

Effect of foliar feeding with Nano fertilizer on the growth of sugarcane (*Saccharum officinarum* L.) cultivars under drip irrigation

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Abstract: The field experiment was conducted during spring season of 2023 in Diyala Governorate, Muqdadiyah District, Abu Saida Subdistrict, and Abu Saba'a Village, located 60 km northeast of Baqubah City, the center of the governorate. The experiment design was factorial experiment according to the randomized complete block design (RCBD) with three replicates. The plant material was sugarcane *Saccharum officinarum* L. The aim was to investigate the impact of three Nano fertilizer levels (Optimus-Plus): 1, 2, and 3 liters h⁻¹ on sugarcane varieties. Nano fertilizer was added after germination and in three times during the months of April, June, and September on four American sugarcane varieties CP72-2086, CP89-2143, CP81-325, and LO3-371. Drip irrigation technology used to water the plants. The results showed that the cultivars LO3-371 and CP81-325 had the highest increase in extractable stems and a significant decrease in non-extractable stems. The cultivars LO3-371 and CP89-2143 significantly reduced the number of green leaves (leaf plant⁻¹), with the lowest average being 6.41 and 5.25 leaves plant⁻¹, respectively. The concentration of 3 L h⁻¹ outperformed in terms of stem height (cm), stem diameter (cm), and total number of stems (stem m⁻²) with the highest averages of 316.12 cm, 2.98 cm, and 26.25 stems m⁻². It also outperformed in terms of the number of extractable and non-extractable stems, as well as the total number of leaves, with the highest averages of 22.50 stems m², 3.75 stems m², and 28.90 leaves plant⁻¹ respectively. Compared to comparison treatment, the results showed significant differences in all interactions between varieties and concentrations in most vegetative characteristics.

Keywords: growth, leaf area, stem height, Nano fertilizer, sugarcane varieties.

Introduction

In tropical and subtropical areas across the world, sugarcane (*Saccharum officinarum* L.) is an indigenous grass (Ram *et al.*, 2022). A perennial monocot, sugarcane can grow up to six meters in height (Chandran *et al.*, 2023). The biggest concentration of sucrose is found in the stem, which also manufactures the sugar.

Furthermore, sucrose extraction and processing are made easier by sugarcane with a low fiber concentration (Kar *et al.*, 2023). One of the world's oldest commodities is sugar. Sugarcane mills contribute significantly to government revenue and job possibilities. It can be made from sugarcane, sugar beet, or other crops with a sugar content (Sahu, 2018).

Many studies have indicated the variation of sugar cane plant varieties in their ability to record the highest number of branches, the number of extractable stems, stem height, and stem weight, and they also vary in their stem production depending on environmental conditions (Zhenrui *et al.*, 2015). The varieties with high quality specifications have played a major role in expanding the areas planted with the crop and increasing the production of stems, sugar yield, and the number of sugar factories. However, the yield and quality of stems depend on several inherited quantitative traits that are affected by environmental factors (Nair, 2011). Nanotechnology is defined as the application of theoretical concepts from the natural sciences to very small levels. Scientifically, it is the creation of structures, systems, and devices with unique properties and functions. Nano science is the science that deals with the study of the tiny world, which is the world of atoms and molecules. If we say that one of the particle dimensions is 100 nanometers, then it falls under the name nano. In 2003, the US Department of Agriculture was the first to indicate that nanotechnology could benefit agriculture and the food industry, which led to changes in agricultural production systems. Nano fertilizers provide a larger space for various metabolic reactions in the plant, which increases the rate of photosynthesis and produces more dry matter and crop productivity (Singh *et al.*, 2017). According to several studies, nanoparticles showed an impact on physiology, development, and plant growth, depending on their concentration, mode of application, and composition. (Tapan & Sivakoti, 2019). In agriculture, nano fertilizers are the important tools for enhancing crop growth, yield, and quality characteristics while increasing nutrient usage efficiency, decreasing fertilizer waste, and lowering

cultivation costs. Nano fertilizers increase crop growth up to optimal concentrations, nano-fertilizers give plants additional surface area for various metabolic processes, which increases photosynthesis and increases crop yield and dry matter production (Qureshi *et al.*, 2018). The drip irrigation system is one of the most modern irrigation systems compared to other irrigation methods. Nanomaterials can eliminate contaminants such as heavy metals and undesired microbes, as well as enhance the quality of soil and water (Raja & Husen, 2020). In order to improve the quality of juice, all available and possible means must be sought to achieve the goals. This study aims to evaluate the response of the sugarcane varieties to the added concentrations of nano fertilizer.

