UNIVERSIDAD TÉCNICA DE MANABÍ
Fundada en 1952

BASES DE LA CIENCIA
REVISTA CIENTÍFICA
FACULTAD DE CIENCIAS BÁSICAS
Portoviejo - Manabí - Ecuador

Ciencias Biológicas

Efecto de las Hormonas de crecimiento Aib y Ana en la propagación por esquejes del cultivo de MAMEY (Mammea americana L.)

Effect of Growth Hormones Iba and Naa on the propagation by cutting of the mamey crop (Mammea americana L.)

Efeito dos Hormônios de crescimento Aib e Ana na propagação por estaquia da cultura de mameeiro (Mammea americana L.)

Autor

Tito Rigoberto Solis Barros
tsolis@uteq.edu.ec

Aurelio David Zapatier Santillan
aurelio.zapatier@uteq.edu.ec

Odalys Morán Maffare
omoranm@uteq.edu.ec

Seyed Mehdi Jazayeri
seyed-mehdi.jazayeri@univ-avignon.fr

Quevedo State Technical University. Faculty of Livestock and Biological Sciences. Quevedo, Los Ríos, Ecuador.

* Autor para correspondencia.

Editor Académico
Ezequiel Zamora-Ledezma

Citación sugerida: olis Barros, T. R., Zapatier Santillan, A. D., Maffare, O. M., Jazayeri, S. M. (2025). *Effect of Growth Hormones Iba and Naa on the propagation by cutting of the mamey crop (Mammea americana L.). Revista Bases de la Ciencia*, 10(1), 33-41. DOI: https://doi.org/10.33936/revbasdelaciencia.v10i1.7148

Recibido: 30/11/2024
Aceptado: 23/02/2025
Publicado: 03/03/2025

Resumen

Este estudio examinó el impacto de las concentraciones de ácido indolbutírico (AIB) y ácido naftalenacético (ANA) en la propagación vegetativa de esquejes de Mammea americana L. Se realizó un ensayo de campo en la provincia de Los Ríos, Ecuador, utilizando un diseño completamente al azar (DCA) con cinco tratamientos y cuatro repeticiones. Los tratamientos incluyeron diferentes dosis de AIB y ANA: T1 (sin hormonas), T2 (1500 mg/L), T3 (2000 mg/L), T4 (2500 mg/L) y T5 (3000 mg/L). Se evaluaron cinco parámetros: número de brotes, longitud de las raíces, porcentaje de enraizamiento, porcentaje de mortalidad y número de raíces a los 45, 52 y 60 días después del trasplante. Los resultados indicaron que el tratamiento T5 (3000 mg/L de AIB + 3000 mg/L de ANA) mostró el mejor desempeño en términos de número de brotes, longitud y desarrollo de raíces, superando significativamente a los demás tratamientos. No se observaron diferencias significativas en el enraizamiento y la mortalidad entre los tratamientos. Se concluye que la aplicación combinada de 3000 mg/L de AIB y 3000 mg/L de ANA promueve efectivamente el desarrollo de raíces y brotes en esquejes de mamey. Estos hallazgos respaldan el uso de AIB y ANA en la propagación vegetativa del mamey y otros cultivos agronómicos relacionados.

Palabras clave: propagación vegetativa, desarrollo de raíces, enraizamiento, brotes.

Abstract

This study examined the impact of concentrations of indole butyric acid (IBA) and naphthaleneacetic acid (NAA) on the vegetative propagation of (Mammea americana L.) cuttings. A field trial was conducted in the Los Ríos province, Ecuador, using a completely randomized design (CRD) with five treatments and four replications. Treatments included different doses of IBA and NAA: T1 (no hormones), T2 (1500 mg/L), T3 (2000 mg/L), T4 (2500 mg/L), and T5 (3000 mg/L). Five parameters were evaluated: number of shoots, root length, rooting percentage, mortality percentage, and number of roots at 45, 52, and 60 days after transplantation. Results indicated that treatment T5 (3000 mg/L IBA + 3000 mg/L NAA) exhibited the best performance in terms of shoot number, length, and root development, significantly outperforming other treatments. No significant differences were observed in rooting and mortality among treatments. It is concluded that the combined application of 3000 mg/L IBA and 3000 mg/L NAA effectively promotes root and shoot development in mamey cuttings. These findings support the use of IBA and NAA in the vegetative propagation of mamey and other related agronomic crops.

