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RESPONSE OF BARLEY TO FOLIAR APPLICATION OF SOME MICRONUTRIENTS UNDER DIFFERENT LEVELS OF SOIL SALINITY

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ABSTRACT

Three field experiments were carried out at three locations (Byalla, Kafr El-Sheikh and El-Hamol) which represent three levels of soil salinity: low level; moderate level and high level, respectively, at Kafr El-Sheikh Governorate, during the two consecutive growing seasons, 1999/2000 and 2000/2001 to study the response of barley plants to foliar application of Zn, Mn and Fe and their combinations.

The obtained results could be summarized as follows:

Grain yield of barley plants was increased by foliar fertilization with micronutrients compared with no micronutrients addition. At low soil salinity level, the highest significant value of grain and straw yields were obtained when Zn, Zn + Mn and Zn + Fe were applied respectively.

At moderate soil salinity level, foliar application of Mn and Zn gave significant higher grain and straw yield respectively. At high level of soil salinity; the yield of grain and straw yields were positively affected by Zn + Fe application. All applied treatments decreased chlorophyll a & b and carotenoids contents in leaves except the mixture of (Zn + Fe + Mn) gave highest increase. Also the mixture of (Zn + Fe + Mn) gave the highest value of nitrogen and protein contents in leaves and kernels. All available macro and micronutrients concentrations in soil were slightly affected with micronutrients. Foliar fertilization of micronutrients improves root and shoot growth and promotes nutrients uptake. foliar fertilization of barley plants grown under saline conditions may help to overcomes disturbances in nutrients uptake and translocation caused by salinity.

Keywords: Salinity, foliar fertilization, micronutrients barley, yield quality

INTRODUCTION

Barley (*Hordeum vulgar* L.) is considered one of the most important cereal crops in the world being used for many purposes such as malting and brewing industry, animal feeding, bread making as is or by mixing with wheat flour in some places, some human food and beverages and many other uses. In Egypt, the cultivated soils represent about 2.5% of the total area of the country (El-Tobgy, 1976). In this respect, the soils of Kafr El-Sheikh are affected widely with salinity hazard.

To utilize these saline soils, it is logically to look for cultivating those crops which have the ability to tolerate salinity either in irrigation water and/or in the soil. Barley (*Hordeum vulgare* L.) is more tolerant to salinity stress than many other field crops and could be grown after the reclamation of saline soils (Anderson and Reinbergs, 1985). Micronutrient deficiency is one of the factors that affect barley production. Before the construction of the Aswan High Dam, there was no acquit problem concerning the application of the

micro nutrient elements for the field crop that was mainly due to the Nile mud which used to supply the soil annually with appreciable amount of these elements (Ashour, 1974).

Currently, some problems appeared due to the deficiency of some micronutrient elements. From the analytical point of view, the most deficient micronutrients are Zn, Fe and Mn (El-Fouly, 1983). He also reported that Egyptian soils are characterized with high pH and low organic matter. Such properties reduced the availability of micronutrients to crops. (Sillanpää, 1982 and El-Fouly *et al.*, 1983). (El-Sayed *et al.*, 1996, Abdon *et al.*, 1971).

Many workers had confirmed the importance of macro and micro elements to the normal growth yield and quality of barley (Abd El-Hadi *et al.*, 1987, Abd El-Hadi, 1993, Amin *et al.*, 1998, El-Fouly, 1993 and El-Fouly and Fawzi, 1996. Glelah *et al.*, 1992, Mohamed, 1990).

Micronutrients had a major role of enzymes activation which involved in photosynthesis and respiration of plant. Some micronutrients are important for development of new leaves and meristems and also sugar translocation from leaves to all organs of plant.

The objective of the current study was to investigate the response of barley to foliar application of the micronutrient elements: Zn, Fe and Mn under different levels of soil salinity.

MATERIALS AND METHODS

Field studies were conducted in three locations at Kafr El-Sheikh Governorate, which different levels of salinity to study the effect of foliar application of Zn, Fe and/or Mn and their combinations on yield and quality of barley. The three locations varied in soil salinity (Table 1).

Some chemical and physical characteristics of the three locations are shown in Table (1). The experimental design in each location was complete randomized block with four replicates.

The experiment was included eight treatments in each location as follows:

1. (Control) solution.
2. Zn (as $ZnSO_4$ 1.5%).
3. Mn (as $MnSO_4$ solution 2%).
4. Fe (as $FeSO_4$ solution 3%).
5. Zn + Mn.
6. Zn + Fe.
7. Mn + Fe.
8. Zn + Mn + Fe.