Materials and methods

A factorial experiment was conducted during the spring season 2020 using randomized complete block design (RCBD) with three replicates on sugarcane *Saccharum officinarum* L. the experiment conducted at Diyala Governorate, Al-Muqdadiyah District, Abu Saida Sub-district, and Abu Saba'a Village, located 60 km northeast of Baqubah City, the governorate center. It was implemented starting on March 1, 2023, to evaluate 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 a concentration of 1, 2, and 3 liters h⁻¹ in addition to the comparison treatment, and was added after germination and three times in the months of April, June, and September on four American sugarcane cultivars CP72-2086, CP89-2143, CP81-325, and LO3-371 under drip irrigation technology, in a soil with a clay loam texture.

Chemical and physical properties of experimental soil

Soil samples were taken before planting from different locations from field at a depth of 0-30 cm and then mixed very well. Representative soil was air dried and passed through a sieve with a hole diameter of 2 mm. physical and chemical properties of soil measured in the Central Laboratory of Soil, Water, and Plant Analysis, College of Agricultural Engineering Sciences, University of Baghdad (Table 1).

Table (1): Some physical and chemical properties of soil before planting

Measurements	Value	Unit
Clay	347.7	g kg ⁻¹
Silt	408.2	g kg ⁻¹
Sand	244.1	g kg ⁻¹
Texture of soil	Clay loam	-
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	g kg ⁻¹
CaCo3	261	mg kg ⁻¹
Ca ⁺²	11.3	meq l ⁻¹
Mg ⁺²	7.3	meq l ⁻¹
Na ⁺	6.2	meq l ⁻¹
HCO ₃	1.5	meq l ⁻¹
Cl ⁻	20.7	meq l ⁻¹
K ⁺	0.19	meq l ⁻¹

The area of experimental unit was 2 x 3 m². We left spaces between the blocks, each with a width of 2 m, and maintained a distance of 70 cm between each experimental unit.

Land preparation and cultivation

Mature sugarcane stem cuttings of three varieties obtained from the sugarcane farm located at the College of Agriculture,

University of Diyala, represented by the Technology Incubator Project (Sugar Industry, Biofuel, and Secondary Industries from Sugarcane) sponsored by the Ministry of Higher Education and Scientific Research, Research and Development Department, Higher Education Incubator Department, The fourth fourth variety (LO3-371) obtained from the fields of the General Company for Sugar Industry in Misan Province. The drip irrigation system was used to water the plants. 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 by 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 controlled manually after appearance of two true leaves, and when the plant reached a length of more than 1 m, blocked the sunlight from the field, thus preventing most weeds from growing. Irrigation was carried out as plants needed, for varying periods ranging from 4 to 12 days until 15/10/2023, thereafter irrigation stopped in preparation for harvest on 12/1/2023. Plant growth traits were calculated along the two midlines of each experimental unit.

Stem height (cm) was measured using a measuring tape from the soil surface to the last node for five plants taken from the protected lines for each experimental unit.

Total number of stems were counted for one square meter of each experimental unit .

Number of extractable and non-extractable stem counted for one square meter of each experimental unit.

Stem diameter (cm) was measured for the same plants that were selected to measure the stem height trait from the five centimeters above the soil surface and using a measuring tape to measure the stem circumference, then the stem diameter was extracted according to the following equation:

Stem diameter = stem circumference / 3.14

Total number of leaves (leaf plant⁻¹) of five plants were counted to measure stem height and stem diameter from each experimental unit .

Number of green leaves (leaf plant⁻¹) of five plants were counted to measure stem height and stem diameter from each experimental unit .

Number of dry leaves (leaf plant⁻¹) of five plants were counted to measure stem height and stem diameter from each experimental unit after 90 days of addition .

Leaf area (cm²)

The length and width of each leaf from each plant were measured, and then the leaf area was calculated before and after 45 and 90 days of addition according to the following equation:

Leaf area = leaf length X maximum leaf width X 0.6274 (Mary & Anitha, 2019).

