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NPK Use Efficiency of some Sunflower Genotypes as Affected by Nano and Conventional Fertilizer Application

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SUNFLOWER (*Helianthus annuus* L.) belonging to family Asteraceae is the most important oilseed crop, its ranks third in world total oil production after soybean and peanuts. Nanotechnology is a new approach to increase agricultural production with premium quality and environmental safety. Nano-fertilizers provide some nano nutrients to enhance plant growth and production. A field experiment was conducted at North Sinai, Egypt (31ₒ 08′ 04.3" N, 33ₒ 49′ 37.2" E) during summer seasons (2021 & 2022) to study the effect of Nano and recommended NPK fertilizers. There were 28 treatments including seven sunflower genotypes (G-245, G-465, A-770, G-775, G-880, G-990, Giza120 cv.) and four fertilizer applications (Nano NPK as 100, 75, 50 %, NPK Recommended). Results showed that Giza-120 with treatment 75 % Nano surpassed in chlorophyll percent in all growth stage at both studied seasons. Also, Giza-120 with application of 50 % Nano gave the highest value in biological and stover yield in 2022 season, while, G-245 genotype with 50% Nano gave the lowest value in total phenols and this the best. Generally, it recommended to cultivate Giza120 with 100 % Nano NPK and/or 75, 50 and 25 %; as this treatment responded positively to Nano application and gave the highest seed yield (t fed^{-1}) followed by G-245 genotype. G-465 and G-245 genotypes with control treatment (recommended NPK) were superior for oil content % and oil yield (t fad^{-1}) at both seasons. Using all treatments (Nano 100, 75 & 50%) x Giza 120 responded positively in seed without hull, protein yield and protein without content in two seasons.

Keywords: Genotypes, sunflower, Nano NPK, NPK recommended.

1. Introduction

Sunflower contains low cholesterol, so it becomes a spark basis of the human diet (**Sumon *et al.*, 2020).** Its seeds contain a high oil percentage (40-50 %) and protein of 26% (**Petraru *et al.*, 2021).** It is a promising oil seed crop because of its short duration, high and wide adaptability to different soils and climatic conditions, drought tolerant and soil salinity, easy for cultivation and high quality of edible oil (**Vadlamudi *et al.*, 2023).** There were high variation between different genotypes, whereas, **Bapir and Mahmood (2022)** illustrated that Velko genotype gave superiority in seed yield, seed oil and protein percentage where the highest percent in oil and protein content (37.66, 22.25%) compared to Baroloro genotype in sunflower. Nitrogen, phosphorus and potassium are essential nutrients for plant growth and increasing development sunflower yield (**Coêlho *et al.*, 2022)**, whereas, nitrogen is promoting plant growth and yield components in all crops. While, phosphorus is one of the most important elements and a key for life to plant growth as its role is critical since it is associated with photosynthesis (**Mahotra *et al.*, 2018).** For potassium, it increased drought tolerance and elevated oil content and improved the quality of sunflower seeds (**LI Shu-tian *et al.*, 2018).** Nanotechnology is a tool for increasing the values of essential oil and vegetative production (**Alhasan, 2020),** it has emerged as a promising alternative to help ameliorate crop growth, productivity and optimizing chlorophyll synthesis (**Hydar *et al.*, 2024; Zhao *et al.*, 2024). Also,** Nanofertilizers play an important role in plant nutrition, through their application soil and foliar spraying on the vegetative system **(Singh *et al.*, 2024 a, b).** It could potentially help in reduction of the quantity of fertilizers applied to crop and reduces fertilizer wastage and minimize environmental pollution (**Upadhyaya *et al.*, 2017; Singh *et al.*, 2017).** There are many benefits had recorded on the implementation Nano-fertilizers, particularly, under climate change condition **(Sári *et al.* 2024),** salinity **(Sári *et al.* 2023; Singh *et al.* 2023**