Keywords: vegetative propagation, root development, rooting, shoots.

Resumo

Este estudo examinou o impacto das concentrações de ácido indolbutírico (AIB) e ácido naftalenoacético (ANA) na propagação vegetativa de estacas de Mammea americana L. Um ensaio de campo foi conduzido na província de Los Ríos, Equador, utilizando um delineamento inteiramente casualizado (DIC) com cinco tratamentos e quatro repetições. Os tratamentos incluíram diferentes doses de AIB e ANA: T1 (sem hormônios), T2 (1500 mg/L), T3 (2000 mg/L), T4 (2500 mg/L) e T5 (3000 mg/L). Cinco parâmetros foram avaliados: número de brotos, comprimento das raízes, porcentagem de enraizamento, porcentagem de mortalidade e número de raízes aos 45, 52 e 60 dias após o transplante. Os resultados indicaram que o tratamento T5 (3000 mg/L de AIB + 3000 mg/L de ANA) apresentou o melhor desempenho em termos de número de brotos, comprimento e desenvolvimento das raízes, superando significativamente os demais tratamentos. Não foram observadas diferenças significativas no enraizamento e na mortalidade entre os tratamentos. Conclui-se que a aplicação combinada de 3000 mg/L de AIB e 3000 mg/L de ANA promove efetivamente o desenvolvimento de raízes e brotos em estacas de mamão. Esses achados apoiam o uso de AIB e ANA na propagação vegetativa do mamão e de outras culturas agronômicas relacionadas.

Palavras-chave: propagação vegetativa, desenvolvimento de raízes, enraizamento, brotos.

Universidad Técnica de Manabí
Fundada en 1952

BASES DE LA CIENCIA
Revista Científica
Facultad de Ciencias Básicas
Portoviejo - Manabí - Ecuador

Introduction

Modern farming techniques are being applied to all sorts of plants, from flowers and fruit trees to grains. These methods aim to speed up growth and boost yields. In this context, the mamey (Mammea americana L.) is no different (Tian et al., 2021). In Ecuador, there is no recorded data on the production volume and cultivated areas of the different types of mamey by institutions such as National Institute of Agricultural and Livestock Research (INIAP), Ministry of Agriculture, Livestock, Aquaculture, and Fisheries (MAGAP), Central American Integration System (SICA), Ecuadorian Federation of Exporters and National Institute of Statistics and Censuses (FEDEXPORT and INEC). However, Central American Integration System and National Institute of Statistics and Censuses (SICA and INEC) do classify mamey as a long-term crop. Interestingly, a study as “Plant Diversity associated with cocoa plantations in two agro-ecological zones in the Coastal Region of Ecuador” found that mamey trees are used as natural borders in Milagro and Yaguachi.

The cultivation of mamey is typically confined to small regions and commonly incorporated into mixed farming systems, yet there hasn’t been a move towards creating large-scale commercial farms (Zequeira-Larios et al., 2021). Ecologically, growing mamey holds significant value because it contributes in the conservation of genetic variety and prevents the disappearance of potentially valuable genotypes. When mamey is woven into conventional farming practices, it supports the growth of sustainable fruit production. Additionally, the food industry gains from the availability of nutritious fruits and the creation of derivative products with added economic value (Cassani & Gomez-Zavaglia, 2022).

Although growth hormones, such as auxins, cytokinins, and gibberellins, are known to influence plant organ growth by stimulating cell elongation or inhibiting growth depending on their type and dosage, their use by farmers is limited. Today, in the Los Rios area, *in-situ* cultivation has become a popular alternative among growers to propagate disease-resistant varieties. This is achieved by selecting seeds from healthy plants with desirable agronomic characteristics during crop establishment.