Statistical analysis

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

according to, using the SPSS program (George & Mallery, 2024) .

Results and discussion

Height, diameter and total number of stems

The results of table 2 showed that there was a significant difference between cultivars in the average stem diameter. The cultivar CP72-2086 had the highest average stem diameter (cm) by 2.76 cm, while cultivar LO3-371 had the lowest average at 2.66 cm, with a growth rate of 3.75%. No significant differences were observed between the cultivars CP72-2086, CP89- 2143, and CP81-325. Also, no significant differences were observed for the same trait between the cultivars LO3-371, CP89- 2143, and CP81-325. This is attributed to the genetic similarity between the varieties in the stem diameter trait or to the inherent trait of each variety (Fiaz *et al.*, 2013).

Regarding the concentrations of Nano fertilizer, the concentration of 3 L h⁻¹ was superior in the average of stem height, stem diameter and total stem number with the highest average of 316.12 cm, 2.98 cm and 26.25 stems m⁻² respectively as , compared to the concentrations of 2 and 1 L h⁻¹ and the comparison treatment, which recorded the lowest average of (292.66, 243.66 and 258.00 cm), (2.76, 2.64 and 2.46 cm), (20.33, 19.58 and 16.91 stems m⁻²) respectively with an increase rate of (8.01, 29.73 and 22.52%), (7.97, 12.87 and 21.13%) and (33.55, 34.06 and 55.23%) respectively. The concentration of 2 L h⁻¹ outperformed on the comparison treatment and concentration 1 L h⁻¹ in the stem height (cm) and record an average of 292.66 cm, while the one latter recorded the lowest average by 258.00 and 243.66 cm, with an increase rate of 13.43 and 20.10% respectively. The concentration of 1 L h⁻¹ did not significantly differ from the comparison

treatment in trait of stem height. The concentration of 2 L h⁻¹ demonstrated superiority in the trait of stem diameter (cm), with an average of 2.76 cm as, compared to the concentration of 1 L h⁻¹ and the comparison treatment, which recorded the lowest average of 2.64 and 2.46 cm, respectively, with an increase rate of 4.54 and 12.19% respectively. The concentration of 1 L h⁻¹ outperformed the comparison treatment in stem diameter (cm) trait, which achieved an average of 2.64 cm, while the comparison treatment recorded the lowest average of 2.46 cm.

In terms of total stem number, the concentration of 2 L h⁻¹ was better, with an average of 20.33 stems m⁻² compared to the comparison treatment, which had the lowest average of 16.91 stems m⁻² and a growth rate of 20.22%. No significant differences were observed between the concentrations of 2 and 1 L h⁻¹ in the total stem number trait. Similarly, the results showed no significant differences between the concentration of 1 L h⁻¹ and the comparison treatment in same trait. Nano-materials are distinguished from regular materials by the small size of their particles and their small surface area (Moghaddasi *et al.*, 2017), 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 (Larue *et al.*, 2012), resulting in increased photosynthesis rate and plant growth by improving nutrient uptake (Singh *et al.*, 2017). The application of micronutrients in agriculture as fertilizers in the form of nanoparticles is an important means of providing essential nutrients for plant growth (Laware & Raskar, 2014). Nanoparticles (NPs) have shown the ability to enhance a wide range of important

physiological processes, including plant growth and photosynthesis (Siddiqi & Husen, 2017).