Barley (Giza 123 cultivar) was sown on 30th November during 1999/2000 and 2000/2001 seasons.

Microelements were sprayed twice: After 50 and 75 days from planting. All the treatments received 45 kg N/fed. (as urea 46.5 % N) splitted at the rate of 200 liter/fed. into equal doses, half dose before the fist irrigation and the rest dose before the second one, 15 kg P_2O_5/fed.

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As super phosphate 15.5% P_2O_5) was used at seed bed preparation and 24 kg K_2O/fed. (as potassium sulphate 48% K_2O) splitted in one dose after 35 days after planting.

Other agricultural practices were followed as recommended for barley cultivation and local conditions of Kafr El-Sheikh Governorate.

Plant samples (flag leaves) were taken at the predicted maximum growth of barley (90 days from sowing) and prepared for chemical analysis. At harvest, soil samples at depth 0-45 cm and kernels and straw samples were taken and prepared for chemical analysis. Available N was extracted by K_2SO_4 5% and determined by microkjeldahl method (Page 1982). Available P, K and micronutrients were extracted by ammonium bicarbonate-DTPA (Soltanpout and Schwab, 1977) and measured by Atomic absorption spectrophotometer. Plant samples were digested using wet ashing technique as described by Chapman and Pratt (1961). P was determined colorimetrically according to the method described by Snell and Snell (1967), K was determined by flame photometer, total N was determined by microkjeldahl and micronutrients were determined by atomic absorption spectrophotometer. Both chlorophyll a & b and carotenoids were determined as described by Wettstein, (1957). The collected data were treated statistically according to Snedecor and Cochran (1980).

RESULTS AND DISCUSSIONS

Growth yield and yield components:

Data presented in Table (2) show that, in both seasons spraying barley plants with the different micronutrient solutions caused a significant increase in plant height (Pl. Ht.) compared to control.

The plants sprayed with individual Zn under high level of soil salinity (El-Hamol location) were much superior in height if compared with the other treated plants. The increases in plant height due to Zn application were 18.1 and 19.4% over the control treatment in the first and second seasons, respectively. There were no significant difference between Zn application and other micronutrient elements and its combinations, except Fe elements and its combinations, except Fe element which gave the lowest value.

With respect to Kafr El-Sheikh locations, (moderate level of soil salinity) and Byalla location (low level of soil salinity) Zn application increased Pl. Ht. by 9, 8.9, 7.6 and 7.1% over the control treatment in the first and second seasons respectively. This increase may be due to the facts that Zn participates in the production of IAA which is essential for the elongation of the plants (Katyal and Randhawa, 1983).

Data in Table (2) indicate that at low, moderate and high level of soil salinity, grain, straw and biological yields of barley plants significantly increased by Zn and/or Fe application in the first seasons while 1000 kernel weight significantly increased with application of any treatments during the two growth seasons. These results are in harmony white those obtained by Hefni (1980), El-Sayed *et al.* (1996) and Abd El-Magid *et al.* (2000).

The increase in grain, straw and 1000 kernel weight may be due to the fact that applying micronutrients delayed the senescence of barley plants through an increased the total dry matter accumulation and yield components (Garg, 1987).

Pigments content:

Data presented in Table (3) show the amounts of chlorophyll a & b and carotenoids in barley leaves as affected by Zn, Mn and Fe. It is clear from such data that all applied treatments decreased chlorophyll a & b and carotenoids content except the mixture of (Zn + Mn + Fe) gave highest increase value compared to control in the two seasons. The obtained results are in harmony wit those found by Sharaf *et al.* (1984).

Macro-nutrients content:

Data listed in Tables (4 & 5) show the effect of Zn, Mn and Fe on macro-nutrients content of barley plants and kernels. It is clear from such data that all applied treatments decreased nitrogen content in barley plants (Flage leaves) compared to control in the two seasons. The highest effect on nitrogen content was manifested by the plants treated with individual Zn. The mixture of (Zn + Mn + Fe) gave highest value of nitrogen if compared to other applied mixtures. But the data in Table (4) show the effect of Zn, Mn and Fe on the nitrogen content of barley kernels. It is clear from such data that all applied treatments increased nitrogen and protein contents compared to control. The highest effect on nitrogen and protein contents under different levels of soil salinity was manifested by the plants treated with individual Zn. The mixture of (Zn + Mn + Fe) gave highest values of nitrogen and protein if compared to other mixtures. The increase in nitrogen content may be due to the effect of used micro-nutrients in the formation and/or the activity of the enzymes responsible for protein synthesis (Abdel-Aziz *et al.*, 1986).

