Effect of plant density and nanometric fertilization on the productivity of sunflower (*Helianthus annuus L.*) crop grown in sandy soil

K. M. A. Makled

Agronomy Department, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt.

* Corresponding author E-mail: khaled.mahmoud@azhar.edu.eg (K. Makled)

ABSTRACT

A field try was led at the Trial Ranch, Personnel of Horticulture, AL-Azhar College Nasr City Exploration Station in Egypt, during the developing times of 2021 and 2022. The fundamental goal was to evaluate the impacts of various portions of nanofertilizer (N0: N1: N2: N3: N4) and plant dispersing choices (D1: 30 cm, D2: 25 cm, D3: 20 cm, and D4: 15 cm with a steady width of 70 cm) on the harvest phenology, vegetative development, and yield of the sunflower cultivar Sakha-53. The outcomes demonstrated that both nanofertilizer application and plant separating essentially affected every one of the qualities assessed in the two seasons. The utilization of nanofertilizer brought about expanded seed yield and positive changes in the deliberate qualities. Likewise, more extensive plant separating from 15 cm to 30 cm showed a continuous improvement in different properties, including crop phenology, number of leaves per plant, leaf region per plant, stem width, head breadth, 1000-seed weight, and seed weight per plant. Prominently, the tightest dispersing of 15 cm prompted taller plants and heavier seeds, at last bringing about higher oil yield. The collaboration between plant separating and Nano-fertilizer likewise assumed a critical part, impacting every one of the concentrated on characteristics. In particular, the blend of D4 × N4 showed the most elevated seed yield (2010 and 1960 kg/took care of) in the two seasons. All in all, these discoveries propose that the mix of thin plant dispersing (15 cm) and the most noteworthy portion of Nano-fertilizer (N4) can fundamentally upgrade the seed yield and oil yield of the sunflower cultivar Sakha-53.

Keywords: Nano-fertilizer; Sunflower; Plant spacing; head diameter; stem diameter; Sakha-53.

INTRODUCTION

Egypt, a country located at the crossroads of three continents, encompasses a vast territory of over one million square kilometers. The country's boundaries are defined by the Mediterranean Sea in the north, Sudan in the south, the Red Sea in the east, and Libya in the west. Additionally, the Sinai Peninsula, which serves as a land bridge connecting Egypt to Southwest Asia, is also an essential part of the country. Egypt's climate is characterized by dry summers and mild winters, with annual precipitation averaging around 50 mm, although it can reach 200 mm on the northern coast. Limited water resources have prompted a decline in cultivated land as urbanization and industrialization have accelerated in response to the astronomical growth of the global population. To meet the needs of this burgeoning population, it is essential to maximize yields per unit area in a sustainable manner that considers economic, social, and environmental factors.

Fortunately, Egypt's recently cultivated desert soils offer a remarkable opportunity to expand oil crop production, particularly sunflower cultivation. Sunflowers are resilient crops that can withstand various climatic fluctuations and stressful conditions, such as Temperature changes, differing photoperiods, salinity issues, soil infertility, and limited water resources. Embracing this opportunity can contribute to nourishing the growing population while sustaining Egypt's economic, social, and ecological well-being. Sunflowers, along with soybeans, canola, and peanuts, are among the four most significant annual crops worldwide that are cultivated for edible oil (FAO, 2020). Sunflower is known for their adaptability to different environments, thanks to their short growing season, neutral photoperiod, and relatively high tolerance for drought. (Weiss, 2000). Research has shown that the choice of Planting distance and cultivars greatly influences the yield and components of sunflowers. Sunflowers, scientifically known as Helianthus annuus L., are an essential annual crop primarily grown for oil production. The seeds of sunflowers contain both oil (36-52%) and protein (28-32%). (Rosa et al., 2009). Sunflower oil is a popular vegetable oil used in cooking, margarine production, paint manufacturing, soap making, and various cosmetics (Bamgboye and Adejumo, 2007). In Egypt, sunflower cultivation is gaining significant attention due to its ability to thrive in low fertility soils found in newly reclaimed areas and its short growth season. This makes it a valuable crop in the face of climate change and its impact on global agricultural systems. Advanced nanotechnology offers a practical solution to enhance crop production, promote sustainability, and ensure food security. By improving input efficiency and minimizing losses, nanotechnology plays a crucial role in increasing agricultural output. Nanomaterials provide a larger specific surface area for fertilizers and pesticides, while also acting as carriers for targeted nutrient delivery, thereby enhancing crop protection.

