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Effect of Foliar Spraying Time by Different Micronutrients Nanoparticles on Sunflower Yield and its Attributes

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Abstract

In order, to assess the effects of foliar spry time by different micronutrients nanoparticles on sunflower (*Helianthus annuus* L.) cultivar, Sakha-53, a field experiment was organized in a randomized complete block design using strip plot arrangement with three replications during 2019 and 2020 seasons at Agronomy Department Farm, Agriculture Faculty, Assiut University, Egypt. Three different foliar spraying times of different micronutrients nanoparticles were allocated horizontally while eight treatments of spraying with different Micronutrient nanoparticles (2 gm/L) were arranged vertically. The results showed that foliar spraying twice after 30 and 50 days from sowing was significantly increased plant height, stem diameter and head diameter in both seasons. In addition, the highest mean values of seed yield (t fed.$^{-1}$) and oil yield (kg fed.$^{-1}$) were recorded when foliar spraying was done threes after 30,50 and 70 days from sowing. Foliar application of Iron, Manganese, and Zinc nanoparticles was superior all other treatments in this respect and registered the highest mean values of all studied yield attributes, seed yield, and oil yield in both seasons. The interaction between spraying time numbers and micronutrients nanoparticles significantly affected all sunflower yield attributes in both growing seasons. The highest mean values of seed yield (3.47 and 3.55 t fed^{-1}) and oil yield (1765.88 and 1770.67 kg fed^{-1}) were obtained from the interaction between T3 × S7 (foliar spraying three times after 30, 50 and 70 days from sowing date × spraying with Iron, Manganese and Zinc). It was concluded that foliar spray threes time at 30, 50 and 70 days from sowing using Iron, Manganese and Zinc nanoparticles could be used as a suitable method for improving seed yield and its attributes of sunflower cultivar, Sakha-53.

Keywords: *Sunflower, foliar spraying times, Micronutrients, Nanoparticles, Seed and Oil yields*

Introduction:

Sunflower (*Helianthus annuus* L.) plays a crucial role in oil production as one of the important oilseeds crops worldwide compared with soya, Canola, and peanut (FAO, 2020). Its oil contains unsaturated fatty acid in high concentrations (Oleic and Linoleic acids) and it is considered as good quality from the health point of view. Numerous studies have shown that sunflower yield and its components are significantly influenced by micronutrients foliar spraying. For the best use of fertilizer, it is necessary to apply or that nutrients being available at the most significant demand, especially for micronutrient applications (Roberts, 2007). Laghari *et al.,*(2014) reported that there was a desirable response in development and yield-related traits of a sunflower when foliar spray times were applied after 40 and 60 days from emergence. Additionally, Courtney *et al.,* (2019) stated that the absorption of phosphoric acid and its translocation by wheat leaves was affected by the foliar application time and use of surfactant in the formulation. Saad *et al.,* (2014) reported that when the zinc foliar application time was delayed until the flowering stage, this led to a significant increase in yield and its components of sunflower.

Nanotechnology is currently used in many fields and is constantly increasing, especially in the field of plant nutrition. Nanoparticles have a mean diameter of less than 100 nm, which means that the chemical and physical characteristics can be changed. (Monica and Cremonini 2009). However, nano-fertilizers have an effective role in the penetration of a plant using the foliar application or by the root architecture. (Raliya *et al.,* 2015). Moreover, nano-fertilizers have distinctive characteristics such as high surface area, high sorption capacity, and controlled-release kinetics to the target areas of the plant, which made it a smart delivery system. (Rameshaiah *et al.,* 2015; Solanki *et al.,* 2015). Micronutrient elements like Iron, Manganese, and Zinc play an important role in the plants, where they lead to increasing leaf area index, followed by increasing light absorption, and consequently increasing dry matter accumulation and yield (Ravi *et al.,* 2008). Iron is an essential factor in chlorophyll formation, photosynthesis, and as an enzyme of systems and respiration in plants (Halvin *et al.,* 1999); hence application of iron nanoparticles increases yield. In wheat, Jaberzadeh *et al.,* (2013) used a foliar application of 2% of Nano-Fe which led to an increase in grain yield by 3.3%. Zinc is a vital component in many enzymes, and it has a stabilizing role in the structure of proteins, membranes, and DNA-binding proteins. (Aravind and Prasad, 2004). Singh (2015) reported that seed oil content increased with the increasing concentration of ZnS nanoparticles in sunflower. In addition, spraying of manganese nanoparticles has been shown to increase growth, yield, and components compared with manganese sulfate on *Vigna radiata* (L.) (Ghafariyan *et al.,* 2013).

