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ENHANCING ADAPTING MAIZE TO CLIMATE CHANGES USING DIFFERENT NITROGEN AND ZINC SOURCES AND THEIR EFFECTS ON GROWTH, YIELD AND QUALITY UNDER NILE DELTA CONDITIONS

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ABSTRACT: Large fluctuations in the weather come within the climate change crisis in Egypt and could lead to an irreversible change in the environment. As a result of these changes, the production of agricultural crops that are not accustomed to such a climate is declining. Significant warming has been manifested over the past 30 years, with average annual temperatures increasing by 0.53°C per decade. So, a field experiment was executed during the two consecutive summer seasons of 2021 & 2022 inside the Nile Delta of Egypt at the experimental farm of Tag El-Ezz research station, ARC, Dakahlia governorate, (located at 30o 59\ N latitude, 31o 58\ E longitude´) to investigate the influence of applying three different combinations of N fertilizer sources as mineral, organic and biological fertilizers and Zinc compounds on yield and its components of corn (*Zea mays* L.) plants (white single cross-type Giza 128). Each experiment contained twelve treatments which were the combinations of the three different nitrogen source combinations (100% of the recommended Min-N, 50% Min-N+ 50% Org- N and 50% Min-N + 50% Org-N +Bio-N)) and four sources of Zinc forums (Control- without), zinc sulfate, zinc- EDTA and zinc- nano). The experimental statistical design was a split-plot system with three replications. The N-treatments were in the main plots, whereas, Zinc forms occupied the sub-plots as a foliar application. The results revealed that the application of Min-N with Org-N in combination with Bio-N resulted in increasing yield and yield components significantly. Application of 50% Min-N+ 50% Org-N combined with Bio-N produced higher length of the ear (cm),, grains weight ear^{-1}, grain yield & biological yield of maize. Foliar application with zinc improved yield and its components of maize and higher length of the ear, 100-grain weight, grains weight per ear, grain yield and biological yield as compared with the control. The best results were observed with ZnO nanoparticle treatment (ZnO-NPs). So, it can be said that fertilizing maize plants with 50%Min-N+ 50% Org-N+ Bio-N combined with spraying plants with zinc nano had a significant impact on yield and its components of maize.

Keywords: Maize, Organic fertilizer, Zinc sources, Nutrient uptake, Productivity, Quality and Yield.

INTRODUCTION

The unfavorable effects of global warming, such as changes in temperature, a change in the rate and patterns of precipitation, and storms formed are increasing with the development of human consumption, as global warming affects in particular the process of recovering the ozone layer. It can be said that hydro fluorocarbons (HFCs) and other greenhouse gases such as oxides increased carbon and nitrogen oxides (CO and NO) affect the ozone layer and thus raise the Earth's temperature, which made it necessary to search for alternatives to solve these crises. Nitrogen pollution resulting from nitrogen fertilizers contributes to several problems in the atmosphere, including global warming that may occur due to the liberation of nitro us oxide (N_2O) from nitrogen fertilizers, which is a greenhouse gas whose impact many times greater than carbon dioxide, which the N cycle affects the release of N_2O, carbon dioxide (CO_2) and methane (CH_4) from agricultural soils (Fagodiya *et al.,* (2020) and Volthof *et al.,* (2009). Therefore, in this research we use an eco-friendly application such as organic matter and bio-fertilizers to make a partial alternative of chemical nitrogen fertilizers.

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Maize (*Zea mays* L.) occupies the third place of most important cereal crop among rice and wheat in Egypt. It is substantial for both human food as well as animal feed. In Egypt, it is significantly important to raise the production of maize to overcome the gap between production and consumption, especially under climate change conditions. Many factors effects on the highest maize yield production i.e., cultivars, nitrogen, micronutrient fertilization, biotic and abiotic stress. Maize is the master source of minerals and calories for most Villagers (FAO, 2011). However, corn is naturally low in protein and minerals, especially Zn. It is a highly nutrient-demanding crop that is critical for micronutrient deficiencies, particularly zinc. Furthermore, the advent of the green revolution, with its high-yielding crop cultivars/ hybrids has exacerbated this situation. It is known as an indicator plant for estimating zinc deficiency in the soil (Ayyar and Appavoo, 2017).

Maize hybrids differed in their productivity as well as their response to nitrogen fertilization. Nitrogen (N) is the most sensitive nutrient in maize production to improve nutritional quality and encourage optimum yield (Miao *et al.*, 2006). Nitrogen fertilization management is one of the largest factors that contribute to increasing maize yield. In plants, nitrogen (N) is the mineral element required in large quantities and is responsible for proteins, amino acids, enzymes synthesis and photosynthetic processes (Hafez and Abdelaal, 2015).

The incorporation of mineral, organic and bio fertilizers is regarded as the best solution for preserving the soil with minimum undesirable effects, increasing fertilizer application efficiency in the soil and reducing the intensive consumption of synthetic fertilizers. Organic and bio-fertilizers are regarded as an environmentally friendly method to sustainable farming (El-zemrany and Faiyad, 2021). They have a positive effect on plant growth and productivity, minimize the bad effects of synthetic fertilizers and reduce several chemicals like NO_2^- & NO_3^- ions in soils and then in plants. So, the path to healthy agriculture with minimum pollution requires the combined use of both N-mineral and N-organic fertilizers (El-Shafey and El-Hawary, 2016). Organic manure also improves the drainage in clayey soil and water-holding capacity of sandy soil, and also, it provides nutrients to soil micro-organisms.

Zinc is an important micronutrient that has a vital role in basic plant metabolic processes and engorage the growth, yield, and quality of corn by enhancing chlorophyll production, nutrient uptake, photosynthetic activity and protein biosynthesis, also, it is essential in the regulation of plant metabolic activities and enzymatic reactions in the (Suganya and Saravanan, 2016). Zn is needed in trace but vital amounts for several key plant physiological pathways to work normally, as, it is a structural constituent or regulatory co-factor of an expanse of different enzymes and proteins in several critical biochemical pathways (Sadeghzadeh, 2013).

Three billion people, often in third world countries suffer from nutrient deficiencies because of micronutrient malnutrition like zinc which includes approximately 33% of the total. According to a World Health Organization report published in 2002, zinc deficiency ranks fifth among the leading causes of malnutrition among people in developing countries (Balakrishnan and Subramanian, 2012). The zinc application to maize crops by foliar spray using different treatments of Zinc chemical forms has shown a positive effect on growth, nutrient uptake, yield productivity and quality. It is important to understand the distribution of Zn in soils for the efficient and effective fertilizer resource management.

