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MAIZE RESPONSE TO ZINC APPLICATION UNDER DEFFERENT PHOSPHORUS FERTILIZATION LEVELS, ITS NUTRIENTS UBTAKE, AND AVAILABILTY IN ALLOUVIAL SOILS

Zein, F. I.; Asmaa A. El- Basuony and H. S. Hamoud
Soil, Water, and Environment Research Institute, ARC, Egypt

ABSTRACT

Two field experiments were conducted during two successive seasons 2006 and 2007 at the experimental farm of Sakha Agric. Rec. Station, Kafer El- Sheikh Government. The aim of this study was to investigate the influence of zinc addition 0, 10, and 20 Kg/ fad. For Zn_0(S) (control), Zn_{10}(S), and Zn_{20}(S), respectively or foliar application with or without urea, 2% urea [U(F)], 500 ppm Zn [Zn (F)] and 2% urea + 500 ppm Zn [U+ Zn (F)], respectively under different levels of phosphorus fertilization 30, 45, and 60 Kg P_2O_5 for P_1, P_2, and P_3 respectively on maize yield and its chemical composition. Ratherfore soil content of P , Zn , Fe, and Mn. The experiments were conducted in split plot design where P levels were the main plot and Zn treatments as were sub plot with four replicates.

The obtained results can be summarized as follows:

- The yield and its components of maize were significantly affected by P and Zn fertilizer treatments.
- Application of P_3 increased grain yield by 12.0 and 12.5% and biomass by 17.6 and 13.8 compared to control treatment (P_1) in 2006 and 2007 seasons.
- Soil application of 10 Kg zn / fad. under P_3 level gave the highest value of grain yield in the two seasons. and of the biomass in the first season, meanwhile [U+ Zn(F)] treatment gave the highest biomass value in the second season. While, the highest value of 1000 grain weight were obtained by [Zn_0 (S)] and [U+ Zn (F)] treatments in the two seasons.
- The maximum values of P maize grain content were obtained by Zn_{20}(S) treatment under P_3 and P_2 in the two seasons respectively.
- the maximum values of P maize stem content were obtained by [Zn_{10}(S)]and [Zn (F)] treatments under P_2 in the two seasons , respectively.
- The maximum values of zn maize grain content were obtained by [U+ Zn (F)] treatment under P_2 level, while [Zn (F)] treatment gave the maximum maize stem zn content under P_3 level in the two seasons.
- The maximum values of maize grain and stem Fe content were obtained by application of [U+ Zn(F)] treatment under P_1 level in the two seasons except grain in the first season. The same treatment also gave the maximum values of Mn of maize grain and stem under P_3 level except the stem in the first season.
- Translocation coefficient (TC%) of heavy metal from stem to grain can be arranged in the following decreasing sequence Zn > Mn> Fe.
- Available P, Fe, and Mn increased by increasing P fertilizer levels from P_1 to P_3, while available Zn increased by increasing P fertilizer levels from P_1 to P_2 but at P_3 it decreased.
- [U+ Zn (F)] treatment gave the highest available P, Fe, and Mn, while the highest available Zn was obtained by [Zn_{20}(S)] treatment.

Keywords: maize (*Zea maize* L.), phosphorus fertilizer, foliar application of Zn, and urea

INTRODUCTION

Maize (*Zea mays* L.) is the most important grain crop in North Africa and produced throughout the country diverse environments. Approximately 8 million tons of grain produced in North Africa annually. The role of maize in human diets is increasing as a result of their favorable nutritional values although it may help to inhibit deficiency diseases mainly in the developing countries (Bodi, *et al.,* 2008),since there is an ever increasing need for increasing maize production in Egypt to meet the continuously increasing demands of growing population. The high yielding maize cultivars absorb large quantities of nutrients element from the soil (Laing *et al.,* 1996).thus it is important to establish the right amounts and type of fertilizers to be applied in order to create the right balance of nutrients into the soil (Murillo *et al.,* 1997). After N, phosphorus is the next most limiting nutrient in many soils (Smith, 2000). Bukvie *et al.,* (2003) concluded that phosphorus fertilization increased the total maize dry matter mass, plant height and stalk diameter. Concerning microelements, Zn is thought to be the most widespread in soil (Cakmak *et al.,* 1999).

A large number of the former investigations, Mengel and Kirkby, 1982) showed that maize is one of sensitive crops to zinc deficit. The most frequent causes affecting soil zinc availability are high soil pH values (Shuman, 1980), carbonate content (Kamparth and Foy, 1971) and organic matter, further soil texture and sorption capacity as well as the mainly studied Zn interaction with other elements such as iron, copper and manganese especially phosphorus (Marschner, 1986). Phosphorus- induced zinc insufficiency occurs due to an increased phosphorus fertilization in soils with high pH moderately supplied with zinc (Shuman, 1980). Wyszkowski *et al.,* 2006 showed that an increased zinc content of soil was accompanied by arise in the content of calcium, magnesium, potassium, phosphorus, and sodium in plants.

This investigation aimed to study the influence of different levels of P fertilization and zinc as soil or foliar application with or without urea on maize yield and its chemical composition. ratherfore soil contents of P, Zn, Fe, and Mn.

MATERIALS AND METHODS

Two field experiments were carried out at Sakha Agricultural Research Station Farm during 2006 and 2007 seasons using (*Zea mays* L Giza 352) in the same plots in a wire proof. The experiment was conducted in split plot design with four replicates. The main plots were P- treatments three levels of 30, 45, and 60 Kg P_2O_5/ fad for P_1, P_2, and P_3 as superphosphates 15% P_2O_5. The sub- plots were zinc treatments as a soil application 0, 10, and 20 Kg Zn / fad in form of $ZnSO_4$. $7H_2O$ for Zn_0 (S) (control), [Zn_{10}(S)], and [Zn_{20}(S)] respectively or as a foliar spray with or without urea *i.e.:* 2% urea[U (F)], 500 ppm Zn [Zn (F)], and 2% urea + 500 ppm Zn [U+ Zn(F)] respectively. All plots of the experiments were treated with 120 Kg N/ fad in form of urea (46% N) splitted in three doses. The first dose (15 Kg N/ fad) was broadcasted together with P fertilizer and 25 K_2O/ fad as potassium sulphate (48% K_2O) at sowing. The second and third doses of urea 52.5 Kg N/ fad were applicated after 4 and 6 weeks from planting. The grain and stem yields were determined after maturity and weighed at 15% moisture content. Grain and stem samples were taken after harvesting and dried in an oven at 70 C for 48 hours. Dry matter was digested by using a mixture of sulphuric and percloric acids (Jackson, 1967). P, Zn, Fe, and Mn were determined in digested plant materials. Representative surface soil samples (0- 15 cm) were collected from the treated plots after maize harvesting. The collected soil samples were air dried and prepared for chemical analysis. Available Zn, Fe, and Mn were extracted by using 0.005 M DTPA according to Lindsay and Norvell, 1978, then determined using the atomic absorption spectrophotometer, Berken Elmr 3300. Available phosphorus was extracted by $NaHCO_3$ according to Olsen, 1954, and then determined spectro photometrically according to Jackson, (1967). The soil characteristics of the experimental location are presented in Table (1). The data were subjected to statistical analysis according to Snedecor and Cochran, (1980)

Table (1): Some chemical and physical properties of the soil surface layer (0- 15cm) before planting

pH*	EC_e d(S)/ m	OM%	Available nutrient mg/ Kg soil						Particle size distribution %			
			N	P	K	Zn	Fe	Mn	Clay	Silt	Sand	Texture
7.55	2.50	1.95	22	5.8	395	1.04	1.56	0.65	52	23.9	24.1	clayes

*** In 1:2.5 soil: water suspension**

RESULTS AND DESCUSSION

I- Yield and some yield components:-

1- Grain yield:

Data of grain yield (Ton/ fad) of *Zea mays* in 2006 / 2007 seasons are presented in Table 2. Analysis of variance revealed that the mean values of grain yield were affected significantly by phosphorus fertilizer treatments and zinc fertilizer (soil or foliar application with or without urea)

a- Effect of P fertilizer levels:

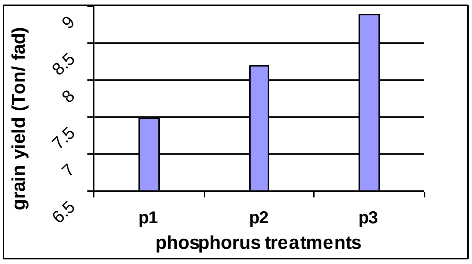
From data in the above Table and fig. 1 (whole mean of all Zn treatment) it can be seen that, maize grain yield mean values were increased by 12.0 and 12.5 % in 2006 and 2007 seasons due to the phosphorus increasing from P_1 to P_3. This could be attributed to the functions of phosphorus in plants; a part of the protein molecule, necessary for transfer of energy during metabolic processes (ATP) and improving seeding vigor. Similar results were obtained by Bukvie *et al.,*(2003).

