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Propagation

Do stimulate® and acadian® promote increased growth and physiological indices of *Hymenaea courbaril* seedlings?

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Abstract- Products that have biostimulant action on forest seedlings, such as those based seaweed Acadian® and hormones, have been used due to their beneficial effect on the physiology and growth of plants, in order to improve the quality of forest seedlings. The present study establishes as research problem: Can doses of Acadian® algae extract and Stimulate® be effective for the initial growth and physiological indices of jatobá seedlings? The variables evaluated were: shoot height (H), stem diameter (SD), increments in stem diameter (ΔSD) and shoot height (ΔH), shoot dry mass (SDM, g plant^{-1}), root dry mass (RDM, g plant^{-1}) and total dry mass (TDM, g plant^{-1}), and Dickson quality index, net assimilation rate (E_A, g.m^{-2}.day), leaf relative growth rate (RA, g.m^{-2}.day), leaf area ratio (F_A, m^2.g^{-1}), specific leaf area (S_A, cm^2.g^{-1}), leaf mass ratio (Fw, g/g^{-1}) as well as nitrogen balance index (NBI) and chlorophylls. The plant growth regulators (Acadian®) at the dose of maximum technical efficiency of 0.28 ml L^{-1} promotes an increase in stem diameter in *Hymenaea courbaril*. Acadian® increases chlorophyll *a* and *b* contents in *Hymenaea courbaril* seedlings. The tested doses of Stimulate® do not increase chlorophyll *a* and *b* contents in *H. courbaril* seedlings.
Index Terms: *Ascophyllum nodosum;* net assimilation rate; nitrogen balance index; chlorophylls; seedling quality.

Stimulate® e acadian® promovem incremento no crescimento e índices fisiológicos de mudas de *Hymenaea courbaril* ?

Resumo- Produtos que apresentam ação bioestimulante em mudas florestais, como a base de alga Acadian® e hormonios vêm sendo utilizados pelo efeito benéfico na fisiologia e crescimento de plantas, com o intuito de melhorar a qualidade de mudas florestais. O presente estudo estabelece como problema de pesquisa: Doses de Acadian® e Stimulate® podem ser eficazes no crescimento inicial e bem como nos índices fisiológicos de mudas de jatobá? As variáveis avaliadas foram: comprimento da parte aérea (H), diâmetro do caule (DC), incremento do diâmetro do caule (ΔDC) e da altura da parte aérea (ΔH), massa seca da parte aérea (MSPA, g plant^{-1}), massa seca das raízes (MSR, g plant^{-1}) e massa seca total (MST, g plant^{-1}), e índice de qualidade de Dickson, taxa de assimilação líquida (E_A g.m^{-2}.dia), taxa de crescimento relativo foliar (RA, g.m^{-2}.dia); razão de área foliar (F_A, m^2 .g^{-1}), área foliar específica (S_A, cm^2.g^{-1}), razão da massa foliar (Fw, g/g^{-1}) e o índice de balanço de nitrogênio (IBN) e clorofilas. O regulador de crescimento de plantas (Acadian®) na dose máxima eficiência técnica 0.28 ml L^{-1} promove incremento em diâmetro do caule em mudas de *Hymenaea courbaril.* O Acadian® promove incremento no conteúdo de clorofilas *a* e *b* em mudas de *Hymenaea courbaril*. As doses testadas de Stimulate® não promovem incremento no conteúdo de clorofilas *a* e *b* em mudas de *Hymenaea courbaril.*
Termos para Indexação: *Ascophyllum nodosum;* taxa de assimilação líquida; índice de balanço de nitrogênio; clorofilas; qualidade de mudas.

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Introduction

The demand for seedlings of native forest species has been increasing due to the awareness about the need for environmental protection and forest restoration programs. Jatobá (*Hymenaea courbaril*) has great forest and environmental importance due to its potential as a carbon-fixing and-storing plant (COSTA et al., 2018). It is also worth mentioning that the bark and leaves of *Hymenaea courbaril* have terpenic and phenolic compounds with anti-microbial, anti-fungal and antibacterial action, which validates its use in traditional medicine. However, jatobá trees currently remain unprotected and threatened by predatory logging in most of the Amazon.

In this scenario, the production of seedlings of native forest species, for the purpose of either logging or enrichment and recovery of degraded areas, is hampered (SMIDERLE et al., 2021a) given the scarcity of information about their needs regarding the lack of adequate techniques and management to expand production within the seedling production sector, a scenario still associated with the scarcity of information and studies in the State of Roraima (SMIDERLE et al., 2020).

