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Scientific and Technological Research Article

Enhancing Rooting in *Morus alba* Cuttings: Effects of Indolebutyric Acid and a Commercial Rooting Agent across Branch Positions

Potenciación del enraizamiento en esquejes de *Morus alba*: efectos del ácido indolbutírico y de un agente de enraizamiento comercial en diferentes posiciones de las ramas

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Abstract: Sericulture is the cultivation of silkworms to produce silk using white mulberry leaves (*Morus alba* L.); thus, the sector's quality production of mulberry seedlings on a large scale is economically important. The production of seedlings through cuttings is the most effective and fastest reproduction method. Still, it can also be enhanced using synthetic rooting agents, increasing the productive potential of white mulberry crops. The current work aims to evaluate the response of cuttings taken from different parts of the branch of *M. alba* var. *Miura* (Apical 1, Apical 2, Medial, Basal 1, and Basal 2) and treated with indolebutyric acid (IBA; 500, 1,000, and 1,500 mg L⁻¹) and commercial rooting agent Forth® (10 % v/v), in addition to a control treatment. After treating the branches, they were placed in polyethylene containers filled with substrate and kept in a greenhouse for 70 days. The application of hormones on cuttings of *M. alba* favored several morpho-agronomic parameters evaluated for the propagules obtained from different positions on the branch. In conclusion, applying 500 or 1,000 mg L⁻¹ of IBA is recommended for the various positions, with Basal 1 and Basal 2 showing higher values in the evaluated parameters than the other positions. The results can help silk breeders optimize white mulberry crop production.

Keywords: protected cultivation, Moraceae, production optimization, propagules, plant growth regulator.

Resumen: La sericultura es el cultivo de gusanos de seda para producir seda mediante hojas de morera blanca (*Morus alba* L.); en consecuencia, la calidad y la producción a gran escala de plántulas de morera son de gran importancia económica para este sector. La producción de plántulas mediante esquejes es el método más eficaz y rápido, que aun así se podría fortalecer con el uso de enraizadores sintéticos para aumentar el potencial productivo de los cultivos de morera blanca. Por lo tanto, el objetivo del trabajo fue evaluar la respuesta de los esquejes tomados de diferentes partes de *M. alba* var. *Miura* (apical 1, apical 2, medial, basal 1 y basal 2) y tratados con ácido indolbutírico (AIB; 500 mg L⁻¹, 1,000 mg L⁻¹ y 1,500 mg L⁻¹) y el enraizador comercial Forth® (10 % v/v), además del tratamiento control. Luego de tratar las ramas, se colocaron en envases de polietileno llenos de sustrato y se mantuvieron en invernadero durante 70 días. La aplicación de las hormonas a los esquejes de *M. alba* favoreció los diferentes parámetros morfoagronómicos evaluados en las diferentes posiciones en las que se obtuvieron los propágulos. Se concluye que la aplicación de 500 o 1,000 mg L⁻¹ de AIB se recomienda para diferentes posiciones, donde basal 1 y basal 2 muestran valores más altos en los parámetros evaluados en comparación con las demás posiciones. Los resultados podrían ayudar a los sericultores a optimizar la producción de moreras blancas.

Palabras clave: cultivo protegido, Moraceae, optimización de la producción, propágulos, regulador del crecimiento vegetal.



Introduction

Moraceae is a family of important genera such as *Ficus*, *Artocarpus*, and *Morus* sp. (Brandão et al., 2021; Li et al., 2021; Okeke et al., 2021). With 1,290 species distributed in 41 genera spread worldwide, around 20 % of this family's total number of representatives occur in Brazil alone (Reflora, 2024; World Flora Online [WFO], 2024). The mulberry tree is a monoecious or dioecious plant and usually has pointed oval leaves that are sometimes irregularly lobed (WFO, 2024). Within the genus *Morus* L., there are more than 150 species, with *Morus alba* L. being the most relevant since its leaves serve as food for the silkworm caterpillars (*Bombyx moris* L.), thus boosting the sericulture market. On the other hand, the discovery of chemical compounds present in *M. nigra* leaves that are useful to the pharmaceutical industry (such as flavonoids and triterpenes) produces a tremendous scientific demand for this genus, attracting resources and research (Oliveira et al., 2018).

Sericulture is the process of obtaining silk thread from the cocoons of moth caterpillars (*B. moris*). Brazilian silk production is highlighted in the West, generating 3,047 tons of cocoons in 2019. The state of Paraná accounts for more than 80 % of national production and is a significant exporter of products from this activity. However, there are certain obstacles to the growth of this sector, such as the drift of chemical products from neighboring cultures on the mulberry trees, climatic adversities, and the lack of technology and technical knowledge to manage the plantation. In this way, it is essential to increase the production of good quality planting materials (QPM; Departamento de economia rural [DERAL], 2021).

