Journal of Medicinal and industrial plants (2024) 2 (2): 26 – 40.
DOI: https://doi.org/10.32894/MEDIP.24.2.3
ISSN: (2959 – 121X)

Journal of Medicinal and Industrial Plants
(MEDIP)
http://medip.uokirkuk.edu.iq/index.php/medip

Effect of Foliar Application of Nano, Conventional NPK Fertilizer and Plant Density on Yield Components and Seed Quality of Sunflower (*Helianthus annuus* L.)

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KEY WORDS:
Foliar fertilization, Different NPK fertilizers, Plant density, yield component, Seed quality.

Received:
15/04/2024
Accepted:
12/05/2024
Available online:
30/06/2024

ABSTRACT
The growing global population and rapid urbanization have put heaviness on farmers to produce more food, leading to increased fertilizer use. This study aimed to explore the effect of application of different levels of nano - conventional NPK foliar applications which was applied at level (F_1= Control (no fertilizer), $F_{2=}$ NPK fertilizer of soil application with 240 kg ha^{-1} (according to standard recommendation), foliar application of Nano NPK with different levels (F_3 = 100 ppm (parts per million), F_4 = 150 ppm and F_5= 200 ppm, while conventional NPK foliar application were: (F_6= 300 ppm, F_7= 500 ppm, F_8 = 700 ppm), at two stages (30 and 55) days after planting during two seasons. The second factor was two distances between the row, (50 and 70 cm) with 30 cm distance between plants. A factorial experiment was conducted using a randomized complete block design (RCBD) with three replicates. Data collection were considered to analyze the yield components and seed quality of sunflower crop. The statistical analysis results indicated a significant effect of studied factors and their interactions on most of the studied traits. The recommended soil NPK fertilizer affected significantly on all of the growth parameters which included the highest values for head diameter (17.97 and 19.62 cm), weight of head (363.33 and 248.00 g plant $^{-1}$), 1000 seed weight (131.65 and 116.21 g) and seed yield (4.40 and 6.02 t ha^{-1}) while the control treatment recorded lowest values for most of studied traits at both growing seasons. Simultaneously, nano NPK application demonstrated positive effects on sunflower quality parameters, leading to increase oil % reached to 26.74 and 25.17 % for F4 treatment. Also, nano NPK foliar application resulted an increased protein percentage and protein yield at F8 treatment, as well as nitrogen content in the seeds compared to lower levels. Overall, conventional NPK foliar application had a more significant impact compared to nano NPK application. Plant density had a significant effect on yield component and quality parameters of sunflower seeds row spacing of 70 cm. Maximum values were observed in all traits except nitrogen %.

تأثير الرش الورقي بمستويات مختلفة من السمادNPK النانوي – التقليدي، المسافة بين الصفوف في حاصل ومكونات الحاصل ونوعية بذور نبات عباد الشمس (*Helianthus annuus* L.)

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الخلاصة

أدى التزايد في عدد سكان العالم والتطور الحضاري إلى اضافة عبء كبير على المزارعين من حيث زيادة المنتوج الغذائي، هذا بدوره أدى إلى زيادة استخدام الأسمدة الكيميائية المصنعة. ولأجل التقليل من مخاطر الاسمدة المصنعة ارتأينا الى دراسة تأثير مستويات مختلفة من الرش الورقي النانوي - التقليدي NPK عند مستويات وتراكيز مختلفة على حاصل ونوعية بذور عباد الشمس . العامل الاول تضمن (F_1 = معاملة المقارنة (من دون سماد)، F_2 = إضافة سماد NPK 240 كغم هكتار$^{-1}$ (حسب التوصية)، F_3= 100 ، F_4= 150، F_5 = 200 جزء في المليون من نانو NPK الرش الورقي ،بينما 300= F_6، F_7= 500، F_8= 700 جزء في المليون من سماد NPK التقليدي الرش الورقي، عملية الرش طبقت في مرحلتين (٣٠ و٥٥) يوم من الزراعة. اما العامل الثاني شملت المسافة بين الصفوف والتي عايرت تحت مسافتين (٥٠، ٧٠) سم لموسمين زراعيين (ربيعي وخريفي). طبقت تجربة عامليه باستخدام تصميم القطاعات العشوائية الكاملة (RCBD) بثلاثة مكررات. تم جمع البيانات وحللت من حيث صفات الحاصل والصفات النوعية للبذور. أشارت نتائج التحليل الإحصائي إلى وجود تأثير معنوي للعوامل المدروسة وتداخلاتها في معظم الصفات المدروسة. وجد أن تسميد التربة بالتركيز الموصي به من سماد NPK أثر معنوياً في جميع صفات الحاصل، حيث سجلت أعلى القيم لصفة قطر الرأس الزهري (١٧.٩٧ و١٩.٦٢) سم، ووزن الرأس (٣٦٣.٣٣ و٢٤٨.٠٠) غرام نبات $^{-1}$، وزن ١٠٠٠ بذرة (١٣١.٦٥ و ١١٦.٢١) غم وحاصل البذور (٤.٤٠ و ٦.٠٢) طن هكتار$^{-1}$. بينما سجلت معاملة المقارنة أقل قيمة لمعظم الصفات المدروسة لكلا الموسمين. بينما أظهرت المعاملة بالسماد NPK النانوي لمعاملة F4 تأثيرا إيجابيا على الصفات النوعية لبذور عباد الشمس، حيث ادى إلى زيادة نسبة الزيت (٢٦.٧٤ و ٢٥.١٧)% . كما أدت المستويات العالية من الرش الورقي سماد NPK النانوي F8 إلى الزيادة في نسبة البروتين وحاصل البروتين في البذور مقارنة بالمستويات المنخفضة .وكان للكثافة النباتية (٧٠ سم بين الصفوف) تأثير كبير في صفات مكونات الحاصل ونوعية البذور لكلا الموسمين. وقد سجلت أعلى القيم ماعد نسبة النايتروجين في البذور. بوجه عام، كان لتطبيق الرش الورقي بـالسماد NPK التقليدي تأثير كبير مقارنة بالرش النانوي .

