Organic biostimulants for vegetative growth of sugarcane (*Saccharum* spp.) in the nursery

Gabriel-Hernández, Magdiel[1]; Osorio-Espinoza, Humberto[1*]; Marroquín-Agreda, Francisco J.[1]; Au-Cárdenas, Cesar. A.[1]; Yerena-Yamallel, José I.[2]; Reyna-González, Ángel M.[2]; Méndez-Martínez, Kevin[1]

[1] Universidad Autónoma de Chiapas. Huehuetán Chiapas, C. P. 30660, México.
[2] Universidad Autónoma de Nuevo León. Monterrey Nuevo León, C. P. 67700. México.
* Correspondence: humberto.osorio@unach.mx

ABSTRACT

Objective: To evaluate the effect of organic root enhancers (mycorrhizae, humic acid soil conditioner, and seaweed extracts) on the vegetative growth of sugarcane (*Saccharum officinarum* L.) seedlings under nursery conditions.

Design/methodology/approach: A completely randomized block design was used with four treatments: mycorrhizae, Bio-Organik® (based on humic acids), AlgaBest® (seaweed extract), and a control (Control); and five replicates. Destructive sampling was carried out at 15, 30, 45, 60, and 75 days after sowing (DAS), to measure plant height, root length, and root biomass.

Results: Mycorrhizae significantly increased plant height at 30 DAS (58.8 cm *vs.* 49.2 cm control). The seaweed extract enhanced early root biomass (0.19 g at 15 DAS), and late-stage root length (44.8 cm at 75 DAS). Both treatments outperformed the control (Tukey, *p*≤0.05).

Limitations on study/implications: There was variable efficacy across growth stages; long-term field validation is needed.

Findings/conclusions: Organic biostimulants improve sugarcane seedling biomass, with mycorrhizae and seaweed extracts showing specific benefits for each stage. These offer sustainable alternatives for nursery propagation.

Keywords: *Saccharum officinarum*, arbuscular mycorrhizae, seaweed extracts, root biomass, sustainable agriculture.

Citation: Gabriel-Hernández, M., Osorio-Espinoza, H., Marroquín-Agreda, F. J., Au-Cárdenas, C. A., Yerena-Yamallel, J. I., Reyna-González, Á. M., & Méndez-Martínez, K. (2025). Organic biostimulants for vegetative growth of sugarcane (*Saccharum* spp.) in the nursery. *Agro Productividad*. https://doi.org/ 10.32854/7qt22j75

Academic Editor: Jorge Cadena Iñiguez
Associate Editor: Dra. Lucero del Mar Ruiz Posadas
Guest Editor: Daniel Alejandro Cadena Zamudio

Received: April 21, 2025.
Accepted: June 29, 2025.
Published on-line: September 9, 2025.

Agro Productividad, 18(7). July. 2025. pp: 37-43.

INTRODUCTION

The sugarcane agroindustry stands out for its significant impact on Mexico's economy. In 2023, this agroindustry reached a production of 55,589,515.48 tons, positioning Mexico as the eighth largest producer worldwide. This agroindustry generated 500,000 direct jobs and 2.4 million indirect jobs in 267 municipalities across 15 states (CONADESUCA, 2023). Sugarcane is a semi-perennial crop that is conventionally propagated through cuttings that have more than three viable buds to emerge (Rehman *et al.*, 2021). The use of chemical