The silk market is dependent on white mulberry leaves (*M. alba*) as food for silkworm caterpillars, and the QPM directly reflects the quantity and, mainly, the quality of the thread produced by the silkworms (Cavalcante-Neto et al., 2018). For this reason, the vegetative propagation of mulberry trees has become efficient, with cuttings being the most commonly used method in Brazil, as clones are produced from a genetically superior matrix, making production economically viable, shortening the initial development process of the plant, and providing ease of handling (Borges et al., 2016).

The pre-rooting of cuttings has been widely used to ensure that, when transplanted in the field, the seedlings have greater development potential compared to those that do not have any roots. Although some species have natural adventitious rooting capacity, several studies have reported that indolebutyric acid (IBA) is an effective plant growth regulator (PGR) for rooting. Likewise, commercial rooters have also shown promising results, ensuring better production for producers and nursery workers. The use of commercial rooters and different doses of IBA has been the focus of recent studies and provides support for new works, such as the study in question (Akhkami et al., 2013; Colombo et al., 2018; Husen et al., 2017; Rafeeq et al., 2020).

Studies evaluating the development of cuttings from different positions of the matrix plant and the correlation with the use of synthetic regulators have already been reported in the literature with different responses among the studied plants and showed preliminary potential for increasing white mulberry production through PGRs (Rocha et al., 2014; Souza et al., 2015). Therefore, the objective of the current work was to evaluate the response of cuttings taken from five positions on the branch of *M. alba* var. *Miura* treated with different doses of IBA and the

commercial rooting agent Forth® and the potential for vegetative growth in each of these branches, aimed at optimizing *M. alba* production.

Materials and Methods

Plant Material

The experiment was conducted in a greenhouse at the Center for Agricultural Sciences at the State University of Londrina (UEL). The mother plants of *M. alba* var. *Miura* were obtained from the collection of mulberry trees at the Agronomic Institute of Paraná in Londrina-PR, Brazil, and collected in July 2022. The plants were approximately one year old, and those with physical, physiological, and phytopathogenic defects were discarded. Healthy plants, which were upright and without signs or symptoms of disease or pests, were selected and taken to UEL with the leaves cut in order to reduce transpiration and the consumption of plant reserves (Correia et al., 2015).

Propagules were obtained from different positions of the central branch of the matrices, which were 1.30 m in height. The mother plants were divided into five parts: Apical 1 and 2 (A_1 , A_2), Medial (M), and Basal 1 and 2 (B_1 , B_2), as shown in Figure 1. With the help of pruning shears, the cuttings were cut to a length of 25 cm, which is why there were five branch divisions in this study (Villalta-Zúñiga et al., 2022). For each new plant, the pruning shears were disinfected with 77° GL alcohol, and different doses of IBA and Forth® were applied to each part of the branch (Azevedo et al., 2017).

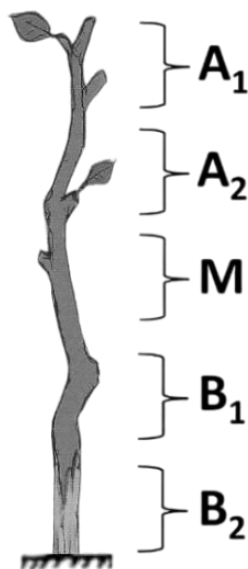


Figure 1. Schematic representation of a matrix of *M. alba* and the different positions from which the propagules were obtained: Apical 1 (A_1), Apical 2 (A_2), Medial (M), Basal 1 (B_1), and Basal 2 (B_2).

Source: Prepared by the authors.

Installation of Treatments

The regulator used was Sigma-Aldrich® IBA. A literature review was performed to select regulator doses, choosing 0 (control), 500, 1,000, and 1,500 mg L⁻¹ (Hawramee et al., 2019). Some works have used higher or lower doses with good results concerning the development of *M. alba* cuttings (Husen et al., 2017; Rafeeq et al., 2020). The commercial rooting agent was from the company Forth®, most commonly found in Brazilian agricultural stores.

To treat the cuttings, the IBA was weighed with a semi-analytical scale (precision ± 0.001 g), and then drops of ethyl alcohol 92.8° INPM were added until its dissolution. The mixture was then diluted with distilled water in the appropriate concentrations. The lower part of each cutting was immersed for 10 seconds in the respective concentrations, including the control treatment with only distilled water. Then, planting was performed, as recommended by Singh et al. (2014). The rooting agent was only diluted in distilled water at a concentration of 10 % v/v, and the cuttings were immersed for 5 minutes before being planted, as standardized and recommended by the manufacturer. The containers used were made from low-density polyethylene (LDPE), with drainage holes and dimensions of 10 cm $\times$ 18 cm and a thickness of 0.5 mm, filled with the substrate based on pine bark and peat (SV Vidaverde®).

The greenhouse where the experiment was carried out had a 100-micron plastic film cover, with the side covered with 80 % shade cloth and N-S geographic orientation. Immediately after planting the propagules, the substrate was moistened using a manual watering can. Subsequent irrigations were performed with micro sprinklers turned on daily for 10 minutes in the morning. The daily maximum and minimum temperatures were recorded during the experimental period with the Incoterm® thermometer, and the lowest and highest temperatures recorded were 4.6 °C and 42.9 °C, respectively.