Materials and methods

Location and duration of the experiment

The study was conducted at the Technical State University of Quevedo, located in Quevedo Canton, Los Ríos Province, Ecuador, at the geographical coordinates 79°28’30” west longitude and 1°2’30” south latitude. The area is characterized by a tropical humid climate, with warm temperatures throughout the year, high relative humidity, and frequent rainfall. The topography of the area has slight undulations, allowing for adequate soil drainage. The experimental phase lasted 90 days, starting in November and ending in February 2022. These conditions are favorable for agricultural activities and experimental research.

Source: PeterHermesFurian, (2024)

Weather conditions

revista.bdlaciencia@utm.edu.ec | Vol. 10, Núm. 1 (33-41): Enero-Junio, 2025 | DOI: 10.33936/revbasdelaciencia.v10i1.7148

The weather conditions were reported based on the data obtained from INAMHI agrometeorological station, located at the experimental station of the Faculty of Livestock and Biological Sciences of the State Technical University of Quevedo (INIAP 2022) as shown in Table 1.

Table 1. Meteorological data of the area during study

Average	Parameters
Temperature (°C)	25.7
Humidity (%)	75.75
Precipitation (mm)	821.8
Heliophany (hours/light/month)	68.48
Topography Units?	2.81

Source: INAMHI agrometeorological station, located in the experimental station of the Faculty of Livestock and Biological Sciences of the State Technical University of Quevedo (INIAP 2022)

Treatments

Two plant hormones including indole butyric acid (IBA) and naphthaleneacetic acid (NAA) in four replicates of different treatments were used as following:

Table 2. Effect of treatments with Indole Butyric Acid (IBA) and Naphthaleneacetic Acid (NAA) at different concentrations

No.	Treatments	Description
1	T1	No Hormone
2	T2	1500 mg/L IBA + 1500 mg/L NAA
3	T3	2000 mg/L IBA + 2000 mg/L NAA
4	T4	2500 mg/L IBA + 2500 mg/L NAA
5	T5	3000 mg/L IBA + 3000 mg/L NAA

Experimental design and statistical analysis

A completely randomized design (CRD) for the experiment was used. This design randomly assigns treatments to experimental units. There were five different treatments, each replicated four times. Before analyzing the data statistically, two important assumptions were applied as normality and homoscedasticity. Normality refers to the data following a normal distribution. Homoscedasticity means the variance of the data is consistent across all groups. the Shapiro-Wilks test was employed to assess normality and the Bartlett test for homoscedasticity. Microsoft Excel was used to organize and manage the data, and R Studio software for the statistical analysis. The variables analyzed were the following: Number of outbreaks, Root length, Percentage of plant rooting (%), Percentage of mortality (%), Number of roots.

Experiment management

Construction of the umbracle

To reduce the light intensity and control the temperature, a 2 x 5m umbracle was built, with a reed structure and a black saran mesh that allowed 20% of light to pass through.

Substrate used

The culture medium used for the rooting of cocoa was a mix of soil and burnt sawdust (1:1), which was placed in black polyethylene sleeves with dimensions of 10 x 20 cm^2 perforated.

ISSN 2588-0764 | Vol. 10, Núm. 1 (33-41): Enero-Junio, 2025 | DOI: 10.33936/revbasdelaciencia.v10i1.7148

Preparation of rooting powders

To prepare the rooting powders, 30 grams of talcum powder were measured out alongside varying concentrations of NAA and IBA hormones. Following the measurement of the hormones, ammonium nitrate was dissolved in 75% alcohol. The mixture was stirred thoroughly until it became a consistent mass, with additional alcohol added as needed. Subsequently, the hormones were incorporated at their specific concentrations. After blending, the mixture was transferred to an empty container, which was then positioned to receive sunlight, and left undisturbed for 24 hours.