Data concern P content in Table (5) indicate that spraying barley plants with Zn, Mn and Fe individually or in mixtures significantly increased P content compared to control. The most favorable treatment in this respect was mixture of (Zn + Mn + Fe) in the two seasons.

As for K content, the results in Table (5) show that application of Zn, Mn and Fe significantly increased K content in the two seasons. The maximum value of K content was obtained by spraying barley plants with (Zn + Fe). The results concern the effect of micronutrients in N, P and K content are in harmony with those obtained by Sharaf *et al.* (1984) and El-Kholany and Hefni (1985).

Micro-nutrients content:

Data of Zn, Mn and Fe contents of barley leaves are shown in Table (5) it is clear from such data that all applied treatments increased Zn content compared to control. The highest values of Zn were resulted by spraying plants with Zn as individual element and with (Zn + Mn + Fe) as mixture. As for Fe content, the best effect in this connection was obtained by spraying barley plants with Fe followed by spraying with mixture (Zn + Mn + Fe). Regarding Mn content, it is clear from the results that foliar application accumulated high amount of Mn. Other applied treatments showed slight increase in Mn content compared to control.

The increase in micro-nutrients content by the different treatments could be attributed to stimulating effect of these treatments on root growth and nutrient uptake. these results are in agreement with those obtained by El-Kholany and Hefni (1985) and Khand and Thakur (1991).

Nutrient status of the soil:

Data in Table (5) show that soil pH was not affected with micronutrients application. While, N and P slightly affected El-Hamol location (high level of soil salinity). Available K decreased with micronutrient elements application.

Micronutrients application led to slightly increase in the amounts of available Zn and Mn under different levels of soil salinity whereas, Fe slightly decreased under moderate and high level of soil salinity.

Finally, it could be concluded that, barley crop needs micronutrients foliar application, specially Zn under high and low levels of soil salinity, while application of Mn is recommended for moderate level of soil salinity due to the lower Mn content of this studied soil.

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استجابة محصول الشعير للرش ببعض العناصر المغذية الصغرى تحت ظروف الأراضى المتأثرة بالأملاح

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أقيمت ثلاث تجارب حقلية فى ثلاث مراكز بمحافظة كفرالشيخ فى موسمى ١٩٩٩/٢٠٠٠م ، ٢٠٠٠/٢٠٠١م لدراسة مدى إستجابة محصول الشعير للرش بمحاليل بعض العناصر المغذية الصغرى وهى الزنك ، المنجنيز ، الحديد ومخلوط هذه العناصر فى صورة مخلبية بتركيزات ١,٥% ، ٢% ، ٣% وأثر ذلك على كمية المحصول وجودة الحبوب لمحصول الشعير جيزه ١٢٣ الذى تم زراعته فى ثلاث مواقع تختلف فى مستويات ملوحة التربة حيث موقع بيلا (يمثل مستوى منخفض فى ملوحة التربة) وموقع كفرالشيخ (يمثل مستوى متوسط فى ملوحة التربه) وموقع الحامول (يمثل مستوى مرتفع فى ملوحة التربه).

وتتلخص النتائج فيما يلى:

١) نباتات الشعير التى تم رشها بأى من العناصر الثلاثة الزنك ، المنجنيز ، الحديد بصورة منفردة أو فى صورة مخاليطها كانت النباتات أكثر طولا من النباتات الغير معاملة وقد تفوقت النباتات فى الطول التى تم رشها بعنصر الزنك عن باقى المعاملات الأخرى وخاصة عند المستوى المنخفض فى ملوحة التربه.

٢) سبب الرش بكل من العناصر المغذية الزنك والمنجنيز والحديد تأثيرا فى زيادة وزن الحبوب فى السنبلة وكذلك وزن الألف حبه مما أدى إلى زيادة كمية محصول الحبوب.

٣) أدى الرش بكل من العناصر (الزنك ، المنجنيز ، الحديد) سواء منفردة أو فى صورة مخلوط إلى زيادة محتوى الحبوب من النيتروجين والبروتين وكذلك زيادة محتوى الأوراق من هذه العناصر وخاصة النباتات المنزرعة تحت مستوى مرتفع فى ملوحة التربه.

