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Scientific Article

Cuttings of *Euphorbia phosphorea* Mart and *Euphorbia enterophora* Drake at different concentrations of indole-butyric acid and analysis of economic viability

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Abstract

Defining seedling production protocols for ornamental species through the use of plant regulators requires economic analysis that demonstrates the real financial returns of such activity to horticulturists. The objective was to evaluate the influence of using indole butyric acid regulator (IBA) on rooting of *Euphorbia phosphorea* (Mart) and *Euphorbia enterophora* (Drake) cuttings, as well as to analyze the economic viability of seedling production with the use of IBA. The cuttings were 10 cm long, and treated with IBA at concentrations of 0; 1,000; 3,000; and 5,000 mg L^{-1}. The cuttings were place in vermiculite substrate and were irrigated daily inside a greenhouse. The experimental design was completely randomized, with 4 replications, containing 5 cuttings per experimental unit. Evaluations were performed 150 days after establishing the experiments. The Net Present Value (NPV) and the Internal Return Rate (IRR) were analyzed to determine the economic viability analysis of using IBA. For *E. phosphorea* there was no significant difference between treatments for cuttings survival, number of roots and length of roots. Callus formation was not observed at the base of the cuttings, and the highest survival percentage was observed in T3 (3,000 mg L^{-1}) and T4 (5,000 mg L^{-1}) treatments. Treatment T1 (control) presented a lower number of roots per cutting (12.8) and higher average length of the three largest roots (12.56 cm). The use of the IBA regulator increased the percentage of rooted cuttings and the number of roots per cutting, and the concentration of 3,000 mg L^{-1} was recommended for *E. phosphorea.* Regarding aspects of economic viability, using IBA at the commercial nursery level is recommended. For *E. enterophora*, IBA is not recommended because it is an easily rooted species (95%), therefore, denotes the economic unfeasibility of its use.
Keywords: ornamental plants, plant regulator, rooting, economic analysis

Resumo

Estaquia de *Euphorbia phosphorea* Mart e *Euphorbia enterophora* Drake sob diferentes concentrações de ácido indol butírico e análise da viabilidade econômica

As definições de protocolos de produção de mudas de espécies ornamentais, com a utilização de reguladores vegetais, demandam análise econômica que demonstrem ao viveirista os reais retornos financeiros de sua atividade. O objetivo foi avaliar a influência da utilização do regulador ácido indol butírico (IBA) na promoção do enraizamento de estacas de *Euphorbia phosphorea* (Mart) e *Euphorbia enterophora* (Drake), bem como analisar a viabilidade econômica da produção de mudas com o uso de IBA. As estacas foram confeccionadas com 10 cm de comprimento, e tratadas com IBA nas concentrações de 0, 1000, 3000 e 5000 mg L^{-1}. As estacas foram acondicionadas em estufa, contendo vermiculita como substrato, irrigadas diariamente. O delineamento experimental foi o inteiramente casualizado, com 4 repetições, contendo 5 estacas por unidade experimental. As avaliações foram realizadas 150 dias após a instalação dos experimentos. Foram analisados o Valor Líquido Presente (VPL) e a Taxa Interna de Retorno (TIR), para compor análise de viabilidade econômica do uso do IBA. Para *E. phosphorea* não houve diferença significativa entre os tratamentos para as variáveis de sobrevivência das estacas, número de raízes e comprimento de raízes. Não foi observada a formação de calos na base das estacas, sendo que o maior percentual de sobrevivência foi observado nos Tratamentos T3 (3000 mg L^{-1}) e T4 (5000 mg L^{-1}). O Tratamento T1 (testemunha) apresentou menor número de raízes por estaca (12,8) e maior comprimento médio das três maiores raízes (12,56 cm). O emprego do regulador IBA aumentou o percentual de estacas enraizadas e o número de raízes por estaca, sendo recomendada a concentração de 3000 mg L^{-1} para *E. phosphorea.* Sob aspectos de viabilidade econômica, recomenda-se o uso do IBA no nível de viveiro comercial. Para *E. enterophora*, não é recomendado o uso de IBA por ser espécie de fácil enraizamento (95%), por conseguinte, denota a inviabilidade econômica quando utilizado.
Palavras-chaves: plantas ornamentais, regulador vegetal, enraizamento, análise econômica.

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Introduction

According to Junqueira and Peetz (2014), the productive sector of flowers and ornamental plants in Brazil has been consistently become more relevant in the national agribusiness, standing out as an economically growing activity. Furthermore, according to IBRAFLOR, in 2016 this sector's global value was R$ 6.65 billion with an estimated annual growth of about 8%.

Several initiatives have been taken by horticulturists to increase the volume of commercialization and profitability, including the search for different native or exotic species with commercial potential.

According to Beckmann-Cavalcante et al. (2014), the inclusion of new exotic and native ornamental plant species in landscaping is a growing reality and is a consequence of the consumer market's desire for new products.

