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Growth regulators in the development of potted *Epidendrum radicans* orchid

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Epidendrum is a terrestrial orchid with great potential for commercialization. However, its considerable height makes it difficult for transport and commercialization. Many species have been controled with growth regulators, including orchids and other ornamental plants. The aim of this study was to evaluate the efficiency of two plant growth regulators, paclobutrazol and chlormequat chloride (CCC), on the vegetative growth of potted *Epidendrum radicans* orchid aiming height control. Paclobutrazol (Cultar) was applied at doses of 0, 5, 10 and 20 mg L^{-1}, and the CCC (Cycocel) at doses of 0, 2000, 4000 and 6000 mg L^{-1}. The regulators were applied once or twice a month, via substrate irrigation. Plants were assessed every two months for plant height, number of shoots per pot and number of inflorescences per pot. CCC had no effect on the final height of *Epidendrum radicans* at the doses applied. Paclobutrazol was effective in controlling plant height at doses of 10 and 20 mg L^{-1}. None of the products influenced the number of inflorescences produced. Chlormequat chloride at a dose of 6000 mg L^{-1} stimulated the production of shoots.

Key words: Paclobutrazol, chlormequat chloride, reduction in height.

INTRODUCTION

Epidendrum radicans or *Epidendrum ibaguensis*, is a terrestrial plant that grows in large tangled, prostrate clumps. The stems are leafy and can be up to one meter long. It puts out many aerial roots. The flowers can be red, yellowish-orange or pink and are grouped in compact inflorescences. The plant can flower many times in a year (Suttleworth, 1994).

The literature documents some studies that have been carried out using growth regulators on *Epidendrum radicans* orchids (Pateli, 2004) to reduce final plant height; on Phalaenopsis hybrids (Wang and Hsu, 1994) to control the length of inflorescences and on *Cattleya mossiae* (Torres and Mogollon, 2002) to achieve a reduction in the number of shoots. Various growth regulators are commercially available, including chlormequat chloride (CCC) and paclobutrazol (Grossi et al., 2009).

According to Barret (2001), chlormequat chloride (known commercially as Cycocel) is recommended for poinsettias, azaleas, geraniums and hibiscus. It can be sprayed onto the plant or applied directly to the substrate (1000 to 4000 mg L^{-1}), but it is not as effective at

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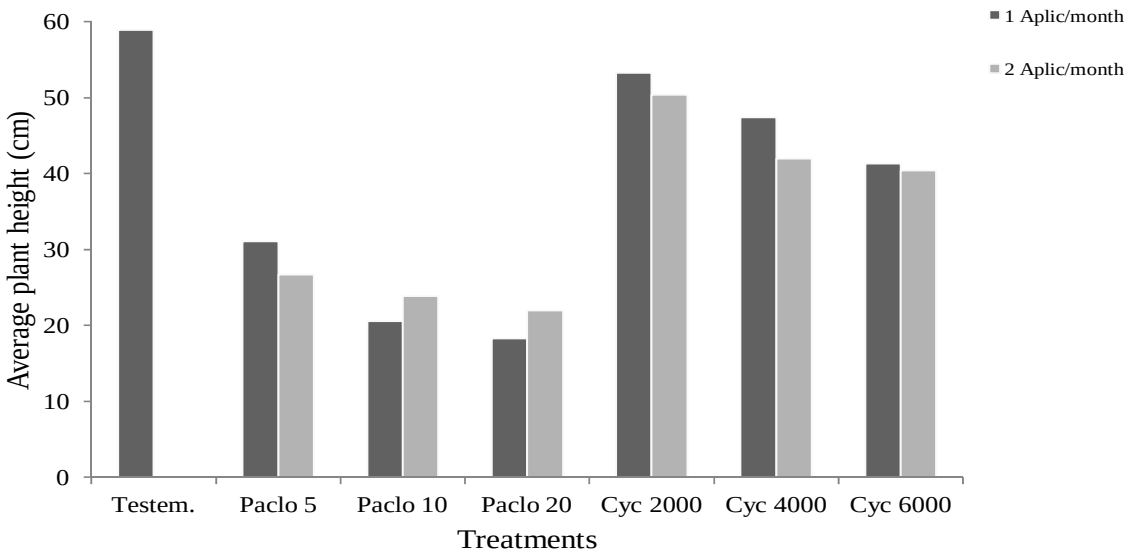

