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Adventitious rooting in cuttings of croton and hibiscus in response to indolbutyric acid and humic acid

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ABSTRACT

Adventitious rooting of ornamental plants can be accelerated by the application of growth regulators, such as auxin. Humic acids, organic matter in soil and organic compounds also have a biostimulant effect. This work evaluated the rooting in cuttings of croton (*Codianeum variegatum* L. Rumph) and hibiscus (*Hibiscus rosa-sinensis* L) in response to the application of different concentrations of indolbutyric acid (IBA) and humic acid (HA). The experiment was carried out in a greenhouse. Apical stem cuttings were treated with solutions at concentrations of: 0, 250, 500, 1000, 2000 mg L^{-1} IBA and 0, 10, 20, 30, 40 mmol L^{-1} HA carbon isolated from vermicomposting. Forty-five days after the applications, the cuttings were removed from the pots containing carbonized rice hull and the following variables were measured: rooting number, length and width of leaves, fresh and dry matter of root and aerial part and root area. The results were subjected to analysis of variance and the qualitative and quantitative effects of the treatments were compared by contrast and regression, respectively. Regression equations were used to determine the maximum efficiency level of root dry matter according to IBA and HA. Higher accumulation of root dry matter was recorded for the treatments with the doses 579 mg L^{-1} IBA and 14 mmol L^{-1} HA and 970 mg L^{-1} IBA and 50 mmol L^{-1} HA for root cuttings of croton and hibiscus, respectively. It was found that the application of eiher IBA or HA at the indicated doses accelerates rooting in cuttings of croton and hibiscus and contributes to the formation of vigorous plants.

Key words: *Codianeum variegatum* L. Rumph, *Hibiscus rosa-sinensis* L., flowers, plant propagation , soil organic matter.

RESUMO

Enraizamento adventício de estacas de cróton e hibisco em resposta à aplicação de ácido indolbutírico e ácido húmico

O enraizamento adventício de plantas ornamentais pode ser acelerado por meio da aplicação de fitorreguladores de crescimento, a exemplo das auxinas. Os ácidos húmicos, a fração da matéria orgânica dos solos e os compostos orgânicos também apresentam efeito bioestimulante. O objetivo deste trabalho foi estudar o enraizamento adventício de estacas de cróton (*Codianeum variegatum* L. Rumph) e de hibisco (*Hibiscus rosa-sinensis* L.) em resposta à aplicação de diferentes concentrações de ácido indolbutírico (AIB) e de ácido húmico (AH). O experimento foi realizado em casa de vegetação, sendo as estacas caulinares apicais tratadas com soluções de concentrações 0, 250, 500, 1000, 2000 mg L^{-1} de AIB e 0, 10, 20, 30, 40 mmol L^{-1} de carbono de AH isolado de vermicomposto. Aos 45 dias após a aplicação dos tratamentos, as estacas foram retiradas dos vasos contendo casca de arroz carbonizada, para medições

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das variáveis: pegamento; número, comprimento e largura das folhas; peso de matéria fresca e seca da raiz e da parte aérea e área radicular. Os resultados foram submetidos à análise de variância e os efeitos qualitativos e quantitativos dos tratamentos foram comparados por contraste e regressão, respectivamente. As equações de regressão foram utilizadas para determinar a dose de máxima eficiência de produção de matéria seca de raiz em função das doses de AIB e AH. As doses de 579 mg L^{-1} de AIB e 14 mmol L^{-1} de C na forma de AH foram as que promoveram maior acúmulo de matéria seca no sistema radicular de estacas de cróton. Em hibiscos, as doses de 970 mg L^{-1} de AIB e de 50 mmol L^{-1} de C na forma de AH foram as que resultaram em maior acúmulo de matéria seca da raiz. Conclui-se que a aplicação de AIB ou AH nas doses indicadas acelera o processo de enraizamento adventício das estacas de cróton e hibisco, contribuindo para formação de mudas vigorosas.

Palavras-chave: *Codianeum variegatum* L. Rumph, *Hibiscus rosa-sinensis* L., floricultura, propagação de plantas, matéria orgânica do solo.

INTRODUCTION

The commercial production of flowers and ornamental plants has grown worldwide due to their high potential for income and employment generation and to the environmental benefits and life quality improvements resulting from its products (Faria, 2005; Landgraf & Paiva, 2005). The Brazilian market for flowers and ornamental plants has grown 15% in 2010 and generated 194.000 direct jobs (Ibraflor, 2011).

Among the ornamental tropical plants there are species that stand out for their lush foliage, such as croton, and for their flower production, such as hibiscus. Croton (*Codianeum variegatum* L. Rumph, Euphorbiaceae) is a semi-woodyshrub, 2 to 3 m in height, native to India, Malaysia and the Pacific Islands. Its showy leaves are latex producing, leathery and can have varied colors, shapes and sizes (McDonald, 2006; Lorenzi & Souza, 2008). The hibiscus (*Hibiscus rosa-sinensis* L., Malvaceae) is a woody shrub, originally from tropical Asia 3 to 5 m in height, with solitary flowers, usually red, pink or white-colored and blooming throughout the year (McDonald, 2006; Lorenzi & Souza, 2008).

