Assiut Journal of Agriculture Science 53 (3) 2022 (1-13) **Website:** http://ajas.journals.ekb.eg/
ISSN: 1110-0486 / EISSN: 2356-9840 **E-mail:** ajas@aun.edu.eg

(Original Article)

Impact of Planting Methods and Foliar Spraying with Zinc Dioxide Nanoparticles on the Seed and Oil Yields of Sunflower

Bahy R. Bakheit[1*]; Elsaady A. Ali[1]; Abdelmoniem A. Omar[2]; Hosny A.A. Hamed[2]

[1]Department of Agronomy, Faculty of Agriculture, Assiut University, Assiut, Egypt
[2]Agronomy Department, Agriculture and Natural resources Faculty, Aswan University, Egypt

[*]Corresponding author email: bahy@aun.edu.eg
DOI: 10.21608/ajas.2022.127476.1115

Abstract

The present study was carried out during the two successive summer seasons of 2020 and 2021 at Agronomy Experimental Farm, Faculty of Agriculture, Assiut University, Assiut, Egypt to investigate the influence of planting methods and foliar spray by zinc oxide nanoparticles on seed and oil yields of sunflower cv. Giza 102. The experiment was laid out in randomize complete blocks design (RCBD) using strip plot arrangement with three replications. The studied planting methods i.e., beds, ridges and drill on flat were arranged vertically while, the studied zinc dioxide nanoparticles concentrations i.e., control, 50, 100, 150. 200 and 250 ppm were allocated horizontally. The obtained results showed that the studied planting methods, zinc oxide nanoparticles concentrations and their interaction had a significant or highly significant effect on most studied traits i.e., 100-ssed weight (g), seed weight head $^{-1}$ (g), seed yield fed^{-1} (kg), seed oil content and oil yield fed.$^{-1}$ (kg). in addition, cultivation of sunflower plants on ridges and spray it with a concentration of 200 parts per million of nanometric zinc oxide gave the highest mean values for the average oil yield per feddan, which amounted to 1403.24 and 1269.93 kg per feddan for the first and second seasons, respectively.

Keywords: *Sunflower, Zinc Dioxide Nanoparticles, Planting Methods*

Introduction

Sunflower (*Helianthus annuus* L.) belongs to family Asteraceae and considered an important oilseed crop in the world. Seeds of sunflower contain approximately 45 to 50% oil with different quality from region to region (Pereyra-Irujo *et al*. 2009). Sunflower oil has a high percentage of unsaturated fatty acid content (about 89 %) and low percentage of saturated fatty acid content (about 11%) . Also, its rich in linoleic acid (Omega 6) and Trochophores (vitamin E) that are very appreciated by consumers all over the world (Onat *et al.,* 2017). therefore, it has a high nutritional value. There are, many uses of sunflower products including human consumption, animal diets, flour and protein isolates for food products (pectin).

Received: 15 March 2022/ Accepted: 16 August 2022/ Published online: 21 August 2022

In Egypt, sunflower production arrived to 15817 ton, which was produced through 15430 faddans with an average of 1.025 ton/ faddans (FAO, 2019)**.** The total quantity of oil produced in Egypt *via* extraction of local as well as imported oilseed covers only two percent of the consumption needs of edible oil. The remaining 98% has been covered through imported oils (Aswaq Financial Co., 2018). There is a big gap in edible vegetable oils in Egypt. There is great interest in improving sunflower production by choosing the suitable cultivar and using the best sowing practices, including; appropriate sowing methods, fertilization, irrigation, pests-control, etc. to increase the production of sunflower oil and decrease the gap between edible oil consumption and production.

Sowing methods is one of the most important agronomic practices which affect the performance of sunflower crop by modifying its phenological and morphological phases. Choosing the suitable sowing method, has been shown to improve water use efficiency, nutrients use efficiency, reduced weed infestation and also reduce seeding rate without reducing yield (Holm *et al.*, 2002). Sowing in narrow rows revealed optimal conditions, yield increase , and adaptive responses to abiotic stresses (Khalifa, 1984). In addition, improvement in water use efficiency is also endorsed due to better availability of plant nutrients; lower weed density in ridges sowing, and ultimately an enhanced final crop yield in furrows sowing method as compared to the flat bed sowing (Nasrullah *et al*., 2009).