The application of products via foliar spraying is a practice known and used for many years, which aims to complement or supplement the needs of plants for a given product (SINGH et al., 2019). In addition to the traditional products used in foliar applications, other compounds currently being used are the plant growth regulators also called biostimulants or phytohormones, which have in their composition: amino acids, humic substances (humic acids and fulvic acids), plant growth hormones, vitamins and various other elements, and may also contain organic substances from algae extract (FRIONI et al., (2021) (KOLACHEVSKAYA et al., 2017).

Plant growth regulators function as activators of cell metabolism in the plant, reactivate physiological processes in different stages of development, stimulate root growth (WANG et al., 2016), induce the formation of new shoots and increase the size of the photosynthesis apparatus (SAEGER et al., 2020).

Carvalho et al. (2018) found that the ideal concentration of Stimulate® optimized plant vigor in *Acacia mangium* (Fabaceae). Oliveira et al. (2020) verified that the vigor of jatobá seedlings treated with Stimulate® at concentrations of 20 and 30 ml L^{-1} contributed decisively to the inhibitory or reduction effect on this variable.

Stimulate® is known to be a commercial product that contains, 0.009% of kinetin, 0.005% of gibberellic acid (GA_3) and 0.005% of indolyl-butyric acid (IBA), auxins, gibberellins and cytokinins (LEAL et al., 2020).

Auxins act mainly in the regulation of growth and promotion of rooting of root primordia, whereas gibberellins have, as one of their main functions, the stimulation of cell division and elongation. In turn, cytokinins mainly stimulate cell division processes (cytokinesis) (CHRYSARGYRIS et al., 2018), while seaweed-based bioregulators have important functions in the plant, especially cytokinin activity (increase in cell division), auxin activity (growth in plant height), gibberellic activity (cell elasticity and plasticity).

Plant vigor analysis is an active area of plant research and many attempts to correlate growth with physiological indices have been made. Physiological indices are determined through growth analysis, which indicates the capacity of the assimilatory system (source) of plants to synthesize and allocate organic matter in the various organs (sinks) that depend on photosynthesis, respiration and translocation of photoassimilates from fixation sites to use or storage sites (CHRYSARGYRIS et al., 2018).

Therefore, physiological indices express the physiological conditions of the plant and quantify the net production derived from the photosynthetic process. This performance is influenced by biotic and abiotic factors (SHUKLA et al., 2019).

In view of the above, the present study establishes the following research problem: Can doses of Acadian® and Stimulate® be effective in the initial growth and physiological indices of jatobá seedlings?

Material and Methods

The study was conducted in a greenhouse of the forestry sector of Embrapa Roraima from September 2020 to January 2021. The species used in the present research was *Hymenaea courbaril*. The seeds were manually collected from trees present in an area of Dense Ombrophilous Submontane Forest with emergent canopy, located at geographic coordinates 1°38'29" North latitude and 60°58'11" West longitude, in the municipality of Boa Vista, RR, Brazil, in August 2020.

After the fruits were collected, the seeds were processed and then sown, two in each polyethylene bag with dimensions of 25 cm in height and 15 cm in diameter, containing approximately four liters of substrate composed of soil + carbonized rice husk + organic compost (1:1:1). Chemical and physical analyses of the substrate (Table 1) were performed using the method of Embrapa (2009) to determine the available contents of macronutrients and micronutrients, pH, exchangeable aluminum (Al), titratable acidity (H + Al) and cation exchange capacity at pH 7 (CEC).

Table 1. Chemical and physical characteristics of the substrate used in the cultivation of jatobá seedlings under nursery conditions, Boa Vista-RR, Brazil

	pH	K	P	Ca	Mg	Al	H+Al	CEC	SB	OM	Zn	Fe	Mn	Cu	B	S
		--------cmol/dm³-------								dag/kg	------------------mg/dm³----------------					
Sub	6.5	0.3	1.7	10.0	2.9	0.0	1.3	14.5	13.2	4.0	23.5	20.3	107.0	0.8	0.8	34.9

Particle size (g kg)			
Medium sand	Silt	Clay	Textural Class
44	19.1	36	Sandy clay loam

pH: hydrogen potential; $H^{+}+Al^{+3}$: potential acidity; SB: sum of bases; CEC: Cation exchange capacity; V: Base saturation; OM: Organic matter.

