Effect of Foliar Application of Nano Nutrients and Amino Acids as a Complementary Nutrition on Quantity and Quality of Maize Grains

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Abstract

In order to study the effect of foliar application of nano-NPK, nano-micronutrients, and nano-amino acids on the growth and yield of maize (Hybrid F1 Furat), a field experiment was carried out during the autumn season (2019) with an area of 1500 m² within the district of (41) – Al-Husseiniyah/ Al-Talea’a district/ Babylon Governorate according to Randomized Complete Block Design (RCBD) for two factors with three replicates. The first factor (nano-NPK) included three treatments: control, nano-NPK (20-20-20), and nano-NPK (12-12-36), while the second factor (nano-micronutrients and nano-amino acids) included four treatments: control, nano-micronutrients, nano-amino acids, nano-micronutrients + nano-amino acids. The studied indicators on maize plant included estimation of nutrient absorption in grains and total absorption (kg H⁻¹), estimation of fertilizer application efficiency (%). The results showed the significant superiority of NPK (12-12-36) spraying in achieving the highest averages of the studied indicators by an increase of (61.53%) in comparison with the comparison treatment for the total absorbed potassium, and an increase of iron and copper absorbed in the grains reached (3.938% and 22.321%), respectively, in comparison with the comparison treatment. And the application of the integrated nano-element fertilizer + nano amino acids achieved the highest averages of iron, manganese and copper absorbed in grains increased by (39.010%, 28.409%, 60.577%), respectively, comparing with the comparison treatment. and the interaction of the two study factors gave the combination of nano NPK (20-20-20) with integrated nano micro elements + nano amino acids the highest averages of nitrogen and phosphorus total absorption and for iron, manganese and copper with an increase of (110.06%, 81.83%, 64.251%), 74.065%, 109.375%), respectively, comparing with the comparison treatment. The highest nitrogen and phosphorous utilization efficiency was recorded at 55.12 and 36.65%, respectively, in comparison with high-potassium nano NPK, which corresponds to the combination of high-potassium NPK nano with nano (trace elements + amino acids) in recording the highest potassium utilization efficiency of 58.51% in comparison with the balanced nano NPK.

Key words: nano-macronutrients, nano-amino acids, yellow corn.

1. Introduction

Maize (Zea mays L.) has many beneficial properties. Its importance in current and future global food security is no less important in the Global carbon budget (C4 plant) as well as its tolerance to dry and semi-arid environments [1]. Maize is one of the important strategic crops, with multiple uses for agricultural and industrial fields, and it occupies the third place in terms of cultivated area and production in the world after the crops of wheat and rice, and because it is a quad carbon plant (C4), it is characterized by high production capacity compared with other cereals crops are also the first on record for average grain yield per unit area [2]. In spite of the significant importance of this crop and the growing interest in its cultivation in Iraq, there is a deterioration in its agricultural production and a decrease in the cultivated areas during the last decade and based on data and statistics issued by the Iraqi Agricultural Statistics Directorate and the Arab Organization for Agricultural Development, the total area cultivated by maize crop decreased from 154.70 thousand hectares in 2007 to 117 thousand hectares in 2010, with a decrease of 24%. The same statistics indicated a decrease in the production rate from 366.66 thousand tons in 2007 to 267 thousand tons in 2010, and a decrease of 27% [3].
A number of factors are responsible for the decline in maize productivity, among which are inadequate crop feeding management and reduced soil fertility are among the most important factors responsible for the decline in maize production [4]. It was also noted that one third of crop productivity was attributable to fertilizers and the rest depended on the efficient use of other agricultural inputs, however the efficiency of nutrient use for conventional fertilizers is barely limited to between 30 – 40 % [5].

Nano-fertilizers are nutrient vectors that are developed using raw materials Substrates of nanoscale ranging from 1 – 100 nm. Nanoparticles have a wide surface area and the ability to retain an abundance of nutrients and release them slowly and stably so as to facilitate the absorption of nutrients that corresponds to crop requirements without any disadvantages associated with specialized fertilizer inputs [6]. In order to achieve the aim of the highest quantitative and qualitative yield of maize versus using the latest standardized methods of fertilization and nutrient delivery to plants, the current study aimed to find out the effect of foliar spraying with:

1. Balanced nano NPK, high potassium, nano trace elements and amino acids, and the interplay between them in the quantitative and qualitative growth indicators of the yellow corn plant.