However, cultivating these plants in commercial nurseries can be difficult due to the lack of knowledge regarding reproductive phenology and propagation techniques that provide higher productivity and profitability for horticulturists.

Research that financially analyzes propagation techniques of new ornamental species are very important for establishing production protocols, as it provides greater safety in decision-making for horticulturists or agricultural investors.

Among the ornamental plants with greatest interest to gardeners are those of the Euphorbiaceae family, especially species of the genus *Euphorbia*. These plants have gained an important place in the market, as they are generally rustic plants and have important ornamental appeal due to their exotic aspect, which is ideal for interior decoration and landscape projects.

Among the *Euphorbia* species that has been exciting commercial interest is *Euphorbia phosphorea* (Mart), which is a native succulent plant from northeastern Brazil, commonly found in the states of Bahia and Paraíba. It develops well in semiarid regions with small precipitation intensities, around 600 mm per year (Machado, 2000). However, *E. phosphorea* has a low survival rate when cuttings are produced without using auxins and other synthetic regulators.

Another ornamental plant from this family is *Euphorbia enterophora* (Drake), which has a strong ornamental appeal as it is very attractive and presents a rustic appearance and is commonly used in landscape projects. However, sexual propagation techniques in nurseries are difficult since these species present very small seeds, making them difficult to collect, sow, store and handle.

Due to the difficulties of asexual propagation that these two species present, the main form of seedling production is vegetative through cuttings, which is one of the most important plant propagation methods, presenting advantages such as low cost and shorter growth time of new seedlings (Silva, 1984; Hartmann et al., 2002).

When plants are cut in commercial nurseries, several factors can interfere in the rooting process, whether they are inherent to the plant itself or to the environment (Nacata et al., 2013), that affect the results due to the loss of time in preparing the cuttings and other procedures that the technique demands. To minimize these losses, cuttings can be improved by using plant regulators (Costa et al., 2007; Dameda et al., 2014).

Using plant regulators to help the rooting process of cuttings is a common practice in seedling production nurseries, especially when the species is difficult to propagate. Synthetic auxins are plant regulators that are widely used in agriculture, and Zuffellato-Ribas and Rodrigues (2001) highlight that auxins are very important for the root formation of cuttings. However, when synthetic auxins are used in studies, little information about seedling production cost is provided to horticulturists.

One of the most commonly used auxins for cuttings propagation is indole butyric acid (IBA). Some authors recommend it for most species as it presents low toxicity at different concentrations when compared to other auxins (Ludwig-Müller, 2000; Hartmann et al., 2002; Alcantara et al. 2008; Zuffellato-Ribas and Rodrigues, 2001).

In ornamental species, treatment with auxins can provide rapidity, uniformity of rooting and higher root volume, ensuring better seedling development (Dole e Gibson, 2006; Beckmann-Cavalcante et al., 2014), and consequently greater productivity and financial gains for the nurseries.

Assaf Neto and Lima (2014) defend the economic feasibility analysis of projects by stating that the Internal Return Rate (IRR) "represents the explicit cost of a debt, or the effective yield of an application. It is equivalent to the interest rate that equals, at any given time, cash inputs with periodic cash outputs." These authors further conclude that "this methodology applies both for measuring the return on an application and for determining the cost of a loan or financing" (Assaf Neto and Lima, 2014). In the same vein, Ross et al. (2013) state that IRR is closely related to Net Present Value (NPV) and its calculation determines a single rate of return that summarizes the merits of a project, solely dependent on cash flows, which is the rate of return that sets the NPV to zero (Ross et al., 2013).

For Fonseca (2010), the NPV is the most recommended criterion for investment decisions since it works with temporal value of money (a resource available today is worth more than tomorrow, because it can be invested and yield interest), cannot be influenced by less qualified decisions (manager preferences, accounting methods, profitability of the current activity) and utilizes all future cash flows generated by the project, reflecting all cash movement. Therefore, using these concepts for economic feasibility analysis in horticultural production projects is accepted and feasible.

It is possible that the most widely used rooting protocols are not the most suitable for *E. phosphorea* and *E. enterophora* cuttings, considering the specificities of these species, such as lower water requirement. Thus, it is important to study IBA concentrations and their influence on production cost, aiming to create specific technical recommendations for the propagation of these plants in nurseries.

Due to the lack of information about IBA use and the economic viability of its use for these species, the present study aimed to evaluate the propagation of *E. phosphorea* and *E. enterophora* through stem cuttings, with different concentrations of IBA plant regulator in a hydroalcoholic solution, performing economic analysis of it use for seedling production.

Material and Methods

From May to November 2014, experiments with the two species were simultaneously conducted in a greenhouse nursery, located in the São Francisco do Sul municipality, Santa Catarina State (26°12’S 48°33’W; average altitude of 9 m). According to the Köppen classification, the climate of the region is Cfa (humid temperate climate with hot summers).

