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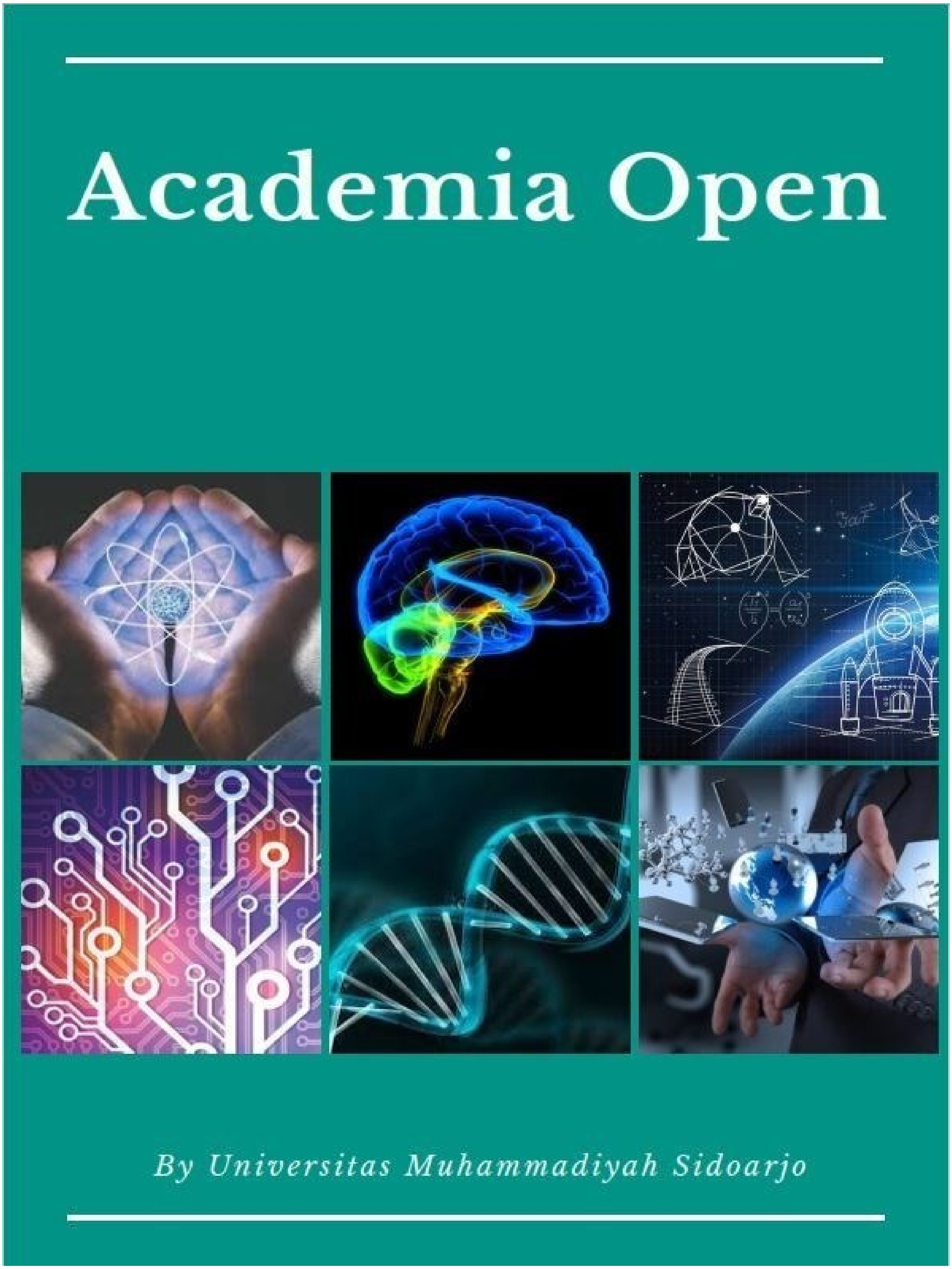

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Response of Sugarcane Varieties L. Saccharum Officinarum to Foliar Feeding with Nano-Fertilizers Under Drip Irrigation Technology

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Abstract

General Background: Sugarcane is a major tropical crop whose productivity depends on efficient nutrient management and irrigation systems. **Specific Background:** Recent advances in nanotechnology have introduced nano-fertilizers capable of enhancing nutrient uptake and improving physiological performance, yet their crop-specific efficacy under drip irrigation remains insufficiently characterized. **Knowledge Gap:** Empirical evidence on how distinct sugarcane varieties respond to varying nano-fertilizer concentrations in field conditions—particularly regarding vegetative growth, yield components, and sucrose accumulation—is still limited. **Aims:** This study evaluated the growth, physiological traits, and yield of four American sugarcane cultivars (CP72-2086, CP89-2143, CP81-325, LO3-371) subjected to three nano-fertilizer concentrations (1, 2, 3 L ha^{-1}) under drip irrigation. **Results:** The 3 L ha^{-1} treatment consistently improved stem height, diameter, leaf area, and stem yield (229.67 t ha^{-1}), while cultivars CP89-2143 and CP81-325 showed the highest sucrose content (up to 16.20%). LO3-371 exhibited the greatest increase in extractable stems and dry biomass. **Novelty:** This study provides the first integrated comparison of nano-fertilizer dose–response patterns across multiple sugarcane varieties under drip irrigation in arid-field conditions. **Implications:** Findings highlight the potential of nano-fertilizers—particularly at 3 L ha^{-1}—to enhance growth efficiency and sugar yield, supporting more sustainable and productive sugarcane management strategies.

