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Organic biostimulant from *Sargassum polycystum* promotes vegetative growth and yield in Sweet Corn (*Zea mays* L.)

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Abstract The use of seaweed extracts of *Sargassum polycystum* as an organic biostimulant in sweet corn production is very promising due to its stimulating bioactive compounds. Results showed that foliar application of seaweed extract linearly increased plant height, stem diameter, plant leaf area, leaf greenness level, length of unhusked cob, diameter of unhusked cob, weight of unhusked cob, sweetness level of sweet corn. Further research should be established on using higher concentration of seaweed extract to determine the optimum concentration for increasing yield of sweet corn. In addition, to have more comprehensive understanding of how seaweed extract improves growth and yield of sweet corn it is suggested to evaluate the biochemical changes in the sweet corn.

Keywords: Biostimulant, *Sargassum polycystum*, Seaweed extracts, Sweet corn

Introduction

Sweet corn (*Zea ma*ys var. saccharata) is increasingly in demand by consumers due to its reliable nutritional value and associated health benefits. According to Szymanek (2012), the main hydrocarbon component of sweet corn is starch. In addition, sweet corn kernels' nutritional value is correlated with both their water content (72.7%) and total solids content (27.3%). Meanwhile its hydrocarbons make up 81% of solid components, followed by proteins (13%), lipids (3.5%), and miscellaneous substances (2.5%). It is very imperative to increase sweet corn productivity in Indonesia to meet food needs, food diversification, export potential, agribusiness development, food security, and food resilience. One of practical effort that can be made to increase sweet corn productivity is by using biostimulants derived from natural sources. Natural biostimulants are natural substances or materials intended to stimulate or enhance the biological activity of living organisms (Khan *et al*., 2009).

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Biostimulants are not fertilizers for plants, but are chemical substances that aid in acquiring nutrients, activate processes in the soil or in plants to increase nutrient availability, increase tolerance to abiotic stress, better yields, and better qualities. By using bio-stimulants, plants can encourage physiological processes such as photosynthesis, respiration, nucleic acid synthesis, and ion absorption. Seaweed is one of the flora resources in coastal ecosystems which can be used as a source of a biostimulant for plant growth (Ali *et al*., 2021) since extracts of this plant contain various biostimulating compounds, including carbohydrates, amino acids, phytohormones, osmoprotectants, and proteins (du Jardin, 2015). According to Deolu-Ajayi *et al.* (2022), seaweeds are classified into three major classes, *i.e*. brown Phaeophyta, red Rhodophyta, and green Chlorophyta. The use of seaweed extracts generated form brown seaweed of *Sargassum polycystum* might serve as an organic biostimulant in sweet corn production due to its bioactive compounds. Recently, Widyaswari *et al*. (2024) reported that the primary secondary metabolites of *S. polycystum* are reactive saponins, alkaloids, flavonoids, and phenol hydroquinone.

Biostimulants made from seaweed was reported to increase plant growth, production and quality and increase nutrient consumption (Arioli *et al*., 2015). Seaweed extracts have been applied in many plants to improve plant growth, productivity, and quality (Jacomassi *et al*., 2022). Seaweed extract application was reported to increase growth, yield and nutrient absorption of sweet corn (Pal *et al*., 2015). In addition, the application of seaweed extracts increased growth and yield of cluster bean plant (Vijayanand *et al*., 2014), chilli pepper (Fatimah *et al*., 2018). Recently, Mohammed *et al*. (2023) concluded that the use of seaweed extracts from *S. polycystum* as biofertilizer had been reported to increase growth, yield and antixidant activity of *Vicia faba* and *Helianthus annuus*. Nevertheless, the use *S. polycystum* extracts as biostimulant through foliar application for sweet corn production has been less evaluated. In addition to crop species, fertilizer form, frequency of application and the stage of plant growth, concentration of foliar fertilizer applied to vegetable crops, is among the key factor to determine the effectiveness of foliar application. This study aimed to determine the optimum concentration of seaweed extracts of *S. polycystum* on sweet corn growth and yield.

