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# EFFECT OF NANOPARTICLES AND ORDINARY ZINC OXIDE FERTILIZER AND HUMIC ACID ON ZINC AND PHOSPHOROUS AVAILABLY IN THE SOIL

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## Abstract

A pot experiment was carried out in the plastic house dedicated to the Department of Soil and Water Resources, using silty loam soil (SiL) collected from the Horticulture Fields Department, College of Agricultural Engineering Sciences, University of Baghdad. To study the effect of adding different levels of nano and ordinary zinc oxide fertilizer interaction with different levels of Humic acid (HA) to the soil and its effects on growth characteristics of *Zea mays* L. crop at the beginning stage of male inflorescence formation. The seeds of (*Zea mays* L.), Baghdad 3, were planted in the autumn season (2018-2019) by seven seeds in each pot and were reduced to three plants pot$^{-1}$ after two weeks of germination. The Randomized Complete Block Design (RCBD) was used in a three-replication factor experiment, the experiment included three factors: Zinc sources, zinc levels, and Humic acid, as well as non-addition treatment (control). They used fertilizers were mixed with the soil by the following types and levels; ordinary ZnO (12 and 18) kg Zn.h$^{-1,}$ and ZnO nanoparticles (12 and 18) kg Zn.h$^{-1}$ and Humic acid HA (0 and 60) kg HA.h$^{-1}$. While Phosphate fertilizer was added at the level of 80 kg P.h$^{-1}$ in one dose before cultivation, Potassium fertilizer was added at the level of 120 kg K.h$^{-1}$ and Nitrogen fertilizer at the level of 240 kg N.h$^{-1}$ in two doses. The data were statistically analyzed and the least significant difference (LSD) was calculated to test the differences between treatments at a probability level of 0.05 using the Genstat program. The results showed that the triple interference resulted in a significant increase in the phosphorous concentration in the soil, as the phosphorus concentration reached 9.73 m P kg$^{-1}$ soil at the stage of formation of the male inflorescence. The bilateral interaction between the average nano zinc oxide and humic acid showed a significant increase in the concentration of phosphorous availability in the soil. In the vegetative stage, it reached 14.68 m P kg$^{-1}$ soil. The addition of humic acid led to a significant increase in the concentration of ready zinc in the soil at the stage of the male inflorescence. The concentration of available zinc reached 11.86 m Zn kg$^{-1}$ soil. The addition of the level 18 kg Zn ha$^{-1}$ to the two stages resulted in a significant increase in the average concentration of zinc and phosphorus in the soil, as it averaged 10.95 m Zn kg $^{-1}$ soil and 13.70 m Pkg $^{-1}$ soil, respectively.