Nanotools, such as nanobiosensors, have practical applications in precise control and management of agricultural inputs like fertilizers, pesticides, and herbicides. These nanotools are essential in supporting the advancement of high-tech farms. Nanoparticles, which are substances smaller than 100 nm, have the potential to revolutionize various fields, including agriculture, environmental engineering, safety and security, water resources, and life sciences. (Baruah and Dutta 2009). The transition of nanotechnology from experimental to practical domains is currently underway, with nanoparticles already being introduced into the environment. While nanotechnology offers solutions to challenges that traditional products cannot address, such as nanoremediation, nanofertilizers, and nanosensors, concerns about the safety of nanoparticles hinder their widespread adoption and utilization (De la Torre-Roche et al. 2013; Mitrano et al. 2015). The use of nanofertilizers in agriculture provides numerous benefits, including improved nutrient utilization efficiency, reduced soil toxicity, minimized negative effects of over-application, and decreased frequency of application. Consequently, nanotechnology holds significant potential for achieving sustainable agriculture, particularly in developing nations (Chen *et al* 2012). The emergence of nanotechnology has introduced various engineered nanoparticles, such as metal oxide nanoparticles, carbon nanotubes, fullerenes, nanowires, and magnetic nanoparticles, which possess unique physical, chemical, and biological characteristics. Improving plant thickness is an urgent way to expand basic growth factors such as light, water, air, and nutritional supplements. This approach expands crop production by promoting earlier development, reducing weed control costs, increasing solar-based energy consumption through yield, and limiting soil moisture dissipation. Plants grown with wider spacing require slightly longer maturation days to achieve physiological development compared to fixed crops (Dhillon et al., 2017).

MATERIALS AND METHODS

Description of experimental site

Two field experiments were conducted during the summer seasons 2021and 2022 at the Experimental Farm at Faculty of Agriculture, AL-Azhar University Nasr city Research Station, Egypt. The experimental site has semi-arid climate, with cool winters and hot dry summers.(Latitude 30°03'16" N 31°19'12" E and mean altitude 80 m above sea level) to examine the effects of plant density and Nano complex application on yield, yield attributes and nutrient uptakes of sunflower *(Helianthus annuus L.)* grown on sandy soil. Sunflower seed of Sakha 53 variety obtained from the Oil Crop Research Section, Field Crop Research Institute, Agricultural Research Center, Giza, Egypt at a rate of 4 kg /fed. were sown on 25th and 27th of April in the first and second seasons, respectively. In both seasons, the experiments were carried out after wheat to avoid any variations in the residual effect of the preceding crop. The area of the experimental unit was 10.5 m^2 (3.5 m length and 3.0 m width). The trials were laid out in a split-plot design in a randomized complete block arrangement with four replications. Plant population density treatments i.e., D1= (0.7x0.3 m) 20,000, D2= (0.7x0.25 m) 24000, D3= (0.7x0.20 m) 30000 and D4= (0.7x0.15 m) 40000 plants/ fed. were assigned to the main plots and Nano complex (microelements) (N0=conventional fertilizer , N1=50, N2=100, N3=150 and N4=200 cm^3 /fed. were assigned in the sub-plots. The Nano was added in three equal doses as a foliar application after the second, third and fourth irrigation. The experiments were laid out under surface irrigation system every 7 days. The soil physical and chemical properties of the experimental area during the two growing seasons the 2021 and 2022 are presented in Table 1.

Agricultural practices

The experimental site was prepared using conventional tillage methods. Sunflower seeds of the Sakha-53 variety were manually planted, and the plants were thinned to one plant per hill after 15 days of planting. The fertilizer used consisted of 45 kilograms of nitrogen (N), 150 kilograms of phosphorus (P2O5), and 50 kilograms of potassium (K2O) per feddan. This fertilizer was applied as ammonium nitrate (33.5% N), calcium superphosphate (15.5% P2O5), and potassium sulfate (48% K2O), respectively. Phosphorus (P) and potassium (K) were applied in a single dose during soil preparation. Nitrogen (N), on the other hand, was divided into three equal doses. The first dose was applied after thinning, and the subsequent doses were added to the soil every 15 days before irrigation. All agricultural

Practices followed the recommended guidelines for sunflower cultivation in sandy soil conditions within the Cairo Governorate.

Studied characters

The following measurements were taken for various traits:

Crop Phenology and Vegetative Growth Traits:

The duration from planting to 50% flowering was determined by visually observing when 50% of the plants in each experimental unit had opened flowers.

The date of physiological maturity was determined by visually observing when 75% of the heads in each experimental unit had turned yellow.

Several vegetative growth traits, including plant height (cm), number of leaves per plant, and leaf area per plant (cm^2), were measured for five randomly selected plants from each experimental unit at 55 days after planting. Leaf area (LA) was calculated using the formula provided by Schneiter (1978): LA = [(L × W) × 0.6684] - 2.45, where L and W represent the maximum length and width of the leaf, respectively.

Yield Attributes:

During harvest, stem diameter (cm), head diameter (cm), 1000-seed weight, and seed weight per plant were measured for five representative plants from each sub-plot selected randomly.

Seed and Oil Yield Traits:

Seed yield (ton/feddan) was determined by harvesting, drying, threshing, and weighing the seeds from the sub-plot. The yield was then converted to kilograms per feddan.

