Response of Sunflower to Foliar Spraying with Micronutrients and Glycine betaine under Salinity Stress Conditions in Newly Reclaimed Soils

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Abstract: In 2023 and 2024 seasons two field experiments were carried out at El-Qasasin district, Ismailia Governorate, Egypt. In which the effect of four mixture of micronutrients concentrations namely tap water (control), 1500, 2500 and 3500 ppm and three concentrations of Glycine betaine namely tap water (control), 50, 100 and 150 mM on yield, its attributes and quality of sunflower (*Helianthus annuus* L.) Giza 102 variety under salinity stress conditions in loamy sandy soils of Ismailia Governorate, Egypt were studied. Increasing concentration of micronutrients up to 3500 ppm significantly increased plant height, stem diameter, head diameter, hundred seed weight, seed weight per head and seed, straw and oil yields per fad as well as seed oil percentage of sunflower. Increasing Glycine betaine concentration up to 100 mM statistically increased all characters. The interaction between mixture of micronutrients and Glycine betaine affected significantly all above-mentioned traits. The highest values of these characters produced from sunflower plants sprayed with 3500 ppm mixture of micronutrients and 100 mM Glycine betaine.

Key words: *Helianthus annuus* L., microelements, antioxidants, saline.

INTRODUCTION

One of the most important sources of edible oils worldwide is sunflower (*Helianthus annuus* L.). In Egypt, the total production of edible oils is about 2% of the consumption (FAO, 2023). In the Nile valley, competition of corn and rice with sunflower over suitable planting area makes increasing the area planted with sunflower is very difficult. This enforces us to expanding sunflower planting area in newly reclaimed sandy soils, in spit off, it faces many problems like salinity stress. There are several treatments which help plants for salinity tolerance such as spraying plants with micronutrients and Glycine betaine. Some micronutrients such as iron, manganese, zinc, boron, copper and molybdenum are very important for plants as they are a component of many enzymes, enhance several metabolic processes namely photosynthesis rate and translocation of sugars, required for synthesis of chlorophyll, proteins and lipids. Boron is concerned with water reactions in the cells and regulates then takes of water into the cells (Marschner, 1986). Also, copper affects water permeability of xylem vessels, in turn, controls water relationships (Kabata-Pendias and Pendias, 1984). Positive effect of micronutrients on yield, its components and yield quality of sunflower were highlighted by Taha *et al.* (2013); Baraich *et al*. (2016); Al-Doori (2017); Faisal *et al*. (2020); Lotha and Dawson (2021); Said and Noaman (2021); Sher *et al*. (2021) and Jagasia *et al.* (2023). Glycine betaine (N, N, N-tri methyl glycine) is an amino acid derivative that synthesized by some plant families such as Compositae (Rhodes 1993; Gorham, 1996 and Blunden *et al*., 1999). To acclimatize adverse salt stress, plants use different antioxidants and accumulate some compounds which known as compatible solutes such as proline, sugars, amino acids and Glycine betaine (Hasegawa *et al*., 2000). In most crop plants, exogenous application of Glycine betaine enhances salt stress tolerance (Yang and Lu, 2005; Demiral and Turkan, 2006; Hamdia and Shaddad, 2010). Glycine betaine, also, reduces lipid peroxidation of the cell membranes and prevents deterioration of photosynthetic protein complexes (Holmstrom *et al*. 2000 and Iqbal *et al*., 2008). Glycine betaine is known to enhance growth of plants and activity of antioxidant enzymes (Ma *et al*., 2006 and Alasvandyari *et al*., 2017), improve chlorophyll content, relative water content, membrane stability and water use efficiency (Radya *et al*. 2018). Useful effect of foliar spraying with Glycine betaine on yield, its attributes and yield quality were documented by Iqbal *et al.* (2005); Kotb and Gaballah (2007); Hussain *et al.* (2008); Safdari-Monfared *et al.* (2020); Gupta *et al*. (2021); Miri *et al.* (2021); Shemi *et al.* (2021) and Pardhi *et al.* (2024). Present study was designed to investigate the response of yield, its attributes and quality of sunflower Giza102 variety to foliar spraying with mixture of micronutrients and Glycine betaine under salinity stress conditions in loamy sandy soils of Ismailia Governorate, Egypt.

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MATERIAL AND METHODS

Two field experiments were conducted during 2023 and 2024 seasons at EI-Qasasin district in Ismailia Governorate to study the effect of micronutrients and Glycine betaine on sunflower (Helianthus annuus L.) Giza 102 variety under salinity stress conditions in newly reclaimed soils. Some physical and chemical properties of the experimental soils in both seasons were analyzed according to Sparks (1996) as shown in Table (1). Irrigation was performed by using water produced from underground well. Some chemical properties of irrigation water according to Sparks (1996) were shown in Table (2). Each experiment included 16 treatments, which were the combinations of four concentrations of micronutrients mixture and four Glycine betaine concentrations as foliar spraying. The experimental design was split plots with four replicates. Four concentrations of micronutrients mixture arranged randomly in the main plots, while four Glycine betaine concentrations were allocated at random in the sub plots. Each experimental sub plot consisted of six ridges, 6 meter in length and 50 cm in width (plot area was 18 m^2).

Table (1): Some physical and chemical properties of the experimental soils in 2023 and 2024 seasons

Season	Sand%	Silt%	Clay%	Texture class	PH	E.C (dSm^{-1})	O. M (%)
2023	84	9.5	6.5	Loam sandy	8.46	4.55	0.43
2024	84	9.5	6.5	Loam sandy	8.39	4.42	0.44
Available nutrients (ppm)							
Season	**N**	**P**	**K**	**Fe**	**Zn**	**Mn**	**Cu**
2023	10.3	5.56	68.1	10.28	0.29	0.46	0.02
2024	10.8	5.94	68.7	10.35	0.31	0.48	0.02
Soluble anions (meq/L)				**Soluble cations (meq/L)**			

Seasons	CO_3^{-2}	HCO_3^{-1}	Cl^{-1}	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^{+1}	K^{+1}
2023	**-**	1.14	28.84	15.52	15.3	6.13	23.77	0.3
2024	**-**	1.16	27.13	15.91	15.6	6.23	21.87	0.5

Table (2): Some chemical properties of irrigation water

PH	E.C(dSm^{-1})	Sodium adsorption Ratio		Residual sodium carbonate			
7.37	4.63	20.88		**-**			
Available nutrients (ppm)							
NH_4	**NO_3**	**P**	**Fe**	**Zn**	**Mn**	**B**	**Cu**
9.8	11.2	0.27	0.01	0.24	0.07	0.76	0.17
Soluble anions (meq/L)				**Soluble cations (meq/L)**			
CO_3	**HCO_3^{-1}**	**Cl^{-1}**	**SO_4^{-2}**	**Mg^{+2}**	**Ca^{+2}**	**Na^{+1}**	**K^{+1}**
-	5.10	38.27	2.93	3.16	5.09	37.78	0.27