Materials and methods

Field experiment was conducted from May to July 2024 at Experimental Farm of Agriculture Faculty, University of Bengkulu, Indonesia (3°76'83.2" S and 102°26'89.28" E)), at elevation of approximately 10 m above sea level. The experiment was arranged in complete randomized block design with four replicates. Treatments consisted of five concentration levels of seaweed extracts, i.e. 0, 5, 10, 15, and 20 %.

Experimental land was plowed and harrowed which were conducted at three and two weeks before planting, respectively. A week before planting 20 soil beds (1 m-width x 5.25 m-length x 0.25m-height) were created. Every raised soil bed was separated by 1 m within the block and 1 m away between the blocks. In addition, at a week before planting, land was fertilized with 65 kg ha^{-1} urea, 130 kg ha^{-1} SP-46, and 100 kg ha^{-1} KCl. At 30 days after planting, sweet corns were fertilized with 195 kg ha^{-1} urea.

Fresh seaweed for extracting was collected from Teluk Sepang beach, Bengkulu City (3°56'23.6" S and 102°16'43.2" E). Seaweeds were washed with clean water, and weighed as much as 100 g, then cut into small pieces and put into a blender. The blending result was added with 100 mL of aquadest, and blended again until smooth. This solution was filtered using Whatman filter paper No. 1. The seaweed extract mixture was centrifuged for 5 minutes at a speed of 5,000 rpm. The supernatant produced from centrifugation was put into a falcon tube and stated as an extract with a concentration of 100% (Sunarpi *et al*., 2010).

Sweet corn seeds (*cv*. Bonanza F-1) were manually sown by placing it into 5 cm in depth, at the spacing of 0.75 m x 0.25 to establish 28 plants per plot. In the absence of precipitations, sweet corn was uniformly irrigated as necessary. Manual weeding was conducted at 3 and 8 weeks after planting. Soil around the sweet corn stems was hilled to toughen plant stands. To prevent pest attacks, sweet corns were sprayed Emamektin benzoate 30 g L^{-1} at 3 and 6 weeks after planting. Plants were also uniformly sprayed with Mankozeb 80% at 4 weeks after planting.

Treatments' applications were conducted by spraying the solution of seaweed extract at 2, 4, 6 and 8 weeks after planting with the volume of 50,100, 150, and 200 mL $plant^{-1}$, respectively. Sprayings were conducted in the morning (+/- 08.00 am) during the calm day and the absence of precipitation.

Sweet corn responses to treatments were evaluated in terms of the plant height (cm), stem diameter (mm), plant leaf area (cm^2), and leaf greenness (SPAD), length of unhusked cob (cm), diameter of unhusked cob (mm), weight of unhusked cob (g), and sweetness level (˚Brix) of sweet corn. Data subjected to homogenous test before analysis of variance by using Statistical Analysis System at $P \leq 0.05$. Trends of significant treatment responses were evaluated by using orthogonal polynomial analysis. Weather data includes monthly rain fall, daily air temperatures, daily relative humidity during the experiment were generated from Meteorology, Climatology, and Geophysical Agency Bengkulu (ID WMO: 96255).

Results

Weather conditions

Daily air temperatures recorded on May to Juli 2024 were 28.4, 27.8 and 27.6 °C, with the average monthly rainfall of 245, 194 and 118 mm. In addition, during those months, the averages relative humidity around the experimental site were 87, 86 and 84 %, respectively. Such weather conditions were suitable for sweet corn growth dan development. Accordding to Wright *et al*. (2005), the average air temperatures to support sweet corn development and growth for sweet corn growth were between 24 and 30 °C.