Oil yield (kg/feddan) was calculated by multiplying the seed yield (kg/feddan) by the oil percentage.

Quality Traits:

Seed oil percentage was estimated using the Soxhlet apparatus, following the method described in A.O.A.C. (2000).

Protein percentage was determined according to the method outlined in A.O.A.C. (2000).

Statistical analysis:

The data were analyzed using statistical procedures as described by Gomez and Gomez (1984) with the MSTAT-C Computer program. To compare the means of different treatments, the least significant difference (LSD) procedure was used at a 5% level of probability.

RESULTS AND DISCUSSION

The results of the study were presented under the following classes:

Effect of Nano complex application:

Crop phenology and vegetative growth traits:

Nano spray application is one of the most important factors which affects the growth and development of the sunflower plant. Data presented in Tables 2, 3 revealed that all crop phenology and vegetative growth traits were influenced significantly by different studied Nano complex application in the two seasons. Do not spray nano (N0) resulted in decrease in the number of days to 50% flowering, plant height, number of leaves/ plant, leaf area/ plant and number of days to maturity in two seasons compared with the nano application (N4) by about (6.38 and 7.50),(3.72 and 3.33),(15.37and 15.04),(11.80 and 12.15) and (7.81 and 8.38) respectively, The number of days taken to attain days to 50% flowering and days to physiological maturity was in order N4>N1>N0. These differences in crop phenology traits under different studied variation between many dose complex Nano and conventional fertilized. Similar findings were reported by Sabir *et al.* (2014), Ditta, and Arshad (2016) , and Nosheen *et al.* (2022). Furthermore, plants can get the full benefit of soil moisture and nutrients during apply complexnano, allowing more accumulated metabolites to be stored in seeds and increase plant height, leaf area/ plant and number of leaves /plant Chaudhuri and Malodia (2017) and Jabeen *et al*. (2018).

Yield attributes:

The data in Tables (2, 3) indicated that Spraying with nano complex resulted in a significant impact on yield attributes in both seasons. The application N4 resulted in the greatest mean values (2.20 and 2.25 cm), (25.34

and 26.61 cm), (74.96 and 75.57 g) and (77.95 and 77.80 g), for stem diameter, head diameter, 1000-seed weight (g) and seed weight / plant (g).in the both seasons, respectively. The lowest mean values of yield components were obtained by sunflower plants N0. The increase of yield attributes in N4 can be attributed to during flowering and seed filling stages which increase the vegetative and reproductive growth periods consequently increase dry matter accumulation in plant organs.

indicated that the used nano complex had the largest vegetative growth duration which allowed plants particularly provide an alternative to conventional chemical fertilizers by introducing the micro-nutrients required for efficient plant growth and development ability to effectively absorption of water and nutrients, hence increasing photo-assimilates in the leaves which might be had a positive influence on head diameter and 1000-seed weight.

Seed and oil yields traits:

The final seed yield is an important trait in evaluating the ability of a crop to adapt to environmental changes. Data in Table 3 show that seed and oil yields were significantly affected by different dose on nanofertilized. The maximum seed yield (1660 and 1650 kg /fed.) and oil yield (646.8 and 644 kg /fed) Compared with N0 the give minimum seed yield (1530 and 1530 kg/fed.) and oil yield (569 and 565.33 kg/fed) in both seasons, respectively. The percentage of increases on N4 for seed yield were 108.50 and 107.84% and for oil yield were 113.67 and 113.92% compared with N0 in 1st and 2nd seasons, respectively.

The highest seed yield may be attributed to the considerable increase in 1000-seed weight and seed weight/plant, higher dry matter accumulation due to higher crop growth rate under N4 (Dhillon *et al*., 2017).

Generally, oil yield depends on seed yield and it's calculated by multiplying the oil content by seed yield. In both seasons, oil yield decreased with delayed sowing dates. Candogan *et al.* (2013) clarified that the increases in seed yield were 6.53, 7.18 and 6.53% and oil yield 11.70, 13.26 and 13.26%, with N3, N2 and N1 respectively, compared to N0 in 2021 season. These results are in conformity to those noted by Lu, *et al* (2002), Hong *et al.* (2005) Sabir *et al.* (2014) and FAO (2020).

Quality traits:

Oil and protein contents in the two seasons were significantly affected by Use of nano fertilization (Table 3). The N4 Spraying plants crop resulted in the highest seed oil content (39.20 and 39.03%) while the lowest seed oil content (37.19 and 36.95%) was obtained from the N0 conventional fertilize in the first and second seasons, respectively. The differences in seed oil concentration because used deverant dose nano were largely due to variations in seed oil ratio, rather than in seed weight (Candogan *et al*. 2013) Nanoparticles are also extremely useful in agriculture where they can alleviate the effects of plant diseases and are active components in nanofertilisers (Jabeen *et al*. (2018).