This work aimed at assessing the response of sunflower cultivar Sakha-53 to foliar spraying time by different micronutrients nanoparticles.

Materials and Methods:

Plant materials and experimental site

Sakha-53 cultivar was sown during the 2019 and 2020 summer seasons at Agronomy department farm, Agriculture faculty, Assiut University, Egypt (lat. 27° 18' N, long 31° 16' E alt and 53 m a.s.l.). The preceding crop of the experimental site for the two seasons was wheat. The physical and chemical properties of the experimental site are shown in Table 1.

Table 1. Some physical and chemical properties of the experimental Soil.

Soil property	Season 2019	Season 2020
Particle - size distribution		
Silt (%)	27.4	27.3
Sand (%)	24.3	25.2
Clay (%)	48.3	47.5
Texture	Clay	Clay
Organic matter (%)	1.75	1.72
Field capacity (%)	42.8	43.2
pH (1:1 suspension)	8.2	8.1
$CaCO_3$ (%)	3.4	3.5
Available element		
Total nitrogen (%)	0.73	0.67
KCl-extractable N (mg kg^{-1} soil)	41.23	40.26
$NaHCO_3$-extractable P (mg kg^{-1} soil)	4.36	4.65
NH_4OAC-extractable K (mg kg^{-1} soil)	49.24	50.86
Fe (mg kg^{-1} soil)	8.96	9.50
Mn (mg kg^{-1} soil)	3.44	3.51
Zn (mg kg^{-1} soil)	0.50	0.55

* Each value represents the mean of three replications.
The above analysis was carried out in the Agricultural Research Center, Soil, Water & Environment Res. Institute Unite of Analysis & studies.

Experimental treatments and design:

The experiment was conducted out in a randomized complete blocks design (RCBD) using a strip plot arrangement with three replications. Three different foliar spraying times of different micro-nutrients nanoparticles were allocated horizontally:

1- T_1: foliar spraying after 30 days from sowing.
2- T_2: foliar spraying after 30 and 50 days from the sowing.
3- T_3: foliar spraying after 30, 50 and 70 days from sowing.

while eight treatments of spraying with different Micronutrient nanoparticles (2 gm/L) were arranged vertically: -

1- S_1: Control: spraying with water.
2- S_2: Super Iron (10% Fe, 5% amino acids and 25% Siderophores and organic acids).
3- S_3: Super Manganese (10% Mn, 5% amino acids, and 25% Siderophores and organic acids).
4- S_4: Super Zinc (10% Zn, 5% amino acids, and 25% Siderophores and organic acids).
5- S_5: $S_2 + S_3$.
6- S_6: $S_2 + S_4$.
7- S_7: $S_3 + S_4$.
8- S_7: $S_2 + S_3 + S_4$.

Cultural practices:

The area of the experimental unit was 10.5 m^2 (as 3.5 long 3.0 m width). Sunflower seeds were hand sown on rows 60 cm distance in hills 25 cm apart on 25th and 26th May in the first and second seasons, respectively.

Measured traits:

1- Yield attributes related traits: The following traits were measured from ten randomly guarded plants from each experimental unit at harvest time: plant height (cm), stem diameter (cm), head diameter (cm), number of seeds $plant^{-1}$, 100 seed weight, and seed weight $plant^{-1}$ were measured.

2- Seed yield (t fed^{-1}): Heads of two bagged inner ridges of each plot were harvested and left two weeks until fully air-dried, then seeds were manually separated and weighted, and converted into t fed^{-1}.

3- Oil percentage (%): Oil percentage in sunflower seeds was estimated by extraction using Soxhlet apparatus and petroleum ether (bp 40- 60°C) as solvent according to A.O.A.C. (1995).

4- Oil yield (kg fed^{-1}): Oil yield = Seed yield fed^{-1} × oil percentage.

Statistical analysis:

All collected data were subjected to the analysis of variance (ANOVA) using the SAS Statistical Software Package v.9.2 (SAS, 2008). Differences between means were compared by Least Significant Range (L.S.R.) values were used according to Duncan (1955).

