



## **Response of second ratoon sugarcane *Saccharum officinarum* L. to algae extract added at different growth stages**

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### **Abstract:**

A field experiment was conducted on the second Raton sugarcane variety CP89-2143 from December 3, 2024, until harvest on January 26, 2026, at the Field Crops Research Station, College of Agriculture, University of Diyala. The aim was to determine the interaction between the optimal concentration of algal extract and the optimal growth stage to achieve the highest stem yield, sugar yield, sucrose content, and juice purity. The experiment was conducted according to the Split Plots Design with three replicates. Each replicate was divided into three Main Plots, which are the growth stages (beginning of the tillering stage, beginning of the elongation stage, and beginning of the early maturity stage). Each Main Plot was divided into four Sub Plots, which are the levels of algal extract (1, 2, and 3 mg/L, as well as a control treatment without spraying). The experimental unit area was 6 m<sup>2</sup>, with a distance of 1 m between each experimental unit and 2 m between each replicate. Each experimental unit included four rows, each 2 m long, with a distance of 1 m between each row. The results showed the following:

1.Spraying the algal extract at a concentration of 2 mg/L at the beginning of the elongation stage resulted in the highest increase in the mean of plant height , reaching 75.9 cm, compared to not spraying the algal extract, which recorded 61.6 cm. Meanwhile, the same concentration, but at the beginning of the tillering stage, achieved the highest increase in the mean of total number of stems, reaching 80.3 tillers , compared to not spraying the algal extract, which recorded 44.6 tillers. The same concentration also caused the highest increase in the mean of stem diameter for all growth stages, reaching 4.5, 4.0 and 3.8 cm, compared to the non-spraying of the algal extract, which recorded 2.8, 3.3 and 3.7 cm for the beginning of the tillering , elongation and early maturity stages, respectively. The same concentration of the algal extract at the beginning of the tillering stage also achieved the highest increase in the mean of stem yield, reaching 85.1 tons.ha, compared to the non-spraying of the algal extract, which recorded 50.8 tons.ha, with an increase of 67.6%.

2. Spraying with a concentration of 2 mg/L of algal extract recorded the highest increase in the mean of sucrose percentage during the different growth stages,

reaching 13.0, 13.2, and 15.0%, compared to not spraying with the algal extract, which recorded 10.8, 10.6, and 10.8% for the beginning of the tillering, elongation, and early maturity stages, respectively. Likewise, the same treatments achieved the highest increase in the mean of juice purity percentage, reaching 74.1, 75.2, and 88.3%, compared to not spraying with the algal extract, which recorded 63.8, 59.4, and 61.9% for the beginning of the tillering, elongation, and early maturity stages, respectively.

3. Spraying with the algal extract at a concentration of 2 mg.L at the beginning of the tillering stage achieved the highest increase in mean of sugar yield, reaching 11.1 tons.h compared to not spraying with the algal extract, which recorded 5.6 tons.h, with an increase of 98.2%.

**Keywords:** sugarcane, ratoon, growth stages, algal extract, stem yield, juice purity, sugar yield.

### **Introduction:**

Sugarcane *Saccharum officinarum* L. is a strategic crop for many countries around the world, due to its use in many food and non-food industries. This crop is difficult to grow in most parts of the world, or some countries have a comparative advantage in its production that differs from other countries (Almubarak, 2025). Due to the economic and political conditions that some countries, including Iraq, are going through, local production does not achieve self-sufficiency in sugar.

Sugarcane belongs to the group of plants that are characterized by their high productivity under suitable climatic conditions, and the plant goes through several stages during its growth period from planting to harvesting. The germination stage lasts between 2-3 weeks, with an optimal temperature between 20-25°C. The tillering stage (bud growth) lasts 4-6 weeks from bud germination, with an ideal temperature between 30-35°C. The elongation stage, also called the main growth stage, lasts between 120-150 days, The early ripening stage, which lasts approximately 90 days, involves a gradual decrease in temperatures to allow the neutral

invertase enzyme to convert monosaccharides into sucrose, which then accumulate in the stems. Watering of the crop is also cut off during this stage, starting from mid-October (Almubarak, 2026).