Figure 1. Plant height of *Epidendrum radicans* one year after commencing applications of paclobutrazol and chlormequat chloride (CCC) growth regulators once or twice a month.

controlling growth as other products. It is considered of low efficacy in controlling plant growth, merely preventing excessive plant size. A number of applications are necessary to obtain any results. When sprayed onto the plant, chlorotic spots are produced on expanding leaves and high doses can cause necrotic spots on the plant (Barret, 2001).

The aim of this study was to assess the efficiency of two growth retardants, paclobutrazol and chlormequat chloride, on the growth and development of potted *Epidendrum radicans* orchids.

MATERIALS AND METHODS

The experiment was conducted in a greenhouse with 50% shading, between June 2008 and January 2010, at the Agronomy Department of the State University of Londrina, Paraná State, Brazil. The coordinates are: 23°23'S latitude, 51°11'W longitude and 566 m elevation. Seedlings (approximately 24 months old) of the red variety of *Epidendrum radicans* Lindt., (Figure 1), were originally obtained by *in vitro* micropropagation. Two seedlings with an initial height of 35 cm were planted in each 2-liter black plastic pot (12 cm high and 13 cm diameter), filled with a mixture of sand + Plantmax commercial substrate (1:1 v:v). Fertilizer was applied every three months by fertigation: NPK (10-30-20) at 1 g L^{-1}. Watering was carried out manually twice a week (200 ml per watering).

The growth regulators used were paclobutrazol (Cultar 250 g L^{-1}) and chlormequat chloride (Cycocel 11.8 %). Treatments with paclobutrazol were dosed at 0, 5, 10 and 20 mg L^{-1}, and with chlormequat chloride at 0, 2000, 4000 and 6000 mg L^{-1}. These solutions were applied directly to the plant substrate (100 ml per pot) and the application frequency was once and twice a month (every fortnight), for 5 months.

The plants were assessed every 2 months for the following characteristics: plant height, number of shoots per pot and number of inflorescences per pot. The experiment was set up using a 6 x 2 + 1 (control) factorial arrangement. A random block design was used with 10 repetitions. The data were subjected to analysis of variance and means compared using the Tukey's test at 5%.

RESULTS AND DISCUSSION

On analyzing the results obtained, it can be seen from Table 1 and Figure 1 that there was a significant difference in average plant heights of 10 replicates. It should be observed that the initial height of the seedlings was 35 cm and the height of the shoots after the start of treatment was less in many cases. This is due to the fact that these growth regulator products has an effect only on new shoots and not in already emerged buds.

Five assessments were performed after the completion of regulatory applications. Height was measured with a tape, the neck of the plant to the base of the inflorescence (cm) on all shoots born. It can be seen from the results in Table 1, that there was no significant interaction between growth regulator application and frequency of application. The shortest plants were those treated with 20 mg L^{-1} paclobutrazol, and the average height of plants treated with 10 mg L^{-1} did not produce any statistical difference from the average height of plants treated with 5 and 20 mg L^{-1}. The highest plant height figures were obtained for treatments with CCC at all three doses, and plants treated with 2000 mg L^{-1} were the tallest, differing from those treated at other doses.

The control (no growth regulator applied) was the tallest (58,93 cm), but did not differ from treatments with the CCC growth regulator at doses of 2000 mg L^{-1} (applied once or twice a month) and 4000 mg L^{-1} (applied

Table 1. Average plant height of *Epidendrum radicans* one year after commencing applications of paclobutrazol and chlormequat chloride (CCC) growth regulators once or twice a month.