***Keywords*: Zinc oxide, humic acid, nanotechnology.**

## Introduction

The maize (*Zea mays* L.) belongs to the Poaceae family, which is considered one of the most important food and industrial cereal crops of this family. Corn grains containing high amounts of vitamin A equal approximately to twenty times that of wheat grains (Orhun, 2013), the yellow maize Cultivation has been distributed over northern, central and southern Iraq, and its area reached 76000 thousand hectares in 2016 and the average production was 3.42 mega gm.h$^{-1}$ (Statistical agriculture office, 2017). However, Iraq's maize production is still below the average of developed countries, Therefore, methods and techniques should be used to increase productivity. Nanotechnology is one of the most modern discoveries of the 21st century, which is used in all fields of life. This technique is a distinct scientific method that involves the modification of the physical and chemical properties of the substance at the molecular or atomic level, which is between 1-100 nm and is the most accurate metric unit of measurement known so far (Ram *et al.*, 2014). It has been used in many fields, including environmental engineering, textiles, biomedicine, construction and water resources, and communication technology and food industry; there is also an opportunity to have a significant impact on the environment, economy, energy and agricultural systems (Veronica *et al.*, 2015). Furthermore, Nanomaterials have been used in agriculture, where Nano fertilizer is used instead of conventional fertilizers to meet the need of the plant from the necessary nutrient, increase productivity and reduce the problem of harmful effects on soil and the environment. This has been encouraged by the fact that Nano fertilizers can be more effective in reducing soil contamination and other environmental hazards that can occur when other commercial fertilizers are used. The advantages available in nano fertilizers are its high surface particle areas and their density and interactions increment on the exchange surfaces of organic and mineral colloids (Ram *et al.*, 2014). Nanotechnology may contribute to the manufacture of fertilizers by designing zinc fertilizers that can release zinc on demand and thereby prevent zinc reactions with soil colloids and microorganisms that reduce zinc availability for crops (DeRosa *et al.*, 2010). Zinc oxide is a high containing zinc fertilizer (Zn-78%), which can provide sufficient amounts of zinc for the plant. At present, studies have been conducted on the use of zinc oxide Nanoparticles in fertilizing some crops on the scope of laboratory studies and pot experiments, where the Zinc oxide Nanoparticles can give better growth, high production rate and improve quality (Prasad *et al.*, 2012). The high range of use of chemical fertilizers without following the fertilizer recommendation caused significant damage to human health and the environment (Mustafa, 2018). Therefore, researchers resorted to the use of various methods to reduce the pollution of chemical fertilizers and the accumulation of nutrients in the soil, which cause plant toxicity and implemented better and more successful and less costly methods through natural organic that improve different soil properties (Flayeh, 2017). Humic acid is one of the organic compounds "commercial economic products" with fast effectiveness that contains many elements, where it is a humus substance that is nutritious to the plant (Mohammad *et al.*, 2014). Humic acid is used to reduce the harmful effects of mineral fertilizers in Soil (Mora *et al.*, 2014), its substances affect increasing the physiological activity of the plant and its impact on the growth and plant content of nutrients. Finally, the current study aims to investigate the effects of adding different levels of ordinary zinc oxide and zinc oxide Nanoparticles interact with different levels of Humic acid (HA) to the soil.

## Materials and Methods

A pot experiment was carried out in a plastic house for the autumn season (2018-2019) using silty loam soil located at the level of soil aggregate (Typic torrifluvent), according to Soil survey staff (2006). Surface soil samples (0-30 cm) were collected from the soil of one Horticulture Department Fields / College of Agriculture / University of Baghdad, randomly (Composite Sample) mixed to form a composite soil sample and air-dried, then sifted through a 4 mm diameter sieve and (20) kg of soil were added in each pot, which represents one experimental unit. A factorial experiment was carried out according to (RCBD) and included nine experimental treatments with three replicates, including comparative treatment that representing soil treatment only (without the addition of Zn and Humic acid). Treatments were randomly distributed to 27 experimental units, while the statistical analysis was conducted according to (ANOVA Test), and the averages were compared with the least significant difference LSD in 0.05 when the statistical analysis was achieved by Statistical Analysis System-SAS (2012) commercial software. Fertilizer sources were added with the following types and levels: ordinary ZnO (12 and 18) kg Zn.h$^{-1}$ and ZnO nanoparticles (12 and 18) kg Zn.h$^{-1}$, where Table 1 shows the chemical properties of zinc nanoparticles and the Table shows some chemical properties of Humic acid HA (0 and 60) kg HA.h$^{-1}$. Nitrogen and potassium added at a constant level for all treatments, where Nitrogen was added in the form of Urea fertilizer (46% N) at 240 kg N.h$^{-1}$ and potassium was added in the form of $K_2SO_4$ (41.5% K) at 120 kg K.h$^{-1}$ with two equal doses. The first dose was mixed with soil before the cultivation and the second dose after 30 days of germination dissolving with irrigation water, moreover, Phosphorus was added in the form of triple super calcium phosphate fertilizer (20% P) at the level of 80 kg P.h$^{-1}$ at one dose before cultivation mixing with the soil. The phosphate fertilizers and the first dose of Nitrogen and potassium fertilizers were mixed with the soil surface layer with a depth (0-15) cm before cultivation, the pot was planted with yellow corn seeds (Baghdad 3) in the autumn season (2018) by 7 seeds in each pot and were reduced to 3 plants.pot$^{-1}$ after two weeks of germination. The bush was removed from each pot, and the corn stem borer *Sesamia cretica* L. was controlled twice by diazinon pesticide (10%), the first is preventive control after the formation of 4-5 leaves, and the second control ten days after the first control (Ministry of Agriculture, 2006). Treatments were irrigated immediately after planting with the preservation of humidity by (80%) of the calculated available water amount for calculating the percentage of humidity in a laboratory at the permanent wilting point, field capacity, and the continuation of irrigation after depleting (50%) of available water (gravimetric method) to return humidity to (80%) of the available water.

