Effect of Gypsum, Iron Chelate and Molybdenum on Some Micronutrient Levels in Maize Grown on Some Soils of Assiut

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ABSTRACT

Molybdenum accentuated Fe deficiency at low levels of available Fe. This interaction may be important in alkaline soils where pH favors a low Fe availability and high Mo availability from native soil levels. When such interactions exist, this information will help interpret the relationship between response predicted by a soil test for available Fe and actual response. This interaction was confirmed in six soil samples in Assiut Governorate Fe uptake and/or Fe concentration was increased in maize plants (*Zea mays* L. three ways cross variety Giza 310) as Mo decreased with adding gypsum at level of 25 ppm of S.Gypsum decreased Mo in plants from 2.41 to 1.26 ppm and increased plants Fe from 57 to 65 ppm. An increase in Mo above native levels decreased the plant Fe concentration from 57 to 51 ppm and Fe uptake by maize from 418 to 369 µg/pot. Moreover, gypsum consistently increased plant Mn concentrations from 70 to 71 ppm, and plant Zn from 56 to 80 ppm. Knowledge of these interactions will help to interpret plant responses to natural levels of these micronutrients in soils and disturbed lands.

INTRODUCTION

In alkaline and calcareous soils, typically located in semiarid regions, many plant species exhibit symptoms of iron (Fe) chlorosis indicated by yellow or pale green leaves with a darker green near the veins. High pH values in such soils usually contribute to a low supply of available Fe and, accordingly, will generally cause Fe chlorosis. In some of these soils, however, plants may absorb less Fe and become deficient in Fe because high available molybdinum (Mo) seems to decrease Fe uptake(Berry and Reisenauer,1967).

Experiments with tomato plants (*Lycopersicon esculentum* Mill., var Marglobe) in nutrient culture indicated that Mo accentuated Fe deficiency at low levels of available Fe (Gerloff *et al.*, 1959; Kirsch *et al.*, 1960). Adding molybdinum added at low Fe levels caused yield depression (El-Sayed,1999). However, addition of Mo at high Fe levels increased yields(Faragallah and El-Sayed, 2002). As the Mo supply increases, higher Fe levels are needed to obtain maximum yields at all Mn levels. This interaction of Fe and Mo could be important in alkaline soils where pH favours a low Fe availability and a high Mo availability from native soil levels (Gerloff *et al.*, 1959). Knowledge of these interactions will help us to interpret plant responses to natural levels of these micronutrients in soils or to induced micronutrient levels from sewage, other wastes and fertilizers. On the other hand, other experiments have shown that Mo uptake was reduced in plants by increasing sulfate levels in the soil (Stout *et al.*, 1951; Reisenauer *et al.*, 1963; Gupta & Munro, 1969; Jones & Ruckman, 1973; Dawood, 2001).

In this paper, an experiment was designed to test the hypothesis of an interaction operating in plant uptake of Fe and Mo in alkaline soils. Therefore ,the objectives of this paper were 1-testing the hypothesis of an Fe and Mo interaction in plant uptake in alkaline soils . 2-Evaluating the effect of adding gypsum on Fe availability to plants and those soils when there is an Fe × Mo interaction.

MATERIALS AND METHODS

Six alluvial soil samples from Assiut Governorate were collected from the surface layer (0-30 Cm) for the experiment. Some physical and chemical properties of the studied soils are shown in Table (1). Eight treatments were used for each soil samples (Table 2). Iron was added as Fe- EDDHA (ethylenediamine di-o-hydroxyph-enylacetic acid), S was added as gypsum ($CaSO_4 . 2H_2O$) and Mo was added as sodium molybdate ($Na_2 MoO_4$). Soil was air-dried, crushed and sieved through a 2 mm screen. Two Kgs of each soil material were thourghly mixed with the respect treatments and placed in 2-liter plastic containers. Each soil sample received 4 ppm Zn as Zn DTPA (diethylenetriamine penta- acetic acid) and 180 ppm N as $Ca (NO_3)_2$ and KNO_3 . All soil samples received 40 ppm P except Sedfa soil samples that received 20 ppm P and Abo Teeg one that did not received any P. Phosphorus was added as superphosphate (15.5% P_2O_5). There were three replicates for each treatment.

Four seeds of maize (*Zea mays* L. three ways cross variety Giza 310) were sown in each container on May 15 and the plants were thinned after 7 days to 2 plants. Water was added daily or as needed to a level equivalent to 0.33 bars suction(Chapman and Pratt,1961). The experiment were carried out in the greenhouse of the faculty of agriculture, Al-Azhar University at Assiut. The aboveground portion of the plants were harvested on August 2, dried at 70°C, weighed, and ground in a

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Table 1. Some physical and chemical properties of the studied soils.