Table 2: Phosphorus and Zinc levels effect on maize grain yield, biomass , and 1000grain weight.

Treat.	2006 season				2007 season			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
Grain yield (Ton/ fad)								
[Zn_0(S]	2.569 c	2.558 c	3.082 d	2.736	2.508 e	2.947 c	3.005 c	2.820
[Zn_{10}-(S)]	3.110 b	3.261a	4.278 a	3.549	2.980 bc	3.520 a	3.676 a	3.392
[Zn_{20}-(S)]	3.010 b	3.075 b	3.486 b	3.190	3.047 ab	3.049 bc	3.230 b	3.108
U(F)	3.042 b	3.082 b	3.174 cd	3.099	2.759 d	3.050 bc	3.231 b	3.013
Zn(F)	3.083 b	3.225 ab	3.246 cd	3.185	3.021bc	3.147 b	3.415 a	3.194
U+Zn (F)	3.326 a	3.230 ab	3.343 bc	3.299	3.180 a	3.345 a	3.435 a	3.320
Mean	3.023	3.072	3.435	3.177	2.916	3.176	3.332	3.141
Biomass (Ton/ fad)								
[Zn_0(S]	6.357 e	7.058 d	8.149 d	7.188	6.372 c	7.549 c	7.693 d	7.205
[Zn_{10}-(S)]	7.753 bc	8.993 a	10.837 a	9.194	7.967 ab	9.358 a	9.528 b	8.951
[Zn_{20}-(S)]	7.430 cd	8.346 b	8.986 c	8.254	7.545 ab	8.027 c	8.599 bc	8.057
U(F)	7.275 d	7.477 c	8.247 d	7.666	7.001 b	7.728 c	8.261 cd	7.663
Zn(F)	8.019 a	8.541 b	8.738 c	8.433	7.931 a	8.445 ab	8.222 cd	8.199
U+Zn (F)	8.341 a	8.584 b	9.891 b	8.938	8.130 a	8.699 a	9.817 a	8.882
Mean	7.529	8.166	9.141	8.279	7.491	8.301	8.687	8.159
1000 grain weight (g)								
[Zn_0(S]	316.2 a	310.1 a	319.9 a	315.4	293.1 b	295.6 a	297.7 a	295.5
[Zn_{10}-(S)]	309.0 ab	311.5 a	294.4 ab	304.9	302.4 b	293.7 a	325.2 a	307.1
[Zn_{20}-(S)]	287.4 bc	303.2 a	309.2 ab	299.9	311.4 a	300.8 a	294.1 a	302.1
U(F)	279.2 c	294.7 a	311.3 ab	295.1	276.0 b	306.9 a	310.7 a	297.9
Zn(F)	261.6 c	307.7 a	296.7 ab	288.6	283.8 b	316.8 a	321.7 a	307.4
U+Zn (F)	283.0 bc	307.5 a	288.6 b	293.0	290.0 b	313.2 a	320.3 a	307.8
Mean	289.4	305.8	303.3	299.5	292.8	304.5	311.6	303.0

***Means followed by a common letter are not significantly different at the level 5% according to DMRT**

(P_1)= 30 Kg P_2O_5 / fad. (P_2)= 45 Kg P_2O_5 / fad, (P_3)= 60 Kg P_2O_5 / fad
[Zn_0(S)]=0Kg Zn/fad, [Zn_{10}(S)] =10Kg Zn/fad, [Zn_{20}(S)]=20Kg Zn/fad as soil application
[U(f)] =2% Urea, [Zn(F)]=500ppm Zn, [U+ Zn (F)] = 2% urea+500ppm Zn as foliar application



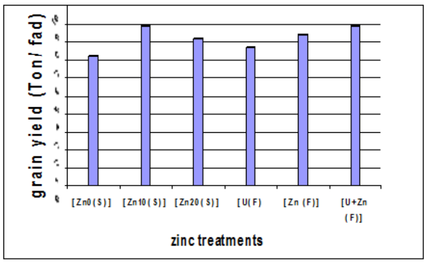


Fig 1: influence of the phosphorus (P) and (Zn) fertilization treatments on grain yield (mean of two seasons)

b. Effect of Zn fertilizer treatments:

Regarding to the effect of zinc fertilizer treatments on grain yield , data in the same Table revealed that the maize grain yield was significantly affected by different application of Zn treatments. Considering the whole mean of P_1, P_2,and P_3 , the maximum mean values of grain yield were 3.549 and 3.392 Ton/ fad in 2006 and 2007 seasons which obtained by application of [Zn_{10}- (S)] treatment followed by (3.299 and 3.320 Ton/ fad) which obtained by application of [U+ Zn (F)] treatment, in the two seasons. These results explained the effectiveness of the Zn treatment on maize plant, where it is recognized as an essential component of several enzyme systems having vital roles in the plant metabolism(Srivastava , 1996). Shaaban and Abou El-Nour, 1996 reported that wheat and corn are sensitive to micronutrient deficiency, especially manganese and zinc. Deficiency of one or more of these nutrients gave rise to nutrient unbalance within the plant organs and resulted in low yields. The effect of foliar application of Zn on grain yield was more pronounced in the presence of 2% urea. El- Kady and Zein, (1997) found that spraying with Zn and 2% urea significantly increased the stem and grain yields, they added that these increments may be due to the fact that applying nitrogen (urea) and microelements increases the indole acetic acid level, chlorophyll content, and net assimilation rate in leaves and increases the total dry matter accumulation and yield components (Hemantaranjan and Garg, 1984).

Fig. 1 showed the influence of P and Zn fertilization treatments on grain yield (mean of two seasons). Grain yield as affected by Zn treatments can be arranged in the following descending order [Zn_{10}- (S)] > [(U+ Zn (F)] > [Zn(F)] > [Zn_{20}-(S)] > [U (F)] > [Zn_0 (S)]. These results prove that the grain yield which obtained by [Zn_{10} (S)] treatment is superior to the other treatments. This finding could be explained by Prasad *et al.,* (1971) who concluded that P/ Zn in corn ear- leaf is limiting valued from 25 to 154, the consequence of such an unfavorable ratio decreased the total dry matter. Grain yield can be ordered as affected by such parameter (P/Zn in stem) as follow: [Zn_{10} (S)] (103) > [U+ Zn (F)] (95.8) > [U (F)] (85) > [Zn_{20} (S)] (77.2) > [Zn (F)] (71.5).

P X Zn interaction had highly significant effect on the maize grain yield in the two seasons.

The highest values of maize grain yield were obtained by the application of [U+ Zn (F)] under P_1 in the two seasons. At P_2 and, P_3 the highest values of maize grain yield were obtained by the application of [Zn_{10} (S)] treatment.

The maximum means of maize grain yield were 4.278 and 3.676 Ton/ fad in 2006 and 2007 seasons which obtained by application of [Zn_{10} (S)] under P_3 treatment, while the minimum means were 2.569 and 2.508 Ton/ fad which obtained by application of [Zn_0 (S)] under P_1, treatment in the two seasons.

2- Biomass:

Data in Table 2 and fig. 2 show that biomass yield of maize was significantly affected with different P fertilizer levels and Zn treatments.

a- Effect of P fertilizer levels:

The trends obtained for biomass yield as influenced by different treatments are similar to those obtained for grain yield where the biomass (whole mean of all Zn treatments) were increased by about 17.6 and 13.8% in 2006 and 2007 seasons as a result of increasing P fertilizer level from P_1 to P_3. Similar effect of phosphorus fertilization was observed by Bukvie *et al.,* (2003) They reported that phosphorus fertilization treatments increased the plant height, plant stalk diameter and total dry matter biomass.

