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EFFICIENCY OF Fe AND Mn APPLICATION METHODS AND LEVELS ON GROWTH, YIELD, YIELD COMPONENTS AS WELL AS NUTRIENT CONTENT O F WHEAT PLANTS

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ABSTRACT : *In order to study the effects of application methods and added levels of iron (Fe) and manganese (Mn) on quantitative and qualitative characteristics of wheat, two field experiments in three factors, i.e. micronutrients (without, iron and manganese) methods of application (grain soaking, soil and foliar application) and added levels (low, medium and high) in form of randomized complete design with four replications and nineteen treatments (1+2X3X3) were conducted at Sids of Agricultural Research Station , A.R.C. Beni Swif Governorate . Variance analysis and comparing the means showed that , irrespective of methods and levels application of iron and manganese surpassed the check treatment in their effect on growth, yield and its components as well as nutrient content and uptake in grains and straw, except 1000- grain weight which was not effect . However manganese concentration was significantly decreased due to iron application . Maximum dry weight , number of spikes / m^2 number of grains / spike , grain and N, P, K and Fe concentration and uptake belonged to the spraying ferrous sulphate with a concentration of 0.2 % . In general, foliar spraying surpassed the other two methods with all studied parameters. Moreover, soil application gave significant effect as soaking treatment . Also, the results indicate that using Fe and Mn at the medium level (0.2 % as iron or manganese sulphate in foliar or soaking methods and 5 kg Fe or Mn sulphate / fed in soil application) gave highest values of the studied parameters comparing with low or high added levels . Finally , as foliar application at rate of 0.2 % iron sulphate improved wheat quality and quantity of wheat plant.*

Key words : *Wheat , Iron, Manganese, Soaking, Foliar, Soil Application, Levels, Growth, Yield and Nutrient Content*

INTRODUCTION

Micronutrients often act as co-factors in enzyme systems and participate in redox reaction, in addition to having several other vital functions in plants. Most importantly, micronutrients are involved in the key physiological processes of photosynthesis and respiration (Marchner, 1995 and Mengel *et al. ,* 2001) and their deficiency can impede these vital physiological processes thus limiting yield gain . There are three main methods of adding micronutrients to crops : soil fertilization , foliar sprays and seed treatments (Johnson *et al. ,* 2005) . Each method has the potential to affect plant micronutrient nutrition both in the treated plant directly and in progeny plants through enrichment of seed by micronutrient treatment of the parent . Foliar applications of micronutrient sprays have been effective towards both goals (Savithri *et al. ,* 1999), but this method is too expensive to be widely practiced by resource – poor farmers in some regions because of the amount of fertilizer, equipment and labour required for repeated spraying . Likewise, the difficulty in obtaining high quality micronutrient fertilizers and spreading them evenly on the soil can be prohibitive . Treating seeds with micronutrients potentially provides a simple inexpensive method for improving micronutrient plant nutrition . Singh *et al.*

(2003) noted that seed priming in water has been shown to decrease time between sowing and emergence and to improve seeding vigour (Parera and Cantliffe , 1994).

Salem and El-Gizawy (2012) reported that foliar spraying with Fe or Mn gave the highest values of maize yield and it's components . Also , many workers stated that priming seeds in solutions of macro or micronutrients has been shown to improve yield , such as Peeran and Natanasabapathy (1980) for rice , Khalid and Malik (1982) and Wilhelm *et al.* (1988) for wheat and Sherrell (1984) for forage legumes , but the potential to damage the seed and inhibited germination by priming at high nutrient concentration has also been reported (Roberts, 1998) . Moreover Farag *et al* (2014) reported that foliar application of micronutrients could be more effective than soil application on seed soaking .

The aim of the present investigation is to evaluate the effect of micronutrient (Fe or Mn) application methods (soil, foliar or soaking) and added levels (low, medium and high) on wheat growth yield and it's components and nutrients content in both grains and straw .

MATERIALS AND METHODS

Two field experiments were conducted during the two consecutive winter seasons of 2013-2014 and 2014-2015 in the experimental field at Sids Agricultural Research Station , Beni Swef Governorate , ARC, Egypt to study the effect of both methods (soil, foliar and soaking application) and application levels (low , medium and high) of iron (Fe) or manganese (Mn) on wheat growth , yield and yield components and plant content of nutrient .The used soil in the two experimental locations characterized by clay loam texture (Klute ,1986) , had pH 7.9 and 8.0 , EC 1.1 and 1.2 (dSm^{-1}); 1.31 and 1.45% organic matter and 20 and 21 mg /kg available N ; 14 and 16 mg /kg available P ; 210 and 205 mg /kg available K ; 6.3 and 6.7 mg /kg available Fe , and 4.5 and 4.1 mg /kg available Mn in the two seasons respectively (Page , 1982) .

Micronutrients were added in the form of sulphate salts . In soil application both added as ferrous [($FeSo_4$-$7H_2O$)-(20%Fe,11.5%S)] or manganese sulphate ($MnSO_4$-$4H_2O$) (24%Mn,14%S) before sowing at rate of 2.5 , 5 and 10 kg sulphate salt, while foliar spray treatments were added at the rate of 0.1 , 0.2 and 0.3% iron or manganese sulphate twice ,after 30 and 45 days of planting . The spraying solution was done at rate of 200 and 300 L/fed in the first and second spraying respectively. As for grain soaking method, solutions of 0.1 , 0.2% and 0.3 % of each Fe and Mn sulphate were made . Gains were soaked in respective solutions for 12 hours , then dried for 12 hours in the shade before sowing . Wheat grains , c.v. sids 12 were planted in plots (plot area was 10.5 m^2 = 1/400 fed) in November 20th and 22nd in the two seasons respectively. Phosphorus at rate of 21 kg P_2O_5 / fed and potassium at rate of 24 kg K_2O/fed as single superphosphate 15% P_2O_5 and potassium sulphate (48 % K_2O) respectively were added before sowing during land preparation, while nitrogen at the rate of 75 kg N/fed was added at two equal doses ; before the first irrigation and the second irrigation as ammonium nitrate fertilizer (35.5% N) . The preceding crop in both seasons was maize . All other cultural practices for wheat production in the district were done. The experiment was laid out in a factorial (with three factors) plot design with four replications . At 75 days from wheat planting, 10 plants were randomly chosen from each plot, which cut above the soil surface to determine plant height (cm) and dry weight / plant (g). At maturity, wheat plants were harvested in May and yield components (number of spikes/m^2, number

of grains/spike and 1000 grain weight, g) , grain yield (ardab /fed) and straw yield , (ton / fed.) were determined . Samples of grains and straw were taken to determine its content of N, P, K , Fe and Mn according to Chapman and Pratt (1978) . Then total nutrient uptake were calculated .

All the obtained data were statistically analyzed according to the procedure described by Snedecor and Cochan (1980). Treatment means were compared by L.S.D at 5% probability level .

RESULTS

Data in Table (1) show that both methods and application rates of Fe and Mn have a significantly effect on both plant height and dry weight/plant compare with the check treatment after 70 days from planting . Iron or manganese application increased plant height by about 4.7 and 5.3 % over control during the two seasons . Also dry weight/plant increased significantly by 9.4% and 8.0 % in the first season and 9.4 and 7.2 % during the second season due to Fe and Mn respectively . It is obvious that the differences between the effect of iron and manganese on plant height were not significant in both seasons .As for the application methods , the results reveal that foliar spraying of Fe and Mn surpassed soil and soaking methods by about 4.0 and 3.7 for plant height and by 0.8 and 2.2 % for dry weight in the first season , respectively . The same trends were obtained in the second season , where soil and soaking methods gave the same values of plant height and dry weight / plant in both seasons. Also, the obtained data show that the added Fe and Mn as soil, foliar or soaking at the medium level produced the tallest with the heaviest dry weight of wheat plants in both seasons. The effect of application levels on plant height or dry weight / plant could be arranged in the descending order as follows: medium > high> low.