Soil property	Soil location					
	Sedfa	Abo Teeg	Dauroot	El-kouseia	Manfalot	Mankabad
Coarse sand,%	2.30	0.30	.50	8.10	9.55	7.30
Fine sand,%	28.99	38.80	21.90	35.70	11.55	20.64
Silt,%	23.65	25.30	32.70	22.30	27.16	22.59
Clay,%	45.06	35.60	44.90	33.90	51.74	49.47
Texture class	C	C.L	C	C.L	C	C
Organic matter,%	1.75	1.90	1.10	1.98	1.30	1.37
pH (paste)	9.89	9.70	9.70	9.65	9.95	9.90
$CaCO_3$,%	2.40	1.5	1.90	2.28	3.01	2.80
EC (d Sm^{-1})	0.33	0.74	0.84	0.76	0.80	0.63
ESP,%	19.09	20.27	22.85	23.48	16.32	21.01
P(ppm)$NaHCO_3$	21	40	17	13	19	16
S(ppm)	12.73	17.16	16.43	14.15	13.62	15.68
DTPA- Mo(ppm)	0.21	1.40	1.00	0.11	0.46	0.19
DTPA- Fe (ppm)	10.5	5.3	3.5	3.5	3.7	4.7
DTPA- Zn (ppm)	1.58	1.91	0.47	1.38	1.14	1.07

C.=Clay, C.L.=Clay Loam.

Table 2. Soil treatments.

No	Treatment	Fe (ppm)	S (ppm)	Mo (ppm)
1	0	0	0	0
2	S	4	0	0
3	Mo	0	25	0
4	Mo +S	0	0	0.052
5	Fe	4	25	0
6	Fe +Mo	4	0	0.052
7	Fe +S	0	25	0.052
8	Fe Mo +S	4	25	0.052

Wiley mill for analysis(Page *et al.*,1982).

Plant samples were digested using of 2:1 acid mixture of nitric to perchloric acids, respectively. Digests were analyzed for Fe, Mn and Zn using Perkin Elmer, 373 model atomic absorption and for Mo using the method of Johnson & Arkley, (1954).

Total S was determined after dry combustion of 0.5 g samples of ball-milled plant material (Chapman & Pratt, 1961 and Page *et al.*,1982). The turbidimetric method of Bardsley and Lancaster (1965) was used to determine sulfate form of S. Extractable soil nutrients listed in Table (1) were measured by the following methods: $NaHCO_3$–extractable P (Watanabe & Olsen, 1965), DTPA – extractable Fe and Zn (Lindsay and Norvell, 1978), extractable SO_4 with 0.016 *M* Ca $(H_2PO_4)_2$ (Fox *et al.*, 1964) and available Mo (Jackson & Meglen, 1975).

Statistical Analysis :

A randomized complete block design, with three replications was used .The obtained data were statistically analyzed by Duncan's multiple range test at

0.05 level (Steel and Torrie, 1982) using the computer program SAS (SAS Institute Inc., 1988).

RESULTS AND DISCUSSION

Table (3) shows dry matter yield of maize and concentrations of Fe, Mo, S, Mn and Zn in plant Table (4) shows the mean values of yield and nutrient contents . Means of these variable calculated over the six types of soil samples are also presented in Table (4) . It is clear that additions of iron chelate or gypsum increased the mean DM yield of maize but those of Mo did not. Applying iron chelate did not increase the yield of maize grown on Abo Teeg clay loam soil, but gypsum significantly increased it. More over, gypsum significantly increased the yield of maize grown on

Table 3. Dry matter yield (DM) of maize and concentrations of Fe, Mo, S ,Mn and Zn in plants as well as Fe uptake as affected by treatments*.

