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Research article

Increasing Zn ratio in a compound foliar NPK fertilizer in relation to growth, yield and quality of corn plant

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Abstract

Corn plants are high nutrient demanding crop but sensitive to zinc (Zn) deficiency in soil. Application of Zn fertilizers could be a viable option to fulfill the crop demand for Zn and also to increase its content in grains. The objective of this study was to study the effect of foliar zinc applications on growth, mineral content and yield of corn plants under field conditions in 2013as well as its quality. Actual yields of maize harvested by farmers are at level much below attainable yield potential of currently cultivated varieties. Among many growth factors zinc was recognized as one of the limiting factors of corn growth and yielding. Corn plants cultivar Giza10 were sprayed with zinc solution at three concentrations (0.0, 1.0, 1.5 and 2 % Zn solution) or foliar application (0.0, 1.0, 1.5 and 2 % Zn) alone or in combination with NPK fertilizer. Results showed that maize with combined application of Zn (1.5%) and NPK fertilizer significantly improved plant height, 1000-grain weight, yield, grain yield and harvest index as compared to the treatment fertilized only with NPK. Zinc increased N, P and K uptake and grain yield of maize plants. Foliar-applied Zn compounds are effective for increasing Zn, Cu and Fe uptake in corn. The optimal rate of zinc foliar spray for achieving significant grain yield response ranged from 1.0 to 1.5 kg Zn/ha as compared to the treatment fertilized only with NPK. Zinc treatment increased N, P and K uptake and grain yield.

Key words: zinc foliar application; NPK foliar application; grain yield; NPK uptake; yield components.

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1. Introduction

Maize (Zea mays L.) ranks the third largest cereal crop after wheat and rice. Its grain is a rich source of many important nutrients which used for multipurpose. Yield of maize crop is alarmingly affected due to deficiency of plant nutrients. The application of essential plant nutrients in optimum quantity and right proportion is a key to enhance and sustain crop productivity [1]. Overall crop nutrition plays a vital role in plant development and it is generally comprised of macronutrients and micronutrients with major role of macro ones, but the micronutrients (Zn, B, Co, Mn, Mo, Cu, Ni and Fe), even being required in smaller amounts are of equally vital for plant growth and development [3]. It is also due to the fact that micronutrients not only enhance the grain yields but contribute to improvement of the quality in terms of grain nutrients [7]. It was further elucidated that micronutrients can increase grain yield up to 50%, as well as increase macronutrients use efficiency [10]. Therefore, we can pursue the role of micronutrients in balanced combinations for getting optimal production. Especially the uses of specific mineral nutrients have become crucial for better plant growth which can be supplemented as a chemical fertilizer in various cropping zones [11].

Zinc (Zn) is an essential micronutrient, involved in production of auxin, a natural plant growth hormone, and many other important plant functions. Zinc deficiency results in poor root development, stunted growth and small leaves internodes. In corn, zinc deficiency depicts as a white or yellow band parallel to the midrib. The most severe symptoms occur on the youngest leaves. Silking and tasseling are delayed and the kernels may be chalky. Zn deficiency symptoms in corn are easy to identify and least confused with other deficiency symptoms [34].

Among the micronutrients, zinc is an essential nutrient for the standard and healthy growth and development of plants. Generally, zinc affects the synthesis of protein in plants hence is considered to be the most critical micronutrient [12]. Zn is also crucial in taking part in plant development due to its catalytic action in metabolism for all crops especially maize [13].

In addition, Zn is used by the plant in many of its vital processes such as synthesis of protein, structure and functions of membrane, expression of genes and oxidative stress tolerance [14]. Similarly, application of $ZnSO4$ significantly increased the maize yield [15]. Therefore, the deficiency of Zn in soil causes deficiency in crops and altogether this has become a problem all over the world with acute zinc deficiency ranges in arid to semi-arid regions of the world [17]. So, Zinc deficiency is a common phenomenon of crops especially in predominantly high pH soils having low zinc. Moreover, the proper method of nutrient application can be another approach for better uptake and utilization of Zn. Amongst different methods, the foliar spray of micronutrients is an efficient one for enhancement of crop productivity [21]. This method of nutrient application is easy and simple in improving plant nutritional conditions of maize [25][27]. Reasons for effectiveness of foliar spray are simple due to its direct application to the leaves [28].

Based on particular studies, soil and foliar applications of zinc enhance the yield of crops [30]. Whereas increased Zn uptake and accumulation in crop grain have been found with both of the soil and foliar application [33].