In addition , the data clearly show that the studied growth parameters of wheat plants did not respond significantly to the interactions among methods and levels application of Fe and Mn. However, the highest values were attained by spraying 0.2 % iron sulphate in both seasons .

Yield components :

Yield components . i.e. number of spikes / m^2 , number of grains / spike and 1000-grain weight of wheat was not significantly affected . Mean values for Fe and Mn treatments indicate that maximum value number of plants affected by both methods and levels application of Fe and Mn are given in Table (2). The statistical analysis of variance shows that application of Fe or Mn had a significant effect on yield components , except 1000-grains weight , which spikes/m^2 (435.5 and 428.9) and number of grains / spike (45.0 in the two seasons) were obtained in plots treated with Fe , followed by those supplied with Mn (429.6 ; 422.6 and 44.6 ; 44.8) in the first and second season respectively . As for the effect of the application methods , the data reveal that foliar spraying gave more number of spikes / m^2 and grains / spike than that of the soil or soaking method . The relative increase of these two parameters due to foliar spraying method reached to 3.5 and 3.4 for number of spike/m^2 ;, and 2.5 and 2.0 % for number of grains/spike comparing with soil and soaking methods in the first season , respectively. Similar trends were obtained in the second season. It's worthy to observe that the difference between the effect of soil and soaking methods on number of spikes/ m^2 and number of grains /spike was not significant in both seasons . The data in the Table (2) also , show that as levels of Fe and Mn increased from zero to the medium level , number of spikes / m^2 and number of grains / spike were increased but they declined at the highest level . Comparing with low level ,

Table (1): Effect of methods and levels of application of Fe and Mn on some wheat growth parameters at 75 days

Micronutrients (A)	Methods (B)	Levels (C)	Plant height (cm)		Dry weight/plant (g)	
			2013/2014	2014/2015	2013/2014	2014/2015
Without micronutrients (control)			36.1	36.0	2.24	2.23
Fe	Soil	2.5 kg/fed	36.1	36.3	2.31	2.30
		5 kg/fed	38.8	38.0	2.52	2.57
		10 kg/fed	37.4	37.3	2.35	2.35
	Mean		37.4	37.2	2.39	2.41
	Foliar	0.1%	37.2	36.8	2.50	2.46
		0.2%	41.7	41.1	2.61	2.59
		0.3%	37.0	38.7	2.53	2.50
	Mean		38.6	38.9	2.55	2.52
	Soaking	0.1%	36.2	36.0	2.30	2.28
		0.2%	38.9	38.1	2.54	2.50
		0.3%	37.5	37.2	2.36	2.35
	Mean		37.5	37.1	2.40	2.38
Mean			37.8	37.7	2.45	2.44
Mn	Soil	2.5 kg/fed	36.2	36.2	2.27	2.25
		5 kg/fed	38.5	38.5	2.53	2.38
		10 kg/fed	37.3	37.5	2.37	2.35
	Mean		37.3	37.4	2.39	2.33
	Foliar	0.1%	37.0	36.8	2.46	2.44
		0.2%	41.6	41.5	2.58	2.56
		0.3%	39.1	38.8	2.50	2.47
	Mean		39.2	39.0	2.51	2.49
	Soaking	0.1%	36.1	36.0	2.28	2.25
		0.2%	38.9	38.7	2.51	2.40
		0.3%	37.4	37.3	2.32	2.36
	Mean		37.5	37.3	2.37	2.34
Mean			38.0	37.9	2.42	2.39
Mean of methods	Soil		37.4	37.1	2.39	2.37
	Foliar		38.9	39.2	2.41	2.39
	Soaking		37.5	37.2	2.36	2.36
Mean of levels	Low		36.5	36.2	2.35	2.33
	Medium		39.7	39.1	2.55	2.50
	High		37.6	37.8	2.41	2.40
L.S.D. at 0.05	A		0.51	0.93	0.02	0.02
	B		0.72	0.95	0.03	0.03
	C		0.65	0.83	0.04	0.05
	AB		NS	NS	NS	NS
	AC		NS	NS	NS	NS
	BC		NS	NS	NS	NS
	ABC		NS	NS	NS	NS

Table (2): Effect of methods and levels of application of Fe and Mn on yield components .

Micronutrients (A)	Methods (B)	Levels (C)	No of spike/m^2		No of grains/spike		1000-grains weight (g)	
			2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015
Without micronutrients (control)			411.3	411.0	43.5	43.3	53.7	50.1
Fe	Soil	2.5 kg/fed	421.6	416.6	44.1	44.2	53.7	50.1
		5 kg/fed	445.2	438.0	44.8	45.1	53.6	50.0
		10 kg/fed	425.6	420.2	44.5	44.3	53.7	50.1
	Mean		430.8	424.9	44.5	44.5	53.7	50.1
	Foliar	0.1%	430.2	421.3	45.3	45.3	53.6	50.2
		0.2%	467.3	460.5	46.1	46.1	53.6	50.1
		0.3%	435.9	427.6	45.8	45.7	53.7	50.0
	Mean		444.5	436.5	45.7	45.7	53.6	50.1
	Soaking	0.1%	421.5	417.5	44.3	44.4	53.6	50.1
		0.2%	445.9	438.2	45.1	45.2	53.6	50.2
		0.3%	426.0	419.8	44.7	44.9	53.7	50.1
	Mean		131.1	425.2	44.7	44.8	53.6	50.1
Mean			435.5	428.9	45.0	45.0	53.6	50.1
Mn	Soil	2.5kg/fed	415.5	409.8	43.8	43.9	53.7	50.1
		5 kg/fed	433.6	428.1	44.5	44.8	53.7	50.2
		10 kg/fed	423.9	417.7	44.1	44.5	53.6	50.1
	Mean		424.3	418.5	44.1	44.4	53.7	50.1
	Foliar	0.1%	431.6	416.5	45.1	45.2	53.7	50.1
		0.2%	449.2	440.1	45.7	45.9	53.6	50.2
		0.3%	440.1	433.3	45.4	45.5	53.7	50.0
	Mean		440.3	430.0	45.4	45.5	53.7	50.1
	Soaking	0.1%	416.3	410.6	44.1	44.0	53.7	50.0
		0.2%	432.5	429.3	44.7	44.9	53.6	50.1
		0.3%	424.1	418.2	44.4	44.5	53.6	50.2
	Mean		424.3	419.4	44.3	44.5	53.6	50.1
Mean			429.6	422.6	44.6	44.8	53.7	50.1
Mean of methods	Soil		427.6	421.7	44.3	44.3	53.7	50.1
	Foliar		442.4	434.9	45.4	45.4	53.6	50.1
	Soaking		427.7	422.3	44.5	44.7	53.6	50.1
Mean of levels	Low		422.8	415.4	44.5	44.5	53.7	50.1
	Medium		445.6	439.0	45.2	45.3	53.6	50.1
	High		429.3	422.8	44.8	44.9	53.7	50.1
L.S.D. at 0.05	A		3.15	2.56	0.21	0.20	NS	NS
	B		4.36	4.15	0.26	0.23	NS	NS
	C		2.67	2.58	0.28	0.22	NS	NS
	AB		NS	NS	NS	NS	NS	NS
	AC		NS	NS	NS	NS	NS	NS
	BC		NS	NS	NS	NS	NS	NS
	ABC		NS	NS	NS	NS	NS	NS

Fe or Mn application at medium level increased number of spikes / m^2 and number of grains / spike by about 5.4 and 1.8 % in the first season and 5.7 and 1.8 % in the second one . The weight of thousand grains did not responded to the level of micronutrients application.With regard to the interactions between studied treatments of methods and application of Fe and Mn, the results reveals that the studied yield components were not significantly affected by all the interactions among the studied factors as shown in Table (2) .

Grain and straw yields .

Data on grain and straw yields of wheat plant affected by the studied treatments of Fe and Mn are given in Table (3) . The effects of Fe and Mn, irrespective of application methods and levels were significant , and improved both grain and straw yields . Maximum grain yield was produced bythe plants received iron (23.0 and 22 ardab / fed) followed by those supplied with manganese (22.2 and 18.5 ardab / fed) in both seasons . On the other hand Mn yielded the highest straw yield , but the difference between it's effect and iron was not significant, It's worthy to mention that iron improved grain yield by about 11.1 and 10% as comparing with control in both seasons.