الكلمات المفتاحية: التسميد الورقي، الأسمدة NPK المختلفة، كثافة النبات، مكونات الحاصل، جودة البذور.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is an essential oilseed crop with its origins in tropical and subtropical regions. Notably, it demonstrates wide adaptability and exhibits high drought tolerance (Ozturk et al. 2017). Sunflower seeds are known for their substantial oil content, ranging from 40% to 50%, and they also contain approximately 26% of protein (Petraru et al. 2021). It is one of the major reliable sources of vegetable oil; seeds are rich in unsaturated fatty acids, vitamins and trace elements, which can destroy the cholesterol synthesis multiple in human body.

Currently, fertilizers play a crucial role in agriculture, contributing significantly to crop cultivation and enhanced productivity. Numerous factors, including genotype variations, environmental conditions, soil fertility, and cultural practices, exert their influence on the growth, seed yield, and various components of crops (Golzarfar et al. 2012; Sadalla et al. 2016). While over the past decade, the issue of environmental pollution, particularly concerning water and soil, has become a pressing concern. The excessive use of chemical fertilizers and pesticides has emerged as a major challenge for global food security and public health in numerous regions around the world (Manjili et al. 2014). Therefore, there is a need to mitigate the damaging influences on the environment induced by chemical fertilization particularly NPK fertilizers. The excessive of N 20%, P 20% and K 20% and inefficient application of these fertilizers, with low nutrient utilization rates, leads to groundwater pollution and soil accumulation. Iraq has also experienced increased drought conditions due to rising temperatures. Moreover, nutrient loss, such as N through leaching and volatilization, P through fixation, and K through leaching and fixation, can result in insufficient nutrient availability during the flowering and seed development stages of the sunflower crop. This deficiency leads to reduced flower numbers, poor seed development, and may be exacerbated by decreased root activity. Given sunflower's high nutrient requirements throughout its growth, providing plant nutrients during critical periods becomes vital. Foliar fertilization emerges as an effective method to supply nutrients rapidly during the crucial flowering and seed development stages. Foliar feeding is directly linked to the plant's enzymatic systems and helps address nutrient deficiencies during these critical growth phases, (Modak and Mallick 2018) .

Nanotechnology proposals a promising solution by allowing the customization of fertilizer production, improving nutrient use efficiency, reducing environmental impact, and ultimately enhancing plant yield. As known, Nano fertilizer is a novel technology that offers a promising alternative to traditional chemical fertilizers in agriculture. One of its key benefits is preventing soil and water pollution by gradually and precisely releasing nutrients into the soil and subsequently to the plants (Naderi and Abedi, 2012; Sekhon, 2014). When Nano NPK fertilizer is applied, it has been observed to enhance plant growth, resulting in higher vegetative biomass yield compared to normal or unfertilized treatments (Hasaneen et al. 2016). On the other hand, cultural practices, like row spacing, play a crucial role in determining sunflower yield and its components. Proper seed rates are also critical as low plant populations may reduce seed yield and oil concentration, while large heads from low plant populations could take longer period to dry down and be challenging to harvest Vahedi et al. (2010). Many growths and yield-contributing characteristics in sunflowers are positively correlated with plant population (Jefferson, 2010). Studies by Süzer (2010) and Ion et al. (2015) have indicated that row spacing significantly affects sunflower yield attributes. Additionally, increasing plant densities from 50,000 to 70,000 plants per hectare has been shown to decrease growth characters, yield attributes, and seed yield of sunflower. Furthermore, plant densities have significant impacts on growth characteristics, yield, oil content, and oil qualities (Abido, 2020).
Despite the importance of fertilization and its potential harm, the focus of this study is to explore the effects of nano and conventional NPK foliar application on sunflower plants and how it influences certain growth characteristics.

MATERIALS AND METHODS

The current study was conducted in Erbil Governorate at Grdarasha Research Station - College of Agriculture Engineering Sciences - University of Salahaddin during two growing seasons (summer 2021 and spring 2022), to investigate the effect of nano and conventional NPK foliar application on some growth parameters and chemical components of N, P and K of sunflower crop under different plant density .

A factorial experiment had been carried out using Randomized Complete Block Design (RCBD) with three replicates. The research implies that each treatment was represented by the combination of levels of three factors. The first factor included different treatments of NPK fertilizer as follow: F_1= control (no fertilizer), F_2 = NPK fertilizer of soil application with 240 kg ha^{-1} (according to standard recommendation), Foliar application of nano NPK with different levels (F_3 = 100 ppm, F_4 = 150 ppm and F_5= 200 ppm as foliar of nano NPK), while conventional NPK foliar application was: (F_6 = 300 ppm, F_7= 500 ppm, F_8 = 700 ppm). The second factor was two distances between the row, (50 and 70 cm) with 30 cm distance between plants. Foliar spraying was performed at two plant growth stages (30 days and 55 days after planting). Furthermore, the field land was divided manually to three replications, each replicate consists of 16 experimental units (plot) the area of each experimental unit was 3×2.5 m^2, the distance between each plot was 0.75 m and between blocks was 1 m. In addition, the amount of water added was also calculated for each irrigation (according to crop requirement). Sunflower seeds were sown time was on the 9^{th} of July 2021 and the 10^{th} of March 2022, and then harvested on the 10^{th} of October 2021 and the 4^{th} of July 2022, for first and second year, respectively. The analysis of chemical and physical properties of the experimental soil were carried out (0 to 30 cm depth). The soil was clay loam in texture, the pH was

7.43, organic matter was 0.86 %, 0.8 E.C. dS/m^{-1}, available nitrogen was 0.09 %, available phosphorus and potassium were 9.5 and 240 ppm respectively.