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c; **El-Ramady *et al.* 2024; Mahawar *et al.* (2024)** and nutrient deficiency **El-Bialy *et al.* (2023).** In sunflower, the effect of Nano-NPK fertilizer application significantly gave superiority, where, it's gave the heavier weight in seed, biological, stalk yields kg ha^{-1} (**Vadlamudi *et al.* 2022). Also,** Nano NPK improving and increasing macro elements content in soil and nutrients use efficiency, thus, increasing crop yields (**Vadlamudi, 2023**). In addition, the highest percent oil content was observed with application Nano-NPK fertilizer compared of control (**Vadlamudi *et al.* 2022**); protein percent **(Bapir & Mahmood, 2022)** and oil, protein content **(Hashim & Kakarash, 2024).** Foliar application of Nano fertilizers lead to higher nutrient use efficiency and has given a rapid response to the growth of crop (**Mahil & Kumar 2019).** Nano fertilizers may consider slow-release of nutrients, enhancing and high nutrient use efficiency, which supply cultivated plants with the suitable amounts of nutrients for a long time compared to conventional fertilizers **(Haydar *et al.*, 2024).** As for effect of nano-fertilizer in some plants, the effect of NPK Nano-fertilizer application was positively significantly and improved growth and yield whereby, led to hike protein content, chlorophyll, macro elements in wheat plants (**Abdel-Aziz *et al.*, 2016); Al-Juthery *et al.*, 2018); Burhan & Hassan 2019);** augment chlorophyll content and biological yield in Maize (**Alzreejawi & Al-Juthery, 2020);** in Lettuce, increment macro elements percent in leaf (**Nofal *et al.*, 2021);** increase macro elements percent in leaf, chlorophyll in Grapevines **(Mohamed *et al.*, 2022);** excess protein content and total phenols in Zaghloul date palm (**AbdEl-Rahman & Abd-El-karim, 2022);** enhance macro element in and chlorophyll in gladiolus plant Rose Supremplant (**Sarhan *et al.*, 2022);** augment macro elements in plant and chlorophyll content in Valencia orange (**El-Shereif *et al.*, 2023);** NPK content in soil cultivated by lettuce **(Abdel-Hakim *et al.*, 2023**); increment chlorophyll and macro elements in Mahogany leaf **(Nofal *et al.* 2024)**, comparing with mineral fertilizers. Finally, Nano k excess macro elements in plant, oil, protein and total phenols percent in onion (**Salama *et al.*, 2024).**

Eventually, the aim of this study come up to the choicer fertilizer treatment to attained the highest production efficiency in missionary genotypes sunflower. Also, to reach tidally availing from applying Nano fertilizer on sunflower in salinity soil condition.

2. Materials and Methods

Site Description

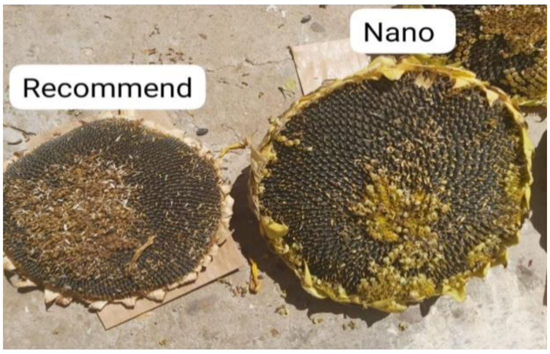
This study was conducted in the Experimental Farm of EL-Arish Agriculture Research Station, Agriculture Research Center (ARC), North Sinai Governorate, (31° 08′ 04.3" N, 33° 49′ 37.2" E) on sunflower during the two consecutive summer seasons of 2021 and 2022. The study aimed to evaluate of seven sunflower genotypes with four different fertilizer treatments under North Sinai conditions. Soil texture was sandy (fine sand 78%) at the study site. Drip irrigation was used and water salinity was 8.38 dsm^{-1} with pH of 7.82.

