RESPONSE OF SOYBEAN PLANTS GROWN ON A CALCAREOUS SOIL TO INORGANIC AND CHELATED IRON SOURCES UNDER SURFACE APPLIED SULPHURIC ACID AS ACIDIFING AMENDMENT

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ABSTRACT

A field experiment was conducted on a calcareous soil at Abou Massoud village (48 km south-west to Alexandria) to evaluate the effect of soil and foliar application of inorganic and chelated iron sources [i.e., $FeSO_4$, Ferrous ammonium sulphate (FAS), Fe-EDTA and Fe-EDDHA] under applied sulphuric acid at the rates of 0 and 20mL H_2SO_4 / m^3 irrigation water as acidifing amendment on soil pH, HCO^-_3 and available Fe in soil as well as photosynthetic pigments, some micronutrients content , soybean yield and its components.

The results indicated that soil pH values and HCO^-_3 concentration in soil showed no significant changes due to the addition of all Fe sources, while the decrease in soil pH values and HCO^-_3 occurred only in the treatments received H_2SO_4. The soil-applied Fe sources and/or H_2SO_4 resulted in a pronounced increase in the soil Fe availability with superiority of Fe-EDDHA. Chlorophyll a, b and carotenoids in leaves significantly increased as a result of applied Fe sources , especially under H_2SO_4, and foliar application gave higher values than those occurred by the soil applied Fe sources. Fe concentration in leaves was positively affected upon the application of all Fe sources, and the treatments receiving H_2SO_4 surpassed unamended ones. Zn and Mn concentrations in soybean leaves had an adverse behavior of Fe concentration, and decreased under the application of all Fe sources and H_2SO_4. This decrease may be due to the antagonistic relationship between Fe and both Zn and Mn.

The beneficial effect of the studied Fe sources and H_2SO_4 as acidifying amendment was positively reflected on increasing soybean yield and its components. Such effect could be attributed to the important role of Fe element in many physiological processes in plant. Concerning soil application of Fe sources , Fe-EDDHA recorded the greatest values of soybean yield and its components compared to the other Fe sources , and Fe sources could be arranged upon their effectiveness in the descending order :

Fe-EDDHA > Fe-EDTA > FAS=$FeSO_4$. Moreover, foliar application of Fe sources produced higher values than those obtained by the soil applied Fe sources, and the former surpassed the latter (irrespective of Fe sources) by 8.53, 4.44 and 7.19% for number of pods plant^{-1}, weight of 100 seeds and seed yield, respectively.

Generally, the greatest values of the aforementioned parameters were produced under the combined application of the soil applied H_2SO_4 with the foliar application of Fe sources.

Key words: Calcareous soil, Inorganic iron, Chelated iron, Sulphuric acid, Soybean.

INTRODUCTION

Iron is an essential element for many plant functions. Some of them are: it is a catalyst to chlorophyll function in plants. Also, Iron is a component in several molecules that are involved in plant respiration and photosynthesis. The enzyme nitrogenase, involved in nitrogen fixation, also contains iron.

Iron chlorosis affects plant in many areas throughout the world, but it is especially evident in crops grown on calcareous soils. Dudal (1977) estimated that up to 39% of the world land surface is a calcareous, and therefore, might be susceptible to Fe deficiencies. Actual occurrence of Fe chlorosis is much lower because of climate, management and choice of Fe-efficient crops in these regions.

Most of Fe deficiencies occur on high pH soils, especially on calcareous soils. The major cause for Fe deficiencies is the very low solubility of Fe oxides. Concentration of Fe species in soil solution range from 0.1 to 10% of that needed for plant nutrition, particularly in calcareous soil (Lindsay, 1984). The primary factor associated with Fe chlorosis under calcareous condition appears to be the effect of the bicarbonate ion (HCO^-_3) in reducing Fe uptake and translocation to leaves.

Susceptibility to Fe chlorosis depends on a plant's response to Fe deficiency stress, which is controlled genetically. Soybean is particularly inefficient in using iron compared to other crops. Whereas, crops like wheat and barley are efficient in taking up iron, and seldom show iron chlorosis. Fields that have produced excellent yields of wheat and barley may have a problem with soybeans (Goos, 1998). Foliar application of iron can be effective treatment, says Goos (1998) who added that leaf absorption of iron is good, and re-greeing of plants is often rapid if the plants are not already too sick. The treatment must be done early to be effective.

Foliar spray application are widely used to correct Fe chlorosis because soil application of most Fe sources particularly in the form of inorganic sources generally are not very effective unless applied very frequently at high rates (Patricia,2000). Rates providing 1 – 3 kg / ha of Fe resulted in increased yields of grain sorghum and corn, and foliar application were more effective than soil application (Anon, 1980). One spray application of $FeSO_4$ (20 – 40 g / L) applied at 140 – 280 L / ha correct mild chlorosis, but several applications were needed to correct several chlorosis (Matocha, 1984). In addition, Mortvedt (1991) reported that correcting of Fe chlorosis is done mainly by foliar spray because soil application generally have a limited effect, especially for annual crops, he also added that inorganic Fe sources applied to soils react rapidly to forms which are not as available to plant; ferrous Fe is oxidized to the ferric form in well-aerated soils, particularly as soil pH increases. Several synthetic chelates and organic complexes have been used with varying success.

