Acclimation of croton and hibiscus seedlings in response to the application of indobultiric acid and humic acid for rooting[1]

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ABSTRACT

The vegetative propagation of ornamental plants can be accelerated by applying plant growth regulators. Amongst them, the use of auxins, plant hormones with physiological effects on cell elongation and rooting have stood out. Alternatively, the application of humic acids, bioactive fraction of soil organic matter, also results in increases in rooting cuttings of ornamental plants. The objective of this work was to study the growth characteristics and the nutritional contents of croton and hibiscus plants during acclimation of seedlings in response to different concentrations of indolebutyric acid (IBA) and humic acid (HA) applied to cuttings for rooting. The experiment was conducted in greenhouse, and the apical stem cuttings were treated with solutions with concentrations of 0, 250, 500, 1000 and 2000 mg $L^{-1}$of IBA and 0, 10, 20, 30 and 40 mg L^{-1} of C from HA. At 45 days of rooting in carbonized rice husk, they were individually transferred to plastic bags of 2.0 dm^3 containing a mixture of soil: sand: manure (2: 1: 1) as substrate. At 90 days of acclimation, the plants were collected for measurement of growth and nutritional variables. The results showed that the application of the IBA stimulates the absorption of nutrients and growth of croton cuttings and transplanted hibiscus, contributing to formation of vigorous seedlings. A similar response occurred with the application of HA in hibiscus cuttings.

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

RESUMO

Aclimatação de mudas de cróton e hibisco em resposta à aplicação de ácido indolbutírico e ácido húmico para enraizamento

A propagação vegetativa de plantas ornamentais pode ser acelerada por meio da aplicação de reguladores de crescimento. Dentre eles, vêm-se destacando o uso de auxinas, hormônios vegetais com efeitos fisiológicos no alongamento celular e no enraizamento adventício. Alternativamente, a aplicação de ácidos húmicos, fração bioativa da matéria orgânica do solo, também resulta em incrementos na formação de raízes de estacas de plantas ornamentais. O objetivo deste trabalho foi estudar as características de crescimento e os teores nutricionais das plantas de cróton e hibisco, durante a aclimatação das mudas, em resposta a diferentes concentrações de ácido indolbutírico (AIB) e de ácido húmico (AH), aplicados para o enraizamento adventício das estacas. O experimento foi conduzido em viveiro, sendo as estacas caulinares apicais tratadas com soluções de concentrações iguais a 0, 250, 500, 1000 e 2000 mg L^{-1} de AIB e de 0, 10, 20, 30 e 40 mg L^{-1} de C de AH. Aos 45 dias de enraizamento das estacas no substrato casca de arroz carbonizado, elas foram transferidas individualmente para sacolas de plástico preto de 2,0 dm^3,

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contendo, como substrato, uma mistura de solo: areia: esterco (2:1:1). Aos 90 dias de aclimatação, as plantas foram coletadas para mensuração das variáveis de crescimento e nutricionais. Os resultados permitiram concluir que a aplicação de AIB estimula a absorção de nutrientes e o crescimento das estacas de cróton e de hibisco transplantadas, contribuindo para formação de mudas vigorosas. Resposta semelhante aconteceu com a aplicação de AH apenas em estacas de hibisco.

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

INTRODUCTION

According to Ibraflor (2012), the area used for growing plants and ornamental flowers all over Brazil is 12 thousand hectares, with around nine thousand farmers and a farm average size of 1.5 hectares. This creates 194,000 direct jobs, of which, 96,000 (49.5%) are related to production, 6,000 (3.1%) are related with distribution, 77,000 (39.7%) are distributed in retail and 15,000 (7.7%) in other functions, especially support, and with a per capita consumption of R$ 20.00 per inhabitant.

With the objective of increasing yield and optimization of acclimation phase of ornamental seedlings, the following has been studied: the use of fitted substrates (Yamamoto *et al*., 2007; Lima *et al*., 2008) and containers (Cunha *et al*., 2005), the association between plants with micorhizal fungi and diazotrophic bacteria (Weber *et al*., 2003; Baldotto, 2010), the use of growth regulators (Lima *et al*., 2008), among others. The objective of such efforts is to accelerate plant growth and to reduce the impact of transference from nursery to the field, increasing yield and seedling quality in less time and at lower costs.

Amongst ornamental plants, it stood out species used for its blooming foliage, such as croton, and flower-producer species, hibiscus, for example. Croton (*Codianeum variegatum* L. Rumph) of the Euphorbiaceae family is a set of semi-hardwood shrubs with 2.0 to 3.0 m of height, latescent, leathery and very attractive leaves, due to their size and shape (Lorenzi & Souza, 2008). Hibiscus (*Hibiscus rosa-sinensis L.*), belongs to Malvaceae Family, is a group of hardwood shrubs, with solitary and red, pink or white flowers, formed all over the year (Lorenzi & Souza, 2008). Because such plants are very appreciated by the population, they need fast propagation methods, with low cost and that assures the formation of vigorous, high-quality seedlings. Therefore, plant propagation by cuttings is a proper method since it allows obtaining a great amount of even, early seedlings with genetic characteristics of the matrix plant (Hartmann *et al*., 2002). Adventitious rooting of cuttings involves the action of auxins, plant hormones transported to the base of the cutting, which act on the formation of meristematic centers, inducing root formation (Hartmann *et al*., 2002). Synthetic auxins, plant growth regulators, such as indobultiric acid (IBA) are used to promote rooting of ornamental plant cuttings at commercial scale (Lima *et al*., 2008). The application of humic acid, the bioactive fraction of humificated organic matter in ornamental plant cuttings may promote the adventitious rooting, which is another technological option (Baldotto *et al*., 2012).