Zinc is considered one of the most important micronutrients for crops, which plays a printable role in many metabolism functions inside plant tissue i.e., gene expression, synthesis of protein, maintaining membranes structural and functional stability, and as a catalyst for a large number of enzymes (Shahhoseini *et al.,* 2020 and Velasco *et al.,* 2020). It is also an essential nutrient for vegetative development (Pandey *et al*. 2010) as it acts as a precursor in Phyto-hormones such as auxins, which affect cell elongation and division. Furthermore, zinc is essential for photosynthesis and facilitates carbohydrate metabolism in plants by stabilizing or activating proteins participation in these processes (Rehman *et al.,* 2012). Application of bulk ZnO or nano-ZnO to plants improves biochemical aspects, growth and consequently yield (Sadak and Bakry 2020).

Nowadays, the use of Nano-fertilizers containing active nanoparticles has increased due to the great benefits that these particles have shown in various fields of agriculture and plant protection (Prasad *et al.,* 2017; Gkanatsiou *et al.,* 2019 and Kolenčík *et al.,* 2020). Moreover, Abou-Bakr *et al*. (2019) revealed that seed index and seed weight head^{-1} (g), Seed yield (kg fed.$^{-1}$), oil percentage (%) and oil yield (kg fed.$^{-1}$) of sunflower were significantly affected by studied zinc oxide nanoparticles concentrations in both seasons in favor to 200 ppm concentration.

The objective of this research was to evaluate the effect of sowing methods and foliar spray by zinc oxide nanoparticles on the seed and oil yields of sunflower.

Materials and methods

The present study carried out during 2020 and 2021 seasons at the Agricultural Experimental Farm, Faculty of Agriculture, Assiut University, Assiut, Egypt, to investigate the influence of sowing methods and foliar spray by zinc oxide nanoparticles on seed and oil yields of sunflower cv. Giza 102. The mechanical and chemical analyses of the experimental soil were presented in Table 1.

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

Properties	2020	2021
Mechanical analysis (%)		
Sand	27.30	27.90
Silt	22.70	22.10
Clay	50.00	50.00
Soil type	Clay	Clay
Chemical analysis		
pH	7.70	7.65
Organic matter %	1.85	1.75
Total N%	0.09	0.08

Strip plot arrangement with three replications under randomize complete blocks design (RCBD) was used in experiment layout. The studied sowing methods i.e., beds, ridges and drilling on flat were arranged vertically while, the studied zinc dioxide nanoparticles concentrations i.e., 50, 100, 150. 200 and 250 ppm plus control (without ZnO NPs) were distributed horizontally. The plot size was 10.5 m^2 (3.5 long * 3.0 m width). Seeds of sunflower cv.102 (Oil Crops Section, Field Crops Research Institute, Agricultural Research Centre, Egypt. seeds of sunflower were hand sown on rows at 60 cm. , drilling, on ridges and on beds (bed width was 120 cm) in hills 20 cm apart during 25^{th} and 26^{th} of June 2020 and 2021 seasons, respectively. Control plants were treated with water (without ZnO NPs) while the others were sprayed by the concentrations of ZnO NPs. The used zinc oxide nanoparticles for foliar spray were produced by Sigma-Aldrich Company (Saint-Louis, MO, USA). The particle size of nano-zinc oxide was about 30 - 40 nm with 99% purity of white color. Solutions of nano-ZnO were prepared at the concentrations of 50, 100, 150, 200 and 250 ppm by dissolving 50, 100, 150,200 and 250 mg nano- ZnO in one liter of distilled water. Spraying was carried out by the back sprayer at a rate of 0.5 liter for each experimental unit at 30 days after sowing. Weeds control was done using Amex 48% (N-sec -butyl-4-tert - butyl – 2,6 – dinitroaniline) before emergency. The preceding winter crops in the two study seasons was wheat. All other recommended cultural practices for sunflower were performed in both seasons.

Studied traits

at harvest the follows traits were measured

1-Hundred seeds weight (g): The average weight in grams of two random 100 seed samples taken randomly from each experimental unit.

2-Seed weight head^{-1} (g): The average weight of separated seeds from five heads chosen randomly from each experimental unit.

3- Seed yield (Kg fed^{-1}): Heads of five bagged inner ridges of each experimental unit were harvested and left two weeks until fully air dried and seeds were manually separated then weighted and transferred to kg fed

4- Seeds oil content (%): oil percentage in sunflower seeds was estimated by extraction using Soxhlet apparatus and petroleum ether (*bp* 60 – 80 °C) as solvent according to A.O.A.C. (2000).

5- Oil yield (kg fed.$^{-1}$): oil yield =seed yield fad.$^{-1}$ × seed oil percentage.

Statistical analysis:

All collected data were analyzed via analysis of variance (ANO…VA) Procedures, using the SAS Statistical Software Package v.9.2 (SAS, 2008). Differences between means were compared by revised least significant difference (R LSD) at 5% level of probability (Gomez and Gomez, 1984). Variances of the two seasons were not homogenous, consequently the combined analysis was not performed.