Soil	Treatment	DM Yield	Fe	Mo (ppm)		S	Mn	Zn	Fe-uptake
		(g/pot)	(ppm)	Native	+ Mo	(ppm)	(ppm)	(ppm)	(μg/pot)
Sedfa (Clay)	0	13.10 a	63 ab	1.63 b	---	651 a	59 b	34 a	825 b
	S	15.00 b	72 c	0.93 a	---	1176 c	76 c	41 b	1080 d
	Mo	12.60 a	56 a	---	3.00 c	734 a	55 ab	33 a	706 a
	Mo + S	15.20 b	72 c	---	1.53 a	1451 d	72 c	34 a	1094 cd
	Fe	14.70 b	65 bc	0.87 a	---	756 a	49 a	35 a	956 c
	Fe + Mo	15.80 b	66 bc	---	2.07 b	818 b	47 a	31 a	1043 cd
	Fe + S	15.40 b	73 c	0.63 a	---	1109 c	54 ab	36 a	1124 d
	Fe + Mo + S	15.60 b	72 c	---	1.10 a	1334 d	51 ab	34 a	1123 d
Abo Teeg (Clay loam)	0	9.50 ab	64 ab	1.57 c	---	893 a	62 b	82 d	608 a
	S	11.10 cd	76 cde	0.94 ab	---	1543 d	88 c	97 f	844 bc
	Mo	9.10 a	58 a	---	5.03 b	959 a	84 c	73 c	528 a
	Mo + S	11.00 cd	71 bc	---	2.67 a	1409 d	86 c	92 e	781 b
	Fe	10.30 abc	83 e	1.30 bc	---	1276 bc	37 a	72 bc	855 bc
	Fe + Mo	9.90 abc	79 de	---	4.17 b	1226 bc	46 a	62 a	782 b
	Fe + S	11.80 d	76 cde	0.73 a	---	1201 b	39 a	58 a	897 c
	Fe + Mo + S	10.90 c	73 cd	---	2.50 a	1359 c	43 a	68 b	796 bc
Dauroot (Clay)	0	2.80 a	52 b	1.80 b	---	509 a	37 cd	56 c	146 a
	S	14.30 c	56 bc	1.10 a	---	956 b	41 d	62 d	801 c
	Mo	2.50 a	38 a	---	6.70 c	601 a	29 bc	66 d	95 a
	Mo + S	15.20 cd	64 c	---	3.40 a	944 b	56 e	67 d	973 d
	Fe	10.60 b	63 c	1.00 a	---	601 a	15 a	38 a	668 b
	Fe + Mo	11.80 b	75 d	---	5.10 b	503 a	15 a	41 ab	885 cd
	Fe + S	17.30 e	74 d	0.70 a	---	876 b	22 ab	40 ab	1280 e
	Fe + Mo + S	16.60 de	75d	---	2.90 a	968 b	28 bc	45 b	1245 e
El-Kosseia (Clay loam)	0	3.50 a	50 a	2.10 b	---	571 a	66 c	56 c	175 a
	S	10.70 c	54 a	1.00 a	---	1351 c	83 d	79 e	578 b
	Mo	3.70 a	50 a	---	8.30 c	605 a	63 c	64 d	185 a
	Mo + S	8.70 b	58 ab	---	4.10 b	1434 c	73 c	92 f	505 b
	Fe	12.70 d	63 bc	1.00 a	---	558 a	19 a	35 a	800 c
	Fe + Mo	13.00 d	58 ab	---	3.80 b	650 a	21 a	42 b	754 c
	Fe + S	17.40 e	70 c	0.80 a	---	979 b	31 b	43 b	1218 d
	Fe + Mo + S	17.70 e	71 c	---	2.20 a	1009 b	28 ab	41 b	1257 d

* Means in a column followed by the same letter do not differ significantly at the 5% level of confidence by Duncan's multiple range test.

Table 3. Continued .

Soil	Treatment	DM Yield	Fe	Mo (ppm)		S	Mn	Zn	Fe-uptake
		(g/pot)	(ppm)	Native	+ Mo	(ppm)	(ppm)	(ppm)	(µg/pot)
Manfalot	0	5.50 a	63 d	3.70 c	----	688 a	108 b	64 b	347 b
(Clay)	S	6.40 a	50 b	1.50 b	----	1659 c	151 d	144 d	320 b
	Mo	5.40 a	39 a	----	9.60 d	650 a	101 b	64 b	211 a
	Mo + S	6.70 a	51 b	----	5.50 c	1724 c	133 c	129 c	342 b
	Fe	12.70 b	76 e	1.10 ab	----	671 a	46 a	49 a	965 d
	Fe + Mo	14.00 b	58 bcd	----	4.80 b	641 a	38 a	51 a	812 c
	Fe + S	17.40 c	54 bc	0.70 a	----	1143 b	45 a	47 a	940 d
	Fe + Mo + S	17.60 c	60 cd	----	2.10 a	778 a	45 a	47 a	1056 e
Mankabad	0	9.70 a	55 bc	4.80 c	----	784 a	94 d	51 c	534 ab
(Clay)	S	10.60 ab	53 abc	2.70 ab	----	1508 c	110 e	63 d	562 ab
	Mo	10.10 a	47 a	----	7.70 c	771 a	84 c	48 bc	475 a
	Mo + S	11.70 bc	53 abc	----	4.20 a	1501 c	107 e	62 d	620 bc
	Fe	14.10 d	51 ab	3.10 b	----	888 ab	47 a	43 ab	719 cd
	Fe + Mo	12.30 c	59 c	----	5.60 b	961 b	65 b	40 a	726 d
	Fe + S	15.40 d	53 abc	2.30 a	----	1408 c	57 ab	43 ab	816 de
	Fe + Mo + S	14.70 d	58 bc	----	3.40 a	1374 c	65 b	43 a	853 e

* Means in a column followed by the same letter do not differ significantly at the 5% level of confidence by Duncan's multiple range test.

