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RESPONSE OF SUNFLOWER (*Helianthus annuus* L.) TO POTASSIUM AND MICRONUTRIENTS FERTILIZATION UNDER DRIP IRRIGATION IN SANDY SOIL

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ABSTRACT

Two field experiments were carried out in the Experimental Farm, El-Khattara, Faculty of Agriculture, Zagazig University, Sharkia Governorate, Egypt during two summer successive seasons (2007 and 2008). The experiments aimed to study the effect of potassium fertilizer levels (0, 24 and 48 kg K_2O per fad.) and micronutrients foliar application (control, Fe, Zn, Mn, Fe + Zn + Mn) on yield and it's attributes of sunflower cultivar Sakha 53, under drip irrigation system in sandy soils. Micronutrients foliar application had significant effects on stem diameter, number of seeds /head, seed weight, seed oil percentage, seed and oil yields/fad.,but both plant height and head diameter were not significantly influenced by the applied treatments. Zn application either sole or in combination with Fe + Mn, caused significant increase in stem diameter, number of seeds per head, seed head weight, seed and oil yields/fad., compared with other micronutrient treatments (combined analysis). The increase of K level up to 48 kg K_2O per fad., significantly increased the aforementioned characters in both seasons and their combined analysis. The interaction between the studied factors revealed significant effect on number of seeds/head, seed weight/head, and seed and oil yields/fad. In most cases, low K level was needed to maximize seed and oil yields/fad., in case plants were fertilized by either Zn alone or in combination with Fe and Mn compared with the control plants. The simple correlation coefficients between seed yield/fad., on one hand and those yield components and growth attributes on the other hand, were positive and highly significant.

Keywords: Sunflower, potassium, micronutrients, Fe, Zn, Mn, drip irrigation, sandy soils

INTRODUCTION

Sunflower (*Heliunthus annuus* L.) is considered to be one of the most important oil seed crops in the world. In Egypt, there is a large gap regarding edible oil where, the local production satisfies 7% only of consumption. Total oils and fats imported in 2010-2011 valued 1.6 million tones (FAO, 2012). Therefore, more care should be given to improve the productivity to meet the shortage of vegetable oil. So, it is of great importance to improve sunflower production, which could be achieved by several agricultural practices, such as potassium fertilization and as well as spraying micronutrients (Fe, Zn and Mn).

It is well known that, sandy soil is very poor regarding micronutrients content. Micronutrients deficiencies are more frequent in many soil types; i.e. alkaline, calcareous and sandy soils. Zinc is an essential micronutrient for higher plants especially oil crops where it is required for the activity of various types of enzymes (dehydrogenases, RNA and DNA polymerases), carbohydrate metabolism and protein synthesis. Zn plays other indirect and significant roles as stabilizer of proteins, membranes, and DNA-binding proteins such as Zn-fingers (Aravind and Prasad, 2003). Furthermore, zinc may be required for chlorophyll production, pollen function and fertilization (Pandey *et al.,* 2006). Zinc is required for the bio-synthesis of some plant growth regulators such as indole-3-acetic

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acid (IAA) (Fang *et al.,* 2008), and for carbohydrate and N metabolism which leads to high yield and production of biomass (Cakmak, 2008). Number of micronutrient elements were tried in order to improve growth and hence yield of sunflower. Babaeian *et al.* (2011) reported that, foliar application of Mn increased sunflower seed yield through the increase of head diameter, number of seeds /head and seed index. Also Abdo *et al.* (2002) got similar results when they tried Fe +Zn + Mn as seed coating. Farzanian *et al.* (2010) reported that, application of mixture of four microelements (Zn,Mn,Fe,B) increased yield as much as 2.34% more than the control, the highest yield obtained due to application of the mixture of four microelements, was 3397 kg/ha, the increase over the control valued 397 kg/ha. Mixture of micronutrients increased seed number and 100–seeds weight by 6.55 and 9.87%, respectively in comparison with control. Nezami and Vafaei (2012) reported that, application of Zn caused significant increase in plant height, number of seeds/head and seed oil content. Positive effect of micronutrients on yield and it's components as well as seed oil content reported by Singh *et al.*, 1996 and Vazin *et al.,* 2011).

