Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1679-9275
ISSN on-line: 1807-8621
Doi: 10.4025/actasciagron.v36i4.18085

The effect of plant growth regulators on height control in potted *Arundina graminifolia* orchids (Growth regulators in *Arundina graminifolia*)

Christina da Silva Wanderley[1*], Ricardo Tadeu de Faria[1], Maurício Ursi Ventura[1] and Wagner Vendrame[2]

*[1]Departamento de Agronomia, Universidade Estadual de Londrina, Rodovia Celso Garcia Cid, Pr-445, Km 380, Cx. Postal 10011, 86057-970, Londrina, Paraná, Brazil. [2]Tropical Research and Education Center, University of Florida, Flórida, United States of America. *Author for correspondence. E-mail: chriscsw@sercomtel.com.br*

ABSTRACT. Orchids have become an important portion of the international floriculture market. *Arundina graminifolia* is a terrestrial orchid that produces attractive flowers, and, although the species could be a potential candidate for the floriculture market, its considerable height makes it difficult to transport and commercialize. A number of plant growth regulators have been utilized to control plant height in ornamentals and other species. Thus, the aim of this study was to evaluate the efficiency of growth regulators, paclobutrazol and chlormequat chloride on the vegetative development of containerized *A. graminifolia* orchid aiming at height control. Paclobutrazol (Cultar) was applied at 0, 5, 10, and 20 mg L^{-1}, and CCC (Cycocel) was applied at 0, 2000, 4000, and 6000 mg L^{-1}. The plants were assessed monthly for the plant height and number of shoots per container. CCC had no effect on the final height of plants at the concentrations applied. In contrast, paclobutrazol was effective in controlling plant height at a concentration of 5 mg L^{-1}, but higher concentrations (10 and 20 mg L^{-1}) proved to be toxic to the plants, causing death to the new shoots. Paclobutrazol at lower concentrations offers a viable means for height control in *A. graminifolia*.

Keywords: paclobutrazol, chlormequat chloride, vegetative development.

Efeito de reguladores de crescimento no controle de altura da orquídea *Arundina graminifolia* em vasos (Reguladores de crescimento em *Arundina graminifolia*)

RESUMO. As orquídeas tornaram-se parcela importante do mercado da floricultura nacional. *Arundina graminifolia* é uma orquídea terrestre, produz flores atraentes e uma espécie que poderia ser uma candidata potencial para o mercado da floricultura, entretanto, sua altura considerável torna difícil seu transporte e comercialização. Alguns reguladores de crescimento de plantas têm sido utilizados para controlar a altura em plantas ornamentais e em outras espécies. O objetivo desse estudo foi avaliar a eficiência dos reguladores de crescimento, paclobutrazol e cloreto de chlormequat no desenvolvimento vegetativo da orquídea *A. graminifolia* em vasos, visando o controle de altura. Paclobutrazol (Cultar) foi aplicado a 0, 5, 10 e 20 mg L^{-1}, e CCC (Cycocel) foi aplicado a 0; 2000; 4000 e 6000 mg L^{-1}. As plantas foram avaliadas mensalmente para altura de planta e número de brotos por vaso. CCC não teve efeito sobre a altura final das plantas nas concentrações aplicadas. Paclobutrazol foi eficaz no controle de altura da planta na concentração de 5 mg L^{-1}, mas concentrações mais elevadas (10 e 20 mg L-1) provou ser tóxico para as plantas, causando a morte em brotos novos. Paclobutrazol em concentrações mais baixas oferece um meio viável para o controle de altura em *A. graminifolia.*

Palavras-chave: paclobutrazol, cloreto de chlormequat, desenvolvimento vegetativo.

Introduction

Arundina graminifolia or *Arundina bambusifolia,* also called bamboo orchid, is a terrestrial orchid with fine leaves, similar to those of the bamboo plant, and stems of 2.5 m or taller. The flowers are similar to Cattleya and are produced in succession, with each flower blooming for 2 or 3 days (SUTTLEWORTH, 1994). As with other ornamentals, this orchid can be problematic, even when grown in containers because of its considerable height, making it difficult to transport and commercialize.

Plant growth regulators are synthetic chemicals used in floriculture to control plant growth. Spraying potted ornamentals or applying the chemicals directly to the substrates produces shorter

plants by comparison with plants not treated with these substances (GROSSI, 2009). Studies found in the literature have reported the successful use of plant growth regulators to reduce final plant height in *Epidendrum radicans* orchids (PATELLI, 2004). Such plant growth regulators have also been used on hybrids of Phalaenopsis (WANG; HSU, 1994) to control the length of inflorescences and have also been successful in limiting shoot growth in *Cattleya mossiae* (TORRES; MOGOLON, 2000).