products to stimulate rooting in sugarcane has been a common practice in agriculture, due to their effectiveness in accelerating root development. The root system is essential for the plant's initial development. In sugarcane, it is of vital importance for the regrowth and vigor of the shoot cycles (Pissolato *et al.*, 2021). The search for sustainable and efficient agricultural practices has led to the implementation of various biological technologies that promote plant development and improve crop productivity. Roots require water, nutrients, and oxygen for optimal development, and an imbalance of any of these resources in the soil will affect their development (Van Antwerpen *et al.*, 2022). Sustainable agricultural practices should boost the growth and prevalence of beneficial microbes. Several studies show that regenerative agriculture manifests soil health by improving microbial diversity and richness. There is a wide variety of regenerative agricultural practices such as mulching, cover crops, interspersed and mixed crops, no-till farming, among others, that would boost productivity (Singh *et al.*, 2023). Biostimulants are substances that promote plant growth, nutrition, and metabolism through different modes of action, although decidedly different from those related to fertilizers; they are supplied to plants at very low doses to induce beneficial effects (Nardi *et al.*, 2016; Yakhin *et al.*, 2017; Rouphael and Colla, 2018). The use of biological rooting agents such as mycorrhizae, humic and fulvic acids, and seaweed is emerging as a promising alternative that could significantly contribute to improving sugarcane production. Therefore, the objective of this research was to evaluate the effect of organic rooting agents on vegetative growth in sugarcane mini-cuttings, as a sustainable alternative under nursery conditions.

MATERIALS AND METHODS

Description of the study area

The study was carried out between April and August 2024, at the Experimental Field of the School of Agricultural Sciences of the Autonomous University of Chiapas, located at 15° 0' 30.68" N, 92° 24' 3.84" W, with an altitude of 33 meters above sea level (Figure 1).

The area has a semi-warm sub-humid climate and annual rainfall of 1100 and 4500 mm (INEGI, 2024). Geologically, the soil is predominantly composed of igneous rocks (>85%) and, to a lesser extent, sedimentary rocks (López-Pérez *et al.*, 2022). Mini-cuttings of sugarcane (*Saccharum officinarum* L.), variety CP 72-2086, were used, each with a viable

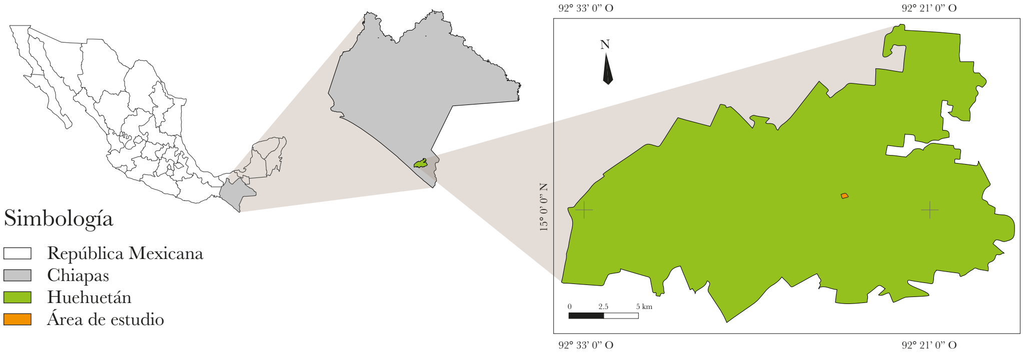

Figure 1. Geographic location of the study area.

bud to ensure sprouting. Sowing was conducted in polyethylene bags (15×23 cm) with perforations at the bottom to facilitate drainage.

Treatments

Four treatments were evaluated: T1. Mycorrhizae (*Rhizophagus intraradices*), containing 40 spores g^{-1}, applied at a dose of 5 g/plant; T2. Bio-Organik® (formulated with 25% phosphorus, 5% total nitrogen, 18.96% organic matter plus humic acid-based conditioners, and 51.04% diluents), at a dose of 1.5 L/ha; T3. AlgaBest® (containing 20% humic acids, 20% fulvic acids, 10% amino acids, 10% seaweed extract, 2% alfalfa plant extract, 1% carbohydrates and 37% diluents), at a dose of 2.0 L/ha; T4. Control (only water was applied). The treatments were distributed in a randomized complete block design with four treatments and five replicates. Destructive sampling was conducted at 15, 30, 45, 60, and 75 days after planting (DAS) and application.