**Table 1:** Some chemical properties of used ZnO nanoparticles

| Model | ZINC OXIDE |
|---|---|
| APS (nm) | 50 |
| Purity (%) | > 99.9 |
| Specific Surface area (m$^2$ g$^{-1}$) | 100 |
| Volume density (g cm$^{-3}$) | 0.30-0.45 |
| Density (g cm$^{-3}$) | 5.60 |
| Crystal form | Cube |
| Color | White |

**Table 2:** Some chemical properties of Humic Acid used in the cultivation.

| | |
|---|---|
| Total Organic Matter | %70 |
| Total Humic Acid (as Dry Basis) | %80 |
| Potassium (as $K_2O$ Dry Basis) | %10 |
| Moisture | %15 |
| pH | 9 – 11 |

Samples of soil were taken before cultivation, then mixed to form a composite sample, air-dried, milled and sifted through a 2mm diameter sieve, where some of its chemical and physical properties were estimated before the cultivation as shown in Table 3. The average height of the plant (cm) for the three plants was calculated from the soil surface to the first internode of the male inflorescence (Al-Sahoki, 1990). As well as, the average leaf area of three plants in each pot in the male inflorescence stage was calculated according to the following equation (Thomas, 1975) leaf area = leaf length x Center width x Correction factor (0.75). The vegetative part of the three plants was collected in each pot in the male inflorescence stage, and the three cultivated plants were cut off and the vegetative part was isolated from the root part of the three plants from each pot. The root was isolated from the surrounding soil, free from any soil residue by washing it with distilled water, the shoot and root were washed with tap water, then with distilled water, and dried and placed in perforated paper bags, then placed in an oven at a temperature of (65°C) until the weight is stable. The dry weight was measured with a sensitive balance for both shoot and root in the male inflorescence stage.

**Table 3 :** Some chemical and physical properties of soil study before the cultivation

| Properties | | Value | Unit |
|---|---|---|---|
| $_{p}$H value | | 7.46 | - |
| Electrical Conductivity (EC) | | 2.13 | ds.m$^{-1}$ |
| Cation Exchange Capacity (CEC) | | 17.0 | cmol. Charge. Kg$^{-1}$soil |
| Organic matter | | 12.1 | gm.kg$^{-1}$soil |
| Gypsum | | 1.08 | |
| Carbonate minerals | | 251 | |
| Dissolved cation ions | Calcium | 2.49 | cmol. Charg.L$^{-1}$ |
| | Magnesium | 1.83 | |
| | Potassium | 0.10 | |
| | Sodium | 2.45 | |
| Dissolved negative ions | Carbonates | Nil | |
| | Bicarbonate | 0.34 | |
| | Sulfates | 1.06 | |
| | Chlorine | 1.58 | |
| Available elements | Nitrogen | 51.3 | mg.kg$^{-1}$soil |
| | Potassium | 136 | |
| | Phosphorus | 10.8 | |
| | Zinc | 6.31 | |
| Field capacity | | 25.3 | **%** |
| Wilt point | | **5.3** | |
| Total Zinc | | 168 | mg.kg$^{-1}$soil |
| Soil separators | sand | 360 | gm.kg$^{-1}$ |
| | Silt | 520 | |
| | Clay | 120 | |
| Texture | | Silty loam soil (SiL) | |