2. The overlap between the study factors on the indicators of quantitative and qualitative growth of the maize plant and determining the best combination in terms of recording the highest studied indicators.

2. The Materials and the working methods

2.1. The Experimental Design

A field experiment was designed to study the effect of foliar spraying of nutrients and nano-amino acids supplementary feeding on the quantitative and qualitative productivity of yellow corn grains (frat hybrids) consisting of two (3 × 4) factors according to a Randomized Complete Block Design (RCBD) with three replications for each treatment. The first factor represented by nano fertilizers NPK consisted of three factors: comparison, nano N, P and K balanced (20-20-20), and nano N, P and high potassium K (12-12-36) respectively, while it was formed The second factor represented by the nano-elements and amino acids from four parameters: comparison, nano-elements, nano-amino acids, and nano (microelements + amino acids).

2.2. The Field preparations

The soil of the field located within the district of (41) - Hussainiya / Al-Tali’a district / Babel Governorate where was prepared before planting by performing plowing, smoothing and leveling operations by the hydraulic agricultural machine, then a sample was taken by the upper at a depth of (0-30 cm) from five sites represented by the four sides of the field and the middle to be a representative sample of field soil after drying it airily and grinding it using ceramic mortar and sifting it with a sieve with a hole of 2 mm diameter and then conducting laboratory analyzes on it in the central laboratory of the College of Agriculture / University of Baghdad, and as in Table (1), according to the following methods:

- The degree of soil reaction (pH): The degree of soil reaction in the saturated paste to the soil was measured using a pH meter according to [7].

- The electrical conductivity (ECe): The electrical conductivity in the saturated paste of the soil was measured using an EC meter, according to [7].

- The Cation exchange capacity (CEC): The exchange capacitance of cationic ions in the soil was estimated using ammonium acetate and sodium acetate according to the method mentioned in [8].

- The organic soil material: The organic soil material was estimated by wet digestion method using (1 standard) of K2Cr2O7 according to mentioned in [8].

- The Carbonate minerals: The carbonate minerals in the soil were estimated by neutralizing them with (1 standard) of HCl and back-correction with (1 standard) of NaOH according to the method mentioned in [7].

- Bulk density: the bulk density of soil was estimated by the method of the mineral cylinder Core sample according to [8].
- The ready nitrogen: The ready nitrogen in the soil was estimated by extracting the soil with KCl at a concentration of (2 standard) and then estimation with the MicroKjeldahl device according to the [9], mentioned in [8].

- The ready phosphorous: The ready phosphorus was extracted in the soil using NaHCO3 at a concentration of (0.5 M) and the color was developed by ammonium molybdates and ascorbic acid, and then phosphorous was estimated using a spectrophotometer at a wavelength of 882 nm according to [7].

- The ready potassium: the ready-made potassium was extracted in the soil with a solution of ammonium acetate (1 standard), after which it was measured with a flame-photometer at a wavelength of 767 nm as mentioned in [8].

- The ready concentrate of micronutrients (iron, manganese, zinc and copper): [10] was adopted with a weight of 10 g of dry soil with air and placed in a 125 ml conical flask with 20 ml of DTPA Extraction Solution [Prepared from a weight of 1.97 g Of Diethylene triamine pentacetic acid (DTPA) and 1.1g of CaCl2, put into a beaker and dissolve with distilled water and complete the volume to 1 liter. 900 mL, and the pH was adjusted to 7.3 by adding 6 N of HCl and the volume was completed to 1 liter, as this solution contains 0.005 mL of DTPA, 0.1 mole of TEA and 0.1 Mm of CaCl2] and placed in a Reciprocal Shaker for two hours and then filtered Suspended by Filter Paper Whatman No. 42, and an appropriate series of standard element concentrations are made to form a calibration curve, and then the absorbance is determined by the Atomic Absorption Spectrophotometer (AAS) (Perkin Elmer, 5000 / US origin) using the lamp for each element in soil extract samples, and the concentration is calculated according to For the calibration curve for each component through the following equation:

\[
\text{Metal (ppm) = ppm Metal (from calibration curve) \times \frac{V}{Wt}}
\]

It represents: \(V = \text{total volume of soil extract (ml), Wt = weight of dry soil with air (g).} \)

- Volumetric distribution of soil separators: the estimation of the volumetric distribution of soil separators by the hydrometer method mentioned in [8].