Experiment Parameters:

Head dimeter (cm): was measured by length measuring tape**.**

Weight of Head (g plant $^{-1}$): was determined from the selected (10) plants, and the head weight means (g) was calculated.

Weight of 1000 seeds (g): measured by accounting a 1000 seeds plant^{-1} then weighing them by using precise balance.

Seed yield (t ha^{-1}): measured by harvesting the plant seeds from the middle lines. The seed yield were collected by grind, sieved and then the seeds weighed. The weight was converted to (ton. ha^{-1}) units. While the seed yield was adjusted to 10.4% moisture.

Oil percentage (%): was calculated by taking two grams of seed from each experimental unit for determining oil %, using Soxhlet apparatus for oil extraction as mentioned by Association of Official Analytical Chemists (A.O.A.C, 1980).

Oil yield (t ha^{-1}): was calculated by using the following formula:

$$\text{Oil yield (t ha}^{-1}) = \text{Oil \%} \times \text{Seed yield (t ha}^{-1}).$$

Protein percentage: was estimated from seeds. Nitrogen percentage was determined using the micro kjeldal apparatus according to kjeldal method (A.O.A.C, 1980), then protein percentage was estimated using the following equation:

$$\text{Protein percentage} = \text{Nitrogen\%} \times 6.25$$

The protein yield (t ha^{-1}): was determined according to the following equation:

$$\text{Protein yield (t ha}^{-1}) = \text{Protein (\%)} \times \text{Seed yield (t ha}^{-1}).$$

Nitrogen content of seed (%): was determined using the micro-kjeldahl apparatus according to kjeldahl method of Bremmer and Mulvaney (1982).

Statistical Data Analysis:

The collected data were subjected to analysis of variance utilizing SAS version 9.1 2003, Duncan's Multiple Range Test (1955) was used for means comparison at 0.05 level of significant.

RESULT AND DISCUSSION

1. Head Diameter (cm):

The size of the sunflower head plays a significant role in determining the yield of achenes. This is because head size affects both the number of achenes per head and the size of each individual achene, ultimately impacting the overall achene yield. The table 1 demonstrates the considerable impact of various fertilizer types and raw spacing on the diameter of the sunflower heads in both growing seasons (2021 and 2022). The highest values 18.50 and 19.97cm were produced by the treatment fertilizer application of conventional NPK 700 ppm and recommended NPK in 2021 while in the 2022 the highest value was 19.62 cm, and it was recorded from normal soil fertilizer (recommended NPK). The observed increase in head diameter can be attributed to the enhanced metabolic activities of the plants resulting from nitrogen fertilization. The higher nitrogen rate is associated with a larger head diameter. The improvement in head diameter can be attributed to increased vegetative growth stimulated by higher levels of fertilization. Waqas et al. (2017) and Naseem et al. (2011) reported that the head diameter of sunflowers showed an increase when the levels of nitrogen (N), phosphorus (P), and potassium (K) were increased. Similar results were also reported by Awais et al. (2013) and Khakwani et al. (2014).

On the other hand, row spacing also had a notable impact on the diameter of the sunflower heads during both the years 2021 and 2022. The maximum head diameters of 17.09 and 16.69 cm were observed with a row spacing of 70 cm, while the minimum head diameters of 16.53 and 15.74 cm were recorded with a row spacing of 50 cm in both growing seasons, respectively. It is evidence that under unfavorable growing conditions, sunflower plants planted in narrow rows exhibit more efficient utilization of growth factors, resulting in larger head diameter. However, increasing the plant population, leads to a reduction in head diameter across all growing conditions. This finding is consistent with the observations of various authors, including (McMaster et al. 2012 and Ion et al. 2015) .

In the case of interaction treatments between plant density and fertilizer treatment, the head diameter was significantly affected by them in both growing seasons. The highest values of 18.50 cm and 19.42 cm were recorded from the interaction treatment of conventional NPK at a concentration of 700 ppm with a row spacing of 70 cm while lowest values 14.63 cm and 12.85 cm were recorded from the interaction treatment of control and a row spacing of 50 cm in both 2021 and 2022, respectively. The head diameter in all growing conditions decreased as the plant population increased, which agrees with the results obtained by different authors (Ion et al.2015, Ibrahim, 2012 and McMaster et al.2012).

Table (1) Effect of nano -conventional NPK fertilizer and row space on sunflower head dimeter (cm)

Fertilizer types	First Season			Second Season		
	Density 1	Density 2	Fertilizer means	Density 1	Density 2	Fertilizer means
F1	14.63 f	16.53 b-e	15.58 cd	12.85 g	14.59 ef	13.72 e
F2	17.77 ab	18.17 ab	17.97 a	19.76 a	19.47 a	19.62 a
F3	15.77 def	15.17 ef	15.47 d	15.42 de	15.34 de	15.38 d
F4	16.50 b-e	16.60 d-e	16.55 bc	15.51 ed	16.30 bcd	15.90 cd
F5	17.23 a-d	17.77 ab	17.50 ab	15.84 cde	17.38 bc	16.61 c
F6	16.70 d-e	16.5b-e7	16.63 bc	13.47 fg	15.15 de	14.31 e
F7	16.03 c-f	17.40 a-d	16.72 b	15.46 de	15.84 cde	15.65 cd
F8	17.60 abc	18.50 a	18.05 a	17.63 b	19.42 a	18.53 b
Density means	16.53 b	17.09 a		15.74 b	16 .69 a	