Recently, the use of nanotechnology is an emerging and promising new technology to assist mainly in farming, which has the potential to cause a new agriculture revolution due to its efficiency in solving many problems related to agriculture with fabulous improvement, compared to conventional farming systems (Uma *et al.*, 2019). Few studies have been conducted to investigate the effects of zinc-nano on maize growth (Abbas *et al.*, 2021). Because of its wide properties, Zn-oxide nanoparticles are gaining popularity among other metal oxides. The United States Food and Drug Administration considers zinc oxide to be one of the safest substances. The present study elucidate the effect of zinc oxide nanoparticles (ZnO-NPs) on the growth and yield of maize.

Many regional and national initiatives strongly encourage The use of organic fertilizers as an essential management strategy for improving soil health and mitigating the effects of climate change. Organic fertilizers, such as compost manure and plant residues can be used as a direct C input into the soil, where it can be stabilized via physical, chemical, and biochemical mechanisms that contribute to long-term C storage in soils (Six *et al.,* 2002) and (Brar *et al.,* 2013). Organic fertilizers contain a various of C compounds that soil microorganisms can use to boost their growth rates and biomass during the mineralization process. Thus, OFs have potent short- and long-term effects on soil microorganisms and play an important role in supporting soil health through increasing microbial activity. Microorganisms release plant-available nutrients and saydrophors during the mineralization of C compounds in OFs. As a result, OFs may indirectly increase C storage in the soil (Lazcano *et al.,* 2021) and (Sokol and Bradford, 2019).

Therefore, the objective of this work intend to ameliorate maize yield and enhance N-fertilization use efficiency in maize plants under climate change conditions through the application of different mineral, organic and bio nitrogen sources and at the same time foliar application of Zn chemical forms and their effects on the nutrient concentration, yield and quality of corn under new climate condition on Nile delta of Egypt.

MATERIALS AND METHODS

Egypt and Dakahlia governorate temperature changes during years of 1900 to 2021to show changes in air temperature to reflect worming in Egypt and study area was shown in Tables 1 and 2.

A field experiment was done during the two sequential summer seasons of 2021 & 2022 inside Nile Delta of Egypt at Tag El-Ezz experimental farm research station, ARC, Dakahlia governorate (located at 30º 59\ N latitude, 31º 58\ E longitude´) to study the impact of applying different mineral, organic and biological sources of N-fertilization and Zinc chemical forms and their effects on growth, yield, quality and soil properties of corn plants using white single cross Giza 128 seeds. Tables (3 & 4) show the physical and chemical contents of randomized samples taken from the soils before sowing and compost according to Klute

Table (1). Showing the annual temperatures C^{O} in Egypt during the past century according to the Climate Change Knowledge Portal.

Year	Temperatures, (C°)		Year	Temperatures, (C°)	
	Egypt	Dakahlia		Egypt	Dakahlia
1900	22.14	20.26	2001	23.15	21.05
1910	21.74	19.55	2003	23.06	20.77
1920	22.00	20.17	2005	22.99	20.62
1930	22.85	21.01	2007	23.13	21.12
1940	22.82	20.75	2009	23.27	21.35
1950	22.20	20.16	2011	22.84	21.41
1960	21.95	21.39	2013	23.40	21.17
1970	22.00	20.39	2015	23.44	21.58
1980	22.43	20.48	2017	23.31	21.68
1990	22.59	20.59	2019	23.38	21.79
2000	22.63	20.44	2021	23.88	22.32

Table (2). Showing the summer temperatures C° in Egypt during the past century according to the Climate Change Knowledge Portal.

Year	Temperatures in Egypt (C^O)
1901-1930	28.99
1931-1960	29.21
1961-1990	29.17
1991-2020	30.25

Table (3): Average values of the properties of the experimental soil.

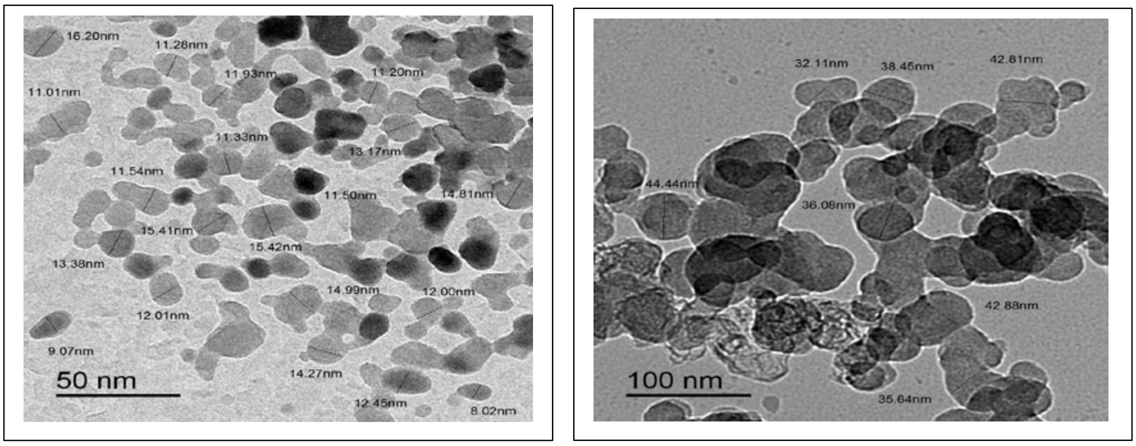
a. Soil physical properties			
Particle size distribution (%)			Textural class
Sand	Silt	Clay	Silt Clay loam
7.80	**60.00**	**32.20**	

b. Soil chemical properties									
pH (1:2.5, soil: water Susp.)	EC, soil past, (dSm^{-1})	Soluble ions (meq L^{-1})							
		Cations				Anions			
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
7.93	3.19	6.46	6.98	17.25	0.33	–	4.32	13.83	12.87

c. Soil nutrient contents						
Macronutrients (Available)($mgkg^{-1}$)			Micronutrients (DTPA extractable)($mgkg^{-1}$)			
N	P	K	Cu	Fe	Mn	Zn
38.99	7.42	206.5	2.15	6.19	3.78	0.08

Table (4). Average values of the properties of the compost.

Properties	Values
EC (1:10) dSm^{-1}	3.87
pH (1:10)	6.53
Moisture content (%)	28.00
O. M. (%)	33.02
O. C. (%)	18.08
Total N (%)	1.32
Soluble ammonium (ppm)	613.00
Soluble nitrate (ppm)	359.00
Total K (%)	0.72
Total P (%)	0.41
C/N ratio	13.7



Figs (1 &2): Images for Zn0-NPs by transmission electron microscope (TEM).

(1986) and Page *et al.*, (1982). To know that zinc is nano-sized, transmission electron microscope (TEM) image was done as shown in Figs (1 & 2), and it measured with an Electron Microscope Unit, Mansoura University.