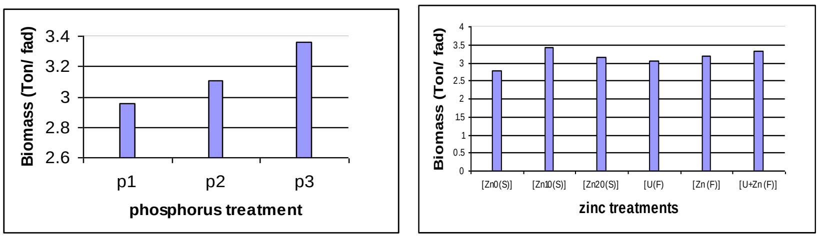


Fig 2 influence of the phosphorus (P) and (Zn) fertilization treatments on biomass (mean of two seasons).

b- Effect of Zn fertilizer treatments:

With respect to soil zinc application, the highest values (whole mean of all P treatments) of biomass yield, 9.194 and 8.951 Ton/ fad, in 2006 and 2007 seasons were obtained by application of [Zn_{10} (S)] treatment in the two seasons. By application of [Zn_{20} (S)] Zn concentration increased in the leaves, so the P/Zn ratio became lower (77.2 mean of two seasons) and biomass yield was decreased.

In regard to foliar zinc application, treatment of [U+ Zn (F)] gave the highest values of biomass yield at all phosphorus fertilizer levels in the two seasons. This could be attributed, as mentioned before, to the high P/Zn ratio (95.8) in leaves as affected by the combination of urea and zinc.

P x Zn interaction had highly significant effect on the maize biomass in 2006 season, while it had a significant effect in 2007.

The highest values of maize biomass were obtained by the application of [U+Zn (F)] treatment under P_1 level in the two seasons and under P_3 level in the second season. [Zn_{10}(S)] treatment gave the highest values of maize biomass under P_2 level in the two seasons and under P_3 level in the first season.

The maximum mean values of biomass (10.837 and 9.817 Ton/Fad in 2006 and 2007 seasons) were obtained by the application of [Zn_{10}(S)] and [U+Zn(F)] treatments under P_3 level in the two seasons respectively.

3- the 1000-grain weight:

The results in Table 2 show that the 1000 maize grain (gm) were significantly affected by different Zn treatments under the same level of P fertilizer. The highest value of 1000 grain weight (319.9 and 325.2g in 2006 and 2007 seasons were obtained by application of [Zn_0(S)] and [Zn_{10}(S)] treatments under P_3. These results were supported by the data obtained by El- Yamani, (1994) who found that a slight increase in the 1000 grain weight of wheat was obtained with zinc application. On the other hand, Zein *et al.,* (2001), found that the effect of zinc on 1000-grain of wheat was generally more pronounced in presence of urea than without it.

II- Content of P, Zn Fe and Mn in maize grain and stem:

1- Phosphorus:

Data in Table 3 showed that the content of P in maize grain and stem were significantly affected by phosphorus and zinc fertilizers

Table 3: Phosphorus and Zinc levels effect on phosphorus content (mg/ kg) of maize grain and stem.

Treatments	2006 season				2007 season			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
P mg/ Kg Grain								
[Zn_0(S]	5178 b	5883 b	4679 c	**5226.7**	4318 c	5259 bc	5215 c	**4930.7**
[Zn_{10}-(S)]	5759 a	5812 b	5921 a	**5830.7**	5541 a	5086 c	5028 c	**5218.3**
[Zn_{20}-(S)]	5921 a	5795 b	6030 a	**5915.3**	4914 b	6152 a	5740 b	**5602**
U(F)	5398 b	5445 c	4322 d	**5055**	4690 b	4695 d	5092 c	**4825.7**
Zn(F)	4523 c	6201 a	5146 b	**5290**	4422 c	5399 b	5614 b	**5145**
U+Zn (F)	5704 a	5756 b	5977 a	**5812.3**	5506 a	5449 b	6334 a	**5763**
Mean	**5413.8**	**5815.3**	**5345.8**	**5521.7**	**4898.5**	**5340**	**5503.8**	**5247.4**
P mg/ Kg Stem								
[Zn_0(S]	856 c	1276 d	1537 c	**1223**	1600b	1716 c	1862 d	**1726**
[Zn_{10}-(S)]	1319 b	2531 a	2238 a	**2029**	1575 b	1818 c	2119 b	**1837**
[Zn_{20}-(S)]	1378 b	1716 c	1675 c	**1589**	1773 a	1799 c	2036 bc	**1869**
U(F)	1196 b	1127 d	1237 d	**1187**	1558 b	1827c	1877cd	**1754**
Zn(F)	1296 b	2117 b	2387 a	**1933**	1577 b	2437a	2298 a	**2104**
U+Zn (F)	1656 a	2000 b	1878 b	**1845**	1779 a	2020 b	1874 cd	**1893**
Mean	**1283.5**	**1795.5**	**1825.3**	**1634.3**	**1643.7**	**1936.2**	**2011.8**	**1863.9**

***Means followed by a common letter are not significantly different at the level 5% according to DMRT**

a- Effect of P fertilizer levels:

From the data in the above Table, it was observed that, (whole mean of all Zn treatments) increasing P fertilizer level from P_1 to P_2 increased maize grain P content by about 7% in 2006 season; however when it increased to P_3 level the concentration decreased by about -1.3% compared with P_1, this is probably due to the dilution effect as a result of increasing maize grain yield. This finding is in agreement with Lisuma, (2006). The corresponding value in 2007 was 8.27% increase as a result of the increase from P_1 to P_2 and 11% increase as a result of the increase from P_1 to P_3. We can observe that in the second season the dilution effect disappeared. This may be due to the increase of available P at P_3 treatment at 2007 as a result of the accumulation effect of P fertilizers. These results are in agreement with those of Bukvie *et al.,*(2003).

From data in the same Table, it is clear that mean values of P content in maize stem increased with increasing P fertilizer levels from P_1 to P_3 in the two seasons. These increments were 29.7 and 18.3 in 2006 and 2007 seasons.

b- Effect of Zn fertilizer treatments

Data of P concentration (whole mean of all P treatments) in maize grain in Table 3 for the two seasons declared that mean values of P increased by increasing the zinc levels. Increasing Zn levels from [Zn_0(S)] (control) to [Zn_{20}(S)] P content in maize grain increased by 11.6 and 12% in the two seasons. This may be attributed to the fact that zinc as a component in dehydrogenises and activator of enzyme system led to production of more solutes and energy that increase activate absorption and translocation of nutrients (Fageria *et al.,* 1997),who came to the same conclusion**.**

The combination of 2% urea and 500 ppm Zn foliar gave the highest P content of maize grain (5812 and 5763 mg P/Kg) than the other foliar treatments. Concerning the effect of zinc levels in the P content of maize stem, data in the same Table showed that, [Zn_{10}(S)] and [Zn (F)] treatments gave the highest value of P content of maize stem (2029 and 2104 mg P/ Kg DW. in the two seasons, respectively)

PX Zn interaction had highly significant effect on the P content of maize grain and stem in the two seasons.

At P_1, the highest values of P maize grain content were obtained by the application of [Zn_{10}(S)] treatment in the two seasons. The highest values at P_2 levels were obtained by [Zn (F)] and [Zn_{20}(S)] treatments in the two seasons. At P_3 the highest values were obtained by [Zn_{20}(S)] and [U+ Zn (F)] treatments**.** The maximum values of P maize grain content 6030 and 6152 mg P / Kg DW. were obtained by [Zn_{20}(S)] under P_3 and P_2 levels in the two seasons, respectively. The maximum values of P content in maize stem (2531 and 2437 mg P/ Kg DW.) were obtained by [Zn_{10}(S)] and [Zn (F)] treatments under P_2 in the two seasons, respectively.

2- Zinc

The results in Table 4 and Fig.(3 and 4) show that Zn content in maize grain and stem were significantly affected by P and Zn fertilization treatments.

Table 4: Phosphorus and Zinc levels effect on zinc content (mg/ kg) of maize grain and stem.