Algal extracts are concentrated natural solutions obtained from seaweed through extraction processes. These extracts are widely used as biostimulants and environmentally friendly organic fertilizers, as they contain bioactive compounds that promote plant growth and improve productivity. They are rich in minerals, vitamins, and amino acids, as well as natural growth regulators such as auxins, cytokinins, and polysaccharides (Khan et al., 2009; Al-Ealayawi and Al-Dulaimy, 2023).

Spraying the algal extract at the beginning of each stage of sugarcane crop growth is for the purpose of determining the appropriate concentration and growth stage that achieves the highest stem yield, sugar yield, best sucrose ratio, and juice purity.

### **Materials and methods:**

A field experiment was conducted on the second Raton sugarcane crop, variety CP89-2143, during the period

from 3/12/2024 until harvest on 26/1/2026 at the Field Crops Research Station - College of Agriculture - University of Diyala, with the aim of knowing the interaction between the best concentration of the algal extract and the best growth stage to achieve the highest yield of stems and sugar yield and the best sucrose ratio and juice purity. The experiment was conducted according to the Split Plots Design with three replicates. Each replicate was divided into three Main Plots, which are the growth stages (beginning of the tillering stage, beginning of the elongation stage, and beginning of the early maturity stage). Each Main Plot was divided into four Sub Plots, which are the levels of algal extract (1, 2, and 3 mg/L, as well as a control treatment without spraying). The experimental unit area was 6 m<sup>2</sup>, with a distance of 1 m between experimental units and 2 m between replicates. Each experimental unit included four rows, each 2 m long, with a distance of 1 m between rows. The algal extract was sprayed early in the morning until the leaves were completely wet. It is an organic fertilizer extracted from two types of marine algae, *Ascophyllum Nodosum* and *Sargassum* sp., consisting of natural growth hormones (gibberellins, auxins, and cytokinins), amino acids, vitamins A, B, C, and E, and major and minor nutrients.

At the end of the maturation stage (270 days after planting), the following characteristics were studied in the plants growing in the two middle rows of each experimental unit, and their average was calculated:

- Stem height (cm): It was measured using a measuring tape from the soil surface to the last node of six plants taken from the midlines of each experimental unit at the beginning of

the tillering, elongation and early maturity stages.

- Total number of stems: The number of stems per square meter of each experimental unit was counted at the beginning of the tillering, elongation, and early maturity stages.

- Stem diameter (cm): This was measured using a Vernia measuring device at three locations: base, middle, and top of the stem. The result was then divided by 3 to obtain the mean of this characteristic for six plants taken from each experimental unit to measure stem height at the beginning of the tillering, elongation, and early maturity stages.

- Stem yield (ton.ha-1): The stem yield was calculated from the weight of the plants within one square meter taken from the two midlines of each experimental unit. It was converted to tons per hectare.

- Percentage of total dissolved solids (Brix %): A drop of juice was taken by pipette into a Brix-hydrometer and the device recorded a representative reading as a percentage of these substances. The process was repeated three times for each sample to ensure the accuracy of the reading. The temperature of the juice was measured at each reading because the device is set to a temperature of 20°C. The reading was then corrected using special tables (Saleh, 1988 and A.O.A.C., 1995).

- Sucrose content in juice (Pol %): 200 ml of juice was taken and placed in a 250 ml glass flask, and 50 g of lead acetate was added to it. After shaking well, the filtration process was carried out. The first 25 ml of the filtrate was disregarded due to the possibility of impurities. After that, 75 ml of the filtrate was taken and placed in a

saccharimeter after ensuring the cleanliness of the sample tube in the device, and the mean of three readings for this characteristic was taken (Saleh, 1988 and A.O.A.C., 1995).

-Juice purity percentage (%):  
Calculated using the following equation:

$$\text{Juice purity (\%)} = \frac{\text{Sucrose percentage}}{\text{Total dissolved solids percentage}} \times 100$$

-Sugar yield (ton ha<sup>-1</sup>): Calculated using the following equation:

$$\text{Sugar yield (ton ha}^{-1}\text{)} = \text{Stem yield per hectare} \times \text{Sucrose percentage}$$

The data were analyzed using the SPSS statistical software, and the Least Significant Difference (LSD) test was chosen to compare the means, at a probability level of 0.05.

