# Response of sugarcane cultivars (Saccharum officinarum L.) to foliar nutrition with nano fertilizer under drip irrigation technology

Amjad Shaker Hamoud Al-Bawi
Ministry of Education, Diyala Education Directorate, School of Abdul Mohsen Al-Kazemi for Boys
E-mail : amjed bio 10@gmail.com

**Abstract**
A field study on the sugarcane (Saccharum officinarum L.) was carried out using the Randomized Complete Block Design (RCBD) with three replicates. in Diyala Governorate, Muqdadiyah District, Abu Saida Sub-district, Abu Saba'a Village, which is 60 km northeast of Baqubah City during the spring season 2023-2024. It was implemented starting from March 1, 2023, to evaluate the effect of three levels of nano fertilizer (1, 2, and 3 liters h-1 in addition to the control treatment) on four American inputs: CP72-2086, CP89-2143, CP81-325, and LO3-371 under drip irrigation technology, and they were added after germination and in three times in the months of April, June, and September. The inputs CP81-325 and LO3-371 were superior in plant dry weight with an average of 584.33 and 549.29 g plant-1, respectively. The cultivars CP89-2143, CP81-325, and CP72-2086 were superior in the sucrose percentage in juice with an average of 14.91, 14.40, and 13.99%, respectively. The concentrations of 3 and 2 L ha-1 were superior in the dry weight of the plant, with an average of 644.75 and 633.41 g plant-1, respectively. The concentration of 3 L ha-1 was superior with a significant increase in the stem yield (ton ha-1) with an average of 229.67 tons ha-1 compared to the concentrations of 2 and 1 L ha-1.The results showed significant differences between all interactions between cultivars and concentrations in most of the studied traits compared to the control .

**Keywords: sugarcane, cultivars, nano fertilizer**

## Introduction

Sugarcane (Saccharum officinarum L.) is a perennial tropical and subtropical crop grown in different parts of the world in north latitude = 0350 C and south latitude = 0350 C around the world [9]. In Pakistan, sugarcane is a cash and industrial crop and is grown on an area of 1217 thousand hectares with an annual production of 73.6 million tons [6]. The cultivation of early-maturing cultivars characterized by high productivity and good quality (with high sugar concentration) in addition to medium-maturing cultivars such as C0976C0331 in the sugarcane farm will change the harvest date to late October and early November instead of mid-December, thus keeping us away from the rainy season and its negative effects. In addition to that, early harvest has other positive aspects for the next year's crop because sugarcane is a perennial crop and remains in the field for several years, so the harvest takes place when the soil is dry, as the passage of heavy machinery does not compress it and raise its apparent density as happens when harvesting during the rainy season. Therefore, introducing early maturing varieties will cause a boom in increasing the quantities of sugarcane supplied to the factory and the sugar production [23]. Nanotechnology is the technology of materials or very small particles, and it is a promising technology that promises tremendous development in various branches of science [19]. Nano materials, with dimensions ranging from 1 to 100 nanometers,

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exhibit different properties compared to their traditional state. Reducing their size to the nanoscale is a scientific revolution, achieved by rearranging atoms and molecules[7].Nanotechnology, capable of creating very small particles, offers significant benefits over regular particles. Its applications span various fields, including agriculture, where nano fertilizers are used to enhance soil properties and plant health [19]. Nano fertilizers have unique properties due to their small size and large surface area, which leads to an increase in the absorption surface and thus increases the photosynthesis process and thus increases production in the plant [21]. And effective management of water resources is the key to the sustainability and profitability of the crop, thus encouraging the development of new techniques for analyzing and managing water efficiently [8]. This study aims to evaluate the effect of three levels of nano fertilizer on four American cultivars of sugarcane.

Materials and methods

A field experiment was conducted according to the Randomized Complete Block Design (RCBD) with three replicates on sugarcane Saccharum officinarum L. in Diyala Governorate, Al-Muqdadiyah District, Abu Saida Subdistrict, Abu Saba' Village, which is 60 km northeast of Baqubah City, during the spring season 2023 to know the effect of three levels of nano fertilizer (Optimus-Plus), which consists of 50% organic materials, 29% free plant amino acids, 20% organic carbon, and 2% nitrogen group with a pH of 5-8% at concentrations of 1, 2, and 3 liters ha-1 in addition to the control treatment, and was added after germination and in three times in the months of April, June, and September on four American cultivars, CP72-2086, CP89-2143, CP81-325, and LO3-371, under drip irrigation technology.