| Table 1. Some chemical and physical properties of field soil before planting. |
|---------------------------------|-----------------|----------------|
| Quality                        | Value          | Measurement unit |
| (pH)                            | 7.5            | ds m⁻¹          |
| (ECe)                           | 2.2            | Cmol c /kg⁻¹ soil |
| Soil organic matter             | 15.0           | g kg⁻¹ soil     |
| Carbonate minerals              | 216            | g kg⁻¹ soil     |
| Bulk density                    | 1.3            | Mg m⁻³          |
| Available Nitrogen              | 15.60          | mg N kg⁻¹ soil  |
| Available Phosphorous           | 13.00          | mg P kg⁻¹ soil  |
| Available Potassium             | 280.00         | mg K kg⁻¹ soil  |
| Available Iron                  | 0.57           | mg Fe kg⁻¹ soil |
| Available Manganese             | 0.34           | mg Mn kg⁻¹ soil |
| Available Zinc                  | 0.30           | mg Zn kg⁻¹ soil |
| Available Copper                | 0.24           | mg Cu kg⁻¹ soil |
| Sand                            | 122            | g kg⁻¹ soil     |
| Silt                            | 579            | g kg⁻¹ soil     |
| Clay                            | 299            | g kg⁻¹ soil     |
| Soil texture                    | Silty clay loam|                 |

The mineral dab fertilizer Diamonium phosphate consisting of nitrogen (N = 18%) and phosphorous (P₂O₅ = 48%) was added to the field soil at once before planting by 200 kg H⁻¹, in addition to adding potassium sulfate K₂SO₄ to the field soil in one batch before planting by 360 kg e⁻¹.

The experiment field of a total area of 1500 square meters was divided into three consecutive sectors, and each sector was divided into 12 centers according to the experiment parameters.
2.3. Cultivation and Crop Management

On 1/8/2019, yellow maize seeds (hybrid Euphrates / South Africa variety) obtained from agricultural offices accredited to the Governorate of Diwaniyah were planted by trenches method by placing two seeds in each hole at a depth of 5-6 cm and at a 25 cm interval between hole. The irrigation process was carried out according to the plant’s need, depending on soil moisture sensing, as well as manual bush control by weeding whenever needed and before fertilization.

Urea fertilizer was added to all experimental units evenly in the amount of 264 kg N H⁻¹ [11] and in three batches; The first batch represented a quarter of the quantity (66 kg H⁻¹) added a month after the cultivation process, and the second batch represented half the amount (132 kg H⁻¹) added a month after the first addition process, while the third batch represented the last quarter (66 Kg H⁻¹) was added a month after the second incremental process to provide plants with nutrients during the different growth stages. The nanoparticles were sprayed by the method of foliar spraying on the shoots of the maize plant with two sprays, both in the early morning, at a rate of 400 liters spraying solution H⁻¹, equivalent to 1.6 kg e⁻¹ and 1.6 liters H⁻¹ for the two sprays of solid and liquid fertilizers respectively the first spray was 50 days after germination, and the second was 14 days after the first spraying, according to the instruction bulletins on the fertilizer envelopes issued by the manufacturers. The yellow corn crop was harvested on 12/20/2019, after all the plants had turned yellow and the cranberry became easily separated from the plant.

2.4. Adding fertilizer applications

2.4.1. The Nano Chelated NPK (20-20-20)

Nano NPK (20-20-20) fertilizer containing nitrogen (N), phosphorous (P₂O₅) and potassium (K₂O) was used in balanced proportions, at a concentration of 2 g L⁻¹ according to the instructions of the manufacturer.

2.4.2. Nano NPK Chelated High Potassium Nano Chelated NPK (12-12-36)

Nano NPK (12-12-36) fertilizer was used, containing nitrogen (N) and phosphorous (P₂O₅), respectively, at 12%, while potassium (K₂O) was 36%, at a concentration of 2 g L⁻¹ according to the instructions of the manufacturer.

2.4.3. The Nano Chelated Complete Micro

An integrated nano-element fertilizer (containing 8% Fe, 1.5% Zn, 1.5% Mn, 0.5% B, 0.5% Mo, and 0.5% Cu in chelated form and absorbed at pH = 3-11), at a concentration of 2 g L⁻¹ according to The manufacturer’s instructions.