The experimental design was completely randomized, with four treatments referring to the four concentrations of indole butyric acid (0; 1,000; 3,000; and 5,000 mgL^{-1}), diluted in hydroalcoholic solution (50% V/V), with four replications and five cuttings per experimental unit, totaling 80 cuttings of *E. phosphorea* and 80 cuttings of *E. enterophora*.

E. phosphorea cuttings were collected in the morning from a single 8-year-old matrix plant (Figure 1a) located on the same property where the experiments were executed. Cuttings were approximately 10 cm long and 1.0-1.2 cm wide with a bevel cut on the base. The cuttings with tender plant tissue were discarded.

The *E. enterophora* cuttings were collected from 2-year-old matrix plants (Figure 1) in the morning period. Cuttings were approximately 10 cm long, with a bevel cut on the base. The diameter was not considered due to its irregular anatomy (oblong) of the branches of this species, as well as the small number of available matrices of this rare species. A stylet blade disinfected with 70% INPM alcohol was used to cut each cutting.

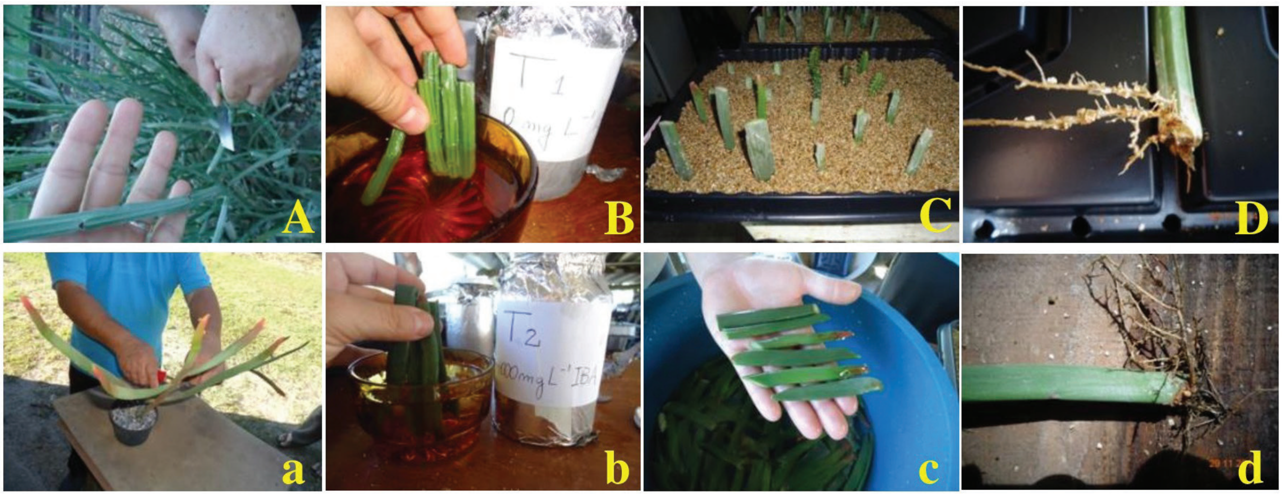

Figure 1. Aspects of cladodes of matrix plants (Aa), IBA treatment of cuttings (Bb), experimental arrangement and morphological aspects of cuttings (Cc), and rooted cuttings (Dd). *E. phosphorea*; (ABCD) *E. enterophora* (abcd).

While preparing cuttings, all the vegetative material was kept in a container with non-chlorinated water to prevent dehydration. Therefore, they were disinfected with sodium hypochlorite solution (0.5%) for 5 min and then rinsed in running water for 5 min.

After rinsing, treatments (T) were applied: T1-0 mgL^{-1} IBA; T2 - 1,000 mg L^{-1} IBA; T3 - 3,000 mg L^{-1} IBA; T4 - 5,000 mg L^{-1} IBA. These solutions were previously prepared in the Chemistry Laboratory at the Instituto Federal Catarinense, Campus Araquari, with Sigma-Aldrich IBA P.A. The cuttings were immersed in the respective solutions for 10 s.

Medium texture vermiculite was used as substrate, which was placed in black plastic trays with holes in the base to prevent water accumulation. One tray was used for each experimental unit. Trays were manually irrigated once a day using a garden watering can.

After 150 days of experiment installation, the following biometric variables were evaluated: Percentage of surviving cuttings (PES); percentage of rooted cuttings (PEE) considering roots with 1 mm length; number of roots per cutting (NRE); length of the three largest roots per rooted cutting (CMR) and percentage of dead cuttings (PEM).

The data collected was subjected to analysis of variance (ANOVA) and variances were analyzed for homogeneity by the Bartlett Test. All variables were homogeneous, and their means were tested by the F test. Results that showed significant differences between treatment means were compared by the Skott-Knott test at 5% probability. Statistical analyses were performed by the Assistat Beta program for Windows®, Version 7.7.