The preceding crop was wheat in both growing seasons. Seeds of sunflower Giza 102 variety were sown on one side of the ridge in hills 20 cm apart on May18 in the two seasons. After 17 days from sowing sunflower plants were thinned to one plant per hill. Four concentrations from these micronutrients (tap water, 1500, 2500 and 3500 ppm) were conducted. Mixture of chelated micronutrients contain zinc 5%, iron 6%, manganese 2%, copper 0.3%, boron 1.5% and molybdenum 0.5% in a chelate form (EDTA) was used. Four concentrations of Glycine betaine (tap water, 50, 100 and 150 mM) were used. The foliar spraying with mixture of chelated micronutrients was done three times after 27, 37 and 51 days from sowing. The volume of solution was 200- 400 Liter

/fad. Foliar spraying with Glycine betaine was done three times after 29, 39 and 53 days from sowing with volume solution 200- 400 Liter /fad. Calcium superphosphate (15.5% P_2O_5) at rate of 300 kg /fad was applied during soil preparing for sowing. Nitrogen in the form of ammonium sulphate (20.5% N) at rate of 100 kg N /fad was applied at four equal doses, after thinning, 30, 40 and 50 days from sowing. Potassium sulphate (48% K_2O) at rate of 150 kg /fad was applied at three equal doses, after 30, 40 and 50 days from sowing. The normal cultural practices for growing sunflower crop at Ismailia Governorate were followed. At harvest time, after 86 days from sowing, samples of ten guarded plants were randomly taken from two inner ridges in each sub plot to determine the following characters namely plant height (cm), stem diameter (cm), head diameter (cm), number of seeds per head, hundred seed weight (g) and weight of seeds per head (g). Seed yield (kg/fad) and straw yield (ton/fad) were estimated from the plants of three inner ridges in each sub plot and the yields per fad were calculated. Seed oil percentage was determined by using the Soxhelt continuous extraction apparatus with petroleum ether as an organic solvent according to A.O.A.C. (1990). Oil yield (kg/fad) was estimated by multiplying seed oil percentage and seed yield/fad. Seed crude protein percentage was determined as a total nitrogen (%) of sunflower seeds using the modified Micro-Kjeldahl Apparatus according to A.O.A.C. (1990), then the obtained values were multiplied by 6.25 (Tripathi et al. 1971). Protein yield (kg/fad) was estimated by multiplying seed crude protein percentage and seed yield/fad. The analysis of variance of split plots design was used according to Snedecor and Cochran (1982). Differences between treatments means were compared using Duncan's Multiple Range Test (Duncan, 1955). Means of treatments followed by the same alphabetical letters are not statistically different according to Duncan’s Multiple Range Test at the 5% level of significance (Duncan, 1955).

RESULTS AND DISCUSSIONS

A- Effect of micronutrients:

Table (3) revealing a significant effect of micronutrients mixture on plant height, stem diameter and head diameter of sunflower, which is true for the two seasons 2023 and 2024. Increasing concentration of micronutrients as foliar spraying up to 3500 ppm significantly increased plant height, stem diameter, head diameter in the two seasons (Table 3). Since micronutrients encourage several enzymes, metabolic processes and photosynthesis rate (Marschner, 1986) in turn increase plant growth characters; this is why such results were expected. These results are in accordance with those recorded by Baraich *et al.* (2016); Emam (2020); Lotha and Dawson (2021); Said and Noaman (2021); Jagasia *et al.* (2023) and Buriro *et al.* (2024).

Table (4) showing that increasing mixture of micronutrients concentration up to 3500 ppm increased number of seeds per head, but the differences among the four concentrations was not great enough to reach the 5% level of significance except between the high concentration (3500 ppm) and control. This was true in the two seasons.

Table (3): Effect of micronutrients and Glycine betaine on plant height (cm), stem diameter (cm), head diameter (cm) of sunflower in 2023 and 2024 seasons

Treatments	Plant height (cm)		Stem diameter (cm)		Head diameter (cm)	
	2023	2024	2023	2024	2023	2024
Micronutrients (ppm)						
Tap water (control)	134.90 D	140.97 D	1.53 D	1.62 D	14.02 D	**14.49 D**
1500 ppm	151.35 C	156.97 C	1.64 C	1.70 C	16.52 C	**16.95 C**
2500 ppm	161.17 B	167.07 B	1.83 B	1.88 B	18.70 B	**19.19 B**
3500 ppm	179.45 A	185.92 A	2.07 A	2.20 A	20.57 A	**20.97 A**
F. test	*	*	*	*	*	*
Glycine betaine (mM)						
Tap water (control)	147.22 C	152.55 C	1.56 C	1.64 C	16.02 C	**16.53C**
50 mM	154.17 B	160.15 B	1.72 B	1.79 B	17.37 B	**17.77 B**
100 mM	165.12 A	170.65 A	1.91 A	2.00 A	18.37 A	**18.73 A**
150 mM	160.35 A	167.60 A	1.88 A	1.97 A	18.05 A	**18.59 A**
F. test	*	*	*	*	*	*
Interaction effect						
M x G	*	*	*	*	*	*

Micronutrients positive effect on number of seeds per head might be due to that micronutrients enhance seeds setting percentage and reduce seeds abortion and incomplete fertilization. Also, some micronutrients such as boron are necessary for pollen grain formation and reproduction process (Marschner, 1986). Confirming results were reported by Jabeen and Ahmad (2011); Al-Doori (2017); Kaleri *et al*. (2019); Rex *et al*. (2020) and Buriro *et al.* (2024). Results recorded in Table (4) illustrate that hundred seed weight and seed weight per head were influenced significantly by spraying sunflower plants with mixture of micronutrients and that was true in the two growing seasons 2023 and 2024. Hundred seed weight and seed weight per head were increased statistically by increasing micronutrients concentration up to 3500 ppm in the two seasons. The increase in hundred seed weight by spraying plants with micronutrients might be attributed to the enhancement of plant growth, photosynthesis rate and enzymes activity in turn increase amount of metabolites synthesized in the leaves and partitioned them to seeds (Marschner, 1986). Similar results were detected by Abdo *et al.* (2002); Abo-El-Wafa and Abd El-Lattief (2006); Kumar *et al.* (2010); Baloch *et al.* (2015); Abdel-Motagally *et al.* (2016); Emam (2020); Faisal *et al.* (2020); Prabhakar *et al.* (2021); Said and Noaman (2021); Sher *et al*. (2021) and Noaman *et al.* (2022). Data in Table (4) show that sunflower plants sprayed with 3500 ppm mixture of micronutrients outweighed those treated with 2500, 1500 ppm and unsprayed control in seed weight per head by 16.58%, 34.47% and 50.07%, respectively in the first season and 19.29%, 34.76 % and 54.83 %, respectively in the second season. These results were expected since mixture of micronutrients increase number of seeds per head and hundred seed weight in turn increase seed weight per head. These findings agree with those stated by El-Ganaini (2009); Siddique *et al.* (2020); Jabeen and Ahmad (2011); Baloch *et al.* (2015); Baraich *et al*. (2016); Jarecki (2022) and Buriro *et al*. (2024).