Regulator	Application frequency			
	Dose (mg L^{-1})	Once a month	Twice a month	Mean
Paclobutrazol	5	31.04	26.71	28.87 ^{B} *
Paclobutrazol	10	20.55	23.87	22.11 ^{BA}
Paclobutrazol	20	18.30	21.92	19.88 ^{A}
CCC	2000	53.22**	50.38**	51.80 ^{D}
CCC	4000	47.36 **	41.97	44.49 ^{C}
CCC	6000	41.34	40.42	40.85 ^{C}
Mean		34.86 ^{a}	35.09 ^{a}	
CV (%)		18.9		
Control		58.93 cm		

* Means followed by the same uppercase letter in the column and lowercase letter in the row did not differ statistically in the Tukey test at 5%. Plant height (cm), **Means followed by ** did not differ statistically from the Control in the Tukey test at 5%.

once a month). This result is in line with Stefanini et al. (2002), who observed that bushy mat grass continued to grow after application of CCC at doses of 1000 and 2000 mg L^{-1}. Holcomb and Gohn (1995) also failed to observe any reduction in the height of poinsettias treated with CCC at 3000 mg L^{-1}.

These results differed from those obtained by Ghora (1998) working with red raspberry, who verified the dose of CCC that reduced plant height without affecting the number of fruits and nodes was 500 mg L^{-1}, and that doses of 1000, 2000 and 4000 mg L^{-1} were toxic. Paclobutrazol at 500 and 1000 mg L^{-1} reduced plant height, but higher doses produced many dwarf plants.

Similar results were obtained by Pateli et al. (2004) working on the *Epidendrum radicans* orchid and using doses of paclobutrazol (5, 10 and 20 mg L^{-1}) and CCC (2000, 4000 and 6000 mg L^{-1}). The authors verified a reduction in main stem length as the regulator dose was increased, but plant height differences were not significant, and found that plant height figures dropped as the growth regulator dose increased and the shortest plants were obtained by treating with paclobutrazol.

Treatments with paclobutrazol at 5 mg L^{-1} (once a month), CCC at 6000 mg L^{-1} (once or twice a month) and CCC at 4000 mg L^{-1} (twice a month) resulted in intermediate plant height, and there was no statistical difference between these treatments.

Analyzing the application frequencies of the growth regulators (once or twice a month), we found that at a frequency of once a month paclobutrazol produces the shortest plants. Treatment applied twice a month with CCC produced the shortest plants. In terms of growth regulator doses, the shortest plants were produced by dosing paclobutrazol at 20 mg L^{-1}, followed by 10 and 5 mg L^{-1}. The similar concentration dependent manner was found for CCC, plants were shortest at 6000 mg L^{-1}, followed by doses of 4000 mg L^{-1} and 2000 mg L^{-1}. Comparing the two regulators, paclobutrazol produced the shortest plants.

When the results for each dose of paclobutrazol at each application frequency (once or twice a month) are compared, there is little difference between them: paclobutrazol at 5 mg L^{-1} produced plant heights of 31,04 to 26.71 cm; 10 mg L^{-1} produced plant heights of 20.55 to 23.87 cm; and 20 mg L^{-1} produced plant heights of 18.30 to 21.92 cm. Comparing CCC for each dose applied and at each application frequency (once or twice a month), it can be seen that 2000 mg L^{-1} for both application frequencies produced plant heights of 53.22 to 50.38 cm; 4000 mg L^{-1} applied once a month CCC produced plant heights of 47.36 cm, which did not differ from the control (58.93 cm).

