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Evaluation of sargassum (*Sargassum* spp.) extracts as a method of organic fertilization of sugarcane

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ABSTRACT

Objective: To evaluate the effect of the application of commercial sargassum extract as foliar biofertilizer in sugarcane cultivation.

Design/methodology/approach: Five fertilization treatments were applied in an experimental plot cultivated with sugarcane: Conventional mineral fertilization (T1); Foliar fertilization with 100% sargassum extract (T2); Foliar fertilization with 50% sargassum extract (T3); Conventional mineral fertilization at 50% plus foliar fertilization with 50% sargassum extract (T4); and control without fertilization (T5), in a completely randomized experimental design.

Results: The greatest stem height was observed in the statistically equal treatments T1, T2 and T4, but higher than that of the control. The longest diameter was observed in the T4 treatment, significantly higher than that of the control, in which a statistically lower number of leaves was also observed. The highest field yield was observed in statistically identical treatments T1, T2 and T4, but higher than that found in the control treatment.

Limitations on study/implications: Further evaluation of commercial sargassum extracts applied as foliar fertilizers in crops is considered necessary to corroborate the results presented here. A study of the action mechanisms of the compounds found in sargassum extract on crop physiology, when applied as foliar fertilizers, is also considered necessary.

Findings/conclusions: Commercial sargassum extract is a sustainable alternative for sugarcane biofertilization, which does not pose a risk of chemical contamination like that of conventional mineral fertilization.

Keywords: Biofertilization, sustainability, sargassum, *Saccharum officinarum*, crop yield.

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INTRODUCTION

Sargassum (*Sargassum* spp.) is a holopelagic macroalgae that forms large floating masses in the oceans. In 2011, the first record of a massive arrival of sargassum in the waters of the Mexican Caribbean was made (Ortegón-Aznar and Ávila-Mosqueda, 2020); later, in 2018, some 47 thousand cubic meters of sargassum per kilometer of beach in Quintana Roo arrived on the Mexican coasts, with two types of algae predominating: *Sargassum fluitans* and *Sargassum natans* (Espinosa-Antón *et al.*, 2024). It is speculated that sargassum proliferation is linked to the increase in temperature in marine waters due to climate change and the influx of nutrients from rivers in Africa and Brazil (García, 2019).

Due to its massive arrival, sargassum began to be considered an environmental problem, since it obstructs the entry of the sun's rays to the seabed, preventing the photosynthesis process of species such as phytoplankton, so its population decreases and with it also the species that depend on it (Espinosa-Antón *et al.*, 2024). In order to try to reduce the amount of sargassum, options for its use have been sought; it has been discovered that, with prior treatment, it has the potential for consumption by some animal species (Casas-Valdez *et al.*, 2006); its use in the pharmaceutical area is being evaluated, and it has been used as a fertilizer in crops, mainly vegetables (Salazar-Salazar *et al.*, 2022).

The objective of the study was to evaluate the application of commercial sargassum extract as a foliar biofertilizer in sugarcane, an important crop in the state of Campeche. In 2018, nearly 16,000 ha were dedicated to growing it, an area that increases each year in the state (SADER, 2019). The use of sargassum extract as a foliar fertilizer would have a positive impact on the environment, and simultaneously the costs of fertilizing sugarcane could be reduced.

MATERIALS AND METHODS

Experimental site

The experiment was carried out on a sugarcane plot (variety Mex 69-290) belonging to a cooperating producer from the Villa de Guadalupe ejido, municipality of Champotón, Campeche, at the slashing stage 3. It was harvested in January 2023, and work began in February of the same year. The crop was managed under rainfed conditions. The climate is type AW1 according to the Koëppen classification modified by E. García (García, 1973), with summer rains. The soil of the experimental plot is clayey and deep, vertisol according to FAO, akalché according to the Mayan classification, quite homogeneous throughout the plot, with a slight slope and very slow internal drainage. It cracks when it dries.

Treatments, repetitions and experimental units

The following treatments were evaluated: T1.- Conventional fertilization according to the technological package of the region (160-80-100 NPK); T2.- Fertilization with commercial sargassum extract of the brand "Sarga extra" (Figure 1) applied on the leaves

Figure 1. Commercial sargassum extract evaluated in the experiment.

at a dose of 125 ml in 20 liters of water (manufacturer's recommendation); T3.- Fertilization with commercial sargassum extract applied on the leaves at 50% (62.5 ml in 20 liters of water); T4.- Combined fertilization with chemical fertilizers at a dose of 50%, plus the application of 50% sargassum extract (fertilization formula 80-40-50, mixed with T3); and T5.- Absolute control without fertilization. In T1 and T4, the fertilizers DAP (18-46-00), urea (46-00-00), and potassium chloride (00-00-60) were used, applying them only once at the beginning of the study, like the sugarcane producers in the area. Each treatment had four repetitions. The experimental units (EU) were five furrows, 1.5 m wide and 10 m long, separated by 2 m from each other to avoid the "edge effect". Four applications of the sargassum extract solution were made, on the dates: February 24, May 8, June 22, and August 6, in the morning, when the stomata of plants remain open.