Results and discussions

Hundred seed weight (g)

Data presented in Table 2 revealed that the studied sowing methods had a significant ($p \leq 0.01$) effect on seed index of sunflower only for the second season, while the differences between the studied sowing methods failed to reach the significance in the first season. Thus, the highest mean value of hundred seed weight of sunflower cv.102 (7.90 g) in the second season was recorded for bed sowing method while the least mean value (5.93 g) was gained from drilling on flat method. In addition, an increase in seed index was noticed by the second season with using sowing on beds compared to the others two methods of sowing amounted to 13.34 and 33.22%, for ridges or drilling on flat, respectively. This could be explained by the role of bed sowing methods in avoiding plants the bad effect of flooding and improving aeration and consequently enhancing nutrient availability and uptake which resulted in heavier seeds due to an increase in translocation of metabolic products to seeds which considered a main sink of sunflower plants. Similar trend was observed by Mahmoud *et al.* (2020) who found that sowing sesame using terraces method gained the heaviest sesame seeds as compared to drill or furrows methods. Furthermore, the hundred seed weight trait of sunflower cv. Giza 102 was affected highly significantly ($p \leq 0.01$) by the tested zinc oxide nanoparticles concentrations in the two growing seasons (Table 2). Sunflower plants which were sprayed by 200 ppm of ZnO NPS produced the maximum mean values of 100- seed weight of sunflower reached about 8.30 and 7.21 g in the first and second seasons, respectively. Zinc has been considered as an essential micronutrient for its role in plants metabolic activities. It regulates the various enzyme activities and requires in biochemical reactions leading to formations of chlorophyll and carbohydrates which led to an increase in seeds weight (Palmer and Guerinot, 2009). Similar trend was obtained by Abou-Bakr *et al.* (2019).

Moreover, the exhibited data in Table 2 focus that the interaction between the studied planting methods and the tested ZnO NPs concentrations had a significant ($p \leq 0.05$) and highly significant ($p \leq 0.01$) influences on 100 seed weight of sunflower cv.102 in the first and second seasons, respectively. Thus, sowing sunflower plants on bed and fertilized it by 200 ppm ZnO NPs in the first season or 50 ppm in the second one gained the maximum mean values of 100 seed weight (8.72 and 8.89 g in the two respective seasons). These aforementioned results can be attributed to the fact that this interaction combined the benefits of the sowing on beds, which is to provide a good environment for growth in terms of ventilation to help the roots breathe and provide the energy needed to absorb water and the necessary nutrients, in addition to the role of zinc, which is necessary in photosynthesis and enzymatic activity, which helped to increase the products of photosynthesis and transfer them from the sources (plant leaves) to the sinks (seeds), which led to the filling of the seeds and an increase in their weight.

Table 2. Means of 100- seed weight of sunflower as affected by planting methods, zinc oxide nanoparticles concentrations and their interaction in 2020 and 2021 seasons.

Season	2020				2021			
Zinc oxide nanoparticles (ppm)	Planting methods			Mean	Planting methods			Mean
	Bed	Ridge	Drill on flat		Bed	Ridge	Drill on flat	
Control	7.47	7.86	7.81	7.71	7.73	6.95	6.64	7.11
50 ppm	7.51	7.66	8.34	7.84	8.89	6.59	5.4	6.96
100 ppm	7.21	7.31	7.03	7.18	8.41	6.78	6.34	7.18
150 ppm	7.66	7.54	7.36	7.52	7.37	7.25	5.38	6.66
200 ppm	8.72	8.43	7.75	8.30	8.15	7.28	6.21	7.21
250 ppm	7.39	7.36	8.29	7.68	6.87	6.98	5.61	6.49
Mean	7.66	7.69	7.76		7.90	6.97	5.93	
F Test and R.LSD 0.05	F Test		Rev LSD 0.05		F Test		Rev LSD 0.05	
Planting methods	**		0.40		**		0.38	
Zinc NPS	**		0.46		**		0.29	
Interaction	*		0.83		**		0.66	

Where* and ** mean significant at 5 and 1 % level of probability, respectively

Seed wight head^{-1} (g)

It's clear from the obtained data in Table 3 that the studied planting methods had a highly significant ($p \leq 0.01$) effect on the seed weight head^{-1} trait in the two growing seasons. The method of planting sunflower on ridges outperformed the rest of the tested cultivation methods and gave the highest seed weight per head, which amounted to 77.23 and 73.34 g per head in the first and second seasons, respectively. This previous result may be attributed to the increase in the number of seeds for the head formed as a result of using the method of planting on ridges (unpublished data), which is the main component of the weight of the seeds per head. Buttar (1995) found higher dry matter of sunflower with ridge sowing as compared to flat method. The previous founding is in a good line with those obtained by Jasmeet *et al*. (2016).