For the economic analysis, data related to the production costs of cuttings, property maintenance, as well as the survey and diagnosis of the operational processes and production infrastructure were considered. Secondary research sources were also used to collect information about interest rates, input prices and labor. The information was compiled to analyze production costs, operations and investments, as well as project feasibility analyses, represented by the NPV (Net Present Value) and IRR (Internal Return Rate) methods, respectively, and their interactions in the CBA (Cost-Benefit Analysis).

Results and Discussion

Experiment with E. phosphorea

The results of the analysis of variance and coefficient of variation for percentage of surviving cuttings (PES), percentage of rooted cuttings (PEE), number of roots per cutting (NRE), length of the three largest roots of each rooted cutting (CMR) and percentage of dead cuttings (PEM) from *E. phosphorea* and *E. enterophora* cuttings evaluated 150 days after the establishing the experiments are presented in Tables 1 and 2, respectively.

Table 1. Percentage of surviving (PES), rooted (PEE) and dead (PEM) cuttings, and average number of roots per cutting (NRE), mean length of the three largest roots (CMR), at 150 days after establishing the *E. phosphorea* experiment.

Concentrations of IBA (mg L^{-1})	PES (%)	PEE (%)	NRE	CMR (cm)	PEM (%)
0	80.0 a*	80.0 a	12.8 a	12.56 a	20.0 a
1,000	85.0 a	85.0 a	14.2 a	9.35 a	15.0 a
3,000	100.0 a	95.0 a	14.5 a	12.04 a	0.0 a
5,000	95.0 a	95.0 a	14.34 a	11.10 a	5.0 a
MÉDIA	90.00	88.75	13.96	11.26	10.00
C.V. (%)	14.81	16.90	14.07	16.36	133.33
X^2	1.346^{ns}**	1.7274^{ns}	0.3566^{ns}	7.7260^{ns}	1.7274^{ns}

C.V. = coefficient of variation.

* Averages followed by the same uppercase letter vertically do not differ significantly from each other by the Skott-Knott test at 5% probability.

** NS = not significant: homogeneous variances by Bartlett's test.

Among the four IBA concentrations used, the lowest survival percentage was found when no IBA regulator was used; presenting 80% live cuttings, inferring that IBA can positively affect the survival of cuttings for this species. With the exception of Treatment 3 (3,000 mg L^{-1}), the other treatments had the same values of surviving and rooted cuttings.

Similar results were observed by Ibañez (2004), who studied the effect of IBA and NAA (naphthalene acetic acid) application on the rooting of *Euphorbia lagascae* cuttings and found greater survival (100%) using IBA at 50 mg L^{-1} for two minutes. In this same study, immersion treatment was applied for 15 seconds, drastically affecting survival (20%). In the control treatment, i.e. without the application of the synthetic regulator, cutting mortality was 50%.

The treatments that presented numerically higher percentages of rooted cuttings were T3 (3,000 mg l^{-1}) and T4 (5,000 mg l^{-1}), although no statistical difference was observed between treatments, with both treatments presenting 95% rooting. The cuttings that did not receive IBA treatment showed a rooting percentage of 80%.

The number of roots per stake was not affected by the different IBA concentrations, and no statistical difference was observed between treatments. However, there was numerically lower root emission in the treatment that did not receive IBA, presenting 11% less roots compared to the treatment that received the highest IBA concentration. Although this difference may be small, it can represent a larger number of surviving cuttings at the end of the production process. Therefore, with no statistical difference between the treatments, using IBA provides a higher number of roots in *E. phosphorea* cuttings.

Herrera et al. (2004) found similar behavior when using IBA in the rooting of laurel (*Laurus nobilis* L.), because cuttings presented a higher number of roots for the species with an increased concentration of the plant regulator.

There was also no significant difference between treatments for the length of the three major roots. However, the longest average length observed was in T1 (control), with 12.56 cm. It is possible that the initial consumption of reserves by the cuttings in this treatment was lower, which could justify the higher root growth observed.

This behavior was different from that observed by Ramtin et al. (2014), who studied the effects of different IBA concentrations on the rooting of *Euphorbia pulcherrima* cuttings. In this work, the root length was longer in the treatment with 1000 mg L^{-1} IBA in hydroalcoholic solution.

Callus formation was not observed in the cuttings, and all living cuttings presented roots and sprouts of the aerial part, as well as bud swelling characteristic of the early development of aerial sprouts. Some horticulturists attribute this behavior to the rusticity of some ornamental species, which show rapid sprouting after rooting.

The regression analysis for the rooted cuttings - PEE variable (Figure 1) shows a positive correlation between cuttings survival and increase in IBA concentration, presenting an R^2 of 0.859.