Humic acid (HA) is formed by heterogeneous molecular aggregates and stabilized by hydrogen bonds and hydrophobic interactions (Piccolo, 2001). It acts in the growth and development of many plants for agronomic purposes. Those effects are reflected in the acceleration of the development of roots and aerial part (Canellas *et al*., 2006; Baldotto *et al*., 2009; Silva *et al*., 2011; Baldotto *et al*., 2012).

The objective of this work was to study the growth characteristics and nutritional contents of croton and hibiscus plants over seedling acclimation in response to the concentrations of indobultiric acid (IBA) and humic acid (HA) applied over adventitious rooting of the cuttings.

MATERIAL AND METHODS

Plant material

Cuttings were made from branches of “brasileirinho” croton matrix plants (*Codianeum variegatum* L. Rumph) and red-flower hibiscus (*Hibiscus rosa-sinensis* L.), found in the Flower Farming Sector of the Universidade

Federal de Viçosa, Florestal Campus, located in Florestal, MG.

The apical stem semi-hardwood cuttings were collected in September, sectioned at 15 cm of length and four apical leaves were maintained.

Treatments

The experimental matrix (5 + 5) consisted of the following study factors for each plant species (croton and hibiscus): five concentrations (0, 250, 500, 1000, 2000 mg L^{-1}) of indobultiric acid (IBA) and five concentrations (0, 10, 20, 30, 40 mmol L^{-1} of carbon) from the humic acid (HA).

Humic acid was isolated from vermicompounds and previously characterized by Baldotto *et al*. (2007) and Busato (2008). The bases of the cuttings were soaked in solutions of HA for 24 hours (Baldotto *et al*., 2009), and in solutions of IBA for ten seconds (Lima *et al*., 2008). For this procedure, the cuttings were placed in plastic glasses with 50 mL of the solutions corresponding to the different treatments (Baldotto *et al*., 2012).

After 45 days of rooting in substrate of carbonized rice husks, the cuttings were individually transferred to 2.0 dm^3 black plastic bags, containing a mixture of soil:sand: manure (2:1:1) as substrate, chemically characterized by the following: SOM = 26 dag kg^{-1}; pH (H_2O) = 5.3; P (Mehlich-1) = 120.0 mg dm^{-3}; K = 118.0 mg dm^{-3}; Ca^{2+} = 22.9 $cmol_c$ dm^{-3}; Mg^{2+} = 1.7 $cmol_c$ dm^{-3}; Al^{3+} = 0.4 $cmol_c$ dm^{-3}, and H+Al = 3.80 $cmol_c$ dm^{-3}.

Seedlings were in the nursery covered by polyethylene mesh in 50% for acclimation. The experimental unit was one plant per plastic bag. The experiment was carried out in a random block design, with five replicates, totalling 100 experimental units.

Growth analysis

At 90 days of acclimation, plants were collect for measurement of the following variables: plant height (H), measured by distance from the plant collar to the leaf apex, using a meter tape; crown diameter (CRD); stem diameter (STD), measured using a digital model Starret 727 pachimeter; number of leaves (NL); root fresh matter mass (RFM) and aerial part fresh matter (APFM); root dry matter mass (RDM) and aerial part dry matter (APDM), obtained by drying in air ventilation oven at 60 ^{o}C for seven days and then weighed.

Nutritional analysis

After drying, leaves were ground in a Wiley-type mill, coupled to a 60-mesh wire $cm^{-2.}$ Then, the resulting powder was submitted to sulphuric digestion combined with hydrogen peroxide for determination of total contents of nitrogen (N), phosphorus, (P), potassium (K), calcium (Ca) and magnesium (Mg), sulphur (S), zinc (Zn), iron (Fe), manganese (Mn), copper (Cu) and boron (B). The Nessler method was used for N; content of P was obtained by molecular absorption spectrophotometry (colorimetry), after reaction with C vitamin and ammonium molybdate at the wavelength of 725 nm; K was determined by flame photometry. Contents of Ca, Mg, Cu, Fe, Mn and Zn were all obtained by molecular absorption spectrophotometry and content of S was achieved by turbidimetry and B was determined by colorimetry (Embrapa, 2009).

Statistical analysis

The evaluation results were submitted to analysis of variance and the treatment effects, for qualitative analysis, were unfolded in average contrasts, according to Alvarez & Alvarez (2006). For quantitative factors, the regression equations were adjusted among the assessed variables and concentrations of IBA and HA. The F test and factor unfolding were applied between 1, 5 and 10% of probability. Regarding regression analysis, the angular coefficients of the equations were tested when presented determination coefficient higher than 0.60. Regression equations were used to determine concentration of maximum physical efficiency of aerial part dry matter, in function of the concentrations of IBA and HA. Values of maximum efficiency concentration were replaced in the regression equation of each variable to estimate them for this condition.

RESULTS AND DISCUSSION

Growth analysis

The results of the growth analyses of croton plants at 90 days of acclimatation, in response to the application of IBA and HA, revealed some modifications in the initial performance, when differences among means (Table 1) were found in the average contrasts (Table 1) and in the regression equations (Table 2) adjusted for the plant growth data in response to the application of plant regulators.