٤) أدى استخدام العناصر المغذية (الزنك ، المنجنز ، الحديد) إلى زيادة محتوى الأوراق من العناصر الصغرى ولكن لم تتأثر محتوى الأوراق من النيتروجين والفوسفور والبوتاسيوم.

٥) نقص محتوى الأوراق من الكلوروفيل أ ، ب والكاروتينات نتيجة الرش بالعناصر المغذية الصغرى.

٦) أوضحت النتائج أن النيتروجين والبوتاسيوم والفوسفور الميسر فى التربه زاد نتيجة الرش بالعناصر الثلاثة (الزنك ، المنجنيز ، الحديد) ماعدا موقع الحامول (المستوى المرتفع فى ملوحة التربه) أدى الرش بالعناصر الصغرى إلى إنخفاض البوتاسيوم الميسر فى التربه.

7) أدى استخدام العناصر الصغرى إلى زيادة تركيز كل من عنصر الزنك ، المنجنيز ، الحديد الميسر بالتربه فى كل من موقعى كفرالشيخ ، بيلا بينما فى موقع الحامول (المستوى المرتفع فى ملوحة التربه) قد إنخفض تركيز الحديد الميسر بالتربه نتيجة الرش بالعناصر الصغرى.

Table (1): Some physical and chemical characteristics of the soil in the three experimental area at soil depth of 0-45 cm during the 1st and 2nd season.

Locations	Water table (cm) at		pH (1: 2.5)		ECe dSm^{-1}		Soil Texture	Available macro-and micronutrients (ppm)*											
								N**		P		K		Zn		Mn		Fe	
	1st	2nd	1st	2nd	1st	2nd		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Byalla	117	115	7.85	7.97	3.04	3.11	Clay loam	125.6	113.0	2.65	2.46	254	235	0.28	0.21	1.78	1.72	2.32	2.13
Kafr El-Sheikh	115	110	7.95	8.12	4.42	4.73	Clay	105.8	101.5	3.74	3.52	324	312	0.52	0.45	1.15	1.10	2.35	2.10
El-Hamol	95	89	8.68	8.29	9.35	9.82	Heavy clay	85.7	76.8	4.15	4.10	478	451	0.43	0.38	1.69	1.43	1.84	1.62

*** Micronutrients, P and K were extracted by Amm. bicarbonate DTPA (Soltanpour and Schwab, 1977)**

**** Available N was extracted by potassium sulphate 5% (Page, 1982)**

1st = First season 1999/2000

2nd = Second season 2000/2001

Table (2): Effect of foliar application of Zn, Mn and Fe on means of growth and yield characteristics of barley growth at three levels of soil salinity at Kafr El-Sheikh Governorate during the 1st and 2nd seasons.

Treatments	Pl. Ht.		BY		GY		SY		1000 kernel weight (gm)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
	Byalla location									
Control	92.1	91.3	13.65	12.83	5.60	4.98	8.05	7.85	53.65	52.10
Zn	99.1	97.8	15.20	13.96	6.75	5.80	8.45	8.16	62.15	61.50
Mn	89.3	86.9	14.75	13.65	5.95	5.20	8.80	8.45	58.70	57.95
Fe	87.2	85.8	14.80	13.82	6.10	5.52	8.70	8.30	59.65	58.46
Zn + Fe	93.3	92.2	15.00	14.42	6.20	5.80	8.80	8.62	61.15	60.30
Mn + Fe	90.2	88.3	14.70	13.60	5.95	5.20	8.75	8.40	59.85	57.90
Zn + Mn	94.5	92.4	14.95	14.21	6.30	6.01	8.65	8.20	61.20	59.70
Zn + Mn + Fe	93.1	92.3	15.10	14.40	6.45	6.25	8.65	8.15	61.90	59.85
L.S.D. 5%	1.22		1.27		1.33		0.18		1.25	
	Kafr El-Sheikh location									
Control	86.4	85.1	12.10	10.97	3.95	3.32	8.15	7.65	43.45	42.10
Zn	94.2	92.7	13.85	12.60	5.20	4.65	8.65	7.95	45.49	43.55
Mn	88.1	86.6	12.95	11.80	4.60	4.10	8.35	7.70	44.20	42.90
Fe	87.7	86.1	13.20	11.97	4.75	4.25	8.45	7.72	44.82	42.95
Zn + Fe	92.8	90.7	13.54	12.20	4.95	4.42	8.59	7.78	45.25	43.53
Mn + Fe	89.3	87.1	13.10	12.01	4.80	4.35	8.30	7.66	44.70	42.85
Zn + Mn	91.5	90.3	13.45	12.40	4.95	4.50	8.50	7.90	45.15	43.45
Zn + Mn + Fe	90.3	88.4	13.60	12.67	5.15	4.82	8.45	7.85	45.30	43.65
L.S.D. 5%	1.26		1.17		1.24		0.16		1.23	
	El-Hamol location									
Control	78.3	76.2	11.85	10.90	3.65	3.15	8.20	7.75	38.39	37.25
Zn	92.5	91.0	13.15	12.55	4.35	4.10	8.80	8.45	41.35	39.85
Mn	89.1	87.8	12.35	12.50	3.82	3.60	9.53	8.90	39.75	38.25
Fe	87.6	85.9	11.95	11.35	3.95	3.50	8.00	7.85	39.95	38.45
Zn + Fe	91.3	89.3	12.13	11.55	4.15	3.75	7.98	7.80	40.85	39.65
Mn + Fe	88.4	86.9	12.10	11.55	3.90	3.65	8.20	7.90	39.85	38.50
Zn + Mn	90.2	88.5	11.99	11.55	4.20	3.80	7.79	7.75	40.73	39.30
Zn + Mn + Fe	91.3	89.1	12.55	11.65	4.30	3.85	8.25	7.80	41.15	39.95
L.S.D. 5%	1.35		1.26		1.36		1.32		1.38	