Table (4): Effect of micronutrients and Glycine betaine on number of seeds per head, hundred seed weight (g) and weight of seeds per head (g) of sunflower in 2023 and 2024 seasons

Treatments	**Number of seeds per head**		**Hundred seed weight (g)**		**Weight of seeds per head (g)**	
	2023	**2024**	**2023**	**2024**	**2023**	**2024**
			Micronutrients (ppm)			
Tap water (control)	771.40 B	794.67 B	5.52 D	5.62 D	45.49 D	**46.72 D**
1500 ppm	782.95 AB	818.47AB	6.09 C	6.23 C	50.77 C	**53.68 C**
2500 ppm	796.82 AB	848.22 AB	6.62 B	6.76 B	58.56 B	**60.64 B**
3500 ppm	815.35 A	877.62 A	8.07 A	8.32 A	68.27 A	**72.34 A**
F. test	*	*	*	*	*	*
			Glycine betaine (mM)			
Tap water (control)	779.50 A	810.46 A	5.83 C	5.97 C	49.68 C	**51.60 C**
50 mM	789.55 A	827.52 A	6.29 B	6.41 B	54.40 B	**56.67 B**
100 mM	800.45 A	853.60 A	7.13 A	7.34 A	59.58 A	**62.67 A**
150 mM	797.02 A	847.40 A	7.05 A	7.20 A	59.42 A	**62.43 A**
F. test	NS	NS	*	*	*	*
			Interaction effect			
M x G	*	*	*	*	*	*

Table (5) shows a significant effect of spraying sunflower plants with mixture of micronutrients on seed and straw yields per fad in the two growing seasons 2023 and 2024. Seed and straw yields per fad were significantly increased with increasing micronutrients concentration up to 3500 ppm and that held true in the two seasons as shown in Table (5). The relative increases in seed yield per fad by spraying sunflower plants with 3500 ppm of micronutrients compared to 2500, 1500 ppm and unsprayed control were 16.29%, 34.79% and 67.07%, respectively in the first season and 16.22 %, 35.97 % and 68.34 %, respectively in the second season (Table 5). The positive effect of micronutrients on seed yield per fad could be due to the fact that micronutrients are a constituent of several enzymes such as catalase and peroxidase and required for synthesis of chlorophyll, proteins and chloroplast ides (Marschner, 1986). Also, micronutrients enhance photosynthesis rate and metabolic processes which reflected on increasing leaves area per plant and leaf area index in turn increase amount of metabolites synthesized in the leaves and partitioned to seeds which reflected favorably on hundred seed weight, number of seeds per head and seed weight per head, ultimately increase seed yield per fad. These results are in conformity with these reported by Abo-El-Wafa and Abd El-Lattief (2006); Baloch *et al.* (2015); Al-Doori (2017); Emam (2020); Lotha and Dawson (2021); Prabhakar *et al.* (2021); Said and Noaman (2021); Sher *et al*. (2021) and Buriro *et al.* (2024). The increase in straw yield per fad by foliar spraying with micronutrients was expected since micronutrients increase plant height, stem and head diameter of sunflower plants as shown in Table 5. In harmony with these results, there are many researchers like Abo-El- Wafa and Abd El- Lattief (2006); Sabra *et al.* (2019); Emam (2020) and Lotha and Dawson (2021) stated that micronutrients increase straw yield per fad.

Table (5): Effect of micronutrients and Glycine betaine on seed yield/fad, straw yield/fad and seed crude protein percentage of sunflower in 2023 and 2024 seasons

Treatments	Seed yield (kg/fad)		Straw yield (ton/fad)		Seed crude protein percentage	
	2023	2024	2023	2024	2023	2024
Micronutrients (ppm)						
Tap water (control)	915.79 D	952.14 D	12.29 D	13.96 D	10.62 D	**11.08 D**
1500 ppm	1135.15 C	1178.81 C	14.30 C	16.05 C	11.73 C	**12.16 C**
2500 ppm	1315.75 B	1379.20 B	15.60 B	17.80 B	12.77 B	**13.26 B**
3500 ppm	1530.07 A	1602.85 A	18.09 A	20.27 A	13.84 A	**14.43 A**
F. test	*	*	*	*	*	*
Glycine betaine (mM)						
Tap water (control)	1028.03 C	1066.37 C	13.50 C	15.20 C	11.13 C	**11.53 C**
50 mM	1162.90 B	1209.06 B	14.70 B	16.53 B	11.82 BC	**12.31 BC**
100 mM	1359.27 A	1432.30 A	16.22 A	18.27 A	12.69 AB	**13.21 AB**
150 mM	1346.55 A	1405.27 A	15.85 A	18.07 A	13.32 A	**13.87 A**
F. test	*	*	*	*	*	*
Interaction effect						
M x G	*	*	*	*	*	*

The results recorded in Tables (5 and 6) demonstrate that spraying sunflower plants with mixture of micronutrients had significant effect on seed crude protein percentage and protein yield per fad during the two seasons 2023 and 2024. Increasing mixture of micronutrients concentration up to 3500 ppm significantly increased seed crude protein percentage and protein yield per fad in the two seasons. The relative increases in seed crude protein percentage by spraying plants with 3500 ppm mixture of micronutrients compared to 2500, 1500 ppm and control were 8.38%, 17.99% and 30.32%, respectively in the first season and 8.82 %, 18.67 % and 30.23 %, respectively in the second season (Table 5). These results may be due to that micronutrients enhance metabolic processes and various enzymes and stimulate synthesis of protein (Marschner, 1986). Similar results were detected by Abdo *et al.* (2002); El-Ganaini (2009); Jabeen and Ahmad (2011); Taha *et al.* (2013) and Jarecki (2022). The positive effect of spraying sunflower plants with mixture of micronutrients on protein yield per fad could be mainly due to the increase in seed yield per fad and seed crude protein percentage. These results are in a good line with those observed by Vahedi (2011); Gowthami and Ananda (2017); Sabra *et al.* (2019) and Jarecki (2022). Data in Table (6) show that there was significant increase in seed oil percentage attributable to spraying plants with mixture of micronutrients in the two seasons 2023 and 2024. Spraying sunflower plants by 1500 ppm mixture of micronutrients overcome insignificantly unsprayed control in seed oil percentage. But increasing mixture of micronutrients concentration from 1500 ppm to 2500 and 3500 ppm induced significant increases in seed oil percentage and that held true in the two seasons (Table 6). Sunflower plants sprayed with 3500 ppm mixture of micronutrients exceeded those treated by 2500, 1500 ppm and control treatment in seed oil percentage by 11.83 %, 23.06 % and 28.27 %, respectively in the first season and 12.90 %, 24.63 % and 30.01 %, respectively in the second season (Table 6). The favorable effect of micronutrients on seed oil percentage was expected since micronutrients enhance metabolic processes, various enzymes, synthesis of many other compounds and translocation of metabolites synthesized from the leaves to seeds (Marschner, 1986). In harmony with these results Vahedi (2011); Baraich *et al.* (2016); Raghu *et al.* (2017); Sabra *et al.* (2019); Emam (2020); Rex *et al.* (2020); Prabhakar *et al.* (2021); Said and Noaman (2021); Sher *et al.* (2021); Babar *et al.* (2024) and Buriro *et al.* (2024) revealed that micronutrients increase seed oil percentage of sunflower. It is obvious from Table (6) that spraying sunflower plants with mixture of micronutrients exhibited significant effect on oil yield per fad in the two seasons. There were consistent and significant increases in oil yield per fad as mixture of micronutrients concentration was raised up to 3500 ppm and that was true during the two seasons (Table 6). The relative increases in oil yield per fad by spraying plants with 3500 ppm mixture of micronutrients compared to 2500, 1500 ppm and control were 30.21, 66.95% and 116.36%, respectively in the first season and 31.32%, 70.51 % and 120.95 %, respectively in the second season (Table 6). The beneficial effect of micronutrients on oil yield per fad might be due to the increase in seed yield per fad and seed oil percentage (Tables 5 and 6). These results are in accordance with those reported by Abo-El- Wafa and Abd El- Lattief (2006); Vahedi (2011); Halli *et al.* (2015); Gowthami and Ananda (2017); Al-Doori (2017); Raghu *et al.* (2017); Sabra *et al.* (2019); Emam (2020); Prabhakar *et al.* (2021) and Said and Noaman (2021).