Also, the highest seed protein content (21. 84 and 21.68%) was obtained from sunflower plants applied (N4), while the lowest seed protein content (20.03 and 20.01%) was produced by conventional fertilize (N0), in both seasons, respectively.

Effect of plants distance:

Crop phenology and vegetative growth traits:

The data presented in Tables 4 and 5 show a clear effect of plant spacing in both seasons. Plant phenology and vegetative growth characteristics were influenced by plant spacing. Most traits showed higher values as plant spacing increased. Specifically, a larger spacing of 30 cm showed better results than a narrower spacing of 15 cm in terms of plant phenology and vegetative growth characteristics. In both seasons, wide spacing performed better than narrow spacing on several traits. In particular, increasing the interval resulted in improvements of 8.96% and 9.76% in days to 50% flowering, 5.36% and 4.53% in days to maturity, and 19.34% and 22.51%, respectively. Number of leaves per plant. The leaf area (cm^2) per plant was 21.51% and 21.95%, respectively. This may be due to the fact that the greater the distance, the more resources are available, such as sunlight, space, nutrients, and soil moisture. This allowed the plants to use these resources more effectively, resulting in higher values of the aforementioned traits compared to plants in confined spaces. Awais et al. (2015) also found that increasing the spacing increased the number of days to flowering and maturity. However, it is important to note that in both seasons, plant height showed the opposite trend as plant spacing increased (plant density decreased). Reducing interplant spacing by up to 15 cm increased plant height. For example, at a distance of 15 cm, the plant heights in the first and second seasons were 157.48 cm and 157.78 cm, respectively, while at a distance of 30 cm, the plant heights in the 2021 and 2022 seasons were 153.13 cm and 153.78 cm. , it was 67 centimeters. This is due to the competition for light between closely planted plants increases, accelerating plant development and main stem elongation. From Emam and Awad (2017) and Li et al. It has been reported that the height of sunflower plants increases significantly when planted densely. (2019). These results are consistent with those of Abido and Abo-El-Kheer (2020) and Farweez et al (2020).

Yield attributes:

Regarding plant spacing the results showed a significant influence on yield attributes in both seasons as presented in Table 5. Using a 30 cm (D1) distance between sunflower plants produced the maximum values for yield attributes, exceeding the 15 cm (D4) distances between plants by (38.07 and 34.44%), (31.36 and 29.20%), (9.64 and 10.26%) and (11.73 and 12.20%) with regard to stem diameter, head diameter, 1000-seed weight and seed weight /plant in 2021 and 2022 seasons, respectively.

This might be due to the sufficiency of environmental conditions such as light, space, nutrients, and soil moisture which have helped increasing the vegetative growth especially leaf area / plant and photosynthesis rate resulting in improved assimilation rate and dry matter accumulation in leaves thus increase yield components traits. Abd EL-Satar et al. (2017) stated that the greatest values of head diameter, 100-seed weight, and seed weight plant-1 were scored by sown sunflower at wider spacing. Kandil et al. (2017) observed that increasing hill spacing from 15, 20, and 25 cm produced thickness stem, the highest head diameter and weight of 1000-seed weight.

These results are in Similar with those obtained by Mahmood (2013), Viorel et al. (2015) and Emam and Awad (2017), Demir (2020) and Singh & Parajuli (2020).

Seed and oil yields traits:

Oil yield is the main indicator of obtaining the high productivity of sunflowers fed-1. Seed and oil yields as affected significantly by plant spacing (Table 5). The maximum seed yield (1.88 and 1.90 ten/fed) and oil yield (0.747 and 0.746 ten/fed) were obtained from the treatment D4 (15 cm spacing) and the treatment D1 (30 cm spacing) produced minimum seed yield (1.29 and 1.31 ten/fed) and oil yield (0.482 and 0.485 ten/fed) in both seasons, respectively.

Narrow spacing had obtained an increase of seed yield by (45.74 and 45.04%) and oil yield by (54.98 and 53. 81%) compared with wider spacing in two seasons, respectively.The increased oil yield is due to the increase in seed yield /fed. regardless of the ratio in oil. Mahmood (2013) revealed that seed yield obtained from narrow plant spacing was significantly higher. Awais et al. (2015) reported that increasing plant density leads to increased seed yield due to increased total dry matter accumulation partitioned to seeds.

Modanlo et al. (2021) indicated that a more dense sow (80000 plant/ ha) as compared to a less dense sow (50000 plant/ ha) could have resulted in an improvement in seed yield by 35.88% and oil yield by 33.62% due to increased photosynthesis and high leaf area index. There are authors (Awais et al., 2015; Viorel et al., 2015; Fakirah et al., 2017; Kandil et al., 2017; Demir, 2020 and Morsy et al., 2022) found that increasing plant density (narrow spacing) led to increased seed and oil yields under favorable conditions.