Study variables

Three response variables were evaluated: Seedling height, measured with a graduated flexometer (accuracy ±0.1 cm), from the base of the stem (ground level) to the young vegetative apex; root length, determined with a flexometer (cm), from the root emergence point to the apex of the main root; and, root biomass. The roots were separated from the aerial part, washed with running water to remove the adhered substrate and dried in a forced-air oven at 75 °C for 72 h until constant weight. The research results were analyzed with the INFOSTAT version 2020e software, and the differences between treatment means with Tukey's test ($P \leq 0.05$).

RESULTS AND DISCUSSION

Height

Seedling height showed significant variations on one of the five sampling dates evaluated (Table 1). At 15 days after sowing (DAS), no significant differences were observed; however, numerical ones were observed between the biostimulants evaluated, with mycorrhizae and humic acids showing the highest values. However, at 30 DAS, the treatment with mycorrhizae showed a significantly greater effect compared to seaweed and the control, although similar to humic acids. At later dates, all biostimulants showed statistically similar behavior. These results coincide with those reported by Juntahum *et al.* (2022), who

Table 1. Means comparison of the height variable at 15, 30, 45, 60 and 75 DAS.

Treatments	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS
Micorrhizae	36.00 a	58.80 a*	67.00 a	64.20 a	78.40 a
Bio-Organik®	35.60 a	54.40 ab	71.40 a	70.20 a	78.60 a
AlgaBest®	32.40 a	50.40 bc	67.00 a	72.60 a	83.60 a
Control	31.80 a	49.20 c	65.40 a	63.80 a	77.60 a
% of CV	11.74	5.16	6.24	7.11	4.41

* Values with the same letter are equal according to Tukey's test at $P \leq 0.05$.

demonstrated that Arbuscular Mycorrhizal Fungi (AMF) positively influence the height of sugarcane seedlings grown in a nursery.

The use of individual sugarcane buds inoculated with mycorrhizae showed shoot regrowth during the early stages of development, with a significant effect observed up to four weeks after planting (DAS). These results suggest that mycorrhizal symbiosis can stimulate early seedling growth, probably due to greater efficiency in nutrient and water uptake during critical establishment phases (Musa *et al.*, 2020). Previous studies indicate that low inoculation doses (50 to 100 spores/plant) favor efficient symbiotic interaction. Therefore, early application of mycorrhizae at optimal concentrations could improve seedling conditioning before transplanting, optimizing their initial development (Moreno, 2022).

Root length

Root length showed significant differences ($p<0.05$) at all evaluation dates (Table 2). At 15 DAS, the seaweed treatment showed significantly higher values than the other treatments. However, at 30 DAS in this trend, the mycorrhizal treatment showed greater root development, statistically outperforming the other biostimulants evaluated.

By the third sampling (45 DAS), mycorrhizae remained significantly different from the control and seaweed, but no statistically significant differences were found with respect to the humic acid treatment. By the fourth evaluation (60 DAS), seaweed again showed significant differences compared to humic acids and the control, although it showed similar results to the mycorrhizae treatment. By the last sampling (75 DAS), the observed trend continued. Both seaweed and mycorrhizae proved to be statistically superior to the other treatments evaluated.

Microbial biostimulants are a key agroecological tool for mitigating abiotic stress in crops. Their mechanism of action operates at multiple physiological levels: (1) hormonal regulation through modulation of indole-3-acetic acid (IAA), cytokinins, gibberellins, and abscisic acid; (2) production of ACC-deaminase , which reduces the levels of ethylene under stress conditions; (3) improved availability of essential nutrients; (4) induction of antioxidant enzymes that counteract oxidative stress (Bahera *et al.*, 2021; Del Buono, 2021).

Their impact on root architecture is particularly relevant. Studies with *Glomus intraradices*, *Exophiala* sp., and *Paecilomyces formosus* have shown that microbial inoculation under conditions of water stress significantly increases soil exploration (40 to 60% greater root length and hyphal development), consequently improving root hydraulic conductivity

Table 2. Means comparison of the root length variable at 15, 30, 45, 60 and 75 DAS.