Researches has recently shown that zinc is one of the most commonly deficient micronutrients in corn. Zinc plays a critical role because it is needed to produce chlorophyll and is necessary for cell elongation. The synthesis of growth hormones and certain cell proteins also relies on sufficient zinc levels. Little research has been conducted relating foliar application of zinc to increased corn yield. Zinc is one of the most important micronutrients in the production of many crop plants such as rice, maize and wheat or soybean, which all are worldwide cultivated. It has been well recognized by scientists that Zinc affects many processes governing plant life cycles. Some metabolic processes such as enzymatic activity, auxin synthesis, carbohydrate

metabolism, protein synthesis are of crucial important for plant growth and in turn for efficient control of nitrogen metabolism. There are also many physiological processes such as pathogen pressure, drought or heat, effectively controlled by Zinc activity and in turn resulting in higher resistance by cultivating plants to abiotic and biotic stresses [41].
Maize is a high nutrient demanding crop, which also requires micronutrients (in particular the Zn) [43] along with major elements for better growth and yield [54]. Zinc deficiency is frequently equal in plants and humans.
The major reason for the incidence of Zn deficiency in human beings in the developing countries is the use of cereal based foods in its place of animal-based diets. To reduce Zn deficiency among the poor people of the developing countries, exercise of Zn enriched food resources is a precondition. Zinc supplementation in addition to food enrichment is expensive approach and merely restricted to certain parts of the globe [20].
Foliar nutrient sprays may be an effective way to correct micronutrient deficiencies, which sometimes results in higher yields and crop quality [5] [44]. Advantages of a foliar application compared to a soil application included rapid plant response, increased convenience and effective placement [46].
It is evident from previous studies that Zn application not only increased the yield but also improved the Zn content in maize crop. Nonetheless, to best of our knowledge, limited information is available on combined use of Zn application concentration on maize plants. This study was, therefore, conducted to evaluate the most effective level of Zn application for crop growth and yield of maize.

2. Material and Methods

This study was conducted under field conditions at the district, Sharkia Governorate, Egypt 2013 to study the efficiency of foliar fertilization by contain zinc beside NPK fertilizers were used for foliar fertilization. The seeds were obtained from Agricultural Research Center. Some physical – chemical characteristics of the studied soil are presented in Table 1.

Table 1. Physical and chemical properties of the studied soil

Soil characteristics	Soil content
Mechanical analysis:	
Fine sand%	24.66
Coarse sand%	9.92
Silt%	12.80
Clay%	52.62
Textural	Clayey
Chemical analysis:	
Organic matter%	1.88
pH *	8.01
EC (dS m^{-1})**	0.15
$CaCO_3$ g kg^{-1}	0.22
Soluble ions ($mmol^{-1}$)	
Ca^{++}	0.46
Mg^{++}	0.28
Na^{+}	0.84
K^{+}	0.08
CO^{-}_3	-
HCO^{--}_3	0.56
Cl^{-}	0.40
SO^{--}_4	0.70
Available-N (g kg^{-1})	3.61
Available-P (g kg^{-1})	1.62
Available-K (g kg^{-1})	0.81

*Soil-water suspension 1:2.5 ** Soil water extract 1:5

Samples of the commonly used commercial fertilizers were obtained from soluble fertilizers contain (19 - 19 - 19) beside micronutrients were used for foliar fertilization (500 ppm Fe, 300 ppm Zn and 300 ppm Mn). Corn seeds were sown on the 15th of June, 2013. The recommended dose of corn plants (130 N + 60 P_2O_5 + 60 K_2O) done following the guidelines given by Ministry of Agriculture. Treatments were arranged in a complete randomized block design with three replicates. Four rates of zinc: 0.0; 1.0; 1.5; 2.0 kg Zn /fed were used foliar spray of zinc prepared according to Zn rates of ZnSO4 was applied on maize foliage at 5th leaf stage. Treatments were as follows:

1- Foliar NPK with rate of Zinc 0.0%.
2- Foliar NPK with rate of Zinc 1.0%.
3- Foliar NPK with rate of Zinc 1.5%.
4- Foliar NPK with rate of Zinc 2.0%.

After 45 and 90 days from planting, three plants were randomly chosen from each plot and taken for determinations:-

Leaf area (cm^2), Fresh and dry weight of leaves (g $plot^{-1}$), Plant height (cm plant-1). Also, samples of corn plants were collected after 120 days from planting and the following parameters were recorded:

Grain yield (ton fed-1), Weight of 100 grains (g), Number of rows in ear, Ear length (cm).

A random sample of 6 plants from each treatment (two plants from each replicate at each sampling date) was chosen after 45 and 90 days from planting. The samples were directly transferred to the laboratory, cleaned with tap water to get them free from any adherent dust or clay, then at harvest, the vegetative samples were separated into two parts ; leaves and grains, where nutrients concentrations were determined and recorded : Total nitrogen (%), Total phosphorus (%), Total potassium (%), Micronutrients (Fe, Zn and Mn).

Methods of analysis

Soil and plant samples were carried out to the laboratory in the National Research Center, oven dried, fine grounded, wet digested and prepared for chemical analysis.

Mechanical analysis of the experimental soil was determined according to the international Pipette method and calcium carbonate content of the soil was determined volumetrically using Calcimeter as described by Black et al[8].

Soil pH was measured using a glass-electrode pH meter with a combined glass/ reference at soil: water 1:2.5. [18].