Regarding the interaction between cultivars and concentrations, the cultivars CP72-2086 and LO3-371 at a concentration of 3 L h⁻¹ achieved the highest increase in stem height with an average of 330.00 and 320.00 cm as compared to the cultivar CP89-2143 for comparison treatment, which recorded the lowest average of 282.16 cm with an increase rate of 35.77 and 32.53%. The cultivar CP89-2143, at a concentration of 3 L h⁻¹, recorded the highest increase in stem diameter, with an average of 3.18 cm, as compared to the cultivars CP72-2086 at a concentration of 2 L h⁻¹, which recorded the lowest average of 2.96. The cultivars CP81-325, at both 2 and 3 L h⁻¹ concentrations, and the cultivar LO3-371, at a concentration of 3 L h⁻¹, gave the lowest average stem diameter by 2.86 cm, with an increase rate of 11.18%. They outperformed the two cultivars CP89-2143 and CP81-325 at a concentration of 1 L h⁻¹, with the lowest average of 2.59 cm and an increase rate of 10.42%. They also outperformed the two cultivars LO3-371 and CP89-2143 at a comparison treatment for the same trait, with an average of 2.38 and 2.22 cm and an increase rate of 8.82 and 16.66%. While the interaction between the LO3-371 cultivar at the concentration of 3 liters h⁻¹ recorded the highest increase in the total branching number trait with an average of 32.00 stems m⁻², compared to the CP81-325 cultivar at the concentration of 3 L h⁻¹, which recorded the lowest average of 27.00 stems m⁻² with an increase rate of 18.51%, which in turn outperforms the CP72-2086 cultivar at the concentration of 3 L h⁻¹, which recorded the lowest average of 24.00 stems m⁻² with an increase rate of 12.50%, which outperforms

the CP72-2086 and LO3-371 cultivars at the concentrations of 2 and 1 L h⁻¹ with the lowest average of 20.00 stems m⁻² with an increase rate of 20.00%. Which outperformed the cultivars CP89-2143, LO3-371 and CP81-325

for concentrations of 0, 2 and 0 L h⁻¹ with the lowest average of 16.33, 16.00 and 15.33 stem m⁻² with an increase rate of 22.47, 25.00 and 30.46% respectively.

Table (2): Effect of Nano-fertilizer concentrations on height, diameter, and total number of stems of sugarcane cultivars

Cultivars	Nano-fertilizer concentrations L h ⁻¹	Stem height (cm)	Stem diameter (cm)	Stems m ⁻²
CP72-2086	0	239.66 de	2.54de	19.00 eg
	1	218.00 e	2.54 de	23.00 cd
	2	276.50 bc	2.96 b	20.00 def
	3	330.00 a	3.02 ab	24.00 bc
CP89-2143	0	282.16 ab	2.22f	16.33 gh
	1	240.66 de	2.59 de	17.66 fgh
	2	300.16 a	2.70 cd	24.66 bc
	3	300.00 ab	3.18 a	22.00 cde
CP81-325	0	256.00 cd	2.70 cd	15.33 h
	1	271.00 bcd	2.59 de	17.66 fgh
	2	278.00 bc	2.86 bc	20.66 cdef
	3	314.50 a	2.86 bc	27.00 b
LO3-371	0	254.16 cd	2.38ef	17.00fgh
	1	245.00 cde	2.86 bc	20.00 def
	2	316.00 a	2.54 de	16.00 gh
	3	320.00 a	2.86 bc	32.00 a
L.S.D (0.05)		0.68	0.18	3.64
Mean of cultivars	CP72-2086	266.04	2.76 a	21.50
	CP89-2143	280.75	2.67 a	20.16
	CP81-325	279.87	2.75 a	20.16
	LO3-371	283.79	2.66 b	21.25
L.S.D (0.05)		N.S.	0.09	N.S.
Mean of Nano-fertilizer	0	258.00 ab	2.46 d	16.91 c
	1	243.66 b	2.64 c	19.58 b
	2	292.66 ab	2.76 b	20.33 b
	3	316.12 a	2.98 a	26.25 a
L.S.D (0.05)		61.84	0.09	1.82

Number of extractable and non-extractable stems and total number of leaves

The results of Table (3) show that there was a significant effect between the cultivars in the average of the number of extractable stems and the number of non-extractable stems, while there was no significant effect between the cultivars in the total number of leaves, as the cultivars LO3-371 and CP81-325 recorded the

highest average in the number of extractable stems, reaching 20.00 and 19.25 stems m⁻², compared to the cultivars CP72-2086 and CP89-2143, which recorded the lowest average, reaching 17.25 and 17.00 stems m⁻², with an increase rate of 15.94, 17.64, 11.59 and 13.23%. While the two varieties LO3-371 and CP81-325 recorded a significant decrease in the average of the number of non-extractable stems trait, as they recorded the lowest average

of 1.25 and 0.91 stems m⁻², compared to the two varieties CP72-2086 and CP89- 2143, which recorded the highest average of 4.25 and 3.16 stems m⁻², with a decrease rate of 70.58, 60.44, 78.58 and 71.20%, respectively. This result appeared opposite to the number of extractable stems, as the two varieties with the highest average of the number of extractable stems LO3-371 and CP81-325 recorded the lowest average of the number of non-extractable stems trait. Giving the cultivar CP89-2143 the highest average number of non-extractable stems indicates that it is less efficient in exploiting its genetic and physiological capabilities by recording the lowest average stem diameter (Table 2).