Results and Discussion

1- Effect of spraying time numbers

The presented data in Table 2 reveal that all studied characteristics were affected significantly by spraying times except seed oil percentage in the first season only. Data showed that T_2 (foliar spraying after 30 and 50 days from sowing) achieved the highest mean values of plant height (221.9 cm and 207.1 cm) and stem diameter (2.7 cm and 3.0 cm) in the two respective seasons. T2 and T3 treatments also gave the highest mean values of 100 seed weight (6.70 and 6.90 g) in the first and second seasons, respectively. In both seasons, T_3 (foliar spraying after 30 and 50 and 70 days from sowing date) achieved the highest mean values of seed yield/plant per g (100.73 and 102.35), seed yield (3.02 and 3.07 t fed^{-1}), and oil yield (1447.61 and 1427.71 kg fed^{-1}), respectively. This may be due to the suitable phase of plant growth, which responded significantly to the foliar application by micronutrients, which resulted in photosynthetic products accumulated in the leaves (source) and transported to the seeds (sink) which enhanced the oil content.

Table 2. Effect of foliar spraying time with micronutrients' nanoparticles on Sunflower yield and its attributes in 2019 and 2020 seasons.

Spraying time	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	100 Seed weight (g)	Seed yield / plant (g)	Seed yield / fed (t)	Seed Oil (%)	Oil yield (kg fed^{-1})
Season 2019								
T1	197.3 c	2.6 b	19.6 b	6.37 b	93.10 c	2.79 c	46.87 a	1314.66 b
T2	221.9 a	2.7 a	20.8 a	6.70 a	95.09 b	2.85 b	47.67 a	1362.25 b
T3	207.2 b	2.7 a	21.0 a	6.48 b	100.73 a	3.02 a	47.70 a	1447.62 a
Season 2020								
T1	197.4 b	2.8 b	22.6 b	6.40 b	94.43 c	2.83 c	45.84 b	1299.01 b
T2	207.1 a	3.0 a	23.7 a	6.61 ab	96.58 b	2.90 b	48.00 a	1392.93 a
T3	198.3 b	2.8 b	22.1 b	6.90 a	102.35 a	3.07 a	46.26 ab	1427.71 a

Means with the same letter indicate insignificant at 5% probability level based on Duncan's multiple range test.

These findings are in a good line with those obtained by Ghulam *et al.,* (2014), Courtney *et al.,* (2019), Broadley *et al.,* (2007), and Saad *et al.,* (2014), reported that delaying the timing of zinc foliar spry to flowering phase caused a significant increase in seed yield and its components of sunflower.

2- Effect of spraying by micronutrients nanoparticle types

Data in Table 3 highlighted that all studied traits were affected significantly by micronutrients nanoparticle types. The treatment S7 (spraying with Fe, Mn, and Zn nanoparticles) was superior to all other treatments in this respect and registered the highest mean values of all studied yield attributes. In addition, this treatment recorded 220.4 and 207.8 cm plant height, 2.9 and 3.0 cm stem diameter, 21.4 and 26.7 cm head diameter, and 7.18 and 7.95 g 100 seed weight in the first and the second growing seasons, respectively. Consequently, the highest mean values of sunflower seed yield and oil yield were obtained from S7 (108.8 and 111.34 for seed yield per plant in g, 3.27 and 3.34 for seed yield t fed^{-1}, 50.72 and 48.29 % for oil seed percentage and 1656.32 and 1614.46 for oil yield fed^{-1} per kg fed^{-1}). This may be due to the critical role of micronutrients in improving field crop production. Indeed, Fe, Mn, and Zn perform a specific function in the plant tissues of field crops including oilseeds. Our results are in consistent with those obtained by Yari *et al.,* (2004); Movahhedy *et al.,* (2009); Ravi *et al.,* (2008) and Heidaria *et al.,* (2011). The desirable effect of zinc may be due to its important role in the activity of growth enzymes, which are responsible for increasing the biological processes, and yield components (Mathpal *et al.,* 2015). It is worth noting that zinc plays an important role in the formation of chloroplasts and proteins synthesis. Iron is also necessary for the process of chlorophyll formation and photosynthesis and is important in plant respiration. (Havlin *et al.,* (1999). Manganese plays important roles in many physiological processes such as photosynthesis, O_2 release, lipids metabolisms, and carbohydrate synthesis. (Wilson *et al.,* 1982). The advantages of using nanoparticles may be attributed to many characteristics such as large surface area, fast mass transfer, easy attachment, improving the stability of agrochemicals, and protecting them from degradation, which in turn led to increased efficiency and reduced quantities of agrochemicals. (Khodakovskaya *et al.,* 2012).