Treat	2006 season				2007 season			
	P_1	**P_2**	**P_3**	**Mean**	**P_1**	**P_2**	**P_3**	**Mean**
				Zn mg/ Kg Grain				
[Zn_0(S]	5.8 c	7.7 c	7.0 b	**6.8**	5.2 c	7.5 d	5.8 c	**6.2**
[Zn_{10}-(S)]	6.4 c	8.8 bc	7.3 b	**7.5**	6.6 c	9.6 c	8.6 b	**8.3**
[Zn_{20}-(S)]	8.7 b	9.6 b	7.7 b	**8.7**	8.7 b	10.2 bc	9.2 b	**9.4**
U(F)	5.4 c	7.0 c	7.8 b	**6.7**	6.5 c	7.5 d	7.9 b	**7.3**
Zn(F)	8.9 b	11.5 a	8.7 b	**9.7**	9.2 b	11.8 ab	11.2 a	**10.9**
U+Zn (F)	11.0 a	12.5 a	11.6 a	**11.7**	12.6 a	13.0 a	12.2 a	**12.6**
Mean	**7.7**	**9.52**	**8.35**	**8.35**	**8.13**	**9.93**	**9.26**	**9.11**
				Zn mg/ Kg Stem				
[Zn_0(S]	12.5 d	22.6 c	15.0 f	**16.7**	13.9 d	18.2 c	12.9 d	**15.0**
[Zn_{10}-(S)]	14.5 cd	25.0 b	20.5 d	**20.0**	17.2 c	19.9 b	15.5 c	**17.5**
[Zn_{20}-(S)]	15.6 c	31.0 a	28.0 b	**24.9**	20.8 b	18.3 c	20.6 b	**19.6**
U(F)	13.0 d	16.0 d	23.5 c	**17.5**	13.8 d	16.5 d	20.0 b	**16.8**
Zn(F)	28.5 a	31.5 a	34.5 a	**31.5**	23.0 a	26.0 a	25.9 a	**25.0**
U+Zn (F)	21.5 b	25.2 b	17.6 e	**21.4**	18.0 c	16.8 cd	15.3 c	**16.7**
Mean	**17.6**	**25.22**	**23.18**	**22.0**	**17.78**	**19.28**	**18.4**	**24.0**

***Means followed by a common letter are not significantly different at the level 5% according to DMRT**

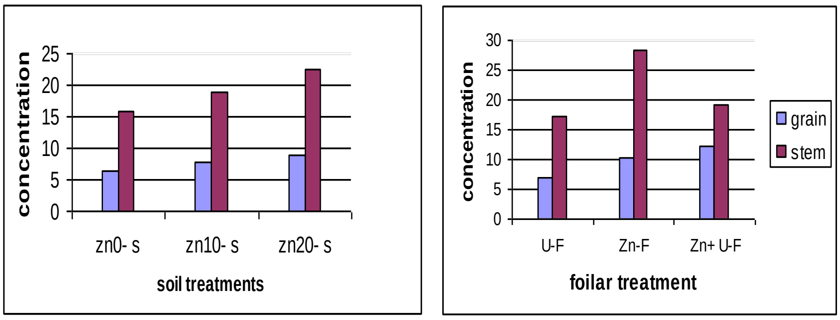


Fig. (3) Zinc concentration (mg/ kg) in maize grain and stem as affected by phosphorus (P) fertilization treatments (mean of two seasons)

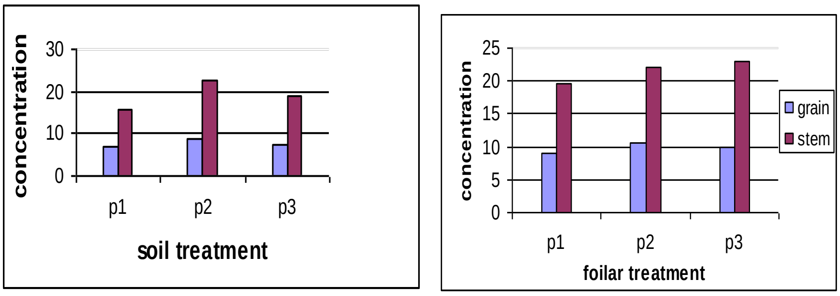


Fig (4). Zinc concentration (mg/ Kg DW.) in maize grain and stem as affected by zinc fertilization treatments(mean of two seasons)

a-Effect of P fertilization treatment:

The results in Table 4 and Fig. 3 (the whole mean of all Zn treatments) showed that with the increasing of P level from P_1 to P_2, the content of Zn in grain increased. the relative increases were (19 and 18 %) in 2006 and 2007, respectively. These increments may be due to the fact that single super phosphate contains 100 mg Zn/Kg (Srivastava, 1996). At P_3 maize grain Zn content was decreased. These results were supported by Ali *et al.,* (1990). They reported that high P fertilization reduced the root of surface area of maize plant and the adverse effect of high P levels increased with plant age due to greater absorption and translocations of P, but poor translocation of absorbed Zn to shoots. Srivastava (1996) added that Zn and P are mutually antagonistic, high P supply has also been shown to interfere with Zn uptake, translocation and utilization by plants. On the other hand, under foliar Zn application, Zn content in maize grain was higher than that of soil. The effect of P_3 on decreasing Zn content in maize grain was decreased.

The results obtained for Zn content of maize stem as influenced by P fertilizer treatments in Table 4 and Fig.3 are similar to those obtained for Zn content in maize grain. It is clear that mean values of Zn content in maize stem was increased by increasing P fertilizer levels from (17.6 and 17.78 mg/ Kg DW.) at P_1 to (25.22 and 19.28 mg/ Kg DW.) at P_2, then decreased to (23.18 and 18.4mg/ Kg DW.) at P_3 in the two season, respectively.

b-Effect of zinc levels fertilizer treatments:

Data in Table 4 and Fig.4 (whole mean of all P levels) indicates that the content of Zn in maize grain and stem increased progressively with the application of soil Zn treatments. These results are supported by Alloway, (1995). He concluded that generally, increases in soil zinc concentrations cause an increase in plant tissues.

Data in the Table and Fig.4 showed that the sequence of Zn content in grain [U+Z (F)> [Z(F) > [U(F), meanwhile Zn content in stem were in this order[Zn(F)] >[Zn+ U(F)]> [U(F). Therefore [U+ Zn(F)] treatment gave the highest content of Zn in maize grain in the two seasons, this treatment increased Zn in maize grain by (41.8 and 50.8 %) in comparison with the control [Zn_0(S)], while [Zn(F)] treatment gave the highest values of Zn content in maize stem (31.5 and 25 mg/ Kg DW) in 2006 and 2007 seasons, respectively. This result explained the effectiveness of urea in translocated Zn from the leaves to the grains. El- Kady and Zein, (1997) and shaaban, (2001) came to similar conclusion.

PX Zn interaction had no significant effect on the Zn content of maize grain while it had highly significant effect in maize stem in the two seasons.

The maximum mean values of Zn in maize grain (9.6 and 10.2 mg/Kg) were obtained by application of [Zn_{20}(S)] treatment under P_2 in the two seasons. The minimum values (5.8 and 5.2 mg/Kg in 2006 and 2007 seasons) were obtained by [Zn_0(S)] treatment under P_1.

With regard to foliar Zn application, the maximum Zn in maize grain values (12.5 and 13.0 mg/Kg in 2006 and 2007 seasons) were obtained by [U+ Zn–F] treatment under P_2.

Data in Table 4 showed that [Zn (F)] treatment gave the highest values of Zn content in maize stem in the two seasons under P_1, P_2, and P_3. The maximum values (34.5 and 26.0 mg/ Kg DW. in 2006 and 2007 seasons) were obtained by [Zn (F)] application under P_3 and P_2, respectively.

Zn content in maize grain ranged between (5.2- 13.0 ppm) with an average of 8.73 ppm which is very close to the normal level (10 ppm) reported by Bodi *et al.,* (2008). Zn content in maize stem ranged between (12.5- 34.5 ppm) with an average of 23.0 ppm which lies within the sufficiency range of Zn in maize leaves (20- 70 ppm), Aboulroos *et al.,* (1996).

3- Iron

The results in Table 5 revealed that Fe content in maize grain and stem were significantly affected by P and Zn fertilizer treatments.

a- Effect of P level fertilizer:

From data in Table 5 (whole mean of all Zn treatments),it is obvious that the addition of P fertilizer to the soil markedly decreased the concentration of Fe in maize grain with application of P_3 treatment by 39.2 and 14.3% compared to P_1 treatment in the first and second seasons, respectively. The corresponding values in maize stem were 31.9 and 31.6%. These results were supported by Sirvastava (1996). He concluded that the capacity of plant to absorb and maintain Fe in a soluble mobile form becomes less at high P concentration in the plant. He added that usually, P concentration in the rhizosphere is much lower than the level at which P-induced Fe deficiency is observed. On the other hand, Sonmezi and Yilmaz

(2000) founded that Fe uptake by grain of barley wasn't affected by applied phosphorus.