## Results and Discussion

### Available zinc in the soil at the vegetative stage (mg Zn kg $^{-1}$ soil):

Table (4) showed that there was no significant increase in the concentration of Available zinc in the soil when adding fertilizer sources, the average concentration of Available zinc in the soil decreased with the addition of humic acid which averaged 8.99 mg Zn kg$^{-1}$ soil compared to not adding humic acid which 11.30 mg Zn kg$^{-1}$ soil, with a decrease rate of 20.44%. As for the effect of the average levels of nanoscale and ordinary zinc oxide fertilizer, the table showed a significant increase in the average concentration of Available zinc in the soil when adding the level 18 kg Zn ha$^{-1}$ to an average of 10.95 mg Zn kg$^{-1}$ soil compared to the level 12 kg Zn ha$^{-1}$, which has an average level of 9.34 mg Zn kg$^{-1}$ soil and coffee With an increase of 17.24%, the bilateral interaction between the average source of ordinary fertilizer and humic acid showed a significant decrease in the Available zinc concentration in the soil when adding humic acid at the vegetative growth stage and it averaged 9.41 mg Zn kg$^{-1}$ soil compared to not adding humic acid which averaged 10.70 mg Zn kg$^{-1}$ soil, with a decrease of 12.06%, and bilateral interaction between the average source of nano fertilizer and the addition of humic acid achieved a significant decrease, as it averaged 8.56 mg Zn kg$^{-1}$ soil, compared to not adding humic acid as it averaged 11.90 mg Zn kg$^{-1}$ Soil, with a decrease of 28.07%. Bilateral interference between the mean sources and levels showed a significant increase in the concentration of ready-made zinc in the soil, as it averaged 10.77 mg Zn kg$^{-1}$ soil with nanostructures at the level 18 kg Zn ha$^{-1}$ compared to the level 12 kg Zn ha$^{-1}$, which averaged 9.69 mg Zn kg$^{-1}$ soil with an increase of 11.15%, as well as the added fertilizer added and the level 18 kg Zn ha$^{-1}$ and an average of 11.12 mg Zn kg$^{-1}$ soil compared to the level of 12 kg Zn ha$^{-1}$ which averaged 8.99 mg Zn kg$^{-1}$ soil and an increase of 23.69% As for the bilateral interaction between the levels, humic acid, and triple interference, it was not significant.

### Available zinc in the soil at the stage of formation of the male inflorescence (mg Zn kg$^{-1}$ level of soil):

Table (5) showed a significant increase in the concentration of ready-made zinc in the soil when adding nanoparticle zinc oxide, as the average zinc concentration was 11.18 mg Zn kg$^{-1}$ soil by adding nanoparticular zinc oxide and 10.50 mg Zn kg$^{-1}$ soil by adding the usual zinc oxide and by a percentage An increase of 6.48%. There was also a significant increase in the concentration of available zinc in the soil from the addition of humic acid at the stage of the male inflorescence, as the concentration of available zinc reached 11.86 mg Zn kg$^{-1}$ soil compared to an average concentration of 9.81 mg Zn kg$^{-1}$ soil without adding humic and with an increase of 20.90 %, The table showed a significant increase in the average concentration of available zinc in the soil when adding a level of 18 kg Zn ha$^{-1}$ as it averaged 11.37 mg Zn kg$^{-1}$ soil compared to the 12 kg Zn ha$^{-1}$ which reached an average level of 10.31 mg Zn kg $^{-1}$ soil with a ratio An increase of 10.28%. The bilateral interaction between the average source of fertilizer and humic acid and between the average sources and levels was not significant, the bilateral interaction between the levels and humic acid was significant in increasing the concentration of ready zinc in the soil at the stage of formation of the male inflorescence, as it reached at the level 18 kg Zn ha$^{-1}$ for fertilizer and level 60 kg ha$^{-1}$ of humic acid 11.95 mg Zn kg$^{-1}$ soil compared to the level of 12 kg Zn ha$^{-1}$ for fertilizer and at the level of 60 kg ha$^{-1}$ of humic acid which averaged 11.77 mg Zn kg$^{-1}$ soil with an increase of 1.53% at the level 18 kg Zn ha$^{-1}$ and no addition of humic. The concentration of ready zinc in the soil was 10.78 mg Zn kg$^{-1}$ Goddess compared to the level of 12 kg Zn ha$^{-1}$, which averaged 8.84 mg Zn kg$^{-1}$ soil, with an increase of 21.95%, while the triple interference was not significant. The significant increase of ready zinc in the soil in the vegetative growth stage when increasing the level of addiction and at the bilateral interaction of the sources of zinc oxide fertilizer with the levels as well as the interaction of the sources of fertilizer with humic acid may be due to the containment of zinc oxide fertilizer added to the soil on the element zinc and by increasing the level of addition the increase of zinc concentration In the soil. the nanotextured was significant in increasing the ready zinc concentration due to the large surface area of the zinc nanoparticle and then high solubility, effective concentration, good efficacy, increasing its density and increasing its reactions on the organic and mineral colloidal surfaces and ease of diffusion Hence, the concentration of zinc increases in the soil. As for the reason for the decrease in the ready zinc in the soil when the binary interference of zinc nanoxide fertilizer with humic acid may be because the root surfaces of most plants are charged with negative charge while the nanomaterials are charged with positive charges and thus lead to the capture of nanomaterials On plant root surfaces (Zhu *et al.*, 2012) this can reduce zinc readiness in the soil solution and with the presence of humic acid the nanomaterials grasping on the root surfaces can become stronger and these results are consistent with (Navarro *et al.*, 2012), as well as containing the soil before planting On the amount of phospho Thus, t increased adsorption of zinc. As for the stage of formation of the male inflorescence when adding nanoscale and regular zinc oxide fertilizer with increasing levels of addition to zinc because the fertilizer contains zinc and increasing root secretions that reduce the degree of soil interaction and thus increasing the readiness of zinc in the soil solution (Ali, 2012), zinc oxide fertilizer The nanoparticles significantly outperformed the usual zinc oxide fertilizer in the amount of ready zinc in the soil due to the large surface area of the zinc nanoparticle and then high solubility, effective concentration, good efficacy, increased intensity and increased interactions on the organic and mineral colloidal surfaces. These results are consistent with what happened to (Monreal *et al.*, 2016 and Rastogi *et al.*, 2017).