Overall, for growth traits of croton seedlings at 90 days of acclimation, in response to the application of IBA and HA, no differences for most of the analysed variables were found, when compared to the control (Table 1). In this same table, when comparing the use of plant regulators, it was possible to verify that IBA application incremented CRD by 11.33% and NL by 20.82%, in croton plants, in comparison to HA application. It is assumed that, endogenous levels of auxins in croton plants are sufficient to stimulate the formation of adventitious roots, allowing this species to be classified as one with easy vegetative propagation by cutting (Baldotto *et al*., 2012), which can be seen in the acclimation period, when there is a lack of differences during growth among plants treated or not with IBA or HA. According to Trewavas & Cleland (1983), the low effect with the application of growth regulator may point to the low tissue sensitivity to the presence of the promotor, in addition to the high endogenous concentration of auxin.

Most of the regression equations adjusted among dependent variables (growth traits) and increasing concentrations of plant regulators (IBA and HA), were curvilinear (quadratic, quadratic roots, cubic and cubic roots) for growth variables in the aerial part and in the roots of croton (Table 2). The variable chosen for identification of the maximum concentration of physical efficiency (MFE) was the dry matter of the aerial part. Regarding IBA, the concentration that provided MFE of aerial part dry matter was 1089.37 mg L^{-1} and for HA, due to the lack of adjustment, the MFE concentration was estimated by the mean of values of the aerial part dry matter (Table 2). Concentrations of MFE were replaced in the regression equation for each variable in Table 2, in order to calculate it for this condition. It was found that the treatment with IBA incremented height (9.40%), crown diameter (0.88%), stem diameter (0.71%), number of leaves (26%), aerial part dry matter mass (27.60%), root fresh matter mass (13.24%) and root dry matter mass (5.63%) in croton plants.

In hibiscus, the results of growth analysis in response to the application of increasing concentrations of IBA and HA showed the effects of those plant regulators (Table 3). The average contrasts (Table 3) showed that the treated hibiscus plants were superior than the control ones for crown diameter, root fresh matter mass and root dry matter mass with IBA; and crown diameter and root fresh matter mass with HA. It can also be seen in this table that the comparison among the plant regulators showed that the use of IBA incremented all variables in comparison to HA, except crown diameter. Indobultiric acid is a synthetic product that, at proper concentrations, acts in the formation of meristematic centers and adventitious roots (Hartmann *et al*., 2002; Pizzatto *et al*., 2011; Baldotto *et al*., 2012), which favours dry mater accumulation in the root system during seedling acclimatation. Similarly, HA

Table 1. Means, average contrasts, relative increments (RI), residual mean square (RMS) and coefficient of variation (CV) for growth traits of croton plants at 90 days of acclimation in response to the application of indobultiric acid (IBA) and humic acid (HA) applied in five concentrations (0, 250, 500, 1000, 2000 mg L^{-1} of IBA and 0, 10, 20, 30, 40 mmol L^{-1} of C from HA), carried out in the random block design with 5 replicates.

Sources of variation (1)	Growth traits (2)							
	H	CRD	STD	NL	APFM	RFM	APDM	RDM
	cm	mm	mm		mg/plant			
IBA0	25.20	22.80	4.27	43	9.53	2.87	1.97	0.71
IBA 250	27.40	21.00	4.46	44	10.03	4.05	2.04	0.72
IBA 500	25.90	24.10	4.11	51	10.95	2.65	2.03	0.60
IBA 1000	28.20	23.00	4.28	54	12.58	4.02	2.50	0.75
IBA 2000	24.20	22.10	4.10	48	9.70	2.68	2.00	0.61
HA0	25.00	26.60	4.79	58	12.60	3.19	2.44	0.59
HA 10	28.00	26.60	4.58	58	12.87	3.38	2.62	0.60
HA 20	25.90	24.70	4.02	54	11.78	3.63	2.19	0.67
HA 30	25.90	24.20	4.10	63	12.97	2.72	2.55	0.57
HA 40	25.40	23.70	3.82	56	10.46	2.32	2.14	0.53
Average contrasts and relative increments (3)								
(-) *vs*. IBA	1.23	-0.25	-0.03	6.55	1.28	0.47	0.18	-0.04
RI (%)	4.86	1.11	0.76	15.30	13.47	16.52	8.92	6.49
(-) *vs*. HA	1.30	-1.80	-0.66*	-0.20	-0.58	-0.17	-0.07	0.00
RI (%)	5.20	7.26	15.99	0.34	4.81	5.69	2.93	0.00
IBA *vs*. HA	-0.14	2.56**	0.02	10.00º	1.58	-0.20	0.28	-0.09
RI (%)	0.54	11.33	0.37	20.82	14.93	6.65	13.28	14.81
RMS	7.89	6.58	0.29	432	12.07	1.01	0.51	0.04
CV (%)	10.76	10.74	12.59	39.19	30.62	32.01	31.77	31.20

(1)Sources of variation show plant regulator and concentrations; (-) = control; IBA = indobultiric acid; HA = humic acid. (2)Growth traits: H = height; CRD = crown diameter; STD = stem diameter; NL = number of leafs; APFM = aerial part fresh matter mass; RFM = root fresh matter; APDM = aerial part dry matter mass; RDM = root dry matter. (3)Average contrasts: control *versus* IBA; control *versus* HA; IBA *versus* HA; Relative increments: 100 (x-y)/y, where x is the mean of the treatment with the highest value and y is the mean of the treatment with the lowest value. *,** and º = significant between 1, 5 and 10% of probability by the F test.