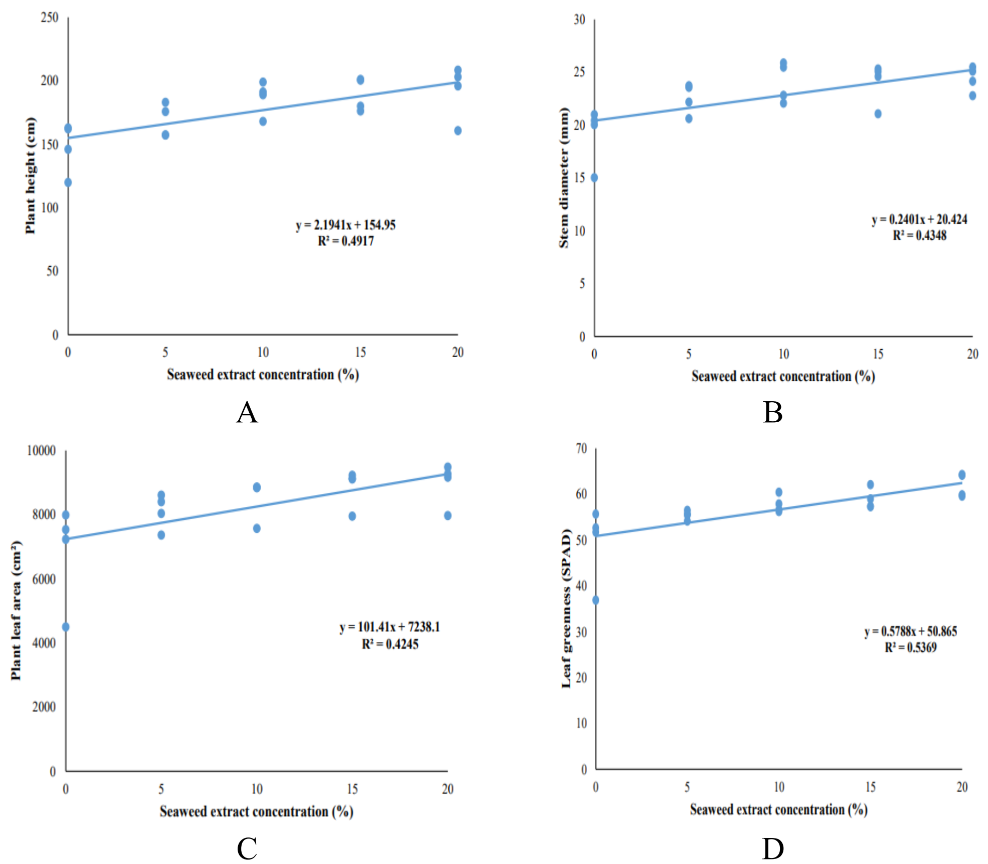

Figure 1. Effects of concentrations of seaweed extracts on plant height [A], stem diameter [B], plant leaf area [C], and leaf greenness [D] of sweet corn

Growth of sweet corn

The application of seaweed extracts significantly affected the plant height, stem diameter, plant leaf area, and leaf greenness of sweet corn. Treatments linearly increased all observed growth variables, the higher the concentrations of seaweed extracts, the higher value of observed variables (Figure 1).

Yield of sweet corn

Similar to growth variables, the application of seaweed extracts significantly affected the length of unhusked cob, diameter of unhusked cob, weight of unhusked cob, and sweetness level of sweet corn. Treatments linearly increased all observed variables of sweet corn yield, the higher the concentrations of seaweed extracts, the higher value of observed variables (Figure 2).