Moreover, Fe chelates were evaluated by Mortvedt (1986) who indicated that soil application of Fe DTPA is effective only in acid soils while FeEDDHA is effective at all soil pH levels. Only about 60% of the Fe DTPA remains chelated at pH 7.5, while all of the Fe in Fe EDDHA remains chelated at all pH levels. Less than 5% of the Fe EDTA remains chelated at pH 7.5, which explains the low effectiveness of this chelate in calcareous soils. The effectiveness of four iron sources, i.e. Fe EDDHA, Fe DTPA, Fe EDTA and $FeSO_4$ to correct lime induced chlorosis of peanut were tested on calcareous soils. Fe EDDHA was the most effective source in correcting Fe chlorosis, whears, $FeSO_4$ was the least effective one (Papastylianou, 1990). Ferrous ammonium sulphate $[(NH_4)_2$

Fe $(SO_4)_2.6H_2O$] was more effective than $FeSO_4$ for grain sorghum (Mortvedt, 1982 and Jerry, 1999). Abd El-Halem *et al*. (2008) found significant increases in soybean yield and Fe concentration in plants upon application of $FeSO_4$ and Fe EDDHA in calcareous soil and Fe EDDHA was superior to Fe SO_4.

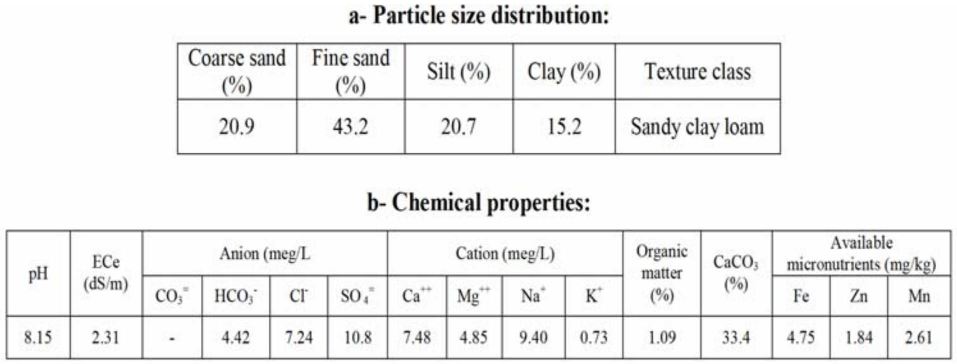
As Fe availability in calcareous soils is influenced by pH, a reduction in soil pH through the use of acidifying amendment should, theoretically, eliminate Fe chlorosis. Soil acidification sometimes is necessary for optimum plant growth and is best performed prior to planting; it is much more difficult in established plantings (Horneck *et al*., 2004). Application of H_2SO_4 to soil decreased the soil pH, $CaCO_3$ content and HCO^-_3 concentration and iron chlorosis was corrected. Chlorophyll and Fe content of leaf samples showed a significant increase over the control (Kalbasi *et al*.,1986 and Koteswara Rao *et al*., 2001).

The objective of this research was to study the effect of soil and foliar application of iron sources under the application of sulphuric acid as acidifying amendment on soil pH, HCO^-_3 and available Fe in soil as well as plant pigments content, micronutrients content and soybean yield.

MATERIALS AND METHODS

A field experiment was conducted during the summer season of 2009 on a calcareous soil at Abou Masooud farm (48 km south-west to Alexandria), Alexandria Governorate, Egypt. The initial physical and chemical properties of the studied soil were determined according to the standard methods as described by Piper (1950) and Black (1965) , and are presented in Table (1).

Table (1): Some physical and chemical properties of the soil under investigation



a- Particle size distribution:

Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Texture class
20.9	43.2	20.7	15.2	Sandy clay loam

b- Chemical properties:

pH	ECe (dS/m)	Anion (meg/L				Cation (meg/L)				Organic matter (%)	$CaCO_3$ (%)	Available micronutrients (mg/kg)		
		$CO_3^=$	HCO_3^-	Cl^-	$SO_4^=$	Ca^{++}	Mg^{++}	Na^+	K^+			Fe	Zn	Mn
8.15	2.31	-	4.42	7.24	10.8	7.48	4.85	9.40	0.73	1.09	33.4	4.75	1.84	2.61

Soybean grains variety Giza 35 were sown in plots with an area of 10.5 m^2 of (3 x 3.5 m). The experiment was designed in a split plot design with three replicates. The treatments included two rates of sulphuric acid, i.e. 0 and 20mL H_2SO_4 / m^3 irrigation water which applied to soil during the agricultural growing season. While iron was applied in four sources namely, ferrous sulphate of 20% Fe ($FeSO_4.7H_2O$), Ferrous ammonium sulphate of 14% Fe [$(NH_4)_2$ Fe $(SO_4)_2.6H_2O$] , Fe-EDTTA (10%Fe) and Fe-EDDHA (6%Fe) as soil application at the rate of 10 mg Fe / kg soil in one dose before sowing or foliar application at the rate of 0.5 g Fe / L after three weeks from sowing and repeated at 10 days intervals till the pre-flowering stage.