Regarding the concentrations of nano fertilizer, the concentration of 3 L h⁻¹ was superior in the average of the number of extractable stems, the number of non-extractable stems and the total number of leaves with the highest average of 22.50 stems m⁻², 3.75 stems m-2 and 28.90 leaf plant⁻¹, compared to the concentrations of 1 and 2 L h⁻¹ and the comparison, which recorded the lowest average of 18.58, 17.66 and 14.75 stems m⁻² in the number of extractable stems with an increase of 21.09, 27.40 and 52.54%, and compared to the concentrations of 2 and 1 L h⁻¹ and the comparison, which recorded the lowest average of 2.66, 2.16 and 1.00 stems m-2 and 24.16, 21.66 and 21.08 leaf plant⁻¹ in the number of non-extractable stems (stem m⁻²) and the total number of leaves (leaf plant⁻¹) increased by (40.97, 73.61, 275.00%), and (19.61, 33.42, and 37.09%), respectively.

While concentrations 1 and 2 L h⁻¹ were superior in terms of the number of extractable stems (stem m⁻²) compared to the comparison with an increase rate of 25.96 and 19.72%, respectively. While the concentration 1 L h⁻¹ recorded a significant decrease in the average

number of non-extractable stems (stem m-2) compared to the comparison with a decrease rate of 53.70%, and no significant differences were observed between the concentration 2 L h⁻¹ and the concentration 3 L h⁻¹ and the comparison in the number of non-extractable stems (stem m-2). The concentration of 2 L h⁻¹ was superior in the number of total leaves (leaf plant-1) compared to the concentration of 1 L h⁻¹ and the comparison was at an increase rate of 11.54 and 14.61%, respectively.

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 (Khanm *et al.*, 2018). While increasing the height of the stem (Table 2) and the number of extractable stems led to an increase in the total number of leaves.

Regarding the interaction between cultivars and concentrations, the cultivar LO3-371 at a concentration of 3 L h⁻¹ achieved the highest increase in the number of extractable stems with an average of 30.00 stems m-2 compared to the cultivar CP81-325 at a concentration of 3 L h⁻¹ and the cultivar CP72-2086 at a concentration of 1 L h-1, which recorded the lowest average of 25.00 and 21.00 stems m⁻² with an increase rate of 20.00 and 42.85% and which outperformed the cultivar CP81-325 at a concentration of 1 L h⁻¹, which recorded the lowest average of 17.66 stems m-2 with an increase rate of 41.56 and 15.90%.

The last interaction for the same trait outperformed the CP81-325 cultivar at a comparison, the CP72- 2086 cultivar at a comparison and the LO3-371 cultivar at a concentration 2 L h⁻¹, as they recorded the lowest average of 13.66, 13.00 and 11.66 stems m⁻² with an increase rate of 29.28, 35.84 and 51.45% respectively.

While the CP89-2143 cultivar for comparison and the CP81-325 cultivar at a concentrations 1 and 2 L h⁻¹ recorded a highly significant decrease in the trait of the number of non-extractable stems with an average of 0.00 stems m⁻² compared to the CP89-2143 cultivar for concentration 3 L h⁻¹, which recorded the highest average of 7.00 stems m⁻² with a decrease rate of 100%. While the cultivar

CP81-325 at a concentration of 3 liters h⁻¹ recorded the highest increase in the total number of leaves (leaf plant⁻¹) with an average of 32.33 leaf plant⁻¹ compared to other interactions and the lowest of them were the cultivars CP72-2086 and CP81-325 for comparison, which recorded the lowest average of 20.00 leaf plant⁻¹ with an increase rate of 61.65%.