Treatments

There were 28 treatments including seven genotypes of sunflower (G-245, G-465, G-770, G-775, G-880, G-990, Giza120 cv. as control) and four different fertilizer treatments (Nano NPK as 100, 75 , 50 %, NPK Recommended as control). Table 1 explicated pedigrees of the studied genotypes. Fertilizer treatments distributions as Nano NPK application protocol are shown in Tables 2, 3, 4, 5.

Table 1. Pedigree of the studied genotypes .

No.	Genotype	Pedigree
1	**G – 245**	Line 8 X Line 3
2	**G – 465**	Line 53 X Line 52
3	**G – 770**	Line 53 X Line 49
4	**G -775**	Line 54 X Line 49
5	**G – 880**	Line 54X Line 52
6	**G – 990**	Line 59 X Line 52
7	**Giza -120**	Line 50 X Line 1



Photos 1, 2. presented yields and filling differentiability of sunflower as affected by recommended and Nano fertilizer treatments after sun drying.

Table 2. The first treatment application and growth stages of sunflower at 2021 and 2022 seasons.

Growth stage	Treatment application	1. First treatment 100% Nano NPK
		100 % Nano NPK
First	**Concentration**	3.8: 1.2: 1.2
	Fertilizer equation	19:06:06
	Quantity	Add 1.5 L of Nano- fertilizer liquid / 21 line / 788 plants
	Adding method	Spraying on the leaves of the plant
	Number of doses	Add on 2 doses at rate of 750 ml. Nano-fertilizer liquid dissolved in 50 L. irrigation water, where total average 50.75 L. to one dose: 1. 1st dose was added after 10 days after sowing (DAS). 2. 2rd dose was added after 15 (DAS).
Second	**Concentration**	3.8: 1.2 :4
	Fertilizer equation	19:06:20
	Quantity	Add 4 L. of Nano- fertilizer liquid / 21 line / 788 plants
	Adding method	Spraying on each parts of the plant
	Number of doses	Add on 3 doses at rate of 1300 ml. Nano-fertilizer liquid dissolved in 50 L. irrigation water total average 51.3 L to one dose : 1. 1st dose was added after 25 (DAS). 2. 2nd dose was added after 30 (DAS). 3. 3rd dose was added after 35 (DAS).
Third	**Concentration**	3: 1: 6
	Fertilizer equation	15:05:30
	Quantity	Add 4.5 L. of Nano- fertilizer liquid / 21 line / 788 plants.
	Adding method	Spraying on each parts of the plant.
	Number of doses	Add on 3 doses at rate of 1500 ml. Nano-fertilizer liquid dissolved in 50 L irrigation water total average 51.5 L to one dose: 1. 1st dose was added after 55 (DAS) 2. 2nd dose was added after 60 (DAS). 3. 3rd dose was added after 65 (DAS).

Genotypes seeds were obtained from Oil Crops Research Section, Field Crops Research Institute, (ARC), Giza, Egypt. The source of Nano - NPK fertilizer was gotten from Nanotech Company, Dream land, Gate 3, Wahat road, 6th October City, Cairo, Egypt. Nano- fertilizer application rate was 25 cm^3 dissolved in 1 L. irrigation water for all treatments by addition rate 2.5 %.

Experiment design

The experimental design was randomized complete block design (RCBD) in split – plots with three replications. The main plots were occupied by the seven studied genotypes, while, the four different fertilizer treatments were assigned to the sub-plots. The distribution of fertilizers treatments had been controlled by water valve. The planting dates of these experiments were 15th May and 1st May at 2021 and 2022 seasons.

Items	Value
Irrigation lines length	15 m
Irrigation lines number	84 lines
Distance between lines	50 cm
Distance within lines	40 cm
Plot area	7.5 m^2

Items	Value
Experiment area	630 m^2
Area per one plant	0.2 m^2
Number of plant in experiment	3150 plants
Number of plants per one treatment.	788 plants
Number of plants per fadden	21000 plants

Table 3. The second treatment application and growth stages of sunflower at 2021 and 2022 seasons.

