2C) in plants treated with PBZ showed the pattern of linear variation, and the untreated ones, the quadratic pattern. The increase in differences between treatments is due to greater accumulation in untreated plants, confirming the persistent influence of PBZ.

The highest accumulations of P were at 370 DAT, with 71.7 mg plant^{-1}, and at 331 DAT, with 263.1 mg plant^{-1}, in treatments with and without PBZ, respectively. Reis (2015) reports higher phosphorus accumulation between 360 and 420 DAT in edible pineapple cv. Pérola. Unlike what was observed in this study, Silva et al. (2020) stated that phosphorus is the nutrient least required by the crop.

The potassium is the most required macronutrient by the culture, ranging from 213 to 509 and from 477 to 1526.6 mg plant^{-1}, in treatments with and without PBZ, respectively. According to Taniguchi et al. (2015) potassium is the element most absorbed by pineapple. According to Silva et al. (2020) high contents of K in leaves can generate a negative correlation with N.

The accumulation of calcium ranged from 78 to 170.9 and from 396 to 662.2 mg plant^{-1} and that of magnesium, from 19.2 to 69 and from 149.8 to 320.3 mg plant^{-1}, in treated plants with and without PBZ, respectively. Ca is present in the formation of the middle lamella of cell walls and magnesium is the central atom of the chlorophyll molecule (Taiz et al., 2017; Fernandes et al., 2018). It is noteworthy that the plants treated with PBZ had similar Mg and P values.

The highest sulfur accumulation in plants treated with (32 mg plant^{-1}) and without (107.9 mg plant^{-1}) PBZ was at 250 DAT. This element participates in photosynthesis and biological nitrogen fixation (Taiz et al., 2017). Furthermore, it has fungistatic, acaricide, and insecticide properties (Fernandes et al., 2018).

The accumulation of sodium, copper and manganese (Figures 3A, 3B, and 3E), in plants treated with and without PBZ, showed a pattern of linear variation. The difference between treatments over time occurred due to the greater accumulation of these elements in untreated plants.

The sodium in plants with and without PBZ was detected. The Na is considered a beneficial and non-essential element and may be a partial substitute for potassium in some species (Fernandes et al., 2018). The Na favors metabolism, photosynthesis, osmosis and ionic balance within cells (Taiz et al., 2017).

The maximum values of 81.4 and 486.0 μg plant^{-1} of copper were quantified (Figure 3B), in plants treated with and without PBZ, respectively. This element is present in many plant enzymes that act in electronic transport (Fernandes et al., 2018).

The iron accumulation (Figure 3C) in PBZ-treated plants showed the pattern of linear variation, while iron accumulation in untreated plants showed the quadratic pattern. The difference in contents in this variable increased with time. The highest iron accumulation, of 1,143.5 and 4,674.1 μg plant^{-1}, occurred at 250 DAT, in plants treated with and without PBZ, respectively. This element acts on protein synthesis and influences photosynthesis (Taiz et al., 2017).

The zinc accumulation (Figure 3D) in plants treated without PBZ showed a linear increasing pattern. At 250 DAT, plants treated without PBZ accumulated 2,662.5 μg plant^{-1}. This element is an enzyme component and activator, a component of RNA polymerase (Fernandes et al., 2018). Reis (2015) reported that the greatest accumulation of this element in the Pérola variety occurs between 18 and 22 months.

