Growth and Mineral Status of Barley Plants As Affected By Drought and Foliar Fertilization

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Abstract: Two field experiments were conducted in the Experimental Farm of the National Research Centre, Shalakan, Kaloubia Governorate during 2005/2006 and 2006/2007 winter seasons to evaluate the foliar fertilization Foliar-X (commercial multi-nutrients) and water deficit at two growth stages and those irrigate regularly on growth and yield of barley c.v. Giza 125. Plant height, number of tiller and spikes / plant and spike length in the first and second seasons, did not show any significant effect by water deficit at heading or late at dough stage. In the first season, dry weight of shoots, spikes and whole plant values were lower when plants subjected to omitting of irrigation at heating than that at dough stage or control plants, however, the differences in whole plant were only significant. The differences in these parameters in plants exposed to water deficit at dough stage and that irrigated regularly were approximately equal. The highest negative effect by omitting of irrigation at heading was higher in the dry weight of the whole plant followed by that on shoots in the second season while in the first, season the degree of depression was similar. Phosphorus concentration in straw drastically decreased by subjection barley plants to drought at heading and at dough stages and at latter stage the effect was pronounced. However, the differences in N and K concentrations seemed to be equal with both drought treatments and the control treatment. Data showed that water deficit led to a depression in K, Fe, Mn and Zn uptake and the depressions continuous as the drought treatment delayed. The differences in K uptake were not great enough to reach the level of significant. Later deficit at heading gave the higher value of N uptake but at dough stage induced decrement but less than that resulted with that at heading. Nevertheless, the water deficit treatment at heading decrease the uptake of P, while, under deficit at dough stage this element pronouncedly increased compare to regular irrigation treatment.

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1. Introduction

Water scarcity is an increasingly important issue in many parts of the world. Climate changes predictions of increase in temperature and decrease in rainfall mean water will become even scarce. Since agriculture is the major water user, efficient use of water in agriculture is needed for the conservation of this limited resource (Farri and Faci, 2006).

In Egypt, the production of cereals in old lands still up tell now not enough to face the increasing demand of the population which increased rapidly in the last decades. The increase of areas and productivity of less water requirement crops in the new cultivated soils are considered one of the important ways for narrowing the cereal gap.

Barley (*Hordeum vulgare L.*) is grown under wide range of environmental conditions. Generally, it grows in areas where water supply is limited and where crop production depends mainly upon rainfall. In Egypt, barley grains and straw are mainly used for animal feed and sometimes grains are used for bread making by some bedowins (Ashour and Selim, 1994). Negative effect of drought on growth and mineral uptake of barley were studied before by many authors: among of them Angum, *et al*. (2002) and Hussein, *et al.* (2006).

Beneficial effects of fertilization through soil application or foliar spray and its interaction with water stress on growth and mineral status of barley plants were reported by Selim (1994); Angas, *et al.* (2006) and Li, *et al*. (2009).

This study was designed to investigate the positive effects of foliar fertilizer on growth and mineral status of barley plants grown under drought through some growth stages.

2. Material and Methods

Two field experiments were conducted in the Experimental Farm of the National Research Centre, Shalakan, Kaloubia Governorate during 2005/2006 and 2006/2007 winter seasons to evaluate the foliar fertilization (Foliar-X) and water deficit at two growth stages and those irrigate regularly on growth and yield of barley c.v. Giza 125. Some physical and chemical properties of soil in the experimental sites were noted in Table (1).

Table (1): Analytical data of the experimental site**.**

A . Soil mechanical analysis

Sand		Silt	Clay	Soil Texture
Course >200 μ %	Fine 200-20μ %	20-2 μ %	< 2 μ %	
7.20	14.25	30.22	48.33	clay

B. Soil chemical analysis

pH 1:2.5	EC dSm^{-1} 1:5	$CaCO_3$ %	CEC mole Kg^{-1}	OM %	Soluble cations and anions meq/100 g soil							
					Na^+	K^+	Ca^{2+}	Mg^{2+}	CO^-_3	HCO^{-3}	Cl^{-1}	SO^{-2}
7.15	1.3	2.53	33.5	1.3	1.82	0.23	2.38	1.27	0.0	0.91	1.9	1.89

Available macro-nutrients %			Available micro-nutrients (ppm)			
N	P	K	Zn	Fe	Mn	Cu
0.47	0.25	0.95	3.1	4.8	7.3	1.2

Soil physical and chemical analysis were done according to the methods described by Cottenie, *et al.* (1982) and Page, *et al.* (1982).