2. Weight of Head (g plant $^{-1}$)

Regarding the head weight per plant, it was significantly influenced by different types of NPK fertilizers, row spacing, and their interaction. As shown in the previous results refer to table 2, the use of the recommended fertilizer led to a noteworthy increase in head weight compared to the control treatment during both growing seasons of 2021 and 2022. The highest values of head weight (363.33 and 248.00g plant $^{-1}$) were observed with the recommended NPK fertilizer, whereas the lowest values (254.00 and 113.83g plant $^{-1}$) were recorded in the control treatment. The observed increase in head weight due to NPK fertilizer application can be attributed to the creation of optimal growth conditions for sunflower crops. NPK fertilizers contain essential macronutrients that support plant growth. This finding aligns with a similar study conducted by Handayati and Sihombing (2019), Bapir and Mahmood (2022), showed a significant difference between the levels of NPK fertilizer tested and they also linked the enhanced growth traits of sunflower to the application of different NPK level. It could be seen from the same table mentioned before that the row spacing had a significant effect on these traits, the highest amount (325.20 and 180.83 g plant $^{-1}$) were obtained from row spacing 70 cm while, the minimum values (295.00 and 151.29 g plant $^{-1}$) were recorded from row spacing 50 cm in both seasons 2021 and 2022, respectively. These results confirmed with the results observed by Ion et al. (2015) who reported that the head weight per plant of sunflower crop were affected differently by row spacing, depending on the soil and climatic conditions. The most favorable weight was achieved with a row spacing of 75 cm under optimal growing conditions. Conversely, under less favorable growing conditions, a row spacing of 50 cm resulted in the lowest weight of head .

The treatment combination of (recommended NPK fertilizer × row spacing 70 cm) resulted in the highest values of the studied traits (389.33 and 284.33 g plant $^{-1}$) in both seasons. on the other hand, (control × row spacing 50 cm) obtained the lowest values (224.33 and 95.00 g plant $^{-1}$), respectively.

Table (2) Effect of nano -conventional NPK fertilizer and row space on sunflower weight of head (g plant $^{-1}$)

Fertilizer types	First Season			Second Season		
	Density 1	Density 2	Fertilizer means	Density 1	Density 2	Fertilizer means
F1	224.33 f	283.67 cde	254.00 e	95.00 e	132.67 de	113.83 d
F2	337.33 a-d	389.33 a	363.33 a	211.67 b	284.33 a	248.00 a
F3	289.00 cde	266.33 ef	277.67 de	137.33 de	138.33 de	137.83 cd
F4	297.67 cde	297.00 cde	297.33 cd	144.33 d	193.67 bc	169.00 c
F5	328.67 cd	360.67 ab	344.67 ab	146.33 d	179.00 bcd	162.67 c
F6	278.00 de	342.33 abc	310.17 abc	93.33 e	152.33 cd	122.83 d
F7	282.00 de	328.00 bcd	305.00 cd	158.33 cd	160.00 cd	159.17 c
F8	323.00 b-e	334.33 a-d	328.67 abc	224.00 b	206.33 b	215.17 b
Density means	295.00 b	325.20 a		151.29 b	180.83 a	

3. 1000 Seed Weight (g):

On average, the data from the table 3 indicates that the application of recommended NPK fertilizer or common NPK fertilizer resulted in the highest mean values in both growing seasons, with recorded values of 131.65 and 116.21 g, respectively. Similar result was observed by Handayati and Sihombing (2019).

The data in table3, also indicates that significant differences were observed between the two plant densities in relation to 1000 seed weight during the first growing season. The highest values were obtained with a row spacing of 70 cm in 2021, recording a value of (124.61 g). However, during the second growing season, no significant differences were observed between the two plant densities in terms of this trait. An increase in plant population was found to be associated with a decrease in the weight of thousand seeds, with the reduction being more pronounced under favorable climatic conditions. This decrease in the weight of thousand seeds due to higher plant populations, and may be attributed to favorable environmental conditions in wider spacing, which allows minimal competition among sunflower plants and increased light penetration within the plant canopy. This spacious environment potentially provides sufficient space for the crop to capture solar energy efficiently and effectively utilize applied nutrients and moisture. As a result, there is a positive impact on leaf area and dry matter production per plant, promoting the conversion of photosynthate into seed rather than vegetative growth. This agronomically beneficial process ultimately leads to higher achene yield per unit area (Ali et al.2012, Ibrahim, 2012 and Ion et al.2015).

Moreover, it was noticed that there was a significant interaction between fertilizer types and plant density. The maximum mean value 133.28 g and 132.52 g were founded in 2021 from the interaction treatment of (recommended NPK fertilizer × row spacing 70 cm) and (conventional NPK 700 ppm × row spacing 70 cm) respectively as compared to the control treatment. On the other hand, in 2022 the highest value was recorded 117.56 g from the interaction treatment of (recommended NPK fertilizer × row spacing 70 cm). Similar results were obtained by Esmail et al. (2014) they noted the significant effect of fertilizer on the seed index of flax.