Quality traits:

Oil and protein traits are the most important component of sunflower seeds to measure their quality. It is apparent from the results given in Table 5 significant impact of plant spacing was observed on oil and protein contents in both seasons. Maximum sunflower seeds oil content (39.72 and 39.36%) was obtained by sunflower plants which were sown at narrow spacing while statistically minimum oil content (37.40 and 37.03%) was attained at a wider spacing in the first and second seasons, respectively.

Gradually increasing plant spacing from 15, 20, 25 up to 30 cm had a positive increase in seed oil content (Abd EL-Satar et al., 2017). Sunflower plants grown under higher density produced light seeds (1000-seed weight) as shown in Table 6 and this might be at the expense of carbohydrate storage rather than oil, which resulted in higher oil content. Seed oil content (%) depends on percentages of hull and oil content in the seed. Awais et al. (2015); Day and Kolsarici (2016); Fakirah et al. (2017); Abido and Abo-El-Kheer (2020); and Farweez et al. (2020).plant spacing at 30 cm (D1) produced significantly higher protein content (21.79 and 22. 09%) as compared to plant spacing 15 cm (D4) which produced statistically minimum protein content (20.59 and 20. 46 %) in both seasons, respectively. The minimum and maximum of seed protein content were recorded from 20 and 40 cm respectively (Day and Kolsarici, 2016). Sown plants at a wider spacing of 25 cm produced higher seed protein content (Abd EL-Satar et al., 2017).

Effect of interactions:

Crop phenology and vegetative growth traits:

Available results in Table 2 evident that all crop phenology and vegetative growth traits were influenced significantly with interaction complex nano doses × plant spacing.N1,N2,N3,N4 and plant spacing 30 cm D1 between plants N1,N2,N3,N4 gave the highest values for the number of days to 50% flowering (57.73,57.76,57.15 and 57.07 days), plant height (cm) (158.89,158.64,159.48 and 157.97 cm), number of days to maturity (90.37,91.21,90.37 and 91.64 days), number of leaves/ plant (26.17,25.85,26.18 and 26.74 leaves), and leaf area/ plant (170.63,171.64,173.93 and 173.87 cm) compared with other interactions in 2021 season,.

The minimum mean values of crop phenology, plant height (cm), number of leaves/ plant and leaf area/ plant were attained by conventional fertilizers (N0) with 15 cm plant spacing (D4) (152.27,19.81 and 125.67) in 2021 season(**Marek et al., 2020**).

Yield attributes:

Results in Tables (2 and 3) showed that the interaction between complex nano doses and plant spacing was significant for stem diameter, head diameter, 1000-seed weight, seed weight /plant, and daily seed weight /plant in both seasons.

The maximum values of yield attributes were obtained with planting sunflower on N4 with 30 cm plant spacing D1 in both seasons, stem diameter was (2.9 and 2.7 cm, head diameter was (29.42 and 29.34cm), 1000-seed weight was (79.78 and 80.28 g) and seed weight/ plant was (82.59 and 83.43 g) in the first and second seasons, respectively. Conversely, the lowest values of all yield components traits were obtained with N0 plus with 15 cm plant spacing D4. The maximum value for 1000-seed weight was produced from the early planting date on 15th March and with wider spacing at 25 cm (Al-Hasawi 2014).

Seed and oil yields traits:

The interaction between nanofertilizer and plant spacing was significant on seed and oil yields by apply nanofertilizer N4 and narrow plant spacing (15 cm, D4) in both seasons (Table3). The increase in the two growing seasons respectively was 170.03 and 163.33% for seed yield and 189.23 and 181.57% for oil yield compared with N0 and wider plant spacing (30 cm, D1).

Quality traits:

The data in Table 3 show that the effect of nanofertilizer complex × plant spacing interaction on oil and protein contents in both seasons.

The highest ratio in sunflower oil content 40.42 and 39.68% was recorded by N3 × plant spacing (25 cm, D4), while the lowest ratio 36.34 and 35.83% was scored from N0 × plant spacing (30 cm, D1) in the first and second seasons, respectively. The same Table illustrated that the maximum value of protein content 22.23 and 22.61% was achieved by N1 × plant spacing (30 cm, D1) and the minimum value of protein content 19.48 and 19.61% in 2019 and 2020 seasons, respectively.

CONCLUSION

The use of chemical fertilizer is disturbing the ecosystem and causing ill effects on human health. Nanofertilizers improve the growth of plants and increase their nutritional quality, productivity, shelf life, and resistance mechanisms against biotic and abiotic stress factors. The application of nanofertilizers maintains the level of nutrients in the Spray on the leaves and enhances the growth and yield of crops by activating various mechanisms. Nanofertilizers play a significant role in improving the quantity and quality of products. A very low concentration of nanofertilizer yields good results, and the chance of their accumulation in the soil is very low, as they travel and work more efficiently. Based on the above results, apply nanocomplex resulted in gradually increased vegetative growth traits, crop phenologyand yield and its attributes for sunflower cv. Sakha 53.