When the seedlings reached 10 centimeters in height, on average, thinning was carried out, leaving the most vigorous. The average temperature within the greenhouse during the experimental period was 25 ± 5 °C and the relative humidity was 60% to 70%. Irrigation was performed manually according to the field capacity. Irrigate the plants, the field capacity for the amount of substrate was determined before the experiment (1.5 litres); this was then taken as the reference for maintaining the supply of water to the plants throughout the experimental period. The plant growth regulators based on Acadian® and Stimulate® were applied through the leaves using a manual atomizer with capacity for 100 mL, by applying 20 mL of the mixture (plant growth regulators and water) per plant, in the afternoon from 16:30 hours, using four different doses of each plant growth regulators. The experimental design used was completely randomized, in a 2 x 4 factorial scheme, corresponding to two plant growth regulators (Acadian® and Stimulate®) and four doses (0, 5.0, 10.0 and 15.0 ml L^{-1}), with five replicates, each of which composed of five seedlings (one in each container). At 90 days after transplanting (DAT), the plants were evaluated for shoot height (H), with a graduated ruler, and stem diameter (SD), with digital caliper. The increments in stem diameter (ΔSD) and shoot height (ΔH) were obtained from the data collected every 30 days, during the period (90 days after transplanting) of plant growth until the end of the experiment.

Then, the plants were dried in a forced air circulation oven at 65 ºC, for 72 hours, until constant mass, to determine the weights of shoot dry mass (SDM, g $plant^{-1}$), root dry mass (RDM, g $plant^{-1}$) and total dry mass (TDM, g $plant^{-1}$), the last of which obtained by summing the weights (SDM + RDM). Dickson quality index was determined using the formula DQI=TDM/[(H/SD) + (SDM/RDM)], according to Dickson et al. (1960). The contents of chlorophyll *a*, chlorophyll *b* and total chlorophyll were determined using a portable chlorophyll meter (Falker model) in two fully expanded leaves from the middle portion of the canopy of each plant in the experimental unit, with measurements performed in two positions on the leaves (opposite sides). Of the four readings, the mean for both sampled leaves was calculated using the meter itself. Leaf area (LA) was obtained using the Li-Cor area meter, LI3100C model.

The values of net assimilation rate (E_A, $g.m^{-2}.day$), Leaf Relative Growth Rate (RA, $g.m^{-2}.day$); leaf area ratio (F_A, $m^2.g^{-1}$), specific leaf area (S_A, $cm^2.g^{-1}$) and leaf mass ratio (Fw, g/g^{-1}) were determined from instantaneous values of Af, Wf and Wt, employed in the equations F_A=Af/Wt, S_A=Af/Wf and Fw=Wf/Wt, according to Radford (1967) and Richards (1969).

At 90 days after transplanting (DAT), the nitrogen balance index (NBI) was determined using the chlorophyll meter (Dualex Model). Between 9 and 11 a.m., measurements were performed on two fully expanded leaves, located in the apical third of each plant.

All variables were subjected to comparison of means by Tukey test at 5% probability level, and quantitative variables were subjected to regression analysis in order to verify the growth response of the plants as a function of time. Data analysis was performed in the Statistical Package Sisvar (FERREIRA, 2014).

Results and Discussion

The analysis of variance revealed that there was significant interaction between plant growth regulators and doses for the evaluated growth variables of jatobá plants. Fig.1 (A) presents the values of shoot height as a function of the doses of Stimulate® and shows that the dose of 2.0 ml L^{-1} of the plant growth regulators results in an 18% increase compared to the control at 90 DAT.

It should also be noted the superiority of jatobá plant height with the dose of 4.0 ml L^{-1}, showing a behavior similar to that obtained with the Stimulate® dose of 2.0 ml L^{-1} for plant height at 60 and 90 DAT (Fig. 1 A).