Table (6): Effect of micronutrients and Glycine betaine on protein yield/fad, seed oil percentage and oil yield/fad of sunflower in 2023 and 2024 seasons

Treatments	Protein yield (kg/fad)		Seed oil percentage		Oil yield (kg/fad)	
	2023	2024	2023	2024	2023	2024
			Micronutrients (ppm)			
Tap water (control)	97.75 D	106.14 D	25.50 C	25.92 C	234.13 D	**247.07 D**
1500 ppm	134.42 C	144.76 C	26.58 C	27.04 C	303.43 C	**320.15 C**
2500 ppm	169.85 B	184.83 B	29.25 B	29.85 B	389.06 B	**415.71 B**
3500 ppm	214.28 A	233.90 A	32.71 A	33.70 A	506.58 A	**545.89 A**
F. test	*	*	*	*	*	*
			Glycine betaine (mM)			
Tap water (control)	116.09 C	124.87 C	26.28 B	26.85 B	272.81 C	**289.08 C**
50 mM	139.95 B	151.80 B	27.85 B	28.30 B	329.56 B	**348.01 B**
100 mM	176.21 A	193.22 A	30.24 A	30.88 A	421.42 A	**453.12 A**
150 mM	184.05 A	199.75 A	29.67 A	30.47 A	409.40 A	**438.61 A**
F. test	*	*	*	*	*	*
			Interaction effect			
M x G	*	*	*	*	*	*

B- Effect of Glycine betaine:

Data presented in Table (3) illustrate that spraying sunflower plants with Glycine betaine had significant effect on plant height, stem diameter and head diameter in the two growing seasons 2023 and 2024.

Increasing Glycine betaine concentration from zero to 50 and 100 mM significantly increased the three aforementioned characters and that was true during the two seasons (Table 3). Sunflower plants sprayed with 100 mM Glycine betaine was statistically in par with those treated by 150 mM in plant height, stem diameter and head diameter, however the last treatment induced significant increase compared to 50 mM and unsprayed control during both seasons (Table 3). These results were expected since Glycine betaine enhances growth of plants (Ma *et al*, 2006). Confirming results were detected by Hussain *et al.* (2008); Safdari- Monfared *et al.* (2020); Shemi *et al.* (2021) and Pardhi *et al.* (2024). Data in Table (4) show that number of seeds per head was increased gradually by increasing Glycine betaine concentration up to 100 mM, which also exceeded 150 mM, however the differences among the four treatments was not significant and that held true during the two seasons. Similar results were recorded by Hussain *et al.* (2008). Table (4) reveals that Glycine betaine concentrations differed significantly regarding their effect on hundred seed weight and seed weight per head in the two seasons 2023 and 2024. Spraying sunflower plants with 100 mM Glycine betaine produced the heaviest hundred seed weight as well as seed weight per head followed by 50 mM and unsprayed control, respectively with significant variations among them and that was true in the two seasons (Table 4). Sunflower plants sprayed with 100 mM Glycine betaine exceeded insignificantly those treated by 150 mM in hundred seed weight and seed weight per head, however the last treatment resulted significant increase compared to 50 mM and unsprayed control in the two seasons (Table 4). The superiority of Glycine betaine in increasing hundred seed weight may be due to its improvement of plant growth and activity of antioxidant enzymes (Ma *et al.* 2006). Also, Glycine betaine enhances chlorophyll content and relative water content (Radya *et al*., 2018) in turn increases the amount of metabolites synthesized in the leaves and partitioned them to fruiting organs (seeds). These results agree with those recorded by Iqbal *et al.* (2005); Hussain *et al.* (2008); Rezaei *et al.* (2012); Sakr *et al.* (2012); Elhakem (2019); Safdari-Monfared *et al.* (2020) and Dawood *et al.* (2021). Concerning positive effect of Glycine betaine on seed weight per head, the relative increases in seed weight per head by spraying plants with 100 mM Glycine betaine compared to those treated with 50 mM and unsprayed control were 9.52% and 19.93%, respectively in the first season and 10.59 % and 21.45 %, respectively in the second season (Table 4). The favorable effect of Glycine betaine on seed weight per head was expected since it increases hundred seed weight and number of seeds per head. Confirming results were emphasized by Safdari-Monfared *et al.* (2020). Data in Table (5) reveal that foliar application of sunflower plants with Glycine betaine exhibited significant effect on seed and straw yields per fad and that held true in the two seasons 2023 and 2024. There were consistent and significant increases in seed and straw yields per fad as Glycine betaine concentration was raised up to 100 mM during the two growing seasons (Table 5). Sunflower plants sprayed with 100 mM Glycine betaine overcome insignificantly those treated by 150 mM in seed and straw yields per fad, however both treatments resulted significant increase compared to 50 mM and treatment of control and that held true in the two seasons (Table 5).