Both species are cultivated in tropical climates and do not tolerate frost or freezing temperatures (Lorenzi & Souza, 2008). Because they are highly appreciated as ornamental plants, the propagation methods need to be fast, of low cost and must ensure the formation of vigorous, healthy plants with the desired genetic characteristics. Vegetative propagation by cuttings allows the propagated plant to retain all the genetic characteristics of the parent plant and the production of large quantities of precocious and uniform seedlings (Hartmann *et al*., 2011).

The adventitious rooting of cuttings involves the action of auxins, plant hormones transported to the base of the cutting that act in the formation of meristematic centers or activate pre-existing meristems that induce root formation (Hartmann *et al*., 2011). The indolbutyric acid (IBA) is a synthetic auxin used to promote rooting of ornamental plants on a commercial scale (Lima *et al*., 2008, Hartmann *et al*., 2011).

As an alternative, humic acids (HA), a bioactive fraction of humified organic matter (Piccolo, 2001), can be used in cuttings of ornamental plants also promoting rooting.

Humic acids comprise a set of heterogeneous organic molecules, assembled in organic aggregates, stabilized by hydrogen bonding and hydrophobic interactions (Piccolo, 2001). Humic acids can promote plant growth and development in several plants of agronomic interest (Rodda *et al*., 2006; Zandonadi *et al*., 2007; Baldotto *et al*., 2009). These effects reflect in the increase of root growth rate, increases in plant biomass and root architecture changes (Canellas *et al*., 2006; Marques Júnior *et al*., 2008; Baldotto *et al*., 2009). Stimulating effects on shoot area should also be highlighted since it increases the accumulation of foliar nutrients and chlorophyll biosynthesis (Baldotto *et al*., 2009).

Current studies on cellular and molecular performance of HA show the stimulation of the activity and synthesis of the enzyme H^+- ATPases in the plasma membrane, which is similar to the effect produced by the auxins (Façanha *et al*., 2002; Canellas *et al*., 2006; Zandonadi *et al*., 2007).

This work is based on the hypothesis that the bioactive fractions of humidified organic matter in the form of HA can promote adventitious rooting in cuttings of ornamental plants and may be an alternative to commercial synthetic growth regulators, such as IBA. The objective was to evaluate rooting, sprouting and growth characteristics of stem cuttings of croton and hibiscus in response to different concentrations of IBA and HA.

MATERIALS AND METHODS

Plant material

Branches from parent plants of croton cv. 'Brasileirinho' (*Codianeumvariegatum* L. Rumph) and red hibiscus (*Hibiscus rosa*-sinensis L.) were used to obtain cuttings. The plants were removed from the campus of the Federal University of Viçosa in Florestal, MG. Softwood stem cuttings from the apical portion with 15 cm in length and four apical leaves were collected in September.

Treatments

The experimental matrix (5 x 5) consisted of the following treatments for each plant species (croton and hibiscus): five doses of indolbutyric acid (IBA) (0, 250, 500, 1000, 2000 mg L^{-1}) and five doses of humic acids isolated from vermicompost (HA) (0, 10, 20, 30, 40 mmol L^{-1} carbon). Humic acids were previously isolated and characterized by Busato (2008). Cutting bases were immersed in solutions of HA for 24 hours (Baldotto *et al*., 2009) and in solutions of IBA for 10 seconds (Lima *et al*., 2008). For this procedure the cuttings were placed in plastic cups containing 50 mL of solution corresponding to the different treatments. The cuttings were transferred to pots (2.0 dm^3) containing carbonized rice hulls, and kept in a greenhouse. The experimental unit consisted of pots containing five cuttings each. A randomized block design with five replications was used, totalizing 100 experimental units.

Growth analysis

Forty-five days after planting, the cuttings were collected and measured for the following variables: stem rooting (SR) regarding the number of rooted cuttings; number, length and width of leaves (NL, LL and WL), root fresh matter (RFM) and shoot fresh matter (SFM), root dry matter (RDM) and shoot dry matter (SDM), in a forced air ventilation oven at 60°C to constant mass, and root area (RA) measured after root scanning and image analysis using Delta-T SCAN ImageAnalyzer.

Statistical analysis

The results were subjected to analysis of variance, and the effects of the treatments were unfolded in mean contrasts for qualitative variables, according to Alvarez V & Alvarez (2006). For quantitative factors, regression equations were adjusted between the means of the variables and doses of IBA and HA. The F test was applied to the unfolded factors at 1, 5 and 10% probability. In the regression analysis, the slopes were assessed for determination coefficients above 0.60. The regression equations were used to establish the dose of maximum efficiency level for root dry matter production as a function of IBA and HA. To estimate this condition, the maximum efficiency doses were replaced in the regression equations of each variable.

RESULTS

Results of analysis of growth in croton and hibiscus in response to increasing concentrations of IBA and HA showed differences in root and shoot growth (Tables 1 and 2). Differences were observed among the variables, considering the mean dose of growth regulators, showing an increase when compared to the controls (Tables 1 and 2).