Table 2. Regression equations for growth traits of croton plants at 90 days of acclimation in response to the application of indobultiric acid (IBA) and humic acid (HA) applied in five concentrations (0, 250, 500, 1000, 2000 mg L^{-1} of IBA and 0, 10, 20, 30, 40 mmol L^{-1} of C from HA)

Variable [1]	Unfolding	Regression equation	R^2
H	IBA concentration	$\hat{y} = 25.34 + 0.0051\,x - 0.0000028^{(P<0.27)}\,x^2$	0.7213
	HA concentration	$\hat{y} = 25.12 + 1.32\,x^{0.5} - 0.209^{(P<0.30)}\,x$	0.6933
CRD	IBA concentration	$\hat{y} = \bar{y} = 22.6$	
	HA concentration	$\hat{y} = 26.68 + 0.134^{o}\,x^{0.5} - 0.102\,x$	0.9121
STD	IBA concentration	$\hat{y} = \bar{y} = 4.24$	
	HA concentration	$\hat{y} = 4.81 - 0.0386\,x - 0.00036^{o}\,x^2$	0.9130
NL	IBA concentration	$\hat{y} = 41.66 + 0.021\,x - 0.0000087^{o}\,x^2$	0.9253
	HA concentration	$\hat{y} = \bar{y} = 43.2$	
APFM	IBA concentration	$\hat{y} = 9.15 + 0.0057\,x - 0.0000027^{*}\,x^2$	0.9022
	HA concentration	$\hat{y} = 12.74 - 0.116\,x + 0.0094\,x^2 - 0.00019^{o}\,x^3$	0.6976
RFM	IBA concentration	$\hat{y} = \bar{y} = 3.25$	
	HA concentration	$\hat{y} = 3.19 + 0.043\,x - 0.0017\,x^2$	0.8720
APDM	IBA concentration	$\hat{y} = 1.88 + 0.00086\,x - 0.00000039^{(P<0.32)}\,x^2$	0.6706
	HA concentration	$\hat{y} = \bar{y} = 2.39$	
RDM	IBA concentration	$\hat{y} = 0.73 - 0.0005\,x + 0.0000008\,x^2 - 0.0000000003^{(P<0.27)}\,x^3$	0.6330
	HA concentration	$\hat{y} = 0.59 + 0.0057\,x - 0.00018^{(P<0.12)}\,x^2$	0.7326

[1]Variable: H = height (cm); CRD = crown diameter (mm); STD = stem diameter (mm); NL = number of leaves; APFM = aerial part fresh matter mass (mg/plant); RMF = root fresh matter (mg/plant); APDM = aerial part dry matter mass (mg/plant); RDM = root dry matter mass (mg/plant); *,º and ^{P} = significant between 5, 10 and P% of probability.

Table 3. Means, average contrasts, relative increments (RI), residual mean square (RMS) and coefficient of variation (CV) for growth traits of hibiscus plants at 90 days of acclimation in response to the application of indobulitiric acid (IBA) and humic acid (HA) applied in five concentrations (0, 250, 500, 1000, 2000 mg L^{-1} of IBA and 0, 10, 20, 30, 40 mmol L^{-1} of C from HA), carried out in random block design with 5 replicates

Sources of variation [1]	Growth traits [2]							
	H	CRD	STD	NL	APFM	RFM	APDM	RDM
	cm	mm	mm		mg/plant			
IBA0	28.88	24.50	4.78	51	18.84	2.14	4.19	0.67
IBA 250	27.60	31.20	5.03	51	24.70	5.16	3.99	1.03
IBA 500	30.20	27.00	4.83	42	20.42	6.63	4.02	1.65
IBA 1000	35.80	27.20	5.03	40	19.86	4.76	3.99	1,07
IBA 2000	36.25	26.00	4.92	60	20.49	2.68	4.59	0.76
HA0	30.86	24.69	4.15	35	13.25	0.84	3.02	0.38
HA 10	30.23	28.86	3.92	41	13.28	1.89	2.62	0.45
HA 20	30.01	30.67	4.25	48	20.97	3.77	4.32	0.83
HA 30	39.20	32.80	5.12	47	24.72	6.19	4.93	0.99
HA 40	29.68	28.50	4.31	45	16.41	2.69	3.42	0.47
Average contrasts and relative increments [3]								
(-) *vs.* IBA	3.59	3.35º	0.17	-2.43	2.53	2.67*	-0.04	0.46º
RI (%)	12.42	13.67	3.53	5.04	13.40	124.41	0.98	69.72
(-) *vs.* HA	1.42	5.52**	0.25	10.26	5.60	2.79*	0.80	0.30
RI (%)	4.60	22.35	6.08	29.32	42.23	331.09	26.43	79.88
IBA *vs.* HA	0.25	1.92º	-0.57**	-5.38	-3.14	-1.20º	-0.49	-0.41**
RI (%)	0.80	7.08	13.11	12.45	17.69	38.89	13.33	66.04
RMS	42.09	15.53	0.43	150	56.47	5.90	1.74	0.24
CV (%)	20.35	14.01	14.10	26.69	38.95	66.07	33.73	59.28

[1]Sources of variation: show the plant regulators and the concentrations; (-) = control; IBA = indobultiric acid; HA = humic acid. [2]Growth traits: H = height; CRD = crown diameter; STD = stem diameter; NL = number of leaves; APFM = aerial part fresh matter mass; RFM = root fresh matter mass; APDM = aerial part dry matter mass; RDM = root dry matter mass. [3]Average contrasts: control *versus* IBA; control *versus* HA; IBA *versus* HA; Relative increments: 100 (x-y)/y, where x is the mean in the treatment with the highest value and y is the mean of the treatment with the lowest value. **, * and º = significant among 1, 5 and 10% of probability by the F test.