Highlight :

- Nano-fertiliser 3 L ha^{-1} consistently improves stem growth and leaf performance.
- Varieties CP81-325, CP89-2143, and LO3-371 show stronger vegetative responses.
- Sucrose and sugar yield increase under optimized nano-fertiliser levels with drip irrigation.

Keywords : Stem Height, Sugar Yield, Nano-fertiliser, Sugarcane Varieties, Drip Irrigation

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Introduction

A perennial tropical and subtropical crop, sugarcane (Saccharum officinarum L.) is grown all over the world [1]. Globally, it is grown in tropical and subtropical regions between latitudes 350°N and 350°S. Grown on 1,217,000 hectares and producing 73.6 million tons annually, sugarcane is a cash and industrial crop in Pakistan [2]. In sugarcane fields, planting early-maturing varieties with high production and good quality (high sugar concentration) alongside medium-maturing types like Co976Co331 will move the harvest date from mid-December to late October and early November. By harvesting early, the detrimental consequences of the wet season are avoided. Additionally, as sugarcane is a perennial crop that stays in the field for several years, early harvesting offers additional benefits for the crop the following year. In contrast to harvesting during the rainy season, harvesting takes place when the soil is dry and heavy machinery does not compact it or raise its bulk density. Consequently, the amount of sugarcane supplied to the factory and the subsequent sugar production will rise significantly as a result of the introduction of early-maturing cultivars [3].

The study of minuscule materials or particles is known as nanotechnology. It is a promising technology that will lead to significant breakthroughs in several scientific fields (Saleh, 2015) [4]. Materials with particles that are between 1 and 100 nanometers in size and behave differently from their typical condition are known as nanomaterials. By reordering their constituent atoms and molecules, these materials can be reduced to the nanoscale, which is a scientific revolution and philosophy[5]. Because nanotechnology can make incredibly small particles of different components, it has the potential to bring about a new scientific revolution. These particles can provide more advantages than regular molecules, and their use has expanded to a variety of industries, including agriculture, where they are used to create fertilisers and nano-fertilisers that are sprayed on plants or added to the soil to enhance its fertility (Saleh, 2015) [4]. Because of their small size and huge surface area, nano ferries have special qualities that result in greater absorption surface area, improved photosynthesis, and higher plant production [6].

In order to keep the soil's moisture level around its field capacity, drip irrigation applies water to the soil gradually and frequently. This is accomplished by strategically placing drippers along the waterline to encourage strong growth and high productivity. Crop sustainability and profitability depend on effective management of water resources, which promotes the creation of innovative technologies for effective water analysis and management [7]. The purpose of this study is to:

1. Identify the potential impact of added fertiliser concentrations on the growth of sugarcane varieties.

2. Evaluate the response of the studied varieties to the added concentration for optimal growth.

3. Determine the optimal concentrations and the most suitable varieties under study to achieve the best morphological characteristics and growth parameters.

Materials and Research Methods:

A. Field Experiment

In the spring of 2020, a first field experiment was carried out using the Randomised Complete Block Design (RCBD) with three replications on the sugarcane plant Saccharum officinarum L. in the Diyala Governorate, Al-Muqdadiyah District, Abi Saida Sub-district, and Abu Saba' Village, which is located 60 kilometres northeast of Baqubah city, the governorate's centre. Beginning on March 1, 2020, three levels of nano-fertiliser (Optimus-Plus), which has a pH of 5-8% and contains 50% organic materials, 29% free plant amino acids, 20% organic carbon, and 2% nitrogen group, were applied at concentrations of 1, 2, and 3 litres ha^{-1} in addition to a control treatment. It was added after germination in three batches in months 4, 6, and 9 on four American varieties, CP72-2086, CP89-2143, CP81-325, and LO3-371 under drip irrigation technology, in soil with a clay loam texture.

B. Some Chemical and Physical Properties of the Soil:

According to the seedling planting experiment, soil samples were collected at a depth of 30 cm from different sites in the field. These samples were well-mixed and indicative of the field soil. After being allowed to air dry, the dirt was run through a 2 mm mesh screen. The Central Laboratory for Soil, Water, and Plant Analysis, College of Agricultural Engineering Sciences, University of Baghdad, carried out chemical and physical investigations of some soil parameters, as listed in Table (1).