In cuttings of croton, the application of IBA resulted in increased SR, NL, WL, RDM, SFM, SDM, while the application of HA promoted increases in LL, RFM and RA, as shown by the means with relative increase in Table 1. However, only the variables NL, SFM and SDM significantly differed by the F test and were influenced by growth regulators, with percentage increases of 20, 15 and 25% for IBA and HA, respectively.

In cuttings of hibiscus, the application of IBA resulted in increases in all measured characteristics when compared with HA. However, only the variable SR was 13% higher (Table 2).

In general, it was possible to observe curvilinear increases in the growth characteristics of cuttings of hisbiscus and croton in response to the concentrations of IBA and AH (Figures 1 and 2, Tables 3 and 4). The response curves for increasing concentrations of growth regulators showed variation of the types quadratic, root mean square, cubic and cube root. The variable RDM was chosen to identify the dose of maximum efficiency (Figures 1 and 2). The concentrations which resulted in higher root dry matter accumulation were determined for IBA and HA, being, for croton, of 579.00 mg L^{-1} IBA and 14.41 mmol L^{-1} C in the form of AH. For this specie these doses resulted in 45.9 and 41.4 mg of RDM. For hibiscus, the higher values of RDM were obtained with 969.69 mg L^{-1} IBA and 49.91 mmol L^{-1} C in the form of HA, resulting in 194 and 49.9 mg/plant, respectively. The remaining variables were estimated using the concentration values of indolbutyric acid and humic acid determined as necessary to achieve the maximal root dry matter production of croton or hibiscus. These values were, then, used to substitute the "X" variable in regression equations showed in Tables 3 and 4 (Tables 5 and 6). In the three last columns the values found for control in each variable were compared with the values obtained for the most efficient dose of each plant regulator. Percentage differences were observed and for most of the assessed characteristics, the percentage differences were greater in hibiscus than in crotons, considering both regulators. The relative growth increases for variable RDM with the application of IBA was of 24% for croton, and 181% for hibiscus. The application of HA resulted in a relative increase of 4% for croton and 15% for hibiscus.

DISCUSSION

Vegetative propagation by cuttings allowed the production of rooted cuttings of hibiscus and croton (Tables 1 and 2). IBA was applied to accelerate seedling formation, with significant positive effects on rooting of stem cuttings of different plant species (Lima *et al.*, 2008; Pizzatto *et al.*, 2011, Santos *et al.* 2011). When applied exogenously, IBA is mainly used to act in the formation of meristematic centers, or to activate pre-existing meristems promoting the formation of root primordia and subsequent development of adventitious roots (Hartmann *et al*., 2011).

Table 1. Growth characteristics of croton plants in response to the application of indolbutiric acid (IBA) and humic acids (HA), applied at five concentrations (0, 250, 500, 1000, 2000 mg L^{-1} IBA and 0, 10, 20, 30, 40 mmol L^{-1} AH Carbon)

Treatment[1]	Growth characteristics[2]								
	SR	NL	WL	LL	RFM	RDM	SFM	SDM	RA
			mm	mm	mg	mg	mg	mg	%
AIB0	4	31	7.01	40.84	322.7700	37.0600	628.8800	95.3350	100
AIB250	5	33	6.27	51.35	353.3000	42.0000	678.1400	118.0700	104
AIB500	5	36	7.82	50.12	260.4000	49.2750	529.5000	107.1000	108
AIB1000	5	33	7.01	46.28	254.5000	44.4400	561.7000	115.7800	86
AIB2000	5	34	6.98	47.76	294.9000	39.7100	575.1000	103.4700	90
AH0	4	32	6.70	47.31	273.1000	39.8150	479.4000	91.6500	100
AH10	4	26	6.72	50.86	339.1000	36.5000	503.1000	80.4400	117
AH20	4	32	6.04	50.19	365.3000	43.2500	550.3000	100.3450	134
AH30	4	25	6.90	49.72	332.0000	39.2950	548.8000	86.1800	90
AH40	4	24	6.49	49.11	201.0000	29.6150	498.3000	73.6150	94
AIB *vs*. AH[3]	-1	-28*	-2.23	10.83	24.6300	-24.0100	-393.4200º	-107.5250**	46
IR (%)[4]	6	20	7	5	2	13	15	25	9
CV (%)	16.24	25.99	16.88	26.12	47.02	43.01	25.82	28.83	41.38

[1] Treatment: indicate growth regulators and doses, [2] Growth characteristics: SR = stem rooting index ; NL = number of leaves, WL = width of the largest leaf; LL = length of largest leaf; RFM= root fresh matter; SFM= shoot fresh matter, RA= root area; RDM= root dry matter; SDM= shoot dry matter. [3] Contrast: AIB versus AH. [4] RI= relative increase, 100 (x-y)/y, where x is the average of the highest value for the treatments and y is the mean of the lowest value for the treatments. **, * e º = Significant at 1, 5 and 10% probability by the F test.