Sunflower plants sprayed with 100 mM Glycine betaine outyielded those treated with 50 mM and control treatment in seed yield per fad by 16.88 % and 32.22 %, respectively in the first season and 18.46 % and 34.32%, respectively in the second season as shown in Table (5). These results were expected since Glycine betaine increases plant growth, total chlorophyll content, relative water content, leaves area per plant, leaf area index (Ma *et al.,* 2006 and Radya *et al.*, 2018), in turn increases amount of metabolites synthesized in the leaves and partitioned them to seeds consequently increases hundred seed weight as well as number and weight of seeds per head (Table 4), in finally increases seed yield per fad. These results agree with those reported by Iqbal *et al.* (2008); Hussain *et al.* (2010); Sakr *et al.* (2012); Shallan *et al.* (2012); Hamedani *et al.* (2019); Safdari-Monfared *et al.* (2020) and Haque *et al*. (2024). The favorable effect of Glycine betaine on straw yield per fad may be due to its positive effect on plant growth as plant height, stem diameter and head diameter per plant (Table 3). Similar results were emphasized by Kotb and Gaballah (2007); Aldesuquy *et al*. (2012) and Kotb and Elhamahmy (2014). Table (5) shows a significant effect of Glycine betaine on seed crude protein percentage in the two seasons 2023 and 2024. Increasing Glycine betaine concentration from zero to 50 mM reflected insignificant increase in seed crude protein percentage in the two seasons (Table 5). Spraying sunflower plants with 100 mM Glycine betaine resulted increase in seed crude protein percentage insignificant compared to 50 mM and significant with unsprayed control and that was true during the two seasons (Table 5). Plants sprayed with 150 mM Glycine betaine was statistically in par with those treated by 100 mM in seed crude protein percentage, however both treatments significantly overcome unsprayed control in the two seasons (Table 5). Sunflower plants sprayed with 150 mM Glycine betaine exceeded those received 100, 50 mM and unsprayed control in seed crude protein percentage by 4.96%, 12.69% and 19.68%, respectively in the first season and 4.99 %, 12.67% and 20.29%, respectively in the second season (Table 5). Confirming results were reported by Makela *et al.* (2000); Aldesuquy *et al*. (2012); Dawood and Sadak (2014); Osman (2015); Ilyas *et al.* (2016); Alasvandyari *et al.* (2017); Gupta *et al*. (2021) and Miri *et al*. (2021). Data in Table (6) demonstrate that Glycine betaine concentrations differed significantly regarding their effect on protein yield per fad in the two seasons 2023 and 2024. Increasing Glycine betaine concentration up to 100 mM significantly increased protein yield per fad and that held true in the two seasons (Table 6). Sunflower plants sprayed with 150 mM Glycine betaine was statistically in par with those treated by 100 mM in protein yield per fad, however both treatments significantly surpassed 50 mM and unsprayed control in the two seasons (Table 6). The increase in protein yield per fad by spraying plants with Glycine betaine might be due to the increase in seed yield per fad and seed crude protein percentage (Table 4). These results are in a good line with those detected by Miri *et al*. (2021). Data in Table (6) illustrate that there was significant effect of Glycine betaine on seed oil percentage during the two seasons 2023 and 2024. Increasing Glycine betaine concentration from zero to 50 mM insignificantly increased seed oil percentage. Both treatments of 100- and 150-mM Glycine betaine resulted statistically similar seed oil percentage, but significantly higher than 50 mM and control and that held true in the two seasons (Table 6). The relative increases in seed oil percentage by spraying plants with 100 mM Glycine betaine compared to 50 mM and control were 8.58 % and 15.07%, respectively in the first season and 9.12 % and 15.01 %, respectively in the second season (Table 6). Similar results were reported by Iqbal *et al.* (2005); Sakr *et al.* (2012) and Bakhoum and

Sadak (2016). It is clear from Table (6) that Glycine betaine concentrations differed significantly regarding their effect on oil yield per fad in the two seasons 2023 and 2024. Increasing Glycine betaine concentration up to 100 mM significantly increased oil yield per fad in the two seasons (Table 6). Sunflower plants sprayed with 100 mM Glycine betaine was statistically in par with those treated by 150 mM in oil yield per fad, however both treatments significantly overcome 50 mM and control and that held true in the two seasons (Table 6). Plants sprayed with 100 mM Glycine betaine outyielded those received 50 mM and control in oil yield per fad by 27.87 % and 54.47 %, respectively in the first season and 30.20 % and 56.75 %, respectively in the second season (Table 6). The positive effect of Glycine betaine on oil yield per fad could be mainly due to the increase in seed yield per fad and seed oil percentage. These results are in a good line with those recorded by Hussain *et al.* (2010); Safdari-Monfared *et al.* (2020) and Siddique *et al.* (2020).

C- Effect of the interaction:-

There was significant interaction between mixture of micronutrients and Glycine betaine on plant height, stem diameter, head diameter, number of seeds per head, hundred seed weight, seed weight per head, seed yield per fad, straw yield per fad, seed oil percentage and oil yield per fad in the two seasons 2023 and 2024 (Table 7). The highest values of all aforementioned characters were produced by spraying sunflower plants with 100 mM Glycine betaine and 3500 ppm mixture of micronutrients.

Table (7): Yield, its attributes and quality of sunflower as significantly affected by the interaction between micronutrients and Glycine betaine in 2023 and 2024 seasons

Character	Season	Highest value	Treatment	Lowest value	Treatment
Plant height (cm)	2023	191.50	3500 ppm Micro. x 100 mM G.B.	127.10	Control Micro. x control G.B.
	2024	198.80		132.40	
Seed weight/head (g)	2023	73.22	3500 ppm Micro. x 100 mM G.B.	42.52	Control Micro. x control G.B.
	2024	78.49		43.88	
Number of seeds/head	2023	821.50	3500 ppm Micro. x 100 mM G.B.	759.60	Control Micro. x control G.B.
	2024	893.71		769.53	
Stem diameter (cm)	2023	2.28	3500 ppm Micro. x 100 mM G.B.	1.35	Control Micro. x control G.B.
	2024	2.44		1.42	
Head diameter (cm)	2023	21.40	3500 ppm Micro. x 100 mM G.B.	13.10	Control Micro. x control G.B.
	2024	21.77		13.56	
100-seed weight (g)	2023	9.22	3500 ppm Micro. x 100 mM G.B.	5.11	Control Micro. x control G.B.
	2024	9.57		5.18	
Seed yield (kg/fad)	2023	1700.69	3500 ppm Micro. x 100 mM G.B.	830.12	Control Micro. x control G.B.
	2024	1782.95		849.88	
Straw yield(ton/fad)	2023	19.75	3500 ppm Micro. x 100 mM G.B.	11.54	Control Micro. x control G.B.
	2024	22.19		12.65	
Seed crude protein %	2023	15.61	3500 ppm Micro. x 150 mM G.B.	10.00	Control Micro. x control G.B.
	2024	16.22		10.33	
Protein yield (kg/fad)	2023	264.49	3500 ppm Micro. x 150 mM G.B.	83.15	Control Micro. x control G.B.
	2024	285.42		87.93	
Seed oil %	2023	35.77	3500 ppm Micro. x 100 mM G.B.	25.05	Control Micro. x control G.B.
	2024	36.95		25.39	
Oil yield (kg/fad)	2023	609.35	3500 ppm Micro. x 100 mM G.B.	208.29	Control Micro. x control G.B.
	2024	658.80		215.78	

While the lowest values were achieved from unsprayed plants with Glycine betaine and mixture of micronutrients in the two seasons (Table 7). Similar results were emphasized by Azzam and Omran (2005); Shemi *et al*. (2021); Soliman *et al*. (2023); Elahi et *al.* (2024) and Yahya and Abdulqader (2024). Significant response of seed crude protein percentage and protein yield per fad to the interaction between Glycine betaine and mixture of micronutrients were observed during the two seasons 2023 and 2024 (Table 7). The highest seed crude protein percentage and protein yield per fad were gained from plants sprayed with 150 mM Glycine betaine and 3500 ppm mixture of micronutrients. While the lowest values were obtained from unsprayed plants with Glycine betaine and mixture of micronutrients and that was true in the two seasons (Table 7).These results are in agreement with those observed by Azzam and Omran (2005) and Elahi et *al.* (2024).

REFERENCES

A.O.A.C. (1990). Official methods of analysis. 15th Ed., Association of Official Agricultural Chemists, Washington, D. C., USA.

Abdel-Motagally, F. M. F.; Mahmoud, M. W. Sh. and Ahmed, E. M. (2016). Response of two peanut varieties to foliar spray of some micronutrients and sulphur application under East of El-Ewinat Conditions. Assiut J. Agric. Sci., 47(1): 14-30.

Abdo, F. A.; Anton, N. A. and Hana, F. R. (2002).The influence of two applying methods of micronutrients mixture with different levels of nitrogen fertilization on sunflower plants grown under sandy soil conditions. J. Agric. Sci. Mansoura Univ. Plant Production, 27(10): 6557-6566.