Table 3. Effect of foliar spraying different micronutrient's nanoparticles on Sunflower yield and yield attributes in 2019 and 2020 seasons.

Micro nano Treatments	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	100 Seed weight (g)	Seed yield / plant (g)	Seed yield / fed (t)	Seed Oil (%)	Oil yield (kg fed^{-1})
Season 2019								
S_1: Control	199.7 d	2.6 c	19.0 d	5.12 e	84.93 d	2.55 d	42.76 d	1089.62 e
S_2: Fe	202.7 cd	2.6 c	20.3 bc	6.59 cd	90.38 cd	2.71 cd	47.48 bc	1287.40 cd
S_3: Mn	206.1 bcd	2.6 c	19.9 cd	6.35 d	91.19 cd	2.74 cd	46.24 c	1267.08 de
S_4: Zn	208.6 bcd	2.6 c	20.3 abc	6.41 d	96.18 bc	2.89 bc	48.08 bc	1383.58 bcd
S_5: Fe+Mn	206.2 bcd	2.7 b	20.8 abc	6.83 bc	94.94 bcd	2.85 bcd	47.08 bc	1340.03 bcd
S_6: Fe+Zn	211.2 bc	2.7 b	21.2 ab	6.88 b	100.20 abc	3.01 abc	48.77 ab	1471.96 abc
S_7: Mn+Zn	215.2 ab	2.6 c	20.9 abc	6.76 bc	103.79 ab	3.11 ab	48.22 bc	1502.74 ab
S_8:Fe+Mn+Zn	220.4 a	2.9 a	21.4 a	7.18 a	108.84 a	3.27 a	50.72 a	1656.32 a
Season 2020								
S_1: Control	190.1 c	2.7 d	17.9 c	5.12 d	89.49 d	2.69 d	44.19 c	1189.25 e
S_2: Fe	193.3 bc	2.7 d	21.4 b	6.51 bc	90.38 cd	2.71 cd	46.25 abc	1253.96 cde
S_3: Mn	199.2 abc	2.7 d	21.4 b	5.85 c	90.96 cd	2.73 cd	45.32 bc	1237.55 de
S_4: Zn	202.6 abc	3.0 ab	21.8 b	6.56 bc	95.60 bcd	2.87 bcd	47.55 ab	1367.73 bcd
S_5: Fe+Mn	204.7 ab	3.0 abc	22.3 b	6.98 b	97.05 bcd	2.91 bcd	47.16 ab	1373.21 bcd
S_6: Fe+Zn	204.1 ab	2.8 cd	25.1 a	7.08 b	105.97 ab	3.18 ab	47.90 ab	1521.45 ab
S_7: Mn+Zn	205.8 ab	2.9 bc	25.9 a	7.03 b	101.50 abc	3.05 abc	46.92 ab	1428.12 bc
S_8:Fe+Mn+Zn	207.8 a	3.0 a	26.7 a	7.95 a	111.34 a	3.34 a	48.29 a	1614.47 a

Means with the same letter indicate insignificant at 5% probability level based on Duncan's multiple range test.

3- Effect of interaction between spraying time numbers and micronutrient's nanoparticle types:

For the interaction effects, the presented data in Tables 4 and 5 show that the interaction between spraying time numbers and micronutrients nanoparticle types significantly affected all sunflower yield attributes in both growing seasons. Thus, the highest mean values of plant height (223.0 and 235.0 cm) were obtained from the interaction between $T_2 \times S_4$ and $T_2 \times S_8$ in the 2019 season and 2020 season, respectively. Meanwhile, the highest mean values of stem diameter and head diameter (3.2 and 27.7 cm) was obtained from $T_2 \times S_7$ in the first season; however, the highest mean values of stem diameter and head diameter (3.1 and 22.7 cm) were obtained from $T_3 \times S_8$ and $T_3 \times S_3$ in the second season respectively. Also, the highest mean values of 100 seed weight (8.49 and 7.68 g) were obtained from $T_3 \times S_7$ and $T_3 \times S_8$ in seasons 2019 and 2020, respectively. Hence, the interaction between spraying time numbers and micronutrients nanoparticle may be due to that the time of nanoparticles application is more important than using the adjuvant with an early application that causes leaf damage, and consequently helping the plant's ability to translocate nutrients by reducing leaf damage. Babaeian *et al.,* (2011b) found an increasing in the seed and oil yields with increasing levels of zinc application when they applied zinc on the sunflower leaves during the flowering stage Moreover, micronutrients nanoparticles enter through the cell wall easily and reach up to the plasma membrane because they have diameters less than the pore size of the plant cell wall (Moore, 2006 and Navarro *et al.,* 2008). The improvement in the agronomic traits of sunflowers because of using foliar application of micronutrients could be attributed to direct and rapid absorption of these micronutrients on the crop's leaves. Our results are consistent with those obtained by other researchers in many crops, including that sunflower (Khurana and Chatterjee, 2001, Fageria 2016). Likewise, Babaeian *et al.,* (2011a) and Abou-Bakr *et al.,* (2019) concluded that foliar application of Zn and Fe led to increasing plant height, 1000-seed weight, seed yield, and oil content of sunflower.