Table 4. Regression equations for growth traits of hibiscus plants at 90 days of acclimation in response to the application of indobultiric acid (IBA) and humic acid (HA) applied at five concentrations (0, 250, 500, 1000, 2000 mg L^{-1} of IBA and 0, 10, 20, 30, 40 mmol L^{-1} of C from HA)

Variable(1)	Unfolding	Regression equations	R^2
H	IBA concentrations	$\hat{y} = 27.27 + 0.0092\,x - 0.0000023^{(P<0.15}x^2$	0.8480
	HA concentrations	$\hat{y} = 31.39 - 1.065\,x + 0.089\,x^2 - 0.00159^{o}\,x^3$	0.7001
CRD	IBA concentrations	$\hat{y} = 24.61 + 0.926\,x^{0.5} - 0.046\,x + 0.00058^{o}\,x^{1.5}$	0.7792
	HA concentrations	$\hat{y} = 24.42 + 0.59\,x - 0.0119^{o}\,x^2$	0.9188
STD	IBA concentrations	$\hat{y} = \bar{y} = 4.92$	
	HA concentrations	$\hat{y} = 4.18 - 0.13\,x + 0.011\,x^2 - 0.00019^{(P<0.35)}\,x^3$	0.9181
NL	IBA concentrations	$\hat{y} = 52.91 - 0.028\,x + 0.000015^{o}\,x^2$	0.8980
	HA concentrations	$w = 34.56 + 0.94\,x - 0.0168^{*}\,x^2$	0.9579
APFM	IBA concentrations	$\hat{y} = 18.93 + 0.97\,x^{0.5} - 0.054\,x + 0.00074^{(P<0.24)}\,x^{1.5}$	0.8058
	HA concentrations	$\hat{y} = 13.20 - 0.65\,x + 0.084\,x^2 - 0.0016^{*}\,x^3$	0.9983
RFM	IBA concentrations	$\hat{y} = 2.15 + 0.32^{o}\,x^{0.5} - 0.00701\,x$	0.9218
	HA concentrations	$\hat{y} = 0.26 + 0.32\,x - 0.00611^{(P<0.30)}\,x^2$	0.6948
APDM	IBA concentrations	$\hat{y} = 4.16 - 0.00056\,x + 0.00000038\,x^2$	0.9790
	HA concentrations	$\hat{y} = 3.03 - 3.49\,x^{0,5} + 1.55\,x - 0.156^{(P<0.15)}\,x^{1.5}$	0.9849
RDM	IBA concentrations	$\hat{y} = 0.64 + 0.05^{(P<0.30)8}\,x^{0.5} - 0.0012\,x$	0.6917
	HA concentrations	$\hat{y} = 0.28 + 0.047\,x - 0.000999^{(P<0.34)}\,x^2$	0.6585

(1) Variable: H = height (cm); CRD = crown diameter (mm); STD = stem diameter (mm); NL = number of leaves; APFM = aerial part fresh matter mass (mg); RFM = root fresh matter mass (mg); APDM = aerial part dry matter mass (mg); RDM = root dry matter mass (mg); *,° and ^{P} = significant between 5, 10 and P % of probability.

Table 5. Means, relative increments (RI), residue mean square (RMS) and coefficient of variation (CV) for nutritional contents of croton plants at 90 days of acclimation in response to the application of indobultiric acid (IBA) and humic acid (HA), applied at five concentrations (0, 250, 500, 1000, 2000 mg L^{-1} of IBA and 0, 10, 20, 30, 40 mmol L^{-1} of C from HA), performed in a random block design with 5 replicates

Sources of variation(1)	Nutritional Contents (2)										
	N	P	K	Ca	Mg	S	Zn	Fe	Mn	Cu	B
	dag kg^{-1}						mg kg^{-1}				
IBA0	2.25	0.45	1.01	2.01	0.69	0.18	60.00	1542.00	97.00	14.33	98.57
IBA 250	2.53	0.55	1.24	2.17	0.73	0.30	77.33	3363.67	98.33	17.67	182.37
IBA 500	2.96	0.65	1.23	2.41	0.78	0.27	85.00	2312.67	109.33	20.33	130.13
IBA 1000	2.48	0.48	1.09	1.69	0.68	0.24	54.67	2662.67	98.00	17.33	116.07
IBA 2000	2.57	0.56	1.29	1.91	0.69	0.21	81.00	1509.33	79.67	17.33	111.93
HA0	2.67	0.49	1.15	1.81	0.66	0.24	61.00	2369.33	97.00	12.33	126.13
HA10	3.04	0.53	1.60	1.96	0.65	0.26	73.00	1408.00	90.33	18.00	103.13
HA20	2.69	0.52	2.68	1.93	0.68	0.40	57.33	3214.67	96.33	12.00	94.00
HA30	2.90	0.58	2.81	2.18	0.72	0.37	61.67	2526.33	94.00	17,.33	115.87
HA40	2.96	0.63	2.25	1.95	0.72	0.47	79.33	1837.67	105.00	23.00	117.47
Average contrasts and relative increments (3)											
(-) *vs*. IBA	0.39**	0.11*	0.20	0.04	0.03	0.07**	14.50	920.08**	-0.67	3.83	36.56*
RI (%)	17.19	25.19	19.74	1.99	4.11	37.73	24.17	59.67	0.69	26.74	37.09
(-) *vs*. HA	0.23**	0.07*	1.19**	0.20*	0.04°	0.14**	6.83	-122.67	-0.58	5.25*	-18.52°
RI (%)	8.66	15.31	103.78	10.93	5.46	59.51	11.20	-5.18	-0.60	42.57	17.21
IBA *vs*. HA	0.29**	0.01	0.93**	-0.07	-0.03	0.11**	-5.13	-6.87	0.07	-0.87	-16.49°
RI (%)	11.41	2.48	78.86	3.77	3.99	46.37	7.72	0.30	0.07	5.24	14.82
RMS	0.07	0.01	0.11	0.00	0.00	0.00	237.97	288612.90	379.97	34.53	952.35
CV (%)	10.08	15.62	19.82	11	8.04	11.47	22.35	23.62	20.20	34.63	25.81