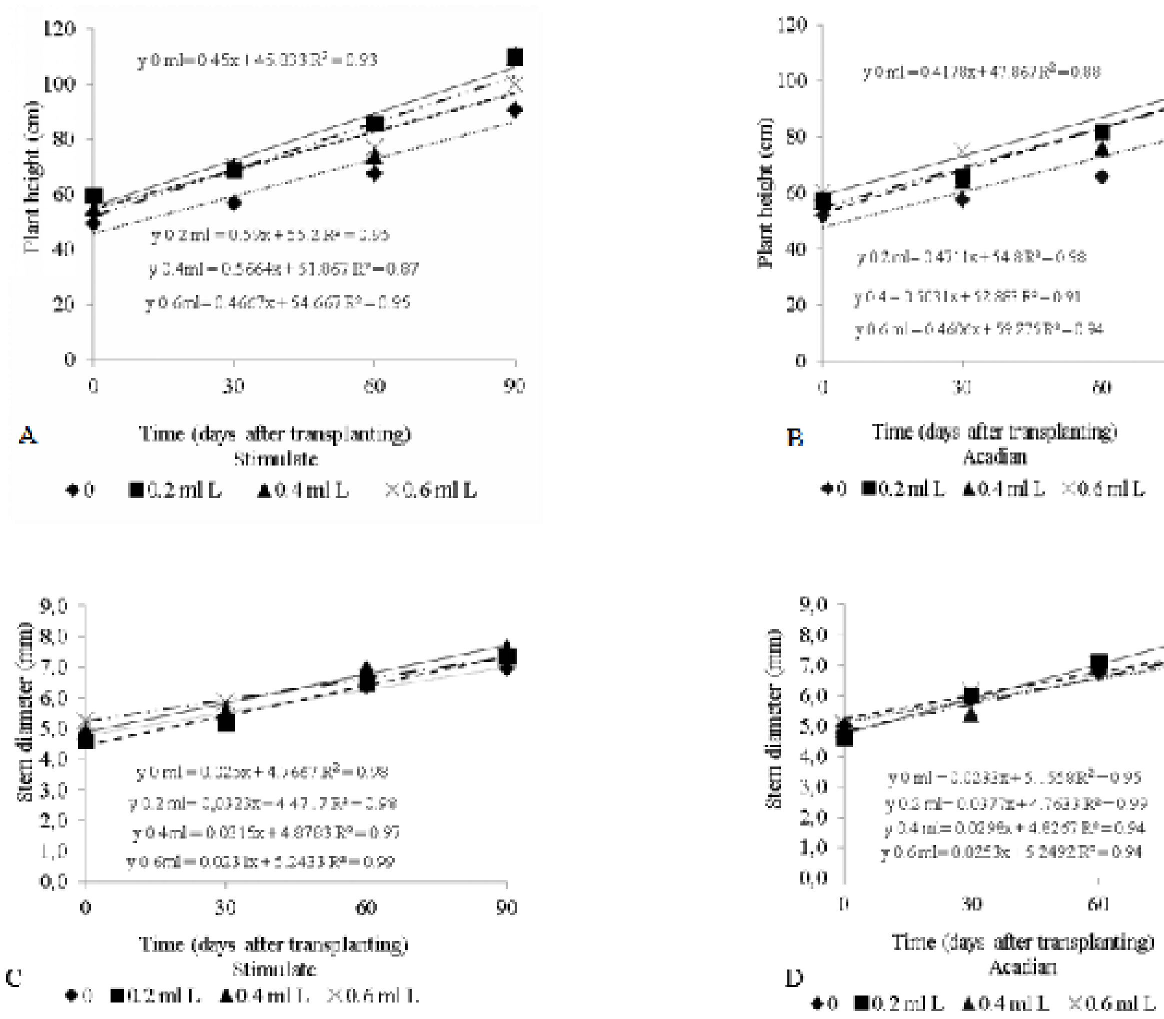

Figure 1. Means values of plant height (A and B) and stem diameter (C and D) obtained with foliar application of two bioregulators at different doses (Stimulate®: 0; 0.2; 0.4 and 0.6 ml L^{-1} (A and C) and Acadian®: 0; 0.2; 0.4 and 0.6 ml L^{-1} (B and D**)** respectively, in *Hymenaea courbaril* seedlings in a greenhouse.

According to Saeger et al. (2020), seaweed extract is a natural source of cytokinins, which in addition to promoting cell division, retards plant senescence, which may influence the photosynthetic rate of crops and consequently lead to higher plant growth, besides explaining the promotion of height with foliar application of Acadian® at 90 DAT at doses of 0.4 and 0.6 ml L^{-1}, showing a gain of approximately 14% compared to the control at 90 DAT.

Another important component is stem diameter, which showed an increase of 19.0% with foliar application at doses of 0.2, 0.4 and 0.6 ml L^{-1} of the bioregulator Stimulate® when compared to the control at 90 DAT (Fig. 1C). As shown in (Fig. 1C), jatobá plants under application of Acadian® at dose of 0.2 ml L^{-1} showed a gain of 12.5% compared to the control in the means of stem diameter, with positive effects on plant growth parameters, so it is indispensable for the maintenance of physiological processes that culminate in biomass production and plant growth.

For Leal et al. (2020), the application of algae extract (Acadian®) causes a larger stem diameter in bell pepper plants, which was also verified in the present study with the dose of 0.2 ml L^{-1} (Fig. 1B and D).

In addition, the mean value for stem diameter was 7.3 mm with foliar application of Acadian® at dose of 0.6 ml L^{-1} (Fig. 1D), similar to the control, which showed mean value of 7.1 mm (Fig. 1D).