Every experiment included 9 treatments, three irrigation treatments in combination with three foliar fertilizer levels. The treatments were as follows **:**

I- **Drought:** 1- Regular irrigation. (D0). 2- Omitting of irrigation at heading stage (D1) 3- Omitting of irrigation at dough stage (D2)

II- **II-Foliar fertilization**: Foliar fertilizer: Foliar-X contains (10% N, 7% P_2O_5, 8% K_2O, 2500 ppm Zn ; 3000 ppm Mn ; 2500 Fe ppm; Cu traces , B traces, S traces, and Mg traces) was sprayed in the rate of (F_0) 0, (F_1)1 and (F_2)2 g/L. Control plants were sprayed with the same distilled water quantity.

The experimental design was split plot in six replicates which the drought treatments equipped the main plots and the foliar fertilization treatments were randomize distributed in the sub plots. Grains of barley (*Hardium vulgare. L*) c.v. Giza 125 were sown in the beginning of December in both seasons. Calcium super phosphate (15.5% P_2O_5) and potassium sulfate (48.5%K_2O) were broadcasted before sowing at the rate of 200 and 100 Kg, respectively. Ammonium sulfate (20.5%N) at the rate of 200 Kg/fed was applied in two equal portions. The 1st was applied after 21 days from sowing and the 2nd was added two weeks latter. The foliar fertilizer (Folia-X) was sprayed twice, 21 and 45 days after sowing. At the end of the growing seasons, data of some growth parameters i.e. stem length, fresh and dry weights of both tillers and spikes were collected. N, P, K Fe, Zn and Mn concentrations barley plants were determined according to Cottenie, *et al.* (1982).

Data collected were subjected to the proper statistical analysis using the methods described by Snedecor and Cochran (1980).

3. Results and Discussion

Growth

1- Drought

Plant height, number of tiller and spikes / plant and spike length, in the first and second seasons, did not show any significant effect by water deficit at heading or late at dough stage. Dry weight of shoots, spikes and whole plant values, in the first season, were lower when plants subjected to omitting of irrigation at heating than that subjected to drought at dough stage or control plants, however, the differences in whole plant were the only significant. The differences in these parameters in plants exposed to water deficit at dough stage and that irrigated regularly were approximately equal (Table 2 and 3). In the second season, drought by omitting of irrigation at heading or dough stages lowered the dry mass of shoots and whole plant, in spite of the depressive effect was less at heading than that at dough stage. Dry weight of spikes showed similar response but the differences not enough to reach the significant level. The highest negative effect by omitting of irrigation at heading was higher in the dry weight of the whole plant followed by that on shoots in the second season while in the first season the degree of depression was approximately similar. These data are in harmony with those obtained by: Qureshi, and Neibling (2009); Braune, *et al.* (2009) and Katerji, *et al.* (2009).

The adverse effect of water deficit in plant growth may be due to the less availability of water surrounding the plant roots which affected the root growth and efficiency of water extraction and the disturbance in water adjustment in the different plant organs (Premachandra, *et al.* 1992 and Kocheva, *et al*. 2004), mineral absorption (Ouda, *et al*. 2005) or through the effect on photosynthesis activity (Baker, 1991; Yadanov, *et al*. 2000 , Tambussi, *et al*. 2005 and Oukarroum, *et al*. 2007), protein formation, antioxidant activity (He, *et al.* 1995 and Oukarroum, *et al*. 2007) and hormonal unbalance (Hare, *et al.* 1997 and Hoad, *et al*. 2001).

