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Effect of Levels and Times of Application of Super Micro Plus Nanofertilizer on Sugar Yield and Quality of Sugarcane Juice, *Saccharum Officinarum L*. Under the Conditions of the Central Region of Iraq

Nidhal Y.A. Alghargan[1]

[1]Diyala Education Directorate, Ministry of Education

Abstract

The experiment was carried out according to a completely randomized block design with three replications, and the data were analyzed statistically, and the results showed the following; (1) The use of nanofertilizer at the level of 2 g.l^{-1} resulted in a significant increase in all the studied characteristics represented in number of milling stems, the percentage of sucrose, the percentage of total dissolved solids, the percentage of juice purity, the stems yield , and the sugar yield, as it reached 54.9 stems.m^{-1}, 15.4%, 17.5%, 88.04%, and 61.5 tons.ha^{-1} and 9.34 tons.ha^{-1} respectively; (2) The spraying of nanofertilizer at the beginning of the tillering stage resulted in a significant increase in most of the studied characteristics represented in mean number of milling stems, the percentage of sucrose, the percentage of total dissolved solids, the stems yield, and the sugar yield, reaching 57.1 stems.m^{-1} , 14.1%, 17.2%, and 53.6 tons.ha^{-1} and 7.63 tons.ha $^{-1}$ respectively .While spraying the nanofertilizer at the beginning of the elongation stage showed a significant increase in juice purity amounted to 84.68%, Compared to the fertilizer application at the beginning of the tillering stage and the beginning of the maturity stage, which recorded 81.85 and 83.51%, respectively; (3) Spraying the plants with nanofertilizer at the level of 2 g.l^{-1} at the beginning of the tillering stage resulted in achieving the highest increase in each of the number of milling stems, the percentage of sucrose, the percentage of total dissolved solids, the percentage of juice purity, the stems yield, and the sugar yield, as it reached 62 stems.m^{-1} ,16.3%, 18.0%, 90.50%, and 66.0 tons.ha^{-1} and 10.30 tons.ha^{-1} respectively.

Keywords: Sugar Cane, Levels of Nanofertilizer, Timing of Application of Nanofertilizer, Qualitative Traits, Sugar Yield

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Introduction

Many field crops in Iraq face various challenges during the growth period until the stage of maturity and harvest, which is reflected negatively in the final yield, which requires thinking of alternatives to overcome these challenges, and among those alternatives was nanotechnology, one of the modern methods that appeared recently in several Fields including agriculture, which occupies an advanced position in the list of uses of nanotechnology (Al-Juthery and et al.2018, Raliya and et,al.2018 and Singh and et,al.2017).

Therefore, the study of the use of nanoparticles by foliar spraying is to resistance the negative effects on sugarcane plants, as the most important challenges are that plants growing in subtropical regions such as Iraq are exposed to environmental conditions that are not suitable for their growth, especially the high temperature during the major vegetative growth period,

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which leads to the death of some plant tillers, and thus ultimately leads to a decrease in crop yield per unit area (Alghargan, 2020).

There are many promising studies on the use of nanotechnology in the agricultural field, especially in crop fertilization. It has been found that the use of nanofertilizers as an alternative to traditional fertilizers achieves many benefits for the plant and the environment, and there are currently different types of nutrients that the plant needs, whether major or minor, in the nano form, which can be used in many field crops, such as nitrogen, phosphorus, potassium, iron, zinc, calcium, and others (Guru,et,al,2015 and Elemike,et, al. 2019) . Therefore, the idea of using Super Micro Plus nanofertilizer, which contains many nutrients, was sprayed on the leaves, with the aim of knowing the extent of its effect on sugar production and the quality of sugarcane juice under the conditions of the central region of Iraq.

Materials and Methods

A field experiment was carried out in one of the agricultural fields belonging to Baladruz township located in Diyala Governorate within the central region of Iraq during the season 2022-2023 in clayey mixture soil, pH 7.4, EC 7.3 dSiemens. m^{-1} and organic matter 7 g.kg of soil,by Completely Randomized Blocks Design . The treatments were randomly distributed with three replications . SUPER MICRO PLUS nano fertilizer contains elements N 5%, P 3%, K 3%, Fe 4.5%, Zn 8%, Ca 6%, Mg 6%, Mn 0.7%, Cu 0.65%, B 0.65% and Mo 0.1 % The first factor included four levels of nanofertilizer, namely (1, 2, and 3) gm l^{-1}, in addition to the control treatment (spraying with water only), while the second factor included spraying times (the beginning of the tillering stage, the beginning of the elongation stage, and the beginning of the maturity stage).