Concerning the application methods , the mean value reveal that foliar spraying method gave the highest grain and straw yields comparing with soil and soaking methods . The relative increase in grain and straw yields caused by foliar the relative increasing in grain and straw yield caused foliar spraying reached to 8.2 and 7.2 % in grain yield and 8.8 and 12.1 % in straw yield over soil and soaking methods respectively in the first season. The corresponding value, in the second season were 4.5 and 4.4 % for grain yield , and 9.4 and 6.1 % for straw yield in the above mentioned order . The statistical analysis reveals that the difference between the effect of soil and soaking methods were not significant in both seasons . Considering the effect of Fe and Mn levels , the results show that both grain and straw yields were positively and significantly affected by the levels of iron and manganese application . It could be arranged in the descending order as follows medium>high>low . Also , it could be noticed that low and high level had statistically the same effect on grain and straw yields.

Regarding the possible interactions between the studied treatments of Fe and Mn the results showed clearly that both grain and straw yields were not significantly affected by these interactions in both seasons which means that the wheat plants sprayed with 0.2 % iron sulphate yielded the highest grain and straw yields followed by those sprayed with 0.2 % manganese sulphate .

Nutrient content .

Table (4 to 7) represent the effect of application methods and levels of F and Mn on N,P,K,Fe and Mn content in grains and straw . The results indicate that the added Fe and Mn have not significante affect nitrogen and potassium content (%) in grain and straw . Phosphorus concentration in both grains and straw Were negatively responded to Fe or Mn . Comparing with control treatment Fe or Mn application decreased P contents in grains and straw by about 12% and 23.0% respectively in the first season. The applied Fe significantly increased iron and decreased manganese in grains and straw . The adverse effect was observed in case of Mn application , where it decreased Fe and increased Mn in grains and straw . The increasing of Fe in grains and straw due to iron application reached to 23.7 and 22.4% over control , while the decreasing of Mn in grains and straw due to iron application reached to 13.4 and 17.7% ,

Table (3): Effect of methods and levels of application of Fe and Mn on grain and straw yields

Micronutrients (A)	Methods (B)	Levels (C)	Grain yield (ardab/fed)		Straw yield (t/fed)	
			2013/2014	2014/2015	2013/2014	2014/2015
Without micronutrients (control)			20.7	20.0	2.9	2.8
Fe	Soil	2.5 kg/fed	21.8	20.1	2.7	2.6
		5 kg/fed	23.3	22.7	3.6	3.4
		10 kg/fed	22.4	21.9	3.0	2.9
	Mean		22.5	21.6	3.1	3.0
	Foliar	0.1%	22.9	21.7	3.1	3.0
		0.2%	25.3	23.5	4.2	4.0
		0.3%	23.7	22.2	3.5	3.3
	Mean		24.0	22.5	3.6	3.4
	Soaking	0.1%	22.0	20.2	2.8	2.7
		0.2%	23.3	22.9	3.7	3.6
		0.3%	22.5	22.2	3.1	2.9
	Mean		22.6	21.8	3.2	3.1
Mean			23.0	22.0	3.3	3.2
Mn	Soil	2.5 kg/fed	20.7	16.9	3.4	3.2
		5 kg/fed	22.4	19.2	3.8	3.6
		10 kg/fed	21.4	18.4	3.7	3.4
	Mean		21.5	18.2	3.6	3.4
	Foliar	0.1%	22.8	18.0	3.5	3.4
		0.2%	24.5	20.2	3.9	3.7
		0.3%	23.2	18.9	3.7	3.5
	Mean		23.5	19.0	3.7	3.5
	Soaking	0.1%	20.9	17.1	3.2	3.3
		0.2%	22.7	19.3	3.6	3.7
		0.3%	21.6	18.4	3.4	3.4
	Mean		21.7	18.3	3.4	3.5
Mean			22.2	18.5	3.5	3.5
Mean of methods	Soil		22.0	19.9	3.4	3.2
	Foliar		23.8	20.8	3.7	3.5
	Soaking		22.2	20.1	3.3	3.3
Mean of levels	Low		21.9	19.0	3.1	3.0
	Medium		23.6	21.3	3.6	3.7
	High		22.5	20.3	3.4	3.4
L.S.D. at 0.05	A		0.23	0.57	0.43	0.47
	B		0.35	0.38	0.14	0.15
	C		0.89	1.71	0.41	0.45
	AB		NS	NS	NS	NS
	AC		NS	NS	NS	NS
	BC		NS	NS	NS	NS
	ABC		NS	NS	NS	NS

*Ardab = 150 kg

Table (4): Effect of methods and levels of application of Fe and Mn on N,P and K concentrations (%) in grains of wheat plant

Micronutrients (A)	Methods (B)	Levels (C)	N %		P %		K %	
			2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015
Without micronutrients (control)			1.21	1.07	0.50	0.46	0.62	0.60
Fe	Soil	2.5kg/fed	1.21	1.17	0.44	0.41	0.62	0.60
		5 kg/fed	1.12	1.12	0.41	0.38	0.60	0.59
		10 kg/fed	1.23	1.20	0.39	0.36	0.63	0.59
	Mean		1.18	1.16	0.41	0.38	0.62	0.59
	Foliar	0.1%	1.14	1.21	0.48	0.45	0.60	0.59
		0.2%	1.22	1.17	0.46	0.43	0.60	0.60
		0.3%	1.21	1.13	0.44	0.42	0.61	0.61
	Mean		1.17	1.17	0.46	0.43	0.61	0.60
	Soaking	0.1%	1.12	1.20	0.46	0.47	0.62	0.60
		0.2%	1.11	1.20	0.44	0.45	0.61	0.59
		0.3%	1.25	1.16	0.42	0.40	0.60	0.59
	Mean		1.16	1.19	0.44	0.44	0.61	0.59
Mean			1.17	1.17	0.44	0.42	0.61	0.59
Mn	Soil	2.5kg/fed	1.23	1.17	0.43	0.40	0.61	0.59
		5 kg/fed	1.12	1.14	0.41	0.38	0.61	0.60
		10 kg/fed	1.17	1.20	0.38	0.35	0.60	0.60
	Mean		1.17	1.17	0.41	0.38	0.61	0.61
	Foliar	0.1%	1.12	1.21	0.49	0.46	0.60	0.60
		0.2%	1.21	1.16	0.47	0.45	0.61	0.59
		0.3%	1.15	1.14	0.45	0.42	0.61	0.60
	Mean		1.16	1.17	0.47	0.44	0.61	0.59
	Soaking	0.1%	1.21	1.21	0.47	0.45	0.61	0.59
		0.2%	1.13	1.22	0.45	0.42	0.61	0.59
		0.3%	1.15	1.14	0.42	0.40	0.61	0.60
	Mean		1.16	1.19	0.45	0.42	0.61	0.59
Mean			1.16	1.18	0.44	0.41	0.61	0.60
Mean of methods	Soil		1.17	1.17	0.41	0.39	0.62	0.60
	Foliar		1.18	1.17	0.47	0.44	0.61	0.06
	Soaking		1.16	1.19	0.45	0.43	0.61	0.60
Mean of levels	Low		1.17	1.20	0.46	0.44	0.61	0.60
	Medium		1.15	1.17	0.44	0.42	0.61	0.60
	High		1.19	1.16	0.42	0.39	0.61	0.60
L.S.D. at 0.05	A		NS	NS	0.31	0.34	NS	NS
	B		NS	NS	0.20	0.13	NS	NS
	C		NS	NS	0.11	0.13	NS	NS
	AB		NS	NS	NS	NS	NS	NS
	AC		NS	NS	NS	NS	NS	NS
	BC		NS	NS	NS	NS	NS	NS
	ABC		NS	NS	NS	NS	NS	NS