Also, data in Table 3 showed that the seed weight. head $^{-1}$ was significantly affected ($p\leq0.05$) and highly significantly ($p\leq0.01$) by the studied ZnO NPs concentrations in both seasons, respectively. Sprayed sunflower plants by 200 ppm ZnO NPs recorded the highest mean values of seed weight. head^{-1} (75.96 and 65.16 g in the two respective seasons). This was expected, since the same ZnO NPs concentration gained the maximum average values with regard to hundred seeds weight as mentioned before (Table 2) . The previous findings are agreement with those obtained by Abou-Bakr *et al.* (2019).

Concerning the effect of the interaction between sowing methods and zinc oxide nanoparticles concentration, data illustrated in Table 3 cleared that the interaction had a highly significant influence on seed weight head $^{-1}$ for the first and second seasons. Thus, sowing sunflower on ridges and fertilized with 200 ppm ZnO NPs gained the highest average values of seed weight. head^{-1} (91.64 and 87.79 g in the two respective seasons). These aforementioned results can be attributed to the fact that this interaction combined the benefits of the sowing on ridges, which provide a good environment for growth in terms of ventilation to help the roots breathe and provide the energy needed to absorb water and the necessary nutrients, in addition to the role of zinc, which is necessary in photosynthesis and enzymatic activity, which helped to increase the products of photosynthesis and transfer them from the sources (plant leaves) to the sinks (seeds), which led to the filling of the seeds and an increase in their weight head^{-}.

Table 3. Means of Seed weight head $^{-1}$ (g)of sunflower as affected by planting methods, zinc oxide nanoparticles concentrations and their interaction in 2020 and 2021 seasons.

Season	**2020**				**2021**			
Zinc oxide nanoparticles (ppm)	**Planting methods**			**Mean**	**Planting methods**			**Mean**
	Bed	**Ridge**	**Drill on flat**		**Bed**	**Ridge**	**Drill on flat**	
control	64.39	72.00	65.12	67.17	43.94	64.11	44.80	50.95
50 ppm	73.56	62.40	64.81	66.92	49.72	69.67	49.39	56.26
100 ppm	66.95	81.93	65.34	71.40	36.99	76.05	55.47	56.17
150 ppm	84.03	86.47	52.59	74.36	57.54	79.24	49.78	62.19
200 ppm	70.26	91.64	66.00	75.96	45.44	87.79	62.25	65.16
250 ppm	65.15	68.95	86.1	73.4	54.94	63.15	54.7	57.60
Mean	70.72	77.23	66.6	------	48.09	73.34	52.73	------
F Test and R.LSD 0.05	F Test		Rev LSD 0.05		F Test		Rev LSD 0.05	
Planting method	**		3.80		**		3.84	
Zinc NPS	*		5.61		**		2.12	
Interaction	**		6.36		**		4.90	

Where, * and ** mean significant at 5 and 1 % level of probability, respectively

Seed yield (kg fed.$^{-1}$):

The presented data in Table 4 showed that the tested sowing methods had a significant ($p \leq 0.05$) and highly significant ($p \leq 0.01$) effects on seed yield / fed.$^{-1}$. during the two respective seasons. Sowing sunflower seeds on ridges out yielded the maximum mean values of seed yield fed.$^{-1}$ (2703.11 and 2566.72 kg fed.$^{-1}$ in the two respective seasons). This was logic since the same trend was observed regarding seed weight. head^{-1} as shown previously in Table 3, since, seed weight. head $^{-1}$ is considered the main component of seed yield fed.$^{-1}$. Similar results were detected by Buttar (1995) and Jasmeet *et al*. (2016).

Also, the results shown in Table 4 indicated that there was a significant effect of the zinc nanometric concentrations under study on seed yield per feddan in the 2020_season and highly significant in the second season. Whereas, spraying sunflower plants with a concentration of 200 parts per million of nanometric zinc oxide led to the highest values of the average seed weight in kilograms per feddan, which amounted to 2658.83 in 2020 season and 2280.60 in the second season. In addition, spraying sunflower plants with a concentration of 150 parts per million of nanometric zinc oxide came in second rank in terms of the amount of seeds per feddan (2602.72 and 2176.53 kg fed.$^{-1}$ in the two respective seasons), with a statistically insignificant difference from the foliar spray with a concentration of 200 ppm. This increase in seed yield per feddan with foliar spraying of 200 parts per million is attributed to the fact that the same concentration of nanometric zinc oxide led to an increase in the components of the crop under study, such as the weight of 100 seeds and the weight of seeds for the head, and thus led to an increase in the weight of seeds per feddan. Similar trend was obtained by Abou-Bakr *et al.* (2019).

