

Effect of growth retardants and stimulants added at the beginning of the tillering stage on some growth traits and stem yield of three sugarcane varieties.

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Abstract :

A field experiment was conducted in mid-March 2024 at the Research Station of the Department of Field Crops Sciences, College of Agriculture, University of Diyala, to determine the response of three varieties of sugarcane –First raton to growth retardants and stimulants. American varieties grown on a sugarcane farm in Maysan Governorate, Republic of Iraq, in 2004. Then, some stems of each of these varieties were transferred and planted in a number of areas in Diyala Governorate and in 14 other governorates in the central, southern and northern regions of Iraq during the period from 2016 to 2025. The growth retardant ethephon was used at a concentration of 2000 mg/L¹ and the growth promoter gibberellin at a concentration of 200 mg/L¹. The spraying process was carried out at the beginning of the tillering stage on March 16, 2024. The experiment included nine treatments. The area allocated for the experimental plot was divided according to a split-plot design with three replicates. The main plots included three treatments, namely the varieties (CP89-2143, CP81-325, and CP72-2086), While the secondary plots included three treatments, namely growth retardants and stimulants (Ethephon and gibberellins, in addition to the control treatment using only distilled water). The most important results showed the following:

-The addition of ethephon to the CP89-2143 variety achieved the highest significant increase in the mean of number of tillers , reaching 59.7 tillers .m², while the addition of gibberellin to the same variety recorded the lowest number, reaching 38.7 tillers .m², compared to the control treatment for the same variety, which recorded 47.3 tillers .m².

-The treatment of adding ethephon to the CP89-2143 variety achieved the highest increase in the mean of leaf area index, which amounted to 1.5, while the treatment of adding gibberellin to the CP89-2143 and CP72-2086 varieties recorded the lowest decrease, which amounted to 0.9 compared to the two varieties, which recorded 1.2 and 1.1, respectively.

-The treatment of adding ethephon to all varieties achieved the highest increase in the mean of stem yield, reaching 92.8, 89.0 and 84.5 tons.ha¹ for varieties CP89-2143, CP72-2086 and CP81-325, compared to the control treatment, which recorded 54.6, 52.0 and 49.9 tons.ha¹, respectively.

Keywords: sugarcane, varieties, growth retardants, growth stimulants , growth traits, stem yield

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Introduction:

Sugarcane *Saccharum officinarum* L. is a perennial tropical and subtropical crop. It is a grass crop that remains in the ground for a long time and produces abundant stems and leaves. Sugarcane is used in many industries, including sugar, biofuel, animal feed, paper, organic fertilizer, biochar, the manufacture of textiles (rayon), plastics, wood (such as MDF and HDF panels), in the perfume and pharmaceutical industries. In the sugarcane industry as an alternative to concrete, the fresh juice industry with medicinal benefits, the wax and yeast industry, the natural food industry for bee colonies, It produces the best material for stabilizing sand dunes, and is used in the ceramics, glass, electronic chips, solar cells, cosmetics, and other industries [4].

Variety is the cheapest technique for enhancing sugarcane productivity, as sugarcane varieties vary in achieving the highest height, stem diameter, number of tillers and leaf area depending on environmental factors [6]. The high quality specifications of the varieties have played a major role in expanding the areas planted with the crop.

It is known that sugarcane plants enter the tillering stage within a short period of time depending on the appropriate temperatures for tillering during that period, which do not exceed 30°C [19], then it will move to the elongation stage, because the crop's productivity depends on the number of tillers that later turn into extractable stems and the height and diameter of the stems, the idea of using growth retardants and stimulants at the beginning of the tillering stage came to

achieve the goal of the study, to evaluate the ability of the varieties used in the experiment to tolerate environmental variations and to determine the best growth regulator, whether it is a growth retardant or a growth stimulant, and the most suitable varieties to obtain the highest number of tillers, the best height and diameter of the stems, the largest leaf area, and the reflection of this effect in increasing the stems yield per unit area.