Table 1: Some Chemical and Physical Properties of Field Soil Before Planting

The measured attribute	The value	unit of measurement
Electrical conductivity EC 1:1	1.3	Dsm^{-1}
soil acidity (pH)	7.11	-------
Available nitrogen (N)	24.21	
Available phosphorus (P)	10.12	$Mg\ kg^{-1}$ soil
Available potassium (K)	341.2	
organic matter O M	7.3	$Mg\ kg^{-1}$ soil
Calcium carbonate $CaCO_3$	261	
Dissolved calcium Ca^{+2}	11.3	

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Soluble magnesium Mg^{+2}		**7.3**	**milliequivalent $Liter^{-1}$**
Dissolved sodium Na^{+}		**6.2**	
Soluble bicarbonate HCO_3		**1.5**	
Dissolved chlorine (Cl)		**20.7**	
Soluble potassium K		**0.19**	
Soil separators	**Sand**	**244.1**	**Gm kg^{-1} soil**
	silt	**408.2**	
	clay	**347.7**	
Tissue classification		**Clay loam**	**clay mixture**

C. Experimental Design:

Four types x four (three stimulants plus control) = sixteen x three replicates = forty-eight experimental units. Measuring 42.5 m in length and 15 m in breadth, the planted field area was 637.5 m^2. Then, using wooden pegs and markings that were 50 cm high, the field was split into three portions. Each portion had dimensions of 3 m by 42.5 m and was further subdivided into 16 experimental units. Each experimental unit was 2 m in length and 3 m in breadth, with a total area of 6 m^2. To prevent the transfer of stimulants between the sections, two-meter-wide gaps were left between them, and each experimental unit was kept 70 cm apart to prevent overlap.

D. Land Preparation and Planting:

In the spring, the planting stalks were chopped and cleaned to prepare the experimental area. As part of the Technology Incubator Project (Sugar Production, Biofuel, and Secondary Industries from Sugarcane), which was funded by the Ministry of Higher Education and Scientific Research – Research and Development Department – Higher Education Incubator Section, mature sugarcane cuttings of three varieties were acquired from the sugarcane farm at the College of Agriculture, University of Diyala. The General Company for Sugar Industry's fields in Maysan provided the fourth variety, LO3-371. After that, tubing connected to the emitters and meter was installed to enable drip irrigation. The primary pump on the water channel was connected to a 5 cm-diameter main pipe that made up the drip irrigation system. After that, sub-pipes with emitters were positioned perpendicular to the main pipe, each having a flow rate of 2.0 litres per hour. The number of emitters was placed in the middle of each row of these 3.5 cm-diameter sub-pipes, which matched the number of rows in the experimental units.

This technique is characterised by an increase in the number of cane branches, which has helped to increase crop production in both quantity and quality. It also reduces lodging of the cane because there is enough soil to stabilise the roots after irrigation operations or in the event of strong winds. It also reduces infestation with pests and insects and reduces the amount of stem cuttings used in cultivation, which lowers production costs.

E. Crop Service and Control:

It is well known that one of the plants most vulnerable to weed competition is sugarcane. By sharing and competing with the plant for nutrients and fertilizers, weeds pose a major threat to output. Additionally, they keep sunlight from reaching every area of the plant as it is growing. When two genuine leaves appeared, manual weeding was done. When the plant grew taller than one meter, it covered the field's sunlight, which stopped the majority of weeds from growing. Up until October 15, 2023, irrigation was done as needed at different intervals of four to twelve days. On January 12, 2023, irrigation was halted in anticipation of harvesting.

Data were measured for several important growth characteristics in the growing plants at the two median lines for each experimental unit, and their average was calculated as follows:

Study of growth characteristics:

- Stem height (cm): Measured using a measuring tape from the soil surface to the last node of five plants taken from the protected rows in each experimental unit.

- Number of salvageable and non-salvage stems (stems per square meter): Counted the stems per square meter of each experimental unit.

- Stem diameter (cm): Measured for the same plants selected for stem height measurement from the 5 cm area above the soil surface. Using a measuring tape, measure the stem circumference, then calculate the stem diameter using the following equation:

Stem Diameter (Stem Circumference)/3.14

- Number of green leaves (plant $leaf^{-1}$): The green leaves of five plants were counted, and stem height and diameter were measured from each experimental unit.

- Leaf area (cm^2): The length and width of each leaf on each plant were measured, and the leaf area was calculated using the following equation: Leaf area = Leaf length × Maximum leaf width × 0.6274 [8].

- Ground area occupied by the plant (cm²): This was calculated using the ratio of the total number of stems per square meter.

- Leaf area index: This was calculated by dividing the leaf area by the ground area occupied by that plant [9].

- 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 atmospheric conditions until the weight stabilized. Quantitative Characteristics Study:

- Stem Yield (ton ha^{-1}): Stem yield was calculated from the weight of plants within one square meter, taken from the two midlines of each experimental unit, and converted to tons per hectare (Appendix 2).

- Sucrose Percentage in Juice (Poly%⁻%): 200 ml of juice was taken and placed in a 250 ml glass flask. 50 g of lead acetate was added, and after thorough shaking, filtration was performed. 75 ml of the filtrate was then taken and placed in a saccharimeter after ensuring the sample tube was clean. The average of three readings for this characteristic was recorded (A.O.A.C., 1995) [10].

- Sugar Yield (ton ha^{-1}): It was calculated according to the following [11]:

Sugar Yield (ton ha^{-1}) = Stem Yield per hectare × Sucrose Percentage

Statistical Analysis

The data were statistically analysed using the ANOVA method as a factorial experiment within a randomised complete block design (RCBD), and the least significant difference (LSD) was chosen to compare the means of the studied treatments under a probability level of 0.05, using SPSS software [12].