Table 4. Means of seed yield (kg fed.$^{-1}$) of sunflower as affected by planting methods, zinc oxide nanoparticles concentrations and their interaction in 2020 and 2021 seasons.

Season	2020				2021			
Zinc oxide nanoparticles (ppm)	Planting methods			Mean	Planting methods			Mean
	Bed	Ridge	Drill on flat		Bed	Ridge	Drill on flat	
Control	2253.65	2520.00	2279.20	2350.95	1537.90	2243.85	1568.00	1783.25
50 ppm	2574.60	2184.00	2268.35	2342.32	1740.20	2438.45	1728.65	1969.10
100 ppm	2343.25	2867.55	2286.90	2499.23	1294.65	2661.75	1941.45	1965.95
150 ppm	2941.05	3026.45	1840.65	2602.72	2013.90	2773.4	1742.30	2176.53
200 ppm	2459.10	3207.40	2310.00	2658.83	1590.40	3072.65	2178.75	2280.60
250 ppm	2280.25	2413.25	3013.50	2569.00	1922.90	2210.25	1914.50	2015.88
Mean	2475.32	2703.11	2333.10	------	1683.33	2566.72	1845.61	-------
F Test and R.LSD 0.05	F Test		Rev LSD 0.05		F Test		Rev LSD 0.05	
Planting methods	**		133		**		134.4	
Zinc NPS	*		196.35		**		74.2	
Interaction	**		222.6		**		171.5	

Where* and ** mean non-significant and significant at 5 and 1 % level of probability, respectively

Regarding the effect of the interaction between the tested sowing methods and the nanometric zinc concentrations under study, the data in Table 4 showed that there was a highly significant effects of this interaction on the characteristics of seed yield per feddan during the two study seasons. Sowing of sunflower plants on ridges and spraying with a concentration of 200 parts per million of nanometric zinc oxide gave the highest values of the average seed yield per feddan, which amounted to 3207.40 and 3072.65 kg per feddan for the first and second seasons, respectively.

Seed oil content (%)

Data in Table 5 reveal that the seed oil content was significantly affected ($p \leq 0.05$) in the 2020 season and highly significantly ($p \leq 0.01$) in the second one by the studied sowing methods. Sowing sunflower seeds on bed surpassed the others studied sowing methods in this respect and recorded the highest mean values of seed oil content in both season which were 43.99 and 40.42 % in 2020 and 2021 seasons, respectively. This could be attributes to the role of bed sowing methods in avoiding sunflower plants the bad effects of flooding and improving aeration and consequently enhancing nutrient availability and uptake which led to an increase in photosynthesis process as well as the transformation of carbohydrate to fatty acids consequently to oil.

Furthermore, data in Table 5showed that the tested zinc oxide nanoparticles concentration had a highly significant ($p \leq 0.01$) effect on seed oil content in the two seasons. Thus, the maximum seed oil content in the 1st season (44.08 %) was obtained from sunflower plants which were sprayed by 150 ppm ZnO NPs concentration while, the highest average value in the second season (41.50 %) was recorded from sunflower plants which were sprayed by 250 ppm ZnO NPs concentration. This might be due to the superiority of ZnO NPs concentration capability in transformation of sugar to fat in seed tissue. The recorded results are in agreement with those obtained by Sankaran *et al.* (2001), Gitte *et al.* (2005) and Abou-Bakr *et al.* (2019).

Concerning the interaction between sowing methods and ZnO NPs concentrations, data presented in Table 5 showed that the interaction between sowing methods and ZnO NPs concentrations had a highly significant ($p \leq 0.01$) effect on seed oil content in both seasons. In addition, the highest average value of seed oil content in the first season was 46.17 % which was recorded from sunflower plants which were planted on beds and sprayed by 100 ppm ZnO NPs concentration . While the corresponding value in the second season was 43.5 % which was recorded from sunflower plants which were planted on beds and sprayed by the high ZnO NPs concentration (250 ppm). This might be ascribed to the role of this interaction. This is attributed to the role of the interaction between the method of sowing on terraces and foliar spraying with nanometric zinc oxide in providing a good environment for growth, increasing enzymatic activity and the photosynthesis process, as well as increasing the efficiency of converting sugars resulting from photosynthesis into oils.