Pl. Ht. = Plant height in cm SY = Straw yield tons/ha BY = Biological yield tons/ha. GY = Grain yield tons/ha
2nd = Second season 2000/2001 1st = First season 1999/2000

Table (3): Effect of foliar application of Zn, Mn and Fe on pigments content in barley plants at the three studied locations (mg/100 mg) during the 1st and 2nd seasons.

Treatment	Chlorophylls								Total chlorophyll			
	a		b		a/b		Total		Carotenoids		carotenoids	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
	Byalla location											
Control	472.75	453.45	241	236	1.96	1.92	713.75	689.45	294.69	285.42	2.42	2.42
Zn	430.15	41530	232	221	1.85	1.88	662.15	636.30	272.25	265.25	2.43	2.40
Mn	442.25	419.25	239	226	1.85	1.86	681.25	645.25	285.10	274.20	2.39	2.35
Fe	471.65	432.50	245	232	1.93	1.86	716.65	664.50	295.20	286.40	2.43	2.32
Zn + Fe	470.10	429.25	242	233	1.94	1.84	712.10	662.25	291.30	285.50	2.44	2.32
Mn + Fe	471.20	425.85	241	232	1.96	1.84	712.00	657.85	291.10	284.45	2.45	2.31
Zn + Mn	451.30	422.75	238	219	1.96	1.93	689.30	641.75	282.30	273.60	2.44	2.35
Zn + Mn + Fe	485.20	461.35	246	235	1.97	1.96	731.20	696.35	294.90	285.70	2.48	2.44
L.S.D. 5%	0.14		0.18				0.27		0.19			
	Kafr El-Sheikh location											
Control	392.22	381.75	238	232	1.65	1.65	630.22	613.75	318.83	314.25	1.98	1.95
Zn	385.15	375.35	215	211	1.79	1.78	600.15	586.35	310.10	306.75	1.94	1.91
Mn	388.20	376.55	219	215	1.77	1.75	607.20	591.55	312.15	3085.45	1.95	1.92
Fe	390.25	385.85	225	223	1.77	1.73	615.25	608.85	319.20	317.25	1.93	1.92
Zn + Fe	390.10	386.25	220	217	1.74	1.78	610.10	603.25	318.50	316.75	1.92	1.90
Mn + Fe	388.90	378.45	224	222	1.74	1.70	612.90	600.45	317.15	314.50	1.93	1.91
Zn + Mn	386.15	374.65	220	218	1.76	1.72	606.15	592.65	314.40	311.85	1.93	1.90
Zn + Mn + Fe	390.30	387.50	227	226	1.72	1.71	617.30	613.50	319.10	316.65	1.93	1.94
L.S.D. 5%	0.13		0.16				0.23		0.18			
	El-Hamol location											
Control	388.15	365.35	209	204	.1.86	1.79	597.15	569.35	240.83	232.25	2.48	2.45
Zn	382.20	362.20	204	202	1.87	1.79	586.20	564.20	235.15	229.75	2.49	2.46
Mn	385.10	364.30	208	203	1.85	1.79	593.10	567.30	236.10	231.65	2.51	2.45
Fe	390.30	369.40	212	209	1.84	1.77	602.30	578.40	240.20	231.95	2.51	2.49
Zn + Fe	390.10	367.25	210	206	1.86	1.78	600.10	573.25	240.10	230.25	2.50	2.49
Mn + Fe	389.80	365.85	210	207	1.86	1.77	599.80	572.85	240.00	229.85	2.50	2.49
Zn + Mn	387.10	364.75	207	204	1.86	1.79	594.10	568.75	236.20	231.25	2.52	2.46
Zn + Mn + Fe	390.10	368.65	210	208	1.86	1.77	600.10	576.65	241.20	233.80	2.49	2.47
L.S.D. 5%	0.12		0.17				0.21		0.17			