After severing, the mamey sapling ends were submerged in water to avert drying out. "Fan"-shaped terminal branches, deemed immature and thus labeled as "young," were distinguished by their pale green shafts devoid of dark blemishes, tender, similarly hued foliage. Cuttings were derived from these limbs, segmenting each into roughly 15 cm long stem stakes, retaining merely one to three viable leaves and trimming away the remainder at the petiole bases. Each cutting was then inserted approximately 0.5 to 1.0 cm deep into growth mediums amalgamated with NAA and IBA hormones. These were then embedded into the mediums at a depth ranging from 3 to 4 cm, arranging a single stake per casing. Finally, the sheathed cuttings, across varied treatments, were enveloped in plastic to create a humid chamber within a shaded area (Tien *et al*., 2020).

Results and Discussion

Number of outbreaks

The data presented in Table 3 show significant differences among the evaluated treatments at 45, 52, and 60 days, according to Tukey's test at a 5% significance level. At these time points, the coefficients of variation were 13.4%, 10.81%, and 22.58%, respectively, indicating a clear trend in the obtained results. It is important to highlight that Treatment 5 (T5), which combined 3000 mg/L of IBA and 3000 mg/L of NAA, exhibited the best performance at 52 and 60 days. However, at 45 days, the highest performance was observed in Treatment 3 (T3), which combined 2000 mg/L of IBA and 2000 mg/L of NAA, suggesting a variation in treatment response depending on the evaluation time.

These statistical differences allow for identifying whether a treatment performs better than the others. The significance of the data is crucial for supporting conclusions and confirming which strategies yield better results.

Table 3. Outcomes of the variable number of outbreaks

Treatments	Number of outbreaks (units)		
	45 days	52 days	60 days
1	1.54 b	2.44 c	2.45 c
2	2.34 a	2.76 bc	4.75 bc
3	2.63 a	3.15 ab	6.25 b
4	2.62 a	3.15 ab	9.93 a
5	2.60 a	3.40 a	11.05 a
C.V.%	13.4	10.81	22.58

Average with the same letters is statistically equal according to Tukey's test ($p \leq 0.05$).

The balance between auxins and cytokinins plays a fundamental role in regulating plant growth. In general, high auxin concentrations promote bud development, while lower levels tend to reinforce apical dominance (Sosnowski *et al.*, 2023) Additionally, it has been noted that the use of auxins can increase the number of buds in cuttings, which is related to greater carbohydrate movement at the base of the plant (Gao *et al.,* 2024). To better understand these results, it is essential to compare them with (Wu *et al*., 2024). This will allow for an analysis of whether the trends observed in this research align with other findings, providing a broader perspective on the topic.

revista.bdlaciencia@utm.edu.ec | Vol. 10, Núm. 1 (33-41): Enero-Junio, 2025 | DOI: 10.33936/revbasdelaciencia.v10i1.7148

Root length

Table 4 shows statistically significant differences in a specific variable at 45, 52, and 60 days, as determined by Tukey's test at a 5% significance level. The coefficients of variation for these time points were 15.06%, 18.18%, and 13.07%, respectively. These results highlight important variations among the evaluated treatments, which are essential for assessing their effectiveness.

On the other hand, Table 4 identifies two treatments that outperformed the others: Treatment 4 (T4), which combines 2500 mg/L of IBA with 2500 mg/L of NAA, and Treatment 5 (T5), with a concentration of 3000 mg/L of both phytohormones. Among them, T5 demonstrated the best performance in the evaluated variables. However, to confirm that this treatment is the most effective overall, a comparative analysis of all studied parameters is necessary to determine whether the differences remain consistent across all variables.

Table 4. Outcomes of the variable root length

Treatments	**Root length (units)**		
	45 days	**52 days**	**60 days**
1	8.05 d	12.93 bc	15.35 bc
2	9.23 cd	11.18 c	12.65 c
3	11.63 c	12.08 bc	14.85 bc
4	14.48 b	14.80 b	16.35 b
5	24.10 a	20.78 a	23.33 a
C.V.%	15.06	18.18	13.07

Average with the same letters is statistically equal according to the Tukey test ($p \leq 0.05$).