Table (5): Effect of methods and levels of application of Fe and Mn on N,P and K concentration (%) in straw of wheat plant

Micronutrients (A)	Methods (B)	Levels (C)	N %		P %		K %	
			2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015
Without micronutrients (control)			0.39	0.40	0.13	0.13	1.51	1.54
Fe	Soil	2.5kg/fed	0.38	0.40	0.10	0.11	1.50	1.55
		5 kg/fed	0.39	0.41	0.08	0.08	1.50	1.54
		10 kg/fed	0.40	0.40	0.06	0.07	1.51	1.55
	Mean		0.39	0.40	0.08	0.09	1.50	1.55
	Foliar	0.1%	0.39	0.39	0.14	0.15	1.51	1.54
		0.2%	0.39	0.41	0.12	0.13	1.51	1.54
		0.3%	0.38	0.41	0.10	0.11	1.50	1.54
	Mean		0.39	0.40	0.12	0.13	1.51	1.54
	Soaking	0.1%	0.40	0.40	0.11	0.12	1.50	1.55
		0.2%	0.39	0.40	0.09	0.09	1.51	1.54
		0.3%	0.39	0.41	0.07	0.08	1.51	1.55
	Mean		0.39	0.40	0.09	0.10	1.51	1.55
Mean			0.39	0.40	0.10	0.11	1.51	1.55
Mn	Soil	2.5 kg/fed	0.38	0.41	0.10	0.11	1.50	1.54
		5 kg/fed	0.39	0.40	0.09	0.09	1.50	1.55
		10 kg/fed	0.39	0.40	0.07	0.08	1.51	1.54
	Mean		0.39	0.40	0.09	0.09	1.50	1.54
	Foliar	0.1%	0.39	0.41	0.14	0.15	1.51	1.55
		0.2%	0.38	0.40	0.13	0.12	1.50	1.54
		0.3%	0.39	0.39	0.10	0.10	1.51	1.54
	Mean		0.39	0.40	0.12	0.12	1.51	1.54
	Soaking	0.1%	0.39	0.39	0.11	0.12	1.52	1.54
		0.2%	0.38	0.40	0.10	0.10	1.51	1.55
		0.3%	0.39	0.41	0.08	0.09	1.51	1.55
	Mean		0.39	0.40	0.10	0.10	1.51	1.55
Mean			0.39	0.40	0.10	0.10	1.51	1.54
Mean of methods	Soil		0.39	0.40	0.09	0.09	1.50	1.55
	Foliar		0.39	0.40	0.12	0.13	1.51	1.54
	Soaking		0.39	0.40	0.10	0.10	1.51	1.55
Mean of levels	Low		0.39	0.40	0.13	0.13	1.51	1.55
	Medium		0.39	0.40	0.10	0.10	1.51	1.54
	High		0.39	0.40	0.08	0.09	1.51	1.55
L.S.D. at 0.05	A		NS	NS	0.02	0.01	NS	NS
	B		NS	NS	0.05	0.04	NS	NS
	C		NS	NS	0.09	0.07	NS	NS
	AB		NS	NS	NS	NS	NS	NS
	AC		NS	NS	NS	NS	NS	NS
	BC		NS	NS	NS	NS	NS	NS
	ABC		NS	NS	NS	NS	NS	NS

Table (6): Effect of methods and levels of application of Fe and Mn on Fe and Mn concentration (mg/kg) in grains of wheat plant

Micronutrients (A)	Methods (B)	Levels (C)	Fe (mg/kg)		Mn (mg/kg)	
			2013/2014	2014/2015	2013/2014	2014/2015
Without micronutrients (control)			44.3	42.0	41.7	40.3
Fe	Soil	2.5kg/fed	47.1	45.3	37.3	37.0
		5 kg/fed	50.3	48.1	34.0	33.8
		10 kg/fed	55.9	55.0	31.5	31.2
	Mean		51.1	49.5	34.3	34.0
	Foliar	0.1%	54.8	53.7	38.9	38.2
		0.2%	60.3	59.0	37.7	37.4
		0.3%	67.7	66.2	36.0	36.0
	Mean		60.9	59.6	37.5	37.2
	Soaking	0.1%	48.5	46.9	38.1	37.8
		0.2%	52.4	50.8	36.9	36.5
		0.3%	56.0	55.2	34.6	34.2
	Mean		52.3	51.0	36.5	36.2
Mean			54.8	53.4	36.1	35.8
Mn	Soil	2.5 kg/fed	38.7	38.0	43.3	43.0
		5 kg/fed	35.0	34.6	48.8	48.2
		10 kg/fed	32.3	32.1	52.0	51.7
	Mean		35.3	34.9	48.0	47.6
	Foliar	0.1%	40.7	40.2	52.7	52.0
		0.2%	39.0	38.6	56.9	56.2
		0.3%	36.5	36.0	65.7	64.9
	Mean		38.7	38.3	58.4	57.7
	Soaking	0.1%	39.3	38.9	44.5	44.0
		0.2%	37.5	37.0	49.1	48.8
		0.3%	35.4	34.1	53.4	53.2
	Mean		37.4	36.7	49.0	48.7
Mean			37.1	36.6	48.5	50.2
Mean of methods	Soil		43.2	42.2	41.2	40.8
	Foliar		49.5	49.0	48.0	47.5
	Soaking		44.9	43.9	42.8	42.5
Mean of levels	Low		44.9	43.8	40.8	42.0
	Medium		45.8	44.7	41.5	43.4
	High		47.3	46.4	45.5	45.2
L.S.D. at 0.05	A		1.82	1.93	2.11	2.23
	B		1.11	1.32	1.14	1.15
	C		0.74	0.93	1.01	1.00
	AB		NS	NS	NS	NS
	AC		2.5	2.7	2.8	2.6
	BC		NS	NS	NS	NS
	ABC		NS	NS	NS	NS

Table (7): Effect of methods and levels of application of Fe and Mn on Fe and Mn concentration (mg/kg) in straw of wheat plant

Micronutrients (A)	Methods (B)	Levels (C)	Fe (mg/kg)		Mn (mg/kg)	
			2013/2014	2014/2015	2013/2014	2014/2015
Without micronutrients (control)			66.5	64.3	20.9	20.2
Fe	Soil	2.5 kg/fed	70.5	68.1	18.0	17.9
		5 kg/fed	75.3	72.7	16.5	16.3
		10 kg/fed	83.1	81.9	15.9	15.7
	Mean		76.3	74.2	16.8	16.6
	Foliar	0.1%	82.0	80.7	19.3	19.0
		0.2%	90.4	88.5	17.8	17.7
		0.3%	96.2	94.1	16.1	16.0
	Mean		89.5	87.8	17.7	17.6
	Soaking	0.1%	72.5	70.2	18.3	18.0
		0.2%	78.0	75.1	17.0	16.6
		0.3%	84.7	80.3	16.3	16.3
	Mean		78.4	75.2	17.2	17.0
Mean			81.4	79.1	17.2	17.1
Mn	Soil	2.5 kg/fed	58.2	54.3	22.0	21.7
		5 kg/fed	51.9	49.7	23.9	23.5
		10 kg/fed	47.1	45.0	25.3	25.0
	Mean		52.4	49.7	23.7	23.4
	Foliar	0.1%	61.4	58.7	26.0	25.7
		0.2%	58.1	55.1	27.9	27.6
		0.3%	53.2	50.7	31.0	30.8
	Mean		57.6	54.8	28.3	28.0
	Soaking	0.1%	57.6	55.6	22.1	22.0
		0.2%	55.4	52.9	24.3	24.1
		0.3%	52.7	50.0	26.2	25.7
	Mean		55.2	52.8	24.2	23.9
Mean			55.1	52.4	25.4	25.1
Mean of methods	Soil		64.4	62.0	20.3	20.0
	Foliar		73.6	71.3	23.0	22.8
	Soaking		66.8	64.0	20.7	20.5
Mean of levels	Low		67.0	64.6	21.0	20.7
	Medium		68.2	65.7	21.2	21.0
	High		70.0	67.0	21.8	21.6
L.S.D. at 0.05	A		2.65	2.41	1.25	1.19
	B		1.34	1.26	0.92	0.85
	C		1.16	1.09	0.91	0.81
	AB		NS	NS	NS	NS
	AC		2.83	2.75	1.30	1.25
	BC		NS	NS	NS	NS
	ABC		NS	NS	NS	NS