Parameters Evaluated and Statistical Analysis

After 70 days of stacking the plants, they were taken to the UEL Phytotechnics laboratory for evaluation. The seedlings were carefully removed from the container, and their roots were washed in running water for data measurement. The diameter of the cuttings (DC), number of nodes (NN), number of shoots (NS), number of leaves (NL), longest root length (LRL), and fresh (FRM) and dry root mass (DRM) were evaluated.

The DC and LRL parameters were measured with a caliper and conventional ruler. In contrast, for the measurement of FRM and DRM, a semi-analytical scale was used (precision ± 0.001 g), with the results expressed in grams (g). For the determination of DRM, paper bags were used in which the roots were individually placed in an oven with forced air circulation at 65 ± 3 °C for 72 hours until a constant mass was obtained (Câmara et al., 2017; Soares et al., 2021). To set up the experiment, each position (A₁, A₂, M, B₁, and B₂) received the five treatments, being T₁: control; T₂: rooting agent at 10 % v/v; T₃: 500; T₄: 1,000, and T₅: 1,500 mg L⁻¹ of IBA, with each treatment containing ten repetitions (with one plant per repetition), thus totaling 250 plants (Figure 2).

The experiment was conducted in a completely randomized design in a 5×5 factorial scheme. Data were submitted for analysis of variance, and if significant, means were compared by Tukey's test at 5 % significance. The assumptions of normality of errors and homogeneity of variances were tested by Shapiro-Wilk and Levene at 5 % significance. If one of the assumptions was corrupted, the data were transformed according to the methodology proposed by Box and Cox (1964). All analyses were performed using R software (R Core Team, 2023).



Figure 2. Seedlings of *Morus alba* var. *Miura* 30 days after cutting and kept in a greenhouse. Source: Authors' archives.

Results and Discussion

No significant interaction was observed between treatments and different positions of propagules for DC, NN, NS, LRL, and FRM. Regarding the treatments applied to the cuttings, IBA generally provided better results, especially at a dose of 1,000 mg L⁻¹ (T₄) for the DC, NN, NS, LRL, and FRM parameters. Furthermore, the control (T₁) did not differ from the rooting agent (T₂; Figure 3) for these same parameters. Regarding the position of the propagules

removed from the mother plant, parts B₁ and B₂ presented better responses than the other positions for the variables DC, LRL, and FRM. All positions were higher than A₁ for NN and NS, as shown in Figure 3.