Growth stage	Treatments application	2. Second treatment 75 % Nano NPK	
		75 % Nano NPK	**25 % Recommended NPK**
First	Concentration	3.8: 1.2: 1.2	Add 15.5% P_2O_5 at rate of 150 kg fad^{-1}
	Fertilizer equation	19:06:06	20 :20: 20
	Quantity	Add 1125 ml. of Nano-fertilizer liquid / 21line / 788 plants	Add 750 g powder NPK / 21 line / 788 plants.
	Adding method	Spraying on the leaves of the plant	Put fertilizer by hand
	Number of doses	Add on 2 doses at rate of 562 ml. Nano-fertilizer liquid dissolved in 50 L irrigation water total average 50.562 L. to one dose: 1. 1st dose was added after 10 (DAS) . 2. 2nd dose was added after 15 (DAS).	Fertilization was applied during soil preparing and before planting dose at rate of 750 g of NPK compound fertilizer powder on once dose.
Second	Concentration	3.8: 1.2: 14	Add at rate 45 N kg fad^{-1}
	Fertilizer equation	19:06:20	20 :20: 20
	Quantity	Add 3 L of Nano- fertilizer liquid / 21 line / 788 plants	Add 2 kg powder NPK / 21 line / 788 plants
	Adding method	Spraying on each parts of the plant	Injection in irrigation water
	Number of doses	Add on 3 doses at rate of 1 L. Nano-fertilizer liquid dissolved in 50 L irrigation water total average 51 L. to one dose: 1. 1st dose was added after 25 (DAS) . 2. 2nd dose was added after 30 (DAS). 3. 3rd dose was added after 35 (DAS).	Add on 5 doses at rate of 400 g of NPK compound fertilizer powder dissolved in 10 L. irrigation water total average 10.400 L to one dose: 1. 1st dose was added after 26 (DAS). 2. 2nd dose was added after 31 (DAS). 3. 3rd dose was added after 36 (DAS). 4. 4th dose was added after 41 (DAS). 5. 5th dose was added after 46 (DAS).
Third	Concentration	3: 1: 6	Add 48% at rate 50 kg fad^{-1}
	Fertilizer equation	15: 5: 30	20 :20: 20
	Quantity	Add 3375 ml. of Nano- fertilizer liquid / 21 line / 788 plants	Add 2.250 kg powder NPK / 21 line / 788 plants
	Adding method	Spraying on each parts of the plant	Injection in irrigation water
	Number of doses	Add on 3 doses at rate of 1125 ml. Nano-fertilizer liquid dissolved in 50 L. irrigation water total average 51.12 L. to one dose: 1. 1st dose was added after 55 (DAS) . 2. 2nd dose was added after 60 (DAS). 3. 3rd dose was added after 65 (DAS).	Add on 3 doses at rate of 750 g of NPK compound fertilizer powder dissolved in 20 L. irrigation water total average 20.750 L. to one dose: 1. 1st dose was added after 32 (DAS) . 2. 2nd dose was added after 37 (DAS). 3. 3rd dose was added after 42 (DAS)

Table 4. The third treatment application and growth stage of sunflower at 2021 and 2022 seasons.