The electrical conductivity (EC) of soil water extract was determined by using the bridge, [32].

Calcium carbonate content of the soil was determined volumetrically using Collins calcimeter as described by Piper et al [48].

Organic matter was determined by Walkley and Black's method as described by Jackson et al [32].

Carbonate and bicarbonate ions, were determined by titration with a standard solution of sulfuric acid using phenolphthalein as an indicator for CO_3^- and methyl-orange for HCO_3^- as described by Jackson et al [32].

Chloride ions were determined by titration with silver nitrate using potassium chromate as an indicator according to Mohr, s method [32].

Sulfates ions were determined by difference between total cations and total anions.

Extraction of exchangeable calcium and magnesium was done, and two cations were determined by titration with versinate along with extract of exchangeable sodium and potassium using 1 M ammonium acetate solution and two cations was determined flame photo metrically [48].

For determination of Nitrogen using Micro Kjeldahl method, 1 g of plant sample taken in a Pyrex digestion tube and 30 mL of conc. H2SO4 carefully added, then 10 g potassium sulphate mixture is placed on sand both on a low flame just to boil the solution, it was further heated till the solution becomes colorless and clear, allowed to cool, diluted with distilled water and transferred 800 mL Kjeldahl flask, washing the digestion flask, next 25 mL of 0.1 N sulphuric acids was taken in the receiving flask and distilled; it was tested for completion of reaction. The flask was removed and titrated against 0.1 N caustic soda solution using Methyl Red indicator for determination of nitrogen described by method Jackson et al [32].

For determination of phosphorous 2 g sample of plant material taken in 100 ml conical flask two spoons of Darco-G-60 is added followed by 50 mL of 0.5 M NaHCo3 solution, next flask was corked, and allowed for shaking for 30 min on shaker. the content was filtered and filtrate was collected in flask from which 5 ml filtrate was taken in 25 mL volumetric flask to this 2 drops of 2, 4- paranitrophenol and 5 N H_2SO_4 drop by drop was added with intermittent shaking till yellow color disappear, content was diluted about 20 mL with distilled water and then 4 mL ascorbic acid was added then the mixture was shacked well and the intensity of blue color at 660 nm on colorimeter was measured according to [58].

For determination of K through flame photometry, standard solution of each mineral was prepared and calibration curve drawn for K element using flame photometry as described by Jackson et al [32].

The data obtained was subjected to analysis variance procedure using SAS [51]. Duncan's Multiple Range Test was adopted for the means comparison among treatments showing significant difference. Effect of N and P fertilizer was partitioned into linear and quadratic components and regressions were calculated for effects significant at 0.05 level of probability.

3. Results and Discussion

Vegetative growth

Data in Table 2 reveal that there are significant differences among average leaf area, plant height and fresh and dry weight as affected by foliar Zn application at 45, 90 days after planting (DAP) and at harvest, respectively. As shown in the same Table, Plant height was significantly improved by Zn application and maximum plant height was recorded with combined application of Zn as (2%) and foliar spray NPK .at 45, 90 days after planting. The lowest plant height was achieved in Zn as (0.0). Highest plant height is a good agronomical management to achieve more biomass in forage crops [50]. This increase may be due to zinc affects the synthesis of protein in plants hence is considered to be the most critical micronutrient [12]. Zn is also crucial in taking part in plant development due to its catalytic action in metabolism for all crops especially maize [13]. Zn is used by the plant in many of its vital processes such as synthesis of protein, structure and functions of membrane, expression of genes and oxidative stress tolerance [14].

There were no significant differences in leaf area between foliar application treatments at 45 days after planting, but the differences were significant at 90 days age. The highest leaf area was related to combined application of Zn as (2%) and foliar spray NPK. Foliar application of Zn significantly improved leaf area of maize [38]. This results may be due to Zn extracts a great influence on basic plant life processes, such as nitrogen metabolism, uptake of nitrogen and protein quality, photosynthesis-chlorophyll synthesis, carbon anhydrase activity, resistance to abiotic and biotic stresses protection against oxidative damage [3][12][45][56].

Zinc also plays an important role in the production of biomass [35][12]. Similar results regarding plant height due to Zn solution were reported by Badshah et al [6] who showed significant increase in leaf area with the foliar application of Zn. As shown in the same Table, the highest mean value of fresh and dry weight were obtained from foliar application NPK+ Zn (2%). On the other hand, the lowest mean value of fresh and dry weight were occurred with foliar application NPK+ Zn (2%). while, the lowest mean value of fresh and dry weight were obtained from NPK application without Zn application. The increase in fresh and dry weight could be interpreted on the basis of the role N and K in improving plant metabolism, enhancing plant merstimatic activity and increasing photosynthesis rate as indicated by Alloway [3].

Fresh and dry weight were significantly improved by Zn application at 45, 90 days after planting and at harvest. Increase in fresh and dry weight with combined application of NPK and Zn as foliar spray might have been the result of increase in the availability of Zn due to direct absorption of the Zn by the foliar spray. Increase in fresh and dry weight by Zn application might be due to increase in tryptophan amino acid and indole acetic acid hormone which are two main factors in fresh and dry weight expansion [50].