respectively in the first season . Mn application decreased Fe in grains and straw by about 16.3 and 17.1% comparing with control in the first season, respectively . Similar trends were obtained in the second season. As for application methods, the results show that nitrogen and potassium contents in wheat grains and straw were not affected by the methods of application . On the other hand phosphorus , iron and manganese in grains and straw significantly responded to application methods of Fe and Mn and the promotive effect could be arranged in the descending order as follows: foliar > soaking > soil application . Levels of micronutrients affected only P, Fe and Mn contents in grains and straw . It is obvious that as the levels of Fe and Mn increased, the P content in grains or straw decreased , since Fe and Mn at high level decreased P content in grains and straw by about 8.69 and 38.5% over the low level in the first season, respectively . The same trend was obtained in the second season . Adverse trend was obtained for the effect of levels on Fe and Mn contents in grains and straw. Irrespective of the used micronutrients and method of application, increasing Fe or Mn significantly increased Fe and Mn content in grains and straw . Addition of micronutrients at high level increased Fe in grains and straw by about (5.3%) and (4.5%) in the first season ; and (5.9%) and (3.7%) in the second season comparing with low level , respectively . Similar trends were obtained for Mn contents in grains and straw in both seasons.

Regarding the interaction between the studied treatments of Fe AND mN, the data reveal that Fe and Mn contents in grains and straw responded only to the interaction between the micronutrients and thierlevel . Although , the mean values of Fe and Mn contents in grains and straw increased as the level of application increased. Iron contents in grains and straw decreased under Mn application. Meanwhile, Mn contents in grain and straw decreased under Fe application . In general the higher P contents in grains and straw were recorded for the wheat plants not treated with Fe and Mn ; while the plants received iron or manganese at the high rate as foliar spraying produced the lowest P content . However, the plants supplied with Fe or Mn as foliar spraying at high levels yielded the highest Fe or Mn in grains or straw , while the lowest Fe or Mn contents were exerted for the plants not treated with micronutrients.

Nutrient uptake

Data of the effect of methods and levels of Fe and Mn application on N,P,K,Fe and Mn uptake in grains and / or straw of wheat plants are given in Tables (8 to 13) . In general , the results show that comparing with control, and irrespective of methods and levels of application , Fe and Mn significantly enhanced N,K,Fe and Mn contents whether by grains or straw, while it inhibited phosphorus uptake in grains , straw and total uptake . Iron surpassed manganese in its effect on N,P,K and Fe uptake in grains , Fe uptake by straw and total N,P and Fe uptake , whereas Mn uptake by grains ; N,P,K and Mn uptake by straw and total K and Mn uptake were significantly higher under Mn than iron application . Concerning the methods of application the data reveal that the added Fe and Mn as foliar spraying induced more positive effect on nutrient uptake than the other two methods . The effect of application methods on nutrients uptake could be arranged in the descending order as follows : foliar > soaking > soil application , with some exception , where the differences between the effect of soaking and soil methods were not significant . As for levels of application , the data indicate that nutrients uptake were significantly affected

Table (8): Effect of methods and levels of application of Fe and Mn on N,P and K uptake by grains of wheat plant

Micronutrients (A)	Methods (B)	Levels (C)	N (kg/fed)		P (kg/fed)		K (kg/fed)	
			2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015
Without micronutrients (control)			37.8	32.0	15.6	13.9	19.8	18.1
Fe	Soil	2.5kg/fed	39.4	35.1	13.4	12.4	20.1	17.9
		5 kg/fed	39.4	38.4	14.4	12.9	21.3	20.4
		10 kg/fed	41.0	39.1	13.8	11.8	20.9	19.1
	Mean		39.9	37.5	13.9	12.4	20.8	19.1
	Foliar	0.1%	39.6	39.8	16.5	14.6	21.0	19.6
		0.2%	45.9	40.8	17.5	15.2	22.4	20.8
		0.3%	43.2	37.8	15.6	14.0	21.4	20.5
	Mean		42.9	39.5	16.5	14.6	21.8	20.3
	Soaking	0.1%	36.8	36.2	15.2	14.2	20.3	18.0
		0.2%	39.1	41.5	15.4	15.5	21.6	20.6
		0.3%	41.9	38.3	14.2	13.3	20.0	19.3
	Mean		39.3	38.7	14.9	14.3	20.6	19.3
Mean			41.6	38.7	15.1	13.8	20.7	19.3
Mn	Soil	2.5kg/fed	38.6	30.1	13.4	10.1	19.3	15.4
		5 kg/fed	37.3	32.4	16.6	10.9	17.2	16.9
		10 kg/fed	37.8	31.7	12.2	9.60	19.5	16.8
	Mean		39.9	31.4	13.1	10.2	18.7	16.4
	Foliar	0.1%	38.1	32.5	16.8	12.4	20.3	16.3
		0.2%	44.8	35.5	17.3	13.6	22.7	18.5
		0.3%	39.7	32.0	15.7	11.9	20.9	16.4
	Mean		40.9	33.3	16.6	12.6	21.3	17.1
	Soaking	0.1%	38.3	31.4	17.7	11.5	19.5	15.5
		0.2%	38.1	34.9	15.3	12.1	20.4	16.7
		0.3%	37.5	31.7	13.6	11.0	20.0	16.8
	Mean		38.0	32.7	14.5	11.5	20.0	16.3
Mean			39.6	32.5	14.7	11.4	20.0	16.6
Mean of methods	Soil		39.3	34.5	13.5	11.3	20.2	17.8
	Foliar		41.9	35.8	16.6	13.6	21.6	18.7
	Soaking		38.7	35.2	15.7	12.9	20.3	17.8
Mean of levels	Low		38.5	34.2	15.0	12.5	20.1	17.2
	Medium		40.8	37.3	15.6	13.4	20.9	19.0
	High		40.2	35.1	14.2	11.9	20.5	18.2
L.S.D. at 0.05	A		1.03	1.01	0.30	0.43	0.41	0.76
	B		0.73	0.39	0.23	0.36	0.77	0.75
	C		0.51	0.55	0.26	0.28	0.36	0.39
	AB		NS	NS	NS	NS	NS	NS
	AC		NS	NS	NS	NS	NS	NS
	BC		NS	NS	NS	NS	NS	NS
	ABC		NS	NS	NS	NS	NS	NS

Table (9): Effect of methods and levels of application of Fe and Mn on N,P and K uptake by straw of wheat plant