Treatments	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS
Micorrhizae	11.20 c	37.00 a*	51.80 a*	39.20 ab	43.60 a
Bio-Organik®	14. 20 b	29.20 b	47.80 ab	38.60 b	34.60 b
AlgaBest®	17. 20 a*	25.40 b	42.80 b	45.60 a*	44.80 a
Control	14. 24 b	28.40 b	42.20 b	37.00 b	34.70 b
% of CV	9.67	7.28	6.72	8.74	7.47

*Values with the same letter are equal according to Tukey's test at $P\leq0.05$.

(Aroca *et al.*, 2007; Khan *et al.*, 2015). These findings are consistent with our results, where mycorrhizal treatments showed greater root development, especially during critical establishment phases (30-75 DAS).

Recent studies show that seaweed extracts stimulate root development by modulating redox homeostasis, particularly through the regulation of antioxidant enzyme systems (Van Tol de Castro *et al.*, 2024). In the sugarcane crop, Arioli *et al.* (2024) demonstrated that these biostimulants significantly alter the composition of the rhizosphere microbiome, suggesting an indirect growth promotion mechanism through modifications in root-associated microbial communities.

The available studies have key limitations: (1) lack of specific characterization of plant-microbiome-biostimulant interactions, and (2) limited information on the temporal persistence of these effects. Our results partially coincide with these findings, where the AlgaBest® treatment (seaweed-based) showed variable efficacy depending on the phenological stage, being particularly effective in the initial (15 DAS) and final (60-75 DAS) studies of development.

Root biomass

The root biomass showed statistically significant differences between treatments (Table 3) at various sampling times. At 15 DAS, the seaweed treatment recorded the highest biomass (0.19 g), significantly exceeding the control and mycorrhizal treatments ($p<0.05$), but similar to humic acids. At 30 DAS, no statistical differences were detected between treatments, which indicates homogeneous behavior at this early stage of development.

With sampling at 40 DAS, the mycorrhizal treatment presented the highest value of biomass (0.98 g), which is significantly higher than the treatments with humic acids, seaweed extract, and the control. At 60 DAS, mycorrhizae, seaweed, and humic acids outperformed the control. However, no statistical differences were found between mycorrhizae and humic acids, suggesting a favorable trend for biostimulants at this stage.

Finally, at 75 DAS, the treatment with seaweed extract reached the highest value (1.36 g), showing a statistically significant difference with respect to humic acids and the control, although not differing from the mycorrhizae. Recent studies affirm that seaweeds have a dual functionality as biostimulants and as soil improvers, promoting plant growth under stress conditions (Nephali *et al.*, 2020; Banakar *et al.*, 2022).

Seaweed extracts are rich in carbohydrates, enzymes and proteins, and can be used to reduce abiotic stress, increase nutrient utilization, and stimulate root growth, quality,

Table 3. Means comparison of the root biomass variable at 15, 30, 45, 60 and 75 DAS.

Treatments	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS
Micorrhizae	0.08 b	0.87 a	0.98 a*	0.89 a*	1.33 ab
Bio-Organik®	0.13 ab	0.81 a	0.82 b	0.75 ab	1.12 bc
AlgaBest®	0.19 a*	0.74 a	0.85 b	0.75 ab	1.36 a*
Control	0.10 b	0.73 a	0.67 c	0.62 b	1.03 c
% of CV	28.2	10.51	8.32	13.34	9.66

* Values with the same letter are equal according to Tukey's test at $P \leq 0.05$.

weight, and microbial activity in the root zone of different plants (Sible *et al.*, 2021; Lau *et al.*, 2022). Despite these beneficial results, microbial biostimulants may exhibit variable effects in different agricultural products. Therefore, further research is needed to explore specific microbes with specific functions (Khalil *et al.*, 2022).

Overall, biostimulant treatments promoted greater root biomass development compared to the control, with seaweed and mycorrhizae treatments being particularly notable, which show a sustained positive effect throughout the evaluation cycle.

CONCLUSIONS

Mycorrhizae (*Rhizophagus intraradices*) promoted greater growth in height (30 DAS) and root biomass (45 DAS), highlighting their role in early nutrient absorption.