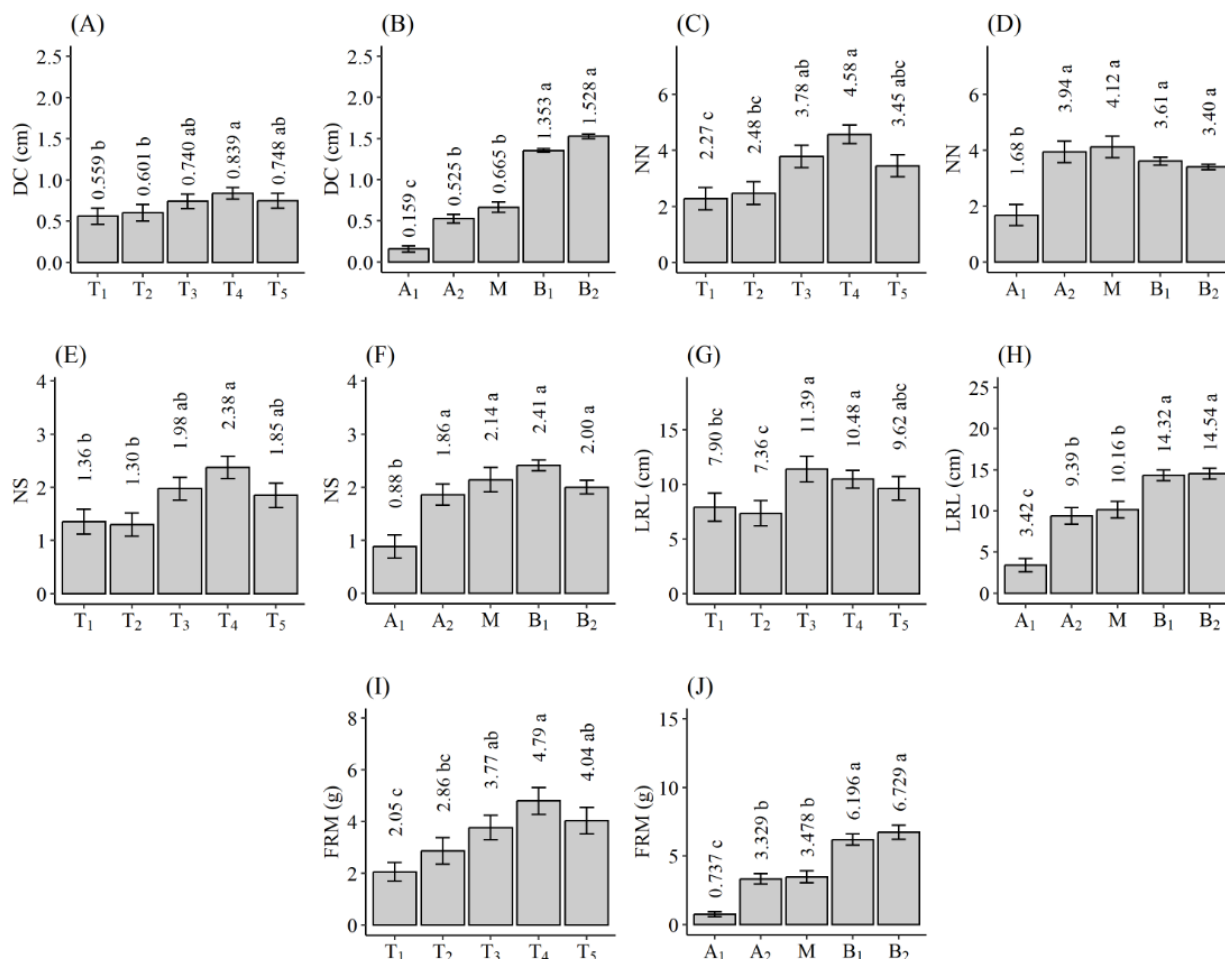


Figure 3. Bar graphs representing factors broken down into treatment and position of propagules of *M. alba* var. *Miura* for the means of diameter of cuttings (DC; A and B) in cm, number of nodes (NN; C and D), number of shoots (NS; E and F), longest root length (LRL; G and H) in cm, and fresh root mass (FRM; I and J) in g. Treatments represented by T₁: control, T₂ rooting agent at 10 % v/v; T₃: 500, T₄: 1,000, and T₅: 1,500 mg L⁻¹ of IBA and positions A₁ (Apical 1), A₂ (Apical 2), M (Medial), B₁ (Basal 1), and B₂ (Basal 2). Means followed by the same lowercase letter in the column do not differ by Tukey's test at 5 % significance. Data transformed to $\sqrt{x+1}$.

Source: Prepared by the authors.

For NL and DRM (Figure 4), there was a significant interaction between the factors. The behavior of both variables was similar in that there were differences between treatments in the same positions and between positions within the same treatment. Some results should be highlighted, such as the superiority of positions B₁ and B₂ compared to the other positions in all treatments and the improvement in the number of leaves (Figure 4A) and DRM (Figure 4B) in the treatments with the highest dose of IBA, particularly 1,000 mg L⁻¹ (T₄) on cuttings A₂ and

M. It is suggested that when the IBA is applied at higher doses, it improves A₂ and M cuttings compared to the control and the rooting agent. As with the other variables, the rooting agent showed no improvement compared to the control.