Micronutrients (A)	Methods (B)	Levels (C)	N (kg/fed)		P (kg/fed)		K (kg/fed)	
			2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015
Without micronutrients (control)			11.5	11.4	3.8	3.7	44.0	43.0
Fe	Soil	2.5kg/fed	10.1	10.2	2.5	2.7	40.3	39.8
		5 kg/fed	14.3	14.2	3.2	3.0	54.3	52.7
		10 kg/fed	11.7	11.3	1.5	1.7	45.0	44.7
	Mean		12.0	11.9	2.4	2.5	46.5	45.7
	Foliar	0.1%	12.5	12.1	4.7	4.9	47.2	46.6
		0.2%	16.0	16.0	4.6	4.8	63.4	61.2
		0.3%	13.5	13.7	3.6	3.8	52.7	51.0
	Mean		14.0	13.9	4.3	.5	54.4	52.9
	Soaking	0.1%	11.0	10.6	2.9	3.0	41.8	41.7
		0.2%	14.7	14.7	3.6	3.5	56.2	55.7
		0.3%	11.8	11.6	1.8	2.0	46.5	44.7
	Mean		12.5	12.3	2.8	2.9	48.2	47.4
Mean			12.8	12.7	3.2	3.3	49.7	48.7
Mn	Soil	2.5kg/fed	13.3	13.5	3.8	3.9	51.4	49.7
		5 kg/fed	14.4	14.0	3.0	2.8	56.6	55.4
		10 kg/fed	16.6	13.8	2.7	2.9	51.5	51.5
	Mean		14.1	13.8	3.2	3.2	53.2	52.2
	Foliar	0.1%	13.5	13.7	4.7	4.9	52.7	52.7
		0.2%	15.1	15.1	5.4	4.7	58.8	57.3
		0.3%	14.1	13.4	3.4	3.2	55.6	53.6
	Mean		14.2	14.1	4.5	4.3	55.7	54.5
	Soaking	0.1%	12.9	13.3	3.9	4.4	49.0	51.2
		0.2%	13.3	14.4	3.2	3.3	54.0	57.0
		0.3%	13.5	14.1	2.9	3.2	51.5	52.9
	Mean		13.2	13.9	3.3	3.6	51.5	53.7
Mean			13.8	13.9	3.7	3.7	53.5	53.5
Mean of methods	Soil		13.1	12.9	2.8	2.9	49.9	49.0
	Foliar		14.1	14.0	4.4	4.4	55.6	53.7
	Soaking		12.9	13.1	3.1	3.3	49.9	48.8
Mean of levels	Low		12.2	12.2	3.6	3.5	47.1	47.0
	Medium		14.6	14.7	3.8	3.7	57.2	56.6
	High		13.2	13.0	2.7	2.8	50.5	49.7
L.S.D. at 0.05	A		0.35	0.32	0.27	0.25	3.2	4.4
	B		0.38	0.32	0.21	0.23	2.8	2.9
	C		0.27	0.26	0.19	0.17	2.6	2.7
	AB		NS	NS	NS	NS	NS	NS
	AC		NS	NS	NS	NS	NS	NS
	BC		NS	NS	NS	NS	NS	NS
	ABC		NS	NS	NS	NS	NS	NS

Table (10): Effect of methods and levels of application of Fe and Mn on total N,P and K uptake by (grain+straw) of wheat plant

Micronutrients (A)	Methods (B)	Levels (C)	N (kg/fed)		P (kg/fed)		K (kg/fed)	
			2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015
Without micronutrients (control)			49.2	43.5	19.9	17.6	63.7	61.0
Fe	Soil	2.5kg/fed	49.5	45.3	15.9	15.0	60.4	57.7
		5 kg/fed	53.7	52.6	17.5	16.0	75.6	73.1
		10 kg/fed	52.7	50.4	15.4	13.6	65.9	63.8
	Mean		52.0	49.4	16.3	14.9	67..3	64.9
	Foliar	0.1%	52.1	51.9	21.3	19.6	68.2	66.2
		0.2%	61.9	56.8	22.2	20.1	83.8	82.0
		0.3%	56.7	51.5	19.2	17.7	74.8	71.5
	Mean		65.9	53.4	20.9	19.1	75.5	73.2
	Soaking	0.1%	47.8	46.8	18.2	17.1	62.1	59.7
		0.2%	53.8	56.2	19.1	19.1	77.8	76.3
		0.3%	53.7	49.9	26.1	15.4	66.5	64.0
	Mean		51.8	51.0	21.1	17.2	68.8	66.7
Mean			53.6	51.6	19.4	17.1	70.5	68.3
Mn	Soil	2.5kg/fed	51.9	43.6	17.3	14.0	70.7	65.1
		5 kg/fed	51.7	46.4	16.9	13.8	73.8	72.3
		10 kg/fed	52.4	45.5	14.9	12.8	71.0	77.3
	Mean		52.0	45.2	16.4	13.5	71.8	71.6
	Foliar	0.1%	51.6	46.2	21.6	17.4	73.0	69.0
		0.2%	59.9	45.6	22.6	18.4	81.5	75.8
		0.3%	53.8	45.4	19.2	15.0	76.5	70.0
	Mean		55.1	47.4	21.3	16.9	77.0	71.6
	Soaking	0.1%	51.2	44.7	18.7	15.9	68.5	66.7
		0.2%	51.4	49.3	18.5	15.3	74.4	73.7
		0.3%	51.0	45.8	16.6	14.4	71.5	69.7
	Mean		51.2	46.6	17.9	15.2	71.5	70.0
Mean			52.8	46.5	18.5	15.2	73.4	71.1
Mean of methods	Soil		52.0	47.5	16.4	14.2	69.6	68.3
	Foliar		56.0	50.4	21.1	18.0	76.3	72.4
	Soaking		51.5	48.8	18.9	16.2	71.1	68.9
Mean of levels	Low		50.7	46.4	18.8	15.5	67.2	64.6
	Medium		55.4	52.0	19.5	17.1	77.8	75.5
	High		53.4	48.1	18.6	14.8	71.0	69.3
L.S.D. at 0.05	A		1.03	1.15	0.36	0.33	1.00	1.18
	B		1.56	1.74	1.03	0.68	1.95	2.50
	C		1.14	1.09	0.41	0.56	1.80	1.96
	AB		NS	NS	NS	NS	NS	NS
	AC		NS	NS	NS	NS	NS	NS
	BC		NS	NS	NS	NS	NS	NS
	ABC		NS	NS	NS	NS	NS	NS

Table (11): Effect of methods and levels of application of Fe and Mn on Fe and Mn uptake by grains of wheat plant

Micronutrients (A)	Methods (B)	Levels (C)	Fe (g/fed)		Mn (g/fed)	
			2013/2014	2014/2015	2013/2014	2014/2015
Without micronutrients (control)			104.5	94.7	122.2	111.8
Fe	Soil	2.5 kg/fed	153.8	136.4	121.8	111.4
		5 kg/fed	176.1	164.1	119.1	115.4
		10 kg/fed	187.5	117.0	105.5	102.2
	Mean		172.5	139.2	115.5	110.0
	Foliar	0.1%	188.6	175.2	134.0	123.5
		0.2%	228.4	207.6	141.2	131.4
		0.3%	240.8	220.7	128.2	120.1
	Mean		219.4	201.2	134.5	125.0
	Soaking	0.1%	159.6	141.9	125.5	114.3
		0.2%	183.4	174.8	129.3	125.7
		0.3%	188.7	183.5	116.5	113.6
	Mean		177.2	166.7	123.8	117.9
Mean			189.7	169.0	124.6	117.6
Mn	Soil	2.5 kg/fed	120.6	96.7	134.8	109.4
		5 kg/fed	117.2	99.3	163.7	109.6
		10 kg/fed	103.9	88.8	167.1	142.9
	Mean		113.9	95.0	155.2	120.6
	Foliar	0.1%	139.0	108.3	180.0	140.2
		0.2%	143.6	117.3	209.4	170.6
		0.3%	126.6	90.6	196.9	183.6
	Mean		136.4	105.4	195.4	164.8
	Soaking	0.1%	123.4	100.0	139.7	133.6
		0.2%	127.5	106.9	167.0	141.3
		0.3%	115.0	94.4	173.3	94.4
	Mean		122.0	100.4	160.0	123.1
Mean			124.1	100.3	170.2	136.2
Mean of methods	Soil		143.2	117.1	135.4	115.3
	Foliar		173.0	153.3	165.0	145.0
	Soaking		149.6	133.6	138.3	120.5
Mean of levels	Low		147.5	126.4	139.3	122.1
	Medium		172.7	145.0	155.0	132.3
	High		160.4	132.5	148.0	126.1
L.S.D. at 0.05	A		2.70	3.89	4.47	4.10
	B		4.45	4.71	3.86	2.79
	C		5.72	5.77	3.90	2.67
	AB		NS	NS	NS	NS
	AC		NS	NS	NS	NS
	BC		NS	NS	NS	NS
	ABC		NS	NS	NS	NS

Table (12): Effect of methods and levels of application of Fe and Mn on Fe and Mn uptake by straw of wheat plant