Results and Discussion

The average stem diameter (cm) and the quantity of harvestable stems (m-2 stems) differ significantly between cultivars, as Table 2 demonstrates. Stem height (cm) did not, however, significantly differ between types. The average stem diameter (cm) of variety CP72-2086 was the highest at 2.76 cm, while variety LO3-371 had the lowest average at 2.66 cm, a 3.75% increase. The stem diameter (cm) of variants CP72-2086, CP89-2143, and CP81-325 did not differ significantly. Similarly, for the same characteristic, there were no discernible differences between variants LO3-371, CP89-2143, and CP81-325. This is explained by either the innate characteristic of each variety or the genetic similarities between the kinds in the stem diameter trait (Fiaz et al., 2013)[13].In contrast to varieties CP72-2086 and CP89-2143, which recorded the lowest average at 17.25 and 17.00 stems m^{-2}, with increases of 15.94, 17.64, 11.59, and 13.23%, varieties LO3-371 and CP81-325 recorded the highest average in the trait of the number of extractable stems (stem m^{-2}) at 20.00 and 19.25 stems m^{-2}. As demonstrated by their higher average non-significant stem height, the superiority of types CP81-325 and LO3-371 in this trait's average suggests that they are more effective at making use of their genetic and physiological capacities. The quantity of harvestable stems reflects this. [14] showed the highest averages of 23.25 and 24.49 stems per square meter, respectively, which are in line with these findings.

Regarding the concentrations of nano fertilizer 1 liter ha^{-1}, the 3 liter ha^{-1} concentration was superior in the average height of the stem (cm), diameter of the stem (cm), and number of extractable stems (stem m^{-2}), with the highest averages of 316.12 cm, 2.98 cm, and 26.25 stem m-2, compared to the 2 and 1 liter ha^{-1} concentrations and the comparison, which recorded the lowest averages of 292.66, 243.66, 258.00 cm, 2.76, 2.64, 2.46 cm, 20.33, 19.58, and 16.91 stem m-2, with increases of 8.01%, 29.73%, 22.52%, 7.97%, 12.87%, 21.13%, 33.55%, 34.06%, and 55.23%, respectively. With an average stem height (cm) of 292.66 cm, the 2 LH^{-1} concentration outperformed the control and 1 LH^{-1} concentration, which had the lowest averages of 258.00 and 243.66 cm, respectively, indicating increases of 13.43% and 20.10%. There were no discernible variations in stem height between the 1 LH^{-1} concentration and the control. With an average stem diameter (cm) of 2.76 cm, the 2 LH^{-1} concentration outperformed the 1 LH^{-1} concentration and the control, which had the lowest averages of 2.64 and 2.46 cm, respectively, indicating increases of 4.54% and 12.19%. With an average stem diameter (cm) of 2.64 cm, the 1 LH^{-1} concentration outperformed the control, which had the lowest average (2.46 cm), indicating a 7.31% gain. In contrast to the 1 and 2 L ha^{-1} concentrations and the control, which recorded the lowest average of 18.58, 17.66, and 14.75 m^{-2} stems, respectively, representing an increase of 21.09%, 27.40%, and 52.54%, the 3 L ha^{-1} concentration had the highest average of 22.50 m-2 stems, 3.75 m-2 stems, and 28.90 leaves. With increases of 25.96% and 19.72%, the 1 and 2 L ha^{-1} concentrations outperformed the control in terms of the quantity of extractable stems (m^{-2} stems).

They provide the plant additional surface area for different metabolic processes, which raises the average rate of photosynthesis and generates more dry matter, both of which boost yield (Singh et al., 2017) [15]. With averages of 330.00 and 320.00 cm, respectively, varieties CP72-2086 and LO3-371, at a concentration of 3 L ha^{-1}, showed the greatest increase in stem height in relation to the interaction between varieties and concentrations. In contrast, the control variety CP89-2143, which showed growth of 35.77% and 32.53%, had the lowest average height of 282.16 cm. At a concentration of 1 L ha^{-1}, this in turn outperforms the CP72-2086 variety, which had the lowest average height of 218.00 cm, indicating a 29.43% increase.

In contrast to the CP72-2086 variety for the 2 L H^{-1} concentration, which recorded the lowest average of 2.96 cm with an increase of 7.43%, and the CP81-325 variety for the 2 and 3 L H^{-1} concentrations and the LO3-371 variety for the 3 L H^{-1} concentration, which gave the lowest average of 2.86 cm with an increase of 11.18%.They outperformed the two varieties LO3-371 and CP89-2143 for comparison for the same trait, with an average of 2.38 and 2.22 cm, with an increase of 8.82 and 16.66%, and the two varieties CP89-2143 and CP81-325 for the concentration of 1 liter ha^{-1}, with the lowest average of 2.59 cm, with an increase of 10.42%.