In terms of number of shoots on the *Epidendrum* plants, there were statistical differences between the treatments, with the highest number of shoots found on plants treated with 6000 mg L^{-1} CCC at both application frequencies (once and twice a month). The lowest number of shoots was obtained for treatments once a month with 20 mg L^{-1} and 5 mg L^{-1} paclobutrazol, as shown in Table 2 and Figure 2. At an application frequency of once a month, the highest numbers of shoots produced, in decreasing order, were for treatments at 6000 mg L^{-1}, 2000 mg L^{-1} and 4000 mg L^{-1} CCC, and 10, 5 and 20 mg L^{-1} paclobutrazol. There was no statistical difference between treatments at doses of 5 and 20 mg L^{-1} paclobutrazol.

At an application frequency of twice a month, the highest numbers of shoots produced, in decreasing order, were for treatments at 6000 mg L^{-1} and 4000 mg L^{-1} CCC; 10 and 20 mg L^{-1} paclobutrazol; 2000 mg L^{-1} CCC and 5 mg L^{-1} paclobutrazol. There were no statistical differences between treatments at doses of 5, 10 and 20 mg L^{-1} paclobutrazol and 2000 mg L^{-1} CCC.

On analyzing the two application frequencies for

Table 2. Average number of shoots on *Epidendrum radicans* one year after commencing applications of paclobutrazol and chlormequat chloride (CCC) growth regulators with an application frequency of once or twice a month.

Regulator	Number of new shoots per pot		
	Application frequency		
	Dose mg L^{-1}	Once a month	Twice a month
Paclobutrazol	5	12.44 ^{Da} *	15.11 ^{Db}
Paclobutrazol	10	15.78 ^{Ba}	16.78 ^{Da}
Paclobutrazol	20	12.33 ^{Da}	16.00 ^{Db}
CCC	2000	20.00 ^{Bb}	15.44 ^{Da}
CCC	4000	17.22 C^{a} **	19.55 C^{b} **
CCC	6000	27.00 ^{Ab}	25.11 ^{Ba}
Mean		17.46 ^{a}	18.00 ^{a}
CV(%)		8.93	
Control		18.00	

* Means followed by the same uppercase letter in the column and lowercase letter in the row did not differ statistically in the Tukey test at 5%. **Means followed by ** did not differ statistically from the Control in the Tukey test at 5%.