## Results and Discussion:

### Total number of stems:

Table 1 shows significant effects between the levels of algal extract and the growth stages of sugarcane, as well as the interaction between them, on the mean of total number of stems. Spraying with the algal extract at a concentration of 2 mg/L resulted in the highest increase in the mean of number of stems at the beginning of the tillering stage, reaching 80.3 tillers.

Table 1: Response of the number of cane stalks of the second ratoon to levels of added algal extract at different growth stages.

Growth stages	Levels of algal extract (mg.L <sup>-1</sup> )				Mean of growth stages
	0	1	2	3	
Tillers	44.6	51.7	80.3	54.8	57.9
Elongation	44.0	44.3	44.3	44.0	44.2
Maturity	44.3	44.3	44.0	44.3	44.3
Mean of algal extract	44.3	46.8	56.2	47.7	
L.S.D 0.05	For the extract 2.8 for growth stages 1.6 for interaction 3.5				

This was followed by the treatments of spraying with the algal extract at concentrations of 3 and 1 mg/L, which recorded a number of tillers of 54.8 and 51.7 tillers, respectively, compared to the control treatment, which recorded 44.6 tillers.

The increase in the mean of total number of stems resulting from spraying the moss extract at the beginning of the tillering stage is probably due to the role of the moss extract in stimulating bud growth, which was reflected positively in the production of a larger number of tillers, which also increased the density of plants per unit area (Merhej et al., 2021). Likewise, the role of the algal extract in enhancing the efficiency of photosynthesis is due to its content of nutrients, which raise the rates of photosynthesis and accelerate the stimulation of buds, leading to an increase in the total number of stems when the crop enters the final stage of maturity (Khan et.al,2009). Al-Sahaf (1989) indicated that seaweed extract contains many essential nutrients for plants that are involved in many vital plant processes such as photosynthesis, respiration, and cellular metabolism, as well as its role in the formation of nucleic acids, enzymes, proteins, and hormones, especially nitrogen, which contributes to increased tillering and vegetative growth.

**Stem height (cm):**

Table 2 data indicates significant interactions between algal extract levels and sugarcane growth stages, as well as their interaction, on mean of stem height. Spraying with 2 mg/L of the algal extract resulted in the greatest increase in mean of stem height across different growth stages, reaching 43.2, 75.9, and 165.4 cm, compared to 32.7, 61.6, and 116.0 cm for the initial tillering, elongation, and early maturity stages, respectively, when the algal extract was not sprayed.

The increase in plant height resulting from spraying the algal

Table 2: Response of plant height (cm) of sugarcane Raton II to levels of added algal extract at different growth stages.

Growth stages	Levels of algal extract (mg.L <sup>1</sup> )				Mean of growth stages
	0	1	2	3	
Tillers	32.7	36.7	43.2	38.0	37.7
Elongation	61.6	63.1	75.9	64.8	66.4
Maturity	116.0	121.3	165.4	125.9	132.2
Mean of algal extract	70.1	73.7	94.8	76.2	
L.S.D 0.05	For the extract 3.9 for growth stages 3.1 for interaction 4.7				

The increase in stem diameter when spraying with the algal extract at the beginning of the growth stages is due to its role in improving growth by increasing the efficiency of photosynthesis and stimulating cell expansion (Khan,2009), or perhaps it is also due to its role in reducing stem height (Table 1) and increasing the number of stems in the plant (Table 2). This is certainly due to the role of the algal extract, which contains a high percentage of minerals, vitamins, and amino acids, as well as natural growth regulators such as auxins, cytokinins, and polysaccharides (Huda et al., 2023). These, in turn, have enabled

extract at this concentration during the growth stages, compared to the control treatment, may be attributed to its effective role in increasing the total number of stems (Table 1). Rizq and Abd Ali (1981) stated that there is an inverse relationship between plant height and the number of tillers, as the higher the plant height, the fewer the number of tillers. The role here is attributed to the algal extract because it contains growth regulators such as auxins, which play an important role in this equation (Al-Ealayawi, and Al-Dulaimy,2023).