Chemical and physical properties of soil

Soil samples were taken before the planting experiment from different locations in the field at a depth of 30 cm and were representative of the field soil and mixed well. The soil was air dried and passed through a sieve with a hole diameter of 2 mm. It was analyzed in the Central Laboratory for Soil, Water, and Plant Analysis, College of Agricultural Engineering Sciences, University of Baghdad (Table 1.(

**Table 1. The physical and chemical properties of soil**

| Measurements | Value | Unit of measurement |
|---|---|---|
| Texture of soil | Clay loam | - |
| Clay | 347.7 | g. $kg^{-1}$ |
| Silt | 408.2 | g. $kg^{-1}$ |
| Sand | 244.1 | g. $kg^{-1}$ |
| Ph | 7.11 | - |
| Ec | 1.3 | ds.$m^{-1}$ |
| N | 24.21 | mg. $kg^{-1}$ |
| P | 10.12 | mg. $kg^{-1}$ |
| K | 341.2 | mg. $kg^{-1}$ |
| Organic matter | 7.3 | mg. $kg^{-1}$ |
| CaCo3 | 261 | mg. $kg^{-1}$ |
| $Ca^{+2}$ | 11.3 | milliequivalent $liter^{-1}$ |
| $Mg^{+2}$ | 7.3 | milliequivalent $liter^{-1}$ |

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| | | |
|---|---|---|
| $Na^+$ | 6.2 | milliequivalent liter$^{-1}$ |
| $HCO_3$ | 1.5 | milliequivalent liter$^{-1}$ |
| $Cl^-$ | 20.7 | milliequivalent liter$^{-1}$ |
| $K^+$ | 0.19 | milliequivalent liter$^{-1}$ |

Land preparation and cultivation

The experimental field area was 637.5 m² (42.5 m × 15 m) and was divided into three blocks, each measuring 3 × 42.5 m and containing 16 experimental units. Each unit measured 2 × 3 m (6 m²). Blocks were separated by 2 m spaces, with 70 cm between individual units, totaling 48 experimental units.

Mature sugarcane stem cuttings of three cultivars were brought from the sugarcane farm at the College of Agriculture, University of Diyala, represented by the Technology Incubator Project (Sugar Industry, Biofuel, and Secondary Industries from Sugarcane) and the fourth variety (LO3-371) from the fields of the General Company for Sugar Industry in Misan Province. The drip irrigation system was installed by a main pipe with a diameter of 5 cm, which connected to the main pump on the river, then sub-pipes with the drippers installed perpendicular to the main pipe with a diameter of 3.5 cm and were equal to the number of lines in the experimental units and in the center of the line. This method is characterized by giving an increase in the number of sugarcane branches, which contributed to increasing the production of the crop in quantity and quality, and reducing the lying of the sugarcane due to the presence of sufficient soil to stabilize the roots after irrigation operations or in the event of strong winds, in addition to reducing the incidence of pests and insects and saving the amount of stem cuttings used in agriculture, and thus saving in production costs. Weeds were removed manually after the appearance of two true leaves, and when the plant reached a length of more than 1 m, it blocked the sunlight from the field, thus preventing most weeds from growing. Irrigation was carried out as needed, for varying periods ranging from 4 to 12 days until 15/10/2023, as irrigation of the crop was stopped in preparation for harvest on 1/12/2023. The plant growth traits were calculated along the two midlines of each experimental unit.

Area of land occupied by the plant (cm2(

It was calculated by the ratio and proportion between the total number of stems per square meter.

Leaf area index

It was calculated by dividing the leaf area by the area of land occupied by that plant.

Dry weight of the plant (g plant-1(

The dry weight of the plant was estimated by cutting the plants into leaves and stems and placing them in perforated paper bags under normal weather conditions until the weight was stable.

Stem yield (ton h-1(

The stem yield was calculated from the weight of the plants within one square meter taken from the two median lines of each experimental unit and converted to tons per hectare.