Potassium (K), one of the three primary nutrients, usual absorbed by plants in larger quantities than any other element; except N (Bukhsh *et al.*, 2009). K plays a vital role as macronutrient in plant growth and sustainable crop production (Pettigrew, 2008). It maintains turgor pressure of cell which is essential for cell expansion. It helps in osmo-regulation of plant cell, assists in opening and closing of stomata (Bukhsh *et al.*, 2010). Application of potassium fertilization caused significant increases in yield and it's attributes of sunflower (El- Kalla *et al.,* 1998; Paraye and Chaubey, 2010 and Ungureanu and Tabara, 2010) .Said (1998) demonstrated that, increasing potassium levels up to 12 or 24 kg K_2O/fad., significantly increased stem diameter, head diameter, seed and oil yields/fad., except plant height and 100-seeds weight. Ahmed and Hassanein (2005) reported that, increasing potassium fertilization level up to 48 kg K_2O/fad., caused significant increase in head diameter, number of seeds/head, weight of seeds/head, seed index, oil percentage, seed and oil yields/fad., under newly cultivated sandy soils. Uchoa *et al.* (2011) found that, the most economical rates of potassium relative to seed and oil production, were 74.5 and 80.1 kg/ha, respectively and the highest seed yield (2038.3 kg/ha), oil content (52.5%) and oil yield (1079.3 kg/ha) were obtained with potassium level of 120 kg/ha. However, Zaidi *et al.* (2012) observed that, K application did not significantly improve plant height, head diameter, seed index and seed yield/ha. Therefore, this study aimed to investigate the effect of potassium level (0, 24 and 48 kg K_2O/fad.) and foliar application of micronutrients with Fe, Mn and Zn alone or in triple combination on yield attributes, yield and seed quality of Sakha 53 sunflower cultivar in sandy soil conditions using drip irrigation system.

MATERIALS AND METHODS

Two field experiments were carried out in the Experimental Farm, El-Khattara, Faculty of Agriculture, Zagazig University, Sharkia Governorate, Egypt during two summer successive seasons (2007 – 2008). The experiment aimed to study the effect of potassium levels (K_0, control; K_1,24 kg K_2O/fad., and K_2, 48 kg K_2O/fad.) and foliar application with Fe, Mn and Zn alone or in triple combination (F_1, control; F_2, Fe in the form of ferrous sulphate (as $FeSO_4$ 7 H_2O); F_3, Zn in the form of zinc sulphate (as $ZnSO_4$ 7 H_2O); F_4, Mn in the form of manganese sulphate (as $MnSO_4$7 H_2O); F_5, Fe (as $FeSO_4$ 7 H_2O) + Zn (as $ZnSO_4$ 7 H_2O) + Mn (as $MnSO_4$ 7 H_2O) on yield attributes, yield and seed quality of Sakha 53 sunflower cultivar in sandy soil conditions under drip irrigation system.

The mechanical and chemical analyses of experimental field soil are presented in Table 1. Available micronutrients were extracted by DTBA according to Lindsay and Norvell (1978). Each experiment included 15 treatments which were the combinations of three levels of potassium fertilizer and five treatments of foliar spraying micronutrients. The micronutrients were sprayed twice on 25 and 40 days after planting. The untreated plants (control) were sprayed with tap water and spreading agent. Fe, Zn and Mn micronutrients in chelated form at the recommended doses were applied at the concentrations of 200 ppm either in sole or in combination treatments.

Table 1. Soil mechanical and chemical analyses of the experimental site in 2007 and 2008 seasons

Properties	First season	Second season
Mechanical analysis		
Sand (%)	93.86	93.76
Silt (%)	3.67	3.76
Clay (%)	2.37	2.38
Texture	Sandy	Sandy
Chemical analysis		
PH	7.96	8.09
EC (dm^{-1})	2.25	2.30
Organic matter (%)	0.129	0.132
Available N (ppm)	13.85	14.23
Available P (ppm)	13.44	19.46
Available K (ppm)	70.92	75.10
Available Zn (ppm)	3.18	3.25
Available Mn (ppm)	2.11	2.25
Available Fe (ppm)	4.42	4.53
Calcium carbonate (%)	0.19	0.21

A split- plot design with three replicates was followed, micronutrients were assigned to the main plots, whereas potassium levels were allocated in the sub plots, respectively.

Sunflower was preceeded by faba bean in both seasons. The area of sub plot was 9.0 m^2 (3x3 m) included 5 rows, 60 cm apart and 20 cm apart between hills with plant density of 35000 plants/faddan. Seeds (3 seeds/hill) were hand drilled on June 25th in both seasons. One plant was left per hill after thinning (3 weeks after planting). Phosphorous fertilizer was applied during seedbed preparation in the form of ordinary of super phosphate (15.5% P_2O_5) at the level of 31.0 kg P_2O_5/fad. Potassium in the form of potassium sulphate (48% K_2O) the level of 48 K_2O/fad.,was added in two equal doses at seedbed preparation and after thinning. Nitrogen fertilizer in form of ammonium sulphate (20.6%N) was added at the level of 90 kg/fad., in 4 equal doses at thinning and then 7 days intervals. Irrigation and other agronomic practices such as weeds, pests and diseases control were performed as recommended. Drip irrigation system using under ground water (around 850 ppm) was followed every 2 days.