Safyan et al reported increased in fresh and dry weight of maize crop with foliar applied Zn. Similarly, Ghaffari et al and Sajedi et al reported increase in the fresh and dry weight of maize due to foliar application against the control due to improved plant growth. It is, therefore, important to include zinc in the commonly applied NPK fertilizers in order to ensure that maize will not have zinc deficiency stress. It is also important to monitor and measure regularly the nutritional status of plants and soils with zinc. It was noticed that there were no significant differences in fresh and dry weight at all plant stages as a result of increasing Zn concentrations in the foliar spray.

Table 2. Effect of foliar Zn application combined with NPK on leaf area, Plant height, Fresh weight and dry weight

Treatments	**Leaf area (cm^2)**		**Plant height (cm)**		**Fresh weight(g)**			**Dry weight(g)**		
	45 days	**90 days**	**45 days**	**90 days**	**45 days**	**90 days**	**Harvest**	**45 days**	**90 days**	**Harvest**
Mean values as affected by application fertilizer										
Foliar Zn + NPK	617.03	635.03	237.19	259.81	159.77	224.91	259.43	83.85	161.41	153.20
Foliar NPK	511.536	521.28	219.52	242.47	146.52	219.45	253.84	78.15	112.20	133.48
F test	**	*	--	*	*	--	*	--	*	*
Mean values as affected by Foliar Zn application ratios										
Zn 0.0%	560.23	584.64	217.36	247.83	153.13	204.66	256.75	74.69	103.25	146.99
Zn 1.0%	612.18	628.17	225.17	246.16	156.45	213.11	256.94	80.17	108.87	153.56
Zn 1.5%	636.27	646.03	240.67	257.23	161.28	234.55	260.42	88.36	124.95	156.57
Zn 2.0%	659.45	681.28	265.54	288.00	168.22	247.36	263.61	92.17	128.55	158.55
LSD at 0.05	24.23	27.07	--	5.56	6.93	5.21	3.15	3.81	3.66	1.98

Generally, foliar NPK applications with 2% Zn are more effective in increasing vegetative growth than the foliar NPK application only. However, foliar application of zinc fertilizer could be very helpful in improving vegetative growth and thus contributing to human nutrition. Heavy and continuous consumption of maize-based diets is generally associated with zinc deficiency in human populations.

Therefore, soil and/or foliar applications of zinc fertilizers should be considered not only for increasing vegetative growth but also for improving nutritional value of grain for human populations. [52].

Yield and its components

The recorded results in Table 3 indicate clearly that there are significant differences between the averages of ear weight, ear length, ear yield and weight of straw at harvest stage under experimental conditions straw as affected by foliar Zn application.

The maximum value of ear weight, ear length, ear yield and weight of straw were produced from foliar NPK application with 2% Zn during the growing season. While, the minimum mean value of aforementioned attribute were occurred with NPK application without Zn application. It is due to the fact that micronutrients not only enhance the grain yields but also improve of the quality in terms of grain nutrients as [7]. It was further elucidated that micronutrients can increase grain yield up to 50%, as well as increase macronutrients use efficiency [10].

These results may be due to Zn extracts has a great influence on basic plant life processes, such as nitrogen metabolism, uptake of nitrogen and protein quality, photosynthesis-chlorophyll synthesis, carbon anhydrase activity, resistance to abiotic and biotic stresses protection against oxidative damage [3][12][45][56]. Zinc also plays an important role in the production of biomass [35][12].

These results are in harmony with those obtained yield by Chaab et al [15] who reported obtained that the application of ZnSO4 significantly increased the maize yield. The increase of total nitrogen uptake induced by zinc application corroborates the thesis of its primary effect on main physiological processes, related to nutrients uptake [3].

In comparison to the NPK control treatment, plants sprayed with 2.0 % Zn significantly increased the yield and its components. This primary component of yield structure showed a significant dependence on total nitrogen uptake by maize canopy and on its accumulation in grain yield. The analysis of this yield parameter corroborated a high sensitivity of maize to foliar zinc spray, as indicated by the increase in grain yield up to Zn rate of 2.0%. This yield structure component showed a slightly higher response to total nitrogen. Results are in close agreement with those reported by Fecenko J et al and Wrońska M et al [19][59].

Maximum grain yield was obtained with NPK+ foliar spray of Zn with 2.0%. Furthermore, the study demonstrated that grain yield in different Zn treatments and NPK individually, were also found significant. Grain yield is an ultimate end product of many yield contributing components, physiological and morphological processes taking place in plants during growth and development. Maximum grain yield can be attributed to the maximum number of grain rows per cob, number of grains per cob and grain weight per cob. Zinc is an important micronutrient needed by the maize plant and its deficiency especially during the grain filling stage reduces the grain yield and efficiency of plants [54].