(1)Sources of variation: show the plant regulators and the concentrations; (-) = control; IBA = indobultiric acid; HA = humic acid. (2)Nutritional contents: correspond to contents of N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; S = sulphur; Zn = zinc; Fe = iron; Mn = manganese; Cu = copper and B = boron. (3)Average contrasts: control *versus* IBA; control *versus* HA; IBA *versus* HA; Relative increments: 100 (x-y)/y, where x is the mean of the treatment with the highest value and y is the mean of the treatment with the lowest value. **, * and ° = significant among 1, 5 and 10% of probability by the F test.

also stimulated root emergence (Silva *et al.*, 2011), with variation in its effect according to the plant species, to the source and to the concentration used (Canellas *et al.*, 2006; Baldotto *et al.*, 2009; Baldotto *et al.*, 2012). Plants with more vigorous root system tolerate better environmental conditions with water stress and low content of available nutrients (Fitter, 1991) therefore, the use of plant regulators during propagation of hibiscus plants by cutting results in better fitted plants for field planting.

The regression equations adjusted for growth of hibiscus plants in response to concentrations of IBA and HA are in Table 4. They were, mostly, curvilinear (quadratic, quadratic roots, cubic, cubic root) for growth of roots and aerial section in hibiscus. It was not possible to adjust regression equation only for crown diameter for IBA treated plants and the mean among the dots in the curve was estimated.

The concentrations that resulted in the greatest accumulation of aerial part dry matter mass in hibiscus plants, that is, the most efficient ones for a seedling with more reserves, were 977.77 mg L^{-1} of IBA and 26.83 mmol L^{-1} of C in the form of HA. The rapid accumulation of dry matter in the shoots is desirable to guarantee energy for the post-planting (Lorenzi & Souza, 2008).

Nutritional status

Nutritional contents of croton plants at 90 days of acclimation ranged in response to the application of IBA and AH (Table 5). There was a better performance of IBA treated plants than the ones treated with HA and control.

The use of IBA in croton plants increased contents of N, P, S, Fe and B, when compared to control (Table 5). In the same table, it is found that the use of HA resulted in the increase in N, P, K, Ca, Mg, S and Cu, as the contents of B decreased when compared to the control. Overall, when the two plant regulators were compared, it was found that the contents of macronutrients N, K, and S achieved their peak when HA was applied, compared to IBA, which was superior only for the content of B.

Regression equations were calculated for nutritional contents of croton plants (Table 6) in response to concentrations of plant regulators. The ways of response found in the experiment were, mostly, curvilinear (quadratic, quadratic roots, cubic, cubic roots) with good adjustments (R > 0.70) and most of them showed positive increment rates.

For hibiscus, increases in almost all nutritional variables were found (Table 7) in response to the HA application. The bio-stimulant action of humic

Table 6. Regression equations for nutritional contents of croton plants at 90 days of acclimatation in response to the application of indobultiric acid (IBA) and humic acid applied at five concentrations (0, 250, 500, 1000, 2000 mg L^{-1} of IBA and 0, 10, 20, 30, 40 mmol L^{-1} of C from HA)

Variable(1)	**Unfolding**	**Regression equation R^2**	
N	IBA concentration	$\hat{y} = 2.20 +0.0028 x-0.0000036 x^2 + 0.0000000011^{(P<0.44)} x^3$	0.8329
	HA concentration	$\hat{y} = 2.67 + 0.599 x^{0.5} – 0.226 x + 0.022^{(P<0.60)}x^{1.5}$	0.7502
P	IBA concentration	$\hat{y} = 0.44+0.0009 x-0.0000013 x^2 + 0.0000000004^{(P<0.36)} x^3$	0.9149
	HA concentration	$\hat{y} = 0.496 + 0.00098 x + 0.000057^{o}x^2$	0.9360
K	IBA concentration	$\hat{y} = 1.02+0,0011 x-0.0000016 x^2+ 0.0000000006^{(P<0,20)} x^3$	0.9726
	HA concentration	$\hat{y} = 0.989 + 0.119 x – 0.0021^{o}x^2$	0.8901
Ca	IBA concentration	$\hat{y} = 1.96+ 0.0023 x – 0.0000038 x^2 + 0.000000001^{(P<0,43)}x^3$	0.8808
	HA concentration	$\hat{y} = 1.82 – 0.0029 x + 0.0012 x^2 – 0.000025^{*}x^3$	0.7054
Mg	IBA concentration	$\hat{y} = 0.68+0.00042 x-0.0000006 x^2+0.0000000002^{(P<0.44)}x^3$	0.8769
	HA concentration	$\hat{y} = 0.6553 – 0.012^{o} x^{0.5} + 0.0038 x$	0.9242
S	IBA concentration	$\hat{y} = 0.19 + 0.007^{(P<0.22)}x^{0.5} – 0.00016 x$	0.7739
	HA concentration	$\hat{y} = 0.23 + 0.0064 x – 0.000014^{(P<0.13)}x^2$	0.8675
Zn	IBA concentration	$\hat{y} = 58.97 + 0.135 x – 0.0002 x^2 + 0.00000008^{(P<0.20)}x^3$	0.9737
	HA concentration	$\hat{y} = 61.02 + 37.14 x^{0.5} – 15.76 x + 1.637^{o}x^{1.5}$	0.9933
Fe	IBA concentration	$\hat{y} = 1644.54 + 114.32^{(P<0.27)}x^{0.5} – 2.64 x$	0.7307
	HA concentration	$\hat{y} = 2361.02 – 2902.38 x^{0.5} + 1229.30 x-124.39^{(P<0.13)}x^{1.5}$	0.8332
Mn	IBA concentration	$\hat{y} = 97.60 + 0.017 x – 0.00001^{(P<0.13)}x^2$	0.8624
	HA concentration	$\hat{y} = 96.46 – 0.5748 x + 0.019^{(P<0.22)}x^2$	0.7770
Cu	IBA concentration	$\hat{y} = 14.42 + 0.33^{(P<0.27)}x^{0.5} – 0.0061 x$	0.7310
	HA concentration	$\hat{y} = 12.37 + 12.87 x^{0.5} – 5.36 x + 0.57^{(P<0.34)} x^{1.5}$	0.9266
B	IBA concentration	$\hat{y} = 99.64 + 13.54 x^{0.5} – 0.72 x + 0.0098^{(P<0.44)}x^{1.5}$	0.8742
	HA concentration	$\hat{y} = 126.47 – 15.91^{(P<0.19)}x^{0.5} +2.33 x$	0.8095