Table 4. Effect of the interaction between foliar spraying time and the micronutrient's nanoparticle types on Sunflower yield attributes in 2019 season.

Spraying time	Micro nano Treatments	Plant height (cm)		Stem diameter (cm)		Head diameter (cm)		100 Seed weight (g)	
T1	S_1: Control	191.3	hi	2.6	e~h	19.1	def	5.12	l
	S_2: Fe	185.0	i	2.4	gh	19.1	def	6.66	d~g
	S_3: Mn	190.0	i	2.6	d~g	18.3	f	5.79	jk
	S_4: Zn	199.0	f~i	2.6	c~fg	19.3	c~f	6.50	e~i
	S_5: Fe+Mn	194.0	ghi	2.7	c~f	19.4	c~f	6.17	hij
	S_6: Fe+Zn	191.7	hi	2.5	e~h	20.7	a~e	6.46	f~i
	S_7: Mn+Zn	211.0	c~g	2.5	e~h	19.9	b~f	7.32	abc
	S_8:Fe+Mn+Zn	216.0	b~f	2.6	e~h	21.2	a~d	6.94	c~f
T2	S_1: Control	208.7	d~h	2.6	c~g	19.1	def	5.16	l
	S_2: Fe	220.0	a~e	2.5	fgh	21.2	a~d	6.41	ghi
	S_3: Mn	216.0	b~f	2.5	e~h	18.7	ef	7.01	cd
	S_4: Zn	212.7	c~f	2.7	c~f	20.4	a~f	6.10	ijk
	S_5: Fe+Mn	223.7	a~d	2.8	bcd	22.3	a	7.68	a
	S_6: Fe+Zn	227.3	abc	2.8	bc	21.4	a~d	6.98	cde
	S_7: Mn+Zn	231.7	ab	2.5	e~h	21.7	abc	7.26	abc
	S_8:Fe+Mn+Zn	235.0	a	2.9	ab	21.9	ab	6.97	cde
T3	S_1: Control	199.0	f~i	2.6	e~h	18.7	ef	5.08	l
	S_2: Fe	203.0	e~i	2.8	bcd	20.5	a~f	6.71	d~g
	S_3: Mn	212.3	c~g	2.7	c~f	22.7	a	6.27	ghi
	S_4: Zn	214.0	b~f	2.4	h	21.4	a~d	6.61	d~h
	S_5: Fe+Mn	201.0	f~i	2.7	cde	20.5	a~f	6.65	d~h
	S_6: Fe+Zn	214.7	b~f	2.6	c~g	21.5	a~d	7.19	bc
	S_7: Mn+Zn	203.0	e~i	2.8	bc	21.2	a~d	5.69	k
	S_8:Fe+Mn+Zn	210.3	c~g	3.1	a	21.1	a~d	7.64	ab

Means with the same letter indicate insignificant at 5% probability level based on Duncan's multiple range test.

Table 5. Effect of the interaction between foliar spraying time and the micronutrient's nanoparticle types on Sunflower yield attributes in 2020 season.