Experimental treatments

Each experiment included twelve treatments consisting of the three different nitrogen source treatments and four treatments of Zinc. A split-plot system was used in the experimental design with three replications. The experimental area consisted of 36 plots. The sub plot area was 12 m^2 (4m ×3m). The N- sources were in the main plots, while, the sub-plots were occupied by zinc forms as a foliar application. Foliar spray of zinc sources 100 ppm was done on the 30^{th}, 45^{th}, and 60^{th} days after sowing.

The main treatments were applied to different nitrogen sources as follows:

1- 100% of the recommended mineral N by the ministry of agriculture (Min-N) with application rate 120 kg N fed^{-1}, as Urea 46% N).

2- 50% mineral N (Min-N) (60kg $Nfed^{-1}$) +50% organic N (Org-N) supplied to the experimental plots as 60kg N fed^{-1} = 4.23 ton compost fed^{-1}.

3- 50% mineral N (Min-N) + 50% organic N (Org-N) supplied to the experimental plots as 60kg N fed^{-1} + (*Azotobacter+ Azospirillium*) inoculation (Bio-N).

Each main plot subdivided into four subplots representing the four different treatments of zinc forms as the following:

1- Zn0 = Control.
2- Zn_1 = zinc sulfate ($ZnSO_4$).
3- Zn_2 = Zn-EDTA.
4- Zn_3 =zinc nano (ZnO-NPs).

The compost was mixed with a 0-20 cm soil surface layer two weeks before sowing. Seeds of maize were sown at a rate of 10 Kg fed^{-1} in hills spaced 20 cm apart during the two seasons, in five ridges of 0.60 m wide and 4 m long. The nitrogen fertilizer (as urea 46% N) was applied in three equal portions according to the treatment, namely after 0, 25 and 50 days after sowing. In addition, potassium fertilizer (as Potassium sulfate, 48% K_2O) was applied at a rate of 24 kg K_2O fed^{-1} and superphosphate (6.6% P) was added at the rate of 30 kg P_2O_5 fed^{-1} according to recommendation by the Ministry of Agriculture and Soil Reclamation (MASR).

In terms of bio fertilization, maize seeds were inoculated with bio-nitrogen fertilizer (*Azotobacter chroococcum* + *Azospirillium brasilense*) and were kindly obtained from Micro bio. Dept., SWERI, ARC, Giza, Egypt. Maize grains were inoculated with *Azospirillum and Azotobacter* liquid culture prior to sowing. As an adhesive agent, Arabic gum was added to liquid culture. Before planting, inoculated grains were air-dried by spreading them out on a plastic sheet for a short period of time. The sawing date was at 7th and 9th of June and the harvest date was at 1st and 4th of October, respectively.

Data recorded

1. Maize Plants Growth parameters

After 70 days of sowing, fresh & dry weights (g. plant^{-1}) were measured. NPK concentrations in-ear leaf were determined in the digested plant materials.

2. At harvest stage

The following characteristics were estimated:

A- Yield and Yield components

Plant height (cm), ear characters (i.e. ear length (cm), ear diameter (cm), 100 grain weight (g), ear weight (g), grains weight ear^{-1}, grain, stalk and biological yield (ton fed^{-1}) were determined.

B- Chemical analysis

Grain were taken from each replicate sample to determine N, P, K and Zn contents. Each replicate's maize grains were digested with H_2SO_4 - $HClO_4$ (3:1 ratio) using the slandered method described by Chapman and Pratt, (1978). The final clear digestion analyzed for N, P, K and Zn content of as follows:

- Nitrogen (N) was determined using the Keldahl method as described by A.O.A.C. (1990). Protein content was calculated by using the formula: Protein %= N × 5.75 according to A.O.A.C. (1988). Phosphorus was determined using the calorimetric method described by Chapman and Pratt (1978). According to Page *et al.*, (1982), potassium was determined using a flam photometer. Zinc content was determined using atomic adsorption spectrophotometer as described by Chapman and Pratt, (1978).

-Nutrients uptake in grain was determined using the following formula:

$$\text{Nutrients uptake } kg\ fed^{-1} = \frac{Nutrient\ concentration\ \times grain\ \ yield\ (kg\ fed^{-1})}{100}$$

- The oil content (%) of maize grains was determined using soxhelt apparatus as described by A.O.A.C. (1990). Grain yield (kg fed.$^{-1}$) was multiplied by protein and oil content (%) to calculate protein and Oil yields (kg fed^{-1}) respectively.

- According to Smith *et al.* (1956), total soluble sugars (TSS) and total carbohydrates content were estimated.

c- Soil analysis

Surface soil samples (0-30) were collected after harvesting the crop from each sub plot to determine the available N, P and K according to Page *et al*. (1982).

Statistical analysis

The results of two years of identical experiments were combined for analysis. According to Gomez and Gomez, (1984) significant differences among treatments means were determined at $P \leq 0.05$ using the LSD test and statistically done using COSTATE Computer Software.

RESULTS AND DISCUSSION

The present study aimed to enhance maize adaptation to climate and improve productivity and increase N-fertilization use efficiency by the application of different nitrogen sources and exogenous nutrition by chemical zinc forms..

1- Vegetative Growth and Nutrients Concentrations at Grain Milk Stage

A significant differences in growth parameters viz., fresh, dry weights and mineral NPK concentration in leaves of aboveground plants after 70 days of sowing (grain milk stage) are shown in Table (5). The application of 50% Min-N+ 50% Org-N+ Bio-N displayed significantly the highest growth parameters i.e. fresh and dry weights (419 and 114.6 g plant^{-1}, respectively), also nutrients concentration i.e. N, P and K (2.83, 0.209 and 1.56 %) respectively.

The results obtained may be due to nutrients being responsible for increased cell enlargement, cell division, growth and photosynthesis which increase plant growth (Yaseen *et al.*, 2019). Bio fertilizers has a beneficial role in plant growth and nutrients uptake, as these organisms may positively affect their host plant, such as nitrogen fixation, production of growth-promoting substances or organic acids, enhancing nutrients uptake (Hassan *et al.*, 2012 and Fitriatin *et al.*, 2021). On the other hand, the improving effect of using organic fertilizer on plant growth may be due to its role in soil amelioration which enhances water holding capacity and increases the availability of macro and micro elements in the soil around the roots system which in turn increases plant growth (Mulyati *et al.*, 2021). These findings are in harmony with Shoman *et al*. (2006) and Hosam El-Din (2007).

The increments of studied vegetative growth parameters such as fresh, dry weights and NPK nutrients concentrations in leaves of corn plants may be because of the vital effects of N on stimulating meristematic activity for producing more organs and tissues, as N plays a major role in the synthesis of structural proteins and other several macromolecules, also, it contributes to several biochemical processes in the plant related to growth (Batyrbek *et al.*, 2022).