1st = First season 1999/2000 2nd = Second season 2000/2001

Table (4): Effect of foliar application of Zn, Mn and Fe on nitrogen content in barley plants at the three studied locations (gm/100 gm).

Treatments	Plant (flag leaf)								Kernels									
	Soluble		Insoluble		Total		Soluble/ insoluble		Soluble		Insoluble		Total		Soluble/ insoluble		Protein	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
	Byalla location																	
Control	0.22	0.21	1.14	1.10	1.36	1.31	0.19	0.19	0.86	0.83	0.89	0.85	1.75	1.68	0.97	0.98	9.73	9.34
Zn	0.15	0.14	1.02	1.00	1.17	1.14	0.15	0.14	0.96	0.94	0.97	0.94	1.93	1.88	0.99	1.00	10.73	10.45
Mn	0.17	0.15	1.04	1.01	1.21	1.16	0.16	0.15	0.92	0.8	0.99	0.93	1.91	1.81	0.93	0.95	10.62	10.06
Fe	0.20	0.17	1.08	1.03	1.28	1.20	0.19	0.17	0.89	0.85	0.86	0.94	1.85	1.79	0.93	0.90	10.29	9.95
Zn + Fe	0.19	0.17	1.06	1.04	1.25	1.21	0.18	0.16	0.93	0.91	0.98	093	1.91	1.84	0.95	0.98	10.62	10.23
Mn + Fe	0.19	0.16	1.07	1.06	1.26	1.22	0.18	0.15	0.91	0.91	0.97	0.95	1.88	1.86	0.94	0.96	10.45	10.34
Zn + Mn	0.20	0.18	1.00	1.01	1.20	1.19	0.20	0.18	0.92	0.90	0.99	0.96	1.91	1.86	0.93	0.94	10.62	10.34
Zn + Mn + Fe	0.21	0.18	1.08	1.06	1.29	1.25	0.19	0.18	0.94	0.92	0.99	0.97	1.93	1.89	0.95	0.95	10.43	10.51
L.S.D. 5%	0.25		0.21		0.35				0.28		0.18		0.42				0.58	
	Kafr El-Sheikh location																	
Control	0.21	0.20	1.11	1.03	1.32	1.23	0.19	0.19	0.98	0.93	0.82	0.81	1.80	1.74	1.20	1.15	10.01	9.67
Zn	0.14	0.13	0.99	0.94	1.15	1.07	0.14	0.14	1.10	1.06	0.85	0.82	1.95	1.88	1.29	1.25	10.84	10.45
Mn	0.16	0.14	0.94	0.92	1.10	1.06	0.17	0.15	0.92	0.88	0.98	0.93	1.90	1.81	0.94	0.95	10.56	10.06
Fe	0.19	0.16	1.01	0.95	1.20	1.11	0.19	0.17	0.95	0.92	0.94	0.92	1.89	1.84	1.02	1.00	10.51	10.23
Zn + Fe	0.19	0.15	0.99	0.96	1.18	1.11	0.19	0.16	1.02	0.95	0.96	0.93	1.98	1.88	1.06	1.02	11.01	10.45
Mn + Fe	0.18	0.17	1.07	1.05	1.25	1.22	0.17	0.16	0.98	0.93	0.91	0.91	1.89	1.84	1.08	1.02	10.51	10.23
Zn + Mn	0.19	0.18	0.95	0.93	1.14	1.11	0.20	0.19	1.04	1.02	0.88	0.87	1.92	1.89	1.18	1.17	10.68	10.51
Zn + Mn + Fe	0.20	0.18	1.06	1.05	1.26	1.23	0.19	0.17	1.05	1.04	0.90	0.88	1.95	1.92	1.17	1.18	10.84	10.68
L.S.D. 5%	0.21		0.24		0.36				0.32		0.28		0.35				0.45	
	El-Hamol location																	
Control	0.23	0.20	1.19	1.13	1.42	1.33	0.19	0.18	0.90	0.85	1.02	1.00	1.92	1.85	0.88	0.85	10.68	10.29
Zn	0.17	0.15	1.02	1.01	1.19	1.16	0.17	0.15	0.99	0.94	1.33	1.25	2.22	2.19	0.74	0.75	12.34	12.18
Mn	0.18	0.16	0.97	0.95	1.15	1.11	0.19	0.17	0.93	0.91	1.05	1.02	1.98	1.93	0.89	0.89	11.01	10.73
Fe	0.21	0.20	1.09	1.03	1.30	1.23	0.19	0.19	0.92	0.91	1.04	1.01	1.96	1.92	0.88	0.90	10.90	10.68
Zn + Fe	0.20	0.19	1.05	1.02	1.25	1.11	0.19	0.19	0.98	0.93	1.00	0.95	1.98	1.88	0.98	0.98	11.01	10.45
Mn + Fe	0.19	0.17	1.09	1.03	1.28	1.20	0.17	0.17	0.94	0.92	1.00	0.91	1.94	1.83	0.94	1.01	10.79	10.17
Zn + Mn	0.20	0.19	1.00	1.01	1.20	1.20	0.20	0.19	0.96	0.94	1.14	1.05	2.10	1.99	0.84	0.89	11.68	11.06
Zn + Mn + Fe	0.21	0.18	1.11	1.10	1.32	1.28	0.19	0.16	0.96	0.93	1.06	1.01	2.02	1.94	0.91	0.92	11.23	10.79
L.S.D. 5%	0.25		0.23		0.38				0.29		0.42		0.45				0.52	

