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The Effect of Different Forms of Zinc and Manganese on the Productivity of Faba Bean Plants

Samia M.S. El-Kalawy*, Zainab A. Zaki and Lamyaa A. Abd El-Rahman

Soils, Water and Environ. Res. Inst., Agric. Res. Centre., Egypt

***Corresponding author:** samiaelklawy652@gmail.com

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Abstract: Two field experiments were conducted in 2022/2023 and 2023/2024 seasons at the Agricultural Research Station farm in Suez, Suez Governorate, Agriculture Research Center to study The effect of different forms of zinc i.e., Zn SO_4 (21 % Zn) at 3g/l, Zn EDTA (15% Zn) at 100 ppm and Zn Nano (NPs Zn) at 50 ppm and manganese i.e., Mn SO_4 (31.8 %Mn) at 2g/l , Mn EDTA (13 %Mn) at 300 ppm and Mn- Nano (NPs Mn) at 50 ppm on the dry weight productivity and seed quality of faba bean plants grown in loamy sand soil. The results indicated that all foliar spraying treatments with Zn or Mn in different forms suppressed dry weight, yield, and its components and chemical constituents in seeds compared to control. Whereas, foliar spraying with Zn nano (NPs Zn) at 50 ppm was the best treatment for increasing dry weight/plant, 100 grain weight, yield / plant, yield of grain and straw/fad, and biological yield N, P, K and Zn contents and their uptake by grains as well as total protein in grains, and N, P, K contents and their uptake by straw. While, spraying with Mn Nano at 50 ppm gave the highest values of Mn concentration in grains and Mn uptake by grains. This treatment (Zn nano (NPs Zn) at 50 ppm produced an increase in total grain yield of about 52.43 and 53.15% equal (0.743 and 0.726 tons/fad.) over control in the 1st and 2nd seasons, respectively. In general, the effect of the treatments was positive on most of the studied traits and their order was as follows from most to least: Zn Nano > Zn EDTA > Zn SO_4 > Mn Nano > Mn EDTA > Mn SO_4 > control (unsprayed**)** in most studding parameters**.**

Key words: Faba bean, zinc, manganese, productivity, productivity, seed quality.

1. Introduction

Faba bean (*Vicia faba* L.) is one of the most important pulse crops in Egypt; it plays an important role in world agriculture due to the high protein content, its ability to fix atmospheric nitrogen, and its capacity to grow well on marginal lands (**Farag and Afiah, 2012**).

Due to its crucial function in the synthesis of numerous enzymes and protein components that are essential to the growth and development of plants, zinc is also regarded as one of the most significant elements in plant micronutrition. By taking part in the metabolism of carbohydrates, it directly increases photosynthesis (**AL-Isawi, 2010)**. It also initiates the synthesis of several amino acids, hormones, and numerous vital enzymes in oxidation and reduction reactions, demolition, and construction processes. Moreover, it serves as a catalyst and promoter for plant growth regulators like (IAA) **(Brian, 2008)**.

Because zinc is either a functional, structural, and regulatory cofactor of many enzymes or a component of other enzymes, it plays a noticeable role in the formation of biomass, chlorophyll, and many enzymes (**Malakooti *et al.*, 2017**). Enzymes involved in hormone concentrations, amino acid metabolism, and respiration are activated by manganese. It is crucial for the release of oxygen during photosynthesis and for a number of Krebs cycle enzymes. Because it takes part in oxidation-reduction reactions, it also contributes significantly to the electron transport system in photosynthesis (**Sharifi and Paymozd, 2016**).

When compared to macromolecules, nanoparticles (NPs) can drastically alter their physical-chemical benefits. According to **Roco (2005**), nanoparticles are molecular aggregates or atoms with sizes ranging from 1 to 100 nm **(Hediat, 2012)**. Due to their distinct physical and chemical properties as well as their large surface area in relation to their size, they have significant advantages that allow them to enhance life quality and boost industry competitiveness **(Homa and Aghili 2014)**. Though there is a wealth of knowledge on the harmful effects of nanoparticles (NPs) in plant systems, not much research has been done on the processes via which NPs affect the growth and development of plants. Growing research in numerous studies indicates that ZnONPs promote plant growth and development (**Siddiqui *et al*., 2015**).

Studies on the effect of foliar application of zinc at different forms on growth , yield and yield components of faba bean plants reported different results (**Sharaf *et al*., 2009; El-Gizawy and Mehasen , 2009; Magdi *et al.*, 2014; Khatab *et al*., 2016; Ali, 2017; El-Agrodi *et al.*, 2017, Abdo 2018, Al-Silawi *et al*., 2018; El-Shafey *et al.*, 2019; Shaban *et al*., 2019; Ismail, and Fayed, 2020; Ahmed *et al*., 2021; El-Sharkawy *et al.*, 2021; Mohammed and Faris , 2021; .Abd Al-Shammari and Jaburi 2022; Rashid *et al* ., 2022; Ragab *et al*., 2022; Nofal et al., 2024** on faba bean).

One of the primary micronutrients, manganese, is essential to plants since it is a part of the enzymes that are involved in photosynthesis and other processes. Manganese is a component of superoxide dismutase, a crucial antioxidant structure that shields plant cells from free radicals that can damage plant tissue (**Millaleo *et al*., 2010**). Because manganese fertilizer improves plant nutrition and boosts photosynthesis in plants, it increases photosynthetic efficiency, which in turn increases agricultural output and quality (**Mousavi *et al*., 2007**).

Many investigators had reported that spraying plants with different forms of manganese had a significant effect on plant growth , yield and seed quality of faba bean (**Teixeira *et al.*, 2004; Ozbahce and Zengin, 2011; Mekkei, 2014; Ozbahce, and Zengin, 2014 on bean; Sharifi and Paymozd. 2016; Kadiem *et al*., 2018; El-Aidy *et al.*, 2021; Hashim, and Hekal 2022 on pea; Alsultan and Alhasany, 2023 Ahmed et al., 2023** on bean).

Therefore, the aim of this research was to find out the best form of zinc or manganese with the aim of increasing the yield and seed quality of faba bean plants grown in sandy soil.

2. Materials and Methods

Two field experiments were conducted in 2022/2023 and 2023/2024 seasons at the Agricultural Research Station farm in Suez, Suez Governorate, Agriculture Research Center to study the effect of different forms of zinc and manganese on the productivity and seed quality of faba bean plants grown in loamy sand soil. The soil of the experiments was analyzed as shown in Table 1.

Table (1). The mechanical and chemical analysis of the experimental soil (Average of the two seasons)

Parameters	Values
1**. *Mechanical analysis***	
Crouse Sand (%)	48.74
Find sand (%)	31.49
Silt (%)	12.03
Clay (%)	7.74
Texture class	**Loamy sand**
2. ***Chemical analysis***	
EC dS/m	2.41
Soluble Cations (meq./ L)	
Ca^{++}	13.0
Mg^{++}	6.0
Na^{+}	4.35
K^{+}	0.45
Soluble Anions (meq/.L	
HCO_3^-	7.90
Cl^-	6.00
$SO_4^=$	9.90
Available (ppm)	
Nitrogen	38.74
Phosphorus	4.52
Potassium	240
Zn	0.30
Mn	0.80

This experiment included seven treatments as follows:

1- Control (sprayed with water)
2- Zn SO_4 (21 % Zn) at 3g/l
3- Zn EDTA (15% Zn) at 100 ppm
4- Zn Nano (NPs Zn) 50 ppm
5- Mn SO_4 (31.8 %Mn) at 2g/l
6- Mn EDTA (13 %Mn) at 300 ppm
7- Mn- Nano (NPs Mn) 50 ppm

These treatments were arranged in a randomized complete blocks design with three replications.

Plot area was 14 m^2 It contained five ridges with 4 m in length and 70 cm in width. Seeds of Giza 717 cultivar were sown on two sides of the ridge at a distance of 15 cm apart. Sowing was done on 23rd and 21st November in 2022/2023 and 2023/2024 seasons, respectively, and using 60 kg seeds /fad. after coating with okadein as bio fertilizer. Seeds of faba bean cultivar used in this investigation were obtained from Legumes Dept., Field Crops Res. Institute, Agric. Res. Center, Giza. Zn and Mn nanoparticles (NPs) were obtained from the fertilizer evaluation Laboratory in the Special Unit of the Environment Department, Land, Water and Environment Research Institute, Agricultural Research Center, Egypt.

Both manganese and zinc in chelated and minerals forms were obtained from Technogen Company, Giza, Egypt. Faba bean plants were sprayed with different forms of Mn and Zn twice the first at 40 days and the second at 60 days after sowing.