Table (5). The impact of different nitrogen sources and exogenous zinc application and their interaction on Fresh, dry weights (g plant^{-1}) and leaf mineral concentrations (%) after 70 days (combined data over both seasons)

Treatments		Fresh weight	Dry weight	Macronutrients in leaves (%)		
		(g plant^{-1})		N	P	K
N- sources						
M1		392	111.4	2.70	0.184	1.41
M2		362	108.6	2.52	0.164	1.26
M3		419	114.6	2.83	0.209	1.56
LSD at 5%		1.30	2.26	0.063	0.003	0.088
Zinc forms						
Zn0		354	96.2	2.61	0.177	1.35
Zn1		410	116.0	2.70	0.189	1.44
Zn2		377	112.6	2.67	0.182	1.39
Zn3		422	121.4	2.75	0.194	1.47
LSD at 5%		2.18	2.08	0.050	0.005	0.028
Interaction effects						
M1	Zn0	348	95.7	2.60	0.177	1.36
	Zn1	412	116.0	2.74	0.185	1.42
	Zn2	386	112.0	2.70	0.182	1.39
	Zn3	422	121.7	2.77	0.192	1.47
M2	Zn0	337	93.5	2.46	0.156	1.20
	Zn1	374	113.1	2.53	0.169	1.30
	Zn2	345	109.0	2.50	0.160	1.24
	Zn3	391	119.1	2.60	0.172	1.33
M3	Zn0	377	99.3	2.78	0.198	1.50
	Zn1	444	118.8	2.85	0.213	1.60
	Zn2	400	117.0	2.81	0.206	1.54
	Zn3	454	123.4	2.88	0.220	1.62
LSD at 5%		3.79	3.61	0.086	0.009	0.094

M1: 100% of the recommended mineral N, M2: 50% Min-N + 50% Org-N and M3: 50% Min-N + 50% Org-N +Bio N, Zn0: Control, Zn1: zinc sulfate, Zn2: zinc EDTA and Zn3: zinc nano2022.

Data presented in table (5) showed that there were significant increase of zinc forms on fresh, dry weights and leaf mineral concentration of maize plants at grain milk stage averaged after 70 days of sowing. Zinc nano treatment gave the highest values for the stated parameters and the relative increases were (19.2 and 26.2 %) for fresh and dry weights respectively and (5.36, 9.60 and 8.89) for NPK concentration in maize leaves. The values of fresh, dry weights and leaf mineral content of maize plants had the descending order of zinc nano > zinc sulfate > Zn EDTA > control. This might be due to the better role of Zn during the reproductive phase of crop growth and flowering. Similar results were referred by (Uma *et al*., 2019). The application of zinc forms increases fresh, dry weights and leaf mineral uptake of corn plants as compared to the control (Abbas *et al.,* 2021).

It is clear from the tabulated data in Table (5) that the interaction effects among nitrogen sources and zinc forms were significant. The highest average values were achieved with 50% Min-N + 50% Org-N +Bio-N integrated with zinc nano, where the lowest average values were recorded with 50% Min-N+50% Org-N and without zinc fertilizer applications.

2- Yield attributes

a. Plant height

The present results denoted that the plant height was significantly affected by applying various nitrogen sources (Table 6). The taller plant height (268 cm) recorded from treatment (50% Min-N +50% Org-N + Bio-N) while the shorter plant height (255cm) was obtained from treatment which received (50% Min-N +50% Org-N).

This result was in line with Awad (2002) who stated that bio-fertilizers have a beneficial role in increasing the soil microorganisms, particularly in the rhizosphere surrounding the root, that create substances induced stimulation in plant growth. The positive impacts of organic manure on plant height are mainly because of enhancing the physical and chemical properties of the soil, making the suitable soil for germination, and developing plant growth that effects on final yield (Jjagwe *et al*., 2020).

On the other hand, the increase in plant height caused by bio-fertilizers could be clarified through the synthesis of growth-promoting compounds as gibberellins, IAA and cytokinins (Mahfouz and Sharaf-Eldin, 2007). A similar result was confirmed by (Ahmad *et al.,* 2013) who said that the impact of different nitrogen sources on plant height can be referred to the fact that nitrogen elevates plant growth and increases the length & number of internodes which increase plant height.

Also, the results elucidated that the exogenous application of chemical forms of Zn had a significant effect on maize plant height at the harvest stage. The maximum plant height was (283 cm) with Zn-nano followed by exogenous application as $ZnSO_4$ (262 cm) followed by Zn-EDTA (252 cm) whereas a minimum plant height of 245cm was noted in the non-foliar application. The influence of exogenous application of ZnO-NPs on plant height at the harvest stage was because of its direct contact on leaves surface area and easily absorption through the plant leaves (Kumar *et al*., 2021).

Wasaya *et al.* (2017) noted that the application of Zn gave a significant increase in growth parameters such as leaf area index and plant height in corn. At the same time, the impact of the interaction on plant height, the highest values (289 cm) were obtained with (50% Min-N +50%Org-N+ Bio-N) plus nano-zinc as expected from the enhanced contribution of organic and biological fertilizers associated with reduced mineral-N fertilization as Ecological management of fertilization to enhance corn production quantity and quality.

b. Ear characteristics

- (Length and diameter)

The ear length and diameter were significantly influenced by the tabulated treatments as shown in Table (6). The highest values of ear length and ear diameter (21.5 and 4.86) were recorded with M3 treatment (50% Min-N+50% Org-N + Bio-N) followed by M1 (100% Min-N) with values (19.8 cm and 4.76cm) for ear length and diameter, respectively. These findings could be attributed

Table (6). The impact of different nitrogen sources and exogenous zinc application and their interaction on Yield attributes (combined data over both seasons).

Treatments		Plant height	Ear length	Ear diameter	100-grain weight	Ear weight	Grains weight ear^{-1}
		cm			g		
N- sources							
M1		260	19.8	4.76	37.19	237.35	190.32
M2		255	19.2	4.65	36.51	215.52	176.00
M3		268	21.5	4.86	38.08	244.35	198.00
LSD at 5%		9.43	0.981	0.032	0.080	1.654	2.34
Zinc forms							
Zn0		245	18.13	4.54	35.37	214.80	169.13
Zn1		262	20.80	4.83	37.68	239.66	195.63
Zn2		252	19.73	4.66	36.39	229.13	180.43
Zn3		283	21.96	4.99	39.60	246.03	207.23
LSD at 5%		2.28	0.404	0.054	0.100	1.043	1.57
Interaction effects							
M1	Zn0	245	17.8	4.57	35.24	217.0	174.0
	Zn1	259	20.5	4.80	37.72	244.0	194.3
	Zn2	253	18.9	4.67	36.52	239.7	182.3
	Zn3	282	22.0	5.00	39.33	248.7	210.7
M2	Zn0	241	17.0	4.40	34.71	196.7	154.7
	Zn1	255	20.2	4.73	37.00	224.7	186.3
	Zn2	246	18.3	4.60	35.52	207.0	166.3
	Zn3	277	21.3	4.87	38.82	233.7	196.7
M3	Zn0	249	19.6	4.67	36.22	230.7	178.7
	Zn1	273	22.0	4.97	38.33	250.3	206.3
	Zn2	257	21.7	4.73	37.15	240.7	192.7
	Zn3	289	22.6	5.10	40.63	255.7	214.3
LSD at 5%		3.96	0.700	0.094	0.173	1.808	1.99