(1)Variable: corresponds to the contents of N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; S = sulphur; Zn = zinc; Fe = iron; Mn = manganese; Cu = copper and B = boron; *,º and ^{P} = significant among 5, 10 and P % of probability.

Table 7. Nutritional contents of hibiscus plants at 90 days of acclimation in response to the application of indolbutiruc acid (IBA) and humic acid (HA) applied in five concentrations (0, 250, 500, 1000, 2000 mg $L^{-1}$of IBA and 0, 10, 20, 30, 40 mmol L^{-1} of C from HA), carried out in a random block design with 5 replicates

Sources of variation[(1)]	Nutritional contents [(2)]										
	N	P	K	Ca	Mg	S	Zn	Fe	Mn	Cu	B
	dag kg^{-1}						mg kg^{-1}				
IBA0	2.63	0.76	3.11	1.78	0.55	0.43	47.00	2251.67	58.33	12.67	138.83
IBA250	3.07	0.66	3.36	1.98	0.64	0.49	45.00	3130.00	68.33	12.00	180.70
IBA500	2.99	0.64	3.05	1.90	0.54	0.46	51.00	2977.33	72.00	12.33	125.40
IBA1000	2.28	0.96	3.11	1.63	0.52	0.46	55.00	2065.33	55.33	16.67	120.93
IBA2000	2.77	0.74	2.80	2.18	0.54	0.43	40.33	2489.00	61.33	10.33	151.83
HA0	2.49	0.35	1.92	1.65	0.33	0.82	40.33	5045.33	262.00	13.67	244.70
HA10	2.51	0.82	2.89	1.98	0.48	0.49	56.00	2777.33	73.67	14.67	196.43
HA20	2.76	0.50	3.12	1.92	0.55	0.43	46.33	1841.33	63.67	11.33	175.33
HA30	2.89	0.67	3.20	1.95	0.61	0.49	44.00	3757.33	89.67	10.33	141.40
HA40	2.48	1.16	2.80	2.09	0.51	0.49	59.00	2227.67	8533	13.33	149.30
	Average contrasts and relative increments [(3)]										
(-) *vs*. IBA	0.15	-0,01	-0,03	0,15	0,01	0,04	0,83	413,75	5,92	0,17	5,88
RI (%)	5.74	1,33	0,87	8,21	2,44	8,40	1,77	18,38	10,14	1,32	4,24
(-) vs. HA	0.17º	0,44**	1.08**	0.34**	0.21**	-0.35**	11.00*	-2394.42**	-183.92**	-1.25º	-79.08**
RI (%)	6.86	125.00	56.42	20.45	64.54	72.63	27.27	90.32	235.54	10.07	47.75
IBA *vs*. HA	-0.12	-0.05º	-0.30º	0.02	-0.06	0.09*	1.47	4208.80**	51.80*	-0.13	37.89**
RI (%)	4.59	7.43	10.72	1.20	12.52	19.47	3.08	162.96	82.14	1.05	26.40
RMS	0.29	0.06	0.33	0.00	0.02	0.03	103.60	107935400.0	7145.07	12.30	1034.00
CV (%)	20.01	36.38	19.85	16.00	24.76	33.47	23.88	221.66	95.01	27.54	19.79

[(1)]Sources of variation: show the plant regulators and the concentrations. [(2)] Nutritional contents: correspond to the contents of N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; S = sulphur; Zn = zinc; Fe = iron; MN = manganese; Cu = copper and B = boron. [(2)] Average contrasts: control *versus* IBA; control *versus* HA; IBA *versus* HA; Relative increments: 100 (x-y) /y, where x is the mean of the treatment with the highest value and y is the mean of the treatment with the lowest value. **, * and º = significant among 1, 5 and 10% of probability by the F test, respectively.

substances comprehends the activity of ATPases, enzymes related to both absorption of nutrients such as "acid growth", mechanisms that have been used to explain its bioactivity (Canellas *et al*., 2006). Humic acid also stimulates the formation of root hair (Silva *et al*., 2011), increasing the absorption area of nutrients by the roots.

The regression equations for contents of plant nutrients in function of the increasing concentrations of IBA and HA are presented in Table 8. The variable chosen to estimate the concentration of maximum physical efficiency was aerial part dry matter mass, whose values were 977.77 mg L^{-1} for IBA and 26.83 mmol L^{-1} of C, for HA. Such concentration of HA resulted in an accumulation of dry matter 61% higher than the control. Significant effect for IBA was not found. Humic acid acts in the formation of meristematic centers, especially in the formation of adventitious root, which, in turn, increment the nutrient absorption and plant growth. Thus, the results obtained show that the use of HA in hibiscus cuttings accelerates plant growth in seedling acclimation. The efficiency of propagation benefits production and commercialization of ornamental plants.