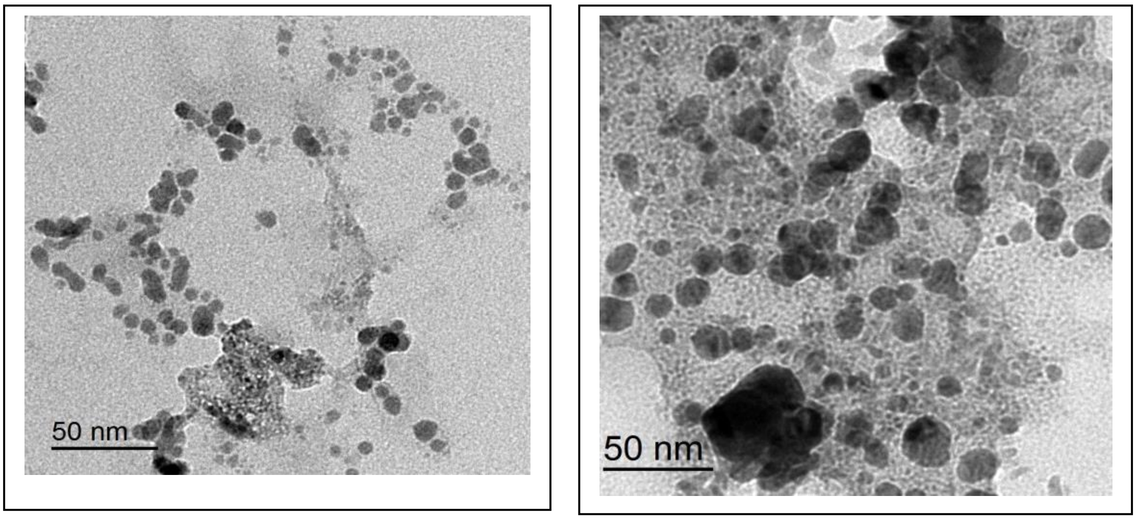

Fig. (1). Transmission electron microscope for Zn and Mn nanoparticles (NPs)

Nitrogen , P, and K fertilizers were added at the rates of 24, 80, and 24 kg/fed. in the form of super phosphate calcium (15.5%), ammonium sulfate (20.5%), and potassium sulfate (48–50%), respectively. Phosphorus was added during soil preparation, and 20 kg N was added after 10 days from cultivation. After that, the rest of nitrogen (60 kg/fed.) was divided into two half portions; the first was added before the first irrigation, and the second portion of nitrogen and all potassium were added before the second irrigation. The normal cultural practices for growing faba bean were practiced.

Data recorded

Plants samples of five plants from each plot were selected randomly at harvesting time to measure the following parameters; dry weights (g/plant), 100- grain weight (g), grain yield / plant, grain yield (ton /fad.), straw yield (ton /fad.). The biological yield (ton/fad.) were calculated (grain yield+ straw yield (ton/fad.).

Grain and straw nutrient content

After being thoroughly cleaned and weighed, faba bean seeds and straw were baked until they reached a consistent dry weight. Using an electric mill, 0.5 g of dried grains and straw from each treatment were ground. Sulfuric and perchloric acids (3:1) were utilized to digest the pulverized materials before they were subjected to chemical examination. **A.O.A.C. (2018)** states that the composition of grains and straw was measured for nitrogen, phosphorus, and potassium during harvest time in both seasons. According to **Craswell and Godwin (1984**), the N, P, and K absorption (kg/fad) was calculated by multiplying the grain and straw yield by the appropriate N, P, and K% concentrations.

The values of total nitrogen in the conversion factor of 6.25 were multiplied to determine the crude protein in grains (**Abdeldaym *et al*., 2018**).

Statistical analysis

Statistical analysis was conducted for all collected data. The analysis of variance was calculated according to **Snedecor and Cochran** (**1980**), mean separation was done according to **Duncan** (**1955**).

3. Results and Discussion

1. Dry weight / plant

Data in Table 2 show that spraying faba bean plants with Mn as Mn SO_4 at 2g/l , Mn EDTA at 300 ppm and Mn- Nano at 50 ppm and with Zn SO_4 at 3g/l, Zn EDTA at 100 ppm and Zn Nano at 50 ppm increased dry weight / plant at harvesting time compared to control (spraying with water) and Zn Nano at 50 ppm gave the highest values of dry weight / plant, followed by Zn EDTA at 100 ppm in both seasons.

The increases in dry weight / plant were about 34.57 and 29.05 % for spraying with Zn Nano at 50 ppm and 27.81 and 23.99 % for spraying with Zn EDTA at 100 ppm over the control in the 1st and 2nd seasons, respectively.

Generally spraying with Zn or Mn as nanoparticles is more effective than application in the form of EDATA or mineral. In this regard, **Prasad *et al.* (2012**) reported that nano-scale zinc oxide increased stem and root growth of peanut as compared with $ZnSO_4$ application.

Micronutrients such as Zn or Mn play a variety of important roles in the functioning of plants, particularly in respiration, photolysis, protein synthesis, carbohydrate metabolism, and the phenyl-propanoid pathway. They also play a role in plant metabolism by influencing the amount of phenolics and lignin in the plant, which in turn affects membrane stability and increases dry weight (**Dutta *et al*., 2017**).The observed increase in growth could perhaps be attributed to zinc's function as a micronutrient in many physiological processes, such as electron transport, stomata control, and enzyme activation, all of which lead to increased dry matter (**Arafat *et al*., 2023**).

Table (2). Effect of different forms of Zn and Mn on the plant dry weight (g) of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
	Values		Relative increases (%) over control treatment	
Control (spraying with water)	28.23 d	27.09 d	--	--
Zn SO_4 (21 % Zn) at 3g/l	34.59 b	30.00 c	22.53	10.74
Zn EDTA (15% Zn) at 100 ppm	36.08 b	33.59 b	27.81	23.99
Zn Nano (NPs Zn) 50 ppm	37.99 a	34.96 a	34.57	29.05
Mn SO_4 (31.8 %Mn) at 2g/l	29.30 d	29.75 c	03.79	09.82
Mn EDTA (13 %Mn) at 300 ppm	31.33 c	29.29 c	10.98	08.12
Mn- Nano (NPs Mn) 50 ppm	31.39 c	29.96 c	11.19	10.59

Manganese is necessary for the formation of chlorophyll and is a key component of the photosystem, which is also involved in cell division and plant growth. Manganese is an activator of RNA polymerase. Manganese has a significant function in the metabolism of lipids. It also plays an important role in the nitrate reduction enzymes, which causes nitrate to accumulate in leaves when manganese levels are low. Additionally, a manganese deficiency will cause a plant's lignin content to decrease, with the drop being more pronounced in the roots. This is a significant issue, particularly in terms of the plant's ability to resist fungal infection of its roots (**Anderson and Pyliotis, 1996**).

These results are harmony with those obtained with **Sharaf *et al*., (2009**) reported that foliar treatment of broad bean and lupin with Zinc (100 ppm) showed significant stimulation in most of the growth and yield characteristics for both plants. Also, **El-Shafey *et al*., 2019**. They showed that spraying faba bean plants with Zn treatment significant increased mean values of shoot dry weight than unsprayed plants in both seasons. However, **Nofal *et al*., 2024** indicated that spraying faba bean with ZnO NPs at 100 ppm increased shoot dry weight/ plant as compared to unsprayed plants.

As for Mn effect, **Teixeira *et al*., 2004; Ozbahce and Zengin, 2011; Ozbahce, and Zengin, 2014 and Ahmed *et al*., 2023** showed that spraying plants with Mn gave the best results for increasing plant dry weight than unsprayed plants on bean.

2. Grain , straw and biological yield

The obtained results in Tables 3, 4, 5 and 6 indicate that spraying faba bean with different forms of Zn and Mn significantly increased grain yield/ plant , 100 grain weight, and grain yield /fad. in both seasons .

As for grain yield / plant and per feddan data in Tables 3 , 4 and Fig.2 show that spraying with Zn Nano at 50 ppm increased grain yield / plant and grain yield /fad. (2.160 and 2.092 ton/fad.), followed by spraying with Zn EDTA at 100 ppm (1.967 and 1.944 ton/fad.) and Zn SO_4 at 3g/l (1.991 and 1.928) in both seasons .

The increases in grain yield/fad. were about 52.43 and 53.15 % (0.743 and 0.726 ton) for Zn Nano at 50 ppm , 38.81 and 42.31 % (0.550 and 0.578 ton) for Zn EDTA at 100 ppm and 40.51 and 41.14 % for and Zn SO_4 at 3g/l over control in the 1st and 2nd seasons, respectively.