Materials and methods:

In mid-March 2024, a field experiment was conducted at the Research Station of the Department of Field Crops Sciences, College of Agriculture, University of Diyala, in a mixed clay soil with a salinity of 41.6 dSm¹ and pH 7.12, to determine the response of three sugarcane varieties to growth retardants and stimulants. American varieties were planted in a sugarcane farm in Maysan Governorate, Republic of Iraq, in 2004. Then, some stems of each of these varieties were transferred and planted in some of the areas in Diyala Governorate and in 14 governorates within the central, southern and northern regions of Iraq during the period from 2016 to 2025 [5]. The spraying process of the vehicles was carried out at the beginning of the tillering stage on March 16, 2024. The experiment included nine treatments. The area allocated for the experiment was divided according to a split-plot design with three replicates. The main plots included three treatments, namely the varieties (CP89-2143, CP81-325, and CP72-2086), while the secondary plots included three treatments, namely growth retardants and stimulants (ethephon and gibberellins), in addition to a control treatment using only distilled water. Ethephon was used

at a concentration of 2000 mg/L¹ and gibberellin at a concentration of 200 mg/L¹. The area of the experimental unit was 9 m², the distance between one experimental unit and another was 1 m, and the distance between one replicate and another was 2 m. The experimental land was irrigated using a drip irrigation system as needed at intervals ranging from 7 to 10 days until mid-October 2024, when irrigation was stopped in preparation for the harvest, which took place on December 23, 2025.

Data were recorded for a number of important growth traits in plants growing in the two medians of each experimental unit and their averages were calculated as follows:

-Stem height (cm): Measured using a measuring tape from the soil surface to the last node.

-Number of tillers: The tillers were counted for one square meter of each experimental unit.

-Stem diameter (cm): Measured using a Vernia measuring instrument from three locations, at the base, middle and top of the stem, and divided by 3 to obtain the mean of this characteristic.

-Number of green leaves: Leaves were counted from the same plants that were taken to measure stem height and diameter.

-Leaf area (cm²/plant¹): The length and width of each leaf of each plant were measured, and then the leaf area was calculated according to the following equation:

Leaf area = leaf length x maximum leaf width x 0.6274 [8.]

-Leaf area index: It was calculated by dividing the leaf area by the area of land occupied by the plant [15] , where the area of land occupied by the plant was calculated in cm².

-Stem yield (tons. h¹): The stems were harvested using special knives for this purpose from the two middle lines after cutting the growing tip of the plants (topping). The harvested stems were then collected and their weight was measured using a special scale prepared for this purpose and the quantity was converted into (tons. h¹).

The data were analyzed according to the analysis of variance method for a factorial experiment with a split-plot design using the statistical program (SPSS). The least significant difference (LSD) test was used to compare the means at a probability level of 0.05.

Results and discussion:

.1 Stem height.

The results in Table 1 indicate that there were effects between varieties, growth retardants and stimulants, and interactions between them in the mean of stem height. The CP81-325 variety caused a significant increase, reaching 212.0 cm, and did not differ significantly from the CP89-2143 variety, which recorded 211.7 cm, compared to the CP72-2086 variety, which recorded 210.6 cm.

Regarding growth retardants and stimulants , the use of gibberellin led to a significant increase in the mean of this trait, reaching 228.2 cm, while ethephon recorded a significant decrease, reaching 196.3 cm compared to the control treatment, which recorded 209.8 cm. As for the interaction, the

treatment of adding gibberellin to the CP89-2143 variety achieved the highest increase, reaching 231.0 cm, while the treatment of adding ethephon to the same variety recorded the lowest decrease, reaching 192.8 cm, compared to the control treatment for the same variety, which recorded 211.4 cm.

Reducing stem height by using ethephon may be due to the role of ethylene released from it in plant tissues in inhibiting the transfer of auxin in stem tissues, which causes a decrease in its ability to stimulate stem elongation and inhibit the growth of buds that form tillers. This is what [20] showed.

The increase in plant height due to gibberellins may be due to the mutual action between the gibberellins used and the natural internal auxin present in the plant, as gibberellins affect cell elongation by increasing the level of internal auxin as a result of its effect either on the process of auxin synthesis or on the process of preventing its oxidation. Some studies have shown that IAA increases the absorption of nutrients within plant tissues, which causes increased plant growth [12. [

Table 1: Effect of growth retardants and stimulants on the mean of the stem height (cm) for sugarcane varieties.