The increments in height (ΔH) and stem diameter (ΔSD), evaluated at 90 DAT, can be observed in (Fig. 2A and 2B). The increase in ΔH with Stimulate® was revealed up to the dose of maximum technical efficiency (DMTE) of 0.32 ml L^{-1}, with a maximum increment of 57.01 cm, while for ΔSD the increase was observed at the DMTE of 0.29 ml L^{-1}, with a maximum increment of 3.03 mm (Fig. 2A and B).

In addition, the maximum ΔH for the Acadian® was 44.9 cm with DMTE of 0.54 ml L^{-1} (Fig. 2A), while for ΔSD with foliar application of Acadian® the DMTE was 0.28 ml L^{-1}, with an increment of 2.82 mm (Fig. 2B). These results are of great relevance because they show that the practice of foliar application of plant growth regulators allows for early obtaining of jatobá seedlings suitable for field planting and/or grafting at 90 DAT.

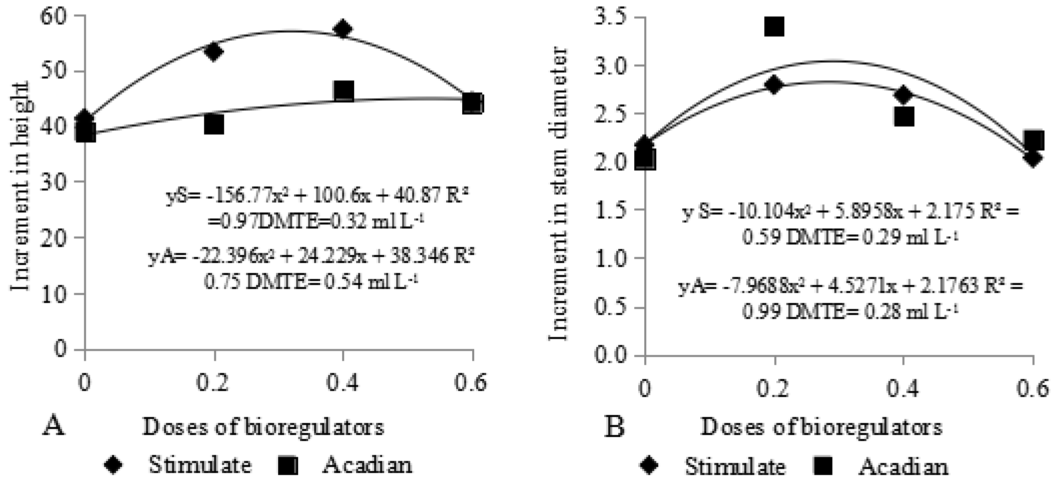

Figure 2. Increment in Height (ΔH) and stem diameter (ΔSD), at 90 DAT, of *Hymenaea courbaril* seedlings, in relation to doses of bioregulators (Stimulate®: 0; 0.2; 0.4 and 0.6 ml L^{-1} (A) and Acadian®:0; 0.2; 0.4 and 0.6 ml L^{-1} (B**)** in greenhouse.

For SDM, the results revealed that there was no significant interaction for the plant growth regulators used in the present study, while for doses there was a significant effect, which makes it possible to state that Stimulate® at dose of 0.4 ml L^{-1} tends to promote higher biomass production during the initial growth stage, when compared to the other doses of Stimulate®. In turn, SDM showed a biomass gain of 25.0% with foliar application of 0.2 ml L^{-1} of Acadian® compared to the control, showing a significant and positive effect, indispensable for the maintenance of physiological processes that culminate in biomass production and plant growth. Furthermore, the 0.4 ml L^{-1} dose of Stimulate® promoted a 35.5% gain in shoot dry biomass (SDM) compared to the control.

According to Calvo et al. (2014), the bioregulator Acadian® consists of phytoprotectant amino acids derived from algae extracts with several functions, including the increase in root volume and dry mass. This fact was observed in jatobá seedlings for RDM at Acadian® doses of 0.2, 0.4 and 0.6 ml L^{-1} with a increase of 37.5% compared to the control. According to Pascale et al. (2017), the ability to accumulate biomass in a given plant organ is related to aspects intrinsic to the genotype, such as the expression, presence and activation of transporters and enzymes, which regulate the absorption, translocation and utilization of nutrients by plants. In this context, for the RDM of jatobá seedlings, the bioregulator Stimulate® at doses of 0.2, 0.4 and 0.6 ml L^{-1} was inferior to Acadian® at the respective doses (Table 2).