### Available phosphorous in the soil at the vegetative stage (mg pkg $^{-1}$ soil):

Table (6) showed a significant increase in the concentration of ready-made phosphorous in the soil from the addition of nanoparticular zinc oxide, as it averaged 13.87 mg P kg kg$^{-1}$ soil compared to an average of 12.98 mg P kg kg$^{-1}$ soil with the addition of the usual zinc oxide and with an increase of 6.86%. Significant increase in the concentration of ready-made phosphorous in the soil when adding humic acid in the two phases. The average ready-made phosphorous concentration was 14.45 mg P kg$^{-1}$ soil compared to an average of 12.04 mg P kg$^{-1}$ soil without adding humic at an increased rate of 20.02%. As for the effect of average levels Nano-zinc oxide fertilizer. The table showed a significant increase in the phosphorous concentration Shake the soil level of the addition of 18 kg Zn ha$^{-1}$, with an average of 13.70 mg P kg$^{-1}$ soil compared to the value at the level of 12 kg Zn ha$^{-1}$, which averaged 13.15 mg P kg$^{-1}$ soil and by an increase of 4.18%. The bilateral interaction between nanoferture and humic acid showed a significant increase when adding humic acid in the vegetative growth stage and it averaged 14.68 mg P kg$^{-1}$ soil compared to not adding humic acid which averaged 13.05 mg P kg$^{-1}$ soil and with an increase of 12.49%, the values of The mean of bilateral interaction between ordinary fertilizer and humic acid is 14.22 mg P kg kg$^{-1}$ soil and 11.74 mg P kg$^{-1}$ soil when no humic acid is added and with an increase of 21.12%, the bilateral interaction between the average sources and levels was not significant, bilateral interference between levels and humic acid Achieved significant increase in the concentration of phosphorous in the soil The level is 18 kg Zn ha$^{-1}$ for zinc oxide fertilizer and the level is 60 kg ha$^{-1}$ for humic acid as it averaged 14.52 mg P kg$^{-1}$ soil, compared to the level 12 kg Zn ha$^{-1}$ which gave the lowest value and reached 14.38 mg P kg$^{-1}$ soil with an increase rate At 0.97%, at the level of 18 kg Zn ha$^{-1}$ and the non-addition of humic acid, the ready-made phosphorous concentration in the soil was 12.87 mg P kg kg$^{-1}$ soil compared to the level of 12 kg Zn ha$^{-1}$ which averaged 11.92 mg P kg$^{-1}$ soil with an increase in its amount 7.97%. Triple overlap was not significant.