Micronutrients (A)	Methods (B)	Levels (C)	Fe (g/fed)		Mn (g/fed)	
			2013/2014	2014/2015	2013/2014	2014/2015
Without micronutrients (control)			192.7	180.0	65.2	52.3
Fe	Soil	2.5 kg/fed	140.6	177.3	48.8	46.7
		5 kg/fed	270.8	246.9	59.1	55.1
		10 kg/fed	249.6	237.8	48.0	45.8
	Mean		180.0	220.7	52.0	49.2
	Foliar	0.1%	254.5	242.5	60.2	57.4
		0.2%	379.3	354.6	74.4	70.4
		0.3%	336.9	311.7	56.6	53.0
	Mean		323.6	302.6	63.7	60.3
	Soaking	0.1%	202.8	189.3	51.0	48.4
		0.2%	288.9	270.7	61.5	59.7
		0.3%	262.3	232.6	50.2	47.0
	Mean		251.3	230.9	54.2	51.7
Mean			251.6	251.4	56.6	53.7
Mn	Soil	2.5 kg/fed	198.3	174.2	75.2	69.8
		5 kg/fed	197.6	179.3	91.2	85.0
		10 kg/fed	173.9	152.6	93.2	84.6
	Mean		189.9	168.7	86.5	79.8
	Foliar	0.1%	215.1	199.9	91.2	87.6
		0.2%	226.4	203.7	108.6	101.9
		0.3%	197.1	177.8	115.0	108.5
	Mean		212.9	193.8	104.9	99.3
	Soaking	0.1%	184.0	183.2	70.4	72.3
		0.2%	199.8	196.1	87.9	89.6
		0.3%	178.8	169.6	88.7	87.0
	Mean		187.5	183.0	82.3	83.0
Mean			196.8	181.8	91.2	87.4
Mean of methods	Soil		185.0	194.7	69.3	64.5
	Foliar		286.3	248.2	84.3	79.8
	Soaking		219.6	207.0	71.5	69.4
Mean of levels	Low		207.6	208.8	66.1	63.3
	Medium		260.5	241.7	80.5	77.0
	High		233.1	213.7	75.3	71.0
L.S.D. at 0.05	A		2.56	2.70	4.66	5.15
	B		3.19	3.34	4.17	4.72
	C		2.87	2.75	3.24	3.44
	AB		NS	NS	NS	NS
	AC		NS	NS	NS	NS
	BC		NS	NS	NS	NS
	ABC		NS	NS	NS	NS

Table (13): Effect of methods and levels of application of Fe and Mn on total Fe and Mn uptake by (grain+straw) of wheat plant

Micronutrients (A)	Methods (B)	Levels (C)	Fe (g/fed)		Mn (g/fed)	
			2013/2014	2014/2015	2013/2014	2014/2015
Without micronutrients (control)			297.2	274.8	178.4	164.1
Fe	Soil	2.5 kg/fed	294.4	313.7	170.6	158.1
		5 kg/fed	446.9	411.0	178.2	170.5
		10 kg/fed	437.1	354.8	153.5	184.0
	Mean		392.8	360.0	167.4	158.9
	Foliar	0.1%	443.1	417.7	194.2	180.9
		0.2%	607.7	561.2	215.6	201.8
		0.3%	577.7	532.4	184.8	173.1
	Mean		542.8	503.8	198.2	185.3
	Soaking	0.1%	362.4	331.2	176.5	162.7
		0.2%	474.3	445.5	190.8	185.4
		0.3%	451.0	416.1	166.7	160.6
	Mean		428.6	397.6	178.0	169.6
Mean			454.7	420.2	181.2	171.3
Mn	Soil	2.5 kg/fed	318.9	270.9	210.0	179.2
		5 kg/fed	314.8	278.6	254.9	194.6
		10 kg/fed	277.8	241.0	260.3	227.5
	Mean		303.8	263.5	241.6	200.4
	Foliar	0.1%	354.1	308.2	271.2	227.8
		0.2%	370.0	321.0	318.0	272.5
		0.3%	323.7	268.4	311.9	292.1
	Mean		349.3	299.2	300.4	264.1
	Soaking	0.1%	307.4	283.2	310.1	205.9
		0.2%	327.3	303.0	254.9	230.9
		0.3%	293.8	264.3	262.0	281.4
	Mean		309.5	283.5	242.3	206.1
Mean			320.9	282.1	261.4	223.5
Mean of methods	Soil		348.3	311.8	204.5	179.7
	Foliar		446.1	401.5	246.3	224.8
	Soaking		380.3	340.6	210.2	187.9
Mean of levels	Low		346.7	320.8	205.4	185.8
	Medium		423.2	386.7	235.3	209.3
	High		393.5	346.2	223.2	197.1
L.S.D. at 0.05	A		11.01	2.35	9.01	5.54
	B		7.62	8.19	7.66	5.05
	C		5.96	6.45	7.13	4.26
	AB		NS	NS	NS	NS
	AC		NS	NS	NS	NS
	BC		NS	NS	NS	NS
	ABC		NS	NS	NS	NS

by the level of application . The effect of level of Fe and Mn on nutrients uptake by grains and/or straw could be arranged in the descending order as follows : medium > high > low level , except phosphorus uptake which could be arranged in the descending order as follows : medium >low> high .The results also reveal that nutrient uptake did not respond to the interactions between treatments . In general , the plants supplied with iron at the medium level as foliar spraying absorbed more N, K and Fe by grains and total uptake ;while , plants treated with Mn recorded the highest Mn uptake in grains and N , K and Mn in straw . On the other hand, untreated plants with Fe and Mn excreted the highest values of phosphorus uptake in grains and / or straw and the lowest values of N , K , Fe and Mn uptake by grains and / or straw .

DISCUSSION

The proper and balanced nutrition is essential for optimal growth and development of wheat and any other plant . The total content of micronutrients in the soil is small , except iron , but they are important terms of crop nutrition . Only a few micronutrients are known to be essential for growth and development of plants . Iron and manganese among the irreplaceable micronutrients. Which have mostly a catalytic function . Supplying micronutrients in soil is currently decreasing due the intensive agriculture and higher yields which led to an overall higher nutrient uptake . High yielding varieties often require higher levels of available nutrients in the soil , because their ability to acquire nutrients is small . One sides nitrogen fertilization or focus on the N,P,K fertilization , however , lead to a dilution of the concentration of micronutrients in the soil and plants (Neuberg 1978) . Intensive tillage or drainage have resulted in stronger immobilization of certain elements , such as Fe and Mn . Highly concentrated fertilizers do not always include these nutrients and there was also a decrease in organic fertilization (Neuberg , 1978) .

One objective of this study was to compare the effectiveness of Fe and Mn with control on wheat growth and nutrient status . The results show that comparing with control the added Fe or Mn improved plant height , dry weight , number of spikes/ m^2 , number of grains/spike and grain and straw yields , while thousand grain weight was not affected . Iron surpassed Mn in the effects on the obevementioned characters , except plant height , which showed that the difference between the effect of Fe and Mn was not significant . N and K concentrations in grains and straw were not affected by micronutrient treatments . On the other hand, the added Fe or Mn significantly decreased P concentration in grains or straw comparing with control . Moreover , Fe application increased iron and decreased Mn concentration in grains or straw , meanwhile , Mn application decreased iron and increased Mn in grains and straw . Nitrogen , phosphorus , potassium and Fe uptake in grains and/or straw were positively affected by iron application , except total K which increased due to Mn application comparing with iron . On the other hand , Mn uptake in grains and/or straw increased by Mn application . The beneficial effect of micronutrients is mainly due to that iron is an important component in many plant enzyme system, such as cytochrome oxidase (electron transport) and cytochrome (terminal respiration step) . Iron is also a component of protein ferredoxin and is required for nitrate and sulfate reduction , N_2 assimilation, and energy (NADP) reduction . It functions as a catalyst or part of an enzyme system associated with chlorophyll formation . It is thought that Fe is involved in protein synthesis and root-tip meristem growth. In addition manganese is involved in the oxidation – reduction processes in the

photosynthetic electron transport system . It is essential in photosystem II for photolysis , acts as a bridge for ATP and enzyme complex phosphokinase and phosphotrans-ferases , and activates IAA oxidase (Jones and Case, 1990) . Similar results were obtained by Ali et al. (2009) who reported that Fe and Mn application enhanced wheat yield and quality .The negative effect of Fe and Mn on P concentration may be due to antagonistic effect between Fe or Mn on P absorption , where the high level of Fe or Mn inhibited P uptake and vice versa (Srivastava and Gupta (1996) . The negative effects of Fe or Mn on Mn and Fe contents in plants could be explained by iron – manganese antagonism . High levels of Mn often cause iron chlorosis in many plants . Also the use of higher rates of iron can induce Mn deficiency . Eptein and Stout (1951) suggested that the antagonistic effect of high Mn levels was mainly on Fe translocation from roots to shoot . It is worthy to notice that the effects of Fe or Mn on nutrient uptake were parallel to its effects on grain and straw yields . This is may be due to that nutrient uptake was calculated by multiplying grain or straw yields by nutrient concentration . These results are similar to those obtained by Mohamed (1994) and Ali *et al.* (2009) .