Abo-El-Wafa, A.M. and Abd El-Lattief, E. A. (2006). Response of some sesame (*Sesamum indicum* L.) cultivars to fertilization treatments by micronutrients, biofertilizer and humix. Assiut Journal of Agricultural Sciences, 37(1): 55-65.

Alasvandyari, F.; Mahdavi, B. and Hosseini, S. M. (2017). Glycine betaine affects the antioxidant system and ion accumulation and reduces salinity-induced damage in safflower seedlings. Archives of Biological Sciences, 69(1): 139-147.

Aldesuquy, H. S.; Abbas, M. A.; Abo-Hamed, S. amy A.;Elhakem, A. H.; and Alsokari, S. S. (2012). Glycine betaine and salicylic acid induced modification in productivity of two different cultivars of wheat grown under water stress. Journal of Stress Physiology & Biochemistry, 8(2): 72-89.

Al-Doori, S. A. M. (2017). Effect of zinc and boron foliar application on growth, yield and quality of some sunflower genotypes (*Helianthus annuus* L.). Mesopotamia Journal of Agriculture, 45(1): 299-318.

Azzam, C. R. and Omran, S. E. H. (2005). The promotive effect of PDB biofertilizer on growth, enzymatic activity and biochemical changes of sunflower (*Helianthus annuus* L.) plants sprayed with micronutrients. The 3rd Conference of Recent Technologies in Agriculture, Fac. of Agriculture, Cairo Univ. Giza 14-16 Nov. 2005. 2: 255-267.

Babar, B. H.; Ijaz, B.; Nawaz, M.; Gill, A. N.;Jian, W.; Haq, M. Z. U.; Aslam, M. T. ;Hassan , M. U.;Gurlee , S.; Alharbi, S. A. and Ansari, M. J. (2024). Effects of potassium and boron fertilization on sunflower yield, oil content, and quality. Chilean journal of agricultural research, 84(6): 729-738.

Bakhoum, G. Sh. H. and Sadak, M. Sh. (2016). Physiological role of glycine betaine on sunflower (*Helianthus annuus* L.) plants grown under salinity stress. Inter. J. of Chem. Tech. Res., 9(3): 158-171.

Baloch, R. A.; Baloch, S. U.; Baloch, S. K.; Baloch, A. B.; Baloch, H. N.; Bashir, W.; Kashani, S.; Saeed, Z.; Baloch, M.; Akram, W.; Badini, S. A.; Ahmed, M. and Ruk, A. S. (2015). Effect of zinc and boron in combination with NPK on sunflower (*Helianthus annuus* L.) growth and yield. Journal of Biology, Agriculture and Healthcare, 5(19): 101-107.

Baraich, A. A. K.; Gandahi, A. W.; Tunio, S. and Chachar, Q. (2016). Influence of micronutrients and their method of application on yield and yield components of sunflower. Pak. J. Bot, 48(5):1925-1932.

Blunden, G.; Yang, M.; Janicsak, G.; Mathe, I.; and Carabot-Cuervo, A. (1999). Betaine distribution in the Amaranthaceae. Biochemical Systematics and Ecology 27: 87-92.

Buriro, N. A.; Memon, H.R.; Kaleri, A. A.; Buriro, N.A.; Jamro, I. A.; Fazal, S.; Baloch, D. M. and Ahmed, S. (2024). Effect of nitrogen and zinc fertilizer levels on the growth and yield of sunflower (*Helianthus annuus* L.). African Journal of Biological Sciences, 6 (15): 13777-13788.

Dawood, M. G. and Sadak, M. Sh. (2014). Physiological Role of Glycine betaine in alleviating the deleterious effects of drought stress on Canola plants (*Brassica napus* L.). Middle East Journal of Agriculture Research, 3(4): 943-954.

Dawood, M. G.; Khater, M. A. and El-Awadi, M. E. (2021). Physiological role of osmoregulators proline and glycine betaine in increasing salinity tolerance of Chickpea. Egyptian Journal of Chemistry, 64(12): 7637-7648.

Demiral, T. and Turkan, I. (2006). Exogenous glycinebetaine affects growth and proline accumulation and retards senescence in two rice cultivars under NaCl stress. Environ. Exp. Bot., 56:72-79.

Duncan, D. B. (1955). Multiple range and multiple "F" tests. Biometrics, 11:1-24.

Elhakem, A. H. (2019). Mitigation of the salinity influences on maize (*zea mays* L.) productivity by exogenous applications of glycine betaine. Journal of Stress Physiology and Biochemistry, 15(3): 21-28.

El-Ganaini, S. S. S. (2009). Effect of phosphate and some micronutrient fertilization on growth, yield and chemical constituents of sunflower (*Helianthus annuus* L.) plants grown under newly reclaimed soil conditions. Fayoum Journal of Agricultural Research and Development, 23(2): 94-107.

Elahia, S.; Nabizadeha, E.; Majidib, A.; Azizic, H. and Miandoabd, M. P. (2024). Efficacy of glycine betaine (G.B.), zinc (Zn), and boron (B) on some quantitative and qualitative characteristics of rainfed chickpea. Journal of Plant Nutrition. 47(10): 1664-1679.

Emam, S. (2020). Estimation of straw, seed and oil yields for flax plants (*Linum usitatissimum* L.) cultivars of foliar application of Mn, Fe and Zn under dry environment. Egyptian Journal of Agronomy, 42(1): 35-46.

Faisal, M.; Iqbal, M. A.; Aydemir, S. K.; Hamid, A.; Rahim, N.; El Sabagh, A.; khaliq, A. and Siddiqui, M. H. (2020). Exogenously foliage applied micronutrients efficacious impact on achene yield of sunflower under temperate conditions. Pak. J. Bot, 52(4): 1215-1221.

FAO STAT, F. (2023). Available online, Food and Agriculture, Organization of the United Nations Resources, Rome, Italy: http://www.Fao. Org/faostat/en/data.

Gehan, Sh. H. B. and Mervat, Sh. S. (2016). Physiological role of glycine betaine on sunflower (*Helianthus annuus* L.) plants grown under salinity stress. International Journal of ChemTech Research. (9)3: 158-171.

Gorham, J. (1996). Glycine betaine is a major nitrogen-containing solute in the Malvaceae. Phytochemistry, 43(2): 367-369.

Gowthami, V. S.S. and Ananda, N. (2017). Growth, yield and quality parameters of groundnut (*Arachis hypogaea* l.) genotypes as influenced by zinc and iron through ferti-fortification. International Journal of Agriculture and Environmental Research, 3(2): 2712- 2718.

Gupta, P.; Rai, R.; Vasudev, S.; Yadava, D. K., and Dash, P. K. (2021). Ex-foliar application of glycine betaine and its impact on protein, carbohydrates and induction of ROS scavenging system during drought stress in flax (*Linum usitatissimum*). Journal of Biotechnology, 337: 80-89.

Halli, H. M. ; Geetha, K. N.; Shankar, A.G. and Arabhanvi, F. (2015). Response of seed treatment with micronutrients, biofertilizers and pesticides on uptake of nutrients, yield & economics of sunflower. Green Farming, 6 (4): 708-711.

Hamdia, M. A. and Shaddad, M. A. K. (2010). Salt tolerance of crop plants. J. Stress Physiol. Biochem., 6: 64-90.