M1: 100% of the recommended mineral N, M2: 50% Min-N + 50% Org-N and M3: 50% Min-N + 50% Org-N +Bio N, Zn0: Control, Zn1: zinc sulfate, Zn2: zinc EDTA and Zn3: zinc nano.

to the adequate supply of nitrogen for photosynthetic activities of the plant as it is a necessary requirement for ear growth. (Khan *et al.*, 2008 and Fanuel and Gifole 2012). Similar results were found by (Yaseen *et al.*, 2019) who recorded that combination between Min- N and Bio-N had a positive influence on yield attributes like ear length and diameter.

The data in Table (6) indicated a significant increase in ear length and diameter with the application of foliar Zn-forms. It is observed that the highest ear length (21.96cm) and diameter (4.99 cm) with relative increase 21.13 and 9.91% were reveled with the addition of nano-Zn followed by exogenous application as $ZnSO_4$ followed by Zn-EDTA whereas minimum values of both ear length and diameter were noticed in the control. Due to the reproductive process of many plants, zinc is involved in the synthesis of some IAA growth hormones and metabolic acid synthesis, which are very important for grain formation as well as increased growth attributes (Suganya and Saravanan (2016) and Abbas *et al.* (2021)). The nano-sized ZnO-NPs are have greater penetration capacity and use efficiency.

As expected the effect of the interaction on both ear length and diameter (Table 6), the highest values (22.6 and 5.10 cm, respectively) were obtained with T12 (50%Min-N+50% Org-N + Bio-N) plus zinc-nano (Kume *et al*., 2021).

- 100-grain weight:

The data in Table (6) for 100-grain weight showed that all treatments differed significantly from one other. Maximum 100-grain weight was shown by (50% Min-N +50% Org-N + Bio-N) 38.08g followed by (100% Min- N) 37.19 g and (50% Min-N +50% Org-N) 36.51g. The importance of mineral nitrogen fertilizer and organic manure is that their combination contains essential elements required for physiological mechanisms of plant growth and yield quality (Batyrbek *et al*., 2022). Because nitrogen considered one of the most important components of nucleic acid, cytoplasm and chlorophyll, it has a vital function in raising vegetative growth and activating photosynthesis, which reflect increases in grains (Mohammed *et al*., 2014). Inoculation of maize grains with the mixture of *Azotobacter and Azospirillum* significantly increased 100-grains weight compared with those of the un inoculated plants.

Such results may be due to the beneficial action of biofertilizers on yield components of plants which caused N fixation or production of plant growth-promoting substances and subsequently affect yield attributes (El Shafey and ElHawary, 2016).

Results appeared that the 100-grain weight was significantly influenced by the foliar application of zinc. The maximum value of 100-grain weight was 39.60 g with the foliar application as Zn-nano followed by foliar application as $ZnSO_4$ followed by Zn-EDTA while the minimum value was 35.37 g with the control. These findings were similar to those of Hariss *et al.,* (2007). This result could be attributed to zinc's role as a co-factor in plant growth enzymatic reactions, activation of chlorophyll formation, photosynthetic enzymes and improved plant growth (Movahhedy-Dehnavy *et al.*, 2009).

At the same time the interaction of (50% Min-N+50%Org-N+Bio-N) and ZnO-NPs foliar application was significant. It gave the highest values of 100-grain weight on maize plants (40.63 g.).

- Ear weight and Grains weight /ear^{-1}

The present study found that ear weight and grains weight of maize is significantly affected by different nitrogen treatments (Table 6). Maximum ear weight was induced by M3 (50% Min-N +50% Org-N + Bio-N) (244.35 g.), followed by M1 (100% Min-N) (237.35 g.) followed by M2 (50% Min-N +50% Org-N) (215.52 g.). At the same time the highest values of grain weight ear-^{1} (198.00 and 190.32 g.) were recorded in M3 treatment followed by M1, respectively. These results may be due to a slow and steady supply of organic and bio-N, which met the N requirements of plants. Increasing ear weight and ear grain weight may be due to the fact that the addition of nitrogen from different sources increased number of leaves per plant and total leaf area, consequently reflected in the enhanced growth, yield, and quality components (Mohammed *et al*., 2022).

Data of ear weight and ear grain weight showed in Table (6) elucidate that ear weight was significantly enhanced by zinc application. The highest ear weight increase was reveled in treatment Zn3 (14.54%) followed by the application of Zn as $ZnSO_4$ treatment recorded (11.57%) followed by the application of Zn as Zn-EDTA treatment recorded (6.67%) in comparison to the non-foliar treatment (Zn0). Similar results have been reported by (Drissi *et al.*, 2015).

Such an enhancement effect could be attributed to this nutrient favorable influence on biological activity and metabolism, as well as its stimulating impact on photosynthetic pigments and enzyme activity, which in turn enhance vegetative plants growth. Wears the ear grains weight (g) was affected significantly by the foliar application of zinc. The maximum value of Grains weight ear^{-1} was 207.23 g with a foliar application as Zn-nano followed by foliar application as $ZnSO_4$ followed by Zn-EDTA while control recorded the minimum value, 169.13 g (Zn0). Acording to Ashrafi *et al.*, (2013), the use of zinc nano oxide activates enzymes by fusing with the formation of chlorophyll in most plants and accelerating the formation of company growth hormone such as tryptophan.

It is obvious from the data, that plants which received (50% Min-N+50% Org-N +Bio-N) and exogenous application of Zn nano gave the highest values of ear weight (255.7 g) and ear grain weight the highest values (214.3 g).

c. Grain, Stalk and Biological Yields:

Table (7) displays data on corn grain, stalk and biological yields as influenced by various treatments under investigation. The addition of mineral, organic and bio fertilizers had a significant effects on grain, stalk and biological yields.

Application of (50% Min-N +50% Org-N + Bio-N), (100% Min-N) and (50% Min-N + 50% Org-N) are significantly augmented maize grain, stalk and biological yields. The use of organic manure conjunction with inorganic fertilizers reduces nitrogen losses, conserves soil nitrogen by forming an organic-mineral complex, and thus ensures continuous N supply to maize plants and greater yields (Batyrbek *et al.*, 2022). The grain, stalk and biological yields were significantly higher as a result of the organic and bio-fertilizer application. The promotion effect of the organic and bio-fertilizer application on root growth and increasing nutrients absorption, which reflected on maize vegetative growth, is in improving yield and its components through an increase in grain number or grain weight. Organic and bio manures have been shown to synthesis and secrete biologically active substances that promote growth Chen, (2006). Increasing the grain, stalk and biological yields due to bio-fertilizer application has been observed by Hassan, (2009). Plant growth linked to the hormones produced by these bacteria as well as root growth. These results fairly agreed with those found by Zaki *et al.*, (2008).