The results are also in agreement with the earlier findings that foliar application of Zn significantly increased the grain yield of maize. These results are also in accordance with a study which exhibited that foliar application of Zn is better to increase the grain yield of maize [27].

Therefore, the deficiency of Zn in soil causes deficiency in crops and altogether this has become a problem all over the world with acute zinc deficiency ranges in arid to semi-arid regions of the world [17]. So, Zinc deficiency is a common phenomenon of crops especially in predominantly high pH soils having low zinc. Moreover, the proper method of nutrient application can be another approach for better uptake and utilization of Zn. Amongst different methods, the foliar spray of micronutrients is an efficient one for enhancement of crop productivity [21].

It was noticed that the best results of ear weight, 100 grains weight, ear length, number of rows, ear yield and weight of straw observed with foliar NPK application with 2.0% Zn. These results are in conformity with those obtained by Ibrahim [31] who found the foliar NPK application with micronutrients could be considered as the best way to reduce the salt accumulation and maintain necessary fertility levels in plant root zone and consequently improve plant growth particularly under saline conditions.

Table 3. Effect of foliar Zn application combined with NPK on ear weight, weight of 100 grain, number of rows, ear length, ear yield and weight of straw at harvest.

Treatments	Ear weight (g)	Weight of 100 grain(g)	Number of rows	Ear length (cm)	Ear yield (ton fed^{-1})	Weight of straw ton fed^{-1}
Mean values as affected by application fertilizer						
Foliar Zn + NPK	351.36	13.71	13.38	18.71	3.18	5.40
Foliar NPK	341.65	13.51	13.25	17.84	3.37	5.14
F test	**	--	--	**	*	*
Mean values as affected by foliar Zn fertilizer ratios						
Zn 0.0%	333.12	13.08	12.47	16.58	2.07	4.17
Zn 1.0%	352.17	13.56	13.36	18.24	3.58	5.23
Zn 1.5%	357.03	13.83	13.67	18.91	3.64	5.97
Zn 2.0%	363.13	14.35	14.00	21.10	3.68	6.21
LSD at 0.05	2.22	0.53	0.34	2.14	0.24	0.11

Chemical composition

Nitrogen

Data presented in the Table 4 reveal that the effect of foliar NPK fertilizer with Zn on nitrogen concentration and its uptake. The results of Table 4 show that there are significant differences between N concentration and its uptake at 45 and 90 DAP. The highest mean value of N concentration and its uptake observed with foliar NPK application with Zn at 45 and 90 DAP and at harvest, respectively.

Meanwhile, the lowest mean value of N concentration and its uptake occurred with foliar NPK application alone at 45, 90 DAP and harvest.

Nitrogen, being one of the major plant nutrients, is often supplied to obtain optimum crop production. N availability is limited in the soil compared with other plant nutrients because its various forms can be leached, volatilized, denitrified, or fixed in the organic fraction of the soil [47]. These conclusions were confirmed with those obtained by Gooding et al [24] reported that the foliar application of NPK reduced nitrogen losses through denitrification and leaching compared with nitrogen fertilizer applications to the soil; the ability to provide nitrogen when root activity is impaired in saline or dry conditions, and uptake late in the season to increase grain nitrogen concentration. Factors that influence the degree of foliar absorption in field conditions have not, however, been clearly defined and losses to the atmosphere and soil can occur.

Afza, R et al reveal that the foliar application of NPK significantly reduced the amount of N_2 fixed. Foliar application of Zn enhances the uptake and accumulation of nitrogen and finally increased the maize grain yield [25].

Mohammad A et al found that the foliar application of NPK with Zn resulted in increasing N concentration in leaves. Bremner et al suggested that the foliar application of NPK with micronutrients can be decreased NH_3 volatilization and NO_2- accumulation in soils.

Also, the highest mean value of N concentration and its uptake were observed with foliar NPK fertilizer combined with 2.0% Zn at 45, 90 DAP and harvest, respectively. Meanwhile, the lowest mean value of N concentration and its uptake occurred with foliar NPK fertilizer without Zn at 45, 90 DAP and at harvest.

Table 4. Effect of foliar Zn application combined with NPK on N concentration and its uptake.

Treatments	**N%**			**N uptake mg/plant**		
	45 days	**90 days**	**Harvest**	**45 days**	**90 days**	**Harvest**
Mean values as affected by application fertilizer						
Foliar Zn + NPK	1.40	1.98	1.87	1.18	2.34	2.94
Foliar NPK	1.17	1.38	1.77	0.95	1.55	2.36
F test	*	*	*	*	*	*
Mean values as affected by Foliar Zn fertilizers ratios						
Zn0.0%	0.91	1.34	0.37	0.68	1.38	0.54
Zn1.0%	1.47	2.05	2.01	1.12	2.23	3.21
Zn1.5%	1.53	2.19	2.49	1.35	2.74	3.95
Zn2.0%	1.68	2.35	2.60	1.55	3.02	4.07
LSD at 0.05	0.16	0.15	0.10	0.20	0.27	0.12

Giskin et al found that the foliar application of N, P, K, S and Zn at the four–five-leaf stages significantly increased the N and P contents of maize seedlings and resulted in an increased final grain yield. This result may be due to that application of N – fertilizer into the foliar resulted in much higher N- fertilizer uptake by plant. These increases in N uptake by plants may be expected that fertilizer- efficiency will be increased if N is applied through foliar application. Frequent N application using foliar methods improves the fertilizer use efficiency by plants more than soil application. Also, applying fertilizer through the foliar application increases the timing flexibility, so that N may be applied at times tailored of fit the plant requirements. These findings are coincided with those obtained by Rolston et al [47].