Table (3). Effect of different forms of Zn and Mn on grain yield / plant (g) of faba bean during 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
	Values		Relative increases (%) over control treatment	
Control (spraying with water)	16.84 d	15.20 f	--	--
Zn SO_4 (21 % Zn) at 3g/l	24.89 b	24.10 b	47.80	58.55
Zn EDTA (15% Zn) at 100 ppm	24.59 b	24.30 b	46.02	59.87
Zn Nano (NPs Zn) 50 ppm	27.00 a	26.15 a	60.33	72.04
Mn SO_4 (31.8 %Mn) at 2g/l	20.63 c	17.50 e	22.51	15.13
Mn EDTA (13 %Mn) at 300 ppm	23.71 b	19.85 d	40.80	30.59
Mn- Nano (NPs Mn) 50 ppm	24.70 b	22.00 c	46.67	44.74

Table (4). Effect of different forms of Zn and Mn on grain yield (ton/fad.) of faba bean during 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
	Values		Relative increases (%) over control treatment	
Control (spraying with water)	1.417 e	1.366 d	--	--
Zn SO_4 (21 % Zn) at 3g/l	1.991 b	1.928 b	40.51	41.14
Zn EDTA (15% Zn) at 100 ppm	1.967 b	1.944 b	38.81	42.31
Zn Nano (NPs Zn) 50 ppm	2.160 a	2.092 a	52.43	53.15
Mn SO_4 (31.8 %Mn) at 2g/l	1.580 d	1.460 d	11.50	06.88
Mn EDTA (13 %Mn) at 300 ppm	1.697 c	1.588 c	9.76	16.25
Mn- Nano (NPs Mn) 50 ppm	1.776 c	1.920 b	25.34	40.56

Respecting 100 grain weight , spraying with Zn Nano at 50 ppm gave the highest values of 100 grain weight (109.47 and 110.41g), followed by Zn EDTA at 100 ppm (105.19 and 107.34g) in both seasons (Table 5). The increases in 100 grain weight were about 27.38 and 32.24 % (23.53 and 26.29 g) for Zn Nano at 50 ppm and 22.41 and 28.57% (19.26 and23.85 g) for Zn EDTA at 100 ppm over control in the 1st and 2nd seasons, respectively.

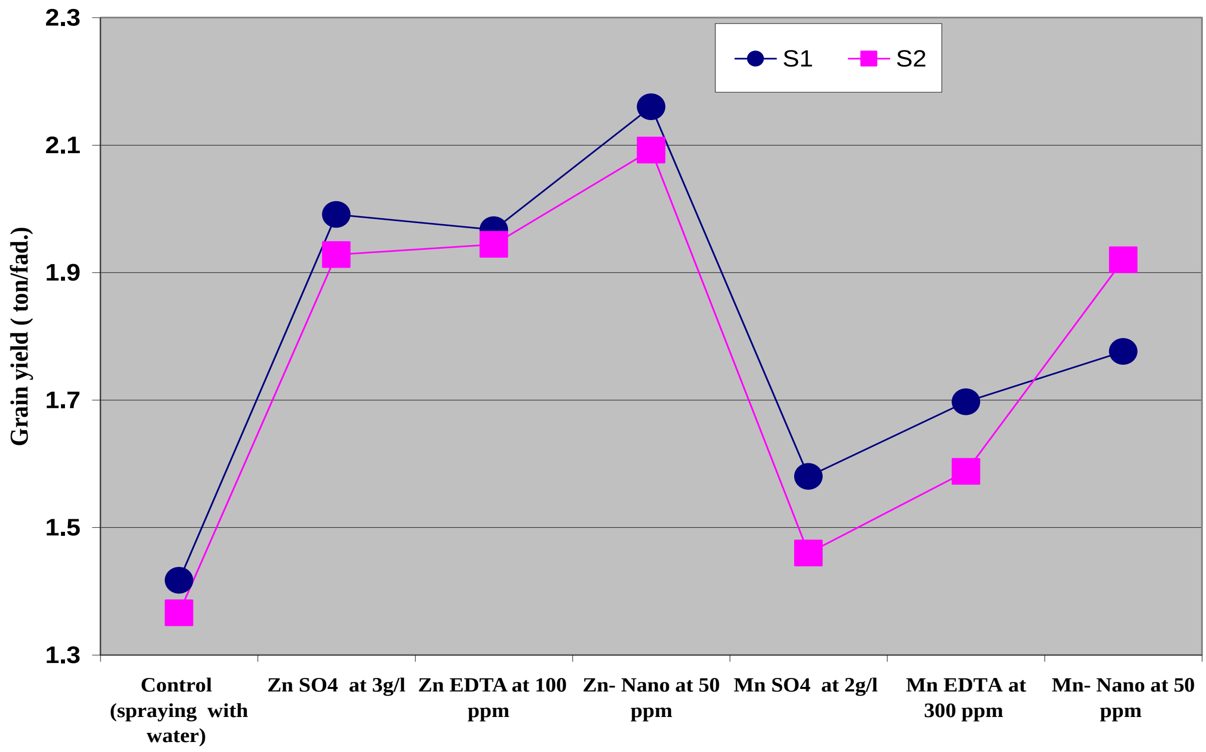

Fig (2). Effect of different forms of Zn and Mn on grain yield (ton/fad.) of faba bean during 2022/2023 and 2023/2024 seasons

Table (5). Effect of different forms of Zn and Mn on 100 grain weight (g) of faba bean during 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
	Values		Relative increases (%) over control treatment	
Control (spraying with water)	85.93 f	83.49 e	--	--
Zn SO_4 (21 % Zn) at 3g/l	98.99 c	97.61 c	15.20	16.91
Zn EDTA (15% Zn) at 100 ppm	105.19 b	107.34 b	22.41	28.57
Zn Nano (NPs Zn) 50 ppm	109.46 a	110.41 a	27.38	32.24
Mn SO_4 (31.8 %Mn) at 2g/l	88.09 e	85.18 e	2.51	2.02
Mn EDTA (13 %Mn) at 300 ppm	92.32 d	92.07 d	7.44	10.28
Mn- Nano (NPs Mn) 50 ppm	99.53 c	95.42 c	15.83	14.29

As for straw yield data in Table 6 illustrate that spraying with Zn Nano at 50 ppm increased straw yield / fed. (3.039 an 2.997), followed by Zn EDTA at 100 ppm (2.886 and2687 ton/fad.) in the both seasons. The increases in straw yield /fad. were about 34.59 and 38.30 % for Zn Nano at 50 ppm and 27.81and 24.0 % for Zn EDTA at 100 ppm over the control in the 1st and 2nd seasons, respectively.

Table (6) . Effect of different forms of Zn and Mn on straw yield (ton/fad.) of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
	Values		Relative increases (%) over control treatment	
Control (spraying with water)	2.258 d	2.167 d	--	--
Zn SO_4 (21 % Zn) at 3g/l	2.767 b	2.400 c	22.54	10.75
Zn EDTA (15% Zn) at 100 ppm	2.886 b	2.687 b	27.81	24.00
Zn Nano (NPs Zn) 50 ppm	3.039 a	2.997 a	34.59	38.30
Mn SO_4 (31.8 %Mn) at 2g/l	2.344 d	2.310 c	3.81	6.60
Mn EDTA (13 %Mn) at 300 ppm	2.506 c	2.343 c	10.98	8.12
Mn- Nano (NPs Mn) 50 ppm	2.511 c	2.397 c	11.20	10.61

With respecting to biological yield (grain yield + straw yield), foliar spray with Zn Nano at 50 ppm increased biological yield (5.199 and 5.089 ton/fad.), followed by Zn EDTA at 100 ppm (4.853 and 4.631 ton/fad.) in both seasons (Table 7 and Fig.3). Foliar spray of fab bean with different forms of Mn and Zn increased biological yield compared to control. The increases in biological yield /fad. were about 41.47 and 44.04 % (equal 1.524 and 1.556 ton) for Zn Nano at 50 ppm and 32.05 and 31.08 % (equal 1.178 and 1.098 ton) for Zn EDTA at 100 ppm over the control in both seasons.

The stimulative effect of Zn Nano at 50 ppm may be due to that Zn Nano increased dry weight/ plant , average weight of 100 grains, grain yield / plant , and straw yield .

From the foregoing results, it could be concluded that foliar spray of faba bean with Zn Nano at 50 ppm , followed by Zn EDTA at 100 ppm increased weight of 100 grains, grain and straw yield as well as and biological yield .

The generation of high-vigor pollen, which increases the likelihood of fertilization and serves as a signal of vegetative growth, is attributed to zinc and results in an increase in grain yield. Zinc may play a role in the production of chlorophyll in plants, as well as in the synthesis of acid (IAA), which is the building block for the synthesis of indole acetic acid, and tryptophane amino, a hormone crucial to plant growth. Zinc also enters the plant through the installation of numerous enzymes that trigger numerous physiological processes, increasing grain yield (**Hafeez *et al*., 20**13).