### Available phosphorous in the soil at the stage of formation of the male inflorescence (mg p kg$^{-1}$ soil):

Table (7) showed a significant increase in the concentration of available phosphorous in the soil from the addition of nanoparticle zinc oxide and an average of 9.25 mg P kg$^{-1}$ soil when adding nanoparticular zinc oxide and 8.81 mg P kg$^{-1}$ soil when adding the usual zinc oxide and an increase of 4.99% There was a significant increase in the concentration of available phosphorous in the soil when adding humic acid and an average of 9.43 mg P kg$^{-1}$ soil compared to an average of 8.64 mg P kg$^{-1}$ soil when no humic acid was added and with an increase of 9.14%. As for the effect of the average levels of nanoparticle and ordinary zinc, Tables showed a significant increase in the concentration of available phosphorous in the soil. The addition of the level 18 kg Zn ha$^{-1}$ and an average of 9.24 mg P kg$^{-1}$ soil compared to its value at the level of 12 kg Zn ha$^{-1}$ which averaged 8.82 mg P kg$^{-1}$ soil with an increase of 4.76%. The bilateral interaction between the average sources of fertilizer and humic acid and between the average Sources and levels between the levels of fertilizer and humic acid were not significant, the triple interference achieved a significant increase in the concentration of ready phosphorus in the soil and the highest increase was at the nanoscale source of zinc oxide fertilizer and the level 18 kg Zn ha$^{-1}$ and the addition of the acid as it averaged 9.73 mg P kg$^{-1}$ soil Compared to the control, it reached 7.23 mg P kg$^{-1}$ soil, with an increase of 34.58%. The significant increase in the concentration of available phosphorous in the soil due to the addition of nanoparticle zinc oxide fertilizer by increasing the levels and adding humic acid as well as bilateral interference at the stage of vegetative growth between (sources and humic) and (levels and humic) as well as triple interference in the stage of male inflorescence all of these interactions had Significant effect in increasing the concentration of available phosphorous in the soil. The reason for this is because the nanoparticle and zinc oxide fertilizer are normal and with increasing levels of addition. The enzymes involved in metabolism, root cell development and permeability of wood (Vitti *et al.*, 2014; Morales-Díaz *et al.*, 2017). When breathing the roots, they produce $CO_2$ that interacts with water and thus produces carbonic acid that works to reduce the degree of soil reaction and thus increase phosphorus readiness in an area. The rhizosphere, as well as humic acid, works to chelate zinc and increase the readiness of phosphorus in the soil. The moral effect of triple interference in increasing the concentration of phosphorus in the soil at the stage of the male inflorescence may be attributed to the fact that the zinc nano feed fertilizer has large interactive surfaces and is easy to spread and dissolve and by increasing the level of addition and the presence of humic acid improves the properties of the soil and the amino acid tryptophan that makes IAA necessary for the elongation of cells enters Zinc in protein formation and representation, as well as in activating the enzymes responsible for forming nucleic acids, and that humic acid has a great ability to ion exchange and regulate the degree of soil interaction and water retention, which leads to increased efficiency of water absorption and pain. Self-contained by the plant (Ali and Mindari, 2016) so it is a large root group and upon breathing the roots produce $CO_2$ that interacts with water and thus produces carbonic acid that works to reduce the degree of soil interaction and then increase the readiness of phosphorous in the rhizosphere and that humic acid works on zinc chelate And increase the readiness of phosphorous in the soil. The correlation coefficient between the concentration of ready phosphorous in the soil in the vegetative stage with the concentration of ready zinc in the soil at this stage is highly significant negative (0.582 ** -) (Appendix 2) and the correlation coefficient between the concentration of ready phosphorous in the soil and the concentration of ready zinc in the vegetative stage When regular zinc oxide was used, it was significantly negative (-0.388 *) (Appendix 2). The value of the correlation coefficient between the concentration of ready-made phosphorous in the soil at the stage of formation of the male inflorescence with the concentration of ready-made zinc in the soil for nanoparticles and the usual highly significant positive (0.745** and 0.825**), respectively (Appendix 2).