In addition, under water limited conditions, Farri and Faci (2006) mentioned that this phenomenon may be related to soil water extraction which considered the more important component to the seasonal Etc of some cereal crops.

2- Foliar fertilization

The application of Foliar-X in the first season, affected significantly the plant height and spike length. The differences in number of tillers and spikes /plant and the dry weight of shoots, spikes and whole plant were not significant (Table 2 and 3). In the second season, plant height, length of spike and dry weight of shoots, spikes and whole plant were significantly responded. Using commercial foliar compounds were raised up in the last decades in Egypt for enhancing growth and increased yield and its traits of different field crops (Deab, 1998; Sinebo, 2005 and Oukarroum, *et al.* 2007). For vegetable and fruit crops for prolonging the period of harvest, improved nutritional values (Reddy, *et al.* 2003) and improved marketing quality and in cereals for improving growth, yield and technological characters (Yassen, *et al*. 2010**).**

Table (2) Growth response of barley plants to Foliar-X spraying and drought First season

Treatment		Stem length	NO. of leaves	NO. of spikes	Length of spikes	Dry matter (g):		
Drought	Foliar-X					Spikes	shoots	Whole
Without (Regular Irrigation)	F0	92.5	5.5	6.44	12.0	8.35	9.10	17.45
	Fl	95.0	7.5	5.40	15.0	10.45	9.80	20.25
	F2	105.0	7.5	5.88	14.0	9.45	13.15	22.60
At heading stage	F0	95.0	6.5	5.13	11.5	13.50	11.20	24.70
	F1	97.5	6.5	5.25	13.5	7.65	9.75	17.40
	F2	95.0	7.0	6.72	12.5	9.40	12.55	21.95
At dough stage	F0	85.0	8.0	5.41	10.5	4.35	6.25	10.60
	F1	90.0	8.0	5.30	12.0	8.65	8.45	17.10
	F2	82.5	.0	5.50	14.0	4.75	4.75	10.50
L.S.D at 5 %		N.S	N.S	N.S	N.S	N.S	N.S	N.S

Table (3): Growth response of barley plants to Foliar-X spraying and drought Second season

Treatment		Stem length	N0. of leaves	N0 of spikes	Length of spikes	Dry matter (g):		
Drought	Foliar-X					Shoots	Spikes	Whole
Without (Regular .Irrigation)	F0	85.2	5.33	8.33	13.0	3.62	3.11	6.73
	Fl	86.3	5.33	8.33	12.2	4.04	6.47	10.51
	F2	92.7	6.33	9.33	13.3	7.87	4.45	12.32
At heading stage	F0	81.3	5.67	8.33	13.3	2.28	1.86	4.64
	Fl	87.8	6.33	8.33	13.4	3.96	4.28	8.24
	F2	90.7	5.67	8.33	13.2	4.25	3.73	7.38
At drough stage	F0	76.3	5.67	8.33	12.3	4.49	3.57	8.06
	Fl	81.4	5.67	8.67	13.6	4.10	3.64	7.74
	F2	82.6	5.67	8.67	13.9	5.27	5.05	10.32
L.S.D at 5 %		N.S	N.S	N.S	N.S	2.14	N.S	3.78

Selim, *et al.* (1992) reported that foliar spry with Metalosite (Commercial foliar fertilizer) increased most of growth and yield components criteria comparing with control. The increase in growth and yield and its components by foliar fertilization may be mainly due to the foliar application of nutrients is readily absorbed by leaves and enhancing the physiological processes (Robredo, *et al*. 2007), to face the great needs of nutrients during some growth stages especially at grain formation and filling(Oosterhuis, 1997) and not lost by evaporation, fixation (Tiemeyer, *et al*. 2007) or solved in the drainage water. El-Kholy and El-Bawab (1998) noticed that the foliar or soil application of fertilizers exerted a positive response on barley and wheat. They added that the superiority of Stimifol as a foliar fertilizer may be attributed to its greater content of N, P and K and vitamins and amino acids and also EDTA. Ahmed and Shalaby (1994) and Shalaby and Ahmid (1994) confirmed these results.