Growth stage	Treatment application	3. Third treatment 50 % Nano NPK	
		50% Nano NPK	**50 % Recommended NPK**
First	**Concentration**	3.8 : 1.2 : 1.2	Add 15.5% P_2O_5 at rate of 150 kg fad^{-1}
	Fertilizer equation	19:06:06	20 :20: 20
	Quantity	Add 750 ml. Nano- fertilizer liquid / 21 line / 788 plants	Add 1.5 kg powder NPK / 21 line / 788 plants
	Adding method	Spraying on the leaves of the plant	put fertilizer by hand
	Number of doses	Add on 2 doses at rate of 375 ml. Nano-fertilizer liquid dissolved in 50 L irrigation water total average 50.375 L. to one dose: 1. 1^{st} dose was added after 10 (DAS) . 2. 2^{nd} dose was added after 15 (DAS).	Fertilization was applied during soil preparing and before planting dose at rate of 1.5 kg of NPK compound fertilizer powder on once dose.
Second	**Concentration**	3.8: 1.2: 4	Add at rate 45 N kg fad^{-1}
	Fertilizer equation	19:06:20	20 :20: 20
	Quantity	Add 2 L. of Nano- fertilizer liquid / 21 line / 788 plants.	Add 4 kg powder NPK / 21 line / 788 plants
	Adding method	Spraying on each parts of the plant.	Injection in irrigation water
	Number of doses	Add on 3 doses at rate of 650 ml. Nano-fertilizer liquid dissolved in 50 L. irrigation water total average 50.65 L. to one dose: 1. 1^{st} dose was added after 25 (DAS) . 2. 2^{nd}dose was added after 30 (DAS). 3. 3^{rd} dose was added after 35 (DAS).	Add on 5 doses at rate of 800 g of NPK compound fertilizer powder dissolved in 10 L. irrigation water total average 10.800 L. to one dose: 1. 1^{st} dose was added after 26 (DAS). 2. 2^{nd} dose was added after 31 (DAS). 3. 3^{rd} dose was added after 36 (DAS). 4. 4^{th} dose was added after 41 (DAS). 5. 5^{th} dose was added after 46 (DAS).
Third	**Concentration**	3: 1 : 6	Add 48 % at rate 50 kg fad^{-1}
	Fertilizer equation	15 : 5 : 30	20 :20: 20
	Quantity	Add 2.25 L. of Nano- fertilizer liquid / 21 line / 788 plants.	Add 4.5 kg powder NPK / 21 line / 788 plants.
	Adding method	Spraying on each parts of the plant.	Injection in irrigation water.
	Number of doses	Add on 3 doses at rate of 750 ml. Nano-fertilizer liquid dissolved in 50 L irrigation water total average 50.75 L to one dose: 1. 1^{st} dose was added after 55 (DAS). 2. 2^{nd} dose was added after 60 (DAS). 3. 3^{rd} dose was added after 65 (DAS).	Add on 3 doses at rate of 1.5 kg of NPK compound fertilizer powder dissolved in 20 L irrigation water total average 21.5 L to one dose: 1. 1^{st} dose was added after 32 (DAS) . 2. 2^{nd} dose was added after 37 (DAS). 3. 3^{rd} dose was added after 42 (DAS).

Table 5. The fourth treatment application and growth stage of sunflower at 2021 and 2022 seasons

Growth stage	Treatment application	4. Fourth treatment recommended NPK
		Recommended NPK
First	**Concentration**	Add 15.5% P_2O_5 at rate 150 kg fad^{-1}
	Fertilizer equation	20 : 20 : 20
	Quantity	Add 3 kg. recommended NPK / 21 line / 788 plants
	Adding method	Put fertilizer by hand
	Number of doses	Fertilization was applied during soil preparing to cultivation dose at rate of 3 kg of NPK compound fertilizer powder on once dose.
Second	**Concentration**	Add at rate 45 kg N fad^{-1}
	Fertilizer equation	20 : 20 : 20
	Quantity	Add 8 kg recommended NPK / 21 line / 788 plants
	Adding method	Injection in irrigation water
	Number of doses	Add on 5 doses at rate of 1.600 kg of NPK compound fertilizer powder dissolved in 10 L. irrigation water total average 11.600 L. to one dose: 1. 1st dose was added after 26 (DAS). 2. 2nd dose was added after 31 (DAS). 3. 3rd dose was added after 36 (DAS). 4. 4th dose was added after 41 (DAS). 5. 5th dose was added after 46 (DAS).
Third	**Concentration**	Add 48 % at rate 50 kg fad^{-1}
	Fertilizer equation	20: 20: 20
	Quantity	Add 9 kg recommended NPK / 21 line / 788 plants
	Adding method	Injection in irrigation water
	Number of doses	Add on 3 doses at rate of 3 kg of NPK compound fertilizer powder dissolved in 20 L. irrigation water total average 23 L. to one dose : 1. 1st dose was added after 32 (DAS) . 2. 2nd dose was added after 37 (DAS). 3. 3rd dose was added after 42 (DAS).