The seaweed extract (AlgaBest®) showed a biphasic effect, stimulated initial root biomass (15 DAS) and root length in advanced stages (75 DAS), associated with its content of humic and fulvic acids and bioactive compounds.

Both biostimulants outperformed the control, confirming their potential as sustainable alternatives for nursery seedling production.

It is recommended to evaluate these treatments under field conditions to validate their persistence and profitability in complete production cycles.

REFERENCES

Arioli, T., Mattner, S. W., Islam, M. T., Tran, T. L. C., Weisser, M., Winberg, P & Cahill, D. M. (2024). Applications of seaweed extracts in agriculture: An Australian perspective. *Journal of Applied Phycology, 36*(2), 713-726. doi.org/10.1007/s10811-023-03120-x

Aroca, R., Porcel, R., & Ruiz-Lozano, J. M. (2007). How does arbuscular mycorrhizal symbiosis regulate root hydraulic properties and plasma membrane aquaporins in *Phaseolus vulgaris* under drought, cold or salinity stresses?. *New Phytologist, 173*(4), 808-816. doi.org/10.1111/j.1469-8137.2006.01961.x

Banakar, S. N., PrasannaKumar, M. K., & Mahesh, H. B. (2022). Red-seaweed biostimulants differentially alleviate the impact of fungicidal stress in rice (*Oryza sativa* L.). *Sci Rep* 12: 5993. doi: 10.1038/s41598-022-10010-8

Behera, B., Supraja, K. V., & Paramasivan, B. (2021). Integrated microalgal biorefinery for the production and application of biostimulants in circular bioeconomy. *Bioresource Technology*, 339, 125588. doi.org/10.1016/j.biortech.2021.125588

Comité Nacional para el Desarrollo Sustentable de la Caña de Azúcar [CONADESUCA]. (2023). La agroindustria de la Caña de Azúcar: Pilar del Desarrollo Productivo en México. (Consultado el 30 de marzo de 2025). Disponible en: https://www.gob.mx/agricultura/sanluispotosi/articulos/la-industria-de-la-cana-de-azucar-pilar-del-desarrollo-productivo-en-mexico-375564?idiom=es

Comité Nacional para el Desarrollo Sustentable de la Caña de Azúcar [CONADESUCA]. (2024). 11° Informe Estadístico del Sector Agroindustrial de la Caña de Azúcar en México, Ciudad de México. 150 pp. Consultado el [26 de marzo de 2024]. Disponible en: https://www.gob.mx/conadesuca/#2953

Del Buono, D. (2021). Can biostimulants be used to mitigate the effect of anthropogenic climate change on agriculture? It is time to respond. *Science of the Total Environment*, 751, 141763. doi.org/10.1016/j.scitotenv.2020.141763

Instituto Nacional de Estadística y Geografía [INEGI]. (2024). Espacio y datos de México. Mapas. Climatología. https://www.inegi.org.mx/app/mapa/espacioydatos/default.aspx?ag=070

Juntaum, S., Ekprasert, J and Boonlue, S. (2022). Efficiency of Arbuscular Mycorrhizal Fungi for the Growth Promotion of Sugarcane Under Pot Conditions. *Sugar Tech* 24, 1738-1747 (2022). https://doi.org/10.1007/s12355-022-01129-z

Khalil, H. A., El-Ansary, D. O., & Ahmed, Z. F. (2022). Mitigation of salinity stress on pomegranate (*Punica granatum* L. cv. Wonderful) plant using salicylic acid foliar spray. *Horticulturae, 8*(5), 375. doi: 10.3390/horticulturae8050375

Khan, A. L., Hussain, J., Al-Harrasi, A., Al-Rawahi, A., & Lee, I. J. (2015). Endophytic fungi: resource for gibberellins and crop abiotic stress resistance. *Critical reviews in biotechnology, 35*(1), 62-74. doi.org/10.3109/07388551.2013.800018