Choi et al suggest that foliar NPK fertilizer with micronutrients increased the water use efficiency which water stress resulting from increased water demand in the fertilized plots improved water use efficiency through increased stomatal control of water loss.

Phosphorous

Data in Table 5 show the effect of foliar NPK application with Zn on phosphorus concentration and its uptake. The results reveal that there are significant differences between P concentration and its uptake at 45 and 90 DAP and at harvest. The highest mean values of P concentration and its uptake were increased with foliar NPK application with Zn at 45 and 90 DAP, respectively.

Table 5: Effect of foliar Zn application combined with NPK on P concentration and its uptake

Treatments	P%			P uptake mg/plant		
	45 days	90 days	Harvest	45 days	90 days	Harvest
Mean values as affected by application fertilizer						
Foliar Zn + NPK	0.24	0.31	0.24	0.60	0.37	0.33
Foliar NPK	0.11	0.28	0.21	0.97	0.29	0.27
F test	*	*	*	*	*	*
Mean values as affected by Foliar Zn fertilizers ratios						
Zn0.0%	0.17	0.28	0.11	0.68	0.29	0.16
Zn1.0%	0.22	0.30	0.19	1.18	0.33	0.29
Zn1.5%	0.27	0.32	0.27	0.24	0.40	0.42
Zn2.0%	0.30	0.34	0.29	0.28	0.44	0.46
LSD at 0.05	0.01	0.05	0.06	0.08	0.24	0.16

Also, the mean values of P concentration and its uptake at harvest were increased with foliar NPK application with Zn. These results are in agreement with the finding of Thalooth et al [55] who found that the application foliar NPK fertilization with micronutrients increased P concentration and its uptake indicating that phosphorus was absorbed poorly by the roots, but was well absorbed by the leaves. Also, the P use efficiency as applied to the soil is very low because more than 80% of the applied P becomes immobile and unusable by the plant because of adsorption, precipitation or conversion to organic form. Also, the highest mean value of P concentration and its uptake were observed with foliar NPK fertilizer with 2.0% Zn at 45, 90 DAP and harvest, respectively. Meanwhile, the lowest mean value of P concentration and its uptake occurred with foliar NPK fertilizer without Zn at 45, 90 DAP and at harvest, respectively. These results are in harmony with those obtained by Yuncai et al [60] who reported that the application of foliar fertilization with micronutrients increased the uptake of K, Ca, Mg and P, which may be attributed to decreased transpiration. Thalooth et al found that it can be oxidation of phosphorus which can occur by microflora in the soil.

Although P is absorbed well by the foliage of many plants. According to Lovell, R. D et al [39] it is also highly toxic to the leaves of plants. It was expected that the phytotoxicity of P, the concentration of P solution for foliar application would be able to be increased to significantly supplement P to plants without causing injury to the foliage. This suggests that even if P can be used as a fertilizer, there would be a challenge to supply a significant amount of P to plants without causing leaf damage by foliar application.

Potassium

Data in Table 6 show the effect of foliar NPK application with Zn on potassium concentration and its uptake. The results show that there are significant differences between K concentration and its uptake at 45 and 90 DAP and at harvest. Also, in the same Table, the maximum mean value of K concentration were occurred with foliar NPK application with Zn at 45, 90 DAP and at harvest, respectively. Also, the maximum mean value of K uptake were observed with foliar application with Zn at 45, 90 DAP and at harvest. On the other hand, the lowest mean value of K concentration were obtained with foliar NPK application alone at 45, 90 DAP and at harvest. These results are in agreement with the results obtained by Kolota et al [37] who found that the foliar NPK application with Zn increased the K concentration and results showed that the benefits of foliar applied plant nutrients in treatments with half rates of preplant fertilization. (Kelly et al 2004) found that potassium availability in agronomic crops has recently decreased due to periodic drought conditions, soil compacting, reduced K applications, lower frequency of soil testing, and higher K fertilizer requirements because of increasing corn yield.