Table 5.Means of seed oil content (%) of sunflower as affected by planting methods, zinc oxide nanoparticles concentrations and their interaction in 2020 and 2021 seasons.

Season	2020				2021			
Zinc oxide nanoparticles (ppm)	Planting methods			Mean	Planting methods			Mean
	Bed	Ridge	Drill on flat		Bed	Ridge	Drill on flat	
Control	43.75	41.75	45.50	43.67	41.00	40.33	38.50	39.94
50 ppm	44.50	40.75	41.83	42.36	38.50	41.00	40.00	39.83
100 ppm	46.17	43.75	40.33	43.42	40.50	36.00	35.00	37.17
150 ppm	42.00	45.50	44.75	44.08	39.33	37.67	38.00	38.33
200 ppm	43.00	43.75	43.75	43.50	39.67	41.33	39.00	40.00
250 ppm	44.50	44.50	41.00	43.33	43.50	42.00	39.00	41.50
Mean	43.99	43.33	42.86	-----	40.42	39.72	38.25	---
F Test and R.LSD 0.05	F Test		Rev LSD 0.05		F Test		Rev LSD 0.05	
Planting methods	*		1.02		**		1.07	
Zinc NPS	**		1.95		**		0.71	
Interaction	**		1.18		**		2.16	

Where, * and ** mean significant at 5 and 1 % level of probability, respectively

Oil yield (kg fed.$^{-1}$)

The results showed in Table 6 indicated that there is a significant effect of the sowing methods used on the characteristics of the oil yield per feddan for both seasons of the study. Sowing on terraces outperformed the other sowing methods under study in this regard and gave the highest values for the averages of this trait, which amounted to 1175.13 and 1017.65 kg fed.$^{-1}$ for the two sowing seasons, respectively. That was an expected results since, the highest average values of the seed yield per fed. was obtained from using the same sowing method as previously explained in Table 5, also, seed yield per fed. is the main component of the of the oil yield per feddan. The aforementioned result was obtained. Similar findings were recorded from Caliskan *et al*. (2004) and Mahmoud *et al*. (2020) in sesame crop.

In the meantime, the obtained data shown in Table 6 indicated that there was a highly significant effect of zinc nanometric concentrations on the oil yield per feddan in the 2020 season and significant in the second season. The highest averages of the oil yield per feddan were obtained from sunflower plants which were sprayed with a concentration of 200 ppm of nanometric zinc oxide, which amounted to 1157.09 and 916.85 kg per feddan for the first and second seasons, respectively. This result was expected, since the same concentration of nanometric zinc oxide led to obtaining the highest average values of the seed yield per feddan, which is the main component of oil yield . The obtained data of the oil yield per feddan. The recent results are in a good line with those obtained by Praksh and Halaswamy (2004), Gitte *et al*. (2005) and Abou-Bakr *et al*. (2019).

Regarding the effect of the interaction between the studied sowing methods and the nanometric zinc concentrations under study, data in Table 4 reveal that there was a highly significant and significant effect of this interaction on the characteristics of oil yield per feddan in the two respective seasons. Sowing of sunflower plants on ridges and sprayed with a concentration of 200 parts per million of nanometric zinc oxide gave the highest mean values for the average oil yield per feddan, which amounted to 1403.24 and 1269.93 kg per feddan for the first and second seasons, respectively. This was logic, since the same interaction was significant with regard to seed yield fed.$^{-1}$ trait.

Table 6. Means of oil yield (kg/fed.) of sunflower as affected by planting methods, zinc oxide nanoparticles concentrations and their interaction in 2020 and 2021 seasons.

Season	2020				2021			
Zinc oxide nanoparticles (ppm)	Planting methods			Mean	Planting methods			Mean
	Bed	Ridge	Drill on flat		Bed	Ridge	Drill on flat	
Control	985.97	1052.10	1037.04	1025.04	630.54	904.95	603.68	713.06
50 ppm	1145.70	889.98	948.85	994.84	669.98	999.76	691.46	787.067
100 ppm	1081.88	1254.55	922.31	1086.25	524.33	958.23	679.51	720.69
150 ppm	1235.24	1377.03	823.69	1145.32	792.07	1044.74	662.07	832.96
200 ppm	1057.41	1403.24	1010.63	1157.09	630.91	1269.93	849.71	916.85
250 ppm	1014.71	1073.90	1235.54	1108.05	836.46	928.31	746.65	837.14
Mean	1086.82	1175.13	996.34	--------	680.715	1017.65	705.52	----
F Test and R.LSD 0.05	F Test		Rev LSD 0.05		F Test		Rev LSD 0.05	
Planting methods	**		60		**		61.20	
Zinc NPS	*		100.35		**		50.20	
Interaction	**		110.00		*		242.3	

Where* and ** mean non-significant and significant at 5 and 1 % level of probability, respectively

Conclusion

It might be recommended that, sowing of sunflower plants on the ridges along with foliar spraying with 200 parts per million of nanometric zinc oxide produce the highest yield of oil per feddan.