Harvest was done after 95 days from sowing (at the physiological maturity). Random sample of five guarded plants from each plot were taken, where the following yield attributes characters were determined: 1- Plant height (cm). 2- Stem diameter (cm). 3 – Head diameter (cm). 4- Number of seeds /head. 5- Seed weight / head (g).

Thereafter, a bulk sample including all sunflower plants in an area of 3.6 $m^2$was harvested manually from the third and fourth central rows to determine seed yield and it's quality as follows: 6 - Seed yield (kg/ fad.). 7- Seed oil content (oil %) which was analyzed according to A.O.A.C. (1984) using soxhlet apparatus and diethyl ether as a solvent. 8- Oil yield (kg/fad.) was calculated by multiplying seed yield (kg/fad.) by seed oil content.

The response of seed yield and it's components was also calculated according to Snedecor and Cochran (1981), using the orthogonal polynomial Tables for interaction between factors under study. The significance of the linear and quadratic components of the response equations was tested and hence the response could be described as linear (first order) or quadratic (second order). The maximum predicted average (Y_{max}) which could have been obtained due to addition of the predicted maximum K level (X_{max}.) were calculated according to Neter *et al.* (1990) and AbdulGalil *et al.,* (2003) using the following equations:

$\hat{Y}$ max = $b^2/4c + Y_0$

X max = $X_0 + b/2c$ (u)

Where:

Y_0 = average recorded at the lowest K level.

b = linear coefficient of the response equation.

c = quadratic coefficient of the response equation.

u = unit of potassium (24 kg K_2O/fad.).

Statistical analysis of each experiment was performed as the methods outlined by Steel *et al.*, (1997). Significances of differences between the various means of different characters under study were compared with the help of Duncan's multiple range test (1955). In the interaction Tables, capital and small letters were used for the comparison among rows and columns means, respectively.

RESULTS AND DISCUSSION

Plant Height, Stem and Head Diameter

Micronutrients fertilization effect

Neither plant height nor head diameter was significantly affected by any of the micronutrients tried, however, stem diameter was significantly affected by their application in both seasons and their combined (Table 2). It is evident that the sole application of Zn or it's combination with Fe and Mn, recorded the thickest stem compared with the control plants or those received Fe or Mn alone. These results indicated that Zn application played stimulatory role in photosynthetic efficiency of sunflower plants, where, probably more photosynthates were available for accumulation in stem as expressed herein in stem diameter rather than stem elongation. The role of Zn in enhancing photosynthesis was ascribed to it's role in activating carbonic anhydrase enzyme (CA) as it facilitate in some way the diffusion of CO_2 to the site as carboxylation. It was suggested that, the enhanced photorespiration in Zn deficient C_3 plants results from the low CA activity and a consequent reduction in the availability of CO_2 at the sites of carboxilation (Hay and Walker, 1989). These results are in harmony with those reported by Abdo *et al.* (2002) as they found significant increase in stem diameter of sunflower by application combination of Zn with Fe and Mn.

Potassium fertilization effect

It is evident from Table 2 that, addition of potassium and the increase of it's level of application resulted in a significant increase in plant height, where, the tallest plants were obtained at the highest K level (48 kg K_2O/fad.). However, head diameter did not respond to the increase of K level beyond 24 kg K_2O/fad., where, the further increase in K level did not cause further significant increase in this attribute. The results in Table 2 also indicated that, stem diameter responded to each increase in K level in the 1st season and was not significantly increased unless the second K increment was applied in the second season and as indicated also by the combined analysis of both seasons. According to these results, sunflower plants were in need for K fertilization. However, plant elongation was more responsive to this addition than either stem or head diameter. In the former, each K increment was accompanied by a significant increase in plant height. However, in the latters, the 1st K increment was quite enough to increase head diameter, but failed to increase stem diameter in the second season and the combined. It was clear that, stem diameter was not significantly increased unless the 2nd K increment was added. These results are interesting as they clearly indicated the positive and enhancing effect of potassium to the growth of sunflower plants. However, these enhancing effects varied among the three attributes under study. Elongation of plants was more responsive to each K increment, but, stem and head diameters were less responsive to this addition. The role of K in photosynthates translocation to the sites of physiological activity is intensively reported in the literature (Saurat and El-Fouly, 1980 and Fageria *et al.,* 2006). Under the present study stem elongation had more priority than stem diameter regarding photosynthates, partitioning and allocation, whereas, head diameter had the least priority in this respect. These results are in accordance with those found by El-Kalla *et al.,* (1998), Ahmed and Hassanein (2005) and Paraye