Varieties	growth retardants and stimulates			Mean of Varieties
	Ethephon	Gibberellin	Control	
CP89-2143	192.8	231.0	211.4	211.7
CP81-325	200.5	225.9	209.6	212.0
CP72-2086	195.7	227.8	208.4	210.6
Mean of retardants and stimulates	196.3	228.2	209.8	
L.S.D 0.05	Varieties 0.937 retardants and stimulates 0.937 interaction 4.063			

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Number of tillers:

The results in Table 2 show significant effects between the varieties, growth retardants and stimulants, and the interaction between them in the mean of number of tillers. the use of the CP89-2143 variety resulted in an increase in the mean of this trait, reaching 48.6 tillers per m², while the CP72-2086 variety recorded a significant decrease, reaching 45.2 tillers per m². regarding growth retardants and stimulants

, ethephon recorded a significant increase, reaching 55.3 tillers per m², while gibberellin recorded a significant decrease in the mean of this trait, reaching 40.2 tillers per m² compared to the control treatment, which recorded 44.8 tillers per m². as for the interaction, the treatment of adding ethephon to the CP89-2143 variety achieved the highest significant increase, reaching 59.7 tillers. m², while the treatment of adding gibberellin to the same variety recorded the lowest number,

reaching 38.7 tillers . m² compared to the control treatment for the same variety, which recorded 47.3 tillers. m².

The superiority of the CP89-2143 variety in the mean of this trait by giving the highest mean of number of tillers is evidence that it is more efficient in exploiting genetic and physiological capabilities. [1] indicated that the number of tillers is affected by the genetic factor and the surrounding environmental factors.

The increase in the number of tillers caused by ethephon may be due to its role in hindering the elongation of the main stem and its subsidiary tillers , which caused the stimulation of the growth and development of the subsequent tillers of the main stem due to the competition for nutrients between it and the tillers formed later [2] . [10] noted that

plants treated with growth retardants had more erect leaves and thus improved light penetration, resulting in a higher density of stems formed later.

The decrease in the number of branches resulting from the use of the growth stimulant gibberellin for the CP89-2143 variety may be due to its role in increasing the elongation of the primary stem (Table 1) by increasing the level of internal auxin, which is mainly concentrated in the terminal bud, when this auxin is transferred through the stem to the lateral buds, it causes a relatively large increase in the concentration of auxins within the tissues of the lateral buds, thus inhibiting their growth [7] . These results may also agree with what [9] indicated about the existence of an inverse relationship sometimes between the number of tillers of sugarcane plants and the height of their plants.

Table 2: Effect of growth retardants and stimulants on the mean of the no. of tillers for sugarcane varieties.

Varieties	growth retardants and stimulates			Mean of Varieties
	Ethephon	Gibberellin	Control	
CP89-2143	59.7	38.7	47.3	48.6
CP81-325	54.0	42.7	43.0	46.6
CP72-2086	52.3	39.3	44.0	45.2
Mean of retardants and stimulates	55.3	40.2	44.8	
L.S.D 0.05	Varieties 0.885 retardants and stimulates 0.885 interaction 4.168			

.3Stem diameter:

The results in Table 3 indicate significant differences between varieties, growth retardants and stimulants, and their interaction in the mean of stem diameter. The use of CP89-2143 variety resulted in a significant increase in the mean of this trait, and it did not differ significantly from CP72-2086 variety,

which reached 2.9 cm for each, compared to CP81-325 variety, which recorded a stem diameter of 2.8 cm. Regarding growth retardants and stimulants, ethephon caused a significant increase in the mean of this trait, reaching 3.5 cm, while gibberellin recorded a significant decrease, reaching 2.2 cm compared to the control treatment, which recorded 2.8 cm. As for the interaction, the treatment of adding ethephon to all varieties CP89-2143, CP81-325 and CP72-2086

achieved the highest increase in the mean of stem diameter, which reached 3.6, 3.5 and 3.5 cm compared to the control treatment for the same varieties, which recorded 2.6, 2.8 and 3.0 cm, respectively. The increase in the mean of stem diameter by adding ethephon may be due to its role in reducing the mean of stem height (Table 1), in addition to its contribution to increasing the thickness and hardness of the

stem internodes, especially the lower ones. [21] showed that the ethylene released from ethephon may stimulate the activity of the enzymes responsible for producing lignin, which increased the thickness and hardness of the stem internodes, especially the lower ones, which caused an increase in the mean of stem diameter.

Table 3: Effect of growth retardants and stimulants on the mean of the stem diameter (cm) for sugarcane varieties.