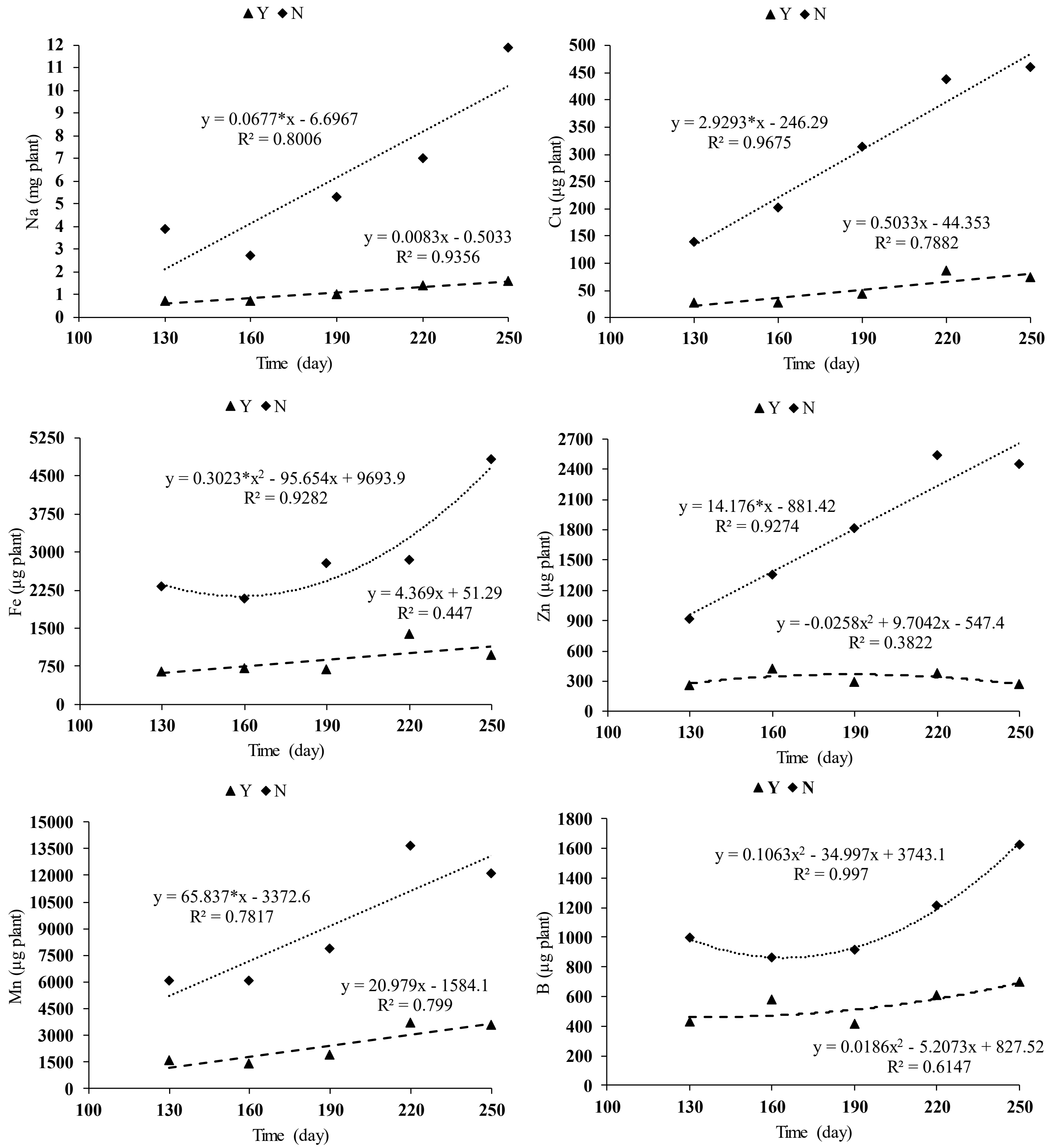
The manganese showed a pattern of linear variation, being the most accumulated micronutrient, compared to the others evaluated, (Figure 3E) in plants treated with PBZ. At 250 DAT, 3,660.6 and 13,086.6 μg plant^{-1} were accumulated in treatments with and without PBZ, respectively. Mn plays roles in chlorophyll synthesis and enzymatic activation (Taiz et al., 2017).

The boron accumulation (Figure 3G) did not show any adjustment pattern for the treatments. In plants treated with and without PBZ, the highest accumulation, of 688.1 and 1,637.6 μg plant^{-1}, respectively, occurred at 250 DAT. This element plays a role in sugar translocation and carbohydrate metabolism (Taiz et al., 2017).