Table 4. Means, yield (DM) of maize and mean concentrations of Fe, Mo, S and Mn as well as Zn in plants as affected by treatments*.

Treatment	DM Yield	Fe	Mo (ppm)		S	Mn	Zn	Fe upptake
	(g/pot)	(ppm)	Native**	+ Mo**	(ppm)	(ppm)	(ppm)	(µg/pot)
0	7.35 a	56.9 b	1.65 b	----	681 a	70.2 c	56.2 c	418
S	11.35 b	59.4 bc	0.94 a	----	1361 d	90.7 d	80.1 d	674
Mo	7.24 a	50.9 a	----	4.51 c	721 a	68.5 c	57.1 c	369
Mo + S	11.43 b	60.1 c	----	2.41 ab	1411 d	86.9 d	78.3 d	687
Fe	12.50 c	64.0 d	0.96 a	----	791 b	34.8 a	44.4 ab	800
Fe + Mo	12.79 c	64.9 d	----	2.87 b	801 b	37.7 ab	43.4 a	830
Fe + S	15.79 d	65.8 d	0.70 a	----	1121 c	40.3 b	43.7 ab	1039
Fe + Mo + S	15.52 d	67.3 d	----	1.62 a	1131 c	42.7 b	45.4 b	1044

* Means in a column followed by the same letter do not differ significantly at the 5% level of confidence by Duncan's multiple range test.
** Data analyzed separately for treatments with native Mo levels and added Mo.

Sedfa ,Dauroot and El-Kosseia soil samples. More increases in the DM yield were obtained by adding the combined treatment of Fe chelate and gypsum to all studied soil samples.

In three of the six soils (i.e. Dauroot, El-Kosseia, and Sedfa) , adding Mo in combination with other treatments did not lead to significant when it was not added with these treatments (Tables 3 and 4).

A-Evidence of Fe×Mo Interaction:

Dry matter yield (DM) variations were inconclusive evidence for this interaction with respect to either initial or added Mo levels, because Mo did not affect DM yields. The depressive effect of the added Mo on the Fe concentration in the plant did not cause an additional decrease in the yield. Added Mo decreased the Fe concentration in the plants from 56.9 to 50.9 ppm and Fe uptake from 418 to 369 µg/pot (Table 4). The effect of added Mo on Fe concentration in the plants is shown in Fig.(1) for each soil. The depressive effect of Mo on

Fe concentration333 in the plants was significant for Dauroot, Manfalot and Mankabad soil samples.

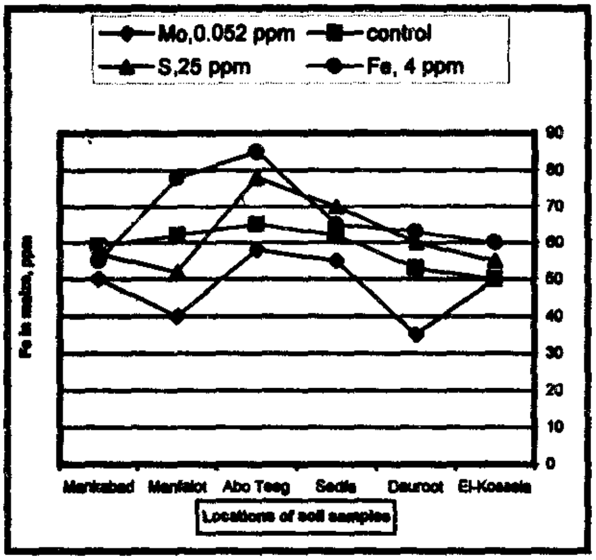

Fig.1.Effect of added Mo,Fe, and gypsum(s) on Fe concentration in maize plants grown on the studied soils.

Iron chelate decreased Mo concentration in the plants (Tables 3 or 4). Fig. (2) shows Mo concentrations in the plants grown on the studied soils with and without added Mo treatments. Added Mo increased the Mo concentration in the plants grown on all soils. An estimated value was used for the Dauroot soil because the sample was insufficient for analysis. Data in Figs. (3 or 4) show that Fe chelate decreased Mo concentration in the plants taken from native and added Mo in the soils.

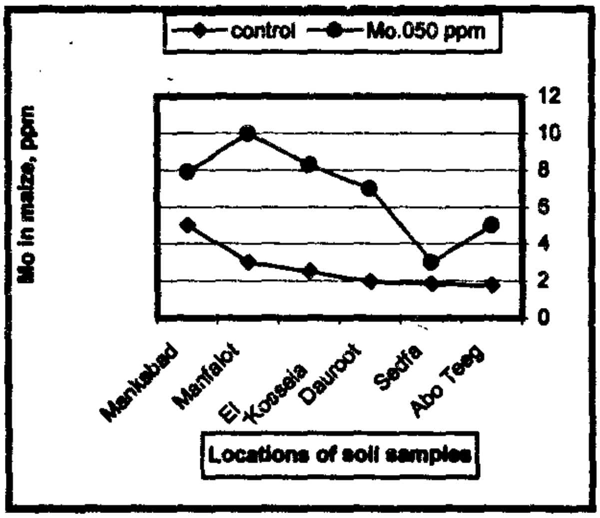

Fig.2.Molybdenum concentration in maize plants grown on the studied soils with and without added Mo.