Varieties	growth retardants and stimulantes			Mean of Varieties
	Ethephon	Gibberellin	Control	
CP89-2143	3.6	2.4	2.6	2.9
CP81-325	3.5	2.2	2.8	2.8
CP72-2086	3.5	2.1	3.0	2.9
Mean of retardants and stimulantes	3.5	2.2	2.8	
L.S.D 0.05	Varieties 0.087 retardants and stimulantes 0.087 interaction 1.201			

Number of green leaves :

varieties and growth retardants and stimulants, and that there was an interaction between them on the mean of number of green leaves.

It is noted from the results of Table 4 that there were no significant effects between the

Table 4: Effect of growth retardants and stimulants on the mean of no. of green leaves for sugarcane varieties.

Varieties	growth retardants and stimulantes			Mean of Varieties
	Ethephon	Gibberellin	Control	
CP89-2143	12.3	12.3	12.0	12.2
CP81-325	11.7	12.0	11.0	11.6
CP72-2086	12.0	11.7	11.7	11.8
Mean of retardants and stimulantes	12.0	12.0	11.6	
L.S.D 0.05	Varieties NS retardants and stimulantes NS interaction NS			

.5Leaf area:

The results in Table 5 show significant effects between varieties, growth retardants and stimulants, and their interaction on mean of leaf area. The use of CP89-2143 variety resulted in an increase in the mean of this trait, reaching 250.2 cm², while CP81-325 variety recorded the lowest mean, reaching 238.3 cm². These results are consistent with the findings of [17], who noted that varieties differed in the mean of leaf area trait.

Regarding growth retardants and stimulants, the use of ethephon led to a significant

increase in the mean of this trait, reaching 250.9 cm², while gibberellin recorded a significant decrease, reaching 238.9 cm² compared to the control treatment, which recorded 243.9 cm². As for the interaction, the treatment of adding ethephon to the CP89-2143 variety achieved the highest increase in the mean of this trait, as it reached 259.8 cm² compared to the control treatment for the same variety, which recorded 248.3 cm². The treatment of adding gibberellin to the CP81-325 variety also recorded the lowest decrease, reaching 233.8 cm² compared to the control treatment, which recorded 239.9 cm².

Table 5: Effect of growth retardants and stimulants on the mean of leaf area (cm²) for sugarcane varieties.

Varieties	growth retardants and stimulants			Mean of Varieties
	Ethephon	Gibberellin	Control	
CP89-2143	259.8	242.4	248.3	250.2
CP81-325	241.1	233.8	239.9	238.3
CP72-2086	251.7	240.6	243.5	245.3
Mean of retardants and stimulates	250.9	238.9	243.9	
L.S.D 0.05	Varieties 1.311	retardants and stimulates 1.311	interaction 6.194	

.6Area of land occupied by the plant (cm²):

The results of Table 6 show significant differences between varieties, growth retardants and stimulants, and their interaction in the mean of area occupied by the plant. The use of CP72-2086 variety resulted in an increase in the mean of area of this trait, reaching 225.3 cm², while CP89-2143 variety recorded a decrease in the mean, reaching 215.2 cm².

Regarding growth retardants and stimulants, the treatment of adding gibberellin recorded a significant increase in the mean of this trait, reaching 252.6 cm², while the treatment of adding ethephon recorded a significant decrease, reaching 182.3 cm² compared to the control treatment, which recorded 224.1 cm². As for the interaction, the use of gibberellin for the CP89-2143 variety resulted in the highest area of land occupied by the plant, reaching 263.4 cm², while the treatment of adding ethephon to the same variety recorded

the lowest decrease, reaching 169.6 cm² recorded 212.5 cm².
compared to the control treatment, which

Table 6: Effect of growth retardants and stimulants on the mean of the area of land occupied by the plant (cm²) for sugarcane varieties.

Varieties	growth retardants and stimulates			Mean of Varieties
	Ethephon	Gibberellin	Control	
CP89-2143	169.6	263.4	212.5	215.2
CP81-325	185.0	238.2	232.7	218.6
CP72-2086	192.4	256.3	227.1	225.3
Mean of retardants and stimulates	182.3	252.6	224.1	
L.S.D 0.05	Varieties 1.502 retardants and stimulates 1.502 interaction 5.667			

.7Leaf area index:

The results of Table 7 show that there were significant differences in the interaction between the varieties and the growth retardants and stimulants, while there were no significant effects between the varieties or between the growth retardants and stimulants in the mean of leaf area index. The treatment of adding ethephon to the CP89-2143 variety achieved the highest increase of 1.5, while the treatment of adding gibberellin to the CP89-2143 and CP72-2086 varieties recorded the lowest decrease of 0.9 compared to the two varieties that recorded 1.2 and 1.1, respectively.