Soil and crop service operations were carried out, such as plowing, smoothing, leveling, drip irrigation, weed control, and others. The harvest took place on January 21, 2023.

The data obtained from the experiment were analyzed according to the method of analysis of variance for a factorial experiment with a Randomized Complete Block Design (RCBD) using the ready-made statistical program (SPSS), and the Least Significant Difference test (L.S.D) was chosen for comparison between the means, at the probability level of 0.05.

Ten plants were cut from each treatment at harvest, and measurements were taken for the following characteristics; (1) Number of milling stems (stems.m^{-1}): The milling stems were counted for one meter from each experimental unit (Alghargan, 2020); (2) Percentage of sucrose in the juice (Pol%): 200 ml of juice is taken and put in a glass flask its volume is 250 ml, 50 gm of lead acetate was added to it, after good shaking, the filtration process was carried out. Discard the first 25 mL of filtrate for possible presence of impurities, Then, 75 ml of the filtrate was taken and placed in a glucose meter (Saccharimeter) after making sure that the sample tube of the device is clean, and taking the average of three readings for this characteristic (Saleh, 1988 and A.O.A.C., 1995); (3) Percentage of total dissolved solids (Brix %): A drop of juice was taken by a pipette into the Brix-hydrometer device. The device recorded a reading represented as a percentage of these substances. The process was repeated three times for each sample to ensure the accuracy of the reading. The temperature of the juice was measured at each reading because The device was set at a temperature of 20 °C, then the reading was corrected using special tables (Saleh, 1988 and A.O.A.C., 1995); (4) Juice purity percentage (%): It was calculated according to the following equation:

Juice purity = sucrose percentage (Pol%) X 100

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Total dissolved solids (Brix %)

Stems yield (ton. ha^{-1}): The stems yield was calculated from the weight of plants within a square meter it was taken from the two middle lines of each experimental unit. It was converted to tons per hectare. (Alghargan and Almubarak, 2023)

Sugar yield (tons.ha^{-1}): It was calculated according to the following equation:

Sugar yield (tons.ha^{-1}) = stem yield (tons.ha^{-1}) X percentage of sucrose.

Results and Discussion

Effect of levels and times of application of nanofertilizer on the mean number of milling stems

The data of Table (1) indicate that there are significant differences between the levels and times of application of nanofertilizers and the interaction between them in the mean number of milling stems . Use of nanofertilizer at the level of 2 g.l^{-1} recorded a significant increase in mean of this trait, reaching 54.9 stems.m^{-1} and did not differ significantly from the use of nanofertilizer at the level of 3 g.l^{-1}, as it reached 54.2 stems.m^{-1} compared to the control treatment, which recorded 51.7 stems. m^{-1} . This may be due to the fact that the levels of 2 g.l^{-1} and 3 g.l^{-1} were appropriate to meet the nutritional requirements of the plant in a manner consistent with yielding the best number of milling stems, Or it may be due to the role of nanofertilizer in increasing the stem diameter (Alghargan and Almubarak, 2023) as a result of its role in storing large quantities of nutrients in the storage tissues of the stem, which was reflected positively in increasing the number of milling stems.

While the treatment of fertilizer spraying was recorded at the beginning of the tillering stage to cause an increase, as it reached 57.1 stems.m^{-1}, as measured by the fertilizer application at the beginning of the elongation stage and the beginning of the maturity stage, which recorded 51.6 and 51.7 stems.m^{-1} respectively . This may be because the plants benefit from the added amount of fertilizer in increasing the number of lateral buds in the plant, which may have caused an increase in number of milling stems (Duhana et al., 2017).

As for the interaction, the treatment of using nanofertilizer at the level of 2 g.l^{-1} at the beginning of the tillering stage achieved the highest increase, reaching 62.0 stems.m^{-1} and did not differ significantly from the use of nanofertilizer at the level of 3 g.l^{-1} at the beginning of the tillering stage, which achieved 59.3 stems.m^{-1} compared to the control treatment, which recorded 51.7 stems.m^{-1}.