Results showed that grain, stalk and biological yields (ton fed^{-1}) of maize were significantly influenced by the foliar application of Zn (Table 7). The maximum value of grain yield is 4.017 ton fed^{-1}, stalk yield is 5.869 ton fed^{-1} and biological yield is 9.886 ton fed^{-1} with the foliar application as Zn-nano followed by foliar application as $ZnSO_4$ then Zn-EDTA while the minimum values were 3.619, 5.286 and 8.905 ton fed^{-1} for grain, stalk and biological yields, respectively comparing with the control (Zn0). These results are in agreement with those obtained by (Uma *et al*., 2019), they revealed that, Zn nano has a small size and large effective surface area of nano particles which could easily pass through the plant membranes leading to better uptake of Zn. Zinc acts as an enzyme stimulator in plants and is directly involved in the bio synthesis of auxin, which produces more cells and dry matter, which is then stored in seeds as sink.

Chauhan *et al.* (2014) reported that the interaction effect of nitrogen and zinc was significant for grain, stalk and biological yields, and the tabulated data showed the same result where the interaction of (50% Min-N+ 50% Org-N+ Bio-N) with nano-Zn foliar application recorded the highest values of grain, stalk and biological yields of maize.

Table (7). The impact of different nitrogen sources and exogenous zinc application and their interaction on maize yield and its components ((combined data over both seasons).

Treatments		Grain yield (ton fed^{-1})	Stalk yield (ton fed^{-1})	Biological yield (ton fed^{-1})	Protein %	Protein yield (kg fed^{-1})	Oil %	Oil yield (kg fed^{-1})	Carbo-hydrates %	TSS %
N- Sources										
M1		3.810	5.714	9.524	11.06	422.31	5.85	213.70	69.55	4.72
M2		3.567	5.431	8.998	10.57	377.92	5.00	167.50	66.20	4.13
M3		4.057	5.802	9.859	11.36	402.17	8.00	308.40	74.05	5.32
LSD at 5%		0.068	0.027	0.086	0.320	1.679	0.078	3.724	0.21	0.065
Zinc Forms										
Zn0		3.619	5.286	8.905	10.25	371.70	6.28	229.87	69.24	4.70
Zn1		3.870	5.769	9.639	11.17	433.41	7.40	289.93	70.26	4.80
Zn2		3.739	5.673	9.412	10.64	398.16	6.77	255.45	69.93	4.17
Zn3		4.017	5.869	9.886	11.93	476.92	7.46	319.66	70.42	5.14
LSD at 5%		0.045	0.054	0.079	0.514	1.950	0.026	1.503	0.17	0.073
Interaction Effects										
M1	Zn0	3.653	5.307	8.960	10.25	374.49	5.85	213.70	69.55	4.72
	Zn1	3.815	5.827	9.642	11.17	426.13	6.80	259.42	70.30	4.00
	Zn2	3.762	5.782	9.544	10.83	407.42	6.55	246.41	69.93	3.85
	Zn3	4.010	5.939	9.949	12.00	481.19	7.50	300.75	70.90	4.77
M2	Zn0	3.350	5.153	8.503	9.91	331.98	5.00	167.50	66.20	4.13
	Zn1	3.642	5.533	9.175	10.52	383.10	7.20	262.22	65.68	4.69
	Zn2	3.483	5.413	8.896	10.35	360.48	5.47	190.52	63.25	3.44
	Zn3	3.792	5.627	9.419	11.50	436.08	7.90	299.57	60.80	5.10
M3	Zn0	3.855	5.397	9.252	10.60	408.62	8.00	308.40	74.05	5.32
	Zn1	4.153	5.947	10.100	11.82	490.96	8.38	348.16	74.80	5.25
	Zn2	3.972	5.824	9.796	10.74	426.59	8.29	329.41	74.55	5.22
	Zn3	4.248	6.040	10.288	12.30	522.50	8.44	358.67	79.55	6.00
LSD at 5%		0.097	0.094	0.138	0.904	3.381	0.090	1.321	0.28	0.095

M1: 100% of the recommended mineral N, M2: 50% Min-N + 50% Org-N and M3: 50% Min-N + 50% Org-N +Bio N, Zn0: Control, Zn1: zinc sulfate, Zn2: zinc EDTA and Zn3: zinc nano.

d- Quality parameters

Judicious use of organic and bio-fertilizers may be effective not only in sustaining crop productivity, soil health and mitigating climate change but also in supplementing plant nutrients and increasing plants adaptation to temperature increase comparing with chemical fertilizers. It is obvious from the tabulated data in table (7) that the inorganic and organic applications differed significantly with regard to quality of maize grains i.e. protein & oil content, protein & oil yield, carbohydrates and TSS. The maximum values of grain protein yield (402.17 kg fed^{-1}), oil yield (308.40 kg fed^{-1}), carbohydrates content (74.05 %) and TSS (5.32 %) were obtained with addition of the combination of three N sources (50% Min- N+50% Org- N + Bio-N).

The increments in maize grain content of protein, oil, carbohydrates and TSS could be attributed mainly to nitrogen added from either inorganic or organic sources and might be due to increased availability and uptake of other nutrients (P and K) that positively affected on the vigor of vegetative growth and accumulation of photosynthesis products and their assimilation, which stimulates maize plants to produce high grain yields. Similar results were obtained by Mohammed *et al.* (2014), and Abdelzaher *et al.* (2017).

Nitrogen is the most important component of plant proteins and is required at all stages of crop development to promote the formation of amino acids Khafagy (2003). The results of this experiment demonstrated that combining inorganic and organic N increased protein content significantly. Furthermore, the non-symbiotic N_2-fixing bacteria produced adequate amounts of cytokinins and IAA by increasing the surface area per unit of root length and enhancing the root hair branching, resulting in an increase in the nutrients uptake from the soil (Hassan *et al*., 2012). A similar result was observed by El- Nagar, (2003) who discovered that nitrogen had a strong influence on protein content, also, the application of nitrogen fertilizer encourages plants to absorb large amounts of N, resulting in higher assimilation rates in the forms of amino acids, enzymes, protein and other nitrogen substances.