The root system, for indirectly defining the seedlings' ability to absorb water and nutrients from the soil solution, becomes an important attribute in the recommendation of vigorous seedlings for a broad range of edaphoclimatic conditions (MENEGATTI et al., 2019a; MENEGATTI et al., 2019b) and still suggests greater guarantee of survival and initial vigor of the seedlings in the post-planting.

Table 2. Mean values for the interaction between plant bioregulators (Stimulate® and Acadian®) and doses for the growth variables shoot dry mass (SDM), root dry mass (RDM), total dry mass (TDM) and Dickson quality index (DQI) of *Hymenaea courbaril* seedlings, at 90 days after transplanting

	SDM		RDM		TDM		DQI	
DOSE	Stimulate®	Acadian®	Stimulate®	Acadian®	Stimulate®	Acadian®	Stimulate®	Acadian®
0	11.17 cA	13.00 bA	8.73 aA	7.40 bA	19.91 bA	20.40 bA	1.39 aA	1.39 cA
0.2	15.47 abA	17.37 aA	9.07 aB	12.24 aA	24.54 aB	29.61 aA	1.44 aB	2.17 aA
0.4	17.24 aA	15.33 abA	8.83 aB	11.50 aA	26.07 aA	26.83 aA	1.57 aA	1.75 bA
0.6	14.06 bA	14.90 abA	8.73 aB	11.63 aA	22.80 abB	26.53 aA	1.51 aA	1.70 bA

[1] Lowercase letters (a,b,c) compare the means for the variables between the doses of bioregulators, and uppercase letters (A,B) compare the means for the variables between the bioregulators, by Tukey test at 5% probability level.

The results obtained for RDM reinforce the hypothesis of greater influence of plant growth regulators on this organ, besides highlighting that RDM determines the results obtained for TDM, since these were different. In addition, it should be noted that the foliar application of Acadian® at doses of 0.2 and 0.6 ml L^{-1} induces superiority in TDM compared to the bioregulator Stimulate® at doses of 0.2 and 0.6 ml L^{-1}. In relation to the total dry mass production of jatobá seedlings (Table 2), the bioregulators Stimulate® and Acadian®, at the end of the experiment at the dose of 0.2 ml L^{-1}, led to accumulations of 24.54 and 29.61 g/plant, respectively. The orders observed were: shoot (63%) > roots (37%) for Stimulate® and shoot (59%) > roots (41%) for Acadian®.

According to Smiderle et al. (2021b), Dickson quality index (DQI) is a good indicator of the quality of seedlings of native forest species in the Northern region of Brazil, because it considers for its calculation the robustness and balance of biomass distribution between organs, and both parameters are considered important for the reliable recommendation of seedling quality. According to these same authors, the value considered ideal for DQI is approximately 2.00 (SMIDERLE et al., 2021b).

According to the results obtained, the Acadian® dose of 0.2 ml L^{-1} resulted in DQI of 2.17, while in seedlings without foliar application of Acadian® (control) the DQI achieved was 1.39, which is below the value considered ideal (Table 2). It is worth pointing out that the bioregulator Stimulate® for the DQI variable did not cause significant differences between the doses applied; however, among the bioregulators tested, the dose of 0.2 ml L^{-1} of Stimulate® (1.44) was inferior to the same dose of the bioregulator Acadian® (2.17).

A behavior similar to that of DQI was obtained for the net assimilation rate (E_A); for the bioregulators tested, the dose of 0.2 ml L^{-1} of Stimulate® was inferior to the same dose of Acadian® (Table3). In general, *Hymenaea courbaril* seedlings that received foliar applications at the different doses of Stimulate® showed a decrease in E_A compared to the control, confirming the inhibitory action in promoting the increase of dry mass at an instant in comparison to the leaf area. Contrarily, the bioregulator Acadian® was better at doses of 0.2 ml L^{-1} and 0.6 ml L^{-1} than at 0.4 ml L^{-1}.

It is important to highlight that, despite the high E_A caused by the 0.2 ml L^{-1} dose of Acadian®, *Hymenaea courbaril* seedlings showed greater vigor at 90 DAT, a behavior that may be associated with the nitrogen and chlorophyll contents (Table 4) in *Hymenaea courbaril* plants, which led to increase in plant biomass, as found for DQI at 90 DAT. In general, *Hymenaea courbaril* seedlings showed a higher leaf area ratio at 90 DAT, and these results are in agreement with those recorded in the literature for leaf area ratio, which expresses the leaf area useful for photosynthesis.