Table 1. Effect of levels and times of application of super micro plus nanofertilizer in mean of number of milling stems (stems.m^{-1})

levels of nanofertilizer (g.l^{-1})	Spray times			Mean of spray levels
	beginning of the tillering stage	beginning of the elongation stage	beginning of the maturity stage	
0	51.7	51.3	52.0	51.7
1	55.3	52.0	51.7	53.0
2	62.0	51.3	51.3	54.9
3	59.3	51.7	51.7	54.2
Mean of spray times	57.1	51.6	51.7	

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L.S.D 0.05	to fertilizer levels 0.9	to spray times 1.1	to interaction 1.8

Effect of levels and times of spraying with nanofertilizer in the percentage of sucrose

The data of Table (2) indicate that there are significant differences between the levels and times of application of nanofertilizer and the interaction between them in the percentage of sucrose. The use of nanofertilizer at the level of 2 g.l⁻¹ recorded a significant increase in the mean of this characteristic, amounting to 15.4%, compared to the control treatment, which recorded 12.1%. The increase in the percentage of sucrose in the juice by using nanofertilizer may be due to its role in increasing the number of milling stems (Table 1), which means an increase in the activity of the neutralizing invertase enzyme in the largest part of the stem, as increasing its activity in mature tissues converts simple sugars into sucrose. Which leads to an increase in the percentage of sucrose in the juice, as Alexander & Montalvo (1973) indicated that the real increase in the percentage of sucrose is due to enzymatic activity.

Or it may be that the increase in the percentage of sucrose in the juice is due to the role of nanofertilizer in increasing the stem diameter of the plants (Alghargan & Almubarak, 2023), and this may have positively affected the percentage of sucrose in the stem, as Rizk & Abd Ali (1981) indicated that the sugar content in thick stems it is usually more than the sugar content in thin stems.

While the treatment of spraying nanofertilizer at the beginning of the tillering stage resulted in an increase of 14.1%, it did not differ significantly from spraying fertilizer at the beginning of the maturity stage, reaching 13.7% compared to the treatment of spraying fertilizer at the beginning of the elongation stage, which recorded 13.2%. This may be due, perhaps, to the role of the fertilizer added at the beginning of the tillering stage, to cause an increase in the leaf area and the number of green leaves in the plant (Alghargan and Almubarak, 2023), which contributed to increasing the ability of plants to carry out the process of photosynthesis and store large quantities of nutrients in the tissues of the plant, which was reflected positively in increasing the percentage of sucrose in the stems, as Alghargan (2020) mentioned that the percentage of sucrose in the stem comes primarily from increasing the photosynthesis process and increasing the efficiency of the process of transporting or accumulation sugars from the stems.

As for the interaction, the treatment of using nanofertilizer at the level of 2 g.l⁻¹ at the beginning of the tillering stage achieved the highest increase, reaching 16.3% compared to the control treatment, which recorded 12.2%.

Table 2. Effect of levels and times of application of Super Micro Plus nanofertilizer in mean of percentage of sucrose (%)

levels of nanofertilizer ($g.l^{-1}$)	Spray times			Mean of spray levels
	beginning of the tillering stage	beginning of the elongation stage	beginning of the maturity stage	
0	12.2	11.7	12.4	12.1
1	12.9	11.9	13.5	12.8
2	16.3	15.2	14.7	15.4
3	15.0	13.8	14.1	14.3
Mean of spray times	14.1	13.2	13.7	

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L.S.D 0.05	to fertilizer levels 0.7	to spray times 0.8	to interaction 0.4

Effect of levels and times of spraying with nanofertilizer in the percentage of total dissolved solids

The data of Table (3) indicate that there are significant differences between the levels and times of spraying nanofertilizers and the interaction between them in the percentage of total dissolved solids. The use of nanofertilizer at the level of 2 g.l⁻¹ recorded a significant increase in the mean of this characteristic, amounting to 17.5%, compared to the control treatment, which recorded 15.2%.

While the treatment of fertilizer spraying at the beginning of the tillering stage resulted in an increase of 17.2%, compared to the treatment of fertilizer spraying at the beginning of the elongation stage and the beginning of the maturity stage, which recorded 15.5 and 16.4%, respectively.