**Table 4 :** Effect of Nano and Ordinary Zinc Oxide Fertilizers and Their Levels and Humic Acid on Ready Zinc Concentration in Soil mg Zn kg $^{-1}$ Soil in the Vegetative Growing Stage of Maize

| **Fertilizer sources** | **Zinc levels Kg Zn.ha$^{-1}$** | **Humic acid levels Kg HA.ha$^{-1}$** | | **Average sources x levels** |
|---|---|---|---|---|
| | | **0** | **60** | |
| ord-ZnO | 12 | 9.57 | 8.41 | 8.99 |
| | 18 | 11.83 | 10.41 | 11.12 |
| Average sources x Humic acid | | 10.70 | 9.41 | 10.06 |
| Nano-ZnO | 12 | 11.57 | 7.81 | 9.69 |
| | 18 | 12.23 | 9.31 | 10.77 |
| Average sources x Humic acid | | 11.90 | 8.56 | 10.23 |
| Average Humic acid | | 11.30 | 8.99 | 10.15 |
| Control | | 6.80* | | |

| **Fertilizer sources** | **Zinc levels kg Zn.ha$^{-1}$** | | **Average sources** |
|---|---|---|---|
| | **12** | **18** | |
| ord-ZnO | 8.99 | 11.12 | 10.06 |
| Nano-ZnO | 9.69 | 10.77 | 10.23 |
| Average levels | 9.34 | 10.95 | 10.15 |

| **Humic acid levels kg HA.h$^{-1}$** | **Zinc levels kg Zn.h$^{-1}$** | | **Humic acid average** |
|---|---|---|---|
| | **12** | **18** | |
| 0 | 10.57 | 12.03 | 11.30 |
| 60 | 8.11 | 9.86 | 8.99 |
| Average levels | 9.34 | 10.95 | 10.15 |

| **Treatments** | **Sources** | **Levels** | **Humic acid** | **Sources X levels** | **sources X Humic acid** | **levels X Humic acid** | **Sources X levels X Humic acid** |
|---|---|---|---|---|---|---|---|
| L.S.D$_{0.05}$ | n.s | 0.37 | 0.37 | 0.53 | 0.53 | n.s | n.s |

**Table 5 :** Effect of Nano and Ordinary Zinc Oxide Fertilizers and Their Levels and Humic Acid on Ready Zinc Concentration in Soil mg Zn kg $^{-1}$ Soil in Male Formation Stage of Maize

| **Fertilizer sources** | **Zinc levels Kg Zn.ha$^{-1}$** | **Humic acid levels Kg HA.ha$^{-1}$** | | **Average sources x levels** |
|---|---|---|---|---|
| | | **0** | **60** | |
| ord-ZnO | 12 | 8.57 | 11.50 | 8.99 |
| | 18 | 10.13 | 11.77 | 11.12 |
| Average sources x Humic acid | | 9.35 | 11.64 | 10.06 |
| Nano-ZnO | 9.10 | 9.10 | 12.03 | 9.69 |
| | 11.43 | 11.43 | 12.13 | 10.77 |
| Average sources x Humic acid | | 10.27 | 12.08 | 10.23 |
| Average Humic acid | | 9.81 | 11.86 | 10.15 |
| Control | | 10.13 * | | |

| **Fertilizer sources** | **Zinc levels kg Zn.ha$^{-1}$** | | **Average sources** |
|---|---|---|---|
| | **12** | **18** | |
| ord-ZnO | 10.04 | 10.95 | 10.50 |
| Nano-ZnO | 10.57 | 11.78 | 11.18 |
| Average levels | 10.31 | 11.37 | 10.84 |

| **Humic acid levels kg HA.h$^{-1}$** | **Zinc levels kg Zn.h$^{-1}$** | | **Humic acid average** |
|---|---|---|---|
| | **12** | **18** | |
| 0 | 8.84 | 10.78 | 9.81 |
| 60 | 11.77 | 11.95 | 11.86 |
| Average levels | 10.31 | 11.37 | 10.84 |

| **Treatments** | **Sources** | **Levels** | **Humic acid** | **Sources X levels** | **sources X Humic acid** | **levels X Humic acid** | **Sources X levels X Humic acid** |
|---|---|---|---|---|---|---|---|
| L.S.D$_{0.05}$ | 0.43 | 0.43 | 0.43 | n.s | n.s | 0.60 | n.s |