Table (7). Effect of different forms of Zn and Mn on biological yield (ton/fad.) of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
	Values		Relative increases (%) over control treatment	
Control (spraying with water)	3.675 e	3.533 e	--	--
Zn SO_4 (21 % Zn) at 3g/l	4.758 b	4.328 c	29.47	22.50
Zn EDTA (15% Zn) at 100 ppm	4.853 b	4.631 b	32.05	31.08
Zn Nano (NPs Zn) 50 ppm	5.199 a	5.089 a	41.47	44.04
Mn SO_4 (31.8 %Mn) at 2g/l	3.924 d	3.770 d	6.78	6.71
Mn EDTA (13 %Mn) at 300 ppm	4.203 c	3.931 d	14.37	11.27
Mn- Nano (NPs Mn) 50 ppm	4.287 c	4.317 c	16.65	22.19

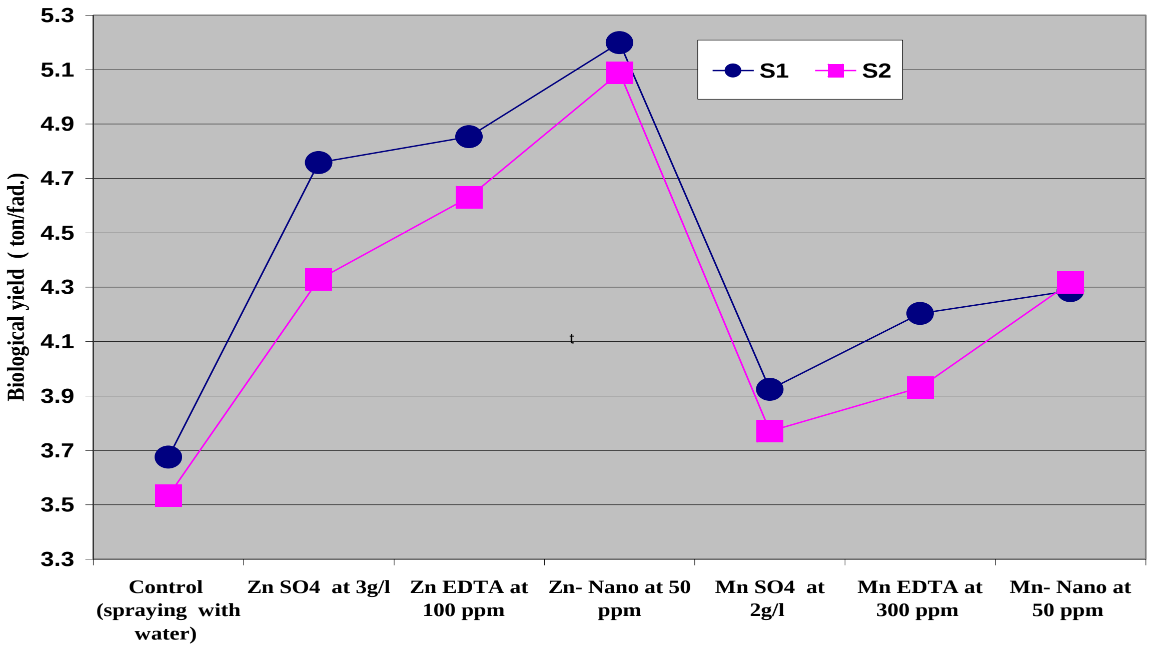

Fig. (3). Effect of different forms of Zn and Mn on biological yield (ton/fad.) of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

Furthermore, because zinc is an essential element for numerous enzyme functions and metabolic processes, it is present in plants in the form of nanoparticles. Lower yields are produced by plants lacking in zinc (**Srivastav *et al.*, 2021**). Additionally, Manganese plays a significant part in the synthesis of complex proteins in faba beans as well as photosynthesis. Manganese is also essential for the faba bean seed **[Sharifi, and Paymozd , 2016].**

As for the response of faba bean plants to sprayed with Zn , **Sharaf *et al.*, (2009**) mentioned that foliar treatment of broad bean with Zinc (100 ppm) showed significant stimulation in most of the growth and yield characteristics for both plants, Also, **Bozorgi *et al.*, (2011)** reported that spraying faba bean plants with Zn increase 100-seed weight. In addition, El-**Habbasha *et al.*, (2013)** indicated that foliar application of Zn significantly increased number of pods/ plant, weight of pods /plant, number of seeds/ plant, weight of seeds/ plant, 100-pod weight, 100-seed weight, pod, seed and straw yield /fad of groundnut However, **Magdi *et al.*, (2014)** mentioned that spraying faba beab plants with $ZnSO_4$ 60 mg/l recorded the highest yield of seeds / plant values and 100-seed weight as compared to unsprayed plants. in addition **Ismail, and Fayed (2020)** indicated that foliar spraying with Zn increased dry seed yield and its components compared to control.

Concerning the effect of Mn yield and its components of plants, **El-Aidy *et al.*, 2021** on pea plants they indicated that the highest seed yield was produced when the plants sprayed with Mn as compared to unsprayed plants. Moreover, **Ahmed *et al.*, 2023** showed that treated bean plants with Mn in chelating compound form (EDTA, 12% Mn) recorded the better yield than that treated with $MnSO_4$ or unsprayed plants. Also, **Alsultan and Alhasany (2023)** indicated that sprayed with manganese at 20 or 40 mg Mn per liter recorded the maximum values of 100 seed weight and total yield /ha as compared to unsprayed plants

3. N , P and K contents and their uptake and total protein in grains

All treatments for Zn or Mn at different forms as foliar spray significantly increased N, P and K contents and their uptake by grains as compared to control treatment in both seasons (Tables 8-14).

Foliar spray with different forms of Mn and Zn gave the highest values of N , P and K contents (Tables 8,9 and 10) and their uptake (Tables 11, 12 , 13 and Figs.4, 5 and 6) as well as total protein in grains (Table 14 and Fig.7). And spraying with Zn Nano at 50 ppm increased the percentages of N (3.07 and 3.01), P(0.550 and 0.556) and K (1.75 and 1.71) in both seasons, respectively also, the same treatment produced the maximum uptake (66.31 and 62.97), (11.88 and 11.63) and , (37.80 and 35.77) for N, P and K uptake kg/fad. in each of the two seasons and total protein (19.19 and 18.81%) in the 1st and 2nd seasons, respectively.

The increases in total protein in grains of faba bean were about 48.302 and 37.40 % for Zn Nano at 50 ppm and 46.83 and 33.31 % for Zn EDTA at 100 ppm over the control in both seasons . for all treatments average amount of total protein were from 12.94 to 19.19 % in the 1st season and were 13.64 to 18.81% in the 2nd season (13.31 and 19.00 % as average of the two seasons).

In general, it was observed that the investigated substances treatments were in the following order, from most to least: Zn Nano > Zn EDTA > Zn SO_4 > Mn- Nano > Mn EDTA> Mn SO_4 > control (unsprayed**) .**

However, spraying both Zn or Mn as nanoparticles is very effective for enhancing N, P, and K content and their uptake by grains well as total protein than spraying in the form of EDATA or mineral. Also, the values of N, P and K contents and its uptake by faba bean grain with both Zn and Mn-EDTA were the best compared to MnSO4 due to the translocation of Zn or Mn away from the treated leaf to other plant parts under EDTA form was faster than the Zn or MnSO4 form.

Table (8). Effect of different forms of Zn and Mn on nitrogen contents in grain of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
	Values		Relative increases (%) over control treatment	
Control (spraying with water)	2.07 d	2.19 e	--	--
Zn SO_4 (21 % Zn) at 3g/l	2.93 ab	2.75 b	41.55	25.57
Zn EDTA (15% Zn) at 100 ppm	3.04 a	2.92 a	46.86	33.33
Zn Nano (NPs Zn) 50 ppm	3.07 a	3.01 a	48.31	37.44
Mn SO_4 (31.8 %Mn) at 2g/l	2.55 c	2.44 d	23.19	11.42
Mn EDTA (13 %Mn) at 300 ppm	2.68 bc	2.43 d	29.47	10.96
Mn- Nano (NPs Mn) 50 ppm	2.78 abc	2.62 c	34.30	19.63

Table (9). Effect of different forms of Zn and Mn on phosphorus contents in grains of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
	Values		Relative increases (%) over control treatment	
Control (spraying with water)	0.317 f	0.306 e	--	--
Zn SO_4 (21 % Zn) at 3g/l	0.517 c	0.492 b	63.09	60.78
Zn EDTA (15% Zn) at 100 ppm	0.533 b	0.512 b	68.14	67.32
Zn Nano (NPs Zn) 50 ppm	0.550 a	0.556 a	73.50	81.70
Mn SO_4 (31.8 %Mn) at 2g/l	0.473 e	0.362 d	49.21	18.30
Mn EDTA (13 %Mn) at 300 ppm	0.487 d	0.452 c	53.63	47.71
Mn- Nano (NPs Mn) 50 ppm	0.493 d	0.462 c	55.52	50.98

Table (10). Effect of different forms of Zn and Mn on potassium contents in grain of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
	Values		Relative increases (%) over control treatment	
Control (spraying with water)	1.31 d	1.40 c	--	--
Zn SO_4 (21 % Zn) at 3g/l	1.60 b	1.69 a	22.14	20.71
Zn EDTA (15% Zn) at 100 ppm	1.63 b	1.68 a	24.43	20.00
Zn Nano (NPs Zn) 50 ppm	1.75 a	1.71 a	33.59	22.14
Mn SO_4 (31.8 %Mn) at 2g/l	1.37 d	1.51 bc	04.58	7.86
Mn EDTA (13 %Mn) at 300 ppm	1.52 c	1.61ab	16.03	15.00
Mn- Nano (NPs Mn) 50 ppm	1.52 c	1.61 ab	16.03	15.00