Concentrations of IBA and HA of MFE were replaced in the regression equations of each variable of Table 8, to estimate them for that condition. It was found that the treatment with HA incremented contents of P (89%), K (67%), Ca (21%), Mg (76%), S (132%) and Zn (9%). The use of IBA also resulted in a greater accumulation of some nutrients than in the control, but this better nutritional composition was not converted into greater content of dry matter.

Finally, the results show that seedling production of croton and hibiscus by using synthetic hormones and bioactive fractions of organic matter (IBA and HA) is an efficient alternative since propagation of croton by cuttings for seedling production was benefited with the application of IBA, which incremented the nutritional status when compared to the control. In addition, for hibiscus, both stimulants presented positive effects in growth and seedling development.

The results support data of Baldotto *et al*. (2012), in the rooting phase of seedlings of croton and hibiscus. Therefore, the effect in rooting leads to a greater efficiency in the following phase, acclimation of seedlings of those ornamental plants.

Table 8. Regression equations for nutritional contents of hibiscus plants at 90 days of acclimation in response to the application of indobultiric acid (IBA) and humic acid (HA) applied at five concentrations (0, 250, 500, 1000, 2000 mg L^{-1} of IBA and 0, 10, 20, 30, 40 mmol L^{-1} of C of AH)

Variable[1]	Unfolding	Regression equation	R^2
N	IBA concentration	$\hat{y} = 2.63 + 0.0028\ x - 0.0000049\ x^2 + 0.0000000018^{o}\ x^3$	0.9972
	HA concentration	$\hat{y} = 2.49 - 0.024\ x + 0.003\ x^2 - 0.00006^{*}x^3$	0.9990
P	IBA concentration	$\hat{y} = 0.768 - 0.00093\ x + 0.0000018\ x^2 - 0.0000000007^{(P<0.16)}\ x^3$	0.9826
	HA concentration	$\hat{y} = 0.35 + 0.98\ x^{0.5} - 0.39\ x + 0.041^{o}x^{1.5}$	0.9967
K	IBA concentration	$\hat{y} = 3.13 + 0.013^{(P<0.24)}x^{0.5} - 0.00047\ x$	0.7510
	HA concentration	$\hat{y} = 1.96 + 0.103\ x - 0.0021^{**}\ x^2$	0.9813
Ca	IBA concentration	$\hat{y} = 1.785 + 0.0011\ x - 0.000002\ x^2 + 0.0000000008^{(P<0,16)}\ x^3$	0.9926
	HA concentration	$\hat{y} = 1.66 + 0.098^{(P<0.15)}x^{0.5} - 0.0062\ x$	0.8479
Mg	IBA concentration	$\hat{y} = 0.5487 + 0.0194\ x^{0.5} - 0.0012\ x + 0.000017^{o}x^{1.5}$	0.7998
	HA concentration	$\hat{y} = 0.32 + 0.0198\ x - 0.00037^{*}\ x^2$	0.9668
S	IBA concentration	$\hat{y} = 0.43 + 0.004^{*}\ x^{0.5} - 0.00009\ x$	0.8000
	HA concentration	$\hat{y} = 0.82 - 0.116^{**}\ x^{0.5} + 0.018\ x$	0.9863
Zn	IBA concentration	$\hat{y} = 46.97 - 1.42\ x^{0.5} + 0.11\ x - 0.0019^{o}\ x^{1.5}$	0.9974
	HA concentration	$\hat{y} = 40.30 + 33.36\ x^{0.5} - 13.04\ x + 1.3^{(P<0.16)}\ x^{1.5}$	0.9830
Fe	IBA concentration	$\hat{y} = 2285.63 + 4.69\ x - 0.0075\ x^2 + 0.000003^{(P<0.19)}x^3$	0.9755
	HA concentration	$\hat{y} = 23123.3 - 9030.85^{*}x^{0.5} + 938.66\ x$	0.9795
Mn	IBA concentration	$\hat{y} = 57.88 + 0.074\ x - 0.00011\ x^2 + 0.00000001^{(P<0.17)}x^3$	0.9809
	HA concentration	$\hat{y} = 260.38 - 87.26^{**}\ x^{0.5} + 9.68\ x$	0.9836
Cu	IBA concentration	$\hat{y} = 12.76 - 0.009\ x + 0.00002\ x^2 - 0.000000009^{o}x^3$	0.9931
	HA concentration	$\hat{y} = 13.66 + 6.95\ x^{0.5} - 3.07\ x + 0.31^{(P<0.13)}x^{1.5}$	0.9892
B	IBA concentration	$\hat{y} = 139.93 + 9.129\ x^{0.5} - 0.6047\ x + 0.009^{o}\ x^{1.5}$	0.7628
	HA concentration	$\hat{y} = 244.81 - 5.30\ x + 0.071^{*}x^2$	0.9783

[1]Variable: corresponds to the contents of N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; S = sulphur; Zn = zinc; Fe = iron; Mn = manganese; Cu = copper and B = boron; **, *,º and ^{P} = significant among 1, 5, 10 and P % of probability.

CONCLUSIONS

The results achieved in this experiment show that the response to application of plant regulators depends on plant genotype and concentration.

The use of IBA and HA at the indicated concentrations favours acclimation of hibiscus plants propagated by cutting, reducing production time of seedlings and benefiting production and commercialization of ornamental plants.

Regarded to croton, the use of IBA at the indicated concentration is also recommended.

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