Among many plant growth regulators, chlormequat chloride (CCC) (known commercially as Cycocel) is recommended for height control in poinsettias, azaleas, geraniums and hibiscus (BARRET, 2001). The chemical can be sprayed onto the plant or applied directly to the substrate (1,000 to 3,000 mg L^{-1}), however a number of applications are necessary for efficacy. Furthermore, possible side effects are chlorotic spots produced on the expanding leaves, and high concentrations can cause necrotic spots on the plant. Paclobutrazol (marketed as Cultar) is another plant growth regulator for height control that can be effective when applied to the substrate at concentrations of 2 to 90 mg L^{-1} (BARRET, 2001).

The aim of this study was to assess the efficiency of two growth regulators, paclobutrazol and chlormequat chloride (CCC), in limiting the height of containerized *Arundina graminifolia* orchids.

Material and methods

Seedlings of *Arundina graminifolia* (D. Don) Hochr (Figure 1) at approximately 6 months old and 40 cm high were planted in 5-L plastic containers (22 cm high x 20 cm diameter) with a mixture of a commercial substrate (pine bark, pH 7, EC 0.8±0.3 mS cm^{-3}, density 600 kg m^{-3}) + soil (0.87% N, 0.25% K, 0.34% Ca, 0.16% Mg, 272 ppm Mn, 84 ppm Cu, 96 ppm Zn, 187 ppm B and 39.75% organic matter, pH 5.7) + carbonized rice husk (1:1:1, v:v:v). Fertilizer was applied every three months by fertigation using NPK (10-30-20) at 1 g L^{-1}. Irrigation was performed twice a week at a rate of 500 mL per watering.

The experiment was conducted in a greenhouse with 50% shading, 370 μmol m^{-2} s^{-1}, between August 2009 and June 2010 at the Agronomy Department of the State University of Londrina, in Paraná State, Brazil. The coordinates are 23º 23'S latitude and 51º 11'W longitude, with an elevation of 566 m and average temperature of 25ºC day and 16ºC night.

The plant growth regulator (PGR) treatments consisted of applications of paclobutrazol (Cultar 250 g L^{-1}) and chlormequat chloride – CCC – (Cycocel 11.8 %) at different concentrations. Paclobutrazol was applied at 0, 5, 10, and 20 mg L^{-1} and chlormequat chloride was applied at 0, 2000, 4000, and 6000 mg L^{-1}. The solutions were applied twice a month directly to the plant substrate (100 mL per container).

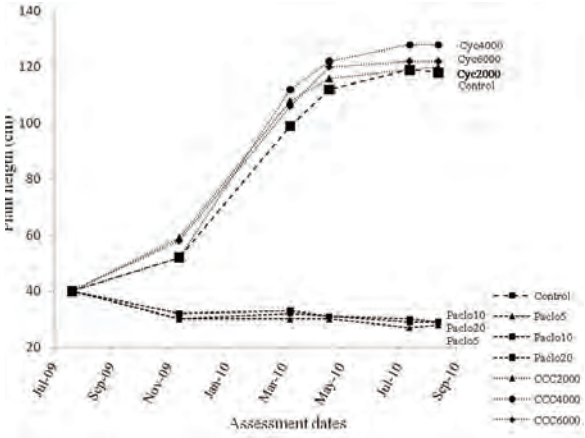

Figure 1. Average height of *Arundina graminifolia* plants during the experiment using paclobutrazol (Paclo) and chlormequat chloride (CCC) growth regulators (in mg L^{-1}) applied twice a month.

The plants were monitored, and the data for the plant height and number of new shoots per plant per container were collected monthly.

The experimental design consisted of a complete randomized block design with 7 treatments and 10 replications per treatment. The data were subjected to an analysis of variance, and the means were compared using the Tukey's test at 5%.

Results and discussion

The control (no PGR applied) plants were significantly taller than those treated with paclobutrazol. However, no significant differences were observed between the control plants and those treated with CCC at 2000, 4000, and 6000 mg L^{-1} (Table 1; Figure 1).