Table 2. Growth characteristics of hibiscus plants in response to the application of indolbutiric acid (IBA) and humic acid (HA), at five concentrations (0, 250, 500, 1000, 2000 mg L^{-1} IBA and 0, 10, 20, 30, 40 mmol L^{-1} to C AH)

Treatment[1]	Growth characteristics[2]								
	SR	NL	WL	LL	RFM	RDM	SFM	SDM	RA
			mm	mm	mg	mg	mg	mg	%
AIB0	4	15	10.77	22.10	20.6200	69.8200	298.7200	59.1000	100
AIB250	4	19	9.36	17.85	40.9400	65.6867	432.9000	146.3400	196
AIB500	5	25	13.28	26.00	104.5000	73.4000	530.6000	190.5200	477
AIB1000	4	28	12.74	23.98	97.7000	61.7600	550.3400	172.0400	370
AIB2000	4	20	11.73	20.27	76.4800	61.2000	422.2200	157.9200	392
AH0	3	10	8.60	16.02	21.9250	17.5750	174.7200	47.9800	100
AH10	3	18	11.11	21.79	52.9400	47.5200	380.1200	120.9600	188
AH20	4	27	10.71	24.21	78.1000	51.7400	481.5000	186.4400	252
AH30	3	16	11.75	20.19	35.8350	35.3150	254.7800	97.0000	111
AH40	4	24	11.63	22.34	81.6400	57.9800	505.9800	161.2400	232
AIB *vs*.AH[3]	-2º	-12	-4.08	-5.64	-69.8000	-112.3000	-121.7366	-1047.9506	-437
IR (%)[4]	13	13	8	5	29	44	24	18	74
CV (%)	23.38	43.36	22.69	29.39	95.34	71.94	103.41	79.21	61.91

[1] Treatment: indicate growth regulators and dosages, [2] Growth characteristics: SR = stem rooting index; NL = number of leaves, WL = width of the largest leaf; LL = length of largest leaf; RFM= root fresh matter; SFM= shoot fresh matter, RA= root area; RDM= root dry matter; SDM= shoot dry matter. [3] Contrast: AIB versus AH. [4] RI= relative increase, 100 (x-y)/y, where x is the mean of the highest value for the treatments and y is the mean of the lowest value for the treatments. **, * e º = Significant at 10% probability by the F test.

Several factors such as concentration, time of the year, cuttings and species affect plant response to the application of IBA (Fachinello *et al*., 2005; Pizzatto *et al*., 2011, Santos *et al*., 2011.) An increased concentration of exogenous IBA promotes stimulatory effect on rooting until reaching a maximum value. From this value on, growth regulators have an inhibitory effect (Fachinello *et al*., 2005), which was verified in the adjustment of the regression equations, which were mostly curvilinear (Figures 1 and 2, Tables 3 and 4).

Among the studied species, the hibiscus cuttings were more responsive to the application of IBA. The concentration of 970 mg L^{-1} promoted greatest accumulation of root dry matter (Tables 4 and 6). Pizzatto *et al*. (2011) also observed increases in the rooting of hibiscus cuttings, using IBA at concentration of 1600 mg L^{-1}. The solution was applied by dipping the cuttings for only 5 seconds. In general, fast treatments tend to be more effective when combined with the highest doses (Cuquel *et al*., 1992).

For croton, the effects promoted by the application of growth regulators IBA or HA were not so noticeable (Table 5). Considering that rooting occurred in the absence of IBA and HA, it is possible to affirm that the endogenous levels of auxins in crotons are sufficient to stimulate the formation of adventitious roots. Therefore, this species is easily propagated by vegetative cuttings. The low effect of growth regulators may indicate a high concentration of endogenous auxin and low sensitivity of the plant tissue to the presence of the growth promoter (Trewavas & Cleland, 1983).

In a study with lettuce roots in response to application of HA isolated from vermicompost, Rodda *et al*. (2006) verified that HA stimulates root formation and plant growth, in the same way as IBA. Similarly, in our study, we observed that HA can also be used in propagation via stem cuttings of ornamental plants to stimulate adventitious root formation and subsequent growth of roots and shoots in cuttings of hibiscus and croton (Tables 1 and 2).

In correspondence with IBA, the effect promoted by HA depends on plant genotype and concentration of the regulator (Rodda *et al*., 2006; Baldotto *et al*., 2009). Thus, it is necessary to estimate the maximum rooting efficiency dose for each plant species (Figures 1 and 2). Other factors such as growing environment and HA source may also