Table (11). Effect of different forms of Zn and Mn on nitrogen uptake by grains (kg /fad) of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
	Values		Relative increases (%) over control treatment	
Control (spraying with water)	29.33 f	29.92 g	--	--
Zn SO_4 (21 % Zn) at 3g/l	58.34 b	53.02 c	98.91	77.21
Zn EDTA (15% Zn) at 100 ppm	59.80 b	56.76 b	103.89	89.71
Zn Nano (NPs Zn) 50 ppm	66.31 a	62.97 a	126.08	110.46
Mn SO_4 (31.8 %Mn) at 2g/l	42.98 e	35.62 f	46.54	19.05
Mn EDTA (13 %Mn) at 300 ppm	45.48 d	38.59 e	55.06	128.98
Mn- Nano (NPs Mn) 50 ppm	49.37 c	50.30 d	68.33	68.11

Table (12). Effect of different forms of Zn and Mn on phosphorus uptake by grains (kg /fad) of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
	Values		Relative increases (%) over control treatment	
Control (spraying with water)	4.49 e	4.18 f	--	--
Zn SO_4 (21 % Zn) at 3g/l	10.29 b	9.49 bc	129.18	127.03
Zn EDTA (15% Zn) at 100 ppm	10.48 b	9.95 b	133.41	138.04
Zn Nano (NPs Zn) 50 ppm	11.88 a	11.63 a	164.59	178.23
Mn SO_4 (31.8 %Mn) at 2g/l	7.47 d	5.29 e	66.37	26.56
Mn EDTA (13 %Mn) at 300 ppm	8.26 cd	7.18 d	83.96	71.77
Mn- Nano (NPs Mn) 50 ppm	8.76 c	8.87 c	95.10	112.20

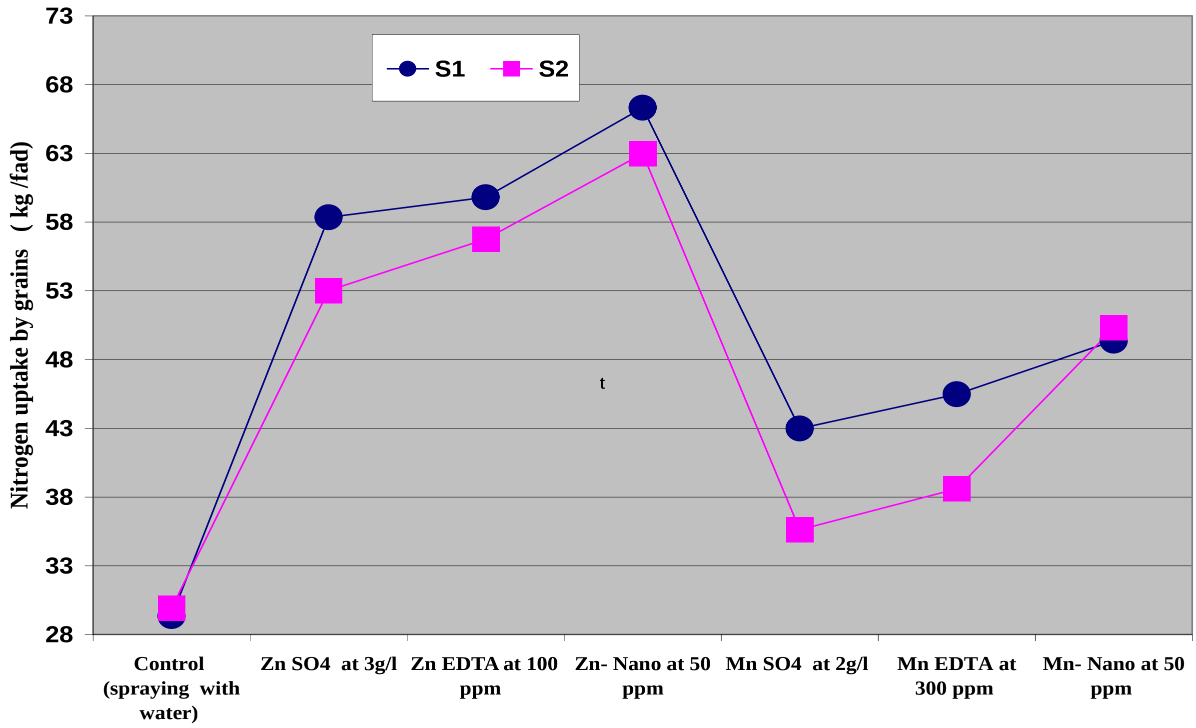

Fig.(4). Effect of different forms of Zn and Mn on nitrogen uptake by grains (kg /fad) of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

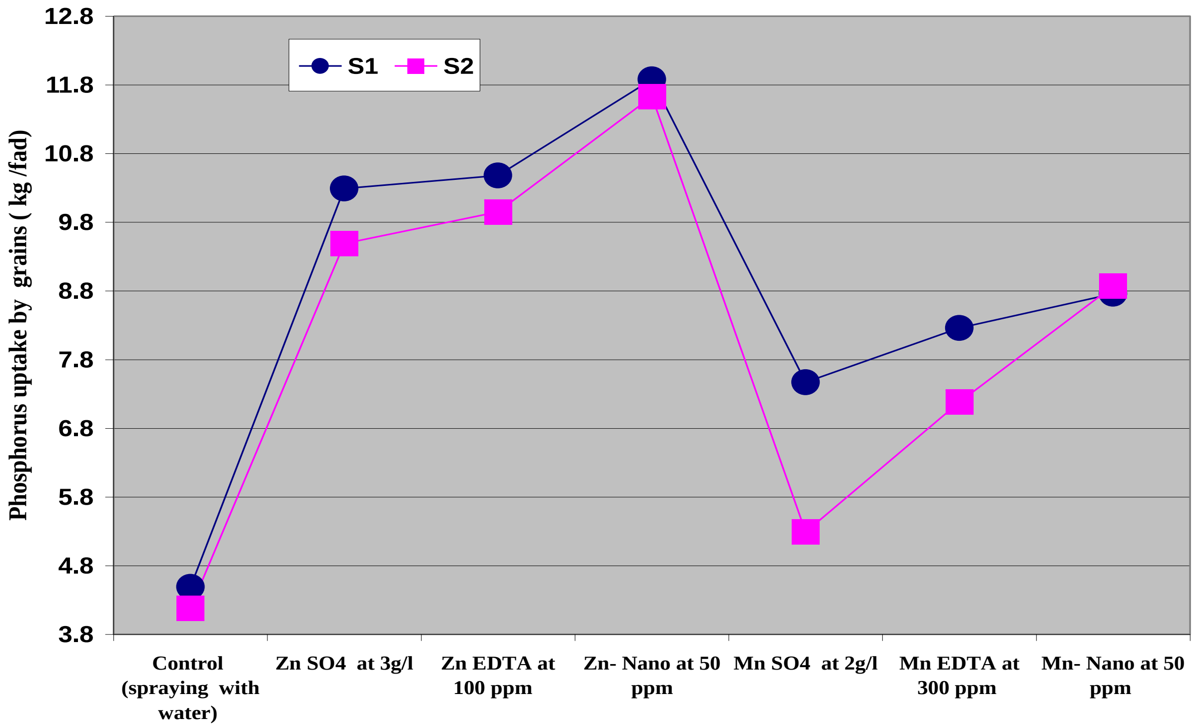

Fig. (5). Effect of different forms of Zn and Mn on phosphorus uptake by grains (kg /fad) of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

Table (13). Effect of different forms of Zn and Mn on potassium uptake by grain (kg /fad) of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
	Values		Relative increases (%) over control treatment	
Control (spraying with water)	18.56 e	19.12 f	--	--
Zn SO_4 (21 % Zn) at 3g/l	31.86 b	32.58 b	71.66	70.40
Zn EDTA (15% Zn) at 100 ppm	32.06 b	32.66 b	72.74	70.82
Zn Nano (NPs Zn) 50 ppm	37.80 a	35.77 a	103.66	87.08
Mn SO_4 (31.8 %Mn) at 2g/l	21.65 d	22.05 e	16.65	15.32
Mn EDTA (13 %Mn) at 300 ppm	25.79 c	25.57 d	38.95	33.73
Mn- Nano (NPs Mn) 50 ppm	27.00 c	30.91 c	45.47	61.66