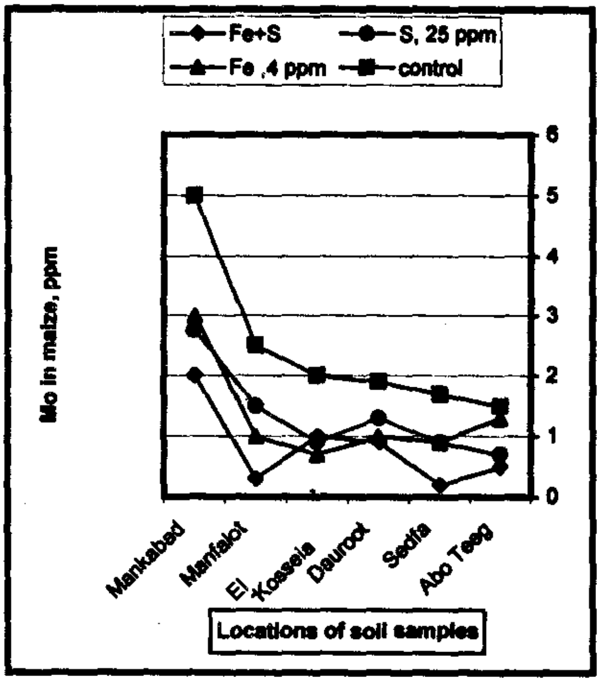

Fig.3. Effect of Fe chelate (Fe-EDDHA) and gypsum on Mo concentration of maize plants grown on the studied soils.

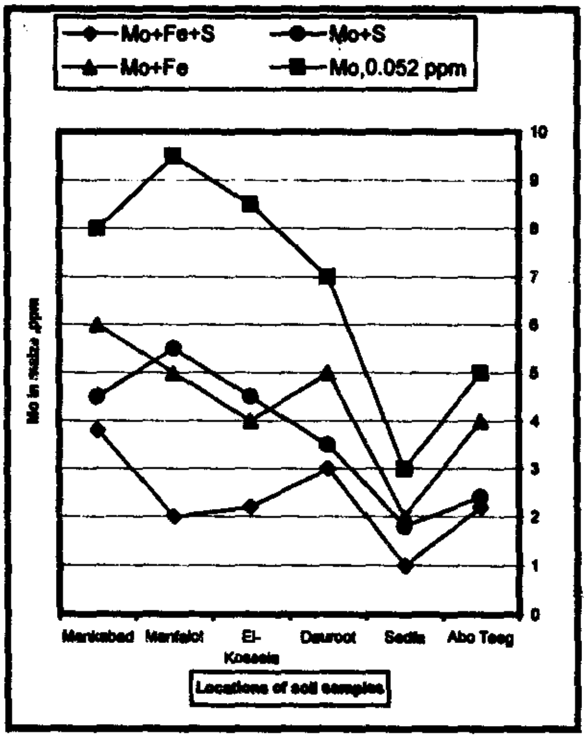

Fig.4. Effect of Fe chelate (Fe-EDDHA) and gypsum on Mo concentration of maize plants grown on the studied soil samples amended with Mo.

The effect of Fe chelate on Mo concentration in the plants was difficult to interpret because large increases in yield were usually associated with added Fe, which could cause a dilution effect on Mo concentration. However, in Sedfa clay soil samples, yield increases were small in response to added Fe chelate, but Fe chelate decreased Mo concentrations in the plants. These data suggest Fe × Mo interaction.

El-Sayed(1999&2001) found that Mo affected Fe levels in tomato. They reported that increasing Mo in the nutrient solution from 0.067 to 6.7 ppm, DM tomato yield decreased from 3.28 to 0.39 g/plant that was correlated with a marked intensification of Fe chlorosis. They suggested that Mo accentuated Fe deficiency because an insoluble Fe molybdate precipitated in the roots. On the other hand, they observed that increased Fe levels of the nutrient solution accentuated Mo deficiency and decreased DM tomato yield.