As for the interaction, the treatment of using nanofertilizer at the level of 2 g.l⁻¹ at the beginning of the tillering stage achieved the highest increase, reaching 18.0%, and did not differ significantly from the use of nanofertilizer at the level of 3 g.l⁻¹ at the beginning of the tillering stage, which achieved 17.4% compared to the control treatment, which recorded 16.9%, and it did not differ significantly from the treatment of using nanofertilizer at the level of 2 g.l⁻¹ at the beginning of the maturity stage, which achieved 17.5% compared to the treatment of using fertilizer at the beginning of the elongation stage, which recorded 16.9%.

Table 3. Effect of levels and times of application of Super Micro Plus nanofertilizer in mean of percentage of total dissolved Solids (%) .

levels of nanofertilizer ($g.l^{-1}$)	Spray times			Mean of spray levels
	beginning of the tillering stage	beginning of the elongation stage	beginning of the maturity stage	
0	16.9	13.6	15.0	15.2
1	16.4	16.2	16.6	16.4
2	18.0	16.9	17.5	17.5
3	17.4	15.4	16.3	16.4
Mean of spray times	17.2	15.5	16.4	
L.S.D 0.05	to fertilizer levels 0.5	to spray times 0.6	to interaction 0.8	

Effect of levels and times of spraying with nanofertilizer in the percentage of juice purity

The data of Table (4) indicate that there are significant differences between the levels and times of spraying nanofertilizers, and the interaction between them in the percentage of juice purity. The use of nanofertilizer at the level of 2 g.l⁻¹ recorded a significant increase in the mean of this characteristic amounted to 88.04%, and it did not differ significantly from the treatment of nanofertilizer at the level of 3 g.l⁻¹ , which amounted to 87.38%, compared to the control treatment, which recorded 80.18%.

While the treatment of fertilizer spraying at the beginning of the elongation stage resulted in a significant increase, reaching 84.68%, Compared to the fertilizer application at the beginning

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of the tillering stage and the beginning of the maturity stage, which recorded 81.85 and 83.51%, respectively.

As for the interaction, the treatment of using nanofertilizer at the level of 2 $g.l^{-1}$ at the beginning of the tillering stage achieved the highest increase, reaching 90.50% compared to the control treatment, which recorded 72.11. It did not differ significantly from the treatment of using nanofertilizer at levels 2 and 3 $g.l^{-1}$ at the beginning of the elongation stage , which amounted to 89.89 and 89.55% for each of them, respectively, compared to the control treatment, which recorded 85.82%.

Increasing the purity by using nanofertilizer may be due to its role in increasing the percentage of sucrose, as the conversion of simple sugars into sucrose by the action of invertase enzymes results in an increase in the purity of the juice (Blackburn, 1987).

Table 4. Effect of levels and times of application of Super Micro Plus nanofertilizer in mean of purity of the juice (%) .

levels of nanofertilizer ($g.l^{-1}$)	Spray times			Mean of spray levels
	beginning of the tillering stage	beginning of the elongation stage	beginning of the maturity stage	
0	72.11	85.82	82.62	80.18
1	78.62	73.44	81.27	77.78
2	90.50	89.89	83.72	88.04
3	86.16	89.55	86.43	87.38
Mean of spray times	81.85	84.68	83.51	
L.S.D 0.05	to fertilizer levels 0.95	to spray times 0.87	to interaction 1.31	

Effect of levels and times of application of nanofertilizers on the mean of stems yield

The data of Table (5) indicate that there are significant differences between the levels and times of spraying nanofertilizers and the interaction between them in mean of stems yield . The use of nanofertilizer at the level of 2 $g.l^{-1}$ recorded a significant increase in the mean of this characteristic, amounting to 66.0 $tons.ha^{-1}$ compared to the control treatment, which recorded 39.4 $tons.ha^{-1}$.

While the treatment of fertilizer spraying at the beginning of the tillering stage resulted in a significant increase, reaching 53.6 $tons.ha^{-1}$ compared to the treatment of fertilizer spraying at the beginning of the elongation stage and the beginning of the maturity stage, which recorded 50.1 and 49.2 $tons.ha^{-1}$ respectively.