The accumulation of macronutrients in the ornamental pineapple crop, hybrid "D", in plants not treated with paclobutrazol, showed potassium as the most required nutrient, followed by nitrogen, calcium, magnesium, phosphorus, and sulfur (K > N > Ca > Mg > P > S). Manganese was the most required, followed by the beneficial element sodium and the micronutrients iron, zinc, boron, and copper (Mn > Na > Fe > Zn > B > Cu).

The potassium was also the most required nutrient in plants treated with paclobutrazol, followed by nitrogen and calcium. However, magnesium and phosphorus showed similar accumulation, with sulfur having the lowest requirement (K > N > Ca > Mg = P > S). Manganese was the most demanded, followed by the beneficial element sodium and the micronutrients iron, boron, zinc, and copper (Mn > Na > Fe > B > Zn > Cu).

The results obtained in the present work, regarding the order of absorption of nutrients, diverged from those obtained by Taniguchi et al. (2015). These authors reported potassium as the nutrient most demanded by ornamental



Source: The author. * Significant by t test; Absence * not significant; Y - PBZ treated plants; N - plants not treated with PBZ.

Figure 3. Pattern of variation of accumulation of: sodium (A), copper (B), iron (C), zinc (D), manganese (E) and boron (F) in plants of hybrid "D" (*Ananas comosus* var. *bracteatus* × *A. comosus* var. *erectifolius*) of ornamental pineapple in pot, cultivated under greenhouse conditions, of 130, 160, 190, 220, and 250 DAT.

pineapple, followed by nitrogen, magnesium, calcium, sulfur and phosphorus. Among micronutrients, manganese was the most absorbed, followed by iron, boron, zinc, and copper. Reis (2015) reported the following order for edible pineapple: K > N > Ca > Mg > S > P and Cl > Fe > Mn > Zn > Cu > B.

The accumulation of nutrients, at 250 DAT, in mg plant^{-1}, in plants without PBZ, was 1302 N; 246.4 of P; 1,268.7 of K; 317.7 Ca, 282.7 Mg; 64.1 of S; 0.46 Cu; 2.4 of Zn; 7,8 of Mn; 1.1 of B; and, 0.011 of Na. In plants treated with PBZ, the accumulation was 484.9 N; 66.0 of P; 449.5 of K; 371.7 of Ca; 59.6 Mg; 64.1 of S; 0.073 of Cu; 0.26 of Zn; 7.8 of Mn; 1.1 of B; and, 0.0016 of Na.

The results of plants not treated with PBZ diverged from those recorded by Taniguchi et al. (2015), in ornamental pineapple plants with 360 days of maturity. These plants, cultivated under similar conditions, showed accumulation, in mg per plant^{-1}, 664.0 of N; 53.0 of P; 1,180.0 of K; 430.0 of Ca; 436.0 µg Mg; 99 of S; 0.25 of Cu; 3.2 of Fe; 0.54 of Zn; 6.8 of Mn; and, 1.9 of B.

Conclusion

The use of paclobutrazol reduces the vegetative growth and the accumulation of fresh and dry mass of the aerial part and of the root system in the ornamental pineapple crop until it reaches the dimensions required for commercialization in pots.

The accumulation of macro and micronutrients and sodium in the ornamental pineapple showed changes in consumption demand. The order of accumulation was: K > N > Ca > Mg > P > S > Mn > Na > Fe > Zn > B > Cu, in plants not treated with PBZ, and K > N > Ca > Mg = P > S > Mn > Na > Fe > B > Zn > Cu, in plants treated with PBZ, showing that the use of paclobutrazol increases boron accumulation.

The plants treated or not with paclobutrazol did not respond to anticipated floral induction with ethylene up to 250 DAT, which could be a genetic characteristic of the "D" hybrid studied.

The plants treated or not with PBZ have potential for sale in pots. However, those treated with the growth regulator became more compact and attractive for commercialization.

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Compliance with Ethical Standards

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