The results obtained in this study demonstrate a significant superiority compared to those reported by (Monge-Pérez & Loría-Coto, 2024), who recorded a length of 20.4 cm for the same variable in a study involving *Sechium tacaco*. This difference suggests that the treatments applied in our study may be promoting greater development compared to the conditions previously analyzed. However, these results are consistent with the observations made by (Reyes-Pérez et al., 2023), who emphasize that optimal propagation requires a precise combination of an appropriate substrate and stimulants based on phytohormones that enhance growth. This concept supports the approach used in our study, in which these factors were considered as key elements in the treatment protocols.

Regarding the effect of the external application of auxins and cytokinins at the base of cuttings, which is well-documented in the literature, our research confirms that these compounds have a positive impact on root length. In agreement with the findings of (Vielba *et al*., 2020), who found that treatment 5, administered over 45 days, promoted the longest adventitious root length in mamey cuttings (*M. americana L.*), we observed similar effects with the treatments evaluated. However, to gain a comprehensive understanding of the effectiveness of each treatment, it is imperative to conduct a detailed statistical analysis of the differences between the five treatments used in this study. This will allow for the precise identification of the treatment that yields the best results in terms of growth and root development. Additionally, it will be necessary to assess whether the observed differences are statistically significant, as only through these analyses can the optimal treatment be identified. This comparative approach, along with the evaluation of the variability of the parameters assessed, will provide a more robust understanding of the most favorable conditions for successful propagation.

Percentage of plant rooting (%)

The study examined the effect of hormone concentrations on the rooting of plant cuttings over periods of 45, 52, and 60 days (Table 5). No statistically significant differences were observed in the percentage of rooting across these time points (Tukey's analysis at a 5% significance level). However, an interesting trend was noted: as the hormone concentration (ranging from 1500 mg/kg to 3000 mg/kg of NAA and IBA) increased, the percentage of rooting tended to decrease. This phenomenon is consistent with previous findings, such as those of (P *et al*., 2023), who indicated that root initiation generally increases with higher auxin concentrations up to a maximum point, after which the rooting response declines, forming an optimal curve. Similarly, the studies by (Sekhukhune & Maila, 2024; Tien *et al*., 2020)but the research on exogenous hormone stimulatory effects on <italic>Actinidia</italic> spp. is still lagging. Kiwifruit plants had been mostly

ISSN 2588-0764 | **Vol. 10, Núm. 1 (33-41): Enero-Junio, 2025** | **DOI: 10.33936/revbasdelaciencia.v10i1.7148**

propagated by seeds. However, vegetative propagation offers several advantages over sexual propagation, among them being crop homogeneity, practicability, and simplicity of the technique. A study was therefore conducted to investigate the potential responses of kiwifruit SCs from <italic>Actinidia deliciosa</italic> rootstock and <italic>Actinidia arguta</italic> male scion SCs treated with indole-3-butyric acid (IBA support this observation. Although the initial post-application stage of NAA and IBA was not directly measured for this parameter, it is possible that an unreported increase in rooting occurred during this phase. However, as time progressed, these differences tended to diminish.

In comparing the results across the five treatments, it is important to note that no significant differences were observed in the rooting percentages. The values obtained for each treatment at 45, 52, and 60 days (Table 5) did not show a clear superiority of one treatment over another. Despite the lack of statistical significance, the observed trends should still be considered for a deeper understanding of the relationship between hormone concentration and rooting response in this study.

Table 5. Outcomes of the variable percentage of rooting

Treatments	Percentage of rooting (units)		
	45 days	52 days	60 days
1	17.50 a	45.00 a	50.25 a
2	21.25 a	43.25 a	69.50 a
3	25.25 a	41.50 a	59.75 a
4	22.50 a	41.00 a	75.25 a
5	24.75 a	27.00 a	75.25 a
C.V.%	18.56	23.43	19.68

Average with the same letters is statistically equal according to the tukey test ($p \leq 0.05$).