As for the interaction, the treatment of using nanofertilizer at the level of 2 $g.l^{-1}$ at the beginning of the tillering stage achieved the highest increase, reaching 66.0 $tons.ha^{-1}$ compared to the control treatment, which recorded 39.4 tons. ha^{-1}.

The increase in stems yield may be due to the role of using nanofertilizers in increasing the number of total stems, increasing their diameter, increasing the number of green leaves in the plant and increasing their area (Alghargan & Almubarak, 2023). Al-Juthery et al. (2018) noticed that the use of nanofertilizers improved the productivity and growth of the wheat plant, as it has the ability to absorb, stick and move from the surface of the leaf through the stomata, which reflected positively in increasing the yield.

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Table 5. Effect of levels and times of application of Super Micro Plus nanofertilizer in mean of stems yield (tons.ha⁻¹)

levels of nanofertilizer (g.l⁻¹)	Spray times			Mean of spray levels
	beginning of the tillering stage	beginning of the elongation stage	beginning of the maturity stage	
0	39.4	39.7	39.1	39.4
1	45.9	42.5	41.8	43.4
2	66.0	60.4	58.2	61.5
3	63.2	57.6	57.6	59.5
Mean of spray times	53.6	50.1	49.2	
L.S.D 0.05	to fertilizer levels 1.4	to spray times 1.1	to interaction 2.0	

Effect of levels and times of spraying with nanofertilizer in mean of sugar yield

The data of Table (6) indicate that there are significant differences between the levels and times of spraying nanofertilizers and the interaction between them in mean of the sugar yield. The use of nanofertilizer at the level of 2 g.l⁻¹ recorded a significant increase in the mean of this characteristic, amounting to 9.34 tons.ha⁻¹ compared to the control treatment, which recorded 4.77 tons.ha⁻¹ an increase of 95.8 %.

While the treatment of nanofertilizer spraying at the beginning of the tillering stage caused a significant increase, reaching 7.63 tons.ha⁻¹ , as measured by the treatment of nanofertilizer spraying at the beginning of the elongation stage and the beginning of the maturity stage, which were recorded as 6.71 and 6.79 tons.ha⁻¹ respectively.

As for the interaction, the treatment of using nanofertilizer at the level of 2 g.l⁻¹ at the beginning of the tillering stage achieved the highest increase, reaching 10.30 tons.ha⁻¹ compared to the control treatment, which recorded 4.81 tons.ha⁻¹ an increase of 114 %.

The increase in the stems yield of sugar cane (Alghargan and Almubarak, 2023) is not the only positive change to increase the sugar yield for the crop. but raising the percentage of sucrose in the juice has an important role in this increase. The large increase in sucrose is a result of the conversion of simple sugars into sucrose by the action of invertases. . In general, increasing the number of milling stems (Table 1) had a positive effect on the percentage of sucrose (Table 2) and the stems yield (Table 5), which directly affected the sugar yield. This indicates that increasing the number of milling stems means an important contribution to increasing the sugar yield, as Almubarak (2013) indicated that increasing the number of milling stems and their heights leads to a significant increase in the stems yield of sugarcane , which affects the sugar yield.

The increase in number of tillers of the crop due to the use of nanofertilizers from the early stages until the maturity stage has led to the opportunity for sugar cane plants to better consume and make optimal use of the main growth requirements because it has become able and efficient to compete on growth requirements, which improves light penetration and increases photosynthesis rates (Almubarak, 2004), and then its effect on increasing the percentage of sucrose in the stems (Table 2) through its role in increasing the amount of this metabolite products directed to the stem , which reflected positively on the sugar yield of the crop.

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Table 6. Effect of levels and times of application of Super Micro Plus nanofertilizer in mean of sugar yield (tons.ha^{-1})

levels of nanofertilizer ($g.l^{-1}$)	Spray times			Mean of spray levels
	beginning of the tillering stage	beginning of the elongation stage	beginning of the maturity stage	
0	4.81	4.64	4.85	4.77
1	5.92	5.06	5.64	5.54
2	10.30	9.18	8.55	9.34
3	9.47	7.95	8.11	8.51
Mean of spray times	7.63	6.71	6.79	
L.S.D 0.05	to fertilizer levels 0.41	to spray times 0.26	to interaction 0.71	

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