References

Abou-Bakr, Asmaa S.; Shalaby, E.M.M.; Mahmoud, A.M.; Ali, E.A. and Hassan, A.M. (2019). Response of two sunflower cultivars to foliar spray by different zinc oxide nanoparticles concentrations. Assiut J. Agric. Sci., 50 (3):16-26.

A.O.A.C. (2000). American Association of official Agricultural Chemists Cereal Chemists Approved Methods of the A.O.A.C, 10th ed. St Paul MN: The Association. USA.

Aswaq Financial Co. Analysis Report, (2018). On the Strategic Commodities Market in Egypt; (24/1/2019). Provided by Engineer Atteia Shaaban, Consultant for Extraction & Refining of Edible Oils; Vice-President of Oils & Oils By-Products Division; Chamber of Food Industry; Federation of Egyptian Industry.

Buttar, G.S. (1995). Effect of date and method of planting-cum-irrigation application on the growth, yield and water relations of sunflower (*Helianthus annuus* L.). Ph.D. dissertation, Punjab Agricultural University, Ludhiana.

Caliskan, S.; Arslan, M.; Arioglu, H. and Isler, N. (2004). Effect of Planting Method and Plant Population on Growth and Yield of Sesame (*Sesamum indicum* L.) in a Mediterranean Type of Environment. Asian J. Plant Sci. 3 (5): 610-613. Codex Alimentarius Commission.

FAO (2019). Faostat :http://www.fao.org/faostat/en

Gitte, A. N; Patil, S.R. and Tike, M.A. (2005). Influence of zinc and boron biochemical and yield characteristics of sunflower, J. of plant Physiology, 10(4): 431-438.

Gkanatsiou, Ch, Ntalli, N.,U., Menkissoglu-Spiroudi, U., and Dendrinou-Samara, C. (2019). Essential Metal-Based Nanoparticles (Copper/Iron NPs) as Potent Nematicidal Agents against Meloidogyne spp. Journal of Nanotechnology Research, 1(2): 44-58.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research. 2nd Edn., John Wily and Sons, New York, pp: 68.

Holm, P.B., Kristiansen, K.N., and Pedersen, H.B. (2002). Transgenic approaches in commonly consumed cereals to improve iron and zinc content and bioavailability. The Journal of nutrition, 132(3): 514S-516S.

Jasmeet S.B.; Mahal, S.S.; Saini, K.S. and Brar, N.S. (2016). Response of sunflower yield to planting methods and irrigation schedules. Indian J. Agric. Res., 50 (1) 2016: 71-75.

Khalifa, F.M., (1984). Effects of spacing on growth and yield of sunflower under two systems of dry farming in Sudan. J. Of Agri. Sci., 103: 213-222.

Kolenčík, M., Ernst, D., Urík, M., Ďurišová, Ľ., Bujdoš, M., Šebesta, M. and G., Kratošová, G. (2020). Foliar application of low concentrations of titanium dioxide and zinc oxide nanoparticles to the common sunflower under field conditions. Nanomaterials, 10(8):1619.

Mahmoud, A.M.; Ali, E.A.; Said, M.T.; Abdelazeem, A.H. and Salem, A.M. (2020). Impact of planting methods on some sesame cultivars production. Assiut J. Agric. Sci., 51 (3) :49-61.

Nasrullah H.M., Cheema, M.S. and Akhtar, M. (2009). Efficiency of different dry sowing methods to enhance wheat yield under cotton-wheat cropping system. Intl. Conference on Sustainable Food Grain Production -Challenges and Opportunities. Oct. 26-27, Univ. Agric. Faisalabad. Pakistan. p-66-72.

Onat, B., Arıoğlu, H., Güllüoğlu, L., Kurt, C. and Bakal, H. (2017). Oil seeds and crude oil production in the world and in Turkey. KSU J Nat Sci, 20: 149-153.

Palmer, C.M., and Guerinot, M.L. (2009). Facing the challenges of Cu, Fe and Zn homeostasis in plants. Nature chemical biology, 5(5): 333.

Pandey, A.C., Sanjay, S.S. and Yadav, S.R. (2010). Application of ZnO nanoparticles in influencing the growth rate of Cicer arietinum. Journal of Experimental nanoscience, 5(6): 488-497.