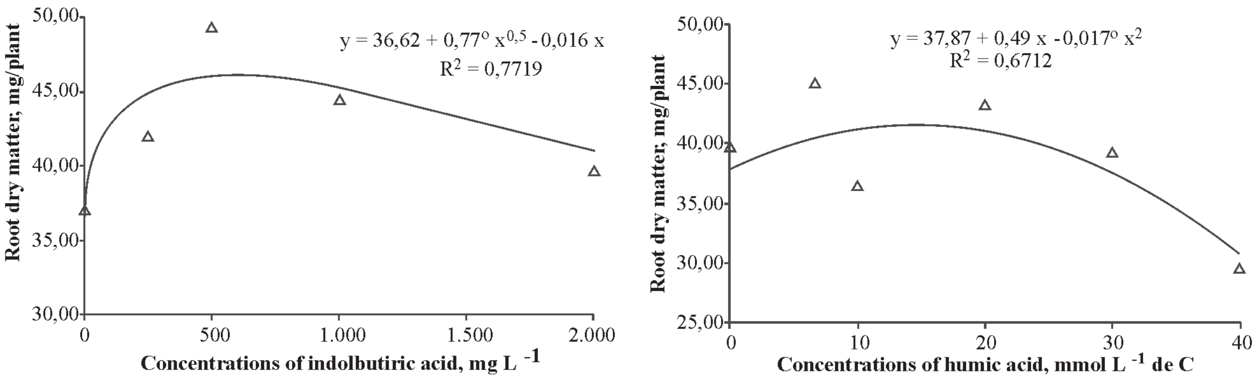

Figure 1. Root dry matter (RDM) of croton plants in response to indolbutiric acid (IBA) and humic acids (HA), applied at five concentrations (0, 250, 500, 1000, 2000 mg L^{-1} IBA and 0, 10, 20, 30, 40 mmol L^{-1} C HA).

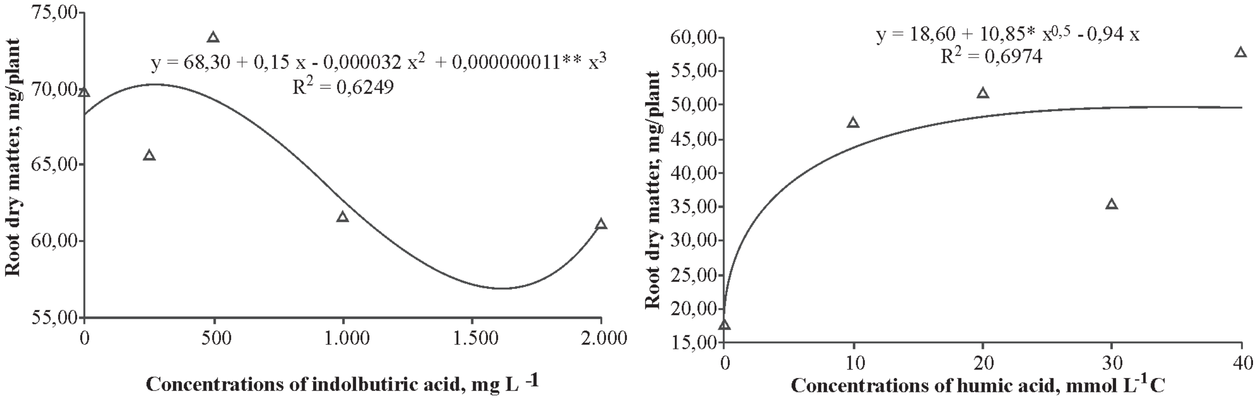

Figure 2. Root dry matter (RDM) of hibiscus plants in response to indolbutiric acid (IBA) and humic acids (HA), applied at five concentrations (0, 250, 500, 1000, 2000 mg L-1 IBA and 0, 10, 20, 30, 40 mmol C L^{-1}HA).

affect plant response to the application of growth regulators (Baldotto *et al*., 2011a, b). Façanha *et al*. (2002) found that HA isolated from vermicompost and sewage sludge promoted root growth in seedlings of corn and coffee using the energization of cell membranes by H^+-pumping ATPases. Proton pumps form electrochemical gradients that maintain the secondary system of ions translocation, which is essential for nutrient absorption (Sondergaard *et al*., 2004). These mechanisms lead to apoplast acidification, which increases cell wall plasticity and promotes cell elongation (Rayle & Cleland, 1992). Therefore, due to the stimulation of root primordium

Table 3. Regression equations for growth characteristics of croton in response to indolbutiric acid (IBA) and humic acid (HA), applied at five concentrations (0, 250, 500, 1000, 2000 mg L^{-1} IBA and 0, 10, 20, 30, 40 mmol C L^{-1}HA)

Variable[1]	Unfolding	Regression equation	R^2
SR	AIB Doses	$\hat{y} = 3.99 + 0.06^{**} x^{0.5} - 0.001 x$	0.9939
	AH Doses	$\hat{y} = 4.37 + 0.015 x - 0.00057^{ï} x^2$	0.8571
NL	AIB Doses	$\hat{y} = 30.52 + 0.02 x - 0.00003 x^2 + 0.00000008^{ï} x^3$	0.9042
	AH Doses	$\hat{y} = 30.21 - 8.19 x^{0.5} + 3.15 x - 0.33^{(P<0.27)} x^{1.5}$	0.7480
WL	AIB Doses	$\hat{y} = \bar{y} = 7.02$	
	AH Doses	$\hat{y} = \bar{y} = 6.57$	
LL	AIB Doses	$\hat{y} = 40.82 + 1.69 x^{0.5} - 0.081 x + 0.001^{**} x^{1.5}$	0.9987
	AH Doses	$\hat{y} = 47.78 + 0.26 x - 0.0058^{ï} x^2$	0.7282
RFM	AIB Doses	$\hat{y} = 342.75 - 0.15 x + 0.000062^{ï} x^2$	0.5877
	AH Doses	$\hat{y} = 267.57 + 11.44 x - 0.33^{**} x^2$	0.9804
SFM	AIB Doses	$\hat{y} = \bar{y} = 594.66$	
	AH Doses	$\hat{y} = 417.12 + 6.47 x - 0.14^{*} x^2$	0.8527
SDM	AIB Doses	$\hat{y} = 96.18 + 1.47^{ï} x^{0.5} - 0.029 x$	0.7221
	AH Doses	$\hat{y} = 91.53 - 33.91 x^{0.5} + 14.74 x - 1.56^{(P<0.14)} x^{1.5}$	0.8497
RA	AIB Doses	$\hat{y} = 98.95 + 0.058 x - 0.00011 x^2 + 0.000000039^{(P<0.18)} x^3$	0.9445
	AH Doses	$\hat{y} = 97.58 + 5.45 x - 0.30 x^2 + 0.0039^{ï} x^3$	0.6906