3- Drought x foliar fertilizer

The interaction effects of varietals differences and drought on yield of barley c.v. Giza 125 were illustrated in Table (2 and 3). These data indicated that in the 1st season, all growth measurements did not significantly responded, but in the 2nd season, dry of stem, spikes, and whole plant significantly affected. In plants irrigated regularly stem, spikes and whole plant dry weight increased with Foliar-X (commercial multi-nutrients) spraying by: 70.35, 13.81 and 61.47%, however, in plants subjected to drought (omitting of irrigation) at heading stage these decline were: 86.41, 100.54 and 92.75 % . In the case of expose barley plants at dough the decrement were 17.37, 32.37 and 63.55% for stem, spikes and whole plant dry weight, compare to plants regularly irrigated, respectively. Asare-Boamah, et al. (1988) recorded that Triadimefon reduced transpiration and protected the plants from drought. It increased leaf diffusive resistance indicating partial closure of the stomates, and treated plants maintained their water potentials while those of the controls were declined. Osmotic potentials of both treated and control leaves fell, but values in the controls were significantly lower than those from the treated plants. They added that after three days after treatment with Triadimefon in both water stressed and non-stressed plants, the abscisic acid (ABA) levels in the leaves of the treated plants were more than twice the levels of the controls. It appears, that the protection conveyed by Triadimefon during water stress is mediated at least partially, via its effects on ABA levels in treated tissue.

These data could be concluded that foliar fertilizer act positively to ameliorate drought negative effects. This phenomenon was very clear when irrigation omitted at heading stage. Furthermore, the enhancement of foliar fertilizer lowered when plant subjected to drought at dough stage to be less than the control plants (Regular irrigation).