Results manifested that all quality parameters (protein content (%), protein yield (kg. fed^{-1}), oil content (%), oil yield (kg. fed^{-1}), carbohydrates content (%) and TSS (%)) in mature maize grains at harvesting were significantly affected by Zn as a foliar application. The maximum relative increases in the harvesting stage were (28.31, 39.06, 1.70 and 9.36 %) for protein yield, oil yield, carbohydrates and TSS, respectively recorded with the application of Zn nano. All previous quality parameters may have been improved by Zn application due to an increase in tryptophan amino acid and indole acetic acid hormone, which are two major factors that caused an increase in grain oil content (%) and oil yield (Grzebisz *et al.,* 2008). Furthermore, the aforementioned findings could be linked to the presence of zinc, which plays an important role in activating several enzymes, and hence the auxin metabolism, metabolic activities, nucleic acid, protein synthesis, carbohydrate metabolism and N and P utilization.

The effect of the interaction between N application and foliar spray of Zn further suggests that there was a significant improvement in the protein content, oil content, carbohydrate content and TSS with the maximum values observed for the treatment (50% Min- N+ 50% Org- N+ Bio-N+ Zn-nano foliar spray) witch increased plants adaption to temperatures increase. These results are in consonance with the results of Swati *et al.* (2014) who reported that the application of nitrogen and zinc induced a more nutrients available to crops result in increased growth and yield attributes of the crop which ultimately elevate the productivity of the crop.

3- Nutrients Content.

The obtained results revealed that nutrients uptake (N, P, K and Zn) of maize grains were significantly affected by applied nitrogen sources (Table, 8), with the highest nutrients uptake obtained by the application of M3 (50% Min-N +50% Org-N+ Bio-N) followed in descending order by M1 (100% Min- N fertilizer) and M2 (50% Min-N +50% Org-N). The maximum value of nutrients uptake were (80.73,16.19, 31.99 kg fed^{-1} and 145.85 mg kg^{-1} for N, P, K and Zn, respectively).

Microbial inoculants improve nutrient availability by fixing atmospheric nitrogen in the rhizosphere and making it readily available to plants and/or produce some biologically active substances, such as IAA, gibberellins and cytokinines, which help in increasing root biomass and thus indirectly help in greater absorption of nutrients from the rhizosphere (Awad, 2002). This findings was in line with Hassan *et al*. (2012) who elucidate that *Azotobacter and Azospirillum* strains produced adequate amounts of IAA and cytokinines, which increase the surface area per unit root length and are responsible for root hair branching and eventually increase nutrients uptake. The constant and optimum release of nutrients from Org-N manure supplemented with the Min-N and Bio-N may be sufficient to meet maize nutrition demand at various stages of crop growth. Furthermore, the presence of growth-stimulating substances in organic manure, such as plant growth hormones and humic acids may be a possible factor in increased nutrients uptake and their effective utilization for photosynthates production and subsequent translocation to sink.

The use of zinc fertilizers increased significantly nutrients uptake (N, P, K and Zn) of maize grains (Table, 8). The effect of the various zinc sources could be summarized as follows: ZnO-NPs > $ZnSO_4$ > Zn-EDTA. The maximum values in N, P, K and Zn uptake in maize grains were 82.46, 20.52, 31.75 kg fed^{-1} and 144.73 mg kg^{-1} respectively with Zn3 (Zn-nano), while, the minimum values were 64.64, 13.61, 23.55 kg fed^{-1} and 115.83 mg kg^{-1} with Zn0 (control). These findings are in concurrence of those detailed by Belay *et al.* (2002). In general, nano-fertilizers are effective fertilizers for meeting plant nutrient requirements (Abdalla *et al.*, 2018).

The interaction of (50% Min-N+50%Org-N+Bio-N) with nano-Zn foliar application was significant, and it recorded the highest values of N, P, K and Zn uptake of maize plants.

Table (8). The impact of different nitrogen sources and exogenous zinc application and their interaction on nutrients uptake and available nutrients in the soil after harvesting stage ((combined data over both seasons).

Treatments		Macro and micro nutrients-uptake in grains				Available nutrient ($mg\ kg^{-1}$)		
		N-uptake	P-uptake	K-uptake	Zn-uptake ($mg\ kg^{-1}$)	N	P	K
		($kg\ fed^{-1}$)						
N- Sources								
M1		73.44	14.25	27.36	125.91	41.15	7.44	217.02
M2		65.72	10.39	24.12	116.98	46.90	7.83	226.90
M3		80.73	16.19	31.99	145.85	51.15	8.33	239.44
LSD at 5%		0.292	0.143	0.165	1.96	0.81	0.032	2.43
Zinc Forms								
Zn0		64.64	13.61	23.55	115.83	48.05	8.09	233.27
Zn1		75.37	18.73	29.71	131.73	45.82	7.78	225.81
Zn2		69.24	15.82	26.29	126.03	46.68	7.95	229.04
Zn3		82.46	20.52	31.75	144.73	45.04	7.66	223.05
LSD at 5%		0.339	0.109	0.175	0.802	0.55	0.052	1.55
Interaction Effects								
M1	Zn0	65.13	14.25	22.53	114.14	43.06	7.57	220.83
	Zn1	74.11	18.31	30.14	125.81	40.39	7.40	216.08
	Zn2	70.85	16.55	24.83	122.44	41.02	7.56	218.23
	Zn3	83.68	19.92	31.95	140.47	40.07	7.25	212.96
M2	Zn0	57.73	10.39	20.88	102.75	48.20	8.00	230.78
	Zn1	66.63	14.20	25.37	118.78	46.51	7.78	225.47
	Zn2	62.69	11.84	23.34	110.00	47.28	7.87	228.40
	Zn3	75.84	17.44	26.92	135.61	45.64	7.67	222.97
M3	Zn0	71.06	16.19	27.24	130.02	52.90	8.70	248.19
	Zn1	85.38	23.67	33.64	150.01	50.58	8.17	235.88
	Zn2	74.19	19.07	30.72	143.07	51.75	8.41	240.49
	Zn3	90.86	24.21	36.39	157.73	49.40	8.07	233.22
LSD at 5%		0.588	0.179	0.289	2.39	1.06	0.090	3.95

M1: 100% of the recommended mineral N, M2: 50% Min-N + 50% Org-N and M3: 50% Min-N + 50% Org-N +Bio N, Zn0: Control, Zn1: zinc sulfate, Zn2: zinc EDTA and Zn3: zinc nano.

4- Nutrients Status in the Soil after harvest.

As shown in Table (8) the highest values of available N, P and K (mg kg^{-1}) at the harvest stage in the soil were recorded with (50% Min-N+ 50% Org-N+ Bio-N) compared to the other treatments. These results are confirmed by Berger *et al.* (2013) who stated that bio-fertilizers may be an alternative for N, P and K fertilization that release the nutrients slowly, favoring long-term soil fertility.

On the other hand, the inorganic and organic fertilizers application increased the available N content of soils. A higher amount of available N was recorded in (50% Min-N +50% Org-N + Bio-N) (51.15 mg kg^{-1}). The increases in available N content with the incorporation of organic may be attributed to N mineralization from organic manure.