[1]Variables: SR = stem rooting index; NL = number of leaves, LL = length of longest leaf (mm), WL = width of longest leaf (mm) RFM= root fresh matter (mg), SFM = shoot fresh matter (mg), SDM = shoot dry matter (mg), RA = root area (% relative to control); **, *, ï and significant at P = 1, 5, 10 and P % probability, respectively.

Table 4. Regression equations for growth characteristics of hibiscus in response to application of indolbutiric acid (IBA) and humic acid (HA), applied at five concentrations (0, 250, 500, 1000, 2000 mg L^{-1} IBA and 0, 10, 20, 30, 40 mmol L^{-1} C HA)

Variable[1]	Unfolding	Regression equation	R^2
SR	AIB Doses	$\hat{y} = \bar{y} = 4.12$	
	AH Doses	$\hat{y} = \bar{y} = 3.64$	
NL	AIB Doses	$\hat{y} = 14.64 + 0.024 x - 0.000011^{**} x^2$	0.9716
	AH Doses	$\hat{y} = 9.31 + 2.01 x - 0.096 x^2 + 0.0014^{(P<0.28)} x^3$	0.6507
WL	AIB Doses	$\hat{y} = 10.68 - 0.35 x^{0.5} + 0.027 x - 0.00042^{(P<0.24)} x^{1.5}$	0.6192
	AH Doses	$\hat{y} = 8.87 + 0.18 x - 0.0027^{ï} x^2$	0.8476
LL	AIB Doses	$\hat{y} = \bar{y} = 22.0408$	
	AH Doses	$\hat{y} = 16.04 + 2.98^{ï} x^{0.5} - 0.33 x$	0.7980
RFM	AIB Doses	$\hat{y} = 21.00 + 0.14 x - 0.00006^{*} x^2$	0.8298
	AH Doses	$\hat{y} = 18.82 + 8.84 x - 0.49 x^2 + 0.0078^{(P<0.23)} x^3$	0.7511
SFM	AIB Doses	$\hat{y} = 317.29 + 0.47 x - 0.00021^{**} x^2$	0.9463
	AH Doses	$\hat{y} = 160.00 + 53.83 x - 3.10 x^2 + 0.05^{(P<0.18)} x^3$	0.8149
SDM	AIB Doses	$\hat{y} = 58.89 + 8.15^{**} x^{0.5} - 0.13 x$	0.9565
	AH Doses	$\hat{y} = 47.84 + 38.43^{(P<0.18)} x^{0.5} - 3.73 x$	0.6051
RA	AIB Doses	$\hat{y} = 83.78 + 17.41^{ï} x^{0.5} - 0.23 x$	0.7195
	AH Doses	$\hat{y} = 90.73 + 26.31 x - 1.53 x^2 + 0.024^{(P<0.28)} x^3$	0.6841

[1] Variables: SR = stem rooting index; NL= total number of leaves; LL= length of longest leaf (mm), WL= width of longest leaf (mm) RFM= root fresh matter (mg); SFM = shoot fresh matter (mg), SDM = shoot dry matter (mg), RA = root area (% relative to control); **, *, ï e ^{P} = significant 1, 5, 10 P % probability, respectively.

Table 5. Values of the growth characteristics of croton cuttings at maximum physical efficiency (MPE) for the variable root dry matter (RDM) in response to the application of indolbutyric acid (IBA) and humic acid (HA), at five concentrations (0, 250, 500, 1000, 2000 mg L^{-1} of IBA and 0, 10, 20, 30, 40 mmol L^{-1} to C AH)