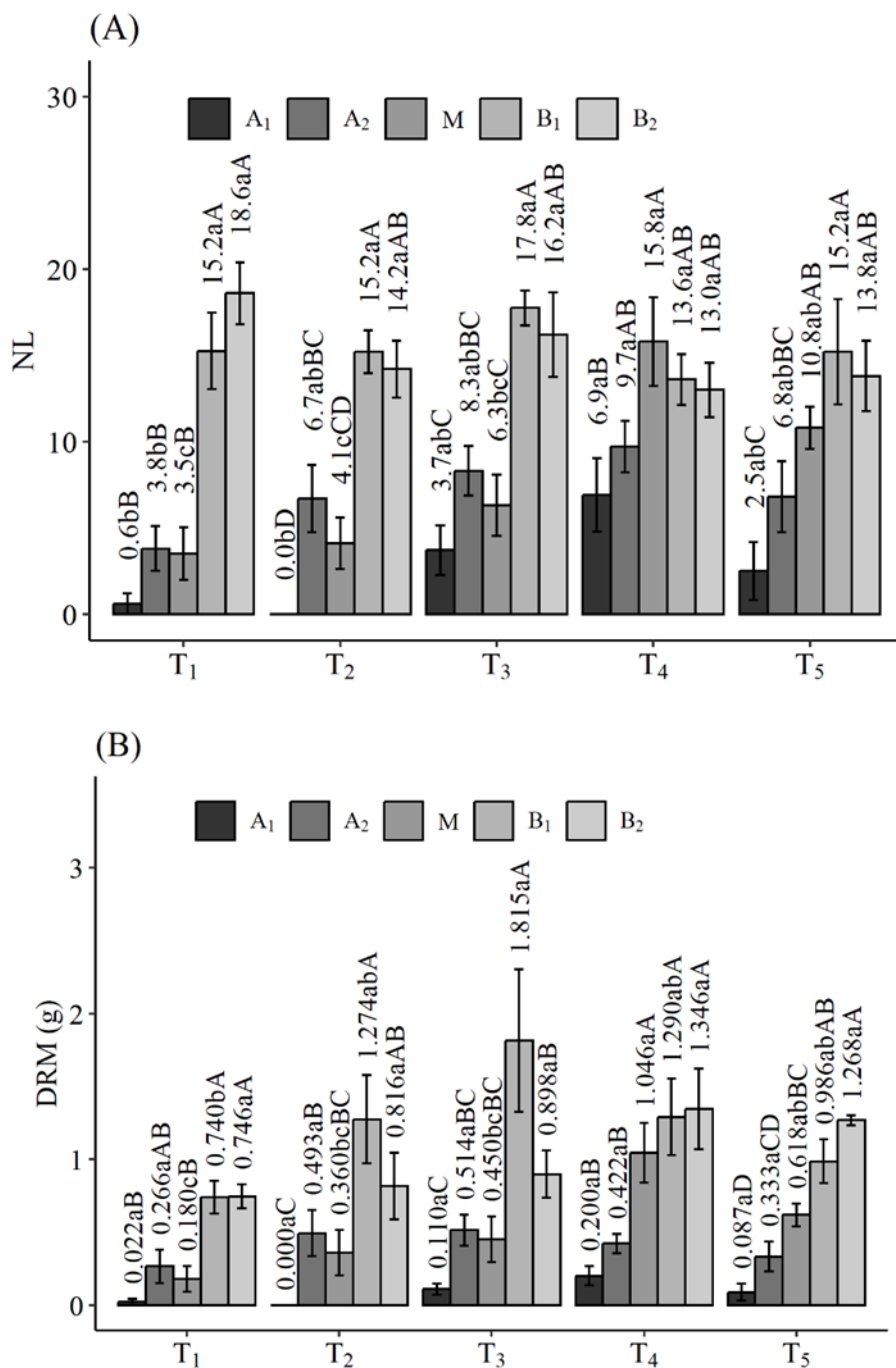


Figure 4. Bar graphs representing the response of *M. alba* var. *Miura* branch positions in each treatment for the means of number of leaves (NL; A) and dry root mass (DRM; B) in grams. Treatments represented by T₁: control, T₂ rooting agent at 10 % v/v; T₃: 500, T₄: 1,000, and T₅: 1,500 mg L⁻¹ of IBA and positions A₁ (Apical 1), A₂ (Apical 2), M (Medial), B₁ (Basal 1), and B₂

(Basal 2). Averages followed by the same lowercase letter in the column and uppercase in the row do not differ by Tukey's test at 5 % significance. Data transformed to $\sqrt{x+1}$.

Source: Prepared by the authors.

Commercial rooting agents benefit plant propagation and development and can be used in a wide range of species, from ornamentals to fruit trees (Santos et al., 2020). However, there is a distinction between the products concerning the composition of their active ingredients, such as vitamins, polyphenols, and amino acids, that may or may not aid in the development of the plant. This difference in composition may explain why certain plants respond to exogenous application while others do not respond or are negatively affected, mainly due to the hormonal and nutritional balance of the plant, which, when in excess or lacking, can influence its physiological processes, growth, and the emission of roots and shoots (García et al., 2022; Silva et al., 2022). In this sense, the mulberry tree may not respond to the compounds in the rooting agent studied because this crop does not interact with it, or the quantity the company recommends is insufficient to influence these variables.

Regarding the positive results of the application of exogenous auxin, Husen et al. (2017) analyzed the rooting of *M. alba* cuttings and the biochemical processes resulting from the application of different doses of IBA. They found increased indole acetic acid oxidase (IAA-oxidase) levels on the 30th day and peroxidase (POX) on the 45th day after cutting the propagules. This increase suggests that both enzymes aid in auxin catabolism and stimulate root initiation processes, which may explain the superior results of IBA treatments in LRL and fresh root mass FRM.

For rooting, here represented by DRM, cutting positions responded differently to T₃ (500 mg L⁻¹ IBA) and T₄ (1,000 mg L⁻¹ IBA), with increasing or decreasing results. However, from T₄ to T₅ (1,500 mg L⁻¹), all positions decreased in DRM (Figure 4), so the best doses for each position are between 500 and 1,000 mg L⁻¹ IBA for the highest DRM. Studies with *M. alba* have shown that cuttings treated with IBA are effective for rooting. When analyzing the influence of IBA on mulberry cuttings, Singh et al. (2014) and Husen et al. (2017) found that the use of this regulator reflected the increase in several variables evaluated, corroborating the results obtained in the current study. The hypothesis is that these increments in the studied parameters are due to factors such as stability and the conjugation rate of the regulator that are responsible for and, therefore, directly linked to the rooting induction. In addition, the variation in the response of this parameter is related to endogenous levels of IAA, which fluctuate according to the number of days the culture is in place and the conditions the cuttings are submitted to.