Sucrose percentage in juice (Polarity(%

200ml of juice was taken and placed in a 250 ml glass beaker, and 50 g of lead acetate was added to it. After shaking well, the filtration process was carried out, and then 75 ml of the filtrate was taken and placed in the Saccharimeter after ensuring the cleanliness of the sample tube in the device and taking the

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average of three readings for this characteristic [1.[

Sugar yield (ton h-1(

It was calculated according to the following equation [18.[

Sugar yield (ton h-1) = Stem yield per hectare × Sucrose percentage

Statistical analysis

The data were statistically analyzed using the ANOVA method as a factorial experiment within the randomized complete block design (RCBD), and the least significant difference (LSD) was chosen to compare the averages of the studied treatments under the probability level of 0.05, using the SPSS program [5.[

Results and discussion

Effect of nano-fertilizer concentrations on area of land occupied by the plant, leaf area index, and dry plant weight of sugarcane cultivars

The results of Table (2) showed that there were no significant differences between the varieties in the area of land occupied by the plant and the leaf area index, while there was a significant effect between the varieties in the dry weight of the plant, as the varieties CP81-325 and LO3-371 outperformed with an average of 584.33 and 549.29 g. plant-1, compared to the variety CP72-2086, which recorded the lowest average of 469.04 g plant-1 with an increase rate of 24.57 and 17.10%, respectively. No significant differences were observed between the varieties CP72-2086, CP89-2143, and LO3-371, and no significant differences were observed for the varieties CP89-2143, LO3-371, and CP81-325 for the same trait. The dry matter yield of the plant results from the efficiency of the leaf surface of the plant in intercepting solar rays and converting this light energy into chemical energy that is later used to reduce carbon dioxide into stable organic compounds representing the dry weight of the plant [3.[

Regarding the concentrations of nano fertilizer, the concentration of 3 Lh-1 was superior in a significant increase in the leaf area index with an average of 0.84 compared to the concentrations of 2 and 1 Lh-1 and the control, which recorded the lowest average of 0.64, 0.58, and 0.56 with an increase rate of 31.25, 44.82, and 50.00%, respectively. While the concentrations of 3 and 2 L-1 were superior in the dry weight of the plant, with an average of 644.75 and 633.41 g plant-1, compared to the concentration of 1 L.ha-1 and the control, which recorded the lowest average of 442.29 and 415.25 g. plant-1, with an increase rate of 45.77, 55.26, and 49.99%, respectively. No significant differences were observed between the different concentrations in the average characteristic of the area of land occupied by the plant.

Nano materials are distinguished from regular materials by the small size of their particles and their small surface area [16], as the small size of the nano-fertilizer particles had a positive effect on increasing the absorption of nutrients. Moreover, nanoparticles can easily move through the inner cortex cells through the Casper strip when their size is less than 36 nm [13], resulting in increased photosynthesis rate and plant growth by improving nutrient uptake [22]. The application of micronutrients in agriculture as fertilizers in the form of nanoparticles is an important means of providing essential nutrients for plant growth [14]. Nanoparticles (NPs) have shown the ability to enhance a wide range of important physiological processes, including plant growth and photosynthesis [20.[

Regarding the interaction between cultivars and concentrations, the cultivar LO3-371 for the concentration of 1 liter h-1 was superior in