Table 2. Plant height, stem diameter and head diameter of sunflower as affected by micronutrients and potassium fertilizer levels during 2007 – 2008 seasons and their combined analysis

Main effects and interaction	Plant height(cm)			Stem diameter (cm)			Head diameter (cm)		
	2007	2008	Comb.	2007	2008	Comb.	2007	2008	Comb.
Micronutrients (M)									
Control (without addition)	130.88	129.50	130.10	1.55c	1.50b	1.55c	11.88	12.55	12.22
Fe	132.73	129.16	130.95	1.63bc	1.37b	1.50c	12.29	12.16	12.23
Zn	136.34	135.84	136.56	1.90a	1.82a	1.86a	12.21	12.61	12.42
Mn	132.23	130.24	130.68	1.70b	1.54b	1.64b	12.09	12.16	12.13
Fe+Zn+Mn	136.11	131.70	133.9	1.90a	1.80a	1.86a	12.90	12.97	12.94
F- test	N.S.	N.S.	N.S.	**	**	**	N.S.	N.S.	N.S.
Potassium fertilizer levels (K)									
Ko (control)	127.76c	126.36b	127.06c	1.63c	1.55b	1.59b	11.66b	11.78b	11.72b
K1 24 kg K_2O/fad.	133.74b	130.29b	132.3b	1.75b	1.50b	1.63b	12.46a	12.56ab	12.52a
K2 48 kg K_2O/fad.	139.48a	137.21a	138.01a	1.87a	1.78a	1.83a	12.71a	13.13a	12.92a
F-test	**	**	**	**	**	**	*	*	*
Interaction									
MxK	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

N.S., * and **: indicate Not significant, significant and highly significant at 0.05 and 0.01 levels, respectively.

and Chaubey (2010). However, Zaidi *et al.*, (2012) reported that K application did not influence plant height and head diameter.

Interaction effect

None of the three growth attributes under study was affected by the interaction between micronutrients and K levels in both seasons and their combined Table 2. These results clearly indicate that, the main effects of each of the two factors under study dominated their interacting effects .This certainly could be attributed to the main effects of potassium rather than the main effect of micronutrients except the effect of Zn on stem diameter. In other words, potassium played the main role in affecting sunflower plant growth followed by Zn. However, the two plant nutrients played separate roles in this respect.

Seed Yield/fad., and it's Components

Results in Table 3 show seed yield/fad., and two main components i.e. seed number/head and seed weight/head as affected by micronutrients application and K fertilizer levels and their interactions in the two seasons and their combined.

Micronutrients fertilization effect

It is evident from Table 3 that, almost all the three micronutrients, under study and their triple combination reflected significant effects on seed yield/fad., and the yield components. Regarding the number of seeds/head, different trends could be observed in the two seasons. However, the combined analysis, indicated that the sole Zn application had more pronounced effect than either Fe or Mn. Therefore, high number of seeds/head was recorded by application of Zn alone or in combination with Fe and Mn. This effect was also observed in seed weight/head according to the combined analysis. Regarding seed yield/fad., the three micronutrients and their combination recorded at par higher yield than the control in the 2nd season. This trend was inconsistent in the 1st season. However, the combined analysis indicated the superiority of the triple combination of the three micronutrients which recorded the highest seed yield/fad., and was significantly at par with that recorded by the sole Zn addition. These results are rather expected as the two yield components responded to Zn either in sole or companion addition, and therefore, could account for the increase in seed yield/fad. Moreover, Zn application significantly increased stem diameter Table 2 which could have been a source of stored assimilates for seed set as expressed in the significant increase of number of seeds/head and seed filling as expressed in the significant increase of seed weight/head. Singh *et al.* (1996) reported that application of $ZnSO_4$, significantly increased seed yield of sunflower. The increase of yield components due to micronutrients application might be due to their positive effects on assimilates translocation, activation of photosynthetic enzymes, chlorophyll formation and improvement of plant growth. Positive effect of micronutrients on seed yield and it's component were reported by Abdo *et al.* (2002), Farzanian *et al.* (2010), Babaeian *et al.*

(2010) and Babaeian *et al.* (2011) and Ebrahimian and Bybordi (2011). However, Nezami and Vafaei (2012) reported that, application of Zn had no significant effect on seed weight/head and seed yield of sunflower.