2.4.4. The Nano Amino Acids

Optimus Plus Nano Amino Acid Fertilizer (an agricultural fertilizer manufactured according to nanotechnology containing 30% amino acids, 5% nitrogen and 3% organic nitrogen) was used at a concentration of 2 ml liter⁻¹ according to the instructions of the manufacturer.

2.5. The Studied Indicators

2.5.1. Estimation of total nutrient uptake (kgH⁻¹)

- The absorbance (content) of the major elements was estimated from the quotient of dividing (concentration of element x dry matter) by 100, as in the following equation:

\[
\text{Uptake of Macronutrient (Kg ha}^{-1}\text{)} = \frac{\text{Nutrient Conc.} \times \text{Dry matter (Kg ha}^{-1}\text{)}}{100}
\]

- The absorbance (content) of the trace elements was estimated from the product (concentration of element x dry matter), as in the following equation:

\[
\text{Uptake of Micronutrient (Kg ha}^{-1}\text{)} = \text{Nutrient Conc.} \times \text{Dry matter (Kg ha}^{-1}\text{)}
\]
The total absorption (content) of the major elements was estimated from the sum of (absorption in grains + absorbance in dry matter yield of the vegetative fraction).

2.5.2. Fertilizer application efficiency estimation (%)

The fertilizer application efficiency of nitrogen, phosphorous and potassium was calculated according to the proposed formula from [12]:

\[
\text{Fertilizer application efficiency} = \left( \frac{\text{comparison treatment in absorbent quantity} - \text{fertilizer with absorbed treatment quantity}}{\text{fertilizer additive quantity}} \right) \times 100
\]

The amount of fertilizer added for nitrogen = 300 kg N h\(^{-1}\), phosphorous = 42 kg P h\(^{-1}\), and potassium=150 kg K h\(^{-1}\).

2.6. The Statistical Analysis

The results data were analyzed statistically using the analysis of variance table according to the aforementioned design (RCBD), and the averages of the coefficients were compared when the differences between them were significant using the L.S.D Least Significant Difference test at a probability level (0.05) [13].

3. The results and discussion

3.1. Total absorption nitrogen (kg N h\(^{-1}\))

The results of Table (2) showed that the total nitrogen absorption with the effect of nano NPK reached the highest significant mean of 286.41 kg N h\(^{-1}\) when spraying with balanced NPK compared with the average nitrogen absorption of the comparison plants 201.82 kg N h\(^{-1}\) with an increase of 41.91%. Also, the spraying of nano-trace elements and amino acids had a significant effect on increasing the absorbed nitrogen, as the treatment with nano (trace elements + amino acids) recorded the highest mean mean of 287.02 kg N h\(^{-1}\), with an increase of 30.91% over the average nitrogen absorption of the comparison plants, which reached 219.25 kg N h\(^{-1}\). It was observed from the overlap between the two study factors to record significant differences for the average of the absorbed nitrogen, as the combination consisting of nano NPK balanced with nano (micro elements + amino acids) as well as the combination of high potassium nano NPK with nano (micro elements + amino acids) achieved the highest average of absorbed nitrogen. 315.62 and 311.79 kg N h\(^{-1}\), respectively, which were not significantly different from each other compared to what was recorded by the other combinations of interference, including the comparison combination with the lowest average of 150.25 kg N h\(^{-1}\), with an increase of 110.06 and 107.51%, respectively. This is due to the same reasons mentioned above, as the stimulation by these nano composites in encouraging vegetative growth stimulates the absorption of additional quantities of mineral elements to meet the plant’s need and the continuity of its vital activities due to the increase in demand for it, as the activity of enzymes that stimulate the transfer of nutrients and minerals helps them in this. As a result of the availability of an active vector device inside the plant, which is related to the continuous stimulation of the root system by the shoot system, which reflects positively on the increase of nitrogen absorbed in the plant.