The increase in leaf area index by using ethephon for the CP89-2143 variety may be due to its role in increasing leaf area (Table 5), reducing the land area occupied by the plant (Table 6), and increasing the number of tillers per unit area (Table 2). The decrease in the leaf area index by using gibberellin for the same variety CP89-2143 may be due to its role in reducing the leaf area, increasing the area of land occupied by the plant, and reducing the number of tillers per unit area. The leaf area index indicates the ratio of leaf area to the land area occupied by the plant. [3] noted that the leaf area index may change with changes in the number of plants per square meter and the distance between lines.

Table 7: Effect of growth retardants and stimulants on the mean of leaf area index for sugarcane varieties.

Varieties	growth retardants and stimulates			Mean of Varieties
	Ethephon	Gibberellin	Control	
CP89-2143	1.5	0.9	1.2	1.2
CP81-325	1.3	1.0	1.0	1.1
CP72-2086	1.3	0.9	1.1	1.1
Mean of retardants and stimulates	1.4	0.9	1.1	
L.S.D 0.05	Varieties NS retardants and stimulates NS interaction			0.497

.8Stem yield (tons.h¹):(

The results of Table 8 show significant effects between varieties, growth retardants and stimulants, and their interaction on the mean of stem yield. The use of CP89-2143 variety resulted in an increase in the mean of this trait, amounting to 73.7 tons.ha¹, while CP81-325 variety recorded a decrease in the mean , amounting to 68.4 tons.ha¹. [14] indicated that the genetic compositions of the varieties differed among themselves in the mean of stem yield trait.

Regarding growth retardants and stimulants , the addition of ethephon caused a significant increase, reaching 88.8 tons ha¹ compared to the control treatment, which recorded 52.2 tons ha¹. As for the interaction, the treatment of adding ethephon to the CP89-2143 variety achieved the highest increase in the mean of this trait, amounting to 92.8 tons.ha¹, compared to the control treatment, which amounted to 54.6 tons.ha¹, while the control treatment for the CP81-325 variety recorded the lowest decrease, amounting to 49.9 tons.ha¹.

The increase in stem yield achieved by adding the growth retardant ethephon to the CP89-2143 variety may be attributed to its role in stimulating early tillering and giving newly formed tillers sufficient time for full growth and development [11] , this has led to a large portion of the nutrients being available to the newly formed tillers , which has made the utilization of these nutrients equal between the tillers and made them more similar and homogeneous in the plants treated with these compounds. Consequently, this has led to these tillers being, at the end of the crop's growth, stems that are extractable and heavier in weight. [18] indicated that primary stems vary in weight and juice richness depending on their age, which may have a positive effect on the stem yield of the crop .

The increase in stem yield achieved from the use of the growth stimulant gibberellin may be attributed to its role in drawing the nutritional stores present in the plant organs to the primary stem and secondary stems, making them extractable and heavier stems, which was positively reflected in the stem yield of the crop. [16] pointed out that the growth stimulant gibberellin works to pull nutrients

from the leaves to the stem in a process known as remobilization. [13] also indicated that gibberellin accelerates the conversion of tryptophan to IAA, and the latter increases the absorption of mineral elements from the soil

or increases the manufacture of nutrients within the plant tissues [12] , which is positively reflected in the stem yield of the crop.

Table 8: Effect of growth retardants and stimulants on the mean of stem yield (tons.ha¹) for sugarcane varieties.

Varieties	growth retardants and stimulates			Mean of Varieties
	Ethephon	Gibberellin	Control	
CP89-2143	92.8	73.7	54.6	73.7
CP81-325	84.5	70.7	49.9	68.4
CP72-2086	89.0	71.2	52.0	70.7
Mean of retardants and stimulates	88.8	71.9	52.2	
L.S.D 0.05	Varieties 2.602 retardants and stimulates 2.602 interaction 3.558			

Conclusion:

We conclude from the current study that it is possible to add ethephon to the CP89-2143 variety at the beginning of the tillering stage to achieve the highest increase in each of the

number of tillers, stem diameter, leaf area and leaf area index, which was positively reflected in giving the highest increase in stem yield with an increase rate of 70%.

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