Nitrogen as ammonium sulphate (20.5%N), phosphorus as superphosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O) were uniformly applied at the rate of 20, 30 and 50 kg/fed, respectively. All the agricultural recommended practices were followed as usual including the irrigation processes.

Photosynthetic pigments:

Photosynthetic pigments (chlorophyll a, b and carotenoides) were extracted from the fourth upper leaves at 70 days age using acetone 85% and determined colorimetrically according to the method described by Wettstein (1957).

Determination of micronutrients in soybean plants:

Samples from the fourth leaves at 70 days age were also taken, dried, ground and digested using H_2SO_4 and H_2O_2 according to Parkinson and Allen (1975). Fe, Mn and Zn were determined using the Atomic Absorption Spectrophotometer (Chapman and Pratt, 1961).

Soil analysis:

Soil samples were collected from all experimental plots after 70 days from sowing. Soluble bicarbonates were determined by titration (Richards, 1954). Soil pH were determined in 1:2.5 (soil:water) suspension using Beckman pH meter (Jackson,1973). Available Fe in soil was extracted using ammonium bicarbonate-DTPA as described by Soltanpour and Schwab (1977).

Statistical analysis:

All obtained data were statistically analyzed and compared by using least significant differences (L.S.D.) according to the procedure described by Gomez and Gomez (1984).

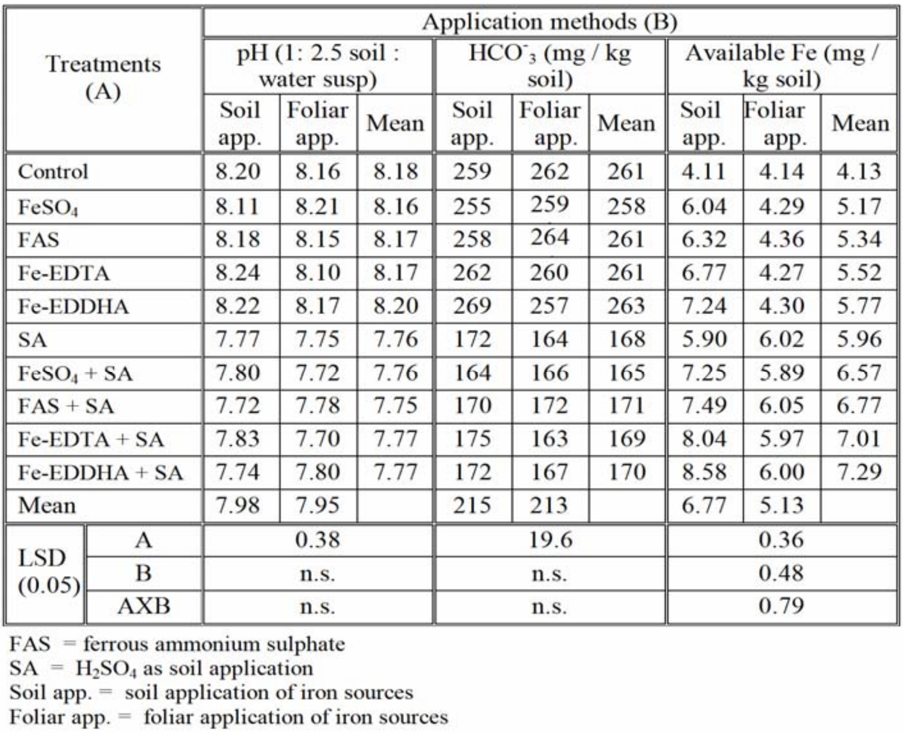
RESULTS AND DISCUSSION

Soil pH, HCO^-_3 and DTPA-extractable Fe in soil:

Data in Table (2) showed that soil pH and HCO^-_3 concentration in soil were significantly decreased due to H_2SO_4 application as compared to those treatments with no H_2SO_4 addition. Otherwise, no significant changes were occurred in pH values and HCO^-_3 content upon the addition of all iron sources.

The important role of acid application in reducing both of soil pH and bicarbonate concentration was reported by Koteswara Rao *et al*., 2001.

Table (2): Effect of applied iron sources in different application methods and sulphuric acid on pH. HCO^-_3 and DTPA- extractable Fe at 70 days after sowing.