Table (3): Effect of Nano-fertilizer concentrations on number of extractable and non-extractable stems and total number of leaves of sugarcane cultivars

Cultivars	Nano-fertilizer concentrations L h ⁻¹	Number of extractable stems	Number of non-extractable stems	Total number of leaves
CP72-2086	0	13.00 ij	6.00 ab	20.00 f
	1	21.00 c	2.00 c	20.33 f
	2	15.00 ghi	5.00 ab	23.33 def
	3	20.00 cde	4.00 b	28.00 bc
CP89-2143	0	16.33 fgh	0.00 c	21.00 ef
	1	16.66 efgh	1.00 c	22.00 def
	2	20.00 cde	4.66 b	22.33 def
	3	15.00 ghi	7.00 a	30.33 ab
CP81-325	0	13.66 hij	1.66 c	20.00 f
	1	17.66 defg	0.00 c	21.00 ef
	2	20.33 cd	0.00 c	24.00 cdef
	3	25.00 b	2.00 c	32.33 a
LO3-371	0	16.00 fghi	1.00 c	23.33def
	1	19.00 cdef	1.00 c	23.33 def
	2	11.66 j	1.00 c	25.66 cd
	3	30.00 a	2.00 c	25.00 cde
L.S.D (0.05)		3.21	2.23	4.11
Mean of cultivars	CP72-2086	17.25 b	4.25 a	23.33
	CP89-2143	17.00 b	3.16 a	23.91
	CP81-325	19.25 ab	0.91 b	24.33
	LO3-371	20.00 a	1.25 b	24.25
L.S.D (0.05)		1.60	1.11	N.S.
Mean of Nano-fertilizer	0	14.75 c	2.16 b	21.08 c
	1	18.58 b	1.00 c	21.66 c
	2	17.66 b	2.66 ab	24.16 b
	3	22.50 a	3.75 a	28.90 a
L.S.D (0.05)		1.60	11.1	2.05

Number of green and dry leaves and leaf area

The results of Table (4) show a significant effect between the cultivars in the average trait of number of green leaves (leaf plant⁻¹), number of dry leaves (leaf plant⁻¹) and leaf area (cm²). The cultivars LO3-371 and CP89-2143 outperformed with a significant decrease in the

trait of number of green leaves (leaf plant⁻¹) with the lowest average of 6.41 and 5.25 leaf plant⁻¹, compared to the cultivar CP72-2086 which recorded the highest average of 7.50 leaf plant⁻¹ with a decrease rate of 14.53 and 30.00% respectively. No significant differences were observed between the cultivars CP72-2086, CP81-325 and LO3-371

in the trait of number of green leaves (leaf plant⁻¹). While the varieties CP89-2143, CP81-325 and LO3-371 recorded the highest average for the number of dry leaves (leaf plant⁻¹) of 18.66, 17.83 and 17.83 leaf plant⁻¹ compared to the cultivar CP72-2086 which recorded the lowest average of 15.83 leaf plant⁻¹ with an increase rate of 17.87 and 13.00% respectively. The significant increase in the number of dry leaves could be attributed to the significant decrease in the number of green leaves for the mentioned varieties, indicating that the plant has reached the maturity stage. Giving the mentioned varieties the highest average for the number of dry leaves is evidence that they are more efficient in reaching the final maturity stage in exploiting their genetic and physiological capabilities by recording an insignificant increase in the average stem height (Table 2), which was reflected in the increase in the average number of dry leaves. While the variety CP72-2086 recorded the highest average in leaf area (cm²) of 384.31 cm² compared to the varieties CP89-2143, CP81-325 and LO3-371 which recorded the lowest average of 339.88, 337.89 and 298.59 cm² with an increase rate of 13.07, 13.73 and 29.60% respectively, this may be due to the same variety giving the highest significant increase in stem diameter (Table 2) and thus reflected in the increase in leaf area.