Percentage of mortality (%)

Regarding the evaluated variable, the Tukey multiple comparison test (at a 5% significance level, Table 6) did not reveal statistically significant differences among treatments at 45, 52, and 60 days. This indicates that none of the treatments exhibited superior performance in terms of mortality rates at the analyzed time points. However, the results obtained in this study contrast with those reported by (Becerra Martínez, 2024), who documented a significantly higher mortality rate compared to the present study. Additionally, the observed mortality rates were lower than the 62.55% reported by (Reyes-Pérez et al., 2023), which may be attributed to differences in production system management or environmental conditions across studies.

Table 6. Outcomes of the variable percentage of mortality.

Treatments	**Percentage of mortality (units)**		
	45 days	**52 days**	**60 days**
1	52.50 a	18.75 a	44.50 a
2	50.25 a	35.25 a	31.63 a
3	48.75 a	29.75 a	40.00 a
4	58.00 a	34.50 a	28.50 a
5	42.75 a	28.25 a	56.25 a
C.V.%	18.13	19.53	21.23

Average with the same letters is statistically equal according to Tukey's test ($p \leq 0.05$).

revista.bdlaciencia@utm.edu.ec | Vol. 10, Núm. 1 (33-41): Enero-Junio, 2025 | DOI: 10.33936/revbasdelaciencia.v10i1.7148

Despite the absence of significant differences among treatments, the results show variability in mortality rates across different time points. In particular, Treatment 2 exhibited a consistent trend toward mortality reduction, showing the lowest values at 52 and 60 days compared to the other treatments. This suggests that the treatment in question may have superior performance in terms of mortality control, justifying a more in-depth evaluation in future studies. Further research is recommended to identify the most effective management practices that may have contributed to these results.

Number of roots

The results presented in Table 7 correspond to the root number variable and show significant statistical differences among treatments, according to Tukey's test at a 5% significance level. Coefficients of variation of 21.55%, 17.51%, and 17.93% were recorded at 45, 52, and 60 days, respectively. In this context, treatment T5 (3000 mg/kg of NAA and IBA) exhibited the highest root number in all evaluations, reaching values of 13.41, 17.15, and 19.15 roots at the three assessment periods. These results confirm the positive effect of a higher auxin concentration on root induction and development compared to lower doses.

The temporal analysis of root number reveals a sustained trend in which T5 proved to be the most efficient treatment, followed by T4 (2000 mg/kg of NAA and IBA), which also presented significantly higher values compared to treatments T1, T2, and T3. These differences highlight the fundamental role of auxins in cell elongation, tissue development, and adventitious root formation, key processes in root system architecture.

A positive correlation has been reported between increased auxin concentrations and improved rooting response, which aligns with the results obtained in this study (Jan *et al*., 2024). However, the physiological response may be influenced by factors such as plant species, edaphoclimatic conditions, and substrate composition. Therefore, it is essential to continue evaluating the interaction of these variables to establish optimal auxin application protocols for the vegetative propagation of this species.

Table 7. Number of roots

Treatments	Number of roots (units)		
	45 days	52 days	60 days
1	2.45 c	4.95 d	6.15 d
2	5.98 b	6.68 d	9.43 c
3	8.43 b	9.10 c	12.26 bc
4	11.7 a	12.53 b	14.51 b
5	13.41 a	17.15 a	19.15 a
C.V.%	21.55	17.51	17.93

Average with the same letters is statistically equal according to Tukey's test ($p \leq 0.05$).

Conclusions

The mixture of IBA and NAA at 3000 mg/L (T5) significantly enhanced the growth of *Mammea americana L*., promoting robust root and leaf development within 60 days. This highlights the synergistic effect of auxins in root formation and tissue growth, emphasizing their utility in tropical plant propagation. While T3 (2000 mg/L) showed higher shoot production at 45 days, its growth slowed afterward, whereas T5 maintained steady growth, suggesting higher auxin concentrations prolong growth and increase viable cuttings. However, excessive auxin use may hinder development, similar to overwatering, underscoring the need for precise dosing. T2 demonstrated lower mortality between days 52 and 60, indicating specific concentrations may improve stress resistance and transplant survival. These findings stress the importance of optimizing auxin levels to strengthen cuttings and enhance their adaptability, ensuring successful propagation and transplantation of *Mammea americana L.* in controlled environments.