Treatments (A)		Application methods (B)								
		pH (1: 2.5 soil : water susp)			HCO^-_3 (mg / kg soil)			Available Fe (mg / kg soil)		
		Soil app.	Foliar app.	Mean	Soil app.	Foliar app.	Mean	Soil app.	Foliar app.	Mean
Control		8.20	8.16	8.18	259	262	261	4.11	4.14	4.13
$FeSO_4$		8.11	8.21	8.16	255	259	258	6.04	4.29	5.17
FAS		8.18	8.15	8.17	258	264	261	6.32	4.36	5.34
Fe-EDTA		8.24	8.10	8.17	262	260	261	6.77	4.27	5.52
Fe-EDDHA		8.22	8.17	8.20	269	257	263	7.24	4.30	5.77
SA		7.77	7.75	7.76	172	164	168	5.90	6.02	5.96
$FeSO_4$ + SA		7.80	7.72	7.76	164	166	165	7.25	5.89	6.57
FAS + SA		7.72	7.78	7.75	170	172	171	7.49	6.05	6.77
Fe-EDTA + SA		7.83	7.70	7.77	175	163	169	8.04	5.97	7.01
Fe-EDDHA + SA		7.74	7.80	7.77	172	167	170	8.58	6.00	7.29
Mean		7.98	7.95		215	213		6.77	5.13	
LSD (0.05)	A	0.38			19.6			0.36		
	B	n.s.			n.s.			0.48		
	AXB	n.s.			n.s.			0.79		

FAS = ferrous ammonium sulphate
SA = H_2SO_4 as soil application
Soil app. = soil application of iron sources
Foliar app. = foliar application of iron sources

Regarding the effect of applied iron sources and H_2SO_4 on the DTPA-extractable Fe (Table 2) resulted revealed that soil application of all iron sources caused pronounced increases in DTPA- extractable Fe**.** Fe-EDDHA recorded the highest value of DTPA- extractable Fe as compared with the other Fe sources. Fe sources could be arranged upon their effectiveness in the following order : Fe-EDDHA> Fe-EDTA > Ferrous ammonium sulphate (FAS) = $FeSO_4$. Mortvedt (1991) reported that inorganic Fe sources applied to soil react rapidly to forms which are not as available to plant; ferrous Fe is oxidized to the ferric form in well-aerated soils, particularly as soil pH increases, and several synthetic chelates and organic complexes have been used with varying success. Moreover, Finck (1982) mentioned that chelates are synthetic organic compounds that contain Fe in a complex form and protect it from reacting in the soil and forming insoluble precipitates and plants can take up the soluble chelate as complete molecules and then metabolize the metal. On the other hand, DTPA-extractable Fe in soil revealed no significant changes due to foliar application of all iron sources.

Sulphuric acid application to soil was associated with significant increases in DTPA-extractable Fe. The combined application of H_2SO_4 and Fe recorded higher values in respect to DTPA-extractable Fe as compared to the treatments received solely application of iron, and the greatest value of DTPA-extractable Fe (8.58 mg / kg soil) was obtained under the treatment of Fe-EDDHA + H_2SO_4. These findings are in agreement with those of Khorsandi (1994) and Koteswara Rao *et al.* (2001) who found that surface applied acid significantly increased DTPA-extractable Fe in calcareous soils from deficient levels to adequate levels and that may likely attributed to the decrease in pH because availability of Fe is pH dependent.

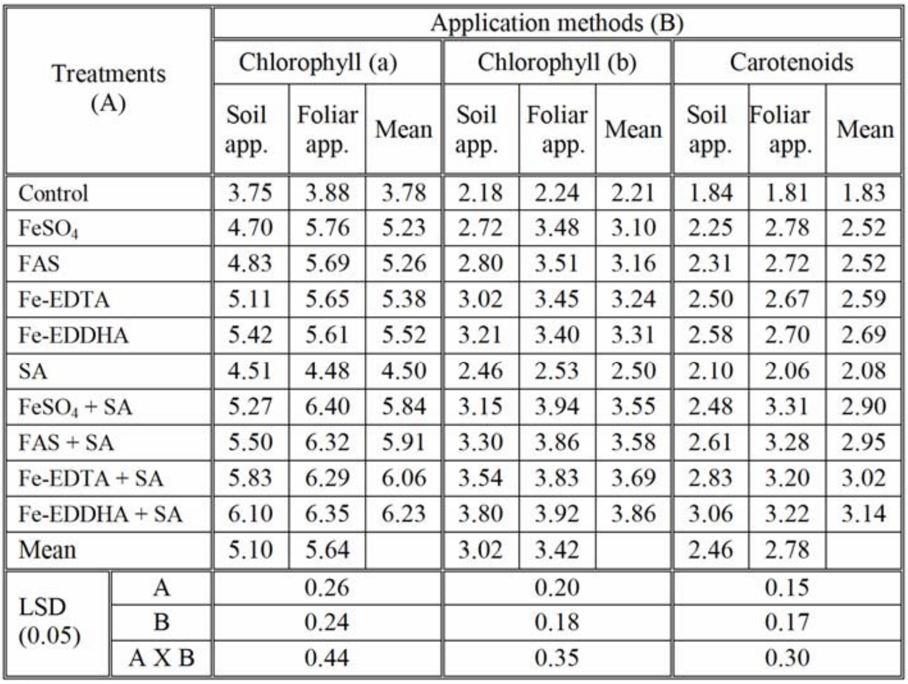
Photosynthetic pigments in soybean leaves:

The content of photosynthetic pigments in soybean leaves at 70 days age as affected by the application of iron sources and sulphuric acid is presented in Table (3). Data demonstrated that all photosynthetic pigments (chlorophyll a, b and carotenoids) were significantly increased due to the different iron sources in both soil and foliar application. The impact of Fe-treatments might be due to the essential role of Fe in the redox reaction of chloroplasts, in the mechanisms of photosynthetic electron transfere and also in the formation of heme and nonheme proteins that are concentrated in chloroplasts (Iturbe-Ormaetxe *et al*., 1995 and Nassar *et al*., 2000).