Regarding the concentrations of nano fertilizer L h⁻¹, the concentrations 3, 2 and 1 L h⁻¹ were superior with an insignificant increase in the average of the number of green leaves (leaf plant⁻¹) compared to the comparison. While the concentration 3 L h⁻¹ was superior in the number of dry leaves (leaf plant⁻¹) with an average of 22.08 leaf plant⁻¹, compared to the concentrations 2 and 1 L h⁻¹ and the comparison, which recorded the lowest average of 17.33, 15.58 and 15.16 leaf plant⁻¹

with an increase rate of 27.40, 41.72 and 45.64%. The same concentration demonstrated superiority in leaf area (cm²), with an average of 416.10 cm², compared to the concentration 2 L h⁻¹ and the comparison, which recorded the lowest average of 342.74 and 296.77 cm², respectively, with an increase rate of 21.40 and 40.20%. No significant differences were observed between the concentration 2 L h⁻¹ and the concentration 3 L h⁻¹ and the comparison in leaf area (cm²). The significant increase in the number of dry leaves and leaf area of the plant as a result of nano fertilizer can be attributed to its role in increasing the growth of the plant's vegetative group by increasing the height and diameter of the stem and the number of branches (Table 2), which led to an increase in the number of leaves and leaf area in the plant.

Regarding the interaction between varieties and concentrations, the results showed a significant decrease in the number of green leaves (leaf plant⁻¹) between the cultivar CP81-325 for the concentrations 1 and 2 L h⁻¹ with an average of 6.00 leaf plant⁻¹ with a decrease rate of 18.14%, and the cultivar LO3-371 at a concentrations 1 and 3 L h⁻¹ with an average of 5.00 leaf plant⁻¹ with a decrease rate of 46.60%, and the cultivar CP89-2143 at a concentration 2 L h⁻¹ with an average of 4.66 and 4.00 leaf plant⁻¹ with a decrease rate of 36.42 and 45.42%, compared to the cultivar CP72-2086 at a concentrations 1 and 2 L h⁻¹, which recorded an average of 7.33 leaf plant⁻¹ and which recorded a decrease rate of 21.43%, compared to the cultivar LO3-371 at a concentration 2 L h⁻¹, which recorded an average of 9.33 leaf plant⁻¹, which recorded a decrease of 48.16%, compared to the cultivar CP89-2143 at a concentration 1 L h⁻¹, which recorded the highest increase for the same trait with an average of 18.00 leaves per plant⁻¹, respectively. While the cultivar CP89-2143 at

3 L h⁻¹ concentration recorded the highest increase in the number of dry leaves (leaf plant⁻¹) with an average of 24.00 leaf plant⁻¹ compared to the cultivar CP72-2086 at 3 L h⁻¹ concentration, the cultivar LO3-371 at 1 L h⁻¹ concentration, and the cultivar CP81-325 at 2 L h⁻¹ concentration, which recorded an average of 19.00, 18.33, and 18.00 leaf plant⁻¹ with an increase rate of 26.31, 30.93, and 33.33%, which recorded the highest average compared to the cultivar CP72-2086 at a comparison and at 1 L h⁻¹ concentration, and the cultivar CP81-

325 at a comparison, which recorded the lowest average of 13.66 and 13.00 leaf plant⁻¹ with an increase rate of 39.09% and 46.15, 34.18, 41.00, 31.77 and 38.46% respectively. While the interaction had no significant effect on the average leaf area (cm²). By employing nanophosphate as a P source, it may be possible to reduce the quantity of phosphorus supplied to wheat plants as superphosphate to less than 25% of the acceptable rate without compromising growth metrics (Alsulaiman & Al-Ansari, 2023).

Table (4): Effect of Nano-fertilizer concentrations on number of green and dry leaves and leaf area of sugarcane cultivars

Cultivars	Nano-fertilizer concentrations L h ⁻¹	Number of green leaves	Number of dry leaves	Leaf area (cm ²)
CP72-2086	0	6.33 de	13.66 ef	350.35
	1	7.33 bc	13.00 f	329.65
	2	7.33 bc	17.66 cde	361.10
	3	9.00 bc	19.00 bcd	496.16
CP89-2143	0	4.00 f	17.00 cdef	341.46
	1	18.00 a	16.00 cdef	329.65
	2	4.66 ef	17.66 cde	309.28
	3	6.33 de	24.00 a	379.16
CP81-325	0	7.00 cd	13.00 f	256.53
	1	6.00 def	15.00 def	301.69
	2	6.00 def	18.00 bcde	385.35
	3	7.00 cd	22.33 ab	398.99
LO3-371	0	6.33 de	17.00 cdef	238.76
	1	5.00 def	18.33 bcd	361.10
	2	9.33 b	16.00 cdef	315.25
	3	5.00def	20.00 abc	390.11
L.S.D (0.05)		07.2	4.39	N.S.
Mean of cultivars	CP72-2086	7.50 a	15.83 b	384.31 a
	CP89-2143	5.25 c	18.66 a	339.88 b
	CP81-325	6.50 ab	17.83 ab	337.89 bc
	LO3-371	6.41 b	17.83 ab	298.59 c
L.S.D (0.05)		1.03	2.19	42.18
Mean of nano-fertilizer concentrations	0	5.91	15.16 b	296.77 c
	1	6.08	15.58 b	305.06 bc
	2	6.83	17.33 b	342.74 b
	3	6.83	22.08 a	416.10 a
L.S.D (0.05)		N.S.	2.19	42.18