Table 6. Effect of foliar Zn application combined with NPK on K concentration and its uptake

Treatments	K%			K uptake mg/plant		
	45 days	90 days	Harvest	45 days	90 days	Harvest
Mean values as affected by application fertilizer						
Foliar Zn + NPK	1.24	1.99	1.90	1.01	2.36	2.95
Foliar NPK	1.17	1.38	1.77	0.97	1.55	2.83
F test	*	*	*	*	*	*
Mean values as affected by Foliar Zn fertilizers ratios						
Zn0.0%	0.56	1.22	0.39	0.42	1.26	0.57
Zn1.0%	1.23	2.14	2.11	0.99	2.33	3.24
Zn1.5%	1.53	2.19	2.51	1.35	2.74	3.93
Zn2.0%	1.64	2.41	2.57	1.51	3.10	4.07
LSD at 0.05	--	0.01	0.056	0.04	--	--

Also, the highest mean value of K concentration was observed with foliar NPK fertilizer with 2.0% Zn at 45, 90 DAP and harvest, respectively. Also, the highest mean value of K uptake were obtained with foliar NPK fertilizer combined with 2.0%Zn at 45, 90 DAP and at harvest. Meanwhile, the lowest mean value of K concentration and K uptake were occurred with foliar NPK fertilizer alone at 45, 90 DAP and harvest. These results are in harmony with those obtained by Rolston et al [47] who indicated that foliar NPK application is a convenient and efficient operate and provides a low –cost approach for correcting K deficiency by allowing low rates frequent applications, thus avoiding excess use and build up of salts while maintaining high nutrient availability.

Micronutrients

Manganese and Zinc

Data in Table 7 reveal that the effect of foliar NPK application and foliar NPK with Zn on manganese and zinc concentration. The results show that there are significant differences between Mg and Zn concentration at 45 and 90 DAP and at harvest.

It was observed that the highest mean values of Mn and Zn concentration were found with foliar NPK application with Zn at 45, 90 DAP and at harvest. Meanwhile, the lowest mean value of Mn and Zn concentration were occurred with foliar NPK application alone.

Table 7. Effect of foliar Zn application combined with NPK on Mn and Zn concentrations

Treatments	Mn %			Zn%		
	45 days	90 days	Harvest	45 days	90 days	Harvest
Mean values as affected by application fertilizer						
Foliar Zn + NPK	0.24	0.27	0.30	0.055	0.078	0.064
Foliar NPK	0.19	0.21	0.29	0.043	0.055	0.053
F test	*	*	*	*	*	*
Mean values as affected by Foliar Zn fertilizers ratios						
Zn0.0%	0.14	0.20	0.18	0.044	0.060	0.044
Zn1.0%	0.25	0.23	0.26	0.056	0.065	0.049
Zn1.5%	0.26	0.31	0.37	0.058	0.082	0.053
Zn2.0%	0.31	0.34	0.38	0.062	0.104	0.110
LSD at 0.05	0.02	0.04	0.01	0.08	0.25	0.13

These results are in harmony with those obtained by Hassan et al [26]. Also, the maximum mean value of Mn concentration was observed with foliar NPK fertilizer combined with 2.0% Zn at 45, 90 DAP and harvest. The maximum mean value of Zn concentration were obtained with foliar NPK fertilizer combined with 2.0% Zn at 45, 90 DAP and at harvest. Meanwhile, the lowest mean value of Mn concentration were obtained with foliar NPK fertilizer without Zn at 45, 90 DAP and at harvest. Also, the lowest mean value of Zn concentration were obtained with foliar NPK fertilizer without Zn at 45, 90 DAP and at harvest. These results are in harmony with those obtained by Alvaa et al [4] who detected increase availability of Mn and Zn by application foliar NPK fertilizer with micronutrients and suggested the possibility of foliar application with conducting successive application. These results are in harmony with those obtained by Hossein et al [29].

Copper and Iron:
Data in the Table 8 reveal that the effect of foliar NPK and foliar NPK fertilizer combined with Zn rates on Copper and Iron concentration. The results of Table show that there are significant differences between Cu and Fe concentration at 45 and 90 DAP and at harvest. It was observed that the highest mean values of Cu and Fe concentration were found with foliar NPK application combined with Zn at 45 and 90 DAP and at harvest. Meanwhile, the lowest mean values of Cu and Fe concentration were occurred with foliar NPK application alone at 45, 90 DAP and at harvest. These results are in harmony with those obtained by Madlain et al [40]. Also, the maximum mean values of Cu and Fe concentration were observed with foliar NPK fertilizer with 2.0% Zn at 45, 90 DAP and harvest. Meanwhile, the lowest mean value of Cu and Fe concentration were observed with foliar NPK fertilizer without Zn at 50% at 45, 90 DAP and at harvest. These results are in harmony with those obtained by Alvaa et al [4] who detected increase availability of Cu and Fe by application foliar NPK fertilizer combined with micronutrients and suggested the possibility of soil pollution with conducting successive application.

Table 8. Effect of foliar Zn application combined with NPK on Cu and Fe concentrations.