Chemical composition of the sargassum extract

The container of the commercial sargassum extract does not indicate the elements it contains (Figure 1), so a chemical analysis was carried out in the soil, plant and water chemical analysis laboratory of the Tabasco Campus of Colegio de Postgraduados, the results of which are included in Table 1. It has high electrical conductivity and very high concentrations of sodium, potassium and magnesium. The last two can function as macro and microelements for crop nutrition, but sodium can eventually cause toxicity. It has very low concentrations of phosphorus and nitrogen in both its nitric and ammonia forms, so the only macroelement available is potassium. It is important to note that it is in high demand by the sugarcane, a fundamental element for the synthesis of sugar.

Experimental design

The experimental plot showed homogeneity in the soil type, so a completely randomized experimental design (CRD) was used.

Response variables

The height, diameter and number of leaves of the plants were evaluated in the six meters and three central rows of each EU. At the end of the study, when the sugarcane was 12 months old, the yield was evaluated by cutting and weighing the stems from each experimental unit.

Table 1. Chemical properties and elements present in the commercial sargassum extract evaluated in the study.

Chemical property		Element	Concentration (mg L^{-1})	Element	Concentration (mg L^{-1})
pH	3.4	$N\text{-}NO_3$	2.43	Na	2,283.00
CE	11.97 dS m^{-1}	$N\text{-}NH_4$	18.85	Fe	0.526
		P	3.17	Cu	0.033
		K	5,224.00	Zn	0.320
		Ca	240.30	Mn	0.391
		Mg	1,187.00	Cd	0.060

Rainfall

The incidental rainfall on one side of the sugarcane plot was quantified using a pluviometer. The crop was not irrigated, so the water stress to which it was subjected was very intense due to the absence of rainfall during a good part of the vegetative cycle, causing a considerable reduction in the size of the plants and in the final yield in all treatments.

Statistical analysis

The CRD analysis of variance was performed for the response variables ($p=0.05$), using the InfoStat statistical package (InfoStat, 2017). The Shapiro-Wilk normality test of the data was performed, as well as Tukey's multiple means comparison ($p=0.05$) in the variables with significant treatment effects (Tukey, 1991).

RESULTS AND DISCUSSION

Rainfall

Total precipitation was only 1,067.9 mm, insufficient to meet the water needs of sugarcane (between 1,487 and 2,122 mm; Garay Jácome *et al.*, 2022). From January to the end of June, there was practically no rain, a behavior that had not been recorded in recent years in Campeche.

Height

The average height of the plants was statistically the same in all treatments ($p>0.05$) for almost the entire cycle; only at the end of the study there were statistical differences observed, for the last three measurement dates. In these, the height in T1 was always higher, although with statistically similar values to those observed in T2, T3 and T4. For the last measurement date, T1, T2, T3 and T4 were statistically equal, although T3 was statistically equal to the control (Figure 2). The plants grew very little in the months without rain and only began to develop when the soil moisture favored growth, without

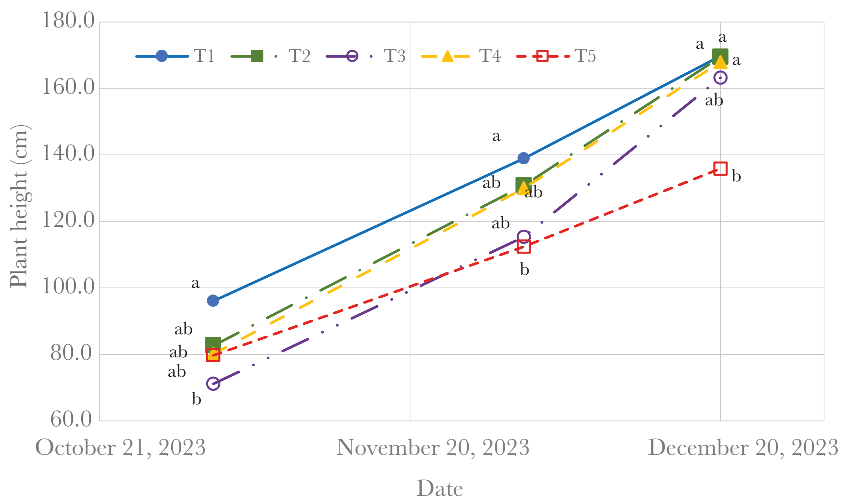

Figure 2. Temporal evolution of sugarcane height for the last three measurement dates in the five treatments. Means with different letters are statistically different (Tukey, $p\leq0.05$).

growing enough: the final average height barely exceeded 169 cm in the treatments with the greatest height, and in the control treatment they only grew 135.9 cm on average.