1st = First season 1999/2000 **2nd = Second season 2000/2001**

Table (5): Concentration of macro and micronutrients in soils and leaves of barley plants as influenced by foliar application of Zn, Mn and Fe at the three studied locations.

Treatments	Soils														Leaves (flag leaves)											
	pH (1: 5)		Available macro and micronutrients (ppm)												Total macro % and micronutrients (ppm)											
			N		P		K		Zn		Mn		Fe		N		P		K		Zn		Mn		Fe	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
	Byalla location																									
Control	7.43	7.47	264	254	3.30	3.10	3.72	364	0.42	0.38	1.79	1.62	2.21	2.10	1.32	1.30	0.18	0.17	0.03	0.03	19.0	17.0	49.0	48.2	464	475
Zn	7.38	7.41	278	265	2.70	2.80	3.70	355	0.39	0.41	1.92	1.73	2.15	2.05	1.15	1.23	0.12	0.13	0.04	0.04	21.5	20.3	49.0	49.0	512	489
Mn	7.35	7.38	252	259	3.10	2.85	3.90	375	0.35	0.38	2.18	1.88	283	2.72	1.10	1.19	0.19	0.20	0.03	0.03	20.6	20.1	59.0	54.6	716	653
Fe	7.37	7.39	260	256	3.28	2.87	415	382	0.45	0.42	2.10	1.92	2.72	2.68	1.20	1.25	0.20	0.22	0.04	0.04	21.4	20.6	52.0	51.9	785	696
Zn + Fe	7.38	7.42	269	268	3.12	2.84	395	374	0.34	0.37	2.08	1.90	2.68	2.64	1.18	1.19	0.19	0.21	0.05	0.04	21.2	21.0	54.0	55.2	773	685
Mn + Fe	7.36	7.37	265	262	3.25	2.85	378	380	0.43	0.41	1.94	1.81	2.65	2.63	1.25	1.23	0.18	0.19	0.04	0.03	20.9	19.5	58.0	56.8	765	692
Zn + Mn	7.39	7.42	275	267	3.13	2.90	374	362	0.50	0.42	2.13	2.10	2.62	2.61	1.14	1.12	0.13	0.15	0.04	0.03	20.8	18.9	58.0	57.3	685	643
Zn+Mn+Fe	7.36	7.38	283	279	3.12	2.95	412	385	0.45	0.45	1.92	1.91	2.79	2.72	1.26	1.24	0.15	0.17	0.04	0.05	21.4	21.2	57.0	57.8	795	715
L.S.D. 5%			2.1		1.6		1.9		2.5		1.7		1.5		2.4		1.4		2.4		2.2		2.3		3.5	
	Kafr El-Sheikh location																									
Control	7.52	7.58	251	235	5.78	5.65	423	416	0.85	0.82	1.59	1.52	1.92	1.83	1.36	1.32	0.15	0.14	0.03	0.03	21.1	20.3	52.0	50.3	483	469
Zn	7.51	7.49	235	238	5.10	5.48	439	403	1.29	0.98	1.32	1.45	1.83	1.81	1.17	1.12	0.13	0.14	0.04	0.04	23.4	23.1	54.0	52.8	682	648