Among the soil application of the four Fe sources, Fe-EDDHA found to be superior over the other Fe sources followed by Fe-EDTA then FAS and $FeSO_4$ which could be ranked in the same order. This trend holds true for all photosynthetic pigments. These results are nearly similar to those obtained by Reed *et al*. (1988) on peach trees and Heitholt *et al*. (2003) on soybean.

Foliar application of all Fe sources produced higher values in respect to photosynthetic pigments than those occurred by the soil-applied Fe sources. The former application method surpassed the latter (irrespective of Fe sources) by 10.6, 13.2 and 13.0% regarding chlorophyll a, b and carotenoids, respectively. In addition, Fe sources did not differ significantly in their effect with regard to the aforementioned parameters.

Table (3): Effect of applied iron sources in different application methods and sulphuric acid on photosynthetic pigments (mg / g dry weight) in soybean leaves at 70 days age.



Treatments (A)		Application methods (B)								
		Chlorophyll (a)			Chlorophyll (b)			Carotenoids		
		Soil app.	Foliar app.	Mean	Soil app.	Foliar app.	Mean	Soil app.	Foliar app.	Mean
Control		3.75	3.88	3.78	2.18	2.24	2.21	1.84	1.81	1.83
$FeSO_4$		4.70	5.76	5.23	2.72	3.48	3.10	2.25	2.78	2.52
FAS		4.83	5.69	5.26	2.80	3.51	3.16	2.31	2.72	2.52
Fe-EDTA		5.11	5.65	5.38	3.02	3.45	3.24	2.50	2.67	2.59
Fe-EDDHA		5.42	5.61	5.52	3.21	3.40	3.31	2.58	2.70	2.69
SA		4.51	4.48	4.50	2.46	2.53	2.50	2.10	2.06	2.08
$FeSO_4$ + SA		5.27	6.40	5.84	3.15	3.94	3.55	2.48	3.31	2.90
FAS + SA		5.50	6.32	5.91	3.30	3.86	3.58	2.61	3.28	2.95
Fe-EDTA + SA		5.83	6.29	6.06	3.54	3.83	3.69	2.83	3.20	3.02
Fe-EDDHA + SA		6.10	6.35	6.23	3.80	3.92	3.86	3.06	3.22	3.14
Mean		5.10	5.64		3.02	3.42		2.46	2.78	
LSD (0.05)	A	0.26			0.20			0.15		
	B	0.24			0.18			0.17		
	A X B	0.44			0.35			0.30		

See footnotes Table 2 for treatment designations.

Concerning H_2SO_4 application, results showed pronounced increases in all photosynthetic pigments and the treatments receiving H_2SO_4 surpassed H_2SO_4 unamended treatments in respect to the photosynthetic pigments. In this concern, the higher values of chlorophyll a, b and carotenoids were occurred under the combined application of Fe sources in foliar application and H_2SO_4.These results are in accordance with those reported by Kalbasi *et al*., (1986) on quince trees and Koteswara Rao *et al*. (2001) on groundnut.

Iron content in soybean leaves:

Data presented in Table (4) revealed that Fe concentration in leaves increased considerably upon application of all Fe sources in both application methods. With regard to the soil-applied Fe sources, they significantly differ in their effect on Fe concentration with superiority of Fe-EDDHA over the other Fe sources and followed in the order of effectiveness by Fe-EDTA>FAS> $FeSO_4$. Heitholt *et al*. (2003) and Abd El-Halem *et al*. (2008) found a pronounced increase in Fe concentration in soybean leaves due to the application of Fe-EDDHA and $FeSO_4$ to the calcareous soil and Fe-EDDHA was superior to $FeSO_4$.