Treatments	**Cu%**			**Fe%**		
	45 days	**90 days**	**Harvest**	**45 days**	**90 days**	**Harvest**
Mean values as affected by application fertilizer						
Foliar Zn +NPK	0.054	0.061	0.034	21.28	19.52	26.39
Foliar NPK	0.034	0.052	0.026	16.27	17.23	24.83
F test	*	*	*	*	*	*
Mean values as affected by Foliar Zn fertilizers ratios						
Zn0.0%	0.042	0.041	0.031	19.54	15.85	19.42
Zn1.0%	0.054	0.062	0.032	20.18	18.57	26.15
Zn1.5%	0.056	0.067	0.034	22.21	21.16	28.62
Zn2.0%	0.064	0.072	0.038	23.18	22.50	31.37
LSD at 0.05	--	--	--	0.43	0.89	1.23

Concentration of nitrogen, phosphorus and potassium in grain
Data presented in the Table 9 reveal that the effect of foliar NPK application and foliar NPK fertilizer rates and their interaction on nitrogen, phosphorus and potassium concentration and its uptake in grain. The results of this Table, show that there are significantly differences between N, P and K concentration and its uptake in grain. The highest mean value of N concentration and its uptake observed with foliar NPK application with Zn. Nitrogen, being one of the major plant

nutrients, is often supplied to obtain optimum crop production. N availability is limited in the soil compared with other plant nutrients because its various forms can be leached, volatilized, denitrified, or fixed in the organic fraction of the soil [47]. These conclusions were confirmed with those obtained by Gooding et al [24] who reported that the foliar application of NPK combined with micronutrients reduced nitrogen losses through denitrification and leaching compared with nitrogen fertilizer applications to the soil; the ability to provide nitrogen when root activity is impaired in saline or dry conditions, and uptake late in the season to increase grain nitrogen concentration. Factors that influence the degree of foliar absorption in field conditions have not, however, been clearly defined and losses to the atmosphere and soil can occur. Afza et al [2] reveal that the foliar application of NPK significantly reduced the amount of N2 fixed. Mohammad et al [42] found that the foliar application of NPK with micronutrients resulted in increasing N concentration in leaves. Bremner et al [9] suggested that the foliar application of NPK can be decreased NH3 volatilization and NO2- accumulation in soils. Also, the highest mean value of N concentration and its uptake were observed with foliar NPK fertilizer combined with 2.0%Zn. Meanwhile, the lowest mean value of N concentration and its uptake occurred with foliar NPK fertilizer without Zn. [23] found that the foliar application of N, P, K and Zn at the four–five-leaf stages significantly increased the N and P contents of maize seedlings and resulted in an increased final grain yield. These results may be due to that application of N – fertilizer into the foliar resulted in much higher N- fertilizer uptake by plant. These increases in N uptake by plants may be expected that fertilizer- efficiency will be increased if N is applied through foliar application.

Table 9. Concentration of nitrogen, phosphorus and potassium% in grain yield

Treatments	grain			grain		
	N%	P%	K%	N uptake kg /fed	P uptake kg/fed	K uptake kg/fed
Mean values as affected by application fertilizer						
Foliar Zn + NPK	1.90	0.37	0.34	65.36	12.48	11.70
Foliar NPK	1.82	0.36	0.30	61.33	12.37	10.11
F test	--	--	--	*	--	*
Mean values as affected by Foliar Zn fertilizers ratios						
Zn0.0%	1.10	0.20	0.18	22.77	4.14	3.73
Zn1.0%	1.34	0.30	0.28	42.61	9.54	8.90
Zn1.5%	1.41	0.33	0.29	45.68	10.69	9.40
Zn2.0%	1.52	0.35	0.34	51.98	11.97	11.63
LSD at 0.05	--	--	--	0.08	0.30	0.11

Also, the maximum mean values of P and K concentration were occurred with foliar NPK application with Zn. Also, the maximum mean value of P and K uptake were observed with foliar NPK application with Zn in grain. On the other hand, the lowest mean value of P and K concentration were obtained with foliar NPK application alone. Also, the lowest mean value of P and K uptake were obtained with foliar NPK application alone. These results are in agreement with the finding of Thalooth et al [55] who found that the foliar NPK fertilization increased P concentration and its uptake indicating that phosphorus was absorbed poorly by the roots, but was well absorbed by the leaves. Also, the P use efficiency as applied to the soil is very low because more than 80% of the applied P becomes immobile and unusable by the plant because of adsorption, precipitation or conversion to organic form. Yuncai et al [60] reported that the application of foliar fertilization increased the uptake of K, Ca, Mg and P, which may be attributed to decreased transpiration. Thalooth et al [55] found that it can be referred to oxidation of phosphorus which can occur by microflora in the soil.

Although P is absorbed well by the foliage of many plants [39]. it is also highly toxic to the leaves of plants. It was expected that the phytotoxicity of P, the concentration of P solution for foliar application would be able to be increased to significantly supplement P to plants without causing injury to the foliage. This suggests that even if P can be used as a fertilizer, there would be a challenge to supply a significant amount of P to plants without causing leaf damage by foliar application

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