Acknowledgement

The author DAZS thanks his parents for the unconditional support during his formative stage. In addition, we would like to thank Dr. Gary Meza Bone and Dr. Carlos Meza Bone for their academic and scientific contributions to the achievement of this project.

Authors' Conflict of Interest Statement

The authors declare no conflict of interest.

References

Aït-Kaddour, A., Hassoun, A., Tarchi, I., Loudiyi, M., Boukria, O., Cahyana, Y., Ozogul, F., & Khwaldia, K. (2024). Transforming plant-based waste and by-products into valuable products using various "Food Industry 4.0" enabling technologies: A literature review. *Science of The Total Environment*, *955*, 176872. https://doi.org/10.1016/j.scitotenv.2024.176872

Becerra Martínez, J. C. (2024). *Efecto de dos reguladores de crecimiento bajo tres concentraciones de auxinas en la propagación de estacas de "cacao" Theobroma cacao L. Var CCN-51, Rioja*. https://repositorio.ucss.edu.pe/handle/20.500.14095/2199

Cassani, L., & Gomez-Zavaglia, A. (2022). Sustainable Food Systems in Fruits and Vegetables Food Supply Chains. *Frontiers in Nutrition*, *9*. https://doi.org/10.3389/fnut.2022.829061

Gao, J., Zhuang, S., & Zhang, W. (2024). Advances in Plant Auxin Biology: Synthesis, Metabolism, Signaling, Interaction with Other Hormones, and Roles under Abiotic Stress. *Plants*, *13*(17), Article 17. https://doi.org/10.3390/plants13172523

Garban, Z., & Ilia, G. (2024). Structure-Activity of Plant Growth Bioregulators and Their Effects on Mammals. *Molecules*, *29*(23), Article 23. https://doi.org/10.3390/molecules29235671

Jan, M., Muhammad, S., Jin, W., Zhong, W., Zhang, S., Lin, Y., Zhou, Y., Liu, J., Liu, H., Munir, R., Yue, Q., Afzal, M., & Wang, G. (2024). Modulating root system architecture: Cross-talk between auxin and phytohormones. *Frontiers in Plant Science*, *15*. https://doi.org/10.3389/fpls.2024.1343928

Janke, R. R., Menezes-Blackburn, D., Al Hamdi, A., & Rehman, A. (2024). Organic Management and Intercropping of Fruit Perennials Increase Soil Microbial Diversity and Activity in Arid Zone Orchard Cropping Systems. *Sustainability*, *16*(21), Article 21. https://doi.org/10.3390/su16219391

Kim, S.-H., Zebro, M., Jang, D.-C., Sim, J.-E., Park, H.-K., Kim, K.-Y., Bae, H.-M., Tilahun, S., & Park, S.-M. (2023). Optimization of Plant Growth Regulators for In Vitro Mass Propagation of a Disease-Free 'Shine Muscat' Grapevine Cultivar. *Current Issues in Molecular Biology*, *45*(10), Article 10. https://doi.org/10.3390/cimb45100487

Monge-Pérez, J. E., & Loría-Coto, M. (2024). Effect of indole-butyric acid on the propagation of tacaco (Sechium tacaco) by air layering. *I+D Tecnológico*, *20*, 94-100.