Mineral status

1) - Drought

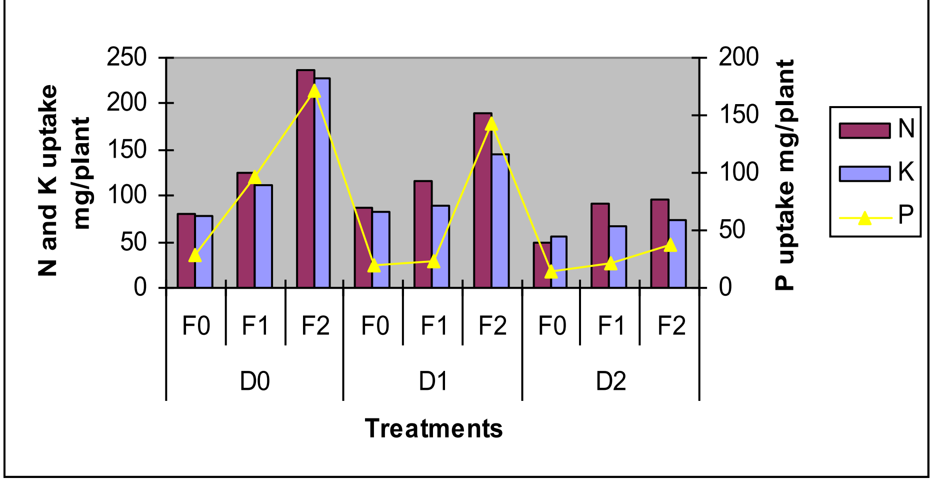
Data in Figs. 1(a and b) showed that phosphorus concentration in straw drastically decreased by subjection barley plants to drought at heading and at dough stages and at latter stage the effect was higher. However, the differences in N and K concentrations seemed to be equal with both drought treatments and the control treatment. Data presented in Fig. 1 (a and b) showed that water deficit led to a depression in K, Fe, Mn and Zn uptake and the depressions continuous as the drought treatment delayed. The differences in K uptake not great enough to reach the level of significant. Water deficit at heading gave the higher value of N uptake but at dough stage induced decrement but less than that resulted with drought at heading. Nevertheless, the water deficit treatment at heading markedly decreased the uptake of P, while, under deficit at dough stage this element pronouncedly increased compare to regular irrigation treatment. Mantagero, *et al* (2007) mentioned that adjustment of water in plant tissues necessary to the adjustment of P status in plants. Hussein, *et al*. (2006) on barley Giza 124 found that the concentration of N and K percentages increased slightly in shoots by omitting of irrigation at elongation stage but the increase in K by drought treatment at dough stage was more than that showed at elongation stage. However, the percentage of P was not affected by omitting of irrigation. Marketable decreases in Fe, Mn and Zn concentration in straw of barley plants were detected by missing of irrigation at heading and dough stages. Moreover, the effect was more by delaying the drought treatment from heading to dough stage. Hussein, *et al*. (2006) also revealed that the concentration of Fe and Cu in shoots of barley plants c.v. Giza 124 clearly decreased by omitting of irrigation and the rate of decreament raised by delaying the omitting of irrigation. Mn slightly increase by both irrigation treatments while Zn showed approximately the same response of P (Youssef, et al., 1999). In desert plants noticed that the majority of ions (K, Ca, Mg, Cl and Na) increased with decreases in soil moisture whereas, the concentration of P and K diminished with deficiency in soil moisture (Angum, *et al*., 2002). Tocker, *et al*. (1999) reported that chloride accumulation in the leaves was generally higher in drought and saline treatments where the control K concentration remained higher in both treatments. Nevertheless, El-Kholy and Hamed (2002) revealed that the drought caused reduction in sodium and potassium uptake of barley shoots. Negative relationship between drought and macronutrients concentration in grains of barley plants were observed. The depression in N,P, K, Fe Mn and Zn concentrations when plants exposed to drought at dough stage was more than that caused by drought at heading stage This means that this finding hold true for the all determinate elements. The uptake of Mn and Zn showed approximately the same response of its concentration in straw. P uptake responded reversely, however, Fe and N showed similar response. El-Zieny, *et al.* (1990) noticed that water deficit increased the concentration of both P and K in stem, leaves and roots but the total amount was decreased. Also, this treatment increased the total carbohydrates in leaves, stem and spikes of barley. El-Faham, *et al.* (1993) on wheat, revealed that K content in grains increased when irrigation skipped at jointing stage and P at jointing and milk ripe stages. They added also, that water stress had a depressive effect on Fe, Mn and Zn contents in grains. Kandil, *et al.* (2000) on maize, found that N and protein content in grains considerably depressed by widening irrigation intervals from 18 to 24 days. Similar responses were shown with macronutrients concentration in grains of barley plants as that of micronutrients by drought treatments.

2) Foliar fertilizer

As was expected that macro or micronutrient concentrations increased with the foliar fertilizer sprayed on vegetative parts of barley plants as shown in Figs (a and b).

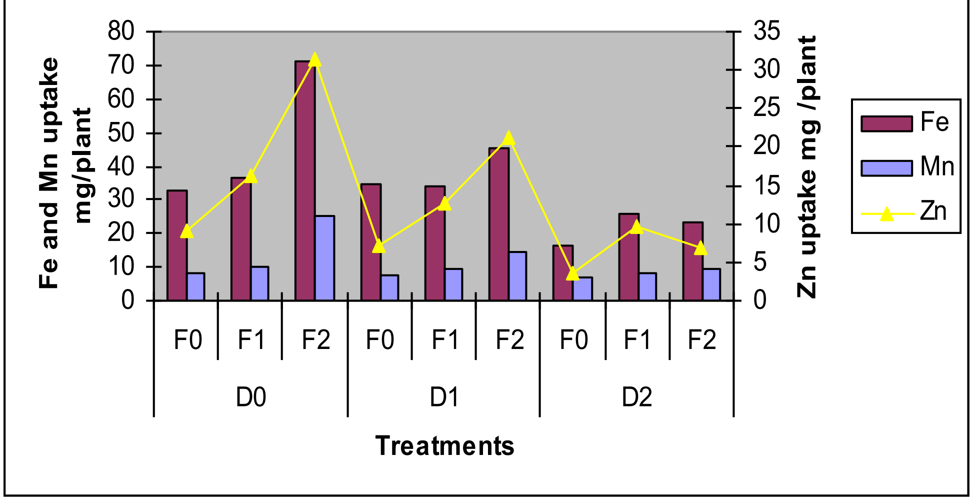
Application of Foliar-X increased the concentration of different nutrients. Data illustrated that Foliar-X spraying increased N, K, and Mn uptake in straw and the increments parallel to the concentration increase in the spraying solution. However, both fertilizer levels gave the same effect on zinc uptake. Furthermore, Fe uptake increased by the used of fertilizers. In grains a positive relationship was detected between the increase of fertilizer concentration and the values of different elements. This was true for the uptake of N, and Zn Fig 2 (a and b). However, P uptake decreased with the first level of fertilizer and tended to increase by the 2nd level but still less than that of the control