Table 2. The effect of studied coefficients on average of total absorption nitrogen (kg N h\(^{-1}\))

| Nano NPK (2 g liters\(^{-1}\)) A | Nano microelements and amino acids | B | Average effect Nano- NPK |
|---------------------------------|-----------------------------------|---|--------------------------|
| Control                         | Control                           | 150.25 | 209.52 | 213.86 | 233.66 | 201.82 |
| NPK (20-20-20)                  | 265.87                            | 276.56 | 287.60 | 315.62 | 286.41 |
| NPK (12-12-36)                  | 241.62                            | 257.14 | 242.53 | 311.79 | 263.27 |
| Average effect of nano- microelements and amino acids | 219.25 | 247.74 | 248.00 | 287.02 |
| L.S.D 0.05                      | A=3.935                           | B=4.544 | AB=7.870 |
3.2. Total absorption phosphorus (kg P h⁻¹)

It was observed from the results of Table (3) that the total phosphorus absorbed significantly increased as a result of the different treatments of nano NPK compared with the comparison plants, as the balanced NPK treatment achieved the highest average of absorbed phosphorus of 31.48 kg P h⁻¹ compared with 24.54 kg P h⁻¹ for the treatment Comparison, with an increase of 28.28%. The significant effect of spraying nano trace elements and amino acids gave its treatment consisting of nano (trace elements + amino acids) the highest average for total absorbed phosphorus was 31.63 kg P h⁻¹, with an increase of 28.42% over the comparison treatment, which recorded 24.63 kg P h⁻¹. With regard to the interaction between the two study workers, it gave, by its combination of nano NPK balanced with nano (trace elements + amino acids), the highest significant mean of absorbed phosphorus was 34.22 kg P h⁻¹, compared with 18.82 kg P h⁻¹, with an increase of 81.83%. This is due to the same aforementioned reasons, as the stimulation by these nano composites in encouraging vegetative growth stimulates the absorption of additional quantities of mineral elements to meet the need of the plant and the continuity of its vital activities due to the increase in demand for them, as the activity of enzymes that stimulate the transfer of nutrients and minerals helps them in this. As a result of the availability of an active vector device inside the plant, which is related to the continuous stimulation of the root system by the shoot system, which is positively reflected in the increase of phosphorus absorbed in the plant.

| Nano NPK (2 g liters⁻¹) | Nano microelements and amino acids | B | Average effect nano- NPK |
|------------------------|-----------------------------------|---|-------------------------|
| Control                | 18.82                             | 26.50 | 25.54 | 27.30 | 24.54 |
| NPK (20-20-20)         | 28.14                             | 31.21 | 32.36 | 34.22 | 31.48 |
| NPK (12-12-36)         | 26.93                             | 29.79 | 31.21 | 33.37 | 30.33 |
| Average effect of nano- microelements and amino acids | 24.63 | 29.17 | 29.70 | 31.63 | L.S.D 0.05 | A=0.358 | B=0.413 | AB=0.716 |

3.3. Total absorption potassium (kg K h⁻¹)

The results of Table (4) show the significant effect of high-potassium NPK in increasing the average potassium absorption of yellow corn plants from 78.74 kg K h⁻¹ of the comparison treated plants to 127.19 kg K h⁻¹ with an increase of 61.53%. As for the spraying of nano fertilizers, trace elements and amino acids, it had a significant effect on the average total potassium absorbed, as the treatment with nano (trace elements + amino acids) recorded the highest significant mean of 120.09 kg K h⁻¹ with an increase of 34.09% over the comparison treatment that recorded 89.56 kg K h⁻¹. The two-way interaction between nano NPK and nano elements and amino acids gave a significant superiority to the average total potassium absorbed from the lowest value recorded of 53.03 kg K h⁻¹ in plants of the comparison combination to the highest value of 140.79 kg K h⁻¹ when plants treated with the combination of nano NPK with nano (Trace elements + amino acids), with an increase of 165.49%. This is related to the same reasons mentioned above, as a result of nanocomposites in encouraging vegetative growth, stimulating the absorption of additional quantities of mineral elements to meet the need of the plant and the continuity of its vital activities. Which reflects positively on the increase of potassium absorbed in the plant.
**Table 4.** The effect of studied coefficients on average of total absorption potassium (kg K h⁻¹).

| Nano NPK (2 g liters⁻¹) | Nano microelements and amino acids | B | Average effect nano- NPK |
|------------------------|----------------------------------|---|-------------------------|
| A                      | Control                           | Nano microelements g liters⁻¹ | Nano Amino Acids (2grm litter⁻¹) | NAA+ NCM |                      |
| Control                | 53.03                             | 86.63                          | 79.89                                | 95.41    | 78.74                |
| NPK (20-20-20)         | 98.27                             | 115.32                         | 112.16                               | 124.07   | 112.45               |
| NPK (12-12-36)         | 117.38                            | 121.09                         | 129.50                               | 140.79   | 127.19               |
| Average effect of nano- microelements and amino acids | 89.56                            | 107.68                         | 107.18                               | 120.09   |                      |
| L.S.D 0.05             | A=2.072                           | B= 2.392                      | AB=4.143                            |