The plants treated with CCC continued to grow after the initial application until the end of the experiment. Although the plant height did not differ significantly among the different paclobutrazol concentrations applied (5, 10, and 20 mg L^{-1}), the plants treated with paclobutrazol were shorter than both the control plants and those treated with CCC (Table 1). At the end of the experiment, the control plants and CCC treated plants reached an average of 125 cm in height, whereas the plants treated with paclobutrazol reached a maximum of 33 cm in height (Table 1).

Table 1. Average plant height of *Arundina graminifolia* during the experiment using paclobutrazol (Paclo) and chlormequat chloride (CCC) growth regulators applied twice a month.

		Plant height (cm)				
Treatment	Concentration	120 DAT	210 DAT	270 DAT	330 DAT	390 DAT
		Dec/	Mar/	May/	Jul/	Sept/
	(mg L^{-1})	2009	2010	2010	2010	2010
Control	0	52 a ⋆	99 a	112 a	119 a	118 a
Paclo	5	30 b	30 b	30 b	27 b	28 b
Paclo	10	30 b	32 b	31 b	29 b	29 b
Paclo	20	32 b	33 b	31 b	30 b	29 b
CCC	2000	59 a	108 a	116 a	119 a	120 a
CCC	4000	52 a	112 a	123 a	128 a	128 a
CCC	6000	58 a	106 a	120 a	122 a	122 a
CV(%)		27.24	20.01	20.02	18.83	18.35
Mean		44	74	80	82	82

⋆The means followed by the same letter did not differ statistically at 5%. The numbers are the means of 10 replications. DAT: Days after transplanting. Paclo: Paclobutrazol. CCC: chlormequat chloride.

The plants treated with paclobutrazol at 10 and 20 mg L^{-1} exhibited deformations of the buds and delayed bud formation, however this was not observed for the plants treated with paclobutrazol at 5 mg L^{-1}. The plants treated with CCC exhibited normal growth and produced buds at the same time as the control plants.

Assessment of the new shoots began at 9 months after the first PGR applications. On the first assessment, control plants were significantly different from the plants treated with paclobutrazol at 5 and 20 mg L^{-1}, but the differences were not exhibited after the subsequent treatments (Figure 2).

There were no significant differences among plants treated with paclobutrazol and CCC for the first assessment (Table 2).

For the second assessment, there were no differences among the treatments. On the final assessment, the plants treated with 5 mg L^{-1} paclobutrazol, exhibited the greatest number of new shoots, which was significantly higher than other treatments, except for paclobutrazol at 20 mg L^{-1} and CCC at 6000 mg L^{-1}.

The plants treated with paclobutrazol at 10 and 20 mg L^{-1} exhibited a reduction in the number of new shoots because numerous shoots died off after emergence (Figure 2).

For the plants treated with CCC, the results differed from those obtained with paclobutrazol in that the formation of new shoots increased as the experiment progressed, which also occurred for the control plants (Figure 2). At the end of the experiment, the control plants and those treated with CCC reached heights of approximately 125 cm, whereas the plants treated with paclobutrazol were no taller than 30 cm (Figures 2 and 3).

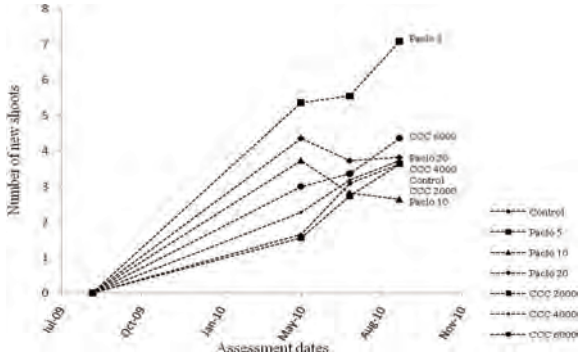

Figure 2. Average number of new *Arundina graminifolia* shoots formed during the experiment using paclobutrazol (Paclo) and chlormequat chloride (CCC) growth regulators (in mg L^{-1}) applied twice a month.

Table 2. Average number of new *Arundina graminifolia* shoots formed during the experiment using paclobutrazol (Paclo) and chlormequat chloride (CCC) growth regulators applied twice a month.