Table 5: Phosphorus and Zinc levels effect on F content (mg/ kg) of maize grain and stem

Treatments	2006 season				2007 season			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
Fe mg/ Kg Grain								
$[Zn_0$(S]	187a	92 c	82 b	**120**	133 b	113 a	111 a	**124**
$[Zn_{10}$-(S)]	146 b	89 c	60 d	**98**	95 d	91 c	82 c	**89**
$[Zn_{20}$-(S)]	103 d	90 c	53 d	**82**	93 d	90 c	84 c	**87**
U(F)	117 c	116 b	91 b	**108**	107c	102 b	103 b	**104**
Zn(F)	93 e	73 d	71 c	**79**	88 d	85 c	76 c	**83**
U+Zn (F)	146 b	125 a	128 a	**133**	144 a	112 a	110 ab	**122**
Mean	**132.0**	**97.5**	**80.3**	**103.3**	**110.0**	**98.8**	**94.3**	**101.07**
Fe mg/ Kg Stem								
$[Zn_0$(S]	396 b	324 a	256 ab	**324**	384 a	280 c	254 b	**280**
$[Zn_{10}$-(S)]	312 c	328 a	278 a	**306**	356 b	238 b	280 a	**320**
$[Zn_{20}$-(S)]	240 d	220 d	140 c	**200**	220 e	236 c	184 c	**212**
U(F)	320 c	260 b	224 b	**268**	324 c	240 c	260 bc	**274.6**
Zn(F)	252 d	224 c	172 c	**216**	280 d	252 c	200 c	**244**
U+Zn (F)	432 a	280 b	260 ab	**324**	400 a	368 a	286 a	**350**
Mean	**325.4**	**272.6**	**221.6**	**273.4**	**327.4**	**274.6**	**224**	**282**

Means followed by a common letter are not significantly different at the level 5% according to DMRT

b-Effect of zinc fertilizer treatments:

With regard to the whole mean of P_1, P_2, and P_3, data in the above table showed that the Fe content in the maize grain as affected by zinc soil treatment can be arranged in this order $[Zn_0(S)]>[Zn_{10}(S)]>[Zn_{20}(S)]$, and in zinc foliar treatment in this order [U+Z(F)]>[U(F)]>[Zn(F)]. Fe content of $[Zn_0(S)]$ (control) treatment increased by 31.6 and 29.8 % compared with $[Zn_{20}(S)]$ treatment in maize grain and by 38.3 and 24.3% in maize stem in 2006 and 2007, respectively. These results prove that excess zinc reduce in the absorption and translocation of Fe (Srivatava 1996). With respect to Fe content in maize stem, it was observed that the effect of P and Zn fertilizer treatments has the same way as grain.

P X Zn interaction had highly significant effect on the Fe content of maize grain and stem in the two seasons.

[U+Zn(F)] treatment gave the highest values of Fe content in grain and stem under P_1, P_2, and P_3 in the two seasons except for P_1 level in the first season, control treatment gave the highest value.

The maximum Fe content in grain (187 and 144 mg/Kg in 2006 and 2007 seasons) were obtained by the application of $[Zn_o(S)]$ and [U+Zn(F)] treatments under P_1, respectively.

The maximum values of Fe content in maize stem (432 and 400) were obtained by the application of [U+Zn(F)] treatment under P_1 in the two seasons.

4- Manganese

The results in Table 6 show that the Mn content in maize grain and stem were significantly affected by P and Zn fertilizer treatments, except in case of Mn stem content in 2007 season where no significant difference was observed.

Table 6: Phosphorus and Zinc levels effect on Mn content (mg/ kg) of maize grain and stem.

Treat.	2006 season				2007 season			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
Mn mg/ Kg Grain								
[Zn_0(S]	32 b	37 c	39 d	**36**	35 c	40 c	42 d	**39**
[Zn_{10}-(S)]	34 b	40 c	40 cd	**38**	36 bc	42 c	43 d	**40.3**
[Zn_{20}-(S)]	42 a	47.0 b	47.0 b	**45.6**	42 a	48 b	49 c	**46.3**
U(F)	42 a	47 b	50 b	**43.1**	38.0 b	50 b	52 b	**46.7**
Zn(F)	33 b	40 c	42.7 c	**38.6**	32 d	47 c	44 d	**39.3**
U+Zn (F)	42 a	52 a	62 a	**52**	44 a	54 a	66 a	**54.4**
Mean	**35.8**	**43.5**	**46.8**	**42.2**	**37.8**	**46.8**	**49.3**	**44.3**
Mn mg/ Kg Stem								
[Zn_0(S]	107 ab	110 bc	112 bc	**109.7**	108 ab	112abc	115 a	**111.7**
[Zn_{10}-(S)]	105 bc	112 b	114 ab	**110.3**	104 b	114 a	115 a	**111**
[Zn_{20}-(S)]	103 c	117 a	117 a	**112.3**	104 b	113 ab	118 a	**111**
U(F)	110 a	109 bcd	112 bc	**110.3**	110 a	108 c	116 a	**111.3**
Zn(F)	109 a	106 d	110 c	**108.3**	107 ab	109 bc	117 a	**111**
U+Zn (F)	110 a	108 cd	111 bc	**109.7**	108 ab	108 c	118 a	**111.0**
Mean	**107.3**	**110.3**	**112.7**	**110.1**	**106.8**	**110.7**	**123.7**	**111.2**

Means followed by a common letter are not significantly different at the level 5% according to DMRT

a-Effect of P-level fertilizer:

Data, in the same table also, revealed that Mn content in maize grain was increased gradually by increasing P-level from P_1 to P_3. It were 35.8 and 37.8 mg Mn/Kg DW. at P_1 and 46.8 and 49.3mgMn/Kg DW. at P_3 in 2006 and 2007 seasons, respectively. The corresponding values in maize stem were 107.3 and 106.8 at P_1, and 112.7 and 123.7 at P_3. This could be explained partly on the fact that single superphosphate contains 57 mg Mn/Kg (Srivatava 1996) and partly to the phosphate fertilizers which affect Mn synergistically by lowering the soil pH. This was in line with the observation by Sonmezi and Yilmaz (2000). They concluded that phosphorus fertilizers increased P and Mn level parley in grain.

b-Effect of Zn fertilizer treatments:

Data in **Table 6** (whole mean of all P treatments) revealed that application of [Zn_{20}(S)] treatment led to an increase in Mn content of maize grain and stem. These increases are 21.1 and 15.8% compared with [Zn_0(S)] in 2006 and 2007, respectively. On the other hand Mn content of maize grain (52 and 54.4 mg/Kg in 2006 and 2007 seasons) were obtained by [Zn+U(F)] application in the two seasons. The lowest Mn content of maize grain (38.6 and 39.3 mg/Kg in 2006 and 2007 seasons) were obtained by [Zn(F)] treatment. The decrement of Mn content in the latter treatment may be due to the antagonistic effect of high Zn concentration in maize stem Table 4 in this treatment as mentioned before.

P X Zn interaction had highly significant effect on the Mn content of maize grain and stem in the two seasons.

[U+ Zn(F)] treatment gave the highest values of Mn in grain and stem under P_1, P_2, and P_3 in the two seasons.

The maximum Mn content in grain (62 and 66 mg Mn/Kg DW.) was obtained by the application of [U+ Zn (F)] treatment under P_3 in the two seasons. Mn content in maize grain ranged from 32.0 to 66.0 ppm with an average of 43.0 and in maize stem ranged from 103 to 118 ppm with an average of 110 ppm which lies within the sufficiency range. According to. Srivastava, 1996 critical Mn content for deficiency in maize grain (4.9 ppm) and in ear- leaf (10.6- 11 ppm)

III- Translocation of Zn, Fe, and Mn in plant:

once the ions have been absorbed through the root and have been transported to the xylem vessel, there is a possibility of movement though out the whole plant. The rate and extent of movement within plants depends on the metal concerned, the plant organ and the age of plant (Alloway, 1995). Translocation coefficient percent (TC) from stem to grain has been calculated according to Zein *et al.,* (2002) as follow:

$$\mathrm{TC\%} = \frac{\text{content of heavy metal in grain (mg/Kg)}}{\text{content of same heavy metal in straw (mg/Kg)}} \times 100$$

TC of Zn, Fe, and Mn are presented in Table 7. Zn, Fe, and Mn are immobile in the plant, thus they move in the xylem vessels as organocomplixes. This reveals their hydrolysis and sorption on charged structural surface, and non specific chemical reaction with other ions simultaneously transported or metabolized, Srivastava, 1996.

TC values of Zn ranged between 25.2 and 79.7% with an average of 44.05%. The high values of TC for Zinc were obtained by the foliar application of zinc combined with urea. This treatment resulted in high concentration of Zn in grain and consequently high TC.

This finding is in agreement with those of Bowman and Panl (1989). They reported that urea is one of the compounds most rapidly absorbed by leaves. In meantime, foliar spraying of urea with certain micronutrients increased penetration of accompanying nutrients.