Conclusion

The two cultivars LO3-371 and CP81-325 gave the highest increase in the number of extractable stems and a significant decrease in

the number of non-extractable stems, and the two cultivars LO3-371 and CP89-2143 were superior with a significant decrease in the number of green leaves. Adding 3 liters h⁻¹ of

nano fertilizer increased most of the vegetative traits in a big way, which plays a big part in increasing production and yield of four sugarcane cultivars compared to concentrations of 1 and 2 liters h⁻¹ and the control. As a result, 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.

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Contributions of authors

T.A.A. and S.A.H.A.; Managing the experiment in the field and collected the data.

A.S.H.A.; suggested the proposal of the article; planned the methodology; project administration, data analysis; writing the manuscript.

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Conflicts of interest

The authors declare no conflicts of interest.

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تأثير التسميد الورقي بالسماد النانوي على نمو أصناف قصب السكر (*Saccharum officinarum* L.) تحت الري بالتنقيط

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المستخلص: أجريت التجربة الحقلية خلال موسم ربيع 2023 في محافظة ديالى، قضاء المقدادية، ناحية أبو صيدا، وقرية أبو سبع، الواقعة على بُعد 60 كم شمال شرق مدينة بعقوبة، مركز المحافظة. صُممت التجربة بأسلوب التجارب العاملية وفقاً لتصميم القطاعات الكاملة العشوائية (RCBD) وبثلاثة مكررات. المادة النباتية المستخدمة كانت قصب السكر *Saccharum officinarum* L. كان الهدف من الدراسة هو دراسة تأثير ثلاثة مستويات من سماد النانو (Optimus-Plus) : 1، 2، و3 لترات/هكتار على أصناف قصب السكر. أضيف سماد النانو بعد الإنبات، وفي ثلاث مرات خلال أشهر أبريل، ويونيو، وسبتمبر، على أربعة أصناف أمريكية من قصب السكر، وهي CP72-2086، وCP89-2143، وCP81-325، وLO3-371. استُخدمت تقنية الري بالتنقيط لسقي النباتات. أظهرت النتائج أن الصنفين LO3-371 وCP81-325 حققا أعلى زيادة في عدد السيقان القابلة للاستخراج، وانخفاضاً ملحوظاً في عدد السيقان غير القابلة للاستخراج. كما حقق الصنفان LO3-371 وCP89-2143 انخفاضاً ملحوظاً في عدد الأوراق الخضراء (ورقة واحدة/نبات)، حيث بلغ أقل متوسط 6.41 و5.25 ورقة واحدة/نبات على التوالي. تفوق تركيز 3 لتر/هكتار في ارتفاع الساق (سم)، وقطر الساق (سم)، وعدد السيقان (م²) بأعلى متوسطات بلغت 316.12 سم، و2.98 سم، و26.25 ساق/م². كما تفوق في عدد السيقان القابلة للاستخراج وغير القابلة للاستخراج، وعدد الأوراق، بأعلى متوسطات بلغت 22.50 ساق/م²، و3.75 ساق/م²، و28.90 ورقة/نبات/م² على التوالي. وبالمقارنة مع معاملة المقارنة، أظهرت النتائج فروقاً معنوية في جميع التفاعلات بين الأصناف، وفي معظم الصفات الخضرية، وفي التركيزات.

الكلمات المفتاحية: ارتفاع الساق، مساحة الورقة، سماد نانوي، أصناف قصب السكر