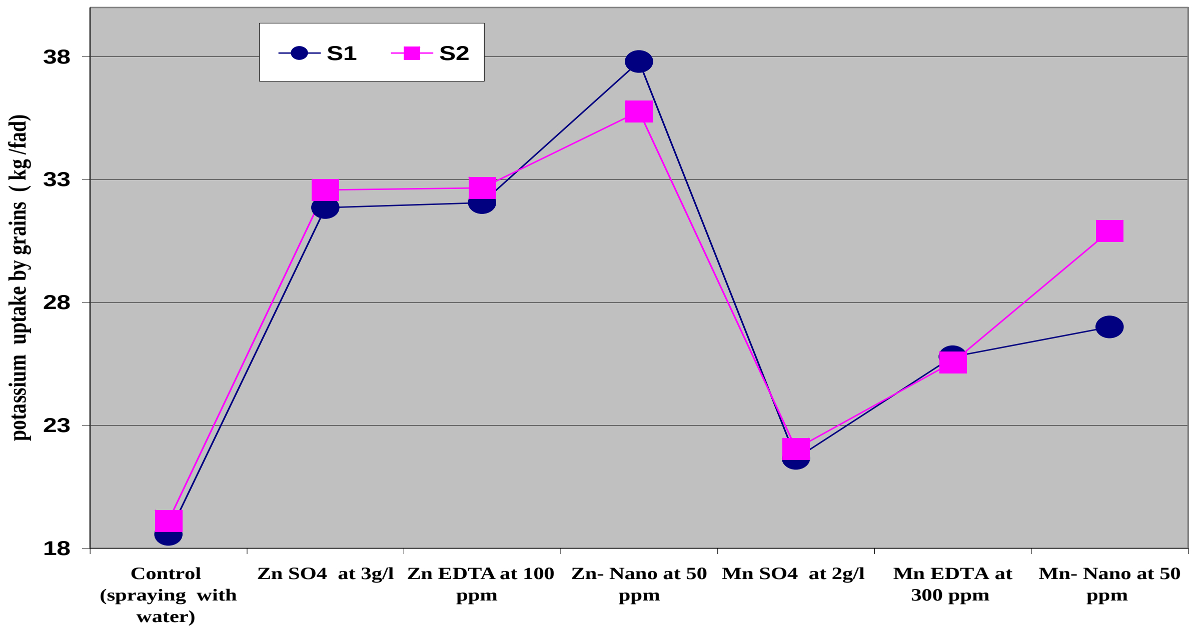

Fig. (6). Effect of different forms of Zn and Mn on potassium uptake by grain (kg /fad) of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

Table (14). Effect of different forms of Zn and Mn on total protein in grain of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
	Values		Relative increases (%) over control treatment	
Control (spraying with water)	12.94 d	13.69 d	--	--
Zn SO_4 (21 % Zn) at 3g/l	18.31 a	17.19 b	41.50	25.57
Zn EDTA (15% Zn) at 100 ppm	19.00 a	18.25 a	46.83	33.31
Zn Nano (NPs Zn) 50 ppm	19.19 a	18.81 a	48.30	37.40
Mn SO_4 (31.8 %Mn) at 2g/l	15.94 c	15.25 c	23.18	11.40
Mn EDTA (13 %Mn) at 300 ppm	16.75 bc	15.19 c	29.44	10.96
Mn- Nano (NPs Mn) 50 ppm	17.38 b	16.38 b	34.31	19.65

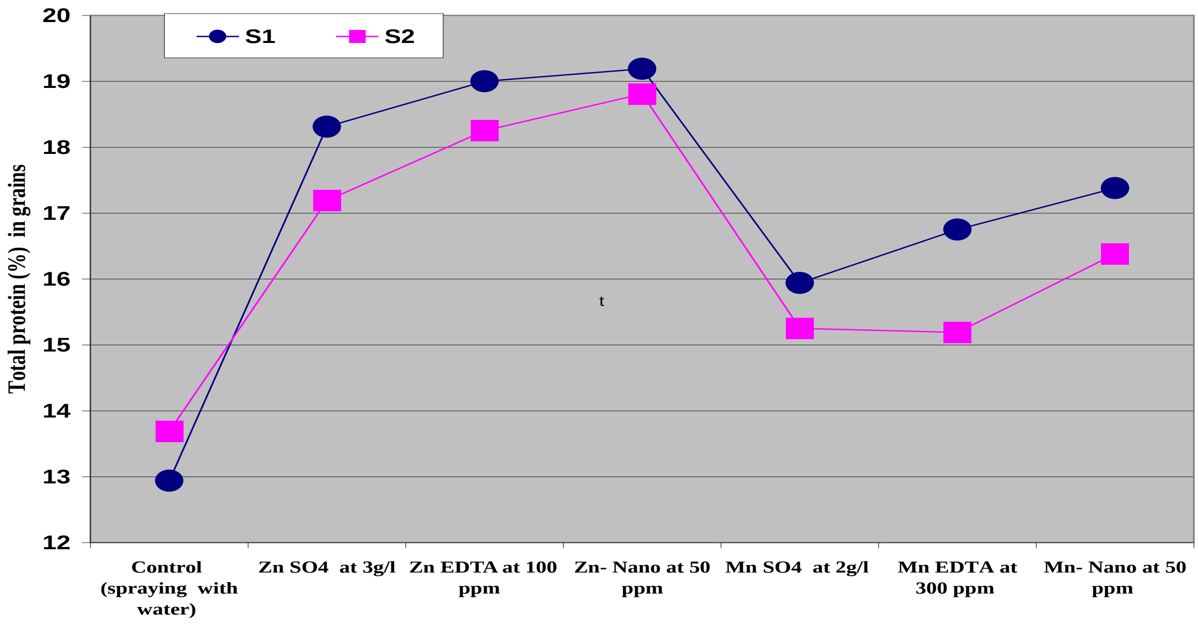

Fig (7). Effect of different forms of Zn and Mn on total protein (%) in grains of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

4. Zinc and manganese concentrations and their uptake by grains

All treatments for Zn or Mn in different forms as foliar spray significantly enhanced Zn and Mn concentrations and their uptake by grains than unsprayed with different sources of Zn or Mn in both seasons, as shown in Tables 15 and 16 as well as Figs 8 and 9. The highest values of Zn concentration (34.2 and 35.2 micrograms/g grain) and Zn uptake by grains (73.87 and 73.64 g/fed.) were produced with the plants that were sprayed with NPs Zn at 50 ppm, followed by spraying with Zn EDTA at 100 ppm, against the control treatment, which produced (15.5 and 15.7 micrograms/g grain) and (21.96 and 21.45 g/fed.) for Zn uptake in the 1st and 2nd seasons, respectively.

As for Mn concentration and their uptake by grains, the same data in Tables 15 and 16 indicated that maximum concentration of Mn (63.5 and 65.2 micrograms/g grain) and Mn uptake (112.78 and 125.18 g/fed) were recorded with the plants that were sprayed with Mn NPs at 50 ppm in both seasons. While control treatment recorded the minimum values of Mn concentration (32.9 and 33.7 micrograms/g grain) and Mn uptake (46.62 and 46.03 g/fed) in the first and second seasons, respectively.

Table (15). Effect of different forms of Zn and Mn on Zinc and manganese concentration in grains (microgram/ g grain) of faba bean at harvest time during 2017/2018 and 2018/2019 seasons

Treatments	Zinc		Manganese	
	2017/2018 season	2018/2019 season	2017/2018 season	2018/2019 season
Control (spraying with water)	15.5 f	15.7 f	32.9 c	33. 7 e
Zn SO_4 (21 % Zn) at 3g/l	25.1 c	27.5 c	33.1 c	33.4 e
Zn EDTA (15% Zn) at 100 ppm	32.2 b	31.9 b	34.2 c	34.6 d
Zn Nano (NPs Zn) 50 ppm	34.2 a	35.2 a	33.0 c	35.6 d
Mn SO_4 (31.8 %Mn) at 2g/l	18.5 e	18.9 e	55.0 b	56.3 c
Mn EDTA (13 %Mn) at 300 ppm	19.0 e	19.9 e	62.2 a	60.3 b
Mn- Nano (NPs Mn) 50 ppm	21.0 d	21.5 d	63.5 a	65.2 a

Table (16). Effect of different forms of Zn and Mn on zinc and manganese uptake in grains(g/fad grain) of faba bean at harvest time during 2017/2018 and 2018/2019 seasons

Treatments	Zinc		Manganese	
	2017/2018 season	2018/2019 season	2017/2018 season	2018/2019 season
Control (spraying with water)	21.96 f	21.45 g	46.62 f	46.03 f
Zn SO_4 (21 % Zn) at 3g/l	49.97 c	53.02 c	65.90 e	64.40 e
Zn EDTA (15% Zn) at 100 ppm	63.34 b	62.01 b	67.27 e	67.26 e
Zn Nano (NPs Zn) 50 ppm	73.87 a	73.64 a	71.28 d	74.48 d
Mn SO_4 (31.8 %Mn) at 2g/l	29.23 e	27.59 f	86.90 c	82.20 c
Mn EDTA (13 %Mn) at 300 ppm	32.24 e	31.60 e	105.55 b	95.76 b
Mn- Nano (NPs Mn) 50 ppm	37.30 d	41.28 d	112.78 a	125.18 a