Record data:

1. Chlorophyll concentration (μ mol m^{-1}): according to **Parry *et al.* (2014).**

2. Seed oil content % (with and without hull) : according to **AOCS (2017).**

3. Total phenols (mg g^{-1}): a sample of 0.5 g from dried hull seeds was then soaked in 80% Ethyl alcohol in dark bottles for three days. Later one ml from the extract was mixed with half ml saturated sodium carbonate (25 g /100 ml H_2O) was added. The absorption of the mixture was measured at 730 nm by a Milt Roy spectronic 601- spectrophotometer at Sugar Crops Research Institute (SCRI), (ARC). A standard curve from the Galic acid was calculated following the same previous steps.

Total phenols (mg g^{-1}) **AOAC (1995),** were calculated according to the following equation:

$$\frac{\mathrm{R} \times F \times 10 \times 1}{\text{Sample weight } \times 1000 \times Volume\ of\ sample}$$

Where:
R is Reading from spectrometer for the sample.
F is Factor obtained from the standard curve.

4. Yields

4.1. Biological (kg), Stover (kg), seed and oil yields (t fad^{-1}): Plants from 1m^2 (5 plants) were harvested and weighted to give seed yield per m^2. Then seed yield (t fad^{-1}) was computed by multiplying seed yield / m^2 by 4200 m^2. In concern to oil yield, it was computed by multiplying seed yield t fad $^{-1}$ by seed oil content with and without hull seeds.

5. Macro elements in plants.

5.1. Macro elements (kg fad^{-1}): sunflower stem and leaves after harvesting, were taken from each treatment, then grinded to determine nitrogen, phosphorus and potassium content. Nitrogen and Potassium were determined according to **Jackson (1973).** Phosphorus content was determined calorimetrically using the ascorbic acid methods by **Watanabe and Olsen (1965).**

5.2. Macro elements use efficiency in plants (kg kg^{-1}): Nutrients efficiency ratio (NER) observed by **Gerloff and Gabelman (1983)** to differentiate genotypes in to efficiency and in efficiency nutrients utilizers in sunflower stem and leaves.

$$NER = \frac{\text{Unit of yield (seed yield kg fad}-1)}{\text{Unit of elements in plant in tissue kg fad}-1} \, (\text{kg kg}^{-1})$$

6. Soil analyses: soil samples were taken at a depth of 0 – 30 cm after the plants were harvested for each treatment to determine the percentage of organic matter, EC and pH, macro elements and use efficiency of macro elements.

6.1. Chemical analyses of soil site: pH, Electrical conductivity Ec (dsm^{-1}) were determined by **Jackson (1973)** and organic matter (%) according to the Walkely and Black method **(Black 1982).**

6.2. Macro elements content (ppm): after harvesting date, nitrogen was determined according to **Black *et al.* (1965),** while, phosphorus content, according to **Olsen *et al.* (1954)** then, determined calorimetrically using the ascorbic acid methods **Watanabe and Olsen (1965),** regarding to potassium content in soil, was determined by **Jackson (1973).**

6.3. NPK use efficiency (%) : use efficiency of macro elements in soil after harvesting date (%), NPK UE % was calculated according to the following equations :

NUE % was calculated according to the following equation :

$$\frac{\text{Percent N before planting} - \text{percent N after harvest}}{\text{Percent N before plant (total)}} \times 100$$

PUE % was calculated according to the following equation :

$$\frac{\text{Percent P before planting} - \text{percent P after harvest}}{\text{Percent P before plant (total)}} \times 100$$