Hamedani, M. Y.; Ghobadi, M.; Ghobadi, M. E.; Jalali-Honarmand, S. and Saeidi, M. (2019). Influence of foliar application of some chemicals on gas exchange, water relations and photosynthetic traits in sunflower (*Helianthus annuus* L.) under different irrigation regimes. Iranian Journal of Field Crops Research, 17(3): 477-489.

Haque, Md. S.; Hossain, Kh. S.; Baroi, A.; Alamery, S.; Attia, K. A.; Hafez, Y. M.; Hussain, Md. T.; Uddin, Md. N. and Hossain, Md. A. (2024). Foliar application of abscisic acid and glycine betaine induces tolerance to water scarcity in wheat. Plant Growth Regulation, 104(3):1209-1225.

Hasegawa, P. M., Bressan, R. A., Zhu, J. and Bohnert, H. J. (2000). Plant cellular and molecular response to high salinity. Ann. Rev. Plant Physiol. Plant Mol. Biol., 51:463-499.

Holmstrom, K. O., Somersalo, M. S. A., Palva, T. E., Welin, B. (2000). Improved tolerance to salinity and low temperature in transgenic tobacco producing glycinebetaine. Journal of Experimental Botany, 51: 177-185.

Hussain, M.; Farooq, M.; Jabran, K.; Rehman, H., and Akram, M. (2008). Exogenous glycinebetaine application improves yield under water-limited conditions in hybrid sunflower. Archives of Agronomy and Soil Science, 54(5): 557-567.

Hussain, M.; Farooq, M.; Jabran, K. and Wahid, A. (2010). Foliar application of glycinebetaine and salicylic acid improves growth, yield and water productivity of hybrid sunflower planted by different sowing methods. Journal of Agronomy and Crop Science, 196(2): 136-145.

Iqbal, N.; Ashraf, M. Y. and Ashraf, M. (2005). Influence of water stress and exogenous glycinebetaine on sunflower achene weight and oil percentage. Int. J. Environ. Sci. Tech., 2(2): 155-160.

Iqbal, N.; Ashraf, M. and Ashraf, M. Y. (2008). Glycinebetaine, an osmolyte of interest to improve water stress tolerance in sunflower (*Helianthus annuus* L.): water relations and yield. South African Journal of Botany, 74(2): 274-281.

Ilyas, N.; Zafar, N.; Batool, N. and Bano, Q. (2016). Impact of exogenously applied glycine betaine on physiological attributes of sunflower under drought stress.19th International Sunflower Conference, Edirne, Turkey, 158-174.

Jabeen, N. and Ahmad, R. (2011). Effect of foliar-applied boron and manganese on growth and biochemical activities in sunflower under saline conditions. Pak. J. Bot., 43(2):1271-1282.

Jagasia, P. V.; Magodia, H. A. and Kale, A. P. (2023). Sulphur and micronutrient impact on sunflower (*Helianthus annuus*) yield and nutrient uptake. International Journal of Plant and Soil Science, 35(21): 248-258.

Jarecki, W. (2022). Effect of varying nitrogen and micronutrient fertilization on yield quantity and quality of sunflower (*Helianthus annuus* L.) achenes. Agronomy, 12 (10): 1-16.

Kabata-Pendias, A. and Pendias, H. (1984). Trace elements in soils and plants. CRC press, INC., U. S. A.

Kaleri, A. A.; Laghari, G. M.; Gandahi, A. W.; Kaleri, A. H., and Nizamani, M. M. (2019). Integrated foliar fertilizer effects on growth and yield of sunflower. Pak. J. Agri., Agril. Engg., Vet Sci., 35(1): 25-28.

Kotb, M. A. and Elhamahmy, M. A. (2014). Improvement of wheat productivity and their salt tolerance by exogenous glycine betaine application under saline soil condition for long-term. Zagazig J. Agric. Res., 41(6): 1127-1143.

Kotb, M. A. A. and Gaballah, A. B. (2007). Influence of glycinebetaine and nitrogen levels on growth and yield of barley (*Hordeum vulgare* L.) under drought conditions. J. Product. & Dev., 12(1): 45-60.

Kumar, B. N. A.; Bhat, S. N. and Shanwad, U. K. (2010). Effect of micronutrients on growth and yield in sunflower (*Helianthus annuus*). Current Advances in Agricultural Sciences, 2(1): 51-52.

Lotha, N. and Dawson, J. (2021). Effect of micronutrients on growth and yield of sunflower (*Helianthus Annuus* L.) variety DRSH-1. The Pharma Innovation Journal, 10(11): 1023-1026.

Ma, Q.; Wang, W.; Li, Y.; Li, D. and Zou, Q. (2006). Alleviation of photoinhibition in drought-stressed wheat (*Triticum aestivum*) by foliar-applied glycinebetaine. Journal of Plant Physiology 163: 165-175.

Mäkelä, P.; Kärkkäinen, J. and Somersalo, S. (2000). Effect of glycinebetaine on chloroplast ultrastructure, chlorophyll and protein content, and RuBPCO activities in tomato grown under drought or salinity. Biologia Plantarum, 43(3): 471-475.

Marschner, H. (1986). Mineral nutrition of higher plants. Academic press INC, USA, 674 pp.

Miri, MR.; Ghooshchi, F.; Moghaddam, H. T.; Larijani, HR. and Kasraie, P. (2021). Evaluation of the effects of glycine betaine and gibberellic acid on antioxidant and biochemical traits of cowpea under drought stress conditions. Journal of Plant Process and Function. 10(42): 313-334.

Noaman, H. M.; Mohamed, A. H., Ibrahim, H. E. A., and Abdel Monsef, O. (2022). Influence of foliar application of some micronutrient's levels on growth, yield, yield attributes, micronutrients content and fatty acids of two groundnut (*Arachis hypogaea* L.) varieties. Egyptian Journal of Agronomy, 44(1): 83-95.

Osman, H. S. (2015). Enhancing antioxidant–yield relationship of pea plant under drought at different growth stages by exogenously applied glycine betaine and proline. Annals of Agricultural Science. 60(2): 389-402.

Pardhi, D. S.; Chandan, A. S.; Devi, O. R.; Ashiq, I. M.; Senchowa, T.; Hussain, R., and Laishram, B. (2024). Effects of glycine betaine and salicylic acid foliar spray on growth of late sown wheat. Plant Archives, 24(2): 2761-2768.

Prabhakar, K.; Kalyani, D. L.; Nayak, S. B.; Venkataramanamma, K.; Neelima, S. and Kumar, D. S. (2021). Effect of boron foliar application at Critical growth stages on sunflower (*Helianthus annuus* L.) seed yield and oil yield. The Pharma Innovation Journal, 10(8): 910-913.

Radya, M. O. A.; Semidab, W. M.; Abd El-Mageedc, T. A.; Hemidad, K. A. and Radye, M. M. (2018). Up-regulation of antioxidative defense systems by glycine betaine foliar application in onion plants confer tolerance to salinity stress. Scientia Horticulturae. 240: 614-622.

Raghu, M. S.; Manjunatha, C. K.; Tuppad, G. B. and Upperi, S. N. (2017). Effect of secondary and micronutrients on growth, yield parameters and nutrient uptake of sunflower (*Helianthus annuus* L.). International journal of medicinal plants research, 6(3): 328-331.