Mn	7.51	7.53	223	236	5.32	5.53	441	421	1.03	0.91	1.82	1.73	0.79	0.96	1.21	1.23	0.16	0.17	0.03	0.03	21.3	21.2	63.0	58.7	693	675
Fe	7.48	7.47	258	241	4.85	5.45	435	423	1.15	0.96	1.62	1.70	0.95	1.14	1.28	1.32	00.18	0.16	0.04	0.04	21.5	21.3	58.0	57.3	721	698
Zn + Fe	7.49	7.48	248	243	5.35	5.52	410	402	1.32	1.12	1.61	1.65	1.53	1.48	1.25	1.22	0.16	0.17	0.04	0.05	22.4	21.8	54.0	54.6	701	693
Mn + Fe	7.50	7.47	255	239	5.12	5.49	432	413	1.10	1.03	1.72	1.63	1.42	1.45	1.26	1.23	0.17	0.18	0.04	0.03	21.2	20.7	59.0	58.7	710	705
Zn + Mn	7.48	7.51	252	240	5.85	5.53	445	3425	1.32	1.15	1.81	1.74	1.63	1.56	1.20	1.21	0.15	0.14	0.03	0.04	22.3	22.1	61.0	60.3	686	674
Zn+Mn+Fe	7.51	7.46	269	245	5.83	5.58	402	412	1.42	1.25	1.51	1.50	1.60	1.58	1.29	1.28	0.17	0.18	0.05	0.05	23.1	22.9	61.0	62.2	710	716
L.S.D. 5%			2.3		1.8		2.1		2.8		1.9		1.7		2.3		1.6		2.5		2.5		3.1		3.8	
	El-Hamol location																									
Control	7.68	7.89	208	203	5.70	5.62	273	262	0.78	0.75	1.78	1.65	1.89	1.85	1.42	1.41	0.21	0.21	0.03	0.03	18.8	18.2	48.0	46.0	435	421
Zn	7.64	7.52	217	209	5.45	5.43	312	260	1.38	0.98	1.95	1.79	1.74	1.73	1.19	1.21	0.19	0.20	0.05	0.04	21.3	22.1	49.0	47.0	523	516
Mn	7.63	7.61	206	205	5.35	5.38	322	275	1.12	1.02	2.68	1.95	0.85	0.95	1.15	1.18	0.22	0.23	0.03	0.03	20.1	21.3	61.0	58.0	653	632
Fe	7.66	7.63	210	208	5.08	5.42	218	254	0.95	0.85	1.87	1.71	0.95	0.94	1.30	1.29	0.26	0.27	0.05	0.04	20.7	20.2	52.0	51.3	713	695
Zn + Fe	7.65	7.55	208	209	5.85	5.45	213	255	1.15	1.03	1.81	1.73	1.47	1.38	1.25	1.26	0.22	0.23	0.05	0.05	21.1	20.8	52.0	53.1	705	696
Mn + Fe	7.64	7.53	211	207	5.32	5.46	212	261	0.85	0.82	1.95	1.82	1.32	1.35	1.28	1.29	0.25	0.24	0.04	0.03	20.5	21.1	58.0	59.2	710	715
Zn + Mn	7.62	7.55	221	210	5.12	5.45	273	261	1.20	0.98	1.98	1.85	1.45	1.43	1.20	1.23	0.20	0.21	0.03	0.03	21.1	20.9	59.0	59.8	671	684
Zn+Mn+Fe	7.65	7.51	225	212	5.43	5.52	245	252	1.46	1.21	1.78	1.72	1.38	1.39	1.32	1.36	0.23	0.24	0.05	0.05	21.2	21.6	58.0	59.9	702	713
L.S.D. 5%			8.2		2.1		3.4		3.6		2.2		2.3		1.8		2.1		2.3		3.5		3.7		4.2	

1st = First season 1999/2000 **2nd = Second season 2000/2001**