A marked interaction between Fe and Mo in tomato plants grown in a nutrient culture was observed by Kirsch *et al.* (1960) and El-Sayed(2003a&b) , but the effects of Fe on Mo uptake by the roots differed from the data of Gerloff *et al.* (1959) . Kirsch *et al* (1960) found that molybdenum uptake by roots was decreased, while Mo concentration in leaves was generally increased as Fe was added. They implied that Fe additions stimulated Mo translocation from roots to leaves. However, total Mo uptake by plants decreased with Fe additions. On the other hand Hanger (1965) suggested that Mo blocked Fe movement from the roots to tops and interfered with a metabolic function of Fe. However ,molybdenum can increase Fe uptake at a marginally adequate Mo level, but at a higher levels, Mo decreases Fe uptake (Berry and Reisenauer , 1967; El-Sayed , 2002). Plants deficient in Mo have the least Fe uptake. Iron translocation from the central vein to leaf margins is less in Mo-starved leaves.

B-Evidence of Fe×Mo×S Interaction:

The effect of added gypsum on DM yields and Fe, Mo and S concentrations in maize plants grown on the studied soils is shown for each soil in Table (3). As a consequence of Fe × Mo interaction, gypsum effect would increase the plant's Fe uptake in the plants grown on Dauroot, El-Kosseia, Manfalot and Mankabad soil samples and increase yields in soils with low available Fe.

Iron chelate or gypsum increased DM maize yield produced from most studied soils and their combined treatment increased DM yields over either treatment (Table 3). This response could be related to the gypsum effect in increasing the plant Fe concentration. In contrast, iron chelate increased DM yields much more than gypsum in El-Kosseia, Manfalot and Mankabad soil samples (Table 3). Gypsum additions increased Fe concentration in plants grown on four soil samples as shown in Fig.(1), but it decreased plant Fe concentration in Manfalot and Mankabad soils. Appling gypsum to Sedfa, Abo Teeg and El-Kosseia soils caused increase in the Fe uptake by the plants (Table 3). Apparently, SO_4 caused the effect of Fe in decreasing the Mo concentration in plants,(Table 3 & Fig.3).Gypsum affected plant Mo concentration in all studied soils, with respect of native Mo (Fig. 3), or amended with Mo (Fig. 4) Gypsum may increase Fe uptake by reducing Mo uptake or concentration in the plants.Five of the six soils were deficient in available Fe (all except Abo Teeg) since added Fe chelate increased maize yield and plant Fe concentration was increased from 52 ppm in untreated plants to 60 ppm in gypsum – treated plants (average for gypsum and gypsum + Mo effects). Uptake of Fe (Table 3) increased from 146 μg/pot in the untreated plants to 887 μg/pot in gypsum – treated plants (average for gypsum and gypsum+ Mo effects). These data indicate that Fe supply was increased by added gypsum .

Dry mater yields induced gypsum and (gypsum + Mo) were lower than those with added Fe and (Fe+Mo) for El-Kosseia soil (Table 3). This lower DM yield was probably due to a lower level of available Fe in the soil. Added gypsum increased the Fe concentration from 50 ppm in untreated plants to 56 ppm in gypsum–treated plants (average of gypsum and gypsum+Mo effects) and increased Fe uptake from 175 μg/pot (untreated) to 578 μg/pot by gypsum treated plants. These data indicate that added gypsum caused lower increase in available Fe to a lesser extent in El-Kosseia than in Dauroot soil samples. A possible explanation of soil – plant differences may be related to the relative gypsum effect on plants Mn and Zn higher concentrations in the two soil samples (Table 3). Applying gypsum induced plant, increase levels of Mn and Zn (27 and 42% respectively) levels in El-Kosseia than in Dauroot soils (12 and 10%, respectively).These higher levels may have reduced the physiological effectiveness of Fe in the plants (Olsen, 1972; Faragallah and El-Sayed,2002).

In Manfalot and Mankabad soils , DM yield increased in response to Fe chelate and with added Fe + gypsum but added gypsum gave a small DM yield increase (Table 5). Dry matter Yield data offered no evidence that added gypsum had any effect on available Fe as a result of an Fe×Mo interaction for the Manfalot soil. Iron concentration was less in the SO_4^- treated plants as compared with untreated plants, However, gypsum–treated plants had very large increases in Mn and Zn concentrations (Table 3 and Fig. 5). In Manfalot soil , added gypsum increased plant Zn concentration two folds. High levels of Mn and Zn could have interfered with Fe uptake and its metabolic function in the plant (Brown & Tiffin, 1962; Lingle *et al.*, 1963; Olsen, 1972;Amer *et el.*,2005). Possibly, this large effect of added SO_4^{--} on Mn and Zn uptake decreased the effect of gypsum on Fe uptake. However, Fe uptake was 665 μg/pot for the four treatments with added gypsum as compared with 584 μg/pot for the four treatments adding gypsum. For the Mankabad soil, iron uptake increased from 614 μg/pot in plants without gypsum treatment to 713 μg/pot in plants that received gypsum.