		Number of new shoots			
		Concentration (mg L^{-1})	240 DAT	270 DAT	330 DAT
Treatment			May/10	Jul/10	Sept/10
Control	Paclo	0	1.64 c ⋆	3.09 a	3.64 b
Paclo	Paclo	5	5.36 a	5.55 a	7.09 a
CCC	CCC	10	3.73 abc	2.82 a	2.64 b
CCC		20	4.36 ab	3.73 a	3.82 ab
		2000	1.55 c	2.73 a	3.64 b
		4000	2.27 bc	3.18 a	3.73 b
		6000	3.00 bc	3.36 a	4.36 ab
	CV(%)		54.59	63.49	49.62
	Mean		3.13	3.49	4.13

⋆The means followed by the same lowercase letter did not differ statistically in the Tukey test at 5%. DAT: Days after transplanting.

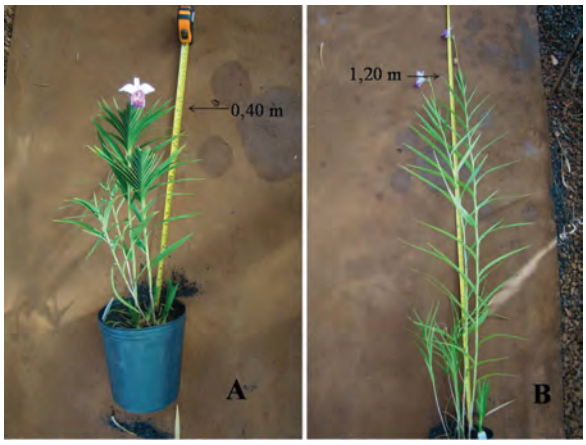

Figure 3. Arundina plants treated with (A) 5 mg L^{-1} paclobutrazol at 0,50 m height and (B) 6000 mg L^{-1} CCC at 1,50 m heigth.

Significant differences were observed in the plant height among the treatments (Table 1). At the beginning of the experiment, all of the plants were approximately 40 cm tall. The first height assessment was performed at four months after the beginning of the experiment when the first responses to the PGR treatments were visible. Similar responses were obtained within the same timeline by Hagiladi and Watad (1992) using *Cordyline.* A clear difference between the treated and untreated plant responses was observed at 120 days after transplanting the seedlings. This result suggests that the effect of paclobutrazol as a gibberellin biosynthesis inhibitor operates at the levels of leaf cell elongation, dry matter production, shoot elongation and other plant characteristics (STEFANINI et al., 2002).

The control plants (no PGR) were taller than those treated with paclobutrazol but shorter than the plants treated with the three concentrations of CCC (2000, 4000, and 6000 mg L^{-1}) and no significant differences were observed among the CCC concentrations. In contrast, Ghora et al. (1998) observed reduced height in red raspberry plants after the application of CCC at 500 mg L^{-1}, an effect that was followed by phytotoxicity at 1000, 2000, and 4000 mg L^{-1}.

North et al. (2010) observed major reductions in the height of *Dombeya burgessiae,* after treatment with 0, 1, 2, and 3 mg L^{-1} CCC, which became more marked at the 3rd, 4th, 5th, and 6th weeks after application compared to the control. For the three concentrations applied, treated plants were shorter than the untreated plants which is likely because CCC completely blocks gibberellin production (NORTH et al, 2010). Hojjati et al. (2009) also obtained shorter zinnia (*Zinnia elegans*) plants with this PGR.

In our study, the plants treated with CCC continued to grow after the applications and were taller than the control plants by the end of the experiment. Stefanini et al. (2002) obtained similar results, verifying that bushy matgrass (*Lippia alba*) plants continued to grow after the application of CCC at doses of 1000 and 2000 mg L^{-1}. This result could be because matgrass is a wild (undomesticated) species similar to Arundina, which showed comparable responses (STEFANINI et al. 2002).

For the paclobutrazol treatments, no differences were observed among the applications (5, 10, and 20 mg L^{-1}). Ruter (1994) obtained similar results working with Pyracantha (*Pyracantha coccinea*) and juniper (*Juniperus chinensis*) with no significant differences for soil applications of paclobutrazol at 0, 5, 10, 20, and 40 mg L^{-1}, in contrast, Pateli et al. (2004) observed that increasing concentrations of paclobutrazol (0, 5, 10, and 20 mg L^{-1}) gradually reduced the length of the main stem in *Epidendrum radicans* orchids. Likewise Hagiladi and Watad (1992) obtained reduced plant height in *Cordyline terminalis* with increased concentrations of paclobutrazol (0, 8, 40, and 200 mg per pot).

The lack of significant differences among the paclobutrazol treatments in our study could be explained by the higher day and night temperatures for the period of the experiment. Higher concentrations of PGRs are required to provide effective height control at high temperatures. However, paclobutrazol was still more effective than CCC in producing shorter plants (Table 1).