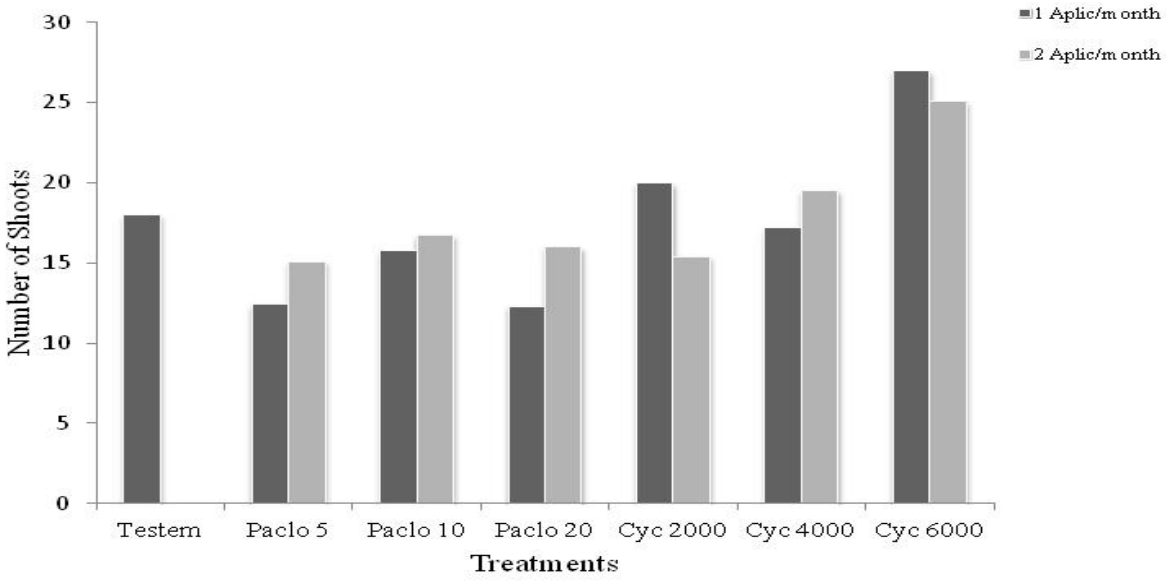

Figure 2. Number of shoots on *Epidendrum radicans* one year after commencing applications of paclobutrazol and chlormequat chloride (CCC) growth regulators with an application frequency of once or twice a month.

Each dose and both regulators, it can be seen that the only instance in which there was no difference between the results for the two application frequencies (once and twice a month) was the treatment with paclobutrazol at 10 mg L^{-1}.

Twice monthly treatments with 5 and 20 mg L^{-1} paclobutrazol and 4000 mg L^{-1} CCC produced a greater number of shoots, and this result differed statistically from the number of shoots produced when the regulators were applied once a month.

Treatment once a month with 2000 mg L^{-1} and 6000 mg L^{-1} CCC produced a greater number of shoots, and this result was statistically higher than the number produced when the regulator was applied twice a month.

Similarly, working with *Epidendrum*, Pateli et al. (2004) treated the plants with two applications per month of paclobutrazol (5, 10 and 20 mg L^{-1}) and CCC (2000, 4000 and 6000 mg L^{-1}) and observed that the number of shoots was not affected by the treatments. These results conflicts with those obtained by Hojjati et al. (2009), who

Table 3. Average number of inflorescences of *Epidendrum radicans* one year after beginning applications of paclobutrazol and chlormequat chloride (CCC) growth regulators once or twice a month.

Regulator	Number of inflorescences per pot			
	Application frequency			
	Dose (mg L^{-1})	Once a month	Twice a month	Mean
Paclobutrazol	5	2.33	3.00	2.67^{A}*
Paclobutrazol	10	2.00	3.33	2.67^{A}
Paclobutrazol	20	2.44	2.67	2.55^{A}
CCC	2000	2.44	3.44	2.94^{A}
CCC	4000	2.11	3.11	2.61^{A}
CCC	6000	2.89	5.00	3.94^{A}
Mean		2.37^{a}	3.42^{b}	
CV (%)		35.05		
Control		2.22	-none differs	

* Means followed by the same uppercase letter in the column and lowercase letter in the row did not differ statistically in the Tukey test at 5%.

observed an increase in the number of side shoots on Zinnia only at a dose of 2000 mg L^{-1} CCC. Bettoni et al. (2009), working with kalanchoe and using doses of 1000 and 2000 mg L^{-1} CCC, found that the number of shoots remained unchanged with two applications of the regulator.

Delaune (2005) obtained different results, working with Clerodendrum. Applications of paclobutrazol at doses of 15, 20 and 35 mg per pot caused a reduction in the number of side shoots on *Clerodendrum ugandense* when applied once a week for three weeks. The residual effect of paclobutrazol was verified by Pateli et al. (2004) in an experiment with *Epidendrum radicans* to be 7.5 months after the last application, but Lever (1986) estimated this effect could vary between 3 and 12 months.

In this study, for plants treated with a dose of 20 mg L^{-1} this effect lasted 19 months, since compact shoots continued to be produced. The leaves on all plants treated with paclobutrazol were a darker green than those of plants treated with CCC. In terms of the number of inflorescences produced during the experiment, there were no statistical differences between the growth regulators, doses and application frequencies by comparison with the control, as can be seen in Table 3 and Figure 3.

When each dosage of paclobutrazol and CCC, and each application frequency (once or twice a month) were compared, there were no statistically significant differences. The results for the increase in the number of inflorescences for all doses of both products at both application frequencies show no statistical differences. This is in line with the findings of Delaune (2005), working with species of *Clerodendrum* treated with applications of paclobutrazol. There was no difference in the number of inflorescences produced by *Clerodendrum ugandense* and *Clerodendrum bungei*. However, it conflicts with the results obtained by Hojjati et al. (2009), who found that applying 2000 mg L^{-1} CCC to *Zinnia* increased the number of flowers.