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the area of land occupied by the plant with an average of 769.23 cm2 compared to the same cultivar for the concentration of 2 liters h-1 and the cultivar CP81-325 for the concentration of 3 liters h-1 and the control, which recorded an average of 625.00 cm2 and the cultivar CP89-2143 for the control, which recorded an average of 619.87 cm2 with an increase of 23.07 and 24.09%, and they were superior to the cultivar CP89-2143 for the concentration of 2 liters h-1 and the cultivar CP72- 2086 for the control, which recorded an average of 500.00 cm2 and the cultivar CP81-325 for the concentration of 2 liters h-1, which recorded an average of 476.19 cm2. The CP89-2143 cultivar for concentration 3 L h-1 recorded an average of 454.54 cm2, and the CP72-2086 cultivar for concentration 1 L h-1 recorded an average of 434.78 cm2 with an increase of 25.00, 31.25, 37.50, and 43.75%, which outperformed the LO3-371 cultivar for concentration 3 L h-1, which recorded the lowest average for the same trait with an average of 312.50 cm2 with an increase of 60.00, 52.38, 45.45, and 28.12%. While the cultivar LO3-371 for the concentration of 3 liters h-1 outperformed in the leaf area index with an average of 1.24 compared to the cultivar CP89-2143 for the concentration of 3 liters h-1, which recorded an average of 0.83, with an increase of 49.39%, and they outperformed on the cultivar CP89-2143 for the concentration of 2 and 1 liters h-1, which recorded an average of 0.61 and 0.59, and the cultivar LO3-371 for control, which recorded an average of 0.58, and the cultivars CP89-2143 and CP81-325 for control and concentration of 1 liters h-1, which recorded an average of 0.55, and the cultivar CP89-2143 for the concentrations of 2 and 1 L. ha-1, which recorded an average of 0.50 and 0.46, and the cultivar CP81-325 for control recorded an average of 0.41 with an increase rate of 77.04, 110.16, 113.79, 125.45, 148.00, 169.56, 202.43, 0.36, 40.67, 43.10, 50.90, 66.00, 80.43 and 102.43%, respectively. While the interaction had no significant effect on the average dry weight of the plant.

Effect of nano-fertilizer concentrations on stem yield, sucrose percentage in juice, and sugar yield of sugarcane cultivars

The results of Table (3) showed that there was a significant effect between the cultivars in the average of the sucrose percentage in juice (Pol %) and the sugar yield (ton h-1). The cultivars CP89-2143, CP81-325, and CP72-2086 outperformed in the sucrose percentage in juice with averages of 14.91, 14.40, and 13.99%, compared to the cultivar LO3-371, which recorded the lowest average of 13.28% with an increase rate of 12.57, 8.43, and 5.34%, respectively. The CP89-2143 cultivar outperformed in sugar yield with an average of 27.78 tons h-1 compared to the CP72-2086, LO3-371, and CP81-325 cultivars, which recorded the lowest average of 23.24, 22.50, and 22.08 tons h-1, with an increase of 19.53, 23.46, and 25.81%, respectively. No significant differences were observed between the cultivars in the average stem yield trait. The increase in the percentage of sucrose in the juice and sugar yield was consistent with the insignificant increase in the stem yield of sugarcane plants recorded by the cultivars CP89-2143 and LO3-371. This variation in the average of these traits between the cultivars may be attributed to their differences in the efficiency of photosynthesis and the resulting increase in the vegetative mass, which led to the increase in sucrose yield.

Regarding the concentrations of nano fertilizer, the concentration of 3 L. ha-1 was superior in a significant increase in the stem yield trait with an average of 229.67 tons. h-1 compared to the concentrations of 2 and 1 L h-1 and the control, which recorded the lowest average of 192.42, 138.70, and 120.29 tons h-1 with an increase rate of 19.35, 65.58, and 90.93%. While the concentration of 2 L h-1 was superior in the same trait compared to the concentration of 1 L h-1 and the control with an increase rate of 38.73 and 59.96%, respectively. While the concentrations of 2, 3, and 1 liter h-1 were superior with a significant increase in the sucrose percentage in juice (%Pol) with an average of 15.05, 14.87, and 14.65% compared to the control that recorded the lowest average of 12.02% with an increase rate of 25.20, 23.71, and 21.88%. The concentration of 3 liter h-1 recorded a significant increase in the sugar yield (ton h-1) with an average of 33.66 tons h-1 compared to the concentrations of 2 and 1 liter h-1 and the control that recorded the lowest average of 27.07, 20.38, and 14.49 tons h-1 with an increase rate of 24.34, 65.16, and 132.29%. While the concentration of 2 L h-1 was superior in the same characteristic compared to the concentration of 1 L h-1 and the control by an increase of 32.82% and 86.81%, and the concentration of 1 L h-1 was superior to the control by an increase of 40.64%, respectively. Using nano fertilizer may increase the number of extractable stems because it forms auxin, which, along with gibberellin, divides cambium cells and differentiates them into wood and bark tissues. Thus, vascular differentiation of the lateral buds occurs, which become connected to those in the main stem, which is positively reflected in the increase in the number of stems [10]. Furthermore, the small size of nanoparticles increases the plant's ability to absorb them, as well as their ability to penetrate plant cell membranes, which improves their growth and productivity [11.[