**Stem diameter (cm):**

Table 3 data shows significant effects between the levels of algal extract and the growth stages of sugarcane, as well as the interaction between them, on the mean of stem diameter. Spraying with the algal extract at a concentration of 2 mg/L resulted in the highest increase in the mean of this characteristic during the different growth stages, reaching 4.5, 4.0, and 3.8 cm, compared to the control treatment, which recorded 2.8, 3.3, and 3.7 cm for the initial tillering, elongation, and early maturity stages, respectively.

which has been reflected positively in increasing the stem diameter.

plants to store large quantities of nutrients in the various plant tissues,

Table 3: Response of stem diameter (cm) of sugarcane Raton II to levels of added algal extract at different growth stages.

Growth stages	Levels of algal extract (mg.L <sup>1</sup> )				Mean of growth stages
	0	1	2	3	
Tillers	2.8	3.1	4.5	3.2	3.4
Elongation	3.3	3.5	4.0	3.6	3.6
Maturity	3.7	3.7	3.8	3.8	3.8
Mean of algal extract	3.3	3.4	4.1	3.5	
L.S.D 0.05	For the extract 0.6 for growth stages 0.3 for interaction 1.1				

**Stem yield (ton ha<sup>-1</sup>):**

Table 4 data indicates significant interactions between algal extract levels and sugarcane growth stages, as well as their interaction, on mean of stem yield. Spraying with 2 mg/L algal extract resulted in the highest increase in mean of stem yield across different growth stages, reaching 85.1, 61.3, and 59.6 tons ha<sup>-1</sup>, compared to 50.8, 51.0, and 50.7 tons ha<sup>-1</sup> for the initial tillering, elongation, and early maturity

stages, respectively, when the algal extract was not sprayed.

Stem yield is the resultant of increases in both height, number and diameter of stems. Many sources indicate that the increases achieved in the number of stems and in the diameter of stems give a strong and positive indication of an increase in stem yield per unit area (Almubarak et al., 2025).

Table 4: Response of the second ratoon sugarcane stem yield (ton.ha) to levels of algal extract added at different growth stages.

Growth stages	Levels of algal extract (mg.L <sup>1</sup> )				Mean of growth stages
	0	1	2	3	
Tillers	50.8	59.1	85.1	61.0	64.0
Elongation	51.0	53.0	61.3	53.8	54.8
Maturity	50.7	52.3	59.6	52.3	53.7
Mean of algal extract	50.8	54.8	68.7	55.7	
L.S.D 0.05	For the extract 4.9 for growth stages 3.6 for interaction 5.7				

**Sucrose percentage (%):**

Table 5 shows significant interactions between the levels of algal extract and the growth stages of sugarcane, as well as the interaction

between them, in the mean of sucrose percentage. Spraying with the algal extract at a concentration of 2 mg/L resulted in the highest increase in the mean of sucrose percentage during the different growth stages, reaching

13.0%, 13.2%, and 15.0%, compared to 10.8%, 10.6%, and 10.8% for the initial tillering, elongation, and early maturity stages, respectively, when the algal extract was not sprayed.

spraying with algal extract increases the sugar concentration in the juice, as it acts as a natural stimulant or biostimulant rich in plant hormones such as cytokinins, auxins, and gibberellins for their role in improving plant metabolism (Stoskoff, 1989).

This is consistent with many researchers who have indicated that

Table 5: Response of the sucrose content (%) in the second ratoon sugarcane stems to levels of added algal extract at different growth stages.