Table (3) Effect of nano -conventional NPK fertilizer and row space on sunflower 1000 seed weight (g)

Fertilizer types	First Season			Second Season		
	Density 1	Density 2	Fertilizer means	Density 1	Density 2	Fertilizer means
F1	110.37 g	118.89 e	114.63 e	92.92 f	93.59 f	93.25 d
F2	130.01 ab	133.28 a	131.65 a	114.85 ab	117.56 a	116.21 a
F3	119.00 e	121.18 e	120.09 cd	95.47 ef	92.65 f	94.06 d
F4	119.42 e	122.06 de	120.74 c	100.95 cd	101.10 cd	101.02 c
F5	127.68 bc	126.29 bc	126.99 b	101.61 cd	103.67 c	102.64 c
F6	114.39 f	120.55 e	117.47 d	96.04 ef	94.99 ef	95.51 d
F7	118.04 e	122.11 de	120.08 cd	99.06 de	101.47 cd	100.27 c
F8	125.66 cd	132.52 a	129.09 b	112.18 b	113.93 ab	113.06 b
Density means	120.57 b	124.61 a		101.72 a	102.29. a	

4. Seed Yield (t ha^{-1})

Seed yield is widely considered as the foremost factor of significance, serving as the ultimate objective and enabling the assessment of treatment effectiveness. Therefore, it is crucial to consider seed yield as the definitive outcome resulting from a combination of various mechanisms, physiological functions, and morphological changes taking place in plants throughout their growth and developmental stages.

The results regarding the seed yield of sunflower, as influenced by the foliar application of NPK and normal fertilizer (recommended NPK), are presented in Table 4. The analysis of variance demonstrated that fertilizer application had a significant effect ($P < 0.05$) on the seed yield. The findings indicated that the highest seed yield of 4.40 and 6.02 t ha^{-1} were achieved in crops treated with soil fertilizer application of NPK (recommended NPK) during the first and second growing seasons (2021 and 2022), respectively. This was followed by the conventional NPK 700 ppm treatment, which resulted in seed yields of 4.25 and 5.10 t ha^{-1} and then nano NPK 200 ppm treatment 4.21 and 4.24 t ha^{-1}. In contrast to, the control treatment yielded the lowest values of (3.57 and 3.90) t ha^{-1} in both seasons respectively. Moreover, the seed yield was improved significantly due to the soil applications of NPK fertilizer, the order of effectiveness was recommended NPK > conventional NPK 700 ppm > nano NPK 200 ppm. This finding aligns with a similar study conducted by Waqas et al. (2017) who mentioned that NPK levels affected significantly seed yield. NPK is known to play vital role in formation of amino acids increasing in the number of cells and dry matter accumulation. Higher dry matter accumulation and better translocation of photosynthates led to increase in yield which in turn resulted in increase in seed yield.

On the other hand, planting density and row spacing had significant effect on seed yield. In 2021, the highest value was recorded at row spacing of 50 cm (4.56 t ha^{-1}) while the lowest value (3.41 t ha^{-1}) was recorded at row spacing 70 cm. On contrary, in 2022 the row spacing 70 cm shows the maximum value (4.68) t ha^{-1} while the minimum value (4.38 t ha^{-1}) was from row spacing 50 cm. This may be due favorable environmental condition in spring sowing 2022 while 2021 was drought year. This finding is agreed with Ion et al. (2015). The greatest yields were achieved when the row spacing was set to 75 cm while the minimum value was recorded at row spacing 50 cm. On the other hand, results were previously reported indicating that increase plant population significantly increase seed yield (Barros et al.2004; Szabó and Pepo 2007). The interaction treatments show maximum value (5.08 and 5.06) t ha^{-1} which were recorded at both interaction treatment of (Recommended NPK × row spacing 50 cm) and (nano NPK 200 ppm × row spacing 50 cm) respectively in 2021. While, in 2022 the highest value was recorded from interaction treatment (recommended NPK × row spacing 70 cm) which was (6.15 t ha^{-1}).

Table (4) Effect of nano -conventional NPK fertilizer and row space on sunflower seed yield (t ha^{-1})

Fertilizer types	First Season			Second Season		
	Density 1	Density 2	Fertilizer means	Density 1	Density 2	Fertilizer means
F1	3.88 cde	3.27 ef	3.57 d	3.73 ef	4.26 def	3.99 d
F2	5.08 a	3.72 def	4.40 a	5.88 ab	6.15 a	6.02 a
F3	4.48 ab	3.43 ef	3.96 bcd	4.13 def	4.73 cd	4.43 cd
F4	4.63 ab	3.39 ef	4.01 abc	4.01 def	5.24 bc	4.62 bc
F5	5.06 a	3.35 ef	4.21 ab	3.98 def	4.50 cde	4.24 cd
F6	4.24 bcd	3.20 f	3.72 cd	3.55 f	4.25 def	3.90 d
F7	4.36 bc	3.20 f	3.78 cd	4.68 cd	4.60 cd	4.64 bc
F8	4.79 ab	3.70 def	4.25 ab	5.06 c	5.13 c	5.10 b
Density means	4.56 a	3.41 b		4.38 b	4.68 a	