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Table 2: Effect of nano-fertiliser concentrations on vegetative growth indicators of sugarcane varieties

varieties	Nano fertiliser concentration per liter ha^{-1}	Stem height (cm)	Stem diameter(cm)	Number of extractable stems (stem m^{-2})
CP72-2086	0	239.66	2.54	13.00
	1	218.00	2.54	21.00
	2	276.50	2.96	15.00
	3	330.00	3.02	20.00
CP89-2143	0	282.16	2.22	16.33
	1	240.66	2.59	16.66
	2	300.16	2.70	20.00
	3	300.00	3.13	15.00
CP81-325	0	256.00	2.70	13.66
	1	271.00	2.59	17.66
	2	278.00	2.86	20.33
	3	314.50	2.86	25.00
LO3-371	0	254.16	2.38	16.00
	1	245.00	2.86	19.00
	2	316.00	2.54	11.66
	3	320.00	2.86	30.00
L.S.D (0.05)		33.68	0.18	3.64
Average varieties	CP72-2086	266.04	2.76	17.25
	CP89-2143	280.75	2.67	17.00
	CP81-325	279.87	2.75	19.25
	LO3-371	283.79	2.66	20.00
L.S.D (0.05)		N.S.	0.09	N.S.
Average stimuli	0	258.00	2.46	14.75
	1	243.66	2.64	18.58
	2	292.66	2.76	17.66
	3	316.12	2.98	22.50
L.S.D (0.05)		61.84	0.09	1.82

The CP81-325 variety at a concentration of 3 liters ha^{-1} and the CP72-2086 variety at a concentration of 1 liter ha^{-1} recorded the lowest average of 25.00 and 21.00 stems m-2, with an increase of 20.00 and 42.85%, respectively, while the LO3-371 variety at a concentration of 3 liters ha^{-1}

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achieved the greatest increase in the number of extractable stems, with an average of 30.00 stems m^{-2}. With increases of 41.56 and 15.90%, these two cultivars fared better than the CP81-325 variety, which had the lowest average of 17.66 stems m-2 at a concentration of 1 liter ha^{-1}.

At a concentration of 2 liters/h^{-1}, the final interaction for the same attribute fared better than the CP81-325, CP72-2086, and LO3-371 variations. The lowest average values of 13.66, 13.00, and 11.66 stem m-2 were recorded, indicating increases of 29.28%, 35.84%, and 51.45%, respectively. The average number of non-retrievable stems (stem m^{-2}), the number of green leaves (leaf per plant), and the leaf area (cm^2) all differ significantly between kinds, as Table 3 illustrates. The average number of non-retrievable stems significantly decreased in varieties LO3-371 and CP81-325, which recorded the lowest averages of 1.25 and 0.91 stems m^{-2}, respectively.

In contrast, the greatest averages of 4.25 and 3.16 stems m^{-2} were reported by types CP72-2086 and CP89-2143, respectively, indicating declines of 70.58%, 60.44%, 78.58%, and 71.20%. In contrast, the two kinds with the highest average number of retrievable stems—LO3-371 and CP81-325—recorded the lowest average number of non-retrievable stems. Cultivar CP89-2143, which has the lowest average stem diameter and the largest average number of non-extractable stems, is less effective in making use of its genetic and physiological capacities (Table 2).

Cultivar CP72-2086 recorded the highest average of 7.50 $leaves^{-1}$, indicating a decrease of 14.53% and 30.00%, respectively, while cultivars LO3-371 and CP89-2143 showed significantly lower numbers of green leaves ($leaf^{-1}$ plant), with averages of 6.41 and 5.25 $leaves^{-1}$, respectively. The quantity of green leaves ($leaf^{-1}$ plant) did not significantly differ between cultivars CP72-2086, CP81-325, and LO3-371. Varieties CP89-2143, CP81-325, and LO3-371 had the highest average number of dry leaves ($leaf^{-1}$ plant) at 18.66 and 17.83 $leaves^{-1}$ plant, respectively, while variety CP72-2086 had the lowest average at 15.83 $leaves^{-1}$ plant, indicating increases of 17.87% and 13.00%, respectively [16].

The plant has attained maturity, as evidenced by the notable decrease in the number of green leaves in these kinds and the notable increase in the number of dried leaves. Their non-significant increase in average stem height (Table 2, Research 2), which was reflected in the higher average number of dry leaves, indicates that these varieties are more effective in reaching final maturity by utilising their genetic and physiological capabilities. In contrast to the CP89-2143, CP81-325, and LO3-371 types, which had the lowest averages of 339.88, 337.89, and 298.59 cm^2, indicating increases of 13.07%, 13.73%, and 29.60%, respectively, the CP72-2086 variety had the largest average leaf area (cm^2) at 384.31 cm^2.

In terms of the nano-fertiliser (L ha^{-1}) concentrations, the 3 L ha^{-1} concentration recorded the highest average of 3.75 stems m^{-2}, indicating decreases of 73.33% and 42.40%, respectively, while the 1 L ha^{-1} concentration and the control group showed a significant decrease with averages of 1.00 and 2.16 stems m^{-2}. The number of non-retrievable stems (m-2 stems) did not significantly differ between the concentrations of 3 and 2 L ha^{-1} or between the 2 L ha^{-1} concentration and the control. With increases of 25.96% and 19.72%, respectively, the concentrations of 1 and 2 L ha^{-1} were superior to the control in terms of the quantity of retrievable stems (m^{-2} stems) (Table 2).