Potassium fertilization effect

It is evident from Table 3 that, number of seeds/head of the plants fertilized with 24 or 48 kg K_2O/fad., outnumber those of the control plants, number of seeds/head did not defer significantly due to supplying either 24 or 48 kg K_2O/fad. However, seed weight/head responded to the two K increments where, each increase in K level was followed by a significant increase in seed weight/head. This was true in the two seasons and the combined analysis and hence could account for the significant increase observed in seed yield/fad., particularly in the 1st season which was reflected in the combined analysis. According to these results, potassium application was indispensable to enhance sunflower plant growth as was expressed in plant height, stem and head diameters (Table 2) and herein, in the number of seeds/head and seed weight/head (Table 3). These growth and yield components improvements were finally reflected in the seed yield/fad. These results are in agreement with those reported by Said (1998) and Ahmed and Hassanein (2005) as they reported significant increase in sunflower seed yield /fad., due to K addition up to levels of 24 and 48 kg K_2O/fad., respectively. Positive effect of K application on seed yield and it's components reported by El-Kalla *et al.* (1998), Saeidi (2007), Paraye and Chaubey (2010), Ungureanu and Tabara, (2010) and Uchoa *et al.* (2011).

Interaction effect

Seed yield/fad., and it's two main components were significantly affected by the interaction between the two factors under study. Tables 3-a, 3-b and 3-c show the interaction effects according to the combined analysis, on seed number/head, seed weight/head and seed yield/fad., in respective order. Regarding number of seeds/head, results in Table 3-a show that, the sunflower control plants which did not receive any micronutrients application, responded significantly to each increase in K level. However, micronutrients fertilized plants with Fe, Zn and Mn or their combination did not respond to the 2nd K increment. These results clearly indicate, the micronutrients fertilized plants were satisfied with only 24 kg K_2O/fad., where, they could maximize the number of seeds/head and under this moderate K level had higher average than the control ones. However, the Zn fertilized plants had the highest average in this respect, which did not vary significantly with the average recorded by the three micronutrients fertilized plants. The response equations of the number of seeds/head to the increase of K level, clearly indicated the possibility of maximizing this number with lower predicted K level than the highest one tried in this study. This level was little bit higher than 24 kg K_2O/fad., which varied among the different micronutrients fertilized plants. The Mn fertilized plants showed linear response to potassium addition, though the capital letters of Duncan multiple range test did not give this indication. According to these results, micronutrients fertilization particularly with Zn could save the needs of sunflower plants from potassium. In other words, the micronutrients played a compensating effect with potassium, where, the high needs of plants from potassium application could be minimized with Zn application or it's combination with the other two micronutrients.

Table 3-b showed that, plants without micronutrients addition respond significantly to each K level increase. Similar response could be detected to that observed by the number of seeds/head, where, the micronutrients fertilized plants were in lower need to K than the control one. However, more K was predicted to be needed to maximize the seed weight /head than that needed to maximize seed number/head. This clearly indicates that, K was more needed for seed filling than for seed setting. It is interesting to note down here that, the lowest predicted K level was recommended when plants were sprayed by the combination of Fe, Zn and Mn.

Regarding seed yield/fad., it is evident from Table 3-c that, the control plants under micronutrients treatments showed linear

Table 3. Number of seeds /head, head seed weight and seed yield /fad., of sunflower as affected by micronutrients and potassium fertilizer levels during 2007 – 2008 seasons and their combined analysis

Main effects and interaction	Number of seeds/head			Head seed weight (g)			Seed yield(kg/fad.)		
	2007	2008	Comb.	2007	2008	Comb.	2007	2008	Comb.
Micronutrients (M)									
Control (without addition)	712.63c	681.10c	696.80c	30.89b	29.68b	30.30c	615.6c	546.8b	581.1c
Fe	797.20ab	724.20bc	760.70b	33.73a	31.59b	32.66b	699.3b	613.9a	656.6b
Zn	816.47ab	822.62ab	819.50ab	33.13ab	35.16a	34.15ab	723.8ab	659.0a	691.4ab
Mn	776.85b	751.78abc	764.30b	35.72a	30.02b	32.91b	702.8b	621.3a	662.0b
Fe+Zn+Mn	836.95a	842.40a	839.70a	35.57a	35.60a	35.58a	761.3a	666.5a	713.9a
F- test	**	*	**	**	**	**	**	**	**
Potassium fertilizer levels (K)									
Ko (control)	707.64b	702.22b	704.90b	29.54c	27.64c	28.62c	609.2c	516.7b	562.9c
K1 24 kg K_2O/fad.	813.26a	775.56ab	794.40a	34.41b	33.01b	33.70b	713.5b	657.2a	685.3b
K2 48 kg K_2O/fad.	843.16a	815.45a	829.32a	37.48a	36.58a	37.04a	779.0a	690.6a	734.8a
F-test	**	*	**	**	**	**	**	**	**
Interaction									
MxK	N.S.	*	**	N.S.	*	*	*	*	*

N.S., * and **: indicate Not significant, significant and highly significant at 0.05 and 0.01 levels, respectively.