5. Oil Percentage (%)

The results of the variance analysis revealed that the effects of different types of NPK fertilizers on oil content were found to be significant at a 5% probability level in both seasons (table 5). In 2021, the use of conventional NPK fertilizer with a concentration of 300 ppm resulted in the highest oil content 27.01%. This value was not significantly different from other treatments except for the recommended fertilizer treatment which yielded the lowest oil content value 22.03 %. Alternatively, in the second growing season of 2022, the fertilizer treatment involving Nano NPK with a concentration of 150 ppm exhibited the highest oil content value 25.17%. Conversely, the control treatment recorded the lowest oil content value 19.45%. Similar results were reported by Hama et al. (2015), Mohammed (2021) and Hafez et al. (2021), demonstrating a significant effect of the fertilizer on oil content. On the other hand, these findings support the observations made by Bakht et al. (2010), indicating that the oil content varied when different combinations of NPK fertilizers were applied, with recorded variations ranging from 37% to 39% across both seasons. Furthermore, the presented table 5 also revealed significant variations in oil content based on row spacing in both the 2021 and 2022 seasons, albeit in contrasting patterns. Specifically, in 2021, the highest oil content 26.21% was recorded with a row spacing of 50 cm, while the lowest value 26.21 % was observed with a row spacing of 70 cm. This decrease can be attributed to a significant reduction in seed oil content at the higher plant density, which could not be compensated by an increase in the number of plants per unit area. The decline in seed oil content may result from intra-plant competition for nutrients and water supply, as well as excessive shading in densely populated areas. These findings align with previous studies conducted by researchers Ibrahim and El-Genbehy (2009); Ishfaq et al. (2009) and Ibrahim (2012) who found that the oil percentage was decreased with increasing plant density. However, in 2022, the maximum oil content 22.51% was achieved with a row spacing of 70 cm, while the lowest value 21.03 % was obtained with a row spacing of 50 cm. These results may be attributed to the optimal number of plants per unit area during planting, which promotes increased vegetative growth and enhances the net results of the photosynthesis process. As a result, there is an increase in the accumulation of dry matter in the seeds, leading to an increase in oil content. These findings align with the studies conducted by Ali et al. (2012) and Ibrahim ,(2009).

In the first year of 2021, the two-factor interactions between conventional NPK at 700 ppm and row spacing at 50 cm showed the highest yield percentage 29.24%, while the interaction between recommended NPK and row spacing at 70 cm yielded the lowest percentage 21.03%. Moving on 2022, the interaction between conventional NPK at 500 ppm and nano NPK at 150 ppm recorded the highest value 26.00%, whereas the lowest value (18.48%) was observed in the interaction treatment involving the control and row spacing at 50 cm. " The results obtained are consistent with the research conducted by Abido and Abo-El-Kheer in 2020, which revealed a significant impact of the interaction between plant density and foliar fertilization on oil content. They reported that the highest oil percentages were observed with the lowest plant density of 23,333 plants per feddan, in addition to foliar spraying with 200 ppm of boron during the years 2018 and 2019.

Table (5) Effect of nano -conventional NPK fertilizer and row space on sunflower oil percentage (%)

Fertilizer types	First Season			Second Season		
	Density 1	Density 2	Fertilizer means	Density 1	Density 2	Fertilizer means
F1	23.80 cde	26.17 a-d	24.98 a	18.48 g	20.43 def	19.45 c
F2	23.04 de	21.03 e	22.03 b	22.05 cd	21.04 cde	21.55 b
F3	26.80 abc	26.10 a-d	26.45 a	22.91 bc	20.91 def	21.91 b
F4	27.93 ab	25.55 bcd	26.74 a	24.34 ab	26.00 a	25.17 a
F5	27.85 ab	25.04 bcd	26.44 a	21.25 cde	20.82 def	21.03 b
F6	29.24 a	24.79 bcd	27.01 a	20.75 def	22.81 bc	21.78 b
F7	24.96 bcd	25.59 bcd	25.27 a	19.03 fg	25.12 a	22.07 b
F8	26.05 a-d	25.06 bcd	25.55 a	19.47 efg	22.94 bc	21.20 b
Density means	26.21 a	24.91 b		21.03 b	22.51 a	

6. Oil Yield (t ha^{-1})

The data in pertaining to oil yield t ha^{-1} from sunflower as affected by foliar application of NPK are presented in Table 6. The analysis of variance reveals that both the application of NPK fertilizer and row spacing as well as their interaction, had a significant effect on the oil yield of sunflower in both 2021 and 2022 ($P < 0.05$). The results clearly demonstrated that the highest oil yield of (112.17 t ha^{-1}) was achieved in crop given foliar application of nano NPK at a concentration of 200 ppm. Conversely, the lowest oil yield of (89.26 t ha^{-1}) was recorded in the control treatment in 2021. Moreover, in 2022, the highest oil yields were achieved with different fertilizer treatments, ranked in terms of effectiveness as recommended NPK > conventional NPK 700 ppm > nano NPK 150 ppm (99.85, 99.04, and 98.54 t ha^{-1}), respectively. These results are consistent with the findings of Mohammed 2021; Shilan and Hama (2022); Handayati and Sihombing (2019); who observed a significant impact of NPK fertilization on oil yield. They reported that the highest oil yield was achieved with an increase in NPK application rate from 40 to 120 kg ha^{-1}. Regarding to planting density and row spacing, the highest oil yields of (119.57 and 103.46 t ha^{-1}) were recorded with a row spacing of 50 cm. while, the lowest oil yields of (84.67 and 77.42 t ha^{-1}) were observed with a row spacing of 70 cm, in both 2021 and 2022, respectively. This result is supported by Süzer

(2010), who reported that both the oil percentage and oil yield of the sunflower crop were significantly influenced by different plant densities.

On the other hand, table 6 revealed that the highest oil yield of (140.49t ha^{-1}) was recorded in the interaction treatment of (nano NPK 200 ppm × row spacing 50 cm), while the lowest oil yield of (78.13 t ha^{-1}) was observed in the interaction treatment of (recommended NPK × row spacing 70 cm) during the first growing season in 2021. In the following year, 2022, the highest oil yields of 120.16, 113.66, and 113.26 t ha^{-1} were achieved from the interaction treatments of recommended NPK, nano NPK 200 ppm, and nano NPK 150 ppm, respectively, all with a row spacing of 50 cm. Conversely, the lowest oil yield of 68.70 t ha^{-1} was obtained from the interaction treatment of the control treatment with a row spacing of 70 cm. The results of the current study support the findings of Suzar (2010), who observed significant effects ($p \leq 0.01$ and $p \leq 0.05$) on the mean oil content and oil yield for three sunflower hybrids, consisting of two dwarf hybrids and one standard-height hybrid. These effects were observed across three study years, under varying nitrogen rates and planting densities.