A second objective of this study was to compare the effects of three methods of micronutrient (Fe and Mn) application , namely soil ; foliar and seed soaking application on growth , yield and its components and nutrients status of wheat plants . The results reveal that , plant height , dry weight/plant , number of spikes/m^2 , number of grains/spike , grain and straw yields and N,P,K,Fe and Mn contents in grain and straw as well as thier uptake in grains and/or straw were highest when the micronutrient application was via spraying methods, followed by soaking , while these parameters were the lowest when the micronutrients application method was via soil application . Fe and Mn application via seed soaking has a moderate efficiency on these parameters . Foliar application of Fe and Mn has proved to be more effective on wheat and minimum loses involved in foliar spray (Sud *et al. ,* 1990). Many investigators concluded that foliar application of nutrient sources during growth stage increased grain and straw yields , grain and straw nutrients concentration and uptake as well as grain protein content such as Nazim *et al.* (2005) , Ali *et al.* (2009) , Yassin *et al.* (2010) , Wazir *et al.* (2011) and Abd El-Ghany *et al.* (2013) . In this concern , Mohamed (1994) mentioned that foliar application of micronutrients was more effective specially under the Egyptian condition , where these nutrients may be converted to unavailable forms if they applied to the soil . On the other hand , the superiority of soaking than soil method may be due to that seed soaking improves the stand establishment , advances phonological events and increases yield and grain content of nutrients (Farooq *et al. ,* (2012) . Also, Munawer *et al.* (2013) stated that seed priming usually increases germination rate and grow rate of plant . Therefore , seed priming with micronutrients is more successful and responsive in vegetables (Kaur *et al. ,* 2002) . Khalid and Melik (1982) found that wheat seed priming with manganese significantly improves growth rate and grain yield . Additionally Parera and Cantliffe (1994) and Harris (1996) reported that seed priming in water has been shown to decrease time between sowing and emergence and to improve seedling vigour , but the potential to damage the seed and inhibit germination by priming at high nutrient concentrations has also been reported by Johnson *et al.* (2005) . Moreover , in case of soaking , the combination with other additives like fungicide could be a complex prerequisite for optimal growth and development .

Application of micronutrients on seed may at least be partial prevention of deficiency during the growing season (Jari and Pavel, 2015) .

The third objective of this study was to state the effectiveness of different micronutrient (Fe and Mn) levels on wheat productivity and nutrient status. According to the analysis of variance of the data obtained from iron and manganese with different levels , it was witnessed that application level has significantly influenced plant height, dry weight / plant , number of spikes / m^2 , number of grains / spike , grain and straw yields as well as nutrient status in grains or straw . Maximum values of these parameters were recorded under the medium level (5 kg iron or manganese sulphate/ fed in case of soil application method and 0.2 % solution of iron or manganese sulphate in case of foliar or seed soaking methods) , followed by high level (10 kg sulphate iron or manganese / fed in case of soil application method and 0.3 % solution of iron or manganese sulphate in case of foliar or seed soaking methods) , while the lowest values were produced under the lowest level (2.5 kg sulphate iron or manganese / fed in case of soil application method and 0.1 % solution of iron or manganese sulphate in case of foliar or seed soaking methods) , except 1000-grains weight , N , P and K content (%) in grains and straw and Mn content (mg/kg) in straw . The weight of thousand grains and N and K concentration in grain and straw did not significantly respond to the different level of Fe or Mn . On the other hand increasing the levels of Fe or Mn significantly decreased phosphorus content in grains or straw . Moreover , Mn content in straw was positively responded to increasing application level of Mn . The inhibition effect of increasing micronutrient (Fe and Mn) level is mainly due to that high applications of essential nutrients like Fe and Mn decreased absorption of other nutrients by roots or transportation from roots to plant shoot (Munawar *et al.* , 2013) . The negative effect of Fe or Mn on P content in grains or straw is mainly due to the antagonistic effect between iron or manganese and phosphorus absorption as mentioned before . These results are in line with those obtained by Awad-Alla (2007) . The interaction effect show that , although the Fe content in grains and straw and Mn content in grains were higher along the medium level , under Fe application , the Fe content in grains and straw increased by increasing Fe level . Also , under Mn application , the Mn content in grains increased as Mn level increased . These results agree with those obtained by Ali *et al* (2009) . Finally , the most favourable treatment for wheat was spraying Fe or Mn using 0.2% sulphate solution twice, 30 day from sowing and 15 day later.

Conclusion

The results of our investigation showed that the addition of iron and manganese as foliar spraying at 0.2% sulphate saltcould be recomended improving wheat growth, yield and nutrient uptake under the conditions of middle Egypt.

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كفاءة طرق اضافة ومستويات الحديد والمنجنيز على النمو والمحصول ومحتوي المغذيات فى نبات القمح

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لدراسة تأثير طرق ومستويات اصافة الحديد والمنجنيز على الخصائص الكمية والنوعيه لمحصول القمح اجريت تجريبتان حقليتين فى ثلاث عوامل وهى العناصر الصغرى (بدون اضافة ، الحديد ، المنجنيز) طرق الاضافه (نقع البذور ، اضافة ارضيه ، رش) والمستويات (منخفض ، متوسط ، مرتفع) والتصميم المستخدم قطاعات كاملة العشوائيه فى اربع مكررات وتسعه عشر معامله ($3\times3\times2\frac{1}{2}+1$) ، وأجريت التجربتان فى محطة بحوث سدس (مركز البحوث الزراعيه) بمحافظة بنى سويف . وقد اظهر التحليل الاحصائى ومقارنة المتوسطات بصرف النظر عن طريقة الاضافه او مستويات الاضافه فأن اضافة الحديد والمنجنيز ادى الى زيادة فى النمو والمحصول ومكوناته وكذلك تركيز وامتصاص العناصر فى الحبوب والقش ما عدا وزن الالف حبة لم يتاثر باضافه الحديد والمنجنيز وكذلك انخفض محتوى المنجنيز انخفاضا معنويا باضافة الحديد وأعلى قيمة للوزن الجاف/نبات وعدد السنابل فى المتر المربع وعدد الحبوب فى السنبله ومحصول الحبوب ومحتوى وامتصاص النتروجين ، والفوسفور والبوتاسيوم والحديد فى الحبوب والقش كان عند رش النبات بكبريتات الحديدوز 0.2% وأن طريقة الرش تفوقت على الطريقتين الاخريتين فى مقاييس الدراسه فاعطت الاضافه الارضيه نفس التاثير المعنوى لطريقة نقع البذور وان رش او نقع البذور بالحديد او المنجنيز عند المستوى المتوسط فى صورة كبريتات بمعدل 0.2% أو الأضافه الأرضيه بمعدل 5 كجم/ف اعطت اعلى قيمه لمقاييس الدراسه مقارنا بالمستوى المنخفض والمرتفع واخيرا اظهرت النتائج ان رش الحديد بمعدل 0.2% فى صورة كبريتات حديدوز حسنت محصول القمح نوعا وكما .

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