Rex,I. R.; Saravanan, D.; Rao, G.B. S.andThiruppathi, M. (2020). Zinc and boron micronutrients on yield and economics of sunflower grown on coastal regions of Northern Tamilnadu, India. Plant Archives, 20(2):2070-2075.

Rezaei, M. A.; Kaviani, B. and Masouleh, A. K. (2012). The effect of exogenous glycine betaine on yield of soybean [*Glycine max* (L.) Merr.] in two contrasting cultivars Pershing and DPX under soil salinity stress. Plant Omics Journal (P. O.J.), 5(2):87-93.

Rhodes, D. (1993). Quaternary ammonium and tertiary sulfonium compounds in higher plants. Annu. Rev. Plant Physiol. Plant Mol. Biol., 44:357-384.

Sabra, D. M.; El-Bagoury , O. H.; El Habasha, S. F., Fergani, M. A.; Mekki, B. B.; El-Housini, E. A. and Abou-Hadid, A. F. (2019). Response of growth characters, yield and yield attributes of groundnut (*Arachis hypogaea* L.) cultivars to some micronutrients foliar spraying application. Plant archives, 19(2): 1896-1903.

glycine betaine application on yield components and oil yield in canola (*Brassica napus* L.). Turkish Journal of Field Crops, 25(1): 32-40.

Said, M. T. and Noaman, H. M. (2021). Effect of foliar spraying time by different micronutrients nanoparticles on sunflower yield and its attributes. Assiut Journal of Agricultural Sciences, 52(3): 22-35.

Sakr, M. T.; El-Sarkassy, N. M. and Fuller, M. P. (2012). Osmo regulators proline and glycine betaine counteract salinity stress in canola. Agronomy for Sustainable Development, 32: 747-754.

Shallan, M. A.; Hassan, H. M. M.; Namich, A. A. M., and Ibrahim, A. A. (2012). Effect of sodium nitroprusside, putrescine and glycine betaine on alleviation of drought stress in cotton plant. Am. Eurasian J. Agric. Environ. Sci., 12(9): 1252-1265.

Shemi, R.; Wang, R.; Gheith, E. M. S.; Hussain, H. A.; Cholidah, L.; Zhang, K.; Zhang , S. and Wang, L. (2021). Role of exogenous-applied salicylic acid, zinc and glycine betaine to improve drought-tolerance in wheat during reproductive growth stages. BMC Plant Biology, 21(574): 1-15.

Shemi, R.; Wang, R.; Gheith, E. S. M.; Hussain, H. A.; Hussain, S.; Irfan, M.; Cholidah, L.; Zhang, K.; Zhang , S. and Wang, L. (2021). Effects of salicylic acid, zinc and glycine betaine on morpho-physiological growth and yield of maize under drought stress. Scientific Reports, 11(1):1-14.

Sher, A.; Sattar, A.; Ijaz, M.; Nawaz, A.; Yasır, T. A.; Hussaın, M. and Yaseen, M. (2021). Combined foliage application of zinc and boron improves achene yield, oil quality and net returns in sunflower hybrids under an arid climate. Turkish Journal of Field Crops, 26(1): 18-24.

Siddique, M. S.; Qadir, G.; Gill, S. M.; Sultan, T.; Ahmed, Z. I. and Hayat, R. (2020). Bio-invigoration of rhizobacteria supplemented with exogenous salicylic acid and glycine betaine enhanced drought tolerance in sunflower. Intl. J. Agric. Biol., 23(5):869-881.

Snedecor, W. G. and Cochran, W. G. (1982). Statistical methods.7th Ed., 2nd printing, Iowa State Univ., Ames. Iowa, USA, 507 pp.

Soliman, Y. M.; Abdul-Hafeez, E. Y.; Ibrahim, O. H. M. and Soliman, T. M. A. (2023). Foliar application of glycine and/or zinc enhances vegetative, fruit and essential oil characters of *Cuminum cyminum* L. under different planting methods. Assiut Journal of Agriculture Science 54 (1): 66-84.

Sparks, D. L. (1996). Methods of soil analysis. Part 1 and 2 Chemical and physical methods, SSSA INCS., Madison, Wisconsin USA.

Taha, M. H.; Shalaby, E. A. and Shanan, N. T. (2013). Improving safflower (*carthamus tinctorius* L.) growth and biological activities under saline water irrigation by using iron and zinc foliar applications. J. Plant Production, Mansoura Univ., 4(8): 1219 - 1234.

Tripathi, R. D.; Srivastava, G. P.; Misra, M. S. and Pandey, S. C. (1971). Protein content in some varieties of legumes. The Allah Abad Farmer, 16: 291-294.

Vahedi, A. (2011). The effects of micronutrient application on soybean seed yield and on seed oil and protein content. Journal of American Science, (7)6: 672-677.

Yahya, R. A. and Abdulqader, O. A. (2024). Effect of soaking and spraying with glycine betaine and microelements of two cultivars of bread wheat Triticum aestivum L. Euphrates Journal of Agricultural Science-16 (2): 45-62.

Yang, X. and Lu, C. (2005). Photosynthesis is improved by exogenous glycinebetaine in salt stressed maize plants. Physiology Plantrum. 124: 343-352.

استجابة عباد الشمس للرش الورقى بالعناصر الصغرى والجليسين بيتاين تحت ظروف الإجهاد الملحى فى الأراضى حديثة الاستصلاح

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أجريت تجربتان حقليتان في موسمي 2023 و 2024 بمنطقة القصاصين بمحافظة الإسماعيلية لدراسة تأثير أربع تركيزات من الرش الورقى بمخلوط العناصر الصغرى هي الرش بالماء (كنترول) و1500و 2500 و3500 جزء فى المليون و كذلك أربع تركيزات من الرش الورقى بالجليسين بيتاين هى الرش بالماء (كنترول) و 50و 100و 150 مللى مول على محصول عباد الشمس ومكوناته و جودته صنف جيزة 102 تحت ظروف الإجهاد الملحى فى الأراضى الرملية الصفراء بمحافظة الإسماعيلية ، مصر.

ويمكن تلخيص النتائج كما يلي:

1- أدى زيادة تركيز مخلوط العناصر الصغرى حتي 3500 جزء فى المليون إلى زيادة معنوية فى ارتفاع النبات و قطر الساق وقطر القرص ووزن المائة بذرة ووزن البذور/ القرص و محصول البذور/فدان و محصول القش/ فدان ومحصول الزيت/ فدان والنسبة المئوية للزيت بالبذور.

2- أدى زيادة تركيز الجليسين بيتاين حتى 100 مللى مول إلى زيادة معنوية فى كل الصفات السابقة.

3- يوجد تأثير معنوى للتفاعل بين مخلوط العناصر الصغرى والجليسين بيتاين على كل الصفات السابقة وقد أمكن الحصول على أعلى القيم لجميع الصفات السابقة بالرش الورقى بمخلوط العناصر الصغرى بتركيز 3500 جزء فى المليون والجليسين بيتاين بتركيز 100 مللى مول.

الكلمات الدالة:- عباد الشمس، العناصر الصغرى، مضادات الاكسدة، الأراضي المتأثرة بالملوحة.