Growth stages	Levels of algal extract (mg.L <sup>-1</sup> )				Mean of growth stages
	0	1	2	3	
Tillers	10.8	11.0	13.0	11.7	11.7
Elongation	10.6	10.9	13.2	11.1	11.5
Maturity	10.8	11.4	15.0	11.7	12.3
Mean of algal extract	10.7	11.1	13.7	11.5	
L.S.D 0.05	For the extract 0.6 for growth stages 0.4 for interaction 1.3				

**Total dissolved solids percentage (%):**

sugarcane growth stages, nor any interaction between them, on the mean of total dissolved solids percentage

Table 6 data shows no significant effects between algal extract levels and

Table 6: Percentage response of total soluble solids (%) in Raton II sugarcane stems to levels of algal extract added at different growth stages.

Growth stages	Levels of algal extract (mg.L <sup>-1</sup> )				Mean of growth stages
	0	1	2	3	
Tillers	17.0	17.5	17.6	17.6	17.5
Elongation	17.9	17.4	17.6	17.2	17.6
Maturity	17.5	17.1	17.0	17.0	17.2
Mean of algal extract	17.5	17.3	17.4	17.3	
L.S.D 0.05	For the extract NS for growth stages NS for interaction NS				

**Juice Purity Percentage (%):**

mean of juice purity across different growth stages, reaching 74.1%, 75.2%, and 88.3%, compared to 63.8%, 59.4%, and 61.9% for the initial tillering, elongation, and early maturity stages, respectively, when the extract was not sprayed.

Table 7 data indicates significant interactions between algal extract levels and sugarcane growth stages, as well as their interaction, on the mean of juice purity percentage. Spraying with 2 mg/L of the algal extract resulted in the highest increase in the

This is probably mainly due to the role of the algal extract in raising the sucrose content in the juice (Table 5) without affecting the percentage of total soluble solids in the juice (Table 6), which was reflected positively in

increasing the purity, in addition to the role of the algal extract in improving the quality and purity, as it helps to raise the polarity and purity of sugarcane juice (Nabti et al., 2017).

Table 7: Response of juice purity percentage (%) in Raton II sugarcane stalks to levels of algal extract added at different growth stages.

Growth stages	Levels of algal extract (mg.L <sup>1</sup> )				Mean of growth stages
	0	1	2	3	
Tillers	63.8	63.1	74.1	66.7	66.9
Elongation	59.4	62.7	75.2	64.7	65.5
Maturity	61.9	66.8	88.3	70.0	71.8
Mean of algal extract	61.7	64.2	79.2	67.1	
L.S.D 0.05	For the extract 4.9 for growth stages 3.7 for interaction 6.8				

#### Sugar yield (ton. ha<sup>-1</sup>):

Table 8 data indicates significant interactions between algal extract levels and sugarcane growth stages, as well as the interaction between these factors, on mean of sugar yield. Spraying with the algal extract at a concentration of 2 mg/L resulted in the highest increase in mean of sugar yield across different growth stages, reaching 11.1, 8.1, and 9.1 tons ha<sup>-1</sup>, compared to 5.6, 5.5, and 5.6 tons ha<sup>-1</sup> for the tillering, elongation, and early maturity stages respectively.

The clear increase in sugar yield resulting from the role of the algal extract may be due to its role in increasing stem yield (Table 4) and raising the sucrose ratio (Table 5), which was reflected positively and clearly in raising the sugar yield. Spraying the algal extract on plants is considered one of the effective agricultural practices to enhance crop quality and increase sugar productivity (Al-Ealayawi and Al-Dulaimy, 2023).

Table 8: Response of sugar yield (ton.ha) in Raton II sugarcane stems to levels of algal extract added at different growth stages.

Growth stages	Levels of algal extract (mg.L <sup>1</sup> )				Mean of growth stages
	0	1	2	3	
Tillers	5.6	6.6	11.1	7.2	7.7
Elongation	5.5	5.8	8.1	6.0	6.4
Maturity	5.6	6.1	9.1	6.2	6.8
Mean of algal extract	5.6	6.2	9.4	6.5	
L.S.D 0.05	For the extract 0.8 for growth stages 0.5 for interaction 2.6				

We conclude from the current study that spraying the algal extract at a concentration of 2 mg/L at the beginning of the tillering stage gives it the highest number of stems per unit area and the highest stem diameter, as well as its role in increasing stem yield by an increase of 67.6% and the highest sugar yield by an increase of 98.2%.

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