Stem diameter

No statistical differences were found during practically the entire study. Starting in the month of June, when the rainfall began, the highest values were observed in T1 or T4, although with statistically similar values in all treatments. In every case the diameter was small, barely exceeding two centimeters, because the plants did not have enough moisture to develop. Significant effects were found only on the last measurement date: the thickest stems were observed in T4, 2.44 cm on average, with the lowest value in the control.

Field performance

Statistically equal values and higher than the rest were observed in T1, T2 and T4 (Figure 3). A significantly lower value than the previous ones was observed in T3, and the statistically lowest value was recorded in T5, where the yield was very low due to drought.

No records of studies were found in which the application of sargassum extract had been evaluated in sugarcane, but it has been assessed in other crops and for other uses: Herrera-Monroy (2015) evaluated sargassum as a substrate for the production of jalapeño pepper and tomato seedlings; they concluded that it can be used as a substrate, but its high sodium concentrations limit its use in plants that are not very tolerant to the element. Sariñana-Aldaco *et al.* (2021) evaluated the effect of foliar application of 17 sargassum extracts on the growth of tomato seedlings. One of the extracts increased height, stem diameter, total fresh and dry matter of the seedlings, as well as the content of proteins, glutathione, phenols, flavonoids and antioxidant capacity of the leaves compared to the control. Salazar-Salazar *et al.* (2022) evaluated the effect of foliar application of fertilizers

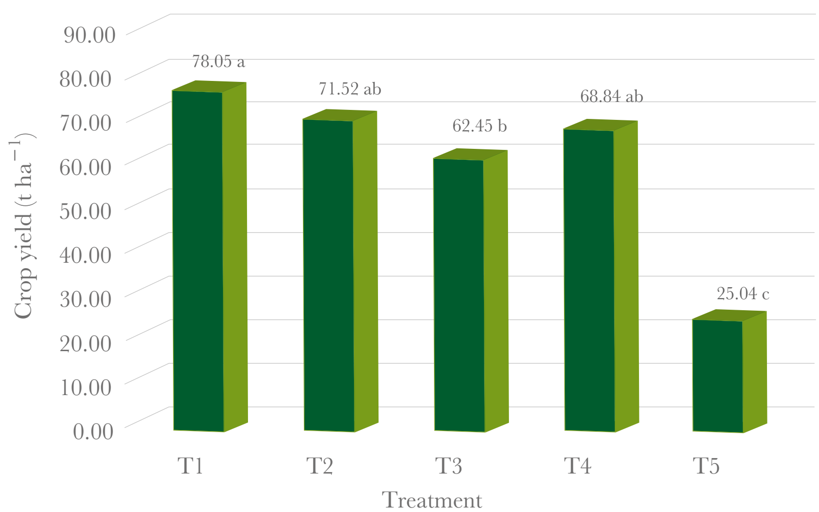

Figure 3. Field sugarcane yield in the evaluated treatments. Means with different letters are statistically different (Tukey, $p \leq 0.05$). T1: conventional fertilization; T2: application of 100% sargassum extract; T3: application of 50% sargassum extract; T4: 50% conventional fertilization plus application of 50% sargassum extract; T5: control treatment.

and sargassum extract on cucumber cv. Modan; with the application of the extract a significantly higher number of commercial and total fruits was obtained, as well as a significantly higher yield.

Although the application of sargassum extract did not significantly improve the growth or yield of the sugarcane obtained, in relation to chemical fertilization, it has the advantage of being of natural origin, so it does not generate the chemical contamination that can be caused by conventional mineral fertilizers. In addition, its use as a biofertilizer contributes to solving the problems of sargassum saturation that have taken place on the beaches of the Mexican Caribbean. Both aspects improve the sustainability of both the sugarcane agroecosystem and the coastal ecosystems. However, it is considered necessary to continue evaluating the effect of the application of commercial sargassum extracts as foliar biofertilizer in different crops, specifically in sugarcane, to corroborate the results presented in this study. Likewise, it is considered important to study the action mechanisms of the compounds present in the sargassum extract on the physiology of crops, when applied as foliar fertilizers.

CONCLUSIONS

The use of commercial sargassum extract as a biofertilizer in sugarcane allowed obtaining statistically equal values in the height and diameter of the stems to those found when conventional mineral fertilization was applied, as well as in the number of leaves in sugarcane, statistically higher than those observed in the control. Regarding the field yield of the cane, it was statistically equal because of the effect of the application of conventional mineral fertilization treatments and foliar sargassum extract (T1, T2 and T4), so the study concludes that commercial sargassum extract is a sustainable alternative for the biofertilization of sugarcane, which does not have the risk of chemical contamination that conventional mineral fertilization represents.

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