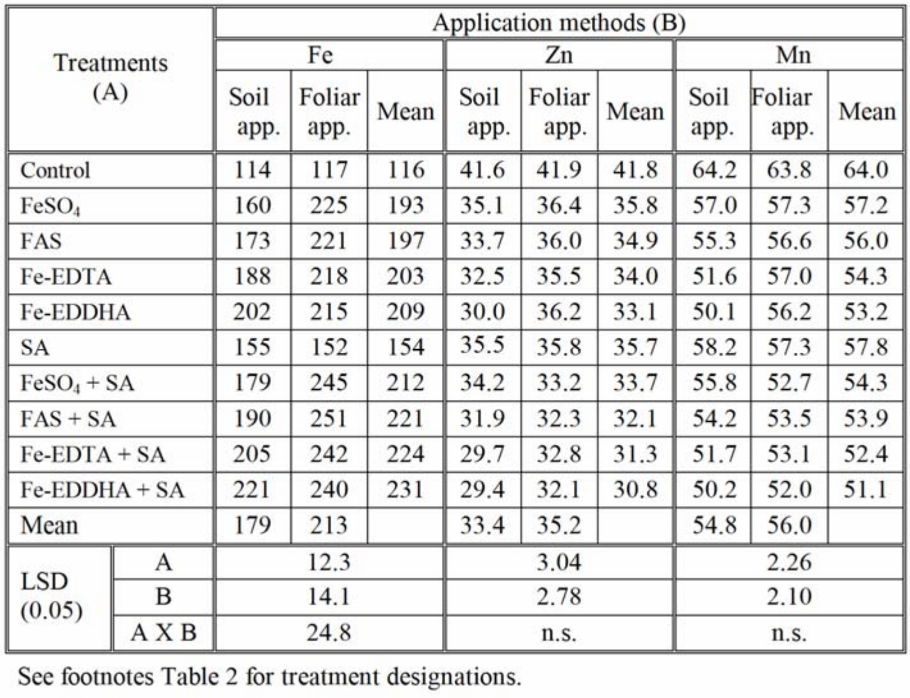
Foliar application of Fe sources was a better application method compared with soil application since it gave a higher Fe concentration in plant leaves, and the former application method surpassed the latter (regardless of Fe sources) by 19.0%. Furthermore, the iron sources were almost similar in their effect regarding Fe concentration. Similar results were reported by Horneck *et al*. (2004).

Sulphuric acid application had a significant positive effect on Fe concentration in soybean leaves and treatments received H_2SO_4 scored higher values as compared to those treatments with no H_2SO_4 addition. In this respect, the combined addition of H_2SO_4 with foliar application of Fe sources produced the highest values of Fe concentration.

Zinc and Mn contents in soybean leaves:

Results in Table (4) showed that Zn and Mn concentrations in soybean leaves had an adverse behavior of Fe concentration. Zn and Mn concentrations significantly decreased due to the application of Fe sources in both soil and foliar applications. The decrease in Zn and Mn concentrations is an indication of the antagonistic relationship between Fe and both Zn and Mn. According to Guzman and Ramero (1988) antagonism between nutrients may occur as a results of one or more of the following: (1) on nutrient may compete with another at the site of its function for incorporation into active site; (2) one nutrient may substitute for another on the absorption sites and (3) one nutrient may be required for the assimilation or metabolism of another.

Table (4): Effect of applied iron sources in different application methods and sulphuric acid on some micronutrient concentrations (mg / kg) in soybean leaves.



Treatments (A)		Application methods (B)								
		Fe			Zn			Mn		
		Soil app.	Foliar app.	Mean	Soil app.	Foliar app.	Mean	Soil app.	Foliar app.	Mean
Control		114	117	116	41.6	41.9	41.8	64.2	63.8	64.0
$FeSO_4$		160	225	193	35.1	36.4	35.8	57.0	57.3	57.2
FAS		173	221	197	33.7	36.0	34.9	55.3	56.6	56.0
Fe-EDTA		188	218	203	32.5	35.5	34.0	51.6	57.0	54.3
Fe-EDDHA		202	215	209	30.0	36.2	33.1	50.1	56.2	53.2
SA		155	152	154	35.5	35.8	35.7	58.2	57.3	57.8
$FeSO_4$ + SA		179	245	212	34.2	33.2	33.7	55.8	52.7	54.3
FAS + SA		190	251	221	31.9	32.3	32.1	54.2	53.5	53.9
Fe-EDTA + SA		205	242	224	29.7	32.8	31.3	51.7	53.1	52.4
Fe-EDDHA + SA		221	240	231	29.4	32.1	30.8	50.2	52.0	51.1
Mean		179	213		33.4	35.2		54.8	56.0	
LSD (0.05)	A	12.3			3.04			2.26		
	B	14.1			2.78			2.10		
	A X B	24.8			n.s.			n.s.		

See footnotes Table 2 for treatment designations.