Pereyra- Irujo , G.A., Izquierdo, N.G., Covi, M., Nolasco, S.M., Quiroz, F. and Aguirrezábal, L.A. (2009). Variability in sunflower oil quality for biodiesel production: a simulation study. *Biomass and Bioenergy*, *33*(3): 459-468.

Praksh, B.G. and Halaswamy, K.M. (2004). Effect of seed hardening through chemical treatments in indication of drought tolerance in sunflower (*Helianthus annuus* L.). Madras J. of Agric., 91(4-6): 330- 332.

Prasad, R., Bhattacharyya, A., and Nguyen, Q.D., (2017). Nanotechnology in sustainable agriculture: recent developments, challenges, and perspectives. Frontiers in microbiology, 8: 1014.

Rehman, H.U., Aziz, T., Farooq, M., Wakeel, A. and Rengel, Z. (2012). Zinc nutrition in rice production systems: a review. Plant and soil, 361(1): 203-226.

Sadak, M.S., Bakry, B.A. (2020). Zinc-oxide and nano ZnO oxide effects on growth, some biochemical aspects, yield quantity, and quality of flax (*Linum uitatissimum* L.) in absence and presence of compost under sandy soil. Bulletin of the National Research Centre, 44(1): 1-12.

Sankaran, M.S.; Mani, S. and Savtthri, S. (2001). Effect of teprosyn and zinc on yield and quality parameters of sunflower (*Helianthus annuus* L.), Madras J. of Agric, 88 (10-12): 717-718.

SAS institute (2008). The SAS System for Windows, release 9.2. Cary NC: SAS Institute.

Shahhoseini, R., Azizi, M., Asili, J., Moshtaghi, N., and Samiei, L. (2020). Effects of zinc oxide nanoelicitors on yield, secondary metabolites, zinc and iron absorption of Feverfew (*Tanacetum parthenium* (L.) Schultz Bip.). Acta Physiologiae Plantarum, 42(4), 1-18.

Velasco, E.A.P.; Galindo, R.B.; Aguilar, L.A.V. ; Fuentes, J.A.G.; Urbina, B.A.P.e; Morales, S.A.L. and Valdés S.S. (2020). Effects of the Morphology, Surface Modification and Application Methods of ZnO-NPs on the Growth and Biomass of Tomato Plants. Molecules, 25, 1282; 1-11.

تأثير طرق الزراعة والرش الورقي بأكســـيد الزنك النانومتري على محصـــولي البذور والزيت لدوار الشمس

باهي راغب بخيت، السعدي عبد الحميد علي، عبد المنعم عوض الله عمر، حسني عبد الرؤوف علي

قسم المحاصيل، كلية الزراعة، جامعة أسيوط، مصر

قسم المحاصيل، كلية الزراعة والموارد الطبيعية، جامعة اسوان، مصر

الملخص

أجريت هذه الدراســـة خلال موســـمي 2020 و2021 في مزرعة المحاصـــيل البحثية، كلية الزراعة، جامعة أسيوط، أسيوط، مصر لدراسة تأثير طرق الزراعة والرش الورقي بأكسيد الزنك النانومتري على محصولي البذور والزيت لعباد الشمس صنف جيزة 102. نفذت التجربة بتصميم القطاعات كاملة العشــوائية (RCBD) بترتيب الشــرائح المنشــقة بثلاثة مكررات. تم ترتيب طرق الزراعة المدروسة هي مصاطب وخطوط وتسطير على ارض مسطحة عموديًا بينما تم تخصيص تراكيز جزيئات الزنك المدروســة هي كنترول، 50، 100، 150، 200، 250 جزء في المليون أفقيًا. وكانت النتائج المتحصـــل عليها أن طرق الزراعة المدروســـة وتراكيز جســـيمات أكســـيد الزنك النانومترية وتفاعلها كان لها تأثير معنوي أو عالي المعنوية على معظم الصـــفات المدروســـة مثل وزن 100 بذرة (جم)، وزن البذرة للراس (جم)، محصـــــول البذور للفدان (كجم)، محتوى البذور من الزيت ومحصــول الزيت للفدان (كجم). بالإضـــافة إلى ذلك، فإن زراعة نباتات عباد الشــمس على خطوط ورشـــها بتركيز 200 جزء في المليون من أكســـيد الزنك النانومتري أعطت أعلى قيم لمتوســـط محصـــول الزيت للفدان والتي بلغت 1403.24 و1269.93 كجم للفدان للموســـم الاول والثاني على التوالي.