Spraying time	Micro nano Treatments	Plant height (cm)		Stem diameter (cm)		Head diameter (cm)		100 Seed weight (g)	
T1	S_1: Control	189.3	ef	2.7	e~h	18.5	j	4.77	l
	S_2: Fe	190.3	def	2.5	hi	21.0	hi	6.97	c~h
	S_3: Mn	196.7	c~f	2.6	f~i	21.5	hi	5.57	i~l
	S_4: Zn	187.7	f	3.0	a~e	21.8	ghi	6.23	f~j
	S_5: Fe+Mn	202.7	b~f	2.9	b~f	21.7	ghi	6.53	e~i
	S_6: Fe+Zn	207.0	a~e	2.7	e~h	24.3	ef	6.76	d~h
	S_7: Mn+Zn	209.3	a~d	3.1	a~d	25.1	b~e	6.61	e~i
	S_8:Fe+Mn+Zn	196.0	c~f	3.1	ab	27.0	a	7.78	a~d
T2	S_1: Control	189.3	ef	2.8	d~h	17.8	j	5.47	jkl
	S_2: Fe	199.3	b~f	3.1	a~d	22.1	ghi	6.43	e~j
	S_3: Mn	204.3	a~f	2.9	b~f	21.9	ghi	5.42	jkl
	S_4: Zn	223.0	a	3.1	abc	23.0	fgh	7.30	b~e
	S_5: Fe+Mn	202.0	b~f	2.9	b~f	23.5	efg	7.23	b~f
	S_6: Fe+Zn	206.0	a~f	2.8	c~g	26.5	abc	7.09	c~g
	S_7: Mn+Zn	216.0	ab	3.2	a	27.7	a	6.00	h~k
	S_8:Fe+Mn+Zn	217.0	ab	3.1	abc	26.8	ab	7.92	abc
T3	S_1: Control	191.7	c~f	2.7	e~h	17.3	j	5.13	kl
	S_2: Fe	190.3	def	2.6	ghi	21.0	hi	6.13	g~k
	S_3: Mn	196.7	c~f	2.7	e~h	20.7	i	6.55	e~i
	S_4: Zn	197.0	c~f	3.0	a~d	20.7	i	6.16	g~j
	S_5: Fe+Mn	209.3	a~d	3.1	a~d	21.7	ghi	7.18	b~g
	S_6: Fe+Zn	199.3	b~f	3.0	a~d	24.5	def	7.41	b~e
	S_7: Mn+Zn	192.0	c~f	2.4	i	24.8	c~f	8.49	a
	S_8:Fe+Mn+Zn	210.3	abc	2.9	a~e	26.3	a~d	8.15	ab

Means with the same letter indicate insignificant at 5% probability level based on Duncan's multiple range test.

Regarding to the interaction effect on seed and oil yields, data in tables 6 and 7show that the interaction between spraying time and micronutrients nanoparticles had a significant effect on seed and oil yields in both growing seasons. The highest mean values of seed yield (115.45 and 118.20 g plant^{-1}), seed yield (3.47 and 3.55 t fed^{-1}), and oil yield (1765.88 and 1770.67 kg fed^{-1}) were obtained from the interaction between $T_3 \times S_7$ (foliar spraying after 30, 50 and 70 days from sowing date × spraying with Iron, Manganese, and Zinc) in the first and second growing seasons respectively. Moreover, the highest mean values for seed oil percentage (52.23 and 51.24 %) were obtained from foliar spraying after 30, 50, and 70 days from sowing date × spraying with Iron and Zinc and foliar spraying after 30 and 50 days from sowing date × spraying with Iron and Manganese in the first and second growing seasons respectively. Meanwhile, the highest oil yield (1765.88 and 1770.67 kg fed^{-1}) were obtained from the interaction T3 × S7 (foliar spraying after 30, 50 and 70 days from sowing date × spraying with Iron, Manganese, and Zinc). Higher seed yield might be associated with foliar fertilization with Iron, Manganese, and Zinc during pollen development. This may increase pollen germination and pollen viability, increasing the translocation of sugars and photosynthesis from source to sink, which enhances the seed setting percentage. The increase in the seed yield of sunflower may also be through a prolonged photosynthetic capacity during flowering and seed-setting or organ development from the biomass increase. Similar findings were reported by Fernández and Eichert, (2009); Movuhdi *et al.,* (2001); Fernández and Brown, (2013) and Kavita *et al.,* (2018).

Table 6. Effect of the interaction between foliar spraying time and the micronutrient's nanoparticle types on Sunflower yield in 2019 season.