In comparison to the control, the average number of green leaves ($leaf^{-1}$ plant) increased non-significantly at concentrations of 3, 2, and 1 L ha^{-1}. In contrast to the 2 LH^{-1} concentration and the control, which had the lowest averages of 342.74 and 296.77 cm^2, indicating increases of 21.40% and 40.20%, respectively, the 3 LH^{-1} concentration fared better than the control in leaf area (cm^2), with an average of 416.10 cm^2. There were no discernible variations in leaf area (cm^2) between the 2 LH^{-1} concentrations, the 3 LH^{-1} concentrations, and the control. This might arise because of the distinctive qualities of nano-fertilisers, which clearly affect the vegetative traits under study.

Their enhanced surface area enhances the absorption surface and direct access into plant cells, and their compact size enables more effective absorption by the plant [17]. The quantity of green leaves (one leaf per plant) and leaf area (cm^2) were among the several vegetative traits that were greatly impacted.

These findings align with [18]. The CP89-2143 variety for comparison and the CP81-325 variety for concentrations of 1 and 2 litres ha^{-1} showed a highly significant decrease in the trait of the number of non-extractable stems, with an average of 0.00 stems m-2. In contrast, the CP89-2143 variety for concentration 3 litres ha^{-1} showed the highest average of 7.00 stems m-2, with a decrease of 100%.

The CP81-325 variety at concentrations of 1 and 2 liters ha^{-1} had an average of 6.00 $leaves^{-1}$ (a decrease of 18.14%), the LO3-371 variety at concentrations of 1 and 3 liters ha^{-1} had an average of 5.00 $leaves^{-1}$ (a reduction of 46.60%), and the CP89-2143 variety at concentrations of 2 liters ha^{-1} had averages of 4.66 and 4.00 $leaves^{-1}$ (a reduction of 36.42% and 45.42%, respectively). In comparison, the CP72-2086 variety reported an average of 7.33 leaves at concentrations of 1 and 2 liters ha^{-1}.

The LO3-371 variety, which recorded an average of 9.33 leaves per $plant^{-1}$ for the 2-liter ha^{-1} concentration, and the CP89-2143 variety, which recorded the highest increase for the same trait with an average of 18.00 leaves per $plant^{-1}$ for the 1-liter ha^{-1} concentration, both showed a decrease of 21.43% and 48.16%, respectively.

Table 3: Effect of nano-fertiliser concentrations on vegetative growth indicators of sugarcane varieties

varieties	Nano fertiliser concentration per liter ha^{-1}	Number of non-extractable stems (stem m^{-2})	Number of green leaves (plant $leaf^{-1}$)	Leaf area (cm^2)
CP72-2086	0	6.00	6.33	350.35
	1	2.00	7.33	329.65
	2	5.00	7.33	361.10
	3	4.00	9.00	496.16

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CP89-2143	**0**	**0.00**	**4.00**	**341.46**
	1	**1.00**	**18.00**	**329.65**
	2	**4.66**	**4.66**	**309.28**
	3	**7.00**	**6.33**	**379.16**
CP81-325	**0**	**1.66**	**7.00**	**256.53**
	1	**0.00**	**6.00**	**301.69**
	2	**0.00**	**6.00**	**385.35**
	3	**2.00**	**7.00**	**398.99**
LO3-371	**0**	**1.00**	**6.33**	**238.76**
	1	**1.00**	**5.00**	**361.10**
	2	**1.00**	**9.33**	**315.25**
	3	**2.00**	**5.00**	**390.11**
L.S.D (0.05)		**2.23**	**4.11**	**2. 07**
Average varieties	**CP72-2086**	**4.25**	**7.50**	**384.31**
	CP89-2143	**3.16**	**5.25**	**339.88**
	CP81-325	**0.91**	**6.50**	**337.89**
	LO3-371	**1.25**	**6.41**	**298.59**
L.S.D (0.05)		**1.11**	**N.S.**	**1.03**
Average stimuli	**0**	**2.16**	**5.91**	**296.77**
	1	**1.00**	**6.08**	**305.06**
	2	**2.66**	**6.83**	**342.74**
	3	**3.75**	**6.83**	**416.10**
L.S.D (0.05)		**1.11**	**2.05**	**N.S.**

In contrast to the CP72-2086 variety at a concentration of 3 liters ha^{-1}, the LO3-371 variety at a concentration of 1 liter ha^{-1}, and the CP81-325 variety at a concentration of 2 liters ha^{-1}, which recorded averages of 19.00, 18.33, and 18.00 leaves^{-1}, respectively, representing an increase of 26.31%, 30.93%, and 33.33%. Compared to the CP72-2086 and CP81-325 varieties, which had the lowest averages of 13.66 and 13.00 leaves^{-1}, respectively, these varieties had the greatest average, indicating a 39.09% increase. 46.15, 34.18, 41.00, 31.77, and 38.46%, in that order.. However, the interaction had no significant effect on the average leaf area (cm^2).