Lau, S. E., Teo, W. F. A., Teoh, E. Y., & Tan, B. C. (2022). Microbiome engineering and plant biostimulants for sustainable crop improvement and mitigation of biotic and abiotic stresses. *Discover Food, 2*(1), 9. doi: 10.1007/s44187-022-00009-5

López-Pérez, A., Colín-García, G., Martínez-Cruz, T. E., & Manuel-Andrés, J. (2022). Mapping Stability and Soil Saturation Indices in the Huehuetan River Basin, Chiapas, Using the SINMAP Model. *Investigaciones geográficas*, (109).. doi.org/10.14350/rig.60586

Moreno, H. M del Rosaio. (2022). Inoculación de hongo micorrízico arbuscular (*Glomus intraradices*) durante la aclimatización de plántulas de caña de azúcar (Tesis Maestría).

Musa, Y., Ridwan, I., Ponto, H., Ala, A., Farid, B. M., Widiayani, N & Yayank, A. R. (2020). Application of Arbuscular Mycorrhizal Fungus (AMF) improves the growth of single-bud sugarcane (*Saccharum officinarum* L.) seedlings from different bud location. *Earth Environ. Sci.* 486. No. 1, p. 012122. DOI 10.1088/1755-1315/486/1/012122

Nardi, S.; Pizzeghello, D.; Schiavon, M.; Ertani, A. Bioestimulantes vegetales: Respuestas fisiológicas inducidas por productos hidrolizados de proteínas y sustancias húmicas en el metabolismo vegetal. *Sci. Agric.* 2016 , 73 , 18-23.

Nephali, L., Piater, L. A., Dubery, I. A., Patterson, V., Huyser, J., Burgess, K., & Tugizimana, F. (2020). Biostimulants for plant growth and mitigation of abiotic stresses: A metabolomics perspective. *Metabolites, 10*(12), 505. doi: 10.3390/metabo10120505

Pissolato, M. D., Cruz, L. P. D., Silveira, N. M., Machado, E. C., & Ribeiro, R. V. (2021). Sugarcane regrowth is dependent on root system size: An approach using young plants grown in nutrient solution. *Bragantia*, 80. doi.org/10.1590/1678-4499.20210039

Rehman, A., Hassan, F., and Qamar, R. (2021). Application of plant growth promoters on sugarcane (*Saccharum officinarum* L.) budchip under subtropical conditions. 10.35495/ajab.2020.03.202

Rouphael, Y.; Colla, G. Acción bioestimulante sinérgica: Diseño de la próxima generación de bioestimulantes vegetales para la agricultura sostenible. *Front. Plant Sci.* 2018, 9, 1655.

Sible, C. N., Seebauer, J. R., & Below, F. E. (2021). Plant biostimulants: A categorical review, their implications for row crop production, and relation to soil health indicators. *Agronomy, 11*(7), 1297. doi: 10.3390/agronomy11071297

Singh, I., Hussain, M., Manjunath, G., Chandra, N., & Ravikanth, G. (2023). Regenerative agriculture augments bacterial community structure for a healthier soil and agriculture. *Frontiers in agronomy*, 5, 1134514. doi.org/10.3389/fagro.2023.1134514

Van Antwerpen, R., Van Heerden, P. D. R., Keeping, M. G., Titshall, L. W., Jumman, A., Tweddle, P. B., & Campbell, P. L. (2022). A review of field management practices impacting root health in sugarcane. *Advances in Agronomy*, 173, 79-162.

Van Tol de Castro, T. A., Tavares, O. C. H., De Oliveira Torchia, D. F., Pereira, E. G., Rodrigues, N. F., Santos, L. A & García, A. C. (2024). Regulation of growth and stress metabolism in rice plants through foliar and root application of seaweed extract from *Kappaphycus alvarezii* (Rhodophyta). *Journal of Applied Phycology, 36*(4), 2295-2310. doi.org/10.1007/s10811-024-03216-y

Yakhin, OI; Lubyanov, AA; Yakhin, IA; Brown, PH. Bioestimulantes en la ciencia vegetal: Una perspectiva global. Portada. *Plant Sci.* 2017, 7, 2049