Regarding the interaction between cultivars and concentrations, the cultivar LO3-371 for the concentration of 3 liters h-1 was superior in stem yield with an average of 329.44 tons h-1 compared to the cultivar CP89-21433 for the concentrations of 2 and 3 liters h-1, which recorded an average of 225.43 and 224.62 tons h-1 with an increase of 46.13 and 46.66%, and they were superior to the cultivar LO3-371 for the concentration of 2 liters h-1 with an average of 160.56 tons h-1 with an increase of 105.18, 40.40 and 39.89%, and they were superior on the cultivar CP72-2086 for control with an average of 96.60 tons h-1 and the cultivar LO3-371 for the concentration of 1 liter h-1 with an average of It reached 85.73 tons h-1, with an increase of 241.03, 133.36, 132.52, 66.21, 284.27, 162.95, 162.00 and 87.28%.

While the cultivar CP89-2143 for concentrations of 3 and 2 liters h-1 was superior in the sucrose percentage in juice with an average of 16.20 and 15.96%, the cultivar CP81-325 for concentration of 3 liters h-1 with an average of 15.90%, and the cultivar CP89-2143 for concentration of 1 liters h-1 with an average of 15.70% compared to the cultivar CP81-325 for concentration of 1 liters h-1 and the control with an average of 13.50%, and the cultivar LO3-371 for concentration of 3 liters h-1 with an average of 13.10%, and the cultivar CP72-2086 for control with an average of 13.00% with an increase rate of 20.00, 23.66, 24.61, 18.22, 21.83, 22.76, and 18.46, 21.37, 22.30, 16.29, 19.84 and 20.76%, which they outperformed on the LO3-371 cultivar for control, which recorded the lowest average of 9.80%, with an increase of 65.30, 62.85, 62.24, 60.20, 37.75, 33.67 and 32.65%, respectively. The LO3-371

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variety for the 3 liter h-1 concentration outperformed the sugar yield (ton h-1) with an average of 43.15 tons h-1 compared to the CP89-2143 cultivar for the 2 liter h-1 concentration, which recorded an average of 35.81 tons h-1 with an increase of 20.49%, and which outperformed on the CP72-2086 cultivar for the 3 liter h-1 concentration with an average of 25.29 tons h-1 with an increase of 70.62 and 41.59%, respectively. And they outperformed on the CP89-2143 cultivar for control with an average of 15.14 tons h-1, the CP81-325 cultivar for concentration 1 liter h-1 with an average of 14.55 tons h-1, the LO3-371 cultivar for concentration 1 liter h-1 with an average of 12.77 tons h-1, the CP72-2086 cultivar for control with an average of 12.55 tons h-1, and the LO3-371 cultivar for control with an average of 11.34 tons h-1, with an increase of 185.00, 196.56, 222.23, 243.82, 280.51, 135.46, 145.01, 179.16, 184.06, 214.37, 67.04, 73.81, 98.04, 101.51, and 123.01%, respectively.

Conclusion

The cultivars CP81-325 and LO3-371 gave the highest increase in the plant dry weight, and the cultivars CP89-2143, CP81-325, and CP72-2086 were superior in the sucrose percentage in juice, while the concentration of nano fertilizer 3 L h-1 led to an increase in most of the studied traits. We recommend further studies into the selection of sugarcane cultivars with high economic returns and rapid maturation, as well as the use of new concentrations of nano fertilizers.