The average plant dry weight (g plant^{-1}) is significantly impacted by the cultivars, as Table 4 demonstrates. In comparison to the lowest average of 469.04 g plant^{-1}, the types CP81-325 and LO3-371 had the highest averages of 584.33 and 549.29 g plant^{-1}, respectively, indicating increases of 24.57% and 17.10%, respectively. The variations CP72-2086, CP89-2143, and LO3-371 did not differ significantly from one another. For the same feature, no discernible changes were found between the types CP89-2143, LO3-371, and CP81-325. The average plant area (cm^2) and leaf area index did not significantly differ amongst the kinds.

The fact that the same kinds showed the most significant increase in the number of extractable stems (Table 2) and a rise in plant dry weight (g plant^{-1}) may be the cause of this. The effectiveness of the plant's leaf surface in absorbing sunlight and transforming it into chemical energy—which is then utilized to reduce carbon dioxide into stable organic compounds that represent the plant's dry weight—determines the dry matter yield (Al-Hindawi & Al-Suhaibani, 2019)[19].

In terms of nano-fertilizer (L-H^{-1}) concentrations, the 3 L-H^{-1} concentration considerably raised the leaf area index with an average of 0.84, while the 2 L-H^{-1} and control concentrations showed the lowest averages of 0.64, 0.58, and 0.56, indicating increases of 31.25%, 44.82%, and 50.00%, respectively. In contrast to the 1 L-H^{-1} concentration and the control concentration, which recorded the lowest averages of 442.29 and 415.25 g-plant, representing increases of 45.77%, 55.26%, and 49.99%, respectively, the 3 L-H^{-1} and 2 L-H^{-1} concentrations significantly increased the

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plant dry weight (g-plant), with averages of 644.75 and 633.41 g-plant, respectively.

A. The average plant area (cm²) did not significantly differ across the various concentrations. This might be because the same concentrations, 2 and 3 L ha^{-1}, produced the most significant increase in stem diameter, number of harvestable stems, and leaf area (Tables 2 and 3), which was mirrored in an increase in plant dry weight (g $plant^{-1}$) and the leaf area index.

In comparison to the same variety at a concentration of 2 liter ha^{-1}, variety CP81-325 at a concentration of 3-liter ha^{-1}, and the control variety, which recorded an average of 625.00 cm², variety LO3-371 at a concentration of 1 liter ha^{-1} demonstrated superiority in plant area (cm²), with an average of 769.23 cm². At concentrations of 23.07% and 24.09%, respectively, it likewise performed better than variety CP89-2143. Additionally, variation CP89-2143 at a concentration of 2 liter ha^{-1}, variety CP72-2086 at a concentration of 500.00 cm², and variety CP81-325 at a concentration of 2-liter ha^{-1}, which recorded an average of 476.19 cm², were all outperformed.

The LO3-371 variety for the 3 L H^{-1} concentration 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%. In contrast, the CP89-2143 variety for the 3 L H^{-1} concentration recorded an average of 454.54 cm², and the CP72-2086 variety for the 1 L H^{-1} concentration.

Table 4: Effect of nano-fertilizers concentrations on vegetative growth indicators of sugarcane varieties

varieties	**Nano fertilizer concentration per liter ha⁻¹**	**Area of land occupied by the plant (cm²)**	**Leaf space guide**	**Dry weight of the plant (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.
Average varieties	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
L.S.D (0.05)		N.S.	N.S.	78.44

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Average stimuli	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

While the LO3-371 variety at a concentration of 3 liters ha^{-1} outperformed the foliage area index with an average of 1.24, compared to the CP89-2143 variety at a concentration of 3 liters ha^{-1}, which recorded an average of 0.83 (an increase of 49.39%), both of which outperformed the CP89-2143 variety at concentrations of 2 and 1 liters ha^{-1}, which recorded averages of 0.61 and 0.59 respectively, the LO3-371 variety for comparison (which recorded an average of 0.58), the CP89-2143 and CP81-325 varieties for comparison and at a concentration of 1 liters ha^{-1} (which recorded an average of 0.55), the CP89-2143 variety at concentrations of 2 and 1 liters ha^{-1} (which recorded averages of 0.50 and 0.46 respectively), and the CP81-325 variety For comparison, the average recorded was 0.41 with an increase 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 plant dry weight trait (g plant^{-1}).

The average sucrose percentage in juice (%Pol) and sugar output (ton ha^{-1}) are significantly impacted by variety, as Table 5 demonstrates. With averages of 14.91, 14.40, and 13.99% for the sucrose percentage in juice (%Pol), varieties CP89-2143, CP81-325, and CP72-2086 outperformed variety LO3-371, which had the lowest average of 13.28% with increases of 12.57%, 8.43%, and 5.34%, respectively.

In terms of sugar yield (ton ha^{-1}), the CP89-2143 variety did better than the other varieties, averaging 27.78 tons ha^{-1}, while the lowest averages were 23.24, 22.50-, and 22.08-tons ha^{-1}, respectively, indicating increases of 19.53%, 23.46%, and 25.81%. The average stem yield (ton ha^{-1}) did not differ significantly amongst the types. The non-significant increase in stem yield of sugarcane cultivars CP89-2143 and LO3-371 was in line with the rise in sucrose percentage in juice (%Pol) and sugar yield.