**3.4. Iron absorption in grains (kg Fe h⁻¹)**

It was evident from the results of Table (5) that the treatment with high-potassium NPK nano-treatment was significantly superior in registering the highest significant mean of the iron absorbed in the grains of the yellow corn plant, which reached 2.217 kg Fe h⁻¹, compared with the comparison treatment, which recorded 2.133 kg Fe h⁻¹, with an increase of 3.938%. As for the effect of spraying nano fertilizers with microelements and amino acids on yellow corn plants, the treatment with nano (trace elements + amino acids) led to a significant increase in the average iron absorbed in the grains, amounting to 2.612 kg Fe h⁻¹ compared to 1.879 kg Fe h⁻¹ for the comparison treatment With an increase of 39.010%. The combination of nano-significant interference NPK balanced with nano (trace elements + amino acids) achieved the highest significant mean of iron absorbed in the grains, reaching 2.720 kg Fe h⁻¹, with a significant superiority over all other combinations, including the comparison combination with the lowest mean of the target trait of 1.656 kg Fe h⁻¹, with an increase of 64.251%. The stimulation carried out by these nanocomposites in encouraging vegetative growth stimulates the absorption of additional quantities of mineral elements to meet the need of the plant and the continuity of its vital activities due to the increase in demand for it. This is in agreement with the ability of elements or nanoparticles to bind to protein carriers that penetrate the cell walls and encourage an increase in the uptake of the material into the plant [14]. These results were consistent with those of [15] on yellow corn.

**Table 5.** The effect of studied coefficients on average iron absorption in grains (kg Fe h⁻¹).

| Nano NPK (2 g liters⁻¹) | Nano microelements and amino acids | B | Average effect nano- NPK |
|------------------------|----------------------------------|---|-------------------------|
| A                      | Control                           | Nano microelements g liters⁻¹ | Nano Amino Acids (2grm litter⁻¹) | NAA+ NCM |                      |
| Control                | 1.656                             | 2.604                         | 1.791                                | 2.480    | 2.133                |
| NPK (20-20-20)         | 1.861                             | 2.393                         | 1.716                                | 2.720    | 2.172                |
| NPK (12-12-36)         | 2.121                             | 2.459                         | 1.651                                | 2.636    | 2.217                |
| Average effect of nano- microelements and amino acids | 1.879                            | 2.485                         | 1.720                                | 2.612    |                      |
| L.S.D 0.05             | A=0.0353                          | B= 0.0408                      | AB=0.0706                           |

**3.5. Zinc absorption in grains (kg Zn h⁻¹)**

The results of Table (6) gave significant differences to the zinc absorbed in grains with the effect of nano NPK, as the balanced treatment with NPK recorded the highest average of the trait in grains with 0.371 kg Zn h⁻¹ compared with the comparison treatment that recorded 0.365 kg Zn h⁻¹ with an increase of 1.644 %. As for the application of nano-elemental and amino acids fertilizers, the highest average of zinc absorbed in the grains was 0.439 kg Zn h⁻¹ when treated with nano-trace elements, with an increase of 54.035% over the comparison treatment plants with a significantly lower average of zinc absorbed in the grains 0.285 kg Zn h⁻¹.
The overlap between the two study workers showed significant differences in the mean of zinc absorbed in the grains, the highest percentage increase of which was 70.943% when comparing the lowest mean of 0.265 kg Zn h\(^{-1}\) recorded by the comparison plants with the highest mean of 0.453 kg Zn h\(^{-1}\) recorded by the comparison plants. For nano NPK with nano microelements. This is due to the stimulation carried out by those nanocomposites in encouraging vegetative growth, stimulating the absorption of additional quantities of mineral elements to meet the need of the plant and the continuity of its vital activities due to the increase in the demand for it. Associated with the continuous stimulation of the shoot-mediated root system, these results were consistent with those of [15] on yellow corn plant.