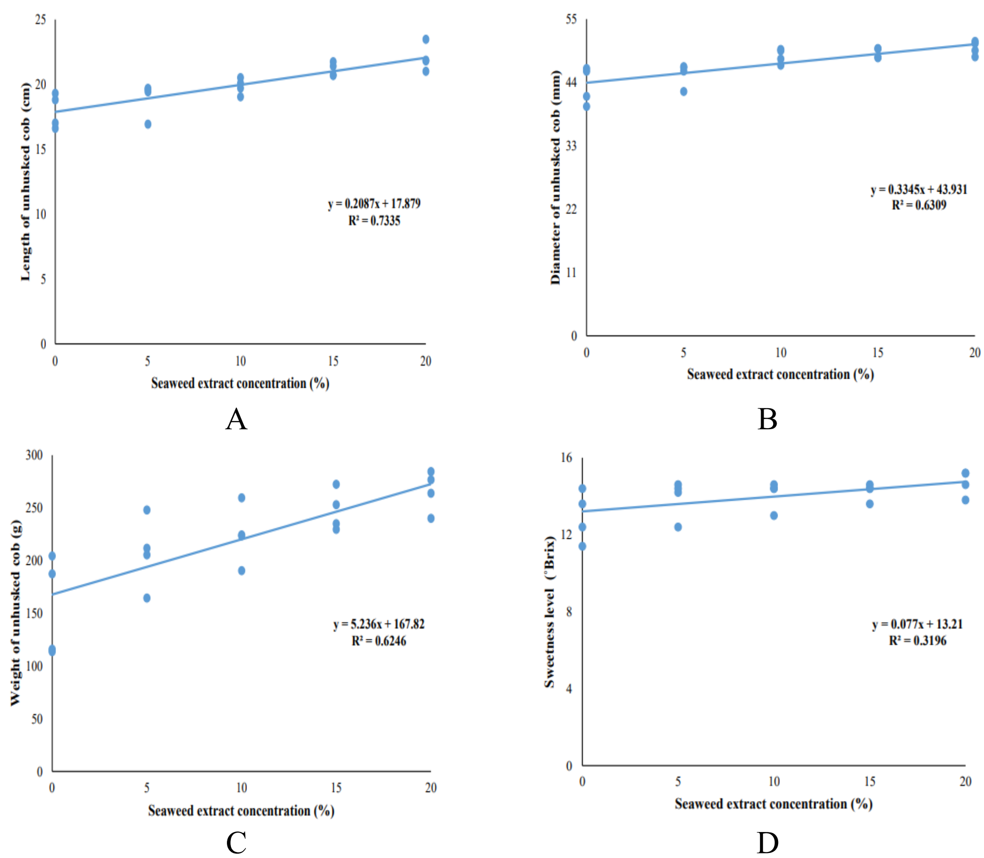

Figure 2. Effects of concentrations of seaweed extracts on length of unhusked cob [A], diameter of unhusked cob [B], weight of unhusked cob [C], and sweetness level [D] of sweet corn

Discussion

The foliar application of seaweed extracts linearly increased plant height (y = 2.1941x + 154.95). This implied that for every increase in the concentration of seaweed extract, plant height increased by 2.2 cm. Plant height is primarily influenced by the apical meristem found at the stem top and root tips. Research conducted by Chen *et al*. (2021) concluded that sugar cane plants sprayed with seaweed extract experienced a significant increase in plant height compared to the control. According to Saragih *et al*. (2013) sweet corn height increased in line with the addition of nitrogen since nitrogen provides sufficient for the plant. In addition, the taller the plant tends to have a larger stem diameter. Increased in stem diameter of sweet corn is very useful to support plant stands. Result indicated that seaweed extract linearly increased stem diameter (y= 0.2401x + 20.424) which implied that if the seaweed extract concentration of 10% and 20%, the stem diameter would be 22.8 mm and 25.2 mm, respectively. Research conducted by Sabh and Shallan (2008) concluded that cross-sections of stems of legume plants treated with seaweed extract increased in the thickness of the epidermis, cortex, cell size and pith compared to the control. Such increased was presumably due to the fact that seaweed extract contains natural growth hormones, especially auxin and cytokinin,) which encourage plant growth through increasing a number of metabolic processes, cell division and enlargement (Ajyaguru *et al*., 2010). Stem diameter is a growth characteristic that has a close relationship with most yield components.

Linearly increased of total leaf area due to application of seaweed extract (y= 101.41x + 7238.1) as presented in Figure 1C inferred that for every single increase of concentration seaweed extract, there will 101.41 cm^2 leaf area increases. Leaf area is a very important trait of plants since it indicates plant potential for photosynthesis and productivity. Research conducted by Ertani *et al.* (2018) concluded that the application of seaweed extract promoted the sweet corn to absorb more micronutrients compared to that of control plant. Increased leaf area was presumably associated with the roles of auxin and cytokinin that presence in the brown seaweed. Increased leaf area will increase absorption and conversion of light energy during the plant photosynthesis to produce more assimilates. Such increased might increase the distribution of photosynthate throughout the plant to support growth of other leaf organs. In addition to leaf area, treatments also linearly increased leaf greenness of sweet corn. The level of leaf greenness generates from SPAD-meter reflects the chlorophyll content of plant leaves, including sweet corn (Kitonga-Mwanza *et al*., 2011). The seaweed extract increased the level of leaf greenness linearly (y= 0.5788x + 50.865). Seaweed extract contains magnesium which is necessary for chlorophyll synthesis (Almaroai and Eissa, 2020). Magnesium is the secondary macronutrients that are essential for plant growth since it is a part of the chlorophyll molecules that responsible in photosynthesis. Generally, the SPAD index could be associated with an increase in nitrogen uptake efficiency and is also an important indicator of leaf chlorophyll biosynthesis and photosynthesis (Mola *et al*., 2020). Overall, the effects of foliar application found in this study were in-line with that of reported by Shivani *et al*. (2025) who concluded that the application of seaweed increased plant height, number of leaves, stem diameter, leaf greenness, and plant dry weight.