A. Variations in photosynthetic efficiency and the ensuing rise in vegetative mass, which resulted in an increase in sucrose production, may be the cause of this variance in the average of these traits between types. In particular, cultivars CP89-2143 and LO3-371 showed a notable rise in the average number of retrievable stems (Table 2) and a significant decrease in the number of green leaves and non-retrievable stems (stem m^{-2}) (Table 3). As a result, the average stem yield increased non-significantly, the sucrose % increased significantly, and the average sugar yield increased significantly.

. In comparison to the 2- and 1-liter ha^{-1} concentrations and the control group, which recorded the lowest averages of 192.42, 138.70-, and 120.29-tons ha^{-1}, indicating increases of 19.35%, 65.58%, and 90.93%, respectively, the 3 liter ha^{-1} concentration greatly increased stem yield (ton ha^{-1}) to an average of 229.67 tons ha^{-1}. In contrast to the control group and the 1 liter ha^{-1} concentration, the 2-liter ha^{-1} concentration also greatly boosted stem yield, with increases of 38.73% and 59.96%, respectively.

. Concentrations 2, 3, and 1 L ha^{-1} demonstrated a significant increase in the sucrose percentage in juice (%Pol) with averages of 15.05, 14.87, and 14.65% compared to the control group, which recorded the lowest average of 12.02%, representing an increase of 25.20%, 23.71%, and 21.88%. Concentrations 2 and 1 L ha^{-1} and the control group, which recorded the lowest averages of 27.07, 20.38-, and 14.49-tons ha^{-1}, representing an increase of 24.34%, 65.16%, and 132.29%.

Concentrations 2, 3, and 1 L ha^{-1} demonstrated a significant increase in the sucrose percentage in juice (%Pol) with averages of 15.05, 14.87, and 14.65% compared to the control group, which recorded the lowest average of 12.02%, representing an increase of 25.20%, 23.71%, and 21.88%. Concentrations 2 and 1 L ha^{-1} and the control group, which recorded the lowest averages of 27.07, 20.38-, and 14.49-tons ha^{-1}, representing an increase of 24.34%, 65.16%, and 132.29%.

In comparison to variety CP89-2143 at concentrations of 2 and 3 liters ha^{-1}, which recorded averages of 225.43- and 224.62-tons ha^{-1}, respectively, representing increases of 46.13% and 46.66%, variety LO3-371 at a concentration of 3 liters ha^{-1} demonstrated superior stem yield (ton ha^{-1}) with an average of 329.44 tons ha^{-1}. At a concentration of 2 liters ha^{-1}, these kinds exceeded variety LO3-371 with an average of 160.56 tons ha^{-1}, indicating increases of 105.18%, 40.40%, and 39.89%.

This, in turn, outperformed variety CP72-2086, which had an average of 96.60 tons ha^{-1}, and variety LO3-371 at a concentration of 1 liter ha^{-1}. ha^{-1} with an average of 85.73 tons ha^{-1} with an increase of 241.03, 133.36, 132.52, 66.21, 284.27, 162.95, 162.00 and 87.28%. While the CP89-2143 variety, at concentrations of 3 and 2 liters ha^{-1}, excelled in the sucrose percentage in juice (%Pol) with averages of 16.20% and 15.96%, respectively, the CP81-325 variety at 3 liters ha^{-1} with an average of 15.90%, and the CP89-2143 variety at 1 liter ha^{-1} with an average of 15.70%, compared to the CP81-325 variety at 1 liter ha^{-1} with an average of 13.50%, the LO3-371 variety at 3 liters ha^{-1} with an average of 13.10%, and the CP72-2086 variety with an average of 13.00%, representing increases of 20.00%, 23.66%, 24.61%, 18.22%, 21.83%, and 22.76%, respectively. 18.46, 21.37, 22.30, 16.29, 19.84, and 20.76%, respectively, outscored the LO3-371 category, which had the lowest average of 9.80%, by an increase of 65.30, 62.85, 62.24, 60.20, 37.75, 33.67, and 32.65%. In the sugar yield characteristic (ton ha^{-1}), the LO3-371 variety (concentration of 3 liters ha^{-1}) outperformed the CP89-2143 variety (concentration of 2 liters ha^{-1}), recording an average of 43.15 tons ha^{-1}, a 20.49% increase. With a concentration of 3 liters ha^{-1}, an average of 25.29 tons ha^{-1}, and rises of 70.62% and 41.59%, respectively, these two types fared better than the CP72-2086 variety.

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Table 5: Effect of nano-fertiliser concentrations on yield indicators for sugarcane varieties

Varieties	Nano fertilizer concentration per liter ha⁻¹	Stem yield (ton ha⁻¹)	Sucrose content in juice (Pol%)	Sugar yield (ton ha⁻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)	58. 10	2.06	7.23
Average varieties	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
Average stimuli	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

By percentage increases of 185.00, 196.56, 222.23, 243.82, 280.51, 135.46, 145.01, 179.16, and 184, they outperformed the CP89-2143 variety (compared to an average of 15.14 tons ha⁻¹), the CP81-325 variety (1 liter ha⁻¹ concentration, average of 14.55 tons ha⁻¹), the LO3-371 variety (12.77 tons ha⁻¹), and the CP72-2086 variety (average of 12.55 tons ha⁻¹).

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