Spraying time	Micro nano Treatments	Seed yield / plant (g)		Seed yield / fed (t)		Seed Oil (%)		Oil yield (kg fed^{-1})	
T1	S_1: Control	84.06	i	2.52	i	42.07	j	1061.08	k
	S_2: Fe	89.47	f~i	2.68	f~i	46.16	e~h	1239.98	ij
	S_3: Mn	89.57	f~i	2.69	fghi	46.16	e~h	1242.12	ij
	S_4: Zn	87.95	ghi	2.64	ghi	49.25	a~e	1299.35	f~i
	S_5: Fe+Mn	86.78	ghi	2.60	ghi	46.76	d~h	1217.91	ij
	S_6: Fe+Zn	96.54	cd	2.90	cd	45.44	f~i	1322.30	e~i
	S_7: Mn+Zn	104.47	b	3.13	b	48.36	b~g	1519.53	cd
	S_8:Fe+Mn+Zn	105.93	b	3.18	b	50.80	ab	1614.98	bc
T2	S_1: Control	85.87	hi	2.58	hi	43.49	hij	1120.25	jk
	S_2: Fe	90.84	e~h	2.73	e~h	47.75	b~g	1300.09	f~i
	S_3: Mn	92.23	d~g	2.77	d~g	46.33	e~h	1283.75	ghi
	S_4: Zn	95.53	cde	2.87	cde	49.91	a~d	1430.29	def
	S_5: Fe+Mn	94.30	c~f	2.83	c~f	47.69	b~g	1347.27	e~i
	S_6: Fe+Zn	98.39	c	2.95	c	48.63	b~f	1433.62	def
	S_7: Mn+Zn	98.52	c	2.96	c	47.18	c~g	1394.61	d~h
	S_8:Fe+Mn+Zn	105.04	b	3.15	b	50.43	abc	1588.11	bc
T3	S_1: Control	84.87	i	2.55	i	42.72	ij	1087.52	k
	S_2: Fe	90.84	e~h	2.73	e~h	48.52	b~f	1322.12	e~i
	S_3: Mn	91.76	d~g	2.75	d~g	46.23	e~h	1275.36	hi
	S_4: Zn	105.08	b	3.15	b	45.08	g~j	1421.11	defg
	S_5: Fe+Mn	103.73	b	3.11	b	46.79	d~h	1454.91	de
	S_6: Fe+Zn	105.67	b	3.17	b	52.23	a	1659.96	ab
	S_7: Mn+Zn	108.37	b	3.25	b	49.11	a~e	1594.06	bc
	S_8:Fe+Mn+Zn	115.54	a	3.47	a	50.92	ab	1765.88	a

Means with the same letter indicate insignificant at 5% probability level based on Duncan's multiple range test.

Table 7. Effect of the interaction between foliar spraying time and the micronutrient's nanoparticle types on Sunflower yield in 2020 season.

Spraying time	Micro nano Treatments	Seed yield / plant (g)		Seed yield / fed (t)		Seed Oil (%)		Oil yield (kg fed^{-1})	
T1	**S_1: Control**	88.06	i	2.64	i	44.88	fgh	1185.69	jk
	S_2: Fe	89.47	hi	2.68	hi	49.72	a~d	1334.58	ghi
	S_3: Mn	88.91	i	2.67	i	44.12	fgh	1178.00	k
	S_4: Zn	87.39	i	2.62	i	44.94	fgh	1178.49	k
	S_5: Fe+Mn	88.74	i	2.66	i	45.67	e~h	1216.10	jk
	S_6: Fe+Zn	106.67	bc	3.20	bc	46.13	efg	1477.02	c~f
	S_7: Mn+Zn	97.80	ef	2.93	ef	45.47	e~h	1334.74	ghi
	S_8: Fe+Mn+Zn	108.37	bc	3.25	bc	45.76	e~h	1487.47	cde
T2	**S_1: Control**	90.54	hi	2.72	hi	43.48	gh	1181.04	k
	S_2: Fe	90.84	ghi	2.73	ghi	45.87	e~h	1250.99	h~k
	S_3: Mn	92.23	ghi	2.77	ghi	47.02	def	1301.13	hij
	S_4: Zn	94.96	fgh	2.85	fgh	47.98	cde	1366.45	fgh
	S_5: Fe+Mn	96.38	efg	2.89	efg	51.24	a	1482.29	c~f
	S_6: Fe+Zn	100.59	de	3.02	de	48.20	b~e	1450.00	d~g
	S_7: Mn+Zn	99.67	def	2.99	def	51.00	ab	1526.24	b~e
	S_8: Fe+Mn+Zn	107.45	bc	3.22	bc	49.17	a~d	1585.26	bc
T3	**S_1: Control**	89.87	hi	2.72	hi	44.22	fgh	1201.01	jk
	S_2: Fe	90.84	ghi	2.73	ghi	43.15	h	1176.31	k
	S_3: Mn	91.76	ghi	2.75	ghi	44.81	fgh	1233.52	ijk
	S_4: Zn	104.46	cd	3.13	cd	49.73	a~d	1558.25	bcd
	S_5: Fe+Mn	106.02	bc	3.18	bc	44.58	fgh	1421.23	efg
	S_6: Fe+Zn	110.65	b	3.32	b	49.36	a~d	1637.34	b
	S_7: Mn+Zn	107.04	bc	3.21	bc	44.30	fgh	1423.37	efg
	S_8: Fe+Mn+Zn	118.20	a	3.55	a	49.94	abc	1770.67	a