Wang and Blessington (1990) verified that increasing concentrations of paclobutrazol promoted height reduction in four tropical foliage species (*Brassaia actinophylla*, *Codiaeum variegatum*, *Syngonium podophylum* and *Plectranthus australis*), with the optimum concentration and the sensitivity of the plants to the regulators varying considerably according to the species. It was noted that the young leaves of treated *Plectranthus australis* were greener and more compact. Similarly, the leaves of Arundina treated with paclobutrazol in our study were more compact and greener than the control plants.

In our study, the paclobutrazol applications did not affect the quality of flowers. Wang and Hsu (1994) reported similar results, with shorter flower stems in Phalaenopsis orchids treated with 400 mg L^{-1} paclobutrazol.

However, the plants treated with 10 and 20 mg L^{-1} paclobutrazol showed many deformations in the shoots and delayed formation of the flower buds, which was not observed in the plants treated at 5 mg L^{-1}. Similarly, higher concentrations of

paclobutrazol induced deformed leaves in *Zinnia elegans* (zinnia) and *Pelargonium hortorum* (geranium) (COX; KEEVER, 1988). According to Lever (1986), increased concentrations of paclobutrazol tend to reduce the activity of the leaf sheath and increase activity in the inflorescence and flower stems. This was not evident in our study, as the highest concentrations induced a delay in the formation of flowers buds, however, no delay in flowering was observed in geranium (COX; KEEVER, 1988).

In Phalaenopsis, the emergence of flowers was increasingly delayed by increasing concentrations of paclobutrazol (WANG; HSU, 1994). In our study, the plants treated with paclobutrazol flowered later than those treated with CCC.

The plants treated with CCC and the control plants exhibited normal growth and bud formation, with no abnormalities identified. The plants treated with paclobutrazol exhibited leaves that were a darker green color, than the leaves of the plants treated with CCC or the control plants.

The residual effect of paclobutrazol in *Epidendrum radicans* was found to last 7.5 months after the final application (PATELI et al., 2004), but Lever (1986) estimated that this effect could vary between 3 and 12 months. In our study, the residual effect of paclobutrazol lasted 8 months (data not shown).

The duration of the effects of paclobutrazol on inhibiting shoot growth in various species has not been studied in great detail, but preliminary studies indicate that the compound is quite persistent (PUROHIT, 1985). Paclobutrazol has been shown to induce new shoot formation in potted *Cordyline terminalis* at 40 and 200 mg per pot (HAGILADI; WATAD, 1992). Similarly, Wang and Blessington (1990) observed reduced shoot formation in *Plectranthus australis,* verifying that there was a reduction in the number of shoots as the dose of paclobutrazol was increased (0, 0.20, 0.40, 0.60, 0.80, and 1.00 mg per pot), but in *Codiaeum variegatum* plants, applications of paclobutrazol at doses of 0, 0.05, 0.10, 0.20, and 0.40 mg per pot resulted in few new shoots.

In Zinnia, Hojjati et al. (2009) observed an increase in new side shoots only for the plants treated with CCC at 2000 mg L^{-1}, whereas, there was no difference in the number of shoots on the plants treated with paclobutrazol. Similarly, Pateli et al. (2004) did not detect any difference in the number of new shoots produced in *Epidendrum radicans* treated with CCC or paclobutrazol. The same was observed by Bettoni et al. (2009) when using CCC in Kalanchoe.

This apparent absence of a regulatory effect in the formation of new shoots may be related to the endogenous levels of gibberellins in the plant, which was insufficient to promote significant changes in shoot formation under the experimental conditions and concentrations of regulators used (SACHS; HACKETT, 1972).

For the second assessment, there were no differences among the treatments and this could be because this assessment was made in the harshest period of winter.

The plants treated with paclobutrazol at 10 and 20 mg L^{-1} exhibited a reduction in the number of new shoots (Figure 3), indicating that many of them died before emerging and did not reach the adult stage. This was most likely due to the toxicity of the product at higher doses.

For the plants treated with CCC, the results differed from those obtained using paclobutrazol in that the production of new shoots was increased as the experiment proceeded, as also occurred with the control plants.

Conclusion

Chlormequat chloride (CCC) had no effect on the growth of *A. graminifolia* at the concentrations used whereas paclobutrazol was effective in reducing the height of *Arundina graminifolia* plants at a concentration of 5 mg L^{-1}. However, concentrations of 10 and 20 mg L^{-1} paclobutrazol were toxic to the plants, killing the new shoots.