KUE % was calculated according to the following equation :

$$\frac{\text{Percent K before planting} - \text{percent K after harvest}}{\text{Percent K before plant (total)}} \times 100$$

Statistical analysis

The data were statistically analyzed according to **Senedecor and Cochran (1990)** using **MSTAT**- C computer program V.4 **(1991)** . The means values were compared at $P < 0.05$ level of probability using Duncan̉s Multiple Range Test **(DMRT) Duncan (1955).**

3. Results and Discussion

1. Chlorophyll content (µ mol m^{-1}).

The chlorophyll in leaves is an important factor than can be affected by NPK application. As shown in Table 6 chlorophyll content as affected by the interaction between studied genotypes and different fertilizer treatments at both studied seasons. Result indicated that Giza-102 responded positively to with Nano application which gave the highest chlorophyll percent with 100, 75m 50 % NPK after 6, 7, 8 weeks from sowing (WAS) in both seasons, followed by G-880 genotype after 8 (WAS) at 2021 and 2022. However, the lowest percent chlorophyll was reported in G-245 genotypes with Nano 75% NPK in 2021 season and G-245 genotype by treatment recommended NPK after 6 at 2022 season. The role of nano-NPK for increasing percent of chlorophyll a, b may be due to the beneficial effect of nano fertilizers in increasing the bioavailability of such necessary nutrients to the growing plants leading to increase chlorophyll forming and improved overall growth of the plant **Saad-Allah and Ragab (2020); EL-Madah *et al.* (2024**)**.** The results are harmony with those obtained by in Wheat **Abdel-Aziz *et al.* (2016); Al-Juthery *et al.* (2018); Burhan and Hassan (2019);** in Maize **Alzreejawi and Al-Juthery (2020);** in Grapevines **Mohamed *et al.* (2022);** in gladiolus plant Rose Supremplant **Sarhan *et al.* (2022);** in Valencia orange **El-Shereif *et al.* (2023**) and in Mahogany leaf **(Nofal *et al.* 2024)** comparing with mineral fertilizers.

Table 6. Chlorophyll content (μ mol l^{-1}) as affected by the interaction between sunflower genotypes and different fertilizer treatments at 6, 7 and 8 weeks after sowing at 2021 and 2022 seasons.