Table 3. Mean values for the interaction between plant bioregulators (Stimulate® and Acadian®) and doses for the physiological indices net assimilation rate (E_A, $g.m^{-2}.day$), leaf relative growth (R_A, $g.m^{-2}.day$), specific leaf area (S_A, $cm^2.g^{-1}$), leaf area ratio (F_A, $m^2.g^{-1}$) and leaf mass ratio (Fw, g/g^{-1}) of *Hymenaea courbaril* seedlings, at 90 days after transplanting

	E_A		R_A	
DOSE	Stimulate®	Acadian®	Stimulate®	Acadian®
0	0.00023 aA	0.00022 bA	0.005093 aA	0.005133 aA
0.2	0.00018 bB	0.00025 aA	0.005140 aB	0.005498 aA
0.4	0.00016 bcA	0.00018 cA	0.005063 aA	0.005218 aA
0.6	0.00014 cB	0.00026 aA	0.005150 aB	0.005523 aA
CV	10.31	10.94	7.34	6.89
	S_A		F_A	
	Stimulate®	Acadian®	Stimulate®	Acadian®
0	8.18 abA	6.62 bB	2.56 aA	2.40 aA
0.2	7.59 bA	7.79 abA	2.59 aA	2.56 aA
0.4	9.21 aA	8.99 aA	3.32 bA	2.85 aB
0.6	10.98 aA	7.33 bB	2.23 aA	1.85 bB
CV	11.56	9.01	8.97	9.89
	F_W		A_F	
	Stimulate®	Acadian®	Stimulate®	Acadian®
0	0.31 aA	0.36 aA	50.827 bA	48.968 bA
0.2	0.34 aA	0.30 bA	63.490 bA	69.781 aA
0.4	0.36 aA	0.32 bA	86.695 aA	76.414 aA
0.6	0.35 aA	0.30 bA	87.802 aA	48.562 bB
CV	6.87	6.23	12.45	12.91

[1] Lowercase letters (a,b) compare the means for the variables between the doses of bioregulators, and uppercase letters (A, B) compare the means for the variables between the bioregulators, by Tukey test at 5% probability level.

As observed for the specific leaf area (S_A), the leaf area ratio (F_A) (Table3) of *Hymenaea courbaril* seedlings showed significant differences between the bioregulators tested and doses evaluated at 90 DAT. In addition, the specific leaf area (S_A) at the dose of 0.2 ml L^{-1} was similar to that obtained with the dose of 0.4 ml L^{-1} of Acadian®, which in turn did not differ from the other doses tested. This may be due to a strategy used by *Hymenaea courbaril* plants in the initial stages of development. After investing in the root system and still in the initial period of growth, plants tend to allocate a large amount of energy to the production of leaves, in order to maximize light capture and energy production, ensuring the maintenance of sufficient leaf area to promote photosynthetic rates higher than respiratory rates (SAEGER et al., 2020). After this period, it is assumed that the plant will allocate a greater amount of photoassimilates for the development in stem diameter (PASCALE et al., 2017).

This redirection of photoassimilates for the expansion of stem diameter was shown in Figure 1D and recorded by the greater increment in SD (Fig. 2B) by *Hymenaea courbaril* plants, when compared with the different doses of Stimulate® (Fig. 1C and Figure 2A), which allowed the best quality index of *Hymenaea courbaril* seedlings at 90 DAT.

In general, with the foliar application of Stimulate® in *Hymenaea courbaril* plants at dose of 0.4 ml L^{-1}, it was found that the leaf area ratio (F_A) was higher than that obtained with the other doses of Stimulate® as well as those of Acadian® (Table 2). These results are in agreement with those recorded in the literature for F_A, which expresses the leaf area useful for photosynthesis (KATIYAR et al., 2021).

The vast majority of plants have better performance than that found for forest species, that is, they have high F_A at the beginning of the cycle, a period in which leaf development occurs for greater light capture, subsequently decreasing due to the interference of upper leaves on the lower ones, characterizing self-shading (HÖNIG et al., 2018), thus reducing the leaf area useful for photosynthesis. In general, when there is an increase in S_A, F_A and A_F, there is a decrease in E_A due to the mutual shading of the leaves (KATIYAR et al., 2021), which was evidenced in the present study (Table 2).

Among the two components of F_A, specific leaf area (S_A) is much more plastic than leaf mass ratio (F_W), especially with regard to the environmental factors. F_W is undoubtedly a conservative growth index regarding environmental conditions, a fact evidenced in the present study in *Hymenaea courbaril* seedlings for the plant growth regulators Acadian®, mainly at the dose of 0.2 ml L^{-1}, because of the proportional balance between leaf dry mass and total dry mass.