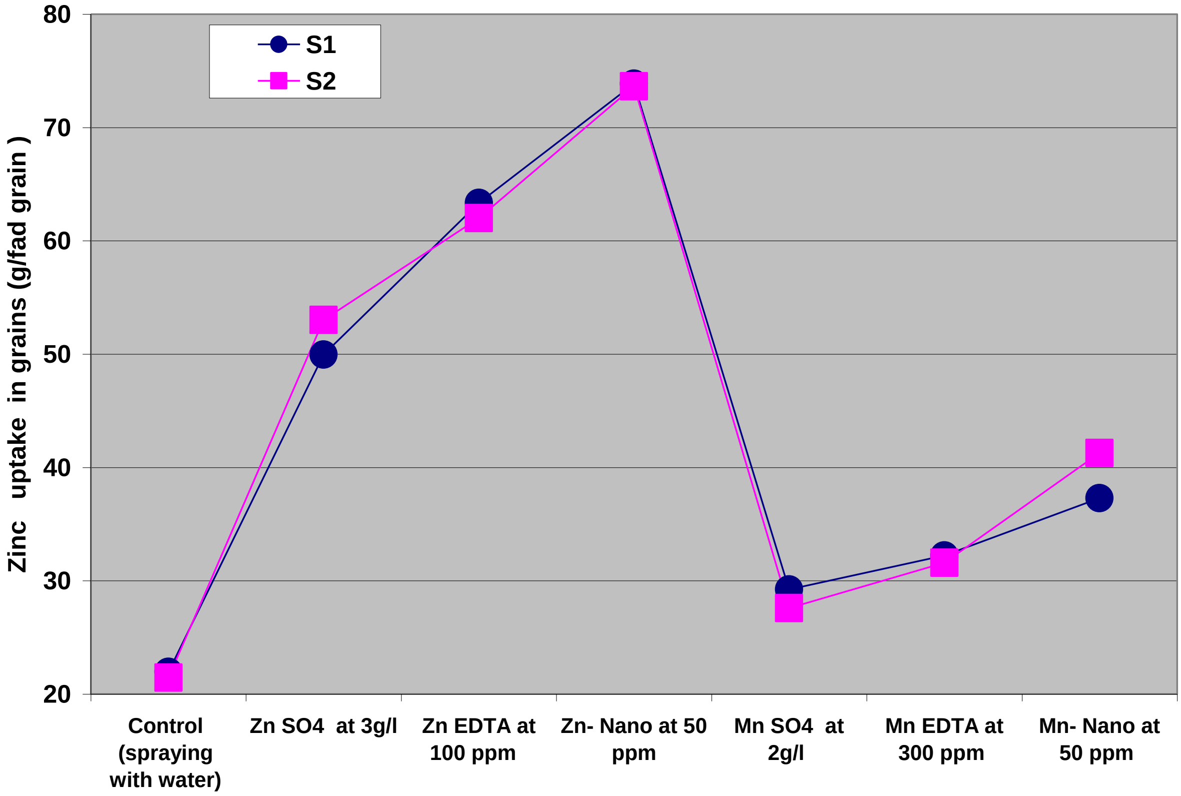

Fig (8). Effect of different forms of Zn and Mn on zinc uptake in grains of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

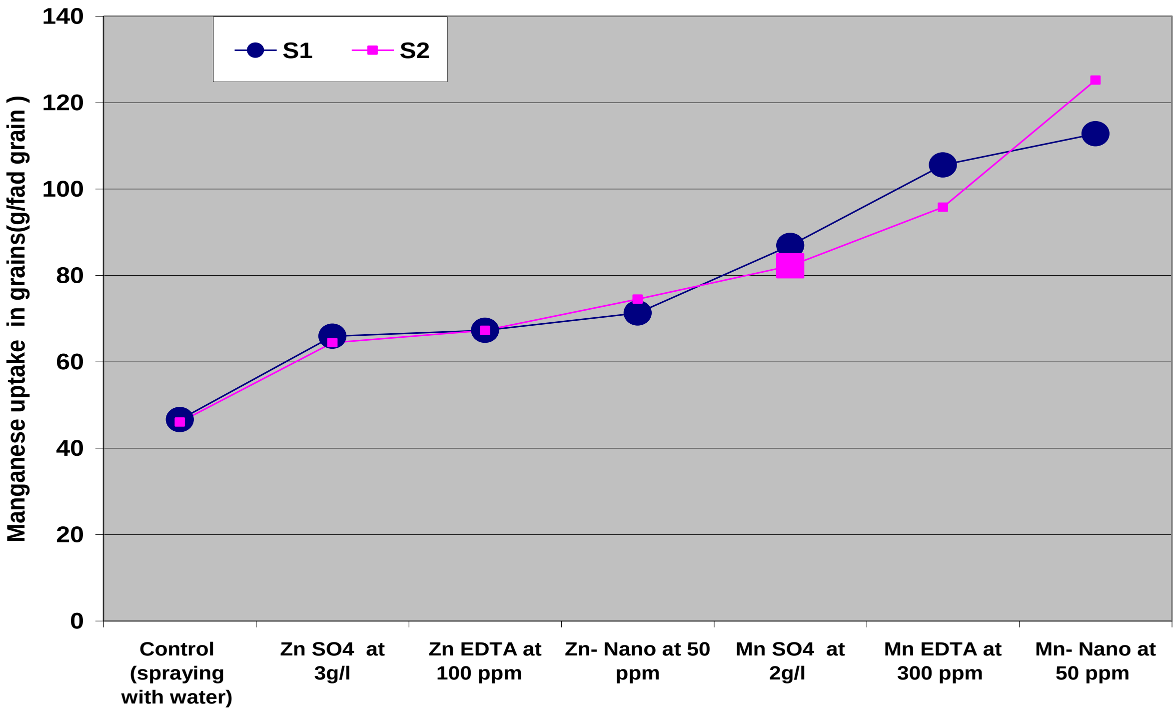

Fig (9). Effect of different forms of Zn and Mn on manganese uptake in grains of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

5. Nitrogen, P and K contents and their uptake by straw

Data in Tables 17-22 shows that, all treatments for Zn or Mn at different forms as foliar spray significantly increased N, P and K- contents and their uptake by straw as compared to control treatment in both seasons.

Spraying with Zn Nano at 50 ppm gave the highest values of N , P and K contents (1.92 and 1.42 %) , (0.160 and 0.158%) and (0.843 and 0.803 %) in the 1st and 2nd seasons, respectively, against control treatment which produced the lowest values (1.13 and 1.02 %), (0.110 and 0.093 %) and (0.613 and 0.623 %) for N , P and K contents in the 1st and 2nd seasons, respectively (Tables 17, 18 and19) .

Table (17). Effect of different forms of Zn and Mn on nitrogen contents in straw of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
	Values		Relative increases (%) over control treatment	
Control (spraying with water)	1.13 e	1.02 e	--	--
Zn SO_4 (21 % Zn) at 3g/l	1.80 bc	1.35 ab	59.29	32.35
Zn EDTA (15% Zn) at 100 ppm	1.87 ab	1.40 ab	65.49	37.25
Zn Nano (NPs Zn) 50 ppm	1.92 a	1.42 a	69.91	39.22
Mn SO_4 (31.8 %Mn) at 2g/l	1.60 d	1.22 d	41.59	19.61
Mn EDTA (13 %Mn) at 300 ppm	1.72 c	1.25 cd	52.21	22.55
Mn- Nano (NPs Mn) 50 ppm	1.85 ab	1.33 bc	63.72	30.39

Table (18). Effect of different forms of Zn and Mn on phosphorus contents in straw of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
	Values		Relative increases (%) over control treatment	
Control (spraying with water)	0.110 c	0.093 d	--	--
Zn SO_4 (21 % Zn) at 3g/l	0.156 ab	0.133 b	41.82	43.01
Zn EDTA (15% Zn) at 100 ppm	0.153 ab	0.155 a	39.09	66.67
Zn Nano (NPs Zn) 50 ppm	0.160 a	0.158 a	45.45	69.89
Mn SO_4 (31.8 %Mn) at 2g/l	0.149 b	0.104 c	35.45	11.83
Mn EDTA (13 %Mn) at 300 ppm	0.151 b	0.109 c	37.27	17.20
Mn- Nano (NPs Mn) 50 ppm	0.152 ab	0.125 b	38.18	34.41

Table (19). Effect of different forms of Zn and Mn on potassium contents in straw of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
	Values		Relative increases (%) over control treatment	
Control (spraying with water)	0.613 f	0.623 e	--	--
Zn SO_4 (21 % Zn) at 3g/l	0.757 c	0.770 b	23.49	23.60
Zn EDTA (15% Zn) at 100 ppm	0.783 b	0.790 a	27.73	26.81
Zn Nano (NPs Zn) 50 ppm	0.843 a	0.803 a	37.52	28.89
Mn SO_4 (31.8 %Mn) at 2g/l	0.627 f	0.723 d	2.28	16.05
Mn EDTA (13 %Mn) at 300 ppm	0.707 e	0.733 d	15.33	17.66
Mn- Nano (NPs Mn) 50 ppm	0.733 d	0.750 c	19.58	20.39

As for N, P and K uptake by straw, the absorption of the three elements by straw took the same trend as the content of the elements in straw in both seasons (Table 20, 21 and 22). In this regard spraying faba bean plants with Zn Nano at 50 ppm produced the maximum values of the uptake by straw (58.35 and 42.56), (4.86 and 4.74.) and (25.62 and 24.07) kg /fad. for N, P and K in the 1st and 2nd seasons, respectively against control treatment which scored (25.52 and 22.10), (2.48 and 2.02) and (13.84 and 13.50 kg) for N, P and K uptake in the 1st and 2nd seasons, respectively, followed by spraying with Zn EDTA at 100 ppm in both seasons. Also, spraying both Zn and Mn as nanoparticles is very effective for enhancing N, P, and K content and their uptake by straw than spraying in the form of EDATA or mineral.