The production of cuttings obtained from the medial part (M) is only possible when using a dose of 1,000 mg L⁻¹ of IBA, which obtained the best response for NL and DRM, followed by a concentration of 1,500 mg L⁻¹. On the other hand, the propagules of positions B₁ and B₂ for NL and B₂ for DRM were not dependent on the synthetic regulator for their best responses. Shao et al. (2018), when studying the physiological responses of *Zizyphus jujuba* Mill., concluded that the responses of the plants to the application of IBA are directly related to the consumption and accumulation of nutrients (such as sugars and proteins) and the endogenous hormonal dynamics in the phloem, which together reflect in adventitious root growth and subsequent plant development. This explains the differences in the mulberry cuttings in the present work.

Martins et al. (2015) showed that herbaceous cuttings of *Campomanesia adamantium* (Cambess.) O. Berg treated with different doses of IBA did not differ considering NN and NS. This was also observed in woody cuttings of this species, which did not differ between themselves for these variables but had better results than the upper parts of the branch, reaching a superiority of 100 %. Such results are similar to those obtained in the present study. Taking as a basis that herbaceous cuttings would be represented here by A₁ and A₂ and woody cuttings by B₁ and B₂, or even M, it is clear that the treatments with IBA for the apical propagules did not express statistical differences for NN and NS, as well as between the most basal propagules (Figure 3). Rocha et al. (2014) evaluated the effect of synthetic auxin on the rooting of different parts of the branch of *Dioscorea* spp. They concluded that the number of roots was significantly influenced by the position on the branch from where the propagule was removed (the basal position being superior to the others), and the IBA treatments did not differ for this variable. Parallel to the present study, Figure 4B shows the increase in DRM according to the more basal position. For B₂, the lowest part obtained, treatments with both IBA and the commercial rooting agent did not cause a significant effect.

In this respect, according to the occurrence of catabolic processes in the metabolic routes of the hormone auxin, the levels of total soluble sugar (TSS) decrease, while in mulberry cuttings treated with IBA, the levels of TSS in the rooting zone are higher, which may be attributed to starch hydrolysis or increased carbohydrate transport to the rooting zone (Husen et al., 2017). Therefore, propagules with a larger diameter, because they have more reserves, will generally respond better to the parameters inherent to rooting and subsequent vegetative growth (Costa et al., 2022; Cox, 2018; Kielse et al., 2013), corroborating the results presented.

With the results achieved in this research, the potential of PGR to improve white mulberry production in several aspects is clear. However, the cost of the product and specialized labor in the area can be a practical obstacle to the proposed work. Studies showing this chain's economic viability are critical to helping silk breeders accept new cultivation methods.

Conclusions

The application of IBA on *M. alba* var. *Miura* cuttings favors several of the morpho-agronomic parameters evaluated for the propagules obtained from different positions on the branch. It is concluded that 500 or 1,000 mg L⁻¹ of IBA is recommended for the different positions, with B₁ and B₂ showing higher values when comparing the parameters with other positions. Based on these results, new studies can be carried out to evaluate the establishment of pre-rooted seedlings after transplantation in the field and analyze the potential of the plant regulator in the development of these seedlings as well as the basal parts of the branch (B₁ and B₂).

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Authors' Contributions

All authors made written contributions and corrections to the manuscript, as follows: Kauê Alexandre Monteiro: conception and project development, methodology and writing of the manuscript; Carlos Eduardo Orlandini Bazalha: conducting the experiment and writing; Gabriel Danilo Shimizu: data interpretation and statistical analysis; Jean Carlo Baudraz de Paula: setting up the experiment; Hugo Roldi Guariz: data collection; Ricardo Tadeu de Faria: design, guidance on conducting, designing and collecting data for the experiment.

Ethical Implications

This article has no ethical implications for its preparation.

Conflict of Interest

Kauê Monteiro was a scholarship holder of the Research-Seda project, sponsored by Bratac Fiação de Seda.

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References

- Ahkami, A. H., Melzer, M., Ghaffari, M. R., Pollmann, S., Ghorbani Javid, M., Shahinnia, F., Hajirezaei, M. R., & Druege, U. (2013). Distribution of indole-3-acetic acid in *Petunia hybrida* shoot tip cuttings and relationship between auxin transport, carbohydrate metabolism and adventitious root formation. *Planta*, 238(3), 499-517. <https://doi.org/10.1007/s00425-013-1907-z>
- Azevedo, F. A., Lanza, N. B., Sales, C. R. G., Silva, K. I., Barros, A. L., & De Negri, J. D. (2017). Pruning in citrus. *Citrus Research & Technology*, 34(1), 17-30. <https://doi.org/10.5935/2236-3122.20130003>
- Borges, J. A., León, M., Marturet, E., & Barrios, M. (2016). Phytostimulation in mulberry cuttings (*Morus alba* L.) by plant extracts. *Bioagro*, 28(3), 215-219. <http://www.redalyc.org/articulo.oa?id=85749314009>
- Box, G. E., & Cox, D. R. (1964). An analysis of transformations. *Journal of the Royal Statistical Society: Series B (Methodological)*, 26(2), 211-243. <https://doi.org/10.1111/j.2517-6161.1964.tb00553.x>