### Table 6. The effect of studied coefficients on average zinc absorption in grains (kg Zn h\(^{-1}\)).

| Nano NPK (2 g liters\(^{-1}\)) | Nano microelements and amino acids | B | Average effect nano- NPK |
|--------------------------------|----------------------------------|---|------------------------|
| Control                        | Control                          | Nano microelements g liters\(^{-1}\) | Nano Amino Acids (2g litter\(^{-1}\)) | NCM + NAA |                      |
| NPK (20-20-20)                 | 0.265                            | 0.453                          | 0.341                          | 0.400     | 0.365                |
| NPK (12-12-36)                 | 0.303                            | 0.436                          | 0.329                          | 0.417     | 0.371                |
| Average effect of nano- microelements and amino acids | 0.286                            | 0.429                          | 0.315                          | 0.406     | 0.359                |
| L.S.D 0.05                     | A=0.0055                         | B= 0.0064                      | AB=0.0110                      |

3.6. Manganese absorption in grains (kg Mn h\(^{-1}\))

The results of Table (7) indicated that significant differences were recorded for the average of manganese absorbed in grains with the effect of the NPK treatment, as the balanced NPK treatment achieved the highest mean mean of 0.560 kg Mn h\(^{-1}\) with an increase of 16.424% compared to the untreated plants that recorded 0.481 kg. Mn h\(^{-1}\). The results also indicated the significant role of spraying nano (trace elements + amino acids) in increasing the manganese absorbed in the grains by 28.409% over the comparison treatment, as both recorded an average of 0.565 and 0.440 kg Mn h\(^{-1}\), respectively. The interaction between the study workers with its combination of nano NPK balanced with nano (trace elements + amino acids) gave the highest mean of the trait in the grains, reaching 0.745 kg Mn h\(^{-1}\), with a significant superiority over all other combinations of average manganese absorbed in the grains, including the comparison combination. The average rate is 0.428 kg Mn h\(^{-1}\), with an increase of 74.065%. This is due to the catalytic role of the plant to increase the absorption of mineral elements and water, as the stimulation performed by these nanocomposites in encouraging vegetative growth stimulates the absorption of additional quantities of mineral elements to meet the plant’s need and the continuity of its vital activities due to the increase in demand for it. Transfer of nutrients and minerals as a result of the availability of an active transporter within the plant associated with the continuous stimulation of the root system by the shoot, and these results were consistent with the results of [15] on the yellow corn plant.

### Table 7. The effect of studied coefficients on average manganese absorption in grains (kg Mn h\(^{-1}\)).

| Nano NPK (2 g liters\(^{-1}\)) | Nano microelements and amino acids | B | Average effect nano- NPK |
|--------------------------------|----------------------------------|---|------------------------|
| Control                        | Control                          | Nano microelements g liters\(^{-1}\) | Nano Amino Acids (2g litter\(^{-1}\)) | NCM + NAA |                      |
| NPK (20-20-20)                 | 0.428                            | 0.639                          | 0.399                          | 0.458     | 0.481                |
| NPK (12-12-36)                 | 0.399                            | 0.562                          | 0.535                          | 0.745     | 0.560                |
| Average effect of nano- microelements and amino acids | 0.493                            | 0.412                          | 0.396                          | 0.491     | 0.448                |
| L.S.D 0.05                     | A=0.0092                         | B= 0.0106                      | AB=0.0184                      |
3.7. Copper absorption in grains (kg Cu h⁻¹)

The results of Table (8) indicated the superiority of all the treatments that included nano NPK in increasing the average copper absorbed in the grains over the comparison treatment with the mean less significant 0.112 kg Cu h⁻¹ corresponding to the highest significant mean of absorbed copper that reached 0.137 kg Cu h⁻¹ when treating with NPK High potassium, with an increase of 22.321%. The significant effect of spraying nano fertilizers with trace elements and amino acids showed that the treatment of nano (trace elements + amino acids) achieved the highest average of copper absorbed in the grains of 0.167 kg Cu h⁻¹ compared with 0.104 kg Cu h⁻¹ for the comparison treatment plants, with an increase of 60.577%. The significant binary overlap of study workers showed, by the combination of nano NPK balanced with nano (trace elements + amino acids), the highest average number of copper absorbed in the grains was 0.201 kg Cu h⁻¹, with a significant difference of 109.375% over the comparison combination with a mean of 0.096 kg Cu h⁻¹. And this stimulation carried out by those nanocomposites in encouraging vegetative growth is through the absorption of additional quantities of mineral elements to meet the need of the plant and the continuity of its vital activities due to the increase in demand for it. Associated with the continuous stimulation of the root system mediated by the shoot system.