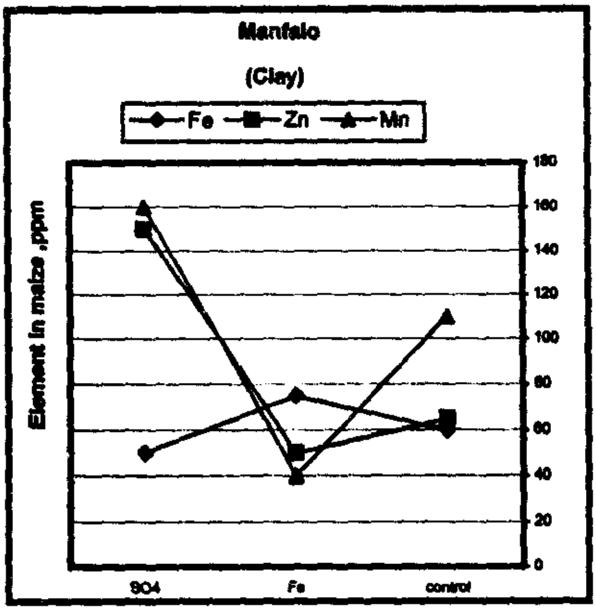

Fig.5. Iron, Mn, and Zn concentrations in maize plants as affected by Fe chelate (Fe-EDDHA) and gypsum treatments in Manfalot (Clay)

Added Fe decreased Mn and Zn concentrations in maize plants (Fig.6). Applying gypsum also increased Fe, Mn and Zn concentrations above those of the untreated plants. Thus, changes in the plant Fe concentration related to added gypsum cannot be evaluated independently from changes in Mn and Zn in plants.

The mechanism by which gypsum increases plant Fe seems to be its effect in decreasing Mo uptake by plants which in turn increases Fe uptake by plant. Another mechanism by which gypsum increases the plant Fe, Mn and Zn concentration could be related to changes in soil pH. Calcium sulfate may lower the pH values which in turn would increase the uptake of these nutrients (Lindsay, 1972; Othman *et al.*, 2004;Atia,2005). The amount of gypsum added (25 ppm S) would produce a solution of 0.006 *M* $CaSO_4$ for a soil water content of

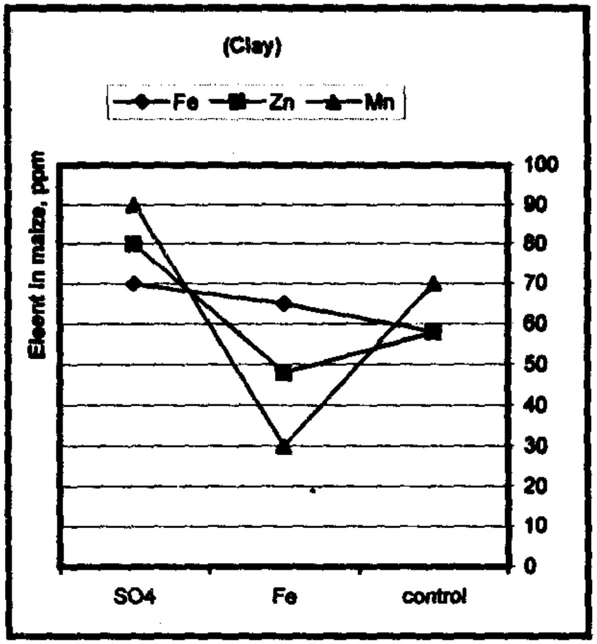

Fig.6. Average Fe, Mn, and Zn concentrations in soils as related to Fe chelate (Fe-EDDHA) and gypsum treatments.

12%. This $CaSO_4$ concentration is quite similar to the concentration of (Ca + Mg) observed in saturation extracts of similar soils. The pH of the saturated paste was measured in the soils after harvesting maize (Table 6). Mean values are shown for treatments 1 and 2 (no SO_4^{--}) and treatments 3, 5, 7 and 8 (with added SO_4^{--}). The pH of Sedfa, Dauroot and El-Kosseia soil samples slightly decreased with adding gypsum. The pH of the other three soils did not change with added gypsum. The pH in the rhizosphere around the roots could have been higher than those measured values on the bulk soil (Riley & Barber, 1969;El-Sayed,2004a&b; Wafaa,2005). The plants absorbed more anions than cations (assuming all N entered roots as NO_3^-) by a factor of 1.4. This excess anion uptake would be balanced in the soil by excretion of HCO_3^- from the roots resulting in higher pH values in the soil near the roots than in the bulk soils.

CONCLUSIONS

The relationship of pH to the mechanism by which gypsum increases plant Fe, Mn and Zn concentration is not consistent for these six soils. The lower pH with added SO_4^{--} in three soils may partially explain the increase in uptake, but additional experiments are needed to confirm whether small changes SO_4^{--} in pH could account for the observed differences in uptake. Data in Table (3) showed that added gypsum consistently increased Fe plant uptake as well as Mn

Table 5. Mean concentrations of Fe, Mn and Zn in maize as affected by treatments in both group of soils*.