**Table 2. Effect of nano-fertilizer concentrations on area of land occupied by the plant, leaf area index, and dry plant weight of sugarcane cultivars**

| Cultivars | Nano-fertilizer concentrations L $h^{-1}$ | Area of land occupied by the plant (cm2) | Leaf area index | Dry plant weight (g $plant^{-1}$) |
|---|---|---|---|---|
| CP72-2086 | 0 | 500.00 | 0.70 | 299.00 |
| | 1 | 434.78 | 0.75 | 354.66 |
| | 2 | 555.55 | 0.67 | 596.00 |
| | 3 | 714.28 | 0.69 | 626.50 |
| CP89-2143 | 0 | 619.87 | 0.55 | 455.00 |
| | 1 | 577.02 | 0.59 | 462.33 |
| | 2 | 500.00 | 0.61 | 687.83 |
| | 3 | 454.54 | 0.83 | 527.00 |
| CP81-325 | 0 | 625.00 | 0.41 | 450.50 |
| | 1 | 580.19 | 0.55 | 489.33 |
| | 2 | 476.19 | 0.80 | 622.00 |
| | 3 | 625.00 | 0.63 | 775.50 |
| LO3-371 | 0 | 418.29 | 0.58 | 456.50 |
| | 1 | 769.23 | 0.46 | 462.83 |
| | 2 | 625.00 | 0.50 | 627.83 |
| | 3 | 312.50 | 1.24 | 650.00 |
| L.S.D (0.05) | | 116.65 | 0.21 | N.S. |
| Mean of cultivars | CP72-2086 | 551.15 | 0.70 | 469.04 |
| | CP89-2143 | 537.86 | 0.64 | 533.04 |
| | CP81-325 | 576.59 | 0.59 | 584.33 |
| | LO3-371 | 531.25 | 0.69 | 549.29 |

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|---|---|---|---|---|
| L.S.D (0.05) | | N.S. | N.S. | 78.44 |
| Mean of nano-fertilizer concentrations | 0 | 540.79 | 0.56 | 415.25 |
| | 1 | 590.30 | 0.58 | 442.29 |
| | 2 | 539.16 | 0.64 | 633.40 |
| | 3 | 526.58 | 0.84 | 644.75 |
| L.S.D (0.05) | | N.S. | 0.10 | 78.44 |

**Table 3. Effect of nano-fertilizer concentrations on stem yield, sucrose percentage in juice, and sugar yield of sugarcane cultivars**

| Cultivars | Nano-fertilizer concentrations L $h^{-1}$ | Stem yield (ton $h^{-1}$) | Sucrose percentage in juice (Pol%) | Sugar yield (ton $h^{-1}$) |
|---|---|---|---|---|
| CP72-2086 | 0 | 96.60 | 13.00 | 12.55 |
| | 1 | 209.71 | 14.50 | 30.40 |
| | 2 | 197.41 | 14.16 | 24.74 |
| | 3 | 176.89 | 14.30 | 25.29 |
| CP89-2143 | 0 | 128.32 | 11.80 | 15.14 |
| | 1 | 151.59 | 15.70 | 23.79 |
| | 2 | 225.43 | 15.96 | 35.81 |
| | 3 | 224.62 | 16.20 | 36.38 |
| CP81-325 | 0 | 140.48 | 13.50 | 18.96 |
| | 1 | 107.80 | 13.50 | 14.55 |
| | 2 | 186.27 | 14.73 | 24.96 |
| | 3 | 187.76 | 15.90 | 29.85 |
| LO3-371 | 0 | 115.77 | 9.80 | 11.34 |
| | 1 | 85.73 | 14.90 | 12.77 |
| | 2 | 160.56 | 15.33 | 22.77 |
| | 3 | 329.44 | 13.10 | 43.15 |
| L.S.D (0.05) | | 10.58 | 2.06 | 7.23 |
| Mean of cultivars | CP72-2086 | 170.15 | 13.99 | 23.24 |
| | CP89-2143 | 182.49 | 14.91 | 27.78 |
| | CP81-325 | 155.57 | 14.40 | 22.08 |
| | LO3-371 | 172.87 | 13.28 | 22.50 |
| L.S.D (0.05) | | N.S. | 1.15 | 3.61 |
| Mean of nano-fertilizer concentrations | 0 | 120.29 | 12.02 | 14.49 |
| | 1 | 138.70 | 14.65 | 20.38 |
| | 2 | 192.42 | 15.05 | 27.07 |
| | 3 | 229.67 | 14.87 | 33.66 |
| L.S.D (0.05) | | 29.05 | 1.15 | 3.61 |

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