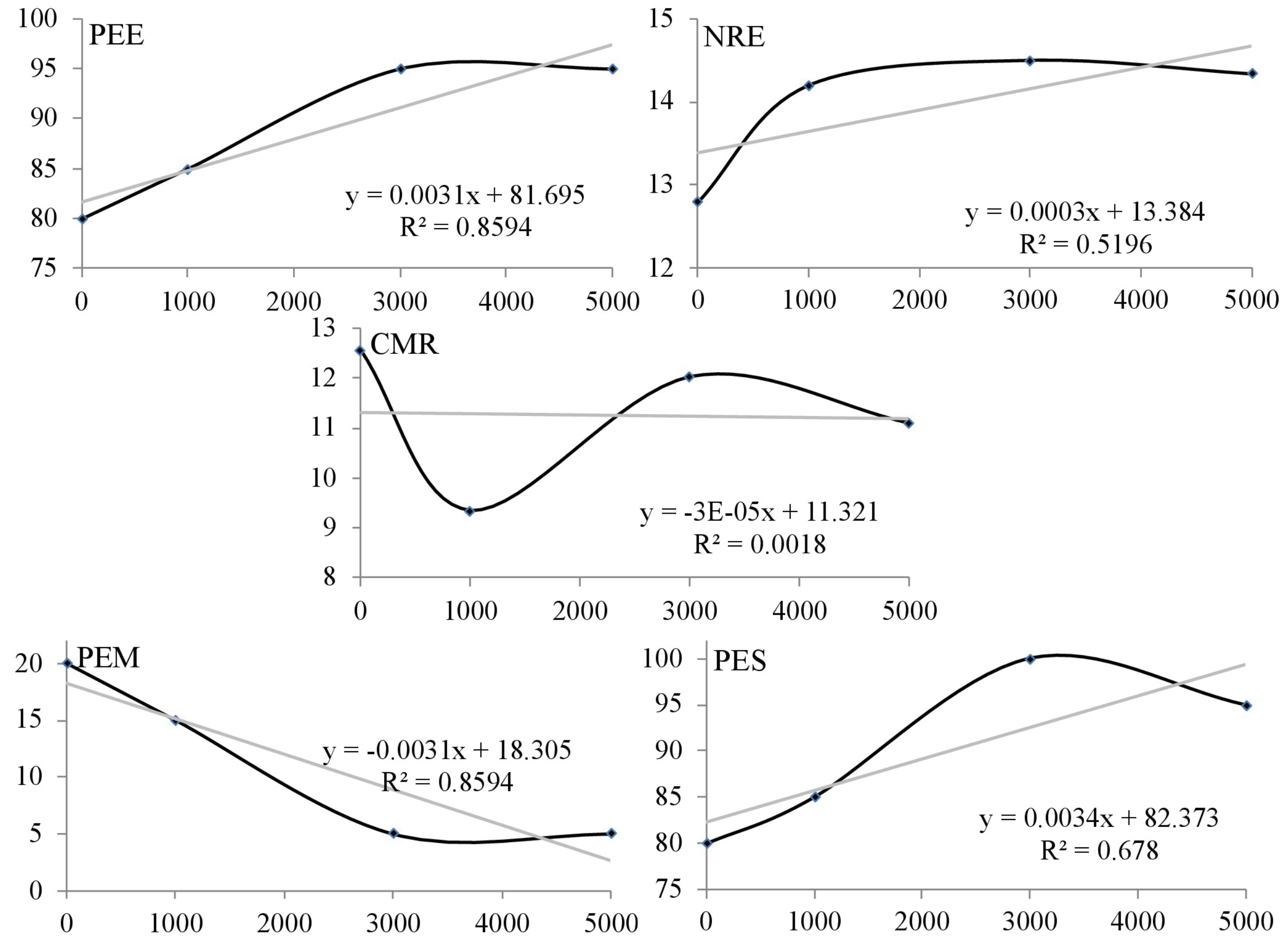

Figure 2. Regression graphs of the percentage of rooted cuttings (PEE); number of roots per cuttings (NRE); length of the three largest roots of each rooted cutting (CMR); percentage of dead cuttings (PEM); percentage of surviving cuttings (PES) as a function of IBA concentration with the respective R^2 of *E. phosphorea*.

On the other hand, in the regression of the average number of roots per cutting, the R^2 was lower (0.519). Even if there was no significant difference for average number of roots per cutting, there was homogeneity between the IBA treatments and lower number of roots without IBA application.

Such result differs from that found by Lopes et al. (2011) in a study with *Ficus benjamina* (L.). Through regression analysis, the authors found a concomitant increase between number of roots and IBA concentration. In this same study, the authors verified that increasing the IBA concentration tends to increase the number of roots emitted by *Ficus benjamina* cuttings, even though there were no significant differences between treatments.