On other words, the superior treatment for N, P, and K content and their uptake by straw was Zn Nano, followed by Zn EDTA, Zn SO_4, Mn- Nano, Mn EDTA, Mn SO_4 and lately T1 treatment (without added Zn or Mn in the different forms).

Table (20). Effect of different forms of Zn and Mn on nitrogen uptake by straw (kg /fad) of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
	Values		Relative increases (%) over control treatment	
Control (spraying with water)	25.52 g	22.10 e	--	--
Zn SO_4 (21 % Zn) at 3g/l	49.81 c	32.40 c	95.18	46.61
Zn EDTA (15% Zn) at 100 ppm	53.97 b	37.62 b	111.48	70.23
Zn Nano (NPs Zn) 50 ppm	58.35 a	42.56 a	128.64	92.58
Mn SO_4 (31.8 %Mn) at 2g/l	37.50 f	28.18 d	46.94	27.51
Mn EDTA (13 %Mn) at 300 ppm	43.10 e	29.29 d	68.89	32.53
Mn- Nano (NPs Mn) 50 ppm	46.45 d	31.88 c	82.01	44.25

Table (21). Effect of different forms of Zn and Mn on phosphorus uptake by straw (kg /fad) of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
	Values		Relative increases (%) over control treatment	
Control (spraying with water)	2.48 d	2.02 d	--	--
Zn SO_4 (21 % Zn) at 3g/l	4.32 abc	3.19 b	74.19	57.92
Zn EDTA (15% Zn) at 100 ppm	4.42 ab	4.16 a	78.23	105.94
Zn Nano (NPs Zn) 50 ppm	4.86 a	4.74 a	95.97	134.65
Mn SO_4 (31.8 %Mn) at 2g/l	3.49 c	2.40 cd	40.73	18.81
Mn EDTA (13 %Mn) at 300 ppm	3.78 bc	2.55 bcd	52.42	26.24
Mn- Nano (NPs Mn) 50 ppm	3.82 bc	3.00 bc	54.03	48.51

Table (22). Effect of different forms of Zn and Mn on potassium uptake by straw (kg /fad) of faba bean at harvest time during 2022/2023 and 2023/2024 seasons

Treatments	2022/2023 season	2023/2024 season	2022/2023 season	2023/2024 season
	Values		Relative increases (%) over control treatment	
Control (spraying with water)	13.84 d	13.50 e	--	--
Zn SO_4 (21 % Zn) at 3g/l	20.95 b	18.48 c	51.37	36.89
Zn EDTA (15% Zn) at 100 ppm	22.60 b	21.23 b	63.29	57.26
Zn Nano (NPs Zn) 50 ppm	25.62 a	24.07 a	85.12	78.30
Mn SO_4 (31.8 %Mn) at 2g/l	14.70 d	16.70 d	06.21	23.70
Mn EDTA (13 %Mn) at 300 ppm	17.72 c	17.17 cd	28.03	27.19
Mn- Nano (NPs Mn) 50 ppm	18.41 c	17.98 cd	33.02	33.19

Zinc has a significant impact on several fundamental plant life processes, including (i) nitrogen metabolism, nitrogen uptake, and protein quality; (ii) photosynthesis, chlorophyll synthesis, and carbon anhydrase activity; and (iii) resistance to biotic and abiotic stresses and protection against oxidative damage (**Tekale *et al*., 2009**). Also, Manganese is necessary for plants to use macronutrients to their fullest potential and helps in the synthesis of carbohydrates. Manganese increases the activity of several enzymes that support respiration, photosynthetic light reactions, and protein synthesis, all of which improve the use of NPK and its conversion into useful seed carbohydrates (**Malakouti and Tehrani, 1999**).

In this regard, according to **Radwan and Tawfik (2004),** micronutrients, such as Zn and Mn may have a beneficial effect on chemical contents because they are involved in a number of crucial biological processes, including the synthesis of chlorophyll, the electron transport system, oxidation-reduction reactions, protein synthesis, and degradation.

In this concern, El **Sayed *et al*. (2012)** showed that spraying with Zn or Mn significantly increased the concentration of total protein in seeds of pea plants compared with control plants.

Our results were in agreement with the findings of **El-Agrodi *et al*., 2017, Abdo 2018, Al-Silawi *et al*., 2018 and Shaban *et al*., 2019**. They demonstrated that after receiving foliar treatments of several forms of zinc, the content of important elements (N, P, and K) in the seeds and straw of faba bean plants was much higher than in untreated plants. Also, **El-Sharkawy *et al.*, 2021** showed that spraying faba bean with Nano-Zn at 1 or 2g /l significantly increased N, P and K contents in seeds as compared to unsprayed plants.

Regarding the effect of Mn on mineral contents and its uptake by haring and straw, **Abdo, and Attia (2007)** showed that the spraying faba bean plants with Mn at 300 ppm increased total protein seeds than unsprayed plants. Also, **Salama *et al*., 2022**) . Illustrated that the best value of nitrogen, phosphorus, potassium content of seeds of common bean plants which treated with MnO_2-NPs concentration (30 ppm) as compared to unsprayed plants

Also, Marzouk *et al*. (2019) showed that Foliar application of zinc or Mn nano- recorded the highest values of N, P and K as well as total protein in seeds of snap bean as compared to unsprayed plants .

From the foregoing results, it could be concluded that, foliar spray with Zn Nano at 50 ppm increased plant dry weight, 100 grain weight, yield / plant, yield of grain and straw/fad, and biological yield N, P, and K contents and their uptake by grains and straw, as well as total protein in grains and Zn uptake.

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تأثير الصور المختلفه للزنك والمنجنيزعلى انتاجيه نبات الفول البلدى

ساميه محمد سعد الكلاوى - زينب عبد الرؤوف ذكى - لمياء عبد الحليم عبد الرحمن

معهد بحوث الاراضى والمياه والبيئة – مركز البحوث الزراعية.

تم إجراء تجربتين حقليتين في موسمي ٢٠٢٢/٢٠٢٣ ، ٢٠٢٣/٢٠٢٤ بمزرعة محطة البحوث الزراعية بالسويس بمحافظة السويس – مركز البحوث الزراعية– مصر لدراسة تأثير الصور المختلفة للزنك (الزنك المعدنى ٢١ % زنك بمعدل ٣ جم/لتر، الزنك المخلبى ١٥ % زنك بتركيز ١٠٠ جزء في المليون والزنك النانو بتركيز ٥٠ جزء في المليون، المنجنيز (المعدنى ٣١,٨ % بمعدل ٢ جم/لتر،المنجنيز المخلبى ١٣ % منجنيز بتركيز ٣٠٠ جزء في المليون والمنجنيز النانو بتركيز ٥٠ جزء في المليون على الوزن الجاف ، الإنتاجية وجودة حبوب نباتات الفول البلدي المزروعة في التربة الطميية الرملية. أشارت النتائج إلى أن جميع معاملات الرش الورقي بالزنك أو المنجنيز بصورها المختلفة أدت إلى زياده الوزن الجاف والمحصول ومكوناته الكيميائية في الحبوب مقارنة بمعامله المقارنه . حيث أن الرش الورقي بمادة النانو زنك بتركيز ٥٠ جزء في المليون كانت أفضل معاملة لزيادة الوزن الجاف/نبات ، ووزن ١٠٠ حبة ، ومحصول/نبات ومحصول الحبوب والتبن/ فدان والمحصول البيولوجي، ومحتوى كل من الحبوب من النيتروجين والفوسفور والبوتاسيوم والزنك والممتص منهم و نسبه البروتين الكلي في الحبوب ، وكذلك محتوى التبن من النيتروجين والفوسفور والبوتاسيوم والممتص منهم . بينما أعطى الرش بالنانو منجنيز بتركيز ٥٠ جزء بالمليون أعلى قيم لتركيز وامتصاص المنجنيز بواسطة الحبوب. وقد أدت معاملة الرش الورقي بمادة النانو زنك بتركيز ٥٠ جزء في المليون إلى زيادة إنتاج الحبوب الكلي بحوالي ٥٢,٤٣ و ٥٣,١٥% (مايعادل ٠,٧٤٣ و ٠,٧٢٦ طن/ فدان) عن محصول الكونترول في الموسمين الأول والثاني على التوالي. وبشكل عام كان تأثير المعاملات موجباً في معظم الصفات المدروسة وكان ترتيبها كما يلي من الأكثر إلى الأقل: Zn Nano > Zn EDTA > Zn SO_4 > Mn Nano > Mn EDTA > Mn SO_4 > المقارنه (غير المرشوشة) في معظم صفات الدراسة.