References

BARRET, J. Mechanisms of action. In.: GASTON, M. L.; KONJOIAN, P. S.; KUNKLE, L. A.; WILT, M. F. (Ed.). **Tips on regulating growth of floriculture crops**. Columbus: OFA, 2001. p. 32-41.

BETTONI, M. M.; GUMPL, E. K.; CUQUEL, F. L.; MÓGOR, A. F. Resposta de calâncoe a reguladores de crescimento. **Revista Brasileira de Horticultura Ornamental**, v. 15, n. 2, p. 153-157, 2009.

COX, D. A.; KEEVER, G. J. Paclobutrazol inhibits growth of Zinnia and Geranium. **HortScience**, v. 23, n. 6, p. 1029-1030, 1988.

GHORA, Y.; VASILAKAKIS, M.; STAVROULAKIS, G. Effect of growth retardants (Cycocel, daminozide and paclobutrazol) on growth and development of red raspberries, cv. *Autumn bliss*, cultivated under plastic greenhouse conditions in Chania-Crete, Greece. **Acta Horticulturae**, v. 513, n. 5, p. 453-460, 1998.

GROSSI, J. A. S. Retardantes de crescimento de plantas ornamentais. **Informe Agropecuário**, v. 30, n. 249, p. 33-35, 2009.

HAGILADI, A.; WATAD, A. A. *Cordyline terminalis* plants respond to foliar spays and medium drenches of paclobutrazol. **HortScience,** v. 27, n. 2, p. 128-130, 1992.

HOJJATI, M.; ETEMADI, N.; BANINASAB, B. Effect of paclobutrazol and Cycocel on vegetative growth and flowering of zinnia (*Zinnia elegans*). **Journal Science Technology Agricultura** and **Nature Research**, v. 13, n. 47B, p. 649-656, 2009.

LEVER, B. G. Cultur – A technical overview. **Acta Horticulturae**, v. 179, n. 1, p. 459-466, 1986.

NORTH, J. J.; LAUBSCHER, C. P.; NDAKIDEMI, P. A. Effect of the growth retardant Cycocel in controlling the growth of *Dombeya burgessiae*. **African Journal of Biotechnology**, v. 9, n. 29, p. 4529-4533, 2010.

PATELI, P.; PAPAFOTIOU, M.; CHRONOPOULOS, J. Comparative effects of four plant growth retardants on growth of *Epidendrum radicans*. **Journal Horticultura** and **Science Biotechnology**, v. 79, n. 2, p. 303-307, 2004.

PUROHIT, S. S. **Hormonal regulation of plant growth and development**. Advanced in Agricultural Biotechnology. Dordrech: Martinus Nijhoff/Dr. W. Junk Publishers, 1985.

RUTER, J. M. Growth and landscape establishment of *Pyracantha* and *Juniperus* after application of paclobutrazol. **HortScience**, v. 9, n. 11, p. 1318-1320, 1994.

SACHS, R. M.; HACKETT, W. P. Chemical inhibition of plant height. **HortScience**, v. 72, n. 5, p. 440-447, 1972.

STEFANINI, M. B.; RODRIGUES, S. D.; MING, L. C. Ação de fitorreguladores no crescimento da erva cidreira brasileira. **Horticultura Brasileira**, v. 20, n. 1, p. 18-23, 2002.

SUTTLEWORTH, F. S. **Orquídeas**: guia dos orquidófilos. Rio de Janeiro: Expressão e Cultura, 1994.

TORRES, J. G.; MOGOLON, N. Efecto del paclobutrazol sobre el desarrollo foliar in vitro de *Cattleya mossiae* Parker ex Hooker durante la fase previa a la aclimatizacion. **Bioagro - Universidad Centroccidental Lisandro Alvarado Venezuela**, v. 14, n. 1, p. 25-28, 2002.

WANG, Y.-T.; BLESSINGTON, M. Growth of four tropical foliage species treated with paclobutrazol or uniconazole. **HortScience**, v. 25, n. 2, p. 202-204, 1990.

WANG, Y.-T.; HSU, T.-Y. Flowering and growth of *Phalaenopsis* orchids following growth retardant applications. **HortScience**, v. 29, n. 4, p. 285-288, 1994.

Received on July 28, 2012.
Accepted on October 18, 2012.