Also, the addition of organic and bio-fertilizers had a positive effect on the available Phosphorus in the soil. The maximum available phosphorus (8.33 mg kg^{-1}) was observed in treatment M3 (50% Min-N +50% Org-N + Bio-N) which was more than the rest of the treatments. The increased microbial activity caused by the combined application of organic manure increased P cycling through microbiological processes, thus decreasing P fixation and increasing its availability to plant over time (Ayaga *et al.,* 2006).

The addition of organic manure has a positive effect on the available potassium in the soil. The available potassium content of soil increased with organic and inorganic fertilizers as compared to its initial status of 206.5 mg kg^{-1}. A higher amount of available potassium in soil was recorded with (50% Min-N +50% Org-N+ Bio-N) followed by (50% Min-N +50% Org-N) then (100%Min-N) respectively, as shown in Table (8). This could be attributed to an increase in potassium release from organic compounds and minerals present in soil via decomposition as well as solubilization by soil microorganisms thus facilitating the release of organically bound potassium.

The findings are also in conformity with the works of Tolanur and Badanur, (2003) who discovered positive changes in the available nutrient status of the soil after adding organic fertilizers manures. That act as a soil amendment, improving water retention capacity and increasing macro and microelements availability in the soil rhizosphere around roots system which in turns stimulated plant growth.

Concerning the application of Zn-fertilizer, it could be observed from the Table (8) that ZnO-NPs gave the lowest values of available N, P and K (45.04, 7.66 and 223.05, respectively) in the soil, while the highest values were associated with Zn0 (48.05, 8.09 and 233.27 respectively). These results may be due to the positive effect of Zn fertilizer on improvement of plant growth and its nutrients uptake which decrease the available N, P and K from the soil. These results are in harmony with those obtained by Barman *et al.,* (2018). The interaction of (50% Min-N+ 50% Org-N+ Bio-N) with non-foliar application with Zn (Zn0) gave the highest values of available N, P and K (52.90, 8.70 and 248.19 respectively) in the soil compared with the other interaction treatment applications.

CONCLUSION

The experiment has shown that combining of inorganic, organic and bio-fertilizers had a positive effect and significantly produced the highest grain and biological yields of maize. Organic and bio-fertilizer supply the plants with nutrient, raise soil quality, crop growth and increase plants adoption to increase the temperature as climate change indicator.

Furthermore, biological fertilization with N_2-fixing bacteria has a huge influence in increasing crop production while decreasing rates of mineral fertilization. It could be said that there is a chance to introduce adapted environmentally friendly management of fertilization using microbial inoculations (*Azotobacter and Azospirillium*) combined with organic manure for reducing the amount of mineral fertilization and improving yielding applets and quality of maize grains. Whereas the microbial inoculations occurred a beneficial effect on nitrogen fixation, mobilizing phosphate, potassium and micronutrients in soil.

It can also produce a plant growth-regulator that led to improving maize yield and adaptation to climate change. Foliar-spraying of Zn in the forms of sulfate, chelate, and ZnO-NPs to maize plants was effective in enhancing yield as well as improving traits and quality of the crop and biological yields as well as their nutrient contents, quality and mitigating the effect of increase temperature.

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تعزيز تكيف الذرة للتغيرات المناخية باستخدام مصادر مختلفة من النيتروجين و الزنك وتأثيرهم علي النمو و المحصول وجودته تحت ظروف دلتا النيل

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الملخص العربي

يمكن أن تؤدي التقلبات الكبيرة في الطقس في ظل أزمة تغير المناخ في مصر إلي تغيرات عكسية في البيئة ونتيجة لهذه التغيرات، فإن انتاج المحاصيل الزراعية الغير معتادة علي مثل هذا المناخ اخذ في التدهور. وقد لوحظ ارتفاع كبير في الحرارة علي مدار الثلاثين عاما السابقة فقد زادت متوسطات درجات الحرارة السنوية بمعدل ٠,٥٣ درجة مئوية لكل عشر سنوات. لذلك أجريت دراسة حقلية خلال موسمي الصيف لعامي ٢٠٢١ و ٢٠٢٢ داخل دلتا النيل في مصر بالمزرعة التجريبية بمحطة البحوث الزراعية بتاج العز التابعة لمركز البحوث الزراعية بمحافظة الدقهلية-(الواقعة على خط عرض ٣٠ درجة ٥٩ شمالاً وخط طول ٣١ درجة و ٥٨ شرقاً) لدراسة تأثير تطبيق ثلاثة مصادر مختلفة من الاسمدة النيتروجينية (معدنية و عضوية وحيوية) والزنك علي المحصول و مكوناته لنباتات الذرة صنف هجين فردي ابيض جيزة ١٢٨. تضمنت كل تجربة اثني عشر معاملة حيث كانت عبارة عن توليفات من ثلاثة معاملات لمصادر مختلفة من النيتروجين (١٠٠٪ من الموصي به من وحدات النيتروجين في صورة معدنية، 50٪ نيتروجين في صورة معدنية+ 50% نيتروجين في صورة عضوية و 50٪ نيتروجين في صورة معدنية+ 50 ٪ نيتروجين في صورة عضوية + نيتروجين حيوي)، و أربع مصادر من الزنك (بدون رش، كبريتات الزنك، الزنك المخلبي والزنك نانو). وكان تصميم التجربة في نظام القطع المنشقة مرة واحدة بتصميم عشوائي داخل المعاملات في ثلاث مكررات. تشمل المعاملات الرئيسية المصادر المختلفة لأسمدة النيتروجين في حين أن المعاملات المنشقة تضمنت مصادر الزنك كرش ورقي. أظهرت النتائج أن:

- إضافة النيتروجين المعدني مع السماد العضوي والحيوي أدى إلى زيادة معنوية في المحصول ومكوناته.
- أدى استخدام ٥٠٪ نيتروجين معدني +50٪ نيتروجين عضوي + النيتروجين الحيوي إلى زيادة طول الكوز، وزن الحبوب للكوز، محصول الحبوب والمحصول البيولوجي للذرة.
- أظهرت النتائج أن الرش الورقي بالزنك أدى إلى تحسين محصول الذرة ومكونات وزيادة في طول الكوز، وزن ١٠٠ حبة، وزن الحبوب للكوز، محصول الحبوب والمحصول البيولوجي مقارنة مع الكنترول. وكانت أفضل النتائج من معاملة الزنك النانو.
- يمكن استنتاج أن تسميد نباتات الذرة بنسبة ٥٠٪ نيتروجين معدني + ٥٠٪ نيتروجين عضوي + النيتروجين الحيوي مع رش النباتات بالنانو زنك كان له تأثير معنوي على محصول ومكونات نبات الذرة.