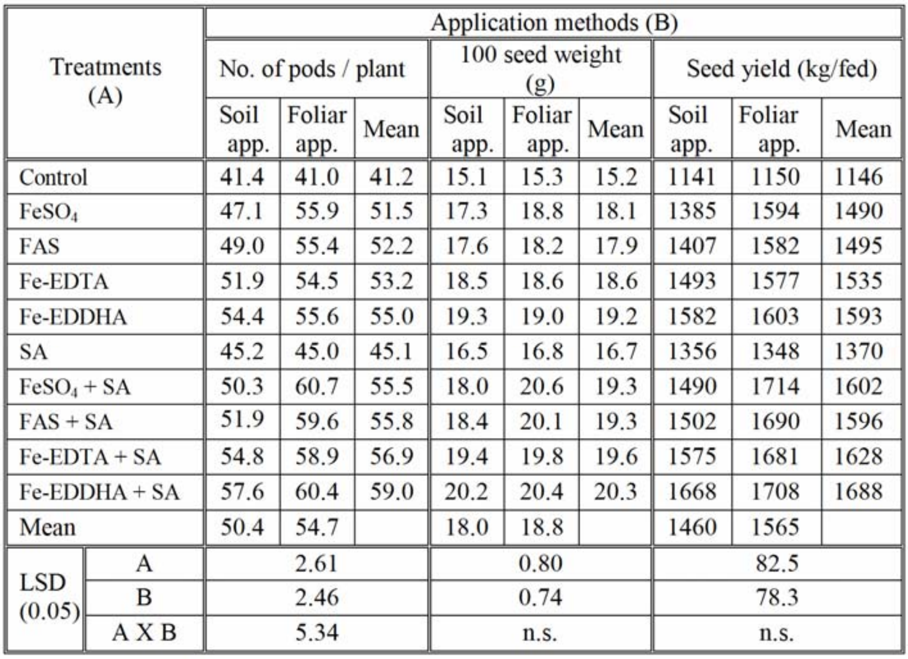
With regard to the soil application of Fe sources (irrespective of H_2SO_4 application), values of Zn concentration decreased from being 41.6 mg / kg (control) to 35.1, 33.7, 32.5 and 30.0 mg / kg and Mn concentration decreased from being 64.2 (control) to 57.0, 55.3, 51.6 and 50.1 mg / kg due to application of FeSO4, FAS, Fe-EDTA and Fe-EDDHA, respectively. These results agree with those of Abd El-Halem *et al*. (2008) who reported that the addition of Fe-EDDHA and $FeSO_4$ to a calcareous soil cultivated with soybean resulted in a decrease in each of Zn and Mn concentrations in soybean leaves and attributed it to the antagonistic effect between Fe and both Zn and Mn. With respect to the foliar application of Fe sources, results showed higher values for Zn and Mn concentrations than those occurred by the soil- applied Fe sources. In addition, Fe sources did not differ significantly in their effect regarding Zn and Mn concentrations.

Application of H_2SO_4 showed a significant decrease in Zn and Mn concentrations, and the values obtained under the combined application of H_2SO_4 and Fe sources were lower to some extent than those recorded under the solely application of Fe.

Seed yield and yield components:

Data in Table (5) showed that the addition of Fe sources in both soil and foliar application significantly augmented number of pods plant^{-1}, weight of 100 seeds and seed yield. Regarding soil application of Fe sources, Fe-EDDHA recorded the highest values of the aforementioned parameters compared to the other Fe sources.

Table (5): Effect of applied iron sources in different application methods and sulphuric acid on yield and yield components of soybean.



Treatments (A)		Application methods (B)								
		No. of pods / plant			100 seed weight (g)			Seed yield (kg/fed)		
		Soil app.	Foliar app.	Mean	Soil app.	Foliar app.	Mean	Soil app.	Foliar app.	Mean
Control		41.4	41.0	41.2	15.1	15.3	15.2	1141	1150	1146
$FeSO_4$		47.1	55.9	51.5	17.3	18.8	18.1	1385	1594	1490
FAS		49.0	55.4	52.2	17.6	18.2	17.9	1407	1582	1495
Fe-EDTA		51.9	54.5	53.2	18.5	18.6	18.6	1493	1577	1535
Fe-EDDHA		54.4	55.6	55.0	19.3	19.0	19.2	1582	1603	1593
SA		45.2	45.0	45.1	16.5	16.8	16.7	1356	1348	1370
$FeSO_4$ + SA		50.3	60.7	55.5	18.0	20.6	19.3	1490	1714	1602
FAS + SA		51.9	59.6	55.8	18.4	20.1	19.3	1502	1690	1596
Fe-EDTA + SA		54.8	58.9	56.9	19.4	19.8	19.6	1575	1681	1628
Fe-EDDHA + SA		57.6	60.4	59.0	20.2	20.4	20.3	1668	1708	1688
Mean		50.4	54.7		18.0	18.8		1460	1565	
LSD (0.05)	A	2.61			0.80			82.5		
	B	2.46			0.74			78.3		
	A X B	5.34			n.s.			n.s.		

See footnotes Table 2 for treatment designations.

Values of the relative increase of number of pods plant^{-1}, weight of 100 seeds and seed yield due to the application of Fe-EDDHA (regardless of H_2SO_4 application) were 32.1, 27.8 and 38.7%, respectively over the control treatment. Fe sources could be arranged upon their effectiveness (regarding the aforementioned parameters) in the descending order: Fe-EDDHA > Fe-EDTA > FAS = $FeSO_4$. The enhancing effect of iron on soybean yield and its components could be attributed to the important role of this element in enzymes activation, metabolism of proteins, and also Fe is characteristic by its ability to undergo oxidation-reduction reactions and to form a component of chlorophyll, which in turn encourages plant to convert light energy to metabolites. These results were in agreement with those obtained by Morvedt (1986) on sorghum, Nassar (2000) on faba bean and Abd El-Halem (2008) on soybean.