Fig.1a: Macronutrients uptake of barlely straw as affected by Foliar X and drought.



D_0: Regular irrigation D_1: Drought by omitting of irrigation at heading stage D_2: Drought by omitting of irrigation at dough stage.
F_0: Sprayed by distilled water F_1: Spraying by 1 g/L Foliar-X F_2: Spraying by 2 g/L Foliar-X.

Fig.1b: Micronutrients uptake of barley straw as affected by folair X and drought.

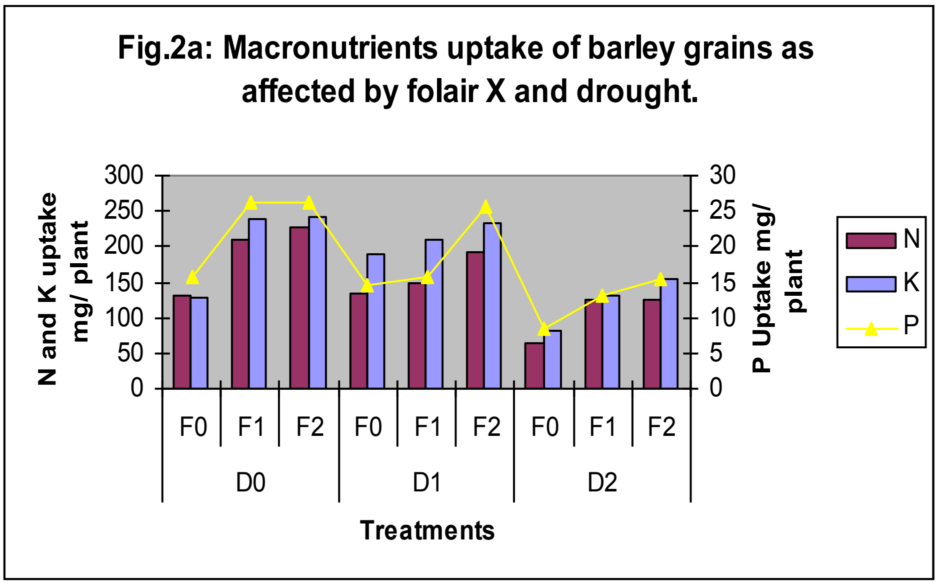


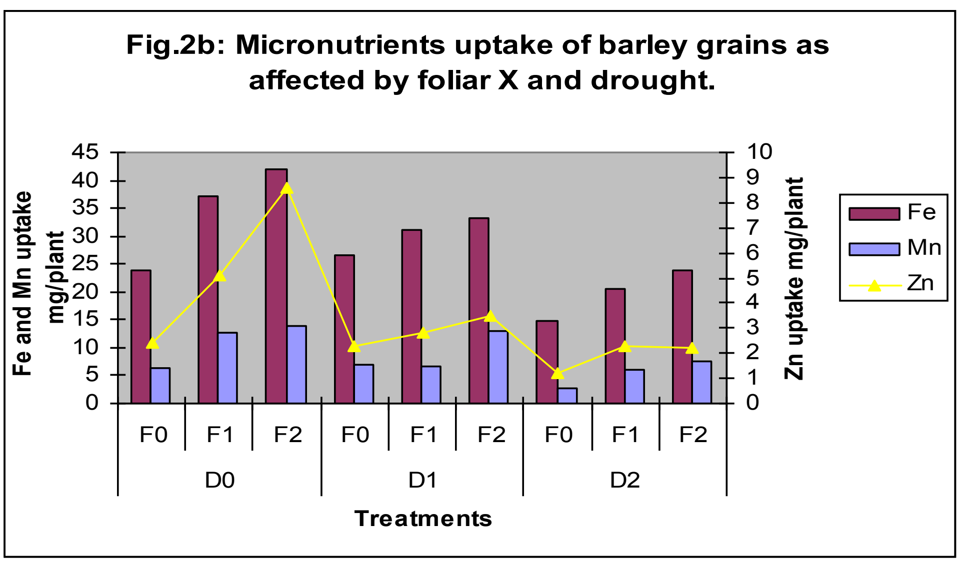
See notation In Fig. 1a

The uptake of K and Fe responded similarly to both fertilizer levels, while, the increment from the 1st fertilizer level more than that caused when spraying the 2 g/L fertilizer solution. Hu, *et al*. (2008) mentioned that the application of foliar fertilization started on the same day as the drought stress began and lasted for 5 days. The optimal level of N, P and K nutrients was chosen. They noticed that nutrient uptake increased by foliar spray of fertilizers solution. Yassen, *et al* (2010) indicated that spraying wheat plants with micro-nutrients either as a single nutrient or as possible combinations increased grain nitrogen concentration and consequently, protein percentage as compared with that of control plants.

3)-Drought x Foliar fertilizer

Fig. 1 (a and b) and Fig 2 (a and b) showed the interactive effect of drought and foliar fertilizer on the concentration of some macro and micronutrients in shoots of barley plants. The concentration of N, P and Mn concentrations increased as the foliar fertilizer increased under two drought treatments and in plants irrigated regularly. As expected that data cleared that Foliar-x application increased the uptake of all estimated macronutrients except P which the reverse was true. The increments were more with the 2nd concentration than that from the 1st one except for Zn uptake which in the 1st level exceeded that with the 2nd level. Under the irrigation treatment in which barley plants subjected to water deficit at heading raised the uptake of different nutrients except for K and Fe with 1st level of Foliar-X. While, when plants exposed to water deficit at dough stage, the nutrients uptake were improved by the 1st as well as 2nd fertilizer dose except for Zn with the higher fertilizer concentration in the sprayed solution.