TC values of Fe in Table 7 were ranged between 21.6 and 49.3 with an average 36.9%. The corresponding TC values of Mn ranged between 29.1 and 55.93 with an average of 39.15. Data of Mn translocation coefficient showed that means of foliar Zn in combination with urea were more efficient treatment in increasing the Mn translocation from maize stem to its grains. Data of translocation coefficient can be arranged according to mean values in the following decreasing sequence Zn > Mn > Fe. These results are in agreement with those of Chaney and Giordano, (1977).

They classified Mn and Zn as elements which were relatively readily tran- located to the plant tips. These results were supported also by srivastava, 1996 and zien *et al.,* (2002) they concluded that all the trace elements are not equally mobile through the phloem. They also added that some trace elements such as Mn , Mo, and Zn are easily moved, while Fe is less mobile, it is translocated in plant as citrate complexes. Soluble ferredoxins may also take part in mobility of Fe in plant tissues.

Table 7 Translocation coefficient (TC %) of Zn, Fe, and Mn

Treatments	2006 season				2007 season			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
Zn (TC %)								
[Zn_0(S]	46.4	34.1	46.6	**40.5**	37.4	41.2	45.0	**41.1**
[Zn_{10}-(S)]	44.1	35.2	35.6	**37.5**	38.4	48.2	55.5	**47.1**
[Zn_{20}-(S)]	55.8	31.0	27.5	**34.2**	41.8	55.7	44.7	**49.5**
U(F)	41.5	43.8	33.2	**38.3**	47.1	45.5	39.1	**43.4**
Zn(F)	31.2	36.5	25.2	**31.9**	40	45.4	44.8	**43.5**
U+Zn (F)	51.2	49.6	65.9	**54.7**	70	77.8	79.7	**75.4**
Mean	**43.8**	**37.7**	**36.7**	**39.0**	**45.7**	**52.2**	**50.1**	**49.1**
Fe(TC%)								
[Zn_0(S]	47.2	28.3	32.0	**37.0**	34.6	40.4	43.7	**42.5**
[Zn_{10}-(S)]	46.8	27.1	21.6	**32.0**	26.7	27.7	29.3	**27.8**
[Zn_{20}-(S)]	42.0	40.9	37.8	**41.0**	42.3	38.1	45.7	**41.0**
U(F)	36.6	44.6	40.6	**40.3**	33.0	42.5	39.6	**37.9**
Zn(F)	36.9	32.6	41.3	**36.6**	31.4	33.7	38.0	**34.0**
U+Zn (F)	33.8	44.6	49.3	**41.4**	36.4	30.4	38.5	**34.9**
Mean	**40.6**	**35.7**	**36.2**	**37.8**	**33.6**	**35.5**	**39.1**	**36.1**
Mn(TC%)								
[Zn_0(S]	29.9	33.6	34.8	**32.8**	32.4	35.7	36.5	**34.9**
[Zn_{10}-(S)]	32.4	35.7	35.1	**34.5**	34.6	36.8	37.4	**36.3**
[Zn_{20}-(S)]	40.8	40.2	40.2	**40.6**	40.4	42.5	41.5	**41.7**
U(F)	29.1	43.1	44.6	**39.1**	34.5	46.3	44.8	**42.0**
Zn(F)	30.3	37.8	38.8	**35.6**	29.9	43.1	37.6	**35.4**
U+Zn (F)	38.2	48.1	55.9	**47.4**	40.7	50.0	55.93	**49.0**
Mean	**33.4**	**39.4**	**41.5**	**38.3**	**35.4**	**42.3**	**42.3**	**39.9**

IV- Availability of P, Zn, Fe, and Mn

1- Phosphorus:

Data in Table 8 indicated that significant effect was obtained for available P with different applications of P and Zn fertilizer treatment.

a- Effect of P fertilizer treatments:

Data in the same table showed that available P ,whole mean of all Zn treatments, generally increased by increasing P fertilizer levels from P_1 to P_3. These increments were 21.4 and 27.7% in the two seasons, respectively.

b- Effect of Zn fertilizer treatments:

Mean values of available P (whole mean of all treatments) in above Table showed that available P decreased with the increasing zinc levels added to the soil from 15.23 mg P/ Kg soil at [Zn_0- (S)] to 13.64 mg P/ Kg soil in the first season. These results may be explained the Zn- P antagonism interaction. This antagonism mainly seems to be based on chemical reaction in the rhizosphere, Olsen, *et al.,*(1991). On the other hand, according to Alloway,(1995) the Zn-P antagonism can be explained on a plant physiological basis. In the second season the mean value became higher and the behavior of available P takes different ways, where it is 18.84 mg P/ Kg DW. at [Zn_{20}- (S)] treatment. These increases may be due to the accumulation effect of P fertilizer in the second season and higher P content than soil Zn. With foliar application the maximum mean (whole mean of P treatment values of available P (17.22 and 17.89 mg/ Kg soil) in 2006 and 2007seasons were obtained from (U+ Zn (F)) treatment. This may be due to the increase of maize biomass with [U+ Zn (F)] followed by [Zn (F)] treatment and therefore the increase of size of maize roots which increased available P for use by plant.

Analysis of variance revealed that PX Zn interaction had highly significant effect on the available P in the two seasons.

Table 8: Phosphorus and Zinc levels effect on P, Zn, Fe, and Mn available in soil.

Treatments	2006 season				2007 season			
	P_1	P_2	P_3	Mean	P_1	P_2	P_3	Mean
P mg/ Kg soil								
[Zn_0(S]	13.31b	15.83ab	16.53bc	**15.23**	13.87bc	20.80a	21.33ab	**18.67**
[Zn_{10}-(S)]	13.72ab	14.30bc	15.83cd	**14.63**	15.63ab	16.27bc	19.37b	**17.09**
[Zn_{20}-(S)]	12.43b	13.70c	14.80d	**13.64**	15.7ab	18.00b	22.83a	**18.84**
U(F)	13.50ab	14.30bc	17.43bc	**15.08**	14.4abc	15.63c	20.44b	**16.83**
Zn(F)	15.22a	15.43ab	18.03ab	**16.22**	13.47c	16.73bc	20.44b	**16.80**
U+Zn (F)	13.6ab	16.6a	21.46a	**17.22**	16.43a	17.73bc	19.5b	**17.89**
Mean	**13.64**	**15.02**	**17.35**	**15.34**	**14.92**	**17.53**	**20.65**	**17.69**
Zn mg/ Kg soil								
[Zn_0(S]	1.42bc	1.44b	1.34bc	**1.4**	1.44c	1.72cd	1.44c	**1.53**
[Zn_{10}-(S)]	1.86b	3.31a	1.66bc	**2.28**	1.82b	2.81b	2.39a	**2.34**
[Zn_{20}-(S)]	2.66a	3.28a	2.62a	**2.85**	2.83a	3.16a	2.58a	**2.86**
U(F)	1.17c	1.36b	1.81b	**1.45**	1.46c	1.85c	1.90b	**1.74**
Zn(F)	1.79b	1.35b	1.19c	**1.44**	1.82b	1.85c	1.70bc	**1.79**
U+Zn (F)	1.8b	1.87b	1.79b	**1.82**	1.35c	1.39d	1.76bc	**1.5**
Mean	**1.78**	**2.1**	**1.74**	**1.87**	**1.79**	**2.13**	**1.96**	**1.96**
Critical value of soil test for Zn deficiency in maize 0.6 ppm (extracted by 0.005 DTPA , Takkar and Mann,1975)								
Fe mg /Kg soil								
[Zn_0(S]	1.8c	1.96c	2.44d	**2.06**	1.68d	2.08d	2.72d	**2.16**
[Zn_{10}-(S)]	1.68cd	1.92c	2.08e	**1.89**	2.08c	2.36cd	2.16e	**2.20**
[Zn_{20}-(S)]	1.44d	2.04c	2.92c	**2.13**	2.36c	2.92b	4.08c	**3.12**
U(F)	2.92a	2.24c	3.44b	**2.87**	1.64d	2.64bc	5.04a	**3.11**
Zn(F)	2.24b	2.80b	3.28b	**2.77**	2.92b	4.36a	4.76ab	**4.01**
U+Zn (F)	2.88a	3.96a	3.96a	**3.60**	4.0a	4.44a	4.56b	**4.33**
Mean	**2.16**	**2.49**	**3.02**	**2.56**	**2.45**	**3.13**	**3.89**	**3.16**
Soil critical level (2.5- 4.5 mg/ Kg soil) (extracted by 0.005 DTPA, Lndsay and Norvel, 1978)								
Mn mg/ Kg soil								
[Zn_0(S]	0.78 e	0.71 c	0.79 d	**0.76**	0.63 e	0.98 c	0.93d	**0.85**
[Zn_{10}-(S)]	0.96 b	0.74 c	0.89 c	**0.86**	0.92 c	0.82 e	1.33 a	**1.02**
[Zn_{20}-(S)]	0.93 b	1.00 a	0.89 c	**0.94**	0.83 d	1.02 c	1.04c	**0.96**
U(F)	0.82 d	0.86 b	1.14 b	**0.94**	0.53 f	0.93 d	1.23b	**0.89**
Zn(F)	1.01 a	0.85 b	1.39 a	**1.08**	0.98 b	1.09 b	1.02c	**1.03**
U+Zn (F)	0.89 c	0.98 a	1.11 b	**0.98**	1.08 a	1.22 a	1.05c	**1.12**
Mean	**0.83**	**0.86**	**1.03**	**0.93**	**0.83**	**1.01**	**1.10**	**0.98**
Soil critical level 0.22- 2.9 mg Mn/ Kg (extracted by 0.005 DTPA, Bansal and Nayyar, 1989								