With respect to plant spacing, wider spacing at 30 cm recorded an increase both of vegetative growth; yield components traits, crop phenology, whereas narrow spacing at 15 cm scored the lower number of days to crop phenology, tallest of plant height, and heaviest seed yield.

The highest seed yield was obtained at 15 cm plant spacing (1880 and 1900 kg/ fed) in both seasons, respectively which was significantly higher over other spacing's.

Generally, utilization Nano fertilize of the crop with 15-cm plant spacing resulting in the maximized seed and oil yields and increase resource use efficiency.

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Table 1: Soil physical and chemical analysis of the experimental site during 2021 and 2022 seasons.

Soil Properties		Physical properties					Chemical properties					
		Clay (%)	Silt (%)	Sand (%) Coarse	Sand (%) Fine	Soil texture	OM (%)	pH	EC ds/m	Available NPK N ppm	P ppm	K ppm
2021	15 cm	2.39	3.79	35.21	58.61	sandy	0.46	8.02	1.76	1.94	1.06	1.19
	30 cm	1.87	3.63	37.44	57.06	sandy	0.31	8.13	1.48	1.34	1.21	1.47
2022	15 cm	2.45	3.91	34.67	58.97	sandy	0.51	8.06	1.81	1.98	1.12	1.02
	30 cm	2.01	3.59	34.82	59.58	sandy	0.35	8.17	1.39	1.62	1.08	1.23

Table 2: Effect of interaction between concentrations of nano fertilization complex and plant spacing on Number of days to 50% flowering, Plant height (cm), Number of leaves/ plant, Leaf area /plant (cm) Stem diameter (cm) and Number of days to maturity(days) of sunflower grown in both seasons.

Traits		Number of days to 50% flowering		Plant height (cm)		Number of leaves/ plant		Leaf area /plant (cm)		Stem diameter (cm)		Number of days to maturity(days)	
Nano	Distance (D)	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
N0	D1	52.34	51.92	150.67	152.89	22.17	21.92	148.94	149.58	2.11	2.04	82.73	83.36
	D2	51.13	51.78	152.47	152.98	21.58	22.25	140.82	142.95	1.94	1.91	81.89	82.36
	D3	51.85	50.59	153.69	152.63	19.48	19.29	132.45	131.23	1.72	1.63	80.87	81.86
	D4	50.23	49.96	152.27	153.96	19.81	19.45	125.67	124.82	1.53	1.51	80.02	80.89
mean		51.39	51.06	152.28	153.12	20.76	20.73	136.97	137.15	1.83	1.77	81.38	82.12
N1	D1	57.73	58.21	153.68	152.79	26.17	25.57	170.63	171.78	2.51	2.49	90.37	91.63
	D2	56.52	56.43	155.82	154.95	24.71	25.23	154.83	155.92	2.25	2.21	88.78	89.78
	D3	53.67	53.38	158.37	157.89	22.85	23.18	145.87	146.89	1.94	2.11	86.68	87.35
	D4	51.46	51.39	158.89	159.36	20.89	20.69	140.23	141.16	1.76	1.81	85.89	86.78
mean		54.85	54.85	156.69	156.25	23.66	23.67	152.89	153.94	2.12	2.16	87.93	88.89
N2	D1	57.76	57.13	153.64	153.79	25.85	26.38	171.64	172.78	2.56	2.52	91.21	91.47
	D2	56.26	55.89	154.47	154.38	24.18	24.85	155.26	156.23	2.28	2.30	87.37	89.24
	D3	53.46	53.69	157.95	158.27	23.67	22.59	146.92	147.43	2.08	2.15	87.17	87.96
	D4	51.92	51.83	158.49	158.69	21.53	20.75	139.83	140.85	1.82	1.90	85.56	86.54
mean		54.85	54.64	156.11	156.28	23.81	23.64	153.41	154.32	2.19	2.22	87.83	88.80
N3	D1	57.15	58.15	153.68	152.98	26.18	25.87	173.93	174.75	2.51	2.55	90.37	91.78
	D2	55.93	55.76	154.93	153.86	25.88	26.92	154.28	155.21	2.31	2.29	88.53	89.37
	D3	52.89	53.83	157.48	157.83	22.75	22.94	146.36	148.47	2.12	2.18	87.03	87.87
	D4	51.36	50.92	158.38	158.74	21.47	19.94	139.49	141.86	1.81	1.87	86.18	86.61
mean		54.33	54.67	156.12	155.85	24.07	23.92	153.52	155.07	2.19	2.22	88.03	88.91
N4	D1	57.07	57.36	153.97	155.91	26.74	25.69	173.87	176.17	2.46	2.51	91.64	91.68
	D2	55.84	56.07	157.48	157.39	25.91	26.83	155.29	156.27	2.28	2.31	88.67	89.52
	D3	52.79	53.87	157.86	157.29	22.68	23.51	146.78	147.73	2.16	2.26	86.82	87.75
	D4	53.87	53.48	157.17	158.15	22.78	21.56	145.21	144.26	1.89	1.90	85.93	89.58
mean		54.89	55.20	156.62	157.19	24.53	24.40	155.29	156.11	2.20	2.25	88.27	89.63
G.M.D		54.06	54.08	155.67	156.73	23.37	23.27	150.42	151.32	2.11	2.12	86.69	87.67
LSD at 5% for	D	0.56	0.38	1.52	1.35	0.49	0.54	1.21	0.94	0.13	0.08	0.31	0.53
	N	0.49	0.54	1.08	1.19	0.42	0.60	1.09	1.32	0.11	0.13	0.27	0.21
	D*N	0.75	0.81	1.86	1.75	0.73	0.65	1.73	1.47	0.26	0.20	0.39	0.63