In some cuttings, the roots originated from a bud located near the cut region, not from the cut itself. As a result, when preparing (cutting) the cuttings, it is recommended that a bud be left at the base of the cutting so it can remain in contact with the substrate. If necrosis occurs in the cut region, roots can be emitted from this bud, guaranteeing the survival of the cutting, as well as the economy of the process.

A relationship between the thickness of the cutting and the number of roots emitted was found, with a tendency for larger diameter cuttings to emit more roots, requiring specific studies to measure this relationship. However, no relationship was found between the diameter of the cuttings and the emission velocity of the new root system. Therefore, the practice of selecting larger diameter cuttings may be positively increasing the survival rates of cuttings.

Experiments with E. enterophora

The treatments with the highest percentage of surviving and rooted cuttings (95%) were those that received lower IBA concentrations (T1 and T2), a condition observed by the statistical difference in relation to the other treatments by the Skott-Knott test at 5% probability (Table 2).

Table 2. Percentage of surviving (PES), rooted (PEE), and dead (PEM) cuttings, and average number of roots per cutting (NRE), mean length of the three largest roots (CMR), at 150 days after establishing the *E. enterophora* experiment.

Concentrations of IBA (mg L^{-1})	PES (%)	PEE (%)	NRE	CMR (cm)	PEM (%)
0	95.0 a*	95.0 a	5.99 b	6.50 a	5.0 a
1000	95.0 a	95.0 a	5.75 b	7.89 a	5.0 a
3000	70.0 b	70.0 b	5.94 b	9.03 a	30.0 b
5000	75.0 b	75.0 b	9.94 a	9.94 a	25.0 b
MÉDIA	83.75	83.75	6.905	8.34	16.25
C.V. (%)	17.00	15.08	30.02	21.66	81.41
X^2	16.636^{ns}**	2.2447^{ns}	3.1291^{ns}	1.4313^{ns}	2.2447^{ns}

C.V. = coefficient of variation.

* Averages followed by the same uppercase letter vertically do not differ significantly from each other by the Skott-Knott test at 5% probability.

** NS = not significant: homogeneous variances by Bartlett test.

This result is similar to that observed by Ferreira et al. (2011) and Winhelmann et al. (2018). These authors found that using IBA had no influence on the survival of *Sapium glandulatum* (Vell.) Pax (Euphorbiaceae) and *Angelonia integerrima* (Sprengel) mini-cuttings, respectively.

The rapid occurrence of sprouts in all the surviving cuttings was observed, which may be due to the rusticity that this species presents.

From these results it can be inferred that the species *E. enterophora* has sufficient endogenous auxin levels for the formation of adventitious roots, which occur after its incision with cell division and consequent development of root apical meristem (Taiz and Zeiger, 2013). This statement is corroborated when the means were submitted to the Skott-Knott test, which shows the superiority of treatments in promoting survival and rooting of cuttings without IBA: T1 (0 mg L^{-1}) and with low concentrations of IBA: T2 (1,000 mg L^{-1}) over those with higher IBA concentrations. The T1 (0 mg L^{-1}) and T2 (1,000 mg L^{-1}) treatments presented higher percentages of surviving and rooted cuttings.

The highest IBA concentration resulted in a higher number of roots per cutting when the Skott-Knott test was performed at 5% probability. For the T4 and T5 treatments, the number of roots per cuttings was 40.24% higher in the treatment with the highest IBA concentration. It is possible that IBA provides a greater number of roots in *E. enterophora* cuttings; however, the survival percentage does not follow this effect.

When analyzing the length of the three largest roots, there was no significant difference between the treatments submitted to the two statistical tests. However, a tendency of higher IBA concentrations to lead to higher average root length was observed, with 9.03 and 9.94 cm in the T4 and T5 treatments, respectively.

In the regression of the average number of roots per cutting, the R^2 was lower (0.681). Even though there was no statistical difference for this item, it is possible to observe the homogeneity between the treatments with IBA and lower number of roots without the application of IBA.

Lopes et al. (2011) also observed this and verified that increasing the IBA concentration tends to increase the number of roots emitted by *Ficus benjamina* cuttings, even though there were no significant differences between treatments.