- Brandão, M. L. P., Romano, C. A., Paz, A. T. S., & de Paula, J. R. (2021). What is the impact of research with *Morus nigra*? A scientometric study. *Research, Society and Development*, 10(2), 1-9. <https://doi.org/10.33448/rsd-v10i2.12838>
- Câmara, F. D. M., Pereira, G. A., Mendonça, V., Pereira, E. C., Silva, F. D. O., de Oliveira, L. M., & Cardoso, R. (2017). Tipos de estacas e concentrações de ácido indol-butírico (IBA) na propagação de amora (*Morus nigra*). *Revista de la Facultad de Agronomía (La Plata)*, 116(2), 187-191. <https://sedici.unlp.edu.ar/handle/10915/66613>
- Cavalcante-Neto, A., Rodrigues, M. L., Gomes, C. A., Silva, M. A., Bezerra, J. M. M., Almeida, L. C., Lima, G. S., Bezerra, E. J., Ribeiro, N. L., Lui, J. F., & Evangelista-Rodrigues, A. (2018). Desempenho do *Bombyx mori* L. utilizando diferentes frequências de trato alimentar na região do Brejo Paraibano *Revista Biociências*, 24(1), 56-63. <https://periodicos.unitau.br/ojs/index.php/biociencias/article/download/2960/1939/11361>
- Colombo, R. C., Assis, A. M. D., Favetta, V., Yamamoto, L. Y., & Roberto, S. R. (2018). Collect seasons, indolebutyric acid and substrates on rooting of 'Bengal' lychee cuttings. *Journal of Agricultural Science*, 10(5), 338. <https://doi.org/10.5539/jas.v10n5p338>
- Correia, A. C. G., Xavier, A., Dias, P. C., Titon, M., & Santana, R. C. (2015). Leaf reduction in minicuttings and microcuttings of hybrid clones of *Eucalyptus globulus*. *Revista Árvore*, 39(2), 295-304. <https://doi.org/10.1590/0100-67622015000200009>
- Costa, J. H. S., Cavalcante, I. T. R., de Medeiros, G. R., Ribeiro, N. L., dos Santos, S. G. C. G., do Nascimento, G. V., da Silva, P. H. F., da Silva Neves, R., & de Macêdo Carvalho, C. B. (2022). Propagação vegetativa de mudas de *Manihot pseudoglaziovii* com diferentes diâmetros de estacas. *REVINSa - Revista do Instituto Nacional do Semiárido*, 1(3), 49-55. <https://editoraverde.org/portal/revistas/index.php/revinsa/article/download/188/304>
- Cox, D. A. (2018). Hartmann and Kester's plant propagation principles and practices. *HortScience*, 53(5), 741-741. <https://doi.org/10.21273/HORTSCI535bkrev-17>
- Departamento de economia rural (DERAL). (2021). Prognóstico Agropecuário – Sericicultura, Relatório anual 2021. *Secretaria da Agricultura e do Abastecimento*, 13(40), 1-9. <https://www.agricultura.pr.gov.br/Pagina/Edicoes-anteriores-Prognostico-Agropecuario>
- García, L. F. V., Escutia, A. N. B., & Farias, A. C. P. (2022). Evaluación de tres enraizadores comerciales en la primera etapa de crecimiento vegetativo de la planta de frambuesa. *ConCiencia Tecnológica*, 63(4), 1-10. <https://www.redalyc.org/journal/944/94472192004/>
- Hawramee, O. A., Aziz, R. R., & Hassan, D. A. (2019). Propagation of white mulberry *Morus alba* L. fruitless cultivar using different cutting times and IBA. *IOP Conference Series: Earth and Environmental Science*, 388(1), 1-11. <https://doi.org/10.1088/1755-1315/388/1/012069>
- Husen, A., Iqbal, M., Siddiqui, S. N., Sohrab, S. S., & Masresha, G. (2017). Effect of indole-3-butyric acid on clonal propagation of mulberry (*Morus alba* L.) stem cuttings: rooting and associated biochemical changes. *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences*, 87(1), 161-166. <https://doi.org/10.1007/s40011-015-0597-7>
- Kielse, P., Bisognin, D. A., Heberle, M., Fleig, F. D., Xavier, A., & Rauber, M. A. (2013). Vegetative propagation of *Cordia trichotoma* (Vell.) Arrab. Ex Steudel from root cuttings. *Revista Árvore*, 37(1), 59-66. <https://doi.org/10.1590/S0100-67622013000100007>
- Li, Z., Yang, Y., Liu, M., Zhang, C., Shao, J., Hou, X., Tian, J., & Cui, Q. (2021). A comprehensive review on phytochemistry, bioactivities, toxicity studies, and clinical