Table (6) Effect of nano -conventional NPK fertilizer and row space on sunflower oil yield (t ha^{-1})

Fertilizer types	First Season			Second Season		
	Density 1	Density 2	Fertilizer means	Density 1	Density 2	Fertilizer means
F1	93.02 de	85.50 e	89.26 d	76.07 gh	68.70 h	72.39 d
F2	117.07 bc	78.13 e	97.57 bcd	120.16 a	79.55 fgh	99.85 a
F3	119.83 bc	89.21 e	104.52 abc	102.07 bc	75.11 gh	88.59 bc
F4	129.24 ab	86.64 e	107.94 abc	113.26 a	83.83 efg	98.54 a
F5	140.49 a	83.84 e	112.17 a	113.66 a	74.02 gh	93.84 ab
F6	123.87 abc	79.21 e	101.54 a-d	99.06 bcd	69.98 h	84.52 c
F7	108.44 cd	82.14 e	95.29 cd	94.45 cde	79.03 fgh	86.74 bc
F8	124.63 abc	92.68 de	108.66 ab	108.98 ab	89.09 def	99.04 a
Density means	119.57 a	84.67 b		103.46 a	77.42 b	

7. Protein Percentage (%)

Table 7 presents the protein content % of sunflower crops influenced by different types of NPK fertilizer and row spacing, including their interaction. The results indicated that the protein percentage significantly varied under the foliar application of conventional NPK 700 ppm and nano NPK 200 ppm fertilizers compared to other fertilizer types. This suggests that these two types of fertilizers were the most effective treatments for enhancing protein content. The highest protein percentages of 24.88% and 19.77% were observed with conventional NPK at a concentration of 700 ppm while, the lowest percentages of 16.22% and 15.36% were observed in the control treatment in both growing season 2021 and 2022, respectively. Hama et al. (2015), Mohammed (2021) and Hafez et al. (2021) all the scientist reported significant effects of fertilizer on the protein percentage in their respective studies. On average, a row spacing had a significant effect on protein content in both seasons, the highest mean values 23.10 and 18.73 % were obtained from a row spacing 70 cm while the lowest protein content 1.23 and 1.36 % were obtained from a row spacing 70 cm in 2021 and 2022, respectively .

Table 7 explained also the significant effect of interaction treatments on protein percentage in both seasons, the maximum mean values (26.94 and 20.97 %) were observed from interaction treatments of conventional NPK at a concentration of 700 ppm and row spacing at 70 cm. While the minimum mean values (15.75 and 15.36 %) were observed from interaction treatments of control and a row spacing at 50 cm, respectively.

Table (7) Effect of nano -conventional NPK fertilizer and row space on sunflower protein percentage (%)

Fertilizer types	First Season			Second Season		
	Density 1	Density 2	Fertilizer means	Density 1	Density 2	Fertilizer means
F1	15.75 p	16..69 n	16.22 h	15.36 h	15.38 h	15.36 e
F2	16.13 o	17.56 m	16.85 g	14.94 h	16.12 g	15.53 e
F3	18.28 l	23.28 f	20.78 f	17.09 f	18.97 c	18.03 d
F4	20.22 j	24.75 d	22.49 d	18.06 e	19.09 c	18.58 c
F5	22.06 h	26.13 b	24.10 b	18.06 e	20.25 b	19.16 b
F6	19.47 k	24.03 e	21.75 e	17.24 f	18.89 cd	18.06 d
F7	21.34 i	25.41 c	23.38 c	18.17 de	20.18 b	19.18 b
F8	22.81 g	26.94 a	24.88 a	18.58 cde	20.97 a	19.77 a
Density means	19.51 b	23.10 a		17.18 b	18.73 a	

8. Protein Yield (t ha^{-1})

The protein yield t ha^{-1} was statistically significant for different type of NPK fertilizer and row spacing, as well as their interaction in both seasons (2021 and 2022) table 8. Conventional NPK with the concentration of 700 ppm was in the first rank and followed by nano NPK 200 ppm in terms of protein yield. The highest mean values 104.52 and 83.34 t ha^{-1} were obtained for conventional NPK with the concentration of 700 ppm, while the lowest protein yields 57.81 and 49.81 t ha^{-1} were obtained from control treatment in 2021 and 2022. The increase in protein yield can be attributed to the growth of vegetation and the subsequent increase in nitrogen content and yield, which, in turn, had a positive effect on the quality of seeds of sunflower crops. The same result was obtained by Bapir and Mahmood (2022), Mohammed (2021) who showed that the significant effect of foliar application of nano fertilizer on protein yields. Also, reviled that the highest values were recorded from nano NPK while the lowest value ha^{-1} were observed from the control treatment. Moving on row spacing, row spacing influenced differently the protein yield according two growing conditions, respectively. The highest protein yields (89.37 and 75.32 t ha^{-1}) were recorded from a row spacing 50 cm while the lowest protein yields (78.63 and 61.74 t ha^{-1}) were recorded from a row spacing 70 cm in 2021 and 2022, respectively. This increasing in protein yield might be associated to the increase in final seed yield and yield components.

The statistical analysis of the data explained that the combination between and different fertilizer types and a row spacing had a significant effect on protein yield. The highest values (109.38 and 88.89 t ha^{-1}) were procured from interaction treatment (conventional fertilizer 700 ppm × row spacing 50 cm) while the lowest protein yields (54.54 and 45.12 t ha^{-1}) were recorded from interaction treatment (control × row spacing 70 cm) in both growing seasons 2021 and 2022, respectively.