In order to improve the forest seedling sector, the use of algae extracts such as plant growth regulators Acadian® has grown, mainly because it is an alternative to the efficient use of nutrients (LEAL et al., 2020).

Among the mineral nutrients, Nitrogen (N) has been considered one of the main limiting factors to photosynthesis (SOUZA et al., 2015), since this nutrient is part of the main constituents of the photosynthetic system, such as chlorophylls and proteins, including the RuBisCO enzyme (catalyst for photosynthetic reduction of CO_2) (KATIYAR et al., 2021). Thus, the foliar application of the bioregulator Acadian® , regardless of the doses tested, caused positive effects on jatobá seedlings, a fact that can be verified in the N Balance Index (NBI), which was higher compared to that found in the control (Table 3), in order to meet the demand for the synthesis of photoassimilates, amino acids and proteins, promoting higher concentrations of chlorophylls, a determinant physiological parameter for plant growth.

It is known that, to perform photosynthesis, higher plants depend on the absorption of light and the significant presence of chlorophylls (Chls) *a* and *b* and carotenoids in the leaves to direct the metabolism of carbohydrates in chloroplast and cytosol through the chemical forms ATP and NADPH (SAEGER et al., 2020). Chlorophylls are related to the photosynthetic efficiency of plants and, consequently, to their growth and adaptability to the different cultivation conditions (SOUZA et al., 2020).

For chlorophyll *a*, *Hymenaea courbaril* plants under application of the bioregulator Acadian® had higher values compared to those under Stimulate®, for all doses tested (Table 4). It is worth pointing out that plants that received application of 0.2 ml L^{-1} had the highest mean values of chlorophyll *a*, chlorophyll *b* and total chlorophyll when compared with the control, since the bioregulator based on Acadian® applied to the leaves of *Hymenaea courbaril* favors the biosynthesis of chlorophyll molecules, as it has a varied amount of products such as algae extracts, compounds containing amino acids, compounds containing humic and fulvic acids (SAEGER et al., 2020) and compounds containing plant regulators (auxins, cytokinins, gibberellins).

In this context, it can be inferred that the use of algae extract in *Hymenaea courbaril* seedlings was efficient for both nutrition and production of phytohormones that Stimulate® growth and development to the point of significantly increasing biomass, robustness and quality of *Hymenaea courbaril* seedlings.

Table 4. Mean values of chlorophyll *a*, (CHL a, µg/mL), chlorophyll *b* (CHL b, µg/mL), total chlorophyll (Total CHL µg/mL) and N balance index (NBI), determined in leaves of *Hymenaea courbaril*, under different plant bioregulators at 90 days

Dose	CHL a. µg/mL		CHL b. µg/mL	
	Stimulate®	Acadian®	Stimulate®	Acadian®
0	36.21 aA	36.06 bA	9.51 aA	8.26 bA
0.2	36.83 aB	38.83 aA	9.08 aA	10.66 aA
0.4	35.91 aB	38.43 abA	8.70 aB	10.63 abA
0.6	35.58 aB	38.46 abA	8.58 aA	10.06 abA
CV%	10.4	8.90	9.64	10.99
	Total CHL µg/mL		**NBI**	
	Stimulate®	Acadian®	Stimulate®	Acadian®
0	45.72 aA	44.32 bA	26.82 aA	26.02 bA
0.2	45.91 aB	47.91 aA	25.31 aB	32.02 aA
0.4	44.61 aB	47.13 aA	26.03 aB	31.78 aA
0.6	44.16 aB	47.04 aA	25.53 aB	29.87 abA
CV%	10.2	11.67	11.05	12.11

[1]Lowercase letters (a,b) compare the means for the variables between the doses of bioregulators, and uppercase letters (A,B) compare the means for the variables between the bioregulators, by Tukey test at 5% probability level.

Conclusions

The bioregulator Acadian® at the dose of maximum technical efficiency of 0.28 ml L^{-1} promotes an increase in the stem diameter of *Hymenaea courbari*l seedlings.

The dose of 0.2 ml L^{-1} of Acadian® is indicated to obtain *Hymenaea courbaril* seedlings with quality, robustness and shorter nursery time.

Acadian® promotes an increase the contents of chlorophyll *a* and *b* in *Hymenaea courbaril* seedlings.

Stimulate® does not promote an increase in the contents of chlorophyll *a* and *b* in *Hymenaea courbaril* seedlings at the tested doses.

Acadian® at dose of 0.2 ml L^{-1} has positive influence on all physiological indices studied in *Hymenaea courbaril* seedlings at 90 days after transplantation.

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