Table 8. The effect of studied coefficients on average copper absorption in grains (kg Cu h⁻¹).

| Nano NPK (2 g liters⁻¹) | Nano microelements and amino acids | B | Control | Nano microelements g liters⁻¹ | Nano Amino Acids (2grm litter⁻¹) | NCM + NAA | Average effect nano- NPK |
|-------------------------|-----------------------------------|---|---------|--------------------------------|----------------------------------|-----------|-------------------------|
| Control                 | 0.096                             | A | 0.138   | 0.077                           | 0.137                            | 0.112     |
| NPK (20-20-20)          | 0.095                             | A | 0.144   | 0.084                           | 0.201                            | 0.131     |
| NPK (12-12-36)          | 0.121                             | A | 0.151   | 0.112                           | 0.163                            | 0.137     |
| Average effect of nano- microelements and amino acids | 0.104                             | A | 0.145   | 0.091                           | 0.167                            | 0.0061    |
| L.S.D 0.05              | A=0.0031                          | B= 0.0035                        | AB=0.0061                        |

3.8. Fertilizer application efficiency (%)

It was noted from the results in Table (9) for the calculation of the efficiency of fertilizer application of nitrogen, phosphorous and potassium in the maize plant that the combination of fertilizer consisting of nano NPK balanced and high in potassium with nano-elements and nano-amino acids had a good effect in increasing the efficiency of fertilizer application (%) of nitrogen And phosphorous and potassium, in which the combination of nano NPK balanced with nano (trace elements + amino acids), the highest utilization efficiency of nitrogen and phosphorus reached 55.12 and 36.65%, respectively. It stood at 58.51%. The lowest utilization efficiency of nitrogen and phosphorous was the effect of the comparator combination of high-potassium NPK, which recorded 30.46 and 19.29%, respectively, while the lowest efficiency of using potassium was recorded with the effect of the comparator combination of the balanced NPK at 30.16%. The significant increase achieved in the quantities of absorbed elements in the grains and the dry matter yield of the vegetative part of the yellow corn plant as a result of treatment with nanofertilizers, whether major or minor ones with amino acids, returns to its catalytic role for the plant to increase the absorption of mineral elements and water, as the stimulus that it performs Nanocomposites in encouraging vegetative growth stimulate the absorption of additional quantities of mineral elements to meet the need of the plant and the continuity of its vital activities due to the increase in demand for it. The activity of enzymes that stimulate the transfer of nutrients and mineral materials as a result of the availability of an active transport system inside the plant is linked to the continuous stimulation of the root system by the vegetative system. This is in agreement with what [16] stated about the ability of elements or nanoparticles to bind to protein carriers that penetrate the cell walls and encourage an increase in the absorption of the material into the plant, aided by the increase in the stem diameter of the plant and the number of transport vessels within it [14] Which reflects positively on the increase in the efficiency of fertilizer use of nitrogen, phosphorus and potassium. These results were consistent with those of [15] on yellow corn.
Table 9. The effect of the studied treatments on fertilizer use efficiency (%).

| Nano NPK       | Control (without spray) Fertilize the ground only | Nano microelements and amino acids NCM + ground fertilization | Nano amino acids NAA + Ground Fertilizer | NCM + NAA+ Fertilize the soil |
|----------------|-----------------------------------------------|-------------------------------------------------------------|----------------------------------------|-------------------------------|
| NPK (20-20-20) | 38.54                                        | 42.10                                                       | 45.78                                  | 55.12                         |
|                | 22.19                                        | 29.49                                                       | 32.22                                  | 36.65                         |
|                | 30.16                                        | 41.52                                                       | 39.42                                  | 47.36                         |
| NPK (12-12-36) | 30.46                                        | 35.63                                                       | 30.76                                  | 53.85                         |
|                | 19.29                                        | 26.11                                                       | 29.50                                  | 34.64                         |
|                | 42.90                                        | 45.37                                                       | 50.98                                  | 58.51                         |

Conclusions

1. The superior significant role of high-potassium nano NPK foliar spray in recording the highest averages of (N, P, K) total absorption and iron, copper and manganese absorbed in grains.

2. The treatment with nano-microelements and nano-amino acids achieved the highest significant averages of most of the important characteristics of the maize plant, and increased the grain content of the macronutrients and micro-absorbed nutrients.

3. Sprinkling with macronutrients and nano-amino acids as supplementary feeding improved the efficiency of application of ground-based fertilizers.

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