Table 3: Effect of interaction between concentrations of nanofertilization complex and plant spacing on Head diameter (cm), 1000-seed weight (g), Seed weight / plant (g), Seed yield (ten/fed.), Seed oil content % and Seed protein content % of sunflower grown in both seasons.

Traits		Head diameter (cm)		1000-seed weight (g)		Seed weight / plant (g)		Seed yield (ten/fed.)		Seed oil content %		Seed protein content %	
Nano	Distance (D)	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
N0	D1	22.67	21.83	72.98	72.82	73.76	73.94	1.18	1.20	36.34	35.83	20.51	20.45
	D2	21.62	20.84	71.87	72.22	71.98	71.67	1.38	1.35	36.85	36.67	20.28	20.17
	D3	20.53	19.83	69.34	70.54	70.74	70.93	1.51	1.52	37.74	37.82	19.84	19.79
	D4	19.76	18.95	68.97	69.65	69.85	70.21	1.61	1.60	37.83	37.47	19.48	19.61
mean		21.15	20.36	70.79	71.31	71.58	71.69	1.53	1.53	37.19	36.95	20.03	20.01
N1	D1	28.79	29.16	79.21	80.28	82.54	83.89	1.32	1.34	37.76	37.85	22.23	22.61
	D2	26.89	27.42	74.89	76.28	77.59	77.67	1.49	1.45	38.65	38.97	22.06	21.93
	D3	23.75	23.65	72.56	73.26	74.39	74.23	1.57	1.67	39.64	38.91	21.79	21.63
	D4	21.56	20.75	71.87	71.43	72.89	72.76	1.94	1.97	39.87	39.65	20.48	20.85
mean		25.25	25.25	74.63	75.31	76.85	77.14	1.63	1.64	38.98	39.10	21.64	21.76
N2	D1	28.98	28.64	79.67	79.78	82.54	82.87	1.32	1.33	37.58	37.11	22.12	22.51
	D2	26.42	27.21	75.47	76.82	78.43	78.64	1.53	1.51	38.84	38.79	21.47	21.41
	D3	23.86	23.27	72.19	72.78	75.89	74.98	1.71	1.69	39.71	39.73	21.54	21.38
	D4	21.39	21.57	71.79	71.34	72.12	73.29	1.92	2.01	40.12	39.63	20.80	20.42
mean		25.16	25.17	74.78	75.18	77.25	77.45	1.64	1.63	39.21	38.88	21.68	21.68
N3	D1	28.98	28.64	79.67	79.78	82.54	82.87	1.32	1.33	37.68	37.41	22.19	22.81
	D2	26.42	27.21	75.47	76.82	78.43	78.64	1.51	1.55	38.94	38.89	21.87	21.81
	D3	23.86	23.27	72.19	72.78	75.89	74.98	1.70	1.69	39.81	39.63	21.84	21.58
	D4	21.39	21.57	71.79	71.34	72.12	73.29	1.91	1.98	40.42	39.68	20.82	20.52
mean		24.75	25.59	74.78	75.07	77.20	77.30	1.63	1.64	38.99	38.77	21.63	21.43
N4	D1	29.42	29.34	79.78	80.28	82.59	83.43	1.32	1.33	37.64	36.96	21.89	22.07
	D2	26.75	26.82	75.37	75.92	78.98	79.15	1.62	1.59	39.91	38.65	22.15	21.79
	D3	23.57	23,74	73.19	73.41	75.67	75.44	1.70	1.72	38.87	40.69	21.91	21.93
	D4	21.62	23.68	72.48	72.65	74.55	73.19	2.01	1.96	40.37	39.83	21.39	20.91
mean		25.34	26.61	75.21	75.57	77.95	77.80	1.66	1.65	39.20	39.03	21.84	21.68
G.M.N		24.33	24.60	74.03	74.49	76.16	76.27	1.62	1.62	38.71	38.55	21.36	21.31
LSD at 5% for													
D		0.51	0.62	0.72	0.48	0.68	0.76	0.015	0.012	0.21	0.32	0.18	0.24
N		0.38	0.48	0.59	0.53	0.39	0.58	0.021	0.027	0.14	0.39	0.26	0.28
D*N		0.69	0.74	0.83	0.70	0.71	0.83	0.022	0.029	0.24	0.47	0.32	0.38

Table 4: Effect of plant spacing (D) on crop phenology, vegetative growth traits and yield components of sunflower during 2019 and 2020 seasons.