Data in Table 8 showed that [Zn (F)] and [U+ Zn(F)] treatments gave the highest values of available P under P_1 level in the two seasons. [U+ Zn (F)] treatment gave the highest value of the available P under P_2 level the two seasons and under P_3 level in the first season, while [Zn_{20}- (S)] treatment gave the highest values in second season under P_3. The maximum values of available P (21.46 and 22.83 mg P / Kg DW. soil) were obtained by application of [U+ Zn (F)] and [Zn_{20}- (S)] treatment in 2006 and 2007 seasons, respectively under P_3.

2- Zinc:

Data in Table 8 and Fig. 5 and 6 showed that available zinc in the studied soil was significantly affected by P and Zn fertilizer treatments.

a- Effect of P fertilizer treatments:

Data in the above Table and Fig.5 showed that mean values of available zinc (whole mean of all zinc treatment) at P_1 were 1.78 and 1.79 mg Zn/ Kg DW. Soil in 2006 and 2007 seasons), at P_2 the corresponding values were 2.1 and 2.13 mg Zn/ Kg DW. Soil. This may be due to, as mentioned before, that superphosphate contains 100 mg Zn/ Kg soil. At P_3 treatment mean value of available Zn were decreased to 1.74 and 1.96 in 2006 and 2007 seasons. These results were supported by Xie and Mackenzie 1989, they concluded that phosphorus fertilization increases specific sorption of Zn on crystalline Fe oxides.

b- Effect of Zn fertilizer treatments:

From data in Fig.6 (whole mean of all P treatments) it can be seen that, mean values of available Zn were possibility increase by 50.9 and 46.5% in 2006 and 2007 due to application of [Zn_{20} (S)] treatment in comparison with [Zn_0 (S)] control, while it is obvious that foliar zinc application with urea or alone had no effect on available soil Zinc. The mean values of available zinc were ranged between 1.44 and 1.82 mg Zn / Kg soil in the two seasons. The slight increase over the [Zn_0 (S)] (control) may be due to the increase of the size of maize roots as a result to increasing the maize biomass.

P X Zn interaction had highly significant effect on the available Zn in the two seasons. Data of available Zn revealed that [Zn_{20}(S)] treatment gave the highest value of available Zn under P_1, P_2, and P_3. The maximum values (3.28 and 3.16 mg Zn/Kg soil) were obtained by [Zn_{20}(S)] treatment under P_2.

Values of available Zn in the studied soil varied from 1.17 to 3.31 mg Zn/Kg soil. These values being within the moderate range (0.7 – 1.5 ppm) to the high range (>1.5 ppm) according to Aboulroos *et al .,* (1996).

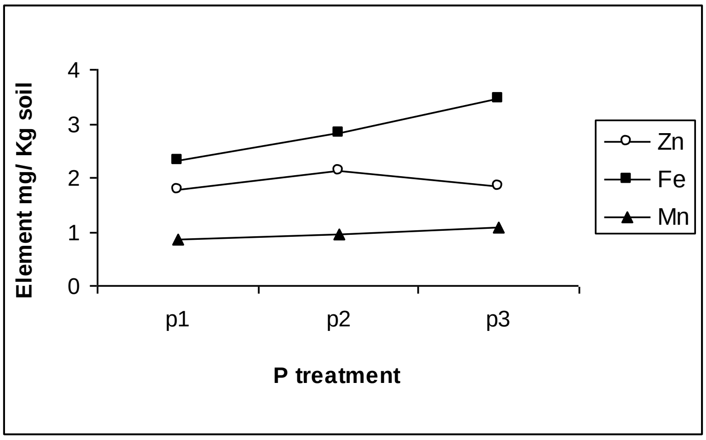


Fig 5: Effect of phosphorus fertilizer treatments on available Zn, Fe, and Mn (mean of the two seasons)

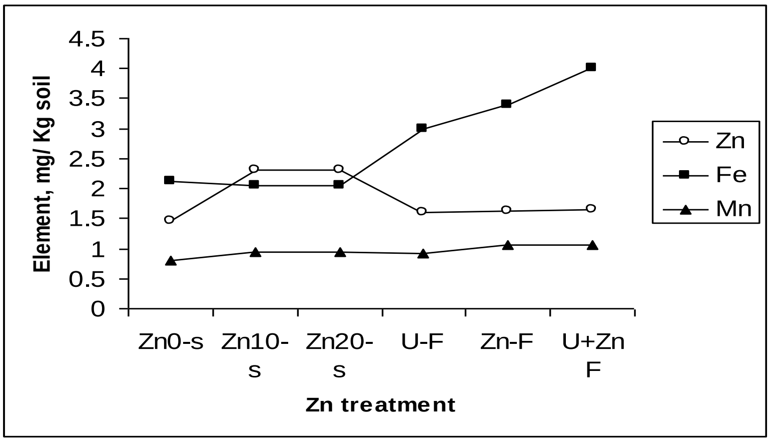


Fig 6: Effect of zinc fertilizer treatments on available Zn, Fe, and Mn (mean of the two seasons)

3- Iron:

Data in Table 8 revealed a significant effect on available Fe with P and Zn fertilization.

a- Effect of P fertilizer treatments:

Data in Table 8 and fig.5 showed that, the highest mean values of available Fe 3.02 and 3.89 mg Fe/ Kg soil (the whole mean of all Zn treatment) were obtained at P_3 in the two seasons. Available Fe as affected by P levels were in order $P_3 > P_2 > P_1$ in the two seasons. although numerous studies indicate that high rate of P fertilizers induced Fe deficiency in solution of culture Mengel, 1984 and Alloway, 1995, it is interest that the results reported here did not show such antagonistic in the reaction effect between available P and Fe in the studied soil, however this antagonist relationship was induced in the maize plant among Fe and P and Zn as mentioned before.

b- Effect of Zn fertilizer treatments:

Data in the same Table and Fig. 6 revealed that mean values of Fe (whole mean of P_1, P_2, and P_3) as affected by Zn treatment can be arranged in this order [U + Zn (F) > [Zn(F)] > [U (F)] > [Zn_{20}(S)] >[Zn_0(S)] (control)> Zn_{10}(S)].(mean of the two seasons). These results showed that the addition of Zn as soil application decreased the available of Fe in the soil. These results are in an agreement with those of srivastava, 1996 who explained that antagonistic interaction between Fe and Zn (in the soil application) is supported to be associated with precipitation of franklinite ($Zn\ Fe_2\ O_4$) which depresses the availability of both metals. Huyer and Page, (1989) added that zinc ion strongly inhibits reduction of Fe^{3+} to Fe^{2+} to affect the uptake of Fe and also the translocation.

P X Zn interaction had highly significant effect on available Fe. Data in Table 8 showed that the highest mean values of available Fe were obtained by [U+Zn(F)] treatment under P_1, P_2, and P_3 in the two seasons, except for P1 in 2006 and P3 in 2007 season. The highest values were obtained by [U(F)] treatment. The maximum values of available Fe (3.96 and 5.04 mg Fe/Kg soil) were obtained by application of [U+Zn(F)] and [U(F)] treatments under P_3 in the two seasons, respectively.

Values of available Fe varied from 1.44 to 5.04 mg/kg with an average of 2.86, being within the critical concentration range of (2.5 – 4.5 mg Fe/Kg soil extracted by 0.005 DTPA) according to Lindsay and Norvell (1978).