Wang and Hsu (1994) observed that applications of paclobutrazol at doses of 50, 100, 200 and 400 mg L^{-1} to *Phalaenopsis* orchids did not produce any statistical differences in the number of lateral inflorescences when treated plants were compared with controls. The results differ from those obtained by Wilkinson and Richards (1991) working with azaleas. They applied paclobutrazol at doses of 0.1, 0.2, 0.3 and 0.4 g per pot and found that the number of buds increased as the doses increased, reaching a total of 80 buds at the highest dose, compared with 4 buds on the control plants.

Working with CCC applied to *Kalanchoe*, Bettoni et al. (2009) observed no differences in the number of flowers at either of the doses used (1000 and 2000 mg L^{-1}), in line with the results obtained in this study. At the end of the experiment, the control plants and those treated with CCC reached heights of around 58 cm, whereas plants treated with paclobutrazol were no taller than 30 cm (Figure 4).

Conclusion

Paclobutrazol was more effective in controlling the plant height of the *Epidendrum radicans* orchid at doses of 10 and 20 mg L^{-1}. Chlormequat chloride (CCC) growth regulator at doses of 4000 mg L^{-1} (twice a month) and 6000 mg L^{-1} (twice a month) had an effect in reducing the height of the *Epidendrum radicans* orchid.

The growth regulators did not influence the number of inflorescences produced. The number of shoots produced was higher for plants treated with chlormequat