Variable[1]	MPE Dose	Control mean	MPE mean	Difference (%)[2]
RDM	579.0039 mg L^{-1} AIB	37.06	45.88	24
	14.4117 mmol L^{-1} C_{AH}	39.81	41.40	4
SR	579.0039 mg L^{-1} AIB	4	4.35	9
	14.4117 mmol L^{-1} C_{AH}	4	4.01	0
NL	579.0039 mg L^{-1} AIB	31	31.38	1
	14.4117 mmol L^{-1} C_{AH}	32	20.02	60
WL	579.0039 mg L^{-1} AIB	7.01	7.02	0
	14.4117 mmol L^{-1} C_{AH}	6.70	6.57	2
LL	579.0039 mg L^{-1} AIB	40.84	48.87	20
	14.4117 mmol L^{-1} C_{AH}	47.31	48.68	3
RFM	579.0039 mg L^{-1} AIB	322.77	335.98	4
	14.4117 mmol L^{-1} C_{AH}	273.00	175.58	55
SFM	579.0039 mg L^{-1} AIB	628.88	594.66	6
	14.4117 mmol L^{-1} C_{AH}	479.40	445.02	8
SDM	579.0039 mg L^{-1} AIB	95.33	104.81	10
	14.4117 mmol L^{-1} C_{AH}	91.65	68.03	35
RA	579.0039 mg L^{-1} AIB	100.00	101.38	1
	14.4117 mmol L^{-1} C_{AH}	100.00	78.60	27

[1] Variable: RFM= root fresh matter (mg), SR = stem rooting index; NL= number of leaves, LL= length of the longest leaf (mm), WL= width of the longest leaf (mm); SFM= shoot fresh matter (mg), RDM = root dry matter (mg), SDM= shoot dry matter (mg) and RA = root area (% relative to control). [2] Difference = 100 (xy) / y, mean for the treatment with the highest value and y is the mean for the treatment with the lowest value.

Table 6. Values of the growth characteristics of hibiscus cuttings at maximum physical efficiency (MPE) for the variable root dry matter production (RDM) in response to application of indolbutyric acid (IBA) and humic acid (HA), at five concentrations (0, 250, 500, 1000, 2000 mg L^{-1} of IBA and 0, 10, 20, 30, 40 mmol L^{-1} to C AH)

Variable[1]	MPE Dose	Control mean	MPE mean	Difference (%)[2]
RDM	969.69 mg L^{-1} AIB	68.8200	193.69	181
	49.91 mmol L^{-1} C_{AH}	57.5750	49.91	15
SR	969.69 mg L^{-1} AIB	4	4	0
	49.91 mmol L^{-1} C_{AH}	3	4	33
NL	969.69 mg L^{-1} AIB	15	30	100
	49.91 mmol L^{-1} C_{AH}	10	22	120
WL	969.69 mg L^{-1} AIB	10.77	13.28	23
	49.91 mmol L^{-1} C_{AH}	8.60	11.86	38
LL	969.69 mg L^{-1} AIB	22.10	22.04	0
	49.91 mmol L^{-1} C_{AH}	16.02	22.19	39
RFM	969.69 mg L^{-1} AIB	20.6200	100.3522	387
	49.91 mmol L^{-1} C_{AH}	21.9250	59.5130	171
SFM	969.69 mg L^{-1} AIB	298.7200	575.6010	93
	49.91 mmol L^{-1} C_{AH}	174.7200	371.8200	113
SDM	969.69 mg L^{-1} AIB	59.1000	186.6298	216
	49.91 mmol L^{-1} C_{AH}	47.9800	145.1035	202
RA	969.69 mg L^{-1} AIB	100	403	303
	49.91 mmol L^{-1} C_{AH}	100	160	60

[1] Variable: RDM = root dry matter (mg), SR = stem rooting index; NL = total number of leaves; LL = length of the longest leaf (mm), WL = width of the longest leaf (mm); RFM= root fresh matter (mg), SFM = shoot fresh matter (mg), SDM =shoot dry matter (mg) and RA = root area (% relative to control). [2] Difference = 100 (xy) / y, mean for the treatment with the highest value and y is the mean for the treatment with the lowest value.

formation and subsequent growth of adventitious roots, HA may act as an alternative to synthetic auxins in the vegetative propagation by cutting

The results indicate that IBA or HA may be used to accelerate rooting in cuttings of croton and hibiscus. This may benefit ornamental plant production and commercialization with a reduction in the time of production of propagules more adapted to field planting.

CONCLUSIONS

Humic acids are able to stimulate rooting in cuttings of croton and hibiscus and represents a technological alternative in the production of ornamentals.

The propagation of hibiscus cutting was higher with the application of 579 mg L^{-1} IBA or 14 mmol L^{-1} C HA. For the rooting of croton cuttings, we recommend the use of 970 mg L^{-1} IBA or 50 mmol L^{-1} C HA.

For both species, IBA showed a higher biostimulating effect than HA and, therefore, higher than the control.

The effect of the exogenous application of growth regulators for adventitious rooting was higher in stem cuttings of hibiscus than in cuttings of croton.

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REFERENCES

Alvarez V VH & Alvarez GAM (2006) Comparações de médias ou testes de hipóteses? Contrastes! Boletim Informativo da Sociedade Brasileira de Ciência do Solo, 31:24-34.

Baldotto LEB, Baldotto MA, Giro VB, Canellas LP, Olivares FL & Bressan-Smith R (2009) Desempenho do abacaxizeiro 'Vitória' em resposta à aplicação de ácidos húmicos durante a aclimatação. Revista Brasileira de Ciência do Solo, 33:979-990.

Baldotto MA, Giro VB, Baldotto LEB, Canellas LP & Velloso ACX (2011a) Initial performance of pineapple and utilization of rock phosphate applied in combination with organic compounds to leaf axils. Revista Ceres, 58:393-401.