Table 3-a. Number of seeds per head of sunflower as affected by the interaction between micronutrients and potassium fertilizer levels , as well as ,response equations and predicted maximum number of seeds of head (Y max) and K level (X max) in the combined data

Micronutrients \ Potassium fertilizer levels (kg K_2O/fad.)	Control	24kg	48kg	$\hat{Y}$= a+bx-cx^2	X max Kg K_2O/fad.	Y max
	C	B	A			
Control	659.8c	687.9d	742.9d	$\hat{Y}$= 659.8 + 41.55 x	------	-----
	B	A	A			
Fe	661.4 c	793.8b	826.9c	$\hat{Y}$= 661.4 + 182.05 x -49.65 x^2	44	828.2
	B	A	A			
Zn	746.7 b	855.3a	856.7b	$\hat{Y}$= 746.7 + 162.2 x - 53.6 x^2	36.31	869.4
	B	A	A			
Mn	683.3c	768.5c	841.2b	$\hat{Y}$= 683.3 + 78.95 x	------	------
	B	A	A			
Fe+Zn+Mn	773.6a	866.6a	878.9a	$\hat{Y}$= 773.6 + 133.35 x - 40.35 x^2	39.65	883.7

Table 3-b. Seed weight per head (g) of sunflower as affected by the interaction between micronutrients and potassium fertilizer levels , as well as , response equations and predicted maximum seed weight (Y max) and K level (X max) in the combined data

Micronutrients \ Potassium fertilizer levels (kg K_2O/fad.)	Control	24kg	48kg	$\hat{Y}$= a+bx-cx^2	X max Kg K_2O/fad.	Y max
	C	B	A			
Control	26.1b	29.3c	35.5d	$\hat{Y}$= 26.1 + 4.7 x	-----	-----
	B	A	A			
Fe	26.8b	34.1b	37.1b	$\hat{Y}$= 26.8 + 9.45 x - 2.15 x^2	52.74	37.18
	B	A	A			
Zn	30.1a	34.6b	37.7b	$\hat{Y}$= 30.1 + 5.2 x - 0.7 x^2	89.14	39.75
	B	A	A			
Mn	28.9b	33.5b	36.3c	$\hat{Y}$= 28.9 + 5.5 x - 0.9 x^2	73.33	37.30
	B	A	A			
Fe+Zn+Mn	31.2a	36.9a	38.6a	$\hat{Y}$= 31.2 + 7.7 x - 2 x^2	46.2	38.61

Table 3-c. Seed yield (kg/fad.) of sunflower as affected by the interaction between micronutrients and potassium fertilizer levels , as well as ,response equations and predicted maximum seed yield (Y max) and K level (X max) in the combined data

Micronutrients \ Potassium fertilizer levels (kg K_2O/fad.)	Control	24kg	48kg	$\hat{Y}$ =a+bx-cx^2	X max Kg K_2O/fad.	Y max
	C	B	A			
Control	496.2c	587.3d	659.9c	$\hat{Y}$= 496.2 + 81.85 x	----	----
	B	A	A			
Fe	551.2 b	684c	734.7b	$\hat{Y}$= 551.2 + 173.8 x - 41.05 x^2	50.81	736.2
	B	A	A			
Zn	605.2a	718.3b	750.9b	$\hat{Y}$= 605.2 + 153.4 x - 40.3 x^2	45.71	751.3
	C	B	A			
Mn	559.6b	683.9c	742.7b	$\hat{Y}$= 559.6 + 157.05 x - 32.75 x^2	57.34	747.8
	B	A	A			
Fe+Zn+Mn	602.7a	753.1a	786a	$\hat{Y}$= 602.7 + 209.2 x - 58.75 x^2	42.72	788.8

response to the increase of K level, whereas the micronutrients fertilized plants showed quadratic response, where, the increase of yield was diminishing. It is quite clear that, both the sole Zn fertilized plants or the combination Zn fertilized ones, recorded lower predicted maximum K level than those fertilized with Fe or Mn alone and certainly the control plants. According to these results, fertilizing sunflower plants with Zn alone or in combination with Fe and Mn could be recommended to maximize the sunflower seed yield/fad., through maximizing it's two main components i.e. number of seeds/head and seed weight/head which could be improved through K fertilization as it enhances plant growth as expressed in plant height, stem diameter and head diameter.