Treatment	Four soils (Dauroot,El-Kosseia,Manfalot,Mankabad).				Two soils (Sedfa,Abo Teeg)			
	DM Yield (g/pot)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Yield (g/pot)	Fe (ppm)	Mn (ppm)	Zn (ppm)
0	7.22 a	56.2 b	55.0 c	56.0 c	7.63 a	58.2 cd	100.4 c	56.6 b
S	12.77 b	63.7 c	71.2 d	68.8 d	8.53 ab	50.6 b	129.6 e	102.6 d
Mo	6.97 a	49.7 a	57.0 c	58.0 c	7.77 a	41.9 a	91.3 b	55.3 b
Mo + S	12.54 b	65.1 cd	70.9 d	70.1 d	9.21 b	50.9 b	119.0 d	94.8 c
Fe	12.06 b	67.7 cde	29.2 a	43.9 a	13.39 c	62.2 d	45.7 a	45.4 a
Fe + Mo	12.62 b	68.5 de	31.4 a	43.0 a	13.13 c	57.9 cd	50.5 a	44.3 a
Fe + S	15.48 c	72.2 e	35.5 b	43.4 a	16.41 d	52.9 bc	49.8 a	44.1 a
Fe + Mo + S	15.21 c	72.0 e	36.8 b	46.2 a	16.15 d	57.9 cd	54.3 a	43.8 a

* **Means in a column followed by the same letter do not differ significantly at the 5% level of confidence by Duncan's multiple range test.**

Table 6. Effect of added gypsum on soil pH of the saturated paste after plant harvest.

Soil	pH	
	Control*	Added SO_4 **
Sedfa	9.84	9.33
Abo Teeg	10.60	10.20
Dauroot	9.84	9.03
El-Kosseia	9.68	9.85
Manfalot	9.88	9.08
Mankabad	9.38	9.18

* **Control = mean value for treatments 1 and 2 (Table 2).**
** **Added SO_4 = mean value for treatments 3, 5, 7 and 8 (Table 2).**

and Zn concentration in all six soils . Since added gypsum had no appreciable effect on pH in three soils (< 0.1 pH), a change in pH seems unlikely to be a cause of the increased Fe uptake.

Iron, Mn and Zn will form uncharged ion – pairs with SO_4^{--} in the soil solution (Adams, 1971;Abdel-Mawly and El-Sayed,1999) and the total element concentration in solution would increase, which suggests a mechanism by which SO_4^{--} may also contribute to the increased uptake rate

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الملخص العربي

تأثير الجبس الزراعي والحديد المخلبي و الموليبدنيم على مستوى بعض العناصر الصغرى في الذرة الشامية النامية في بعض أراضي أسيوط

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التفاعل بين بعض العناصر الغذائية مثل تراكم الموليبدنيم Mo في وجـود مسـتوى مـنخفض من الحديد Fe يكون مفيداً جداً في الأراضـي القلوية حيث يلعب pH دوراً هاماً في إنخفاض تيسر Fe وارتفاع تيسر Mo .

عندما يوجد هذا التفاعل فإن ذلك يساعد على تفسير العلاقة والتنـبؤ بإستجابة التربة الفعلية لتيسر الحديد، حيث أن هذا التفاعل يكـون ثابـتاً في الأراضي الستة التي تم دراستها وزراعتها بالذرة الشامية هجين ثلاثي صنف جيزة ٣١٠ "Maize (*Zea mays* L.) three ways cross variety Giza 310".

أوضحت النتائج ما يلي :

- عـند إضافة الجبس الزراعي عندS 25 ppm حدث إزدياد في تركيز Fe(من 57 ppm إلى 65 ppm) بينما حدث تناقص في تركيز Mo (من 2.41 ppm إلى 1.26 ppm).
- عـند إضـافة الجـبس الزراعي حدث تناقص لـ Mo من 2.41 ppm إلى 1.26 ppm بينما حدث زيادة في تركيز Fe من 57 ppm إلى 65 ppm في نباتات الذرة الشامية .
- الـزيادة في تركيز Mo عن المستوى الطبيعي يصاحبه نقص في تركـيز Fe مـن 57 ppm إلى 51 ppm، بينما كان إمتصاص الحديـد يتراوح مابين ٤١٨ إلى ٣٦٩ ميكروجرام/ إصيص في نباتات الذرة الشامية.
- حدثـت زيـادة في تركيز Mn من 70 ppm إلى 71 ppm، وتركيز Zn من 56 ppm إلى 80 ppm في نباتات الذرة الشامية عند اضافة الجبس الزراعي بمعدل 25 ppm S.