Table (8) Effect of nano -conventional NPK fertilizer and row space on sunflower protein yield (t ha^{-1})

Fertilizer types	First Season			Second Season		
	Density 1	Density 2	Fertilizer means	Density 1	Density 2	Fertilizer means
F1	61.08 f	54.54 f	57.81 e	54.50 f	45.12 g	49.81 e
F2	81.91 cd	65.26 ef	73.59 d	79.48 b	60.87 def	70.18 bc
F3	81.87 cd	79.92 cd	80.90 bcd	70.24 c	61.32 def	65.78 cd
F4	93.56 bc	84.00 cd	88.78 b	78.63 b	62.93 cde	70.78 bc
F5	111.67 a	87.61 bcd	99.64 a	84.50 ab	65.96 cd	75.23 b
F6	82.50 cd	76.80 de	79.65 cd	68.08 cd	56.71 ef	62.39 d
F7	93.03 bc	81.22 cd	87.13 bc	78.23 b	63.26 cde	70.75 bc
F8	109.38 a	99.66 ab	104.52 a	88.89 a	77.78 b	83.34 a
Density means	89.37 a	78.63 b		75.32 a	61.74 b	

9. Nitrogen Content of Seed (%)

The data presented in table 9 for the first growing season in 2021 clearly shows that different NPK fertilizer types, row spacing, and their interaction had a significant impact on nitrogen % content of seed. Among the NPK fertilizer types, the highest Nitrogen % value (3.98%) was recorded when using conventional NPK with a concentration of 700 ppm, whereas the lowest value (2.60%) was observed in the control treatment. The increase in the percentage of nitrogen in the dry vegetative parts and seeds of sunflower plants is linked to the addition of mineral NPK formulations. This leads to an increase in the availability of elements for plants, consequently resulting in higher concentrations of these elements in the plant. This, in turn, plays a role in the biological processes, growth, and branching of the plant's root system, thereby enhancing the efficiency of nutrient absorption. This is in line with previous studies by Mohammed (2021) who reported that the Nitrogen actively contributes to all plant activities, stimulating the redirection and transportation of all metabolic products, especially nitrogenous and phosphatic compounds, towards filling the toward filling the endosperm, reducing competition from other plant parts for these vital activities. Furthermore, similar results were reported by Bapir and Mahmood (2022) and Hafez et al. (2021) which mentioned that the utilization of various nano fertilizers led to a significant increase in the nitrogen percentage found in sunflower seeds. Specifically, when Nano NPK was applied as a foliar treatment, it resulted in the highest nitrogen values for both Ranya and Saruchawa. In contrast, the control treatment showed the lowest nitrogen values. Regarding row spacing, Nitrogen % was highest (3.70%) with a row spacing of 70 cm, and lowest (3.12%) with a row spacing of 50 cm. Furthermore, when examining the interaction between fertilizer type and row spacing, the highest Nitrogen % content of seed value (4.31%) was recorded from the interaction treatment of conventional fertilizer with 700 ppm concentration and a row spacing of 70 cm. Conversely, the lowest value (2.52%) was recorded from the interaction treatment of control and a row spacing of 50 cm. Moving on to the second growing season in 2022, the same table revealed that different types of NPK fertilizer and row spacing had a non-significant effect on Nitrogen % in the studied sunflower genotype. However, in contrast, the interaction between them had a significant effect on this trend. The maximum value (2.55%) was recorded with the interaction treatments of Nano NPK 100 ppm and Nano NPK 150 ppm in conjunction with a row spacing of 50 cm, while the minimum value (2.15%) was recorded from the interaction treatment of Control and a row spacing of 70 cm. The positive impact on nitrogen content could be attributed to achieving an optimal nutrient balance in the crops through the application of nitrogen-based fertilizers.

Table (9) Effect of nano -conventional NPK fertilizer and row space on sunflower nitrogen content of seed %

Fertilizer types	First Season			Second Season		
	Density 1	Density 2	Fertilizer means	Density 1	Density 2	Fertilizer means
F1	2.52 p	2.67 n	2.60 h	2.40 ab	2.15 b	2.32 a
F2	2.58 o	2.81 m	2.70 g	2.20 b	2.35 ab	2.28 a
F3	2.93 l	3.73 f	3.33 f	2.55 a	2.35 ab	2.45 a
F4	3.24 g	3.96 d	3.60 d	2.55 a	2.25 b	2.35 a
F5	3.53 h	4.18 b	3.86 b	2.25 b	2.30 ab	2.28 a
F6	3.12 k	3.85 e	3.48 e	2.40 ab	2.20 b	2.30 a
F7	3.42 i	4.07 c	3.74 c	2.40 ab	2.40 ab	2.40 a
F8	3.65 g	4.31 a	3.98 a	2.30 ab	2.40 ab	2.35 a
Density means	3.12 b	3.70 a		2.38 a	2.30 a	

weight of a thousand grains as primary indicators for selecting genotypes that excel in trait of grain yield.

CONCLUSIONS

Sunflower yield and quality are impacted by NPK fertilizer. Proper nutrient management is essential for the successful cultivation of sunflower crop. The study demonstrated that nano and conventional NPK foliar applications, in addition to recommended NPK fertilizer could enhance sunflower growth parameters and nutrient content. However, recommended fertilizer and conventional NPK foliar application had a more pronounced effect. Farmers and researchers can utilize these findings to optimize fertilizer application strategies and achieve higher sunflower crop yields.

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