Seed Oil Content (%) and Oil Yield (kg/fad.)

Micronutrients fertilization effect

No significant differences could be detected among the different micronutrients fertilization treatments and the control regarding the seed oil content in the 1st season (Table 4). This was almost true in the 2nd season with only one exception where, the Fe +Zn + Mn treated plants had significantly higher seed oil content than the control ones. This effect was ascertained by the combined analysis, where, the aforementioned plants and these fertilized with Zn alone were at par averages which were higher than those recorded by the control. These results refer to a noticeable favorable effect of Zn application on oil accumulation in sunflower seeds. Results also indicate that, neither the increase in number of seeds/head nor the increase in seed weight/head was on the expense of seed oil content. In other words, the favorable effect of Zn was in favor of yield quantity and as well yield quality where, no dilution effect was caused by the increase of seed yield/fad., on the seed oil content. This in turn was reflected in the oil yield/fad., but, the significant increase in this yield average was only in favor of the three micronutrients combination treatment (Fe +Zn + Mn) when compared with the average recorded by the control. Many researchers reported that micronutrient elements supplying, can lead to increase of seed oil percentage (Singh *et al.*, 1996; Abdo *et al.*, 2002 and Nezami and Vafaei, 2012).

Potassium level effect

Results in Table 4 show that, seed oil content was not significantly increased unless the level of K was increased to 48 kg K_2O/fad. However, the combined analysis indicated that, 24 kg K_2O/fad., was quite enough to increase this content where, the further increase in K level did not add further significant increase in seed oil content. These effects were different regarding the oil yield/fad. where, each increment in K level was accompanied by a significant increase in oil yield/fad., in the 1st season and the combined analysis. These results reflect the effect of K fertilization on seed oil content and particularly seed yield/fad., and the two main components related to the oil yield/fad. These results are in harmony with those obtained by El-Kalla *et al.* (1998), Said (1998), Ahmed and Hassanein (2005) and Uchoa *et al.* (2011).

Interaction effect

According to the combined analysis the oil yield/fad., was significantly affected by the interaction between micronutrient treatments and K levels 4-a. It is quite interesting to note down herein, that this interaction reflect it's effect on seed yield/fad., previously observed in Table (3-c), where, the response of control plants to the increase of K level was linear, whereas, the response of micronutrients fertilized plants was quadratic i.e. diminishing. Therefore, the results in Table (4-a) strengthen the view that, the micronutrients treated plants were in need for a lower predicted K level which ranged from 44 to 55 kg K_2O/fad., to maximize the oil yield/fad., compared with an unpredicted K level by the control plants.

Yield Analysis

The correlation coefficient

The simple correlation coefficients calculated between the seed yield/fad., on one hand and these yield components and growth attributes on the other hand were positive and highly significant are shown in Table 5.

Conclusion

Results of this experiments revealed that spraying sunflower plants with Zn in combination with Fe and Mn and adding K- fertilizer levels up to 24 or 48 kg K_2O/fad., could be recommended to maximize the sunflower seed and oil yields (kg/fad.).

Table 4. Seed oil content and oil yield of sunflower as affected by micronutrients and potassium fertilizer levels during 2007 – 2008 seasons and their combined analysis

Main effects and interaction	Seed oil content (%)			Oil yield (kg/fad.)		
	2007	2008	Combined	2007	2008	Combined
Micronutrients (M)						
Control (without addition)	31.26	31.30b	31.28b	192.8c	171.5c	182.3c
Fe	31.63	32.43ab	32.03ab	221.7b	200.0b	210.9b
Zn	32.3	32.81ab	32.55a	234.5ab	218.3ab	225.4ab
Mn	31.58	32.35ab	31.96ab	222.8b	201.7ab	212.2b
Fe+Zn+Mn	32.35	33.18a	32.80a	246.9a	221.5a	234.5a
F- test	NS	*	**	**	*	**
Potassium fertilizer levels (K)						
Ko (control)	31.08b	31.49b	31.29b	189.5c	164.5c	176.4c
K1 24 kg K_2O/fad.	32.01ab	32.71ab	32.38a	228.8b	215.0b	222.1b
K2 48 K_2O/fad.	32.37a	33.05a	32.71a	253.oa	228.4a	240.7a
F-test	*	**	**	**	**	**
Interaction						
MxK	N.S.	N.S.	N.S.	N.S.	*	*

N.S., * and **: indicate Not significant, significant and highly significant at 0.05 and 0.01 levels, respectively.