4- Manganese (Mn):

The results in Table 8 show that available Mn was significantly affected by P and zn fertilization.

a-Effect of P fertilizer treatment:

Data in the above Table and Fig. 5 (whole mean of all Zn treatments) showed that mean value of available Mn increased as P-levels increased in the two seasons. These increments were 19.4 and 24.6% by applied P_3 in comparison with P_1 treatment in the two seasons. These results are partly due to increasing the solubility of Mn by forming manganese phosphate, and partly due to the fact that superphosphat contains 57 mg Mn/Kg as mentioned before. These results supported by Srivastava (1996). He concluded that phosphate fertilizers affect Mn either synergistically or antagonistically by lowering the soil PH or by increasing Mn sorption capacity of soil, respectively.

b- Effect of Zn treatment:

Data in Table 8 and Fig.6 showed that mean values of available Mn (whole mean of all P treatments) as affected by Zn treatments can be arranged in the order [U+ Zn(F)] > [Zn(F)] > [Zn_{20}(S)] > [U(F)] >[Zn_{10}(S)] >[Zn_0(S)] (mean of the two seasons). The mean values of available Mn by the Zn Foliar application treatments was (1.01 mg Mn/Kg soil) while the mean values of soil Zn application was (0.94 mg Mn / Kg soil). These results revealed that available Mn slightly increased by zinc foliar application than soil application. This finding could be, as mentioned before, due to the antagonistic interaction between Zn in soil and Mn (Alloway, 1995).

P X Zn interaction had highly significant effect on the available Mn. From the same Table, it can be seen that ([U+ Zn(F)] gave the highest available Mn under P_1 and P_2 in the second season, while in the first season [Zn(F)] treatment gave the highest values under P_1 and P_3. Also [Zn_{20}(S)] and [Zn_{10}(S)] treatments gave the highest values in the first season under P_2 and in the second season under P_3.

The maximum values of available Mn (1.39 and 1.33 mg Mn / Kg soil) were obtained by the application of [Zn(F)] and [Zn_{10}(S)] treatments in 2006 and 2007, respectively.

Values of the available Mn varied from 0.63 to 1.39 with an average of 1.01 being within the critical concentration (0.22- 2.9 mg Mn/ Kg soil extracted by 0.005 DTPA) according to Bansal and Nayyar (1989).

It may be more convenient to take into consideration that although there were no addition of Fe or Mn in the experiment, the concentrations of their available contents in soil were within the critical levels. This can be explained by Srivastava(1996). He concluded that rhizosphere zone receives appreciable amounts of organic acids from roots and H^+ released by roots reduces the pH and dissolve many relatively insoluble trace elements through complexation or chelation to increase their mobilization to plant root by mass flow and diffusion.

CONCLUSION

From data in Table 9 we can conclude that:

1- Grain yield and biomass increased by different percentages form P_1 to P_2 and from P_2 to P_3.

2- The nutritional values of maize grain increased with the increasing P, Zn, and Mn from P_1 to P_2, while it decreased from P_2 to P_3.

3- The fertility of the soil increased as the available studied elements increased at the two P fertilizer levels, except for Zn in P_3.

With regard to the methods of Zn application, foliar application of Zn combined with urea is the recommended one because it avoids the antagonism interaction in the soil with other elements.

Table 9: Relative increase (∆ %) in the all studied factors due to phosphorus fertilizer treatments.

Factors	**∆%(P_1 , P_2)**	**∆%(P_2 , P_3)**
Grain yield	4.9	7.7
Biomass	8.8	7.6
P maize grain content	7.6	-2.8
Zn maize grain content	18.6	-10.2
Fe maize grain content	-21.0	-14.5
Mn maize grain content	18.6	6.0
Available P	12.6	14.6
Available Zn	15.6	-14.6
Available Fe	17.8	18.7
Available Mn	8.5	12.2

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استجابة الذرة للتسميد بالزنك تحت مستويات مختلفة من التسميد الفوسفاتي وامتصاصه لبعض العناصر الغذائية وتيسيرها في التربة

فاروق إبراهيم زين ، أسماء أحمد البسيوني و حسن سعد حمود
معهد بحوث الأراضي والمياه والبيئة- مركز البحوث الزراعية – القاهرة – مصر

أقيمت تجربتين حقليتين في المزرعة البحثية- محطة البحوث الزراعية بسخا – كفر الشيخ- مصر خلال الموسمين المتعاقبين ٢٠٠٦ و ٢٠٠٧ .

الهدف من البحث دراسة تأثير التسميد بالزنك بالإضافة الأرضية بمستويات (٠ و ١٠ و ٢٠ كجم زنك للفدان) أو التسميد بالرش بالزنك في وجود يوريا أو بمفرده (٢% يوريا أو زنك بتركيز ٥٠٠ جزء في المليون للفدان أو مخلوط من اليوريا والزنك) تحت ثلاث مستويات من التسميد الفوسفاتي بمعدل (٣٠ و ٤٥ و ٦٠ كجم فو٢ أ٥ / فدان) على محصول الذرة (جيزة ٣٥٢) ومكوناته وامتصاصه لعناصر الفوسفور و الزنك و الحديد و المنجنيز ومدى يسر هذه العناصر في التربة. وقد أقيمت التجربة في تصميم قطع منشقة مرة واحدة مع أربع مكررات وكان العامل الرئيسي هو مستويات الفوسفور والعامل تحت الرئيسي هو معاملات الزنك.

ويمكن تلخيص النتائج كما يلي:

- محصول الذرة ومكوناته تأثرت معنوياً بالتسميد الفوسفاتي والزنك.
- محصول حبوب الذرة زاد بنسبة ١٢ و ١٢,٥ % . والمحصول الحيوي بنسبة ١٧,٦ و ١٣,٨ في الموسم الأول والثاني على التوالي بزيادة التسميد الفوسفاتي إلى المستوي الثالث (٦٠ كجم فو٢ أ٥ / فدان) مقارنة بمعاملة الكنترول (٣٠ كجم فو٢ أ٥ / فدان).
- أعطت معاملة الزنك الأرضي بمستوى ١٠ كجم زنك للفدان أعلي محصول حبوب مع مستوي التسميد الفوسفاتي الثالث في الموسمين وأعلى محصول حيوي في الموسم الأول. بينما كان أعلى محصول حيوي في الموسم الثاني بمعاملة الرش بالزنك مع اليوريا تحت مستوي التسميد الفوسفاتي الثالث أيضاً.
- أعلى تركيز للفوسفور في حبوب الذرة كان مع معاملة الزنك الأرضي بمعدل ٢٠ كجم / فدان ومستوى التسميد الفوسفاتي الثالث في الموسم الأول ومع المستوي الثاني (٤٥ كجم فو٢ أ٥ / فدان) في الموسم الثاني
- أعلي تركيز فوسفور بسيقان الذرة كان معاملة التسميد الأرضي (١٠ كجم زنك / فدان) ومعاملة الرش باليوريا (٢%) تحت مستوى التسميد الفوسفاتي الثاني في الموسمين على التوالي.
- أعلى تركيز للزنك في حبوب الذرة كان مع معاملة الرش بمخلوط الزنك مع اليوريا مع المستوى الثاني للتسميد الفوسفاتي في الموسمين
- أعلى تركيز زنك في سيقان الذرة كان مع معاملة الرش بالزنك ٥٠٠ جزء في المليون / فدان ومستوى التسميد الفوسفاتي الثالث والثاني على التوالي.
- محتوى الحبوب والسيقان من الحديد أعطي أعلى قيمة مع معاملة الرش بالزنك مع اليوريا ومستوى التسميد الفوسفاتي الأول (الكنترول) فيما عدا حبوب الموسم الأول. وأعطت نفس المعاملة أعلى محتوى من المنجنيز في كلا من الحبوب والسيقان تحت مستوى التسميد الفوسفاتي الثالث فيما عدا سيقان الموسم الأول.
- بحساب معامل الانتقال للعناصر الثقيلة (TC%) كان ترتيبها كالآتي : زنك > المنجنيز > الحديد.
- تزداد العناصر الميسرة من الفوسفور الحديد والمنجنيز مع زيادة معدل التسميد الفوسفاتي بينما الزنك الميسر يزداد مع المستوى الأول إلى الثاني ثم يقل عند الثالث.
- معاملة الرش بالزنك مع اليوريا أعطت أعلى فوسفور وحديد ومنجنيز ميسر بينما كان أعلى زنك ميسر مع معاملة الزنك الأرضي (٢٠ كجم زنك/ فدان)