**Table 6 :** Effect of Nano and Ordinary Zinc Oxide Fertilizers and their Levels and Humic Acid on the Ready Phosphorus Concentration in Soil mg Pkg$^{-1}$ Soil in the Vegetative Growing Stage of Maize

| **Fertilizer sources** | **Zinc levels Kg Zn.ha$^{-1}$** | **Humic acid levels Kg HA.ha$^{-1}$** | | **Average sources x levels** |
|---|---|---|---|---|
| | | **0** | **60** | |
| Ord-ZnO | 12 | 11.57 | 14.13 | 12.85 |
| | 18 | 11.90 | 14.30 | 13.10 |
| Average sources x Humic acid | | 11.74 | 14.22 | 12.98 |
| Nano-ZnO | 12 | 12.27 | 14.63 | 13.45 |
| | 18 | 13.83 | 13.73 | 14.28 |
| Average sources x Humic acid | | 13.05 | 14.68 | 13.87 |
| Average Humic acid | | 12.04 | 14.45 | 13.43 |
| Control | | 10.53* | | |

| **Fertilizer sources** | **Zinc levels kg Zn.ha$^{-1}$** | | **Average sources** |
|---|---|---|---|
| | **12** | **18** | |
| Ord-ZnO | 12.85 | 13.10 | 12.98 |
| Nano-ZnO | 13.45 | 14.28 | 13.87 |
| Average levels | 13.15 | 13.70 | 13.43 |

| **Humic acid levels kg HA.h$^{-1}$** | **Zinc levels kg Zn.ha$^{-1}$** | | **Humic acid average** |
|---|---|---|---|
| | **12** | **18** | |
| 0 | 11.92 | 12.87 | 12.04 |
| 60 | 14.38 | 14.52 | 14.45 |
| Average levels | 13.15 | 13.70 | 13.43 |

| **Treatments** | **Sources** | **Levels** | **Humic acid** | **Sources X levels** | **sources X Humic acid** | **levels X Humic acid** | **Sources X levels X Humic acid** |
|---|---|---|---|---|---|---|---|
| L.S.D$_{0.05}$ | 0.36 | 0.36 | 0.36 | n.s | 0.51 | 0.51 | n.s |

**Table 7 :** Effect of Nano and Ordinary Zinc Oxide Fertilizers and their Levels and Humic Acid on Ready Phosphorus Concentration in Soil mg P kg$^{-1}$ Soil in Male Formation Stage of Maize

| **Fertilizer sources** | **Zinc levels Kg Zn.ha$^{-1}$** | **Humic acid levels Kg HA.ha$^{-1}$** | | **Average sources x levels** |
|---|---|---|---|---|
| | | **0** | **60** | |
| Ord-ZnO | 12 | 7.80 | 9.33 | 8.57 |
| | 18 | 8.80 | 9.30 | 9.05 |
| Average sources x Humic acid | | 8.30 | 9.32 | 8.81 |
| Nano-ZnO | 12 | 8.80 | 9.33 | 9.07 |
| | 18 | 9.13 | 9.73 | 9.43 |
| Average sources x Humic acid | | 8.97 | 9.53 | 9.25 |
| Average Humic acid | | 8.64 | 9.43 | 9.03 |
| Control | | 7.23 * | | |

| **Fertilizer sources** | **Zinc levels kg Zn.ha$^{-1}$** | | **Average sources** |
|---|---|---|---|
| | **12** | **18** | |
| Ord-ZnO | 8.57 | 9.05 | 8.81 |
| Nano-ZnO | 9.07 | 9.43 | 9.25 |
| Average levels | 8.82 | 9.24 | 9.03 |

| **Humic acid levels kg HA.h$^{-1}$** | **Zinc levels kg Zn.ha$^{-1}$** | | **Humic acid average** |
|---|---|---|---|
| | **12** | **18** | |
| 0 | 8.30 | 8.97 | 8.64 |
| 60 | 9.33 | 9.52 | 9.43 |
| Average levels | 8.82 | 9.24 | 9.03 |

| **Treatments** | **Sources** | **Levels** | **Humic acid** | **Sources X levels** | **sources X Humic acid** | **levels X Humic acid** | **Sources X levels X Humic acid** |
|---|---|---|---|---|---|---|---|
| L.S.D$_{0.05}$ | 0.25 | 0.25 | 0.25 | n.s | n.s | n.s | 0.51 |

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