Table 4-a. Seed oil yield (kg/fad.) of sunflower as affected by the interaction between micronutrients and potassium fertilizer levels, as well as, response equations and predicted maximum number of seed oil yield (Y max) and K level (X max) in the combined data

Micronutrients \ Potassium fertilizer levels (kg K_2O/fad.)	Control	24kg	48kg	$\hat{Y} = a+bx-cx^2$	X max Kg K_2O/fad.	Y max
	C	B	A			
Control	150.7c	185.4d	210.7c	$\hat{Y} = 150.7 + 30\,x$	----	----
	C	B	A			
Fe	172.1 b	220.3c	240.3b	$\hat{Y} = 172.1 + 62.3\,x - 14.1\,x^2$	53.02	240.9
	B	A	A			
Zn	192.3a	235.1b	248.8b	$\hat{Y} = 192.3 + 57.35\,x - 14.55\,x^2$	47.29	249.2
	C	B	A			
Mn	173.6b	221.2c	241.9b	$\hat{Y} = 173.6 + 61.05\,x - 13.45\,x^2$	54.46	243.8
	B	A	A			
Fe+Zn+Mn	193.1a	248.4a	261.9a	$\hat{Y} = 193.1 + 76.2\,x - 20.9\,x^2$	43.15	262.6

Table 5. Simple correlation coefficient among sunflower yield/fad., and some of it's attributes (combined)

Characters	Plant height	Stem diameter	Head diameter	No. of seeds/head	Seed weight/head
Seed yield (kg/fad.)	0.5150**	0.5731**	0.6264**	0. 7132**	0.8576**
Plant height (cm)		0.5329**	0.3803**	0.4349**	0.4040**
Stem diameter(cm)			0.5111**	0.5758**	0.5486**
Head diameter(cm)				0.4207**	0.6189**
Number of seeds/head					0.6377**
Seed weight/head (g)					-

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استجابة دوار الشمس للتسميد بالبوتاسيوم والعناصر الصغرى تحت نظام الري بالتنقيط فى الأراضي الرملية

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أقيمت تجربتان حقليتان خلال موسمى ٢٠٠٧ و٢٠٠٨ بالمزرعة التجريبية بكلية الزراعة- جامعة الزقازيق بمنطقة الخطارة - بمحافظة الشرقية، لدراسة استجابة دوار الشمس صنف سخا ٥٣ لثلاثة معدلات من السماد البوتاسى (صفر ،٢٤ و٤٨ كجم بو٢أ/فدان) وخمس معاملات من العناصر الصغرى (بدون إضافة أو الكنترول،إضافة الحديد ،إضافة الزنك ،إضافة المنجنيز، إضافة الحديد + الزنك + المنجنيز)، ويمكن تلخيص أهم النتائج على النحو التالى: أدت إضافة العناصر الصغرى رشا على المجموع الخضرى إلى حدوث زيادة معنوية لصفات قطر الساق، عدد بذور القرص، وزن بذور القرص، محتوى البذور من الزيت، محصول البذور والزيت (كجم / فدان) بينما لم يتأثر كل من ارتفاع النبات و قطر القرص معنويا بمعاملات العناصر الصغرى خلال موسمي الدراسة و التحليل المشترك، ولقد أدت إضافة الزنك منفردا أو مع الحديد والمنجنيز إلى زيادة معنوية فى قطر الساق ،عدد بذور القرص،وزن بذور القرص، ومحصولي البذور والزيت للفدان (كجم) مقارنة بمعاملات العناصر الصغرى الأخرى. أدى إضافة السماد البوتاسى حتى ٤٨ كجم بو٢أ/فدان إلى حدوث زيادة معنوية لجميع الصفات السابق ذكرها خلال موسمى الدراسة والتحليل المشترك. أوضحت نتائج التحليل التجميعى للموسمين التاثير المعنوى لتداخل الفعل بين العناصر الصغرى ومستويات السماد البوتاسى على عدد بذور القرص ووزن بذور القرص ومحصولى البذور والزيت وتبين أن استخدام الصنف سخا ٥٣ مع إضافة الثلاثة عناصر الصغرى(حديد + منجنيز + زنك) والتسميد البوتاسي بمعدل ٢٤ أو٤٨ كجم بو٢أ/فدان يؤدى الى معظمة محصولى البذور والزيت (كجم/فدان). أظهر محصول البذور/فدان ارتباط موجب ومعنوى مع كل من ارتفاع النبات، قطر الساق، قطر القرص، عدد بذور القرص ووزن بذور القرص.