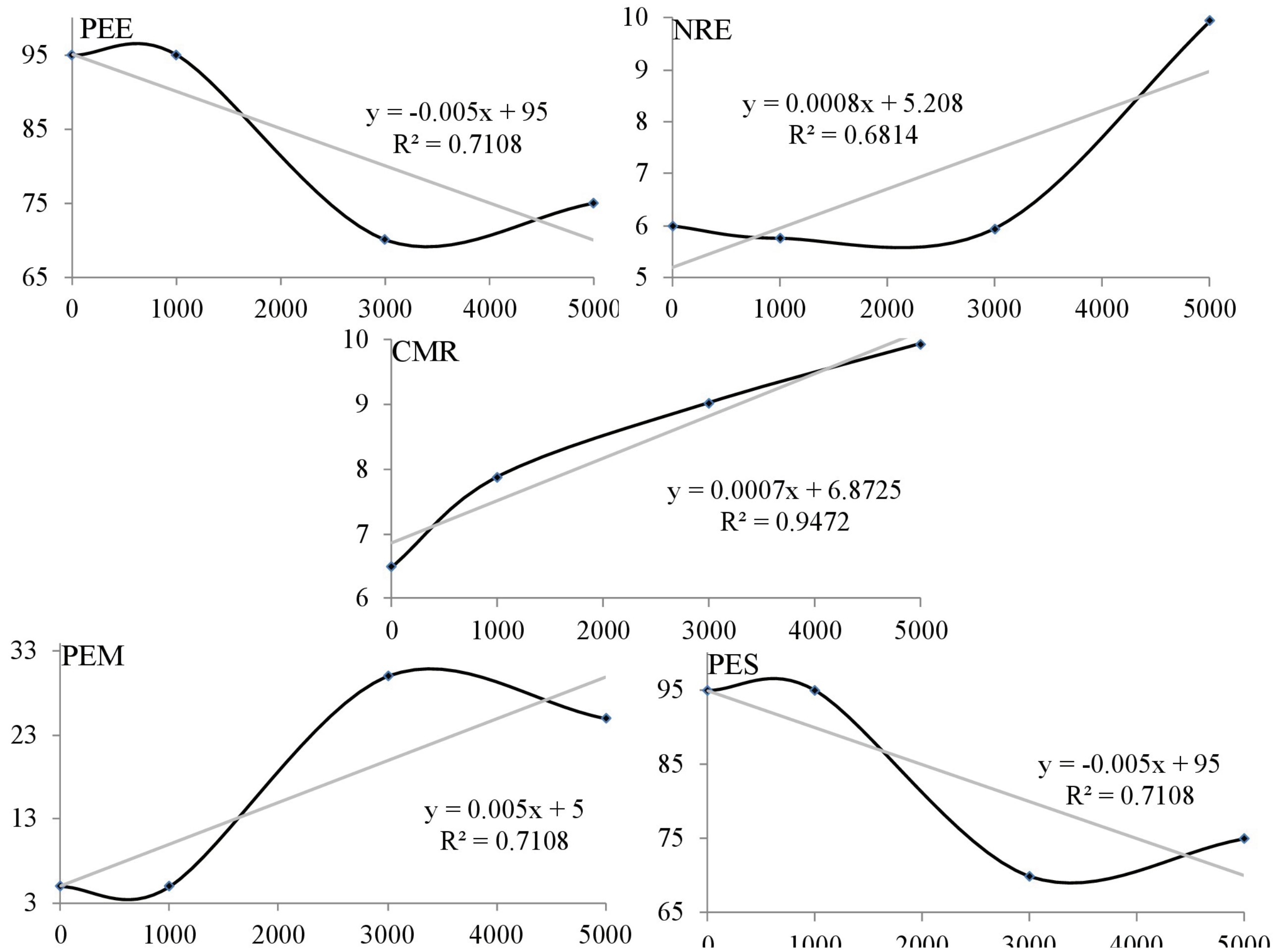

Figure 3. Regression graphs of the percentage of rooted cuttings (PEE); number of roots per cutting (NRE); length of the three largest roots of each rooted cutting (CMR); percentage of dead cuttings (PEM); percentage of surviving cuttings (PES) as a function of IBA concentration with the respective R^2 of *E. enterophora*.

Economic analysis related to IBA use

Although there are numerous studies about the importance of using IBA for the seedling production of various species, few economic surveys have been carried out, especially those that indicate the economic viability of such projects and demonstrate the advantages and disadvantages of using IBA in nurseries for horticulturists.

Crepaldi (1998) points out that studying the cost and economic viability is fundamental, as it seeks to evaluate the actual efficiency, not only considering the production gain, but also the economic gain. Thus, it is possible to reach the highest production revenue and provide the real cost-benefit of this practice, providing and combining the resources used in its production, aiming for better results.

For this work all costs and revenues were ordered in annual cash flows, incident at the end of each production cycle (annual). The technical coefficients of labor, inputs and equipment needed to perform each activity were determined. All stages of the production cycle were contemplated: seedling production with and without IBA, growth of seedlings in nursery environment with respective maintenance and transplantation of seedlings to larger pots, among others stated by the horticulturists. Land compensation and management/administration costs were not considered.

The economic analysis was based on the calculation of the c (NPV) and the Internal Return Rate (IRR), based on costs declared by the producer of 100 seedlings lots for each annual production cycle over 5 years (60 months). From the NPV and IRR calculations, the sensitivity analysis of the activity against the most significant costs and the price received for each seedling of each species by the nurseries was calculated. For the calculations, a Minimum Attractiveness Rate (TMA) of 8% a.a. was considered.