Traits	Number of days to 50% flowering		Plant height (cm)		Number of leaves/ plant		Leaf area /plant (cm)		Stem diameter(cm)		Number of days to maturity(days)	
Distance	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
D1	56.41	56.55	153.13	153.67	25.42	25.09	167.80	169.01	2.43	2.42	89.26	89.98
D2	55.14	55.19	155.03	154.71	24.45	25.22	152.10	153.32	2.21	2.20	87.05	88.05
D3	52.93	53.07	157.07	156.78	22.29	22.30	143.68	144.35	2.00	2.07	85.71	86.56
D4	51.77	51.52	157.48	157.78	21.30	20.48	138.09	138.59	1.76	1.80	84.72	86.08
mean	54.06	54.08	155.68	155.74	23.36	23.27	150.42	151.32	2.10	2.12	86.69	87.67
LSD 0.05	0.56	0.38	1.52	1.35	0.49	0.54	1.21	0.94	0.13	0.08	0.31	0.53

Traits	Head diameter (cm)		1000-seed weight (g)		Seed weight / plant (g)		Seed yield (ten/fed.)		Seed oil content %		Seed protein content %	
Distance	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
D1	27.77	27.52	78.26	78.59	80.79	81.40	1.29	1.31	37.40	37.03	21.79	22.09
D2	25.62	25.90	74.61	75.61	77.08	77.15	1.51	1.49	38.64	38.39	21.57	21.42
D3	23.11	22.75	71.89	72.55	74.52	74.11	1.64	1.66	39.15	39.36	21.38	21.26
D4	21.14	21.30	71.38	71.28	72.31	72.55	1.88	1.90	39.72	39.25	20.59	20.46
mean	24.41	24.37	74.04	74.51	76.17	76.30	1.58	1.59	38.73	38.51	21.33	21.31
LSD 0.05	0.51	0.62	0.72	0.48	0.68	0.76	0.015	0.012	0.21	0.32	0.18	0.24

تأثير الكثافة النباتية والتسميد النانومتري على إنتاجية محصول دوار الشمس المنزرع فى الأراضى الرملية

خالد محمود عبد الوهاب مقلد

قسم انبات، كلية الزراعة، جامعة الأزهر، القاهرة، مصر

* البريد الإلكتروني للباحث الرئيسي: khaled.mahmoud@azhar.edu.eg

الملخص العربي:

أجريت الدراسة الميدانية بالمزرعة التجريبية (محطة بحثية) بمزرعة كلية الزراعة جامعة الأزهر بمدينة نصر خلال موسمى 2021 – 2022م و الهدف من الدراسة التقييم الفسيولوجى للمحصول والنمو الخضرى والمحصولى للصنف سخا53 تحت 5 تركيزات من الاسمدة النانومترية ن0 و ن1 و ن2 و ن3 و ن4 وخيارات تباعد بين النباتات على نفس السطر 30سم ,25سم , 20سم و15سم بعرض خط ثابت 70سم أشارت النتائج الى وجود تأثيرمعنوى للسماد النانومترية وتباعد النباتات والتفاعلات بينهم فى جميع الصفات المدروسة فى كلا الموسمين وادى استخدام وتطبيق الأسمدة النانومترية الى زيادة انتاجية البذور بالاضافة الى مجمل الصفات محل الدراسة ومن ناحية اخرى اظهرت معاملة المسافة بين النباتات من 15 الى 30سم زيادة تدريجية فى خصائص النبات المختلفة والمحصول الاقتصادى وعدد الأوراق /نبات ومساحة الورقة / نبات وقطر الساق وقطر الراس ووزن 1000 بذرة وطول الساق ووزن المحصول الاقتصادى. الأهم من ذلك زيادة فى انتاج الزيت وكان للتفاعل بين التسميد النانومترى ومسافات الزراعة بين النباتات تاثير معنوى على جميع الصفات محل الدراسة وعلى وجه التحديد التفاعل بين ن4*د4 الى انتاج اعلى كميه فى انتاج البذور (2010 و1960 كجم / فدان) فى الموسم الاول والثانى على التوالي.

الكلمات الاسترشادية: الأسمدة النانونية, زهرة الشمس, مسافات الزراعة, قطر قرص زهرة الشمس, قطر الساق, سخا 53.