- studies on *Ficus carica* Linn. leaves. *Biomedicine & Pharmacotherapy*, 137(111393), 1-10. <https://doi.org/10.1016/j.biopha.2021.111393>
- Martins, W. A., Mantelli, M., Santos, S. C., Netto, A. P., & Pinto, F. (2015). Cutting and concentration of plant regulators on rooting of *Campomanesia adamantium*. *Revista de Ciências Agrárias*, 38(1), 58-64. <https://doi.org/10.19084/rca.16869>
- Okeke, E. T., Oladimeji, A. T., Ani, A. K., Onukwuli, O. D., & Odera, R. S. (2021). Effect of using different chemically modified breadfruit peel fiber in the reinforcement of LDPE composite. *Materials Testing*, 63(3), 286-292. <https://doi.org/10.1515/mt-2020-0041>
- Oliveira, T. D., Costa, C. C., Estevam, D. D. P., Medeiros, I. D. A., Lima, E. D. S., Santos, V. M., Oliveira Filho, A. A., & Oliveira, H. D. (2018). *Morus nigra* L.: systematized review of botanical, phytochemical and pharmacological properties. *Archives of Health Investigation*, 7(10), 450-454. <https://doi.org/10.21270/archi.v7i10.3023>
- R Core Team. (2023). R: *A language and environment for statistical computing*. R Foundation for Statistical Computing. <https://www.R-project.org/>
- Rafeeq, J., Mughal, A. H., Zaffar, S. N., Dutt, V., Ahmad, K., & Raja, T. (2020). Effect of IBA on rooting and growth of *Morus alba* shoot cuttings under temperate conditions of Kashmir. *International Journal of Chemical Studies*, 8(4), 3800-3802. <https://doi.org/10.22271/chemi.2020.v8.i4av.10239>
- Reflora. (2024). *Moraceae* in Flora e Funga of Brazil. *Jardim Botânico do Rio de Janeiro*. <http://reflora.jbrj.gov.br/reflora/floradobrasil/FB66>
- Rocha, L. E., Trindade, R. C. P., & de Lemos, E. E. P. (2014). Rooting of yam cuttings (*Dioscorea* spp.). *Communicata Scientiae*, 5(4), 486-492. <https://doi.org/10.14295/cs.v5i4.427>
- Santos, J. L. C., de Brito, E. L., de Sousa, A. V. A. R., Saraiva, J. F. C. S., & Diniz, F. O. (2020). Evaluation of commercial rooter in different types of desert rose cuttings. *Topics in Agrarian Sciences*, 5(1), 45-53. <https://doi.org/10.36229/978-65-86127-17-1>
- Shao, F., Wang, S., Huang, W., & Liu, Z. (2018). Effects of IBA on the rooting of branch cuttings of Chinese jujube (*Zizyphus jujuba* Mill.) and changes to nutrients and endogenous hormones. *Journal of Forestry Research*, 29(6), 1557-1567. <https://doi.org/10.1007/s11676-017-0557-6>
- Silva, A. C., Correia, T. D., Souza, M. M., Ferreira, J. T., Adão, A. S., Roberto, L. A., & Ribeiro, C. H. M. (2022). Influence of commercial on the vegetative propagation of *Echeveria lilacina* Kim. & Moran. *Research, Society and Development*, 11(10), 1-7. <https://dx.doi.org/10.33448/rsd-v11i10.32499>
- Singh, K. K., Choudhary, T., & Kumar, A. (2014). Effect of various concentrations of IBA and NAA on the rooting of stem cuttings of mulberry (*Morus alba* L.) under mist house condition in Garhwal hill region. *Indian Journal of Hill Farming*, 27(1), 125-131. https://kiran.nic.in/pdf/IJHF/Vol27_1_new/15.%20EffectofVariousConcentrationsofIBAandNAAontheRooting.pdf
- Soares, A. D. A. V. L., Furlaneto, F. D. P. B., Funai, C. H., & Gazola, E. (2021). Performance of mulberry cultivars (*Morus* spp.) in response to different stem cuttings and fertilizers. *Colloquium Agrariae*, 17(4), 47-58. <https://doi.org/10.5747/ca.2021.v17.n4.a448>
- Souza, S. R., Cavalcante, M. Z. B., Lima, M. P. D., Alixandre, T. F., & Nascimento, R. T. (2015). Vegetative propagation of hibiscus with different types of cuttings and IBA concentrations. *Communicata Scientiae*, 6(3), 291-296. <https://doi.org/10.14295/cs.v6i3.679>
- Villalta-Zúñiga, O. N., Elizondo-Salazar, J. A., & Russo, R. O. (2022). Vegetative propagation of mulberry cuttings (*Morus alba* L.), in greenhouse conditions: communication. *Brazilian*

Journal of Animal and Environmental Research, 5(2), 2474-2483.
<https://doi.org/10.34188/bjaerv5n2-083>
World Flora Online (WFO). (2024). Moraceae.
<https://www.worldfloraonline.org/search?query=moraceae>