Means with the same letter indicate insignificant at 5% probability level based on Duncan's multiple range test.

These findings can be attributed to the role of micronutrients of stimulating and enhancing plant enzymatic activity. Moreover, microelements have an essential role in photosynthesis and translocation of assimilates to the seed by applying Fe, Mn, and Zn at prober time of application. These findings are in a good line with those obtained by Heidaria *et al.,* (2011); Yari *et al.,* (2004) and Mohammad *et al.,* (2012). On other hand, the reduction on seed and oil yields at control might be attributed to micronutrient deficiency which in turn resulted in reduction of growth and development of plant, less photosynthetic activity and less translocation of photosynthates to sink, reduced source to sink ratio which further resulted in decreased yield and yield attributes.

Conclusion

It was concluded that foliar spray threes time at 30, 50 and 70 days from sowing using Iron, Manganese and Zinc nanoparticles could be considered a convenient strategy for improving sunflower yield and its attributes on Sakha-53 cultivar.

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تأثير توقيت الرش الورقي بالمغذيات الصغرى النانومترية على المحصول ومساهمته في دوار الشمس

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الملخص

تم اجراء تجربه حقليه بمزرعة قسم المحاصيل – كلية الزراعة – جامعة اسيوط خلال موسمي 2019–2020 لتقييم تأثير توقيت الرش الورقي بالمغذيات الصغرى النانومترية على صنف سخا –53 لمحصول دوار الشمس(*Helianthus annuus* L.) ، استخدم لذلك تصميم القطاعات كاملة العشوائية باستخدام ترتيب القطاعات المنشقة في ثلاث مكررات. حيث وزعت معاملات الرش الورقي بالمغذيات الصغرى النانومترية على ثلاث اعمار. وأظهرت النتائج أن الرش الورقي مرتين بعد 30 و50 يوم من الزراعة أدى إلى زيادة معنوية في ارتفاع النبات وقطر الساق وقطر الرأس في كلا الموسمين. كما سجلت أعلى قيم متوسطات لمحصول البذور (طن فدان$^{-1}$) ومحصول الزيت (كجم فدان$^{-1}$) عند الرش الورقي بالمغذيات الصغرى النانومترية على ثلاث مرات 30 و50 و70 يومًا من الزراعة. بالإضافة الي ذلك اوضحت النتائج تفوق الرش الورقي بالحديد والمنجنيز والزنك في الصورة النانومترية على جميع المعاملات الأخرى في هذا الصدد مسجلا أعلى قيم متوسطات لجميع مساهمات المحصول المدروسة ومحصول البذور ومحصول الزيت في كلا الموسمين. كما أثر التفاعل بين عدد مرات الرش ونوع المغذيات الصغرى النانومترية تأثيراً معنوياً على جميع مكونات محصول دوار الشمس في موسمي النمو، حيث تم الحصول على أعلى متوسطات لقيم محصول البذور (3.47 و3.55 طن فدان$^{-1}$) ومحصول الزيت (1765.88 و1770.67 كجم فدان$^{-1}$) من التفاعل بين $T_3 \times S_7$ (الرش الورقي على ثلاث مرات بعد 30، 50، 70 يومًا من الزراعة × الرش بالحديد والمنجنيز والزنك في الصورة النانومترية). ويمكن استنتاج أن المعاملة بالرش الورقي على ثلاث مرات بعد 30 و50 و70 يومًا من الزراعة باستخدام جزيئات الحديد والمنجنيز والزنك النانومترية تعتبر استراتيجية مناسبة لتحسين صفة محصول دوار الشمس ومساهماته للصنف سخا 53.