See notation In Fig. 1a

Macro as well as micronutrients concentrations in grains were affected positively by the two Foliar-x concentrations but the increases raised up to the highest level used . Generally, the increment in all elements measured, with few exceptions, by the 2nd level of fertilizer more than one fold of that caused by the 1st fertilizer level. Concerning the macronutrients, the highest increase was in Fe concentration (91.12 % compare to grains of the non-sprayed plants) by the use of the 2nd level of fertilizer. In the case of micronutrients, the highest increase was in Mn which reached 131.82 and 127.59 % compare to grains of non-sprayed plants by application the 2nd rate of fertilizer on plants subjected to drought at heading or at dough stages.

Continuous increases were shown either in macro or micronutrients uptake as a result of increasing the foliar fertilizer rates in plants irrigated regularly. However, when drought induced at heading, only N showed the same response, meanwhile, the 1st rate of fertilizer sprayed resulted in higher values of K and Mn. P, Fe and Zn uptake gave the similar trend to both fertilizer rates. Grains of plants received 1 % Foliar-X showed the great values of mineral uptake with one exception for P which this rate of fertilizer did not exert difference but increase by the second rate of this fertilizer. Ouda, *et al.* (2005) concluded that the application of Potassium-P fertilizer during plant growth provided the growing plants with potassium, which enhancing the ability of barley plants to tolerate water stress. Similarly, it provided the growing plants with phosphorus which enhanced the metabolic activities. Furthermore, Hussein, *et al.* (2006) demonstrated that application of some complete foliar fertilizers improved the uptake of nutrients in shoots of barley plants and this reflected in the water stress tolerant.

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