The United States dollar (US$) was used as an index, applying the following exchange rate: US$1.00 = R$ 3.6275 quoted on 05/15/2018 (BANCO CENTRAL DO BRASIL, 2018).

The results of the financial analysis calculations are shown in Table 3 and show that using IBA is approved by all economic assessment methods, when considering a time gradient of 60 months for both species studied.

This result corroborates the study by Miguel et al (2009), which analyzed the profitability index in sugarcane crops using plant regulators, obtaining results superior to those of the control, resulting in higher productivity and consequently higher profitability index.

For both species (*E. enterophora* and *E. phosphorea*), the IRR was higher than the interest rate of attractiveness

(8% a.a.) in all treatments, thus presenting a higher than expected minimum profitability when compared to the profitability of other investments (trade-offs). From the result of this analysis, it appears that the two species can generate a positive return for horticulturists, representing profitability between 37 to 100% higher than 8 a.a.

Table 3. Results of investment analysis methods for projected future cash flows over a 60-month period from *E. enterophora* and *E. phosphorea* seedling production.

Treatments	NPV (US$)	IRR (%)	PRI (months)	CBA
		E. enterophora		
T1	1,691.60	100	36	2.29
T2	1,636.50	86	36	2.24
T3	680.70	39	48	1.62
T4	762.00	37	48	1.67
		E. phosphorea		
T1	1,173.00	75	36	1.94
T2	1,290.80	72	36	2.02
T3	1,717.80	75	36	2.28
T4	1,453.40	59	36	2.10

NPV – Net Present Value; **IRR**– Internal Return Rate; **PRI**-Investment Recovery Period; **CBA-** Cost-Benefit Analysis.

The economic analysis evaluating the production cycle of the species *E. enterophora* shows an initial Investment Recovery Period (IRP) in 36 months for the treatments with lower IBA concentration (T1 and T2). The treatment without IBA (T1) indicates a higher profit in the period analyzed (NPV), especially due to the influence that the IBA price represents in the composition of economic analysis, characterizing the most impacting cost against IBA use is the cost of acquisition of the input, quoted at approximately US$31.97 per 1 gram.

While economically analyzing the production of sweet corn cultivated with the application of biostimulating hormones, Jesus et al. (2016) also concluded that the input expenses is the item that most burdened production costs, highlighting the acquisition and treatment of seeds.

Therefore, the treatment that did not use IBA (T1) was more economically viable when compared to the treatments that received IBA doses, presenting a profit (NPV) of 3.26%, 59.76% and 54.95% higher compared to T2, T3 and T4, respectively.

The (T1) also presented a higher IRR than the other treatments, and a payback (IRP) as early as 36 months. When compared to treatments with higher IBA (T3 and T4) concentrations and those without IBA (T1), those with IBA presented a payback only after 48 months, i.e., 12-months longer for the return of invested capital than those without IBA.

Similar results are presented by Santini et al. (2015), who assessed the economic viability of using biostimulating hormones in soybean seeds and argue that there has been a reduction in the net investment margin, emphasizing that producers who choose to use it may obtain higher production costs and no higher production yields.

According to results of the economic analysis, it can be inferred that IBA use is unnecessary and not recommended, especially regarding viability and return on capital, as well as production systems that consider the same conditions of this study for *E. enterophora*.

For *E. phosphorea* species, all treatments showed the same trend of a positive NPV, with T3 showing the highest profit (NPV of US$1,717.80), being 31.72% higher than T1 that did not receive IBA (NPV of US$1,173.00). This treatment also presents a higher Cost-Benefit Analysis (CBA) with a 2.28 index.

This thirty-point difference in the NPV percentage, as well as the higher cost-benefit ratio, may represent a significant capital gain for horticulturists in the long run. Therefore, the use of IBA is recommended considering a nursery-level seedling production cycle within 60 months.

Among all the treatments, the IRR ranged between 59% and 75% higher than the Minimum Attractiveness Rate-TMA of 8% a.a., with the T1 and T3 treatments showing the best returns, with a rate of 75% for both.

The analysis reveals that the investment payback period (IRP-Payback) is 36 months for all treatments that *E. phosphorea* was submitted to.

Conclusions

Using IBA proved to be efficient for seedling production through *E. phosphorea* cuttings, reducing cutting mortality at doses from 3,000 mg L^{-1}. Thus, considering the economic aspects analyzed, IBA use is recommended for commercial production.

Seedling production through *E. enterophora* cuttings is facilitated by the fact that this is an easily rooted species; therefore, it is not necessary to apply IBA for its vegetative propagation. Concentrations from 3,000 mg L^{-1} tend to reduce the survival percentage of cuttings for this species. Considering economic aspects, IBA use is not recommended for the production of *E. enterophora* seedlings under commercial nursery conditions.

Author Contributions

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