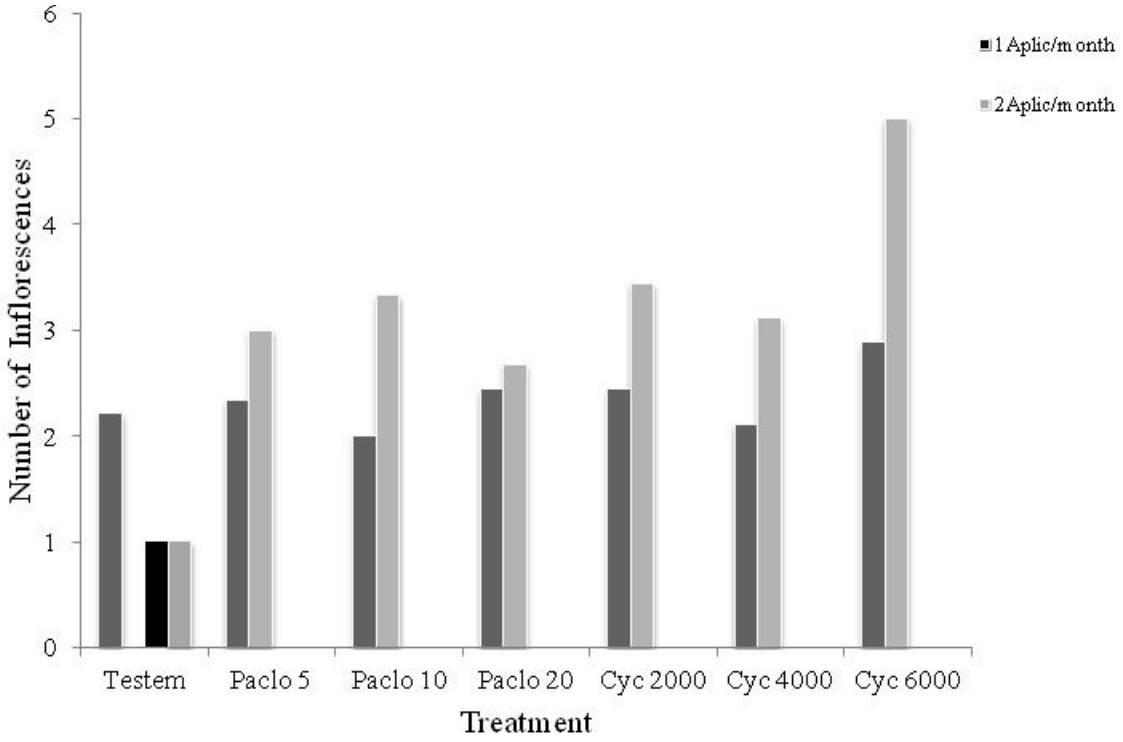

Figure 3. Number of inflorescences of *Epidendrum radicans* one year after beginning applications of paclobutrazol and chlormequat chloride (CCC) growth regulators once or twice a month.

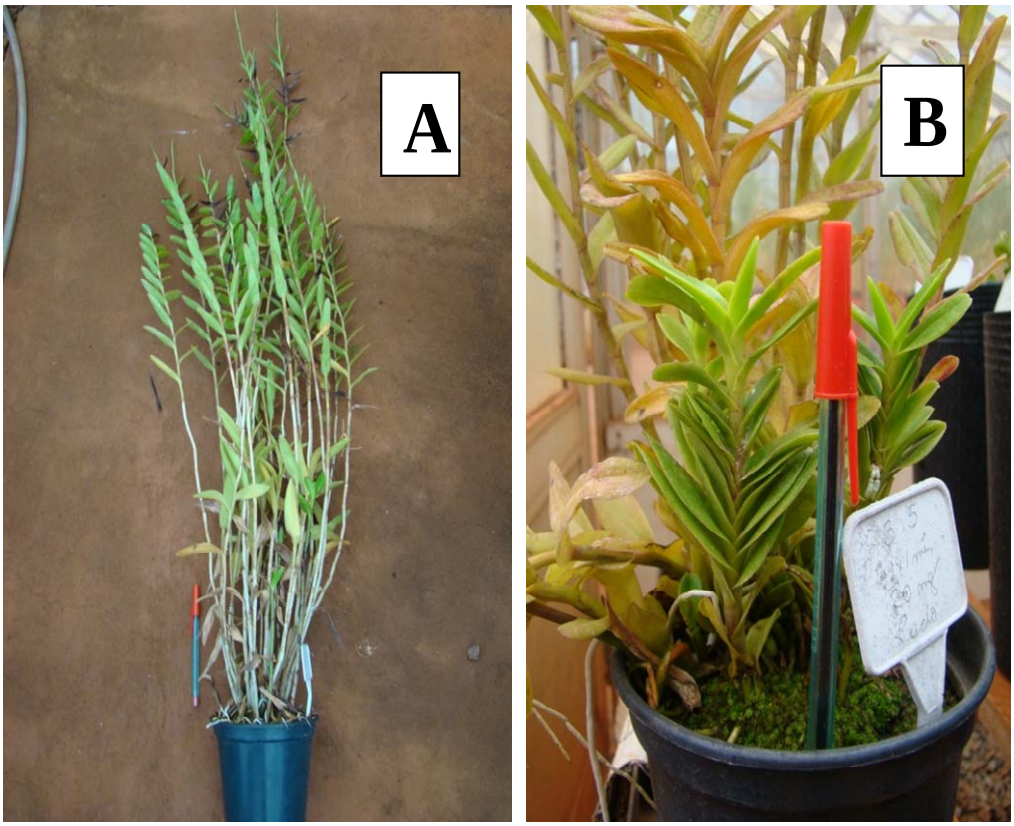

Figure 4. Epidendrum plants with treatments: (A) Control plant and (B) Paclobutrazol (20 mg L^{-1}).

chloride at a dose of 6000 mg L^{-1}, whereas the number of new shoots dropped when paclobutrazol was used, whatever the dose.

Conflict of Interest

The authors have not declared any conflict of interest.

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