Baldotto MA, Muniz RC, Baldotto LEB & Dobbss LB (2011b) Root growth of *Arabidopsis thaliana* (L.) Heynh. treated with humic acids isolated from typical soils of Rio de Janeiro state, Brazil. Revista Ceres, 58:504-511.

Busato JG (2008) Química do húmus e fertilidade do solo após adição de adubos orgânicos. Tese de Doutorado. Universidade Estadual do Norte Fluminense Darcy Ribeiro, Campos dos Goytacazes. 135p.

Canellas LP, Zandonadi DB, Olivares FL & Façanha AR (2006) Efeitos fisiológicos de substâncias húmicas - o estímulo às H^+-ATPases. In: Fernandes MS (Ed.) Nutrição Mineral de Plantas. Viçosa, Sociedade Brasileira de Ciência do Solo. p.175-200.

Cuquel FL, Granja P & Minami K (1992) Avaliação do enraizamento de estacas de crisântemo (*Chrysanthemum morifolium* L.) cv. White Reagan 606 tratadas com ácido indolbutírico (IBA). Scientia Agricola, 49:15-22.

Fachinello JC, Hoffmann A & Nachtigal JC (2005) Propagação de plantas frutíferas. Brasília, Embrapa Informação Tecnológica. 221p.

Façanha AR, Façanha ALO, Olivares FL, Guridi F, Santos GA, Velloso ACX, Rumjanek VM, Brasil F, Schripsema J, Braz-Filho R, Oliveira MA & Canellas LP (2002) Bioatividade de ácidos húmicos: efeito sobre o desenvolvimento radicular e sobre a bomba de prótons da membrana plasmática. Pesquisa Agropecuária Brasileira, 37:1301-1310.

Faria RT (2005) Floricultura: as plantas ornamentais como agronegócio. Londrina, Editora Mecenas. 116p.

Hartmann HT, Kester DE, Davies RT & Geneve RL (2011) Plant propagation: principles and practices. 8ªed. New Jersey, Prentice Hall. 915p.

Instituto Brasileiro de Foricultura - Ibraflor (2011) Apresentação Ibraflor dados de mercado 01/2011. Disponível em: <http://www.ibraflor.com/ns_mer_interno.php>. Acessado em: 02 de julho de 2012.

Landgraf PRC & Paiva PDO (2005) Produção e comercialização de flores em Minas Gerais. Informe Agropecuário, 26:07-11.

Lima DM, Silva CL, Ritter M, Biasi LA, Zanette F & Zuffellato-Ribas KC (2008) Substratos e auxinas no enraizamento de estacas caulinares de espinheira-santa. Scientia Agraria, 9:85-89.

Lorenzi HE & Souza HM (2008) Plantas ornamentais no Brasil: arbustivas, herbáceas e trepadeiras. 4ªed. Nova Odessa, Instituto Plantarum. 1088p.

Marques Júnior R, Canellas LP, Silva LG & Olivares FL (2008) Promoção de enraizamento de microtoletes de cana-de-açúcar pelo uso conjunto de substâncias húmicas e bactérias diazotróficas endofíticas. Revista Brasileira de Ciência do Solo, 32:1121-1128.

McDonald E (2006) As 400 melhores plantas de jardim. Uma enciclopédia prática de anuais, vivazes, bolbos, árvores e arbustos. 2ªed. Lisboa, Lisma Editora. 432p.

Piccolo A (2001) The supramolecular structure of humic substances. Soil Science, 166:810-832.

Pizzatto M, Wagner Júnior A, Luckmann D, Pirola K, Cassol DA & Mazaro SM (2011) Influência do uso do AIB, época de coleta e tamanho de estaca na propagação vegetativa de hibisco por estaquia. Revista Ceres, 58:4877-4892.

Rayle DL & Cleland RE (1992) The acid growth theory of auxin-induced cell elongation is alive and well. Plant Physiology, 99:1271-1274.

Rodda MRC, Canellas LP, Façanha AR, Zandonadi DB, Almeida DL, Guerra JGM & Santos GA (2006) Estímulo no crescimento e na hidrólise de ATP em raízes de alface tratadas com humatos de vermicomposto. I - efeito da concentração. Revista Brasileira de Ciência do Solo, 30:649-656.

Santos JP, Davide AC, Teixeira LAF, Melo AJS & Melo LA (2011) Enraizamento de estacas lenhosas de espécies florestais. Cerne, 17:293-301.

Sondergaard TE, Schulz A & Palmgren MG (2004) Energization of transport processes in plants. Roles of plasma membrane H+-ATPase. Plant Physiology, 136:2475-2482.

Trewavas AJ & Cleland RE (1983) Is plant development regulated by changes and the concentration of growth substances or by changes in the sensitivity of growth substances? Trends in Biochemical Sciences, 8:354-357.

Zandonadi DB, Canellas LP & Façanha AR (2007) Indolacetic and humic acids induce lateral root development through a concerted plasmalemma and tonoplast H^+ pumps activation. Planta, 225:1583-1595.