Concerning the foliar application of Fe sources, results showed higher values in respect to soybean yield and its components than those obtained by the soil-applied Fe sources, and the former application method surpassed the latter(irrespective of Fe sources) by 8.53, 4.44 and 7.19% regarding number of pods plant^{-1}, weight of 100 seeds and seed yield , respectively. Fe sources were almost similar in their effects with regard to the aforementioned parameters. These results agree with those of Rehm (2005) who found that the foliar application of three iron materials ($FeSO_4$, Fe-DTPA and Fe-EDDHA) resulted in a pronounced increase in soybean yield over the control treatment, and these iron materials did not differ significantly in their effect regarding soybean yield.

Application of H_2SO_4 showed a significant positive effect on each of number of pods plant^{-1}, weight of 100 seeds and seed yield , and treatments received H_2SO_4 recorded higher values as compared to those treatments with no H_2SO_4 addition, and such positive effect was occurred under all Fe sources. In this concern, the greatest values of the aforementioned parameters were produced by the combined application of H_2SO_4 with foliar application of Fe sources. These results agree with those obtained by Kalbasi *et al.* (1986).

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استجابة نباتات فول الصويا النامية فى أرض جيرية لمصادر من الحديد المعدنى والمخلبى تحت الإضافة السطحية لحامض الكبريتيك كمعالج حامضى

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أجريت تجربة حقلية فى أرض جيرية بقرية أبو مسعود جنوب الأسكندرية ب 48 كم وذلك لتقييم مصادر مختلفة من الحديد فى صورتيه المعدنية (كبريتات الحديدوز و كبريتات الحديدوز الأمونيومية) والمخلبية (Fe-EDTA and Fe-EDDHA) عن طريق الإضافة الأرضية والرش إما فى صورة معاملات منفردة أو مشتركة مع الإضافة الأرضية لحامض الكبريتيك بمعدل (20 mL H_2SO_4 / m^3 irrigation water) كمحسن أرضى لتحميض التربة-وتأثير ذلك على رقم حموضة التربة وتركيز آيون البيكربونات والحديد الميسر فى التربةوكذلك على إنتاجية محصول فول الصويا ومحتوى الأوراق من صبغات التمثيل الضوئى وعناصر الحديد والزنك والمنجنيز.

وقد أظهرت النتائج المتحصل عليها أن إضافة حامض الكبريتيك أدت إلى خفض ال soil pH فى التربة وتركيز آيون البيكربونات. بينما لم تتاثر قيم الpH وتركيز آيون البيكربونات بأى من مصادر الحديد المختلفة، كما أدت الإضافة الأرضية لكلا من صور الحديد المختلفة و حامض الكبريتيك إلى زيادة ملحوظة فى الحديد الميسر مع تفوق ال Fe-EDDHA فى هذه الزيادة على مصادر الحديد الأخرى. علاوة على ذلك فقد أدت الإضافة الأرضية والرش لكل من مصادر الحديد المختلفة وكذلك حامض الكبريتيك إلى زيادة معنوية فى محتوى الأوراق من صبغات التمثيل الضوئى (كلوروفيل a و كلوروفيلb والكاروتين) وكذلك الحديد مع تفوق الإضافة عن طريق الرش لمصادر الحديد المختلفة. من الناحية الأخرى أثرت إضافة كلا من مصادر الحديد و حامض الكبريتيك تأثيرا سلبيا على محتوى الأوراق من عناصر الزنك والمنجنيز وهذا نتيجة للعلاقة التضادية بين الحديد وكلا من الزنك والمنجنيز.

وقد إنعكست تلك التأثيرات المفيدة للمعاملات تحت الدراسة بصورة ايجابية على زيادة كل من محصول بذور فول الصويا ومكوناته ، ومن الممكن ان نعزو التأثيرات الإيجابية لمصادر الحديد المختلفة إلى الدور الهام لعنصر الحديد فى العديد من المعاملات الفسيولوجية فى النبات. وبالنظر إلى الإضافة الأرضية لمصادر الحديد فقد سجل Fe-EDDHA قيم أعلى لمحصول البذور ومكونات المحصول لفول الصويا مقارنة بمصادر الحديد الأخرى، ومن الممكن ترتيب مصادر الحديد المختلفة تبعا لتأثيرها الايجابى كما هو موضح فى الترتيب التنازلى التالى:

Fe-EDDHA > Fe-EDTA > Ferrous ammonium sulphate = $FeSO_4$

علاوة على ذلك فقد أعطت الإضافة عن طريق الرش لمصادر الحديد المختلفة قيم أعلى للمحصول ومكوناته عنها فى حالة الإضافة الأرضية، وويؤكد ذلك تفوق الإضافة بالرش عنها فى حالة الإضافة الأرضية (بغض النظر عن مصادر الحديد) بنسب 8.53 ، 4.44 ، 7.19% لكل من عدد القرون/نبات ، وزن 100 بذره ، محصول الحبوب على التوالى.

وعموما فقد تحققت أعلى القيم لكل من المتغيرات السابق ذكرها تحت الإضافة المزدوجة لكل من حامض الكبريتيك مع الإضافة بالرش لمصادر الحديد المختلفة.