The length of the sweet corn unhusked cobs linearly increased due to seaweed extract application (y= 0.2087x + 17.879), indicated that that for every increase in the concentration of seaweed extract, length of unhusked cob increased by 0.21 cm. So did with its diameter of unhusked cob (Figure 2B) which had linear relationship of y= 0.3345x + 43.931. This implied that every increase in the concentration of seaweed extract, diameter of unhusked cob increased by 0.33 mm. Increased length and diameter of unhusked cob of sweet corn will eventually increase the weight of unhusked cob. The linear increased of the weight of unhusked cob, y= 5.236x + 167.82 with the increase of 5.2 g for every increased seaweed concentration. Such increases might have been due to the effects of seaweed extracts on the distribution of photosynthate from vegetative parts (roots, stems, leaves) to developing generative parts of plant (Khan *et al*., 2009), including sweet corn. These findings were in line to Pal *et al*. (2015), who concluded that foliar applications of seaweed extract significantly increased the growth, nutrient uptake, and yield of sweet corn, as well as its B:C ratio parameters. The presence of the hormonal substances in the seaweed extract, especially cytokinin, might be responsible to the yield increases (Vijayanand *et al*., 2014). Increases in weight and size of the sweet corn cob cytokinins might be due to its effects on promoting cell division, nutrient uptakes, photosynthesis and delaying senescence which in turn improving kernel filling (Sosnowski *et al*., 2023). However, sweet corn yields from this experiment ranged from 7.6 to 12.4 tons ha^{-1}, which was lower than potential yield Bonanza F1 variety (14 to 18 tons ha^{-1}). This implied that the concentration of seaweed extract must be increased to achieve the range of yield potential for this variety.

Linear increased the sweetness level of sweet corn (y= 0.077x + 13.21, implied that every single percent increased of seaweed extract will increase the sweetness level by 0.08 °Brix. This result was in line to that of reported by Chen *et al*. (2021) who concluded that application of seaweed extracts increased the sweetness level of sugar cane. Our findings were supported by Shivani *et al.* (2025) who found that the foliar application of seaweed extract to length and diameter of cobs. This experiment also revealed that the application of seaweed extracts linearly increased the percentage of marketable cobs (y=0.011x + 0.69).

It is important to point out that there are several factors that might determine the effectiveness of foliar application of seaweed extract, including concentration, dose, time, method of application and compatibility between the bio-stimulants and the targeted plants. Recently, Fahrurrozi *et al*. (2025) successfully identified the content of photosynthetic pigments, water content, ash content, protein, total fat, total phenol, carbohydrates and 15 types of amino acids in brown seaweed from *S. polycystum*. Those detected amino acids were consisted of seven essential amino acids (L-histidine, L-threonine, L-arginine+tyrosine, L-methionine, L-valine, L-phenylalanine and L-isoleucine) and eight non-essential amino acids (L-aspartic acid, L-glutamic acid, L-serine, L-glutamine, L-glycine, L-alanine, L-leucine and L-lysine). These compounds might have strongly promoted the growth and yield of sweet corn by acting as biostimulants. Nevertheless, to have more comprehensive understanding of how seaweed extract improves growth and yield of sweet corn it is suggested to evaluate the biochemical changes in the sweet corn, such as proline and other biochemistry traits.

In conclusion, the application of seaweed extract to sweet corn plants linearly increased affected the plant height, stem diameter, plant leaf area, leaf greenness, length of unhusked cob, diameter of unhusked cob, weight of unhusked cob, and sweetness level of sweet corn. Further research should be addressed on the use of higher concentrations of seaweed extracts.

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Conflicts of interest

The authors declare no conflict of interest.

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