P, V. N., M, R. L., & N, S. H. H. (2023). Effects of Different Root Inducing Agents on Cutting Propagation of Tea (Camellia sinensis). *Annual Research & Review in Biology*, *38*(6), 30-37. https://doi.org/10.9734/arrb/2023/v38i630590

Reyes-Pérez, J. J., Llerena-Ramos, L. T., Torres-Rodríguez, J. A., & Hernández-Montiel, L. G. (2023). Oligogalacturonide dose optimization on the vegetative propagation of two cocoa clones (Theobroma cacao L.) under controlled conditions in the nursery. *Terra Latinoamericana*, *41*. https://www.scielo.org.mx/scielo.php?pid=S0187-57792023000100121&script=sci_abstract&tlng=en

Sapna, F. N. U., Raveena, F. N. U., Chandio, M., Bai, K., Sayyar, M., Varrassi, G., Khatri, M., Kumar, S., Mohamad, T., Sapna, F. N. U., Raveena, F. N. U., Chandio, M., Bai, K., Sayyar, M., Varrassi, G., Khatri, M., Kumar, S., & Mohamad, T. (2023). Advancements in Heart Failure Management: A Comprehensive Narrative Review of Emerging Therapies. *Cureus*, *15*. https://doi.org/10.7759/cureus.46486

Sekhukhune, M. K., & Maila, M. Y. (2024). Exogenous IBA stimulatory effects on root formation of Actinidia deliciosa rootstock and Actinidia arguta male scion stem cuttings. *Frontiers in Sustainable Food Systems*, *8*. https://doi.org/10.3389/fsufs.2024.1461871

revista.bdlaciencia@utm.edu.ec | Vol. 10, Núm. 1 (33-41): Enero-Junio, 2025 | DOI: 10.33936/revbasdelaciencia.v10i1.7148

Sosnowski, J., Truba, M., & Vasileva, V. (2023). The Impact of Auxin and Cytokinin on the Growth and Development of Selected Crops. *Agriculture*, *13*(3), Article 3. https://doi.org/10.3390/agriculture13030724

Tian, Z., Wang, J.-W., Li, J., & Han, B. (2021). Designing future crops: Challenges and strategies for sustainable agriculture. *The Plant Journal*, *105*(5), 1165-1178. https://doi.org/10.1111/tpj.15107

Tien, L. H., Chac, L. D., Oanh, L. T. L., Ly, P. T., Sau, H. T., Hung, N., Thanh, V. Q., Doudkin, R. V., & Thinh, B. B. (2020). Effect of auxins (IAA, IBA and NAA) on clonal propagation of *Solanum procumbens* stem cuttings. *Plant Cell Biotechnology and Molecular Biology*, *21*(55-56), 113-120.

Vielba, J. M., Vidal, N., José, M. C. S., Rico, S., & Sánchez, C. (2020). Recent Advances in Adventitious Root Formation in Chestnut. *Plants*, *9*(11), Article 11. https://doi.org/10.3390/plants9111543

Wu, X., Gong, D., Zhao, K., Chen, D., Dong, Y., Gao, Y., Wang, Q., & Hao, G.-F. (2024). Research and development trends in plant growth regulators. *Advanced Agrochem*, *3*(1), 99-106. https://doi.org/10.1016/j.aac.2023.11.005

Zequeira-Larios, C., Santiago-Alarcon, D., MacGregor-Fors, I., & Castillo-Acosta, O. (2021). Tree diversity and composition in Mexican traditional smallholder cocoa agroforestry systems. *Agroforestry Systems*, *95*(8), 1589-1602. https://doi.org/10.1007/s10457-021-00673-z

Author contributions

Authors	Contribution
Tito Rigoberto Solis Barros	Conceptualization, formal analysis, validation, project management, methodology, funding acquisition and preparation of the original draft.
Ronald Oswaldo Villamar-Torres	Conceptualization, formal analysis, validation, project management, methodology, funding acquisition and preparation of the original draft.
Aurelio David Zapatier Santillan	Research, methodology.
Odalys Morán Maffare	Research, methodology and corrections
Seyed Mehdi Jazayeri	Review and editing

ISSN 2588-0764 | Vol. 10, Núm. 1 (33-41): Enero-Junio, 2025 | DOI: 10.33936/revbasdelaciencia.v10i1.7148