Chlorophyll content (μ mol l^{-1})							
Weeks after sowing		**2021**			**2022**		
Genotypes	**Nano NPK**	**6**	**7**	**8**	**6**	**7**	**8**
G-245	**100**	43.01 bcd	52.24 def	71.92 abc	44.93 cd	45.39 ef	76.00 hi
	75	41.27 cd	43.70 f	82.25 ab	46.25 cd	53.11 def	81.43 e-i
	50	46.45 bcd	48.39 def	75.44 abc	43.81 d	50.49 c-f	79.57 f-j
	0	47.83 bc	50.59 def	83.02 ab	41.31 d	44.55 f	83.10 d-i
G-465	**100**	44.93 bcd	45.39 def	81.26 ab	45.68 cd	49.06 def	83.21 d-i
	75	46.25 bcd	53.11 c-f	79.37 ab	45.08 cd	55.31 c-f	87.50 b-g
	50	43.81 bcd	50.49 def	68.16 abc	47.20 cd	54.96 c-f	81.41 e-i
	0	41.32 cd	44.55 ef	62.01 d	41.59 d	47.70 def	76.58 g-j
G-770	**100**	45.93 bcd	52.58 def	68.13 abc	48.88 cd	56.12 c-f	69.92 j
	75	45.05 bcd	48.92 def	74.10 abc	45.39 cd	49.38 def	84.24 d-i
	50	42.38 bcd	48.28 def	73.90 abc	42.38 d	49.14 def	92.69 a-d
	0	41.55 bcd	46.39 def	68.93 abc	41.70 d	49.39 def	84.10 d-i
G-775	**100**	42.49 bcd	63.75 b-f	77.00 abc	42.31 d	68.04 a-f	78.66 f-j
	75	45.11 bcd	64.38 a-d	74.34 abc	47.53 cd	68.00 a-e	84.17 d-i
	50	41.64 bcd	67.99 c-f	68.88 d	42.31 d	71.14 b-f	76.19 hij
	0	41.83 bcd	54.79 c-f	69.05 abc	41.50 d	56.72b-f	73.73 ij
G-880	**100**	45.96 bcd	55.47 c-f	87.99 ab	49.30 cd	59.06 a-e	102.77 a
	75	47.45 bc	60.02 c-f	83.19 ab	49.74 d	71.10 a-e	101.47 a
	50	43.26 bcd	58.12 c-f	83.42 ab	43.81 d	59.66 b-f	88.13 b-f
	0	42.94 bcd	60.09 c-f	80.21 ab	43.99 d	62.41 a-f	86.30 c-h
G-990	**100**	48.67 b	66.05 a-f	70.99 abc	55.82 c	72.85 a-d	92.19 a-e
	75	46.22 bcd	62.16 b-f	66.99 abc	47.70 cd	67.10 a-f	87.36 b-g
	50	41.75 bcd	66.26 a-f	72.41 abc	42.32 d	66.26 a-f	96.33 abc
	0	39.63 d	66.57 a-f	85.35 ab	40.67 d	68.91 a-f	88.89 b-f
Giza-120	**100**	74.32 ab	82.13 abc	96.40 a	75.84 b	75.87 abc	102.11 a
	75	78.72 a	84.75 ab	97.39 a	78.99 ab	82.75 ab	97.39 ab
	50	79.49 a	70.25 a-e	92.45 a	86.01 a	67.27 a-f	95.46 abc
	0	78.02 a	89.15 a	85.35 ab	77.88 ab	87.33 a	86.18 c-h
Significant		*	*	*	*	*	* *

*Means having the same letter within each column are not significantly differed at 0.05 level according to DMRT.

2. Seed oil content (hull and no hull %).

The oil content stayed one of the most important evaluation parameters of sunflower quality, whereat, Data in Table 7 shows that there were high significant differences on oil content with and without hull affected by the interaction between sunflower genotypes and different fertilizer treatments. In concern in oil content with hull, G-465 and G-245 genotypes with treatment control 0 % Nano was superiority wherein, gave the highest values 37.68 &38.88 % and 37.44 and 38.64 % at 2021 and 2022 seasons, respectively, G-465 genotype increased 84.79 and 69.42 % as compared to Giza120 in oil content with hull. Concerning to oil content without hull, G-465 genotype with control treatment gave superiority 50.24 & 51.44% at both studied seasons. Whilst, the lowest percent were recorded in Giza120 x75 with hull gave the minimum percent 22.24& 21.04 % and 50 % Nano without hull 34.75 & 35.85 % in oil content, respectively. Thus, using treatment control with G-465 genotype increased (69.4, 84.8 %) as compared to Giza120 x 75% Nano the lowest percent with hull seeds oil content at both studied seasons. The variances in seed oil content may be due to the genetic factors. These results had opposite trend from **Alhasan (2020)**; **Bapir and Mahmood (2022)**; **Maklid (2023)** who observed that application nano- fertilizer gave superiority in oil content and **Vadlamudi *et al.* (2022)** and **Bapir and Mahmood (2022)** who stated the highest oil content 41.44% was recorded conventional fertilizer + NPK Nano in sunflower, and Nano K increase oil content in onion **Salama *et al.* (2024).**

Table 7. Chemical and biochemical analyses in sunflower hull and non- hull seeds as affected by the interaction between sunflower genotypes and different fertilizer treatments at 2021 and 2022 seasons.

Genotypes	Nano NPK %	Oil content with hull (%)				Oil content without hull (%)				Phenols (mg g^{-1}) with hull			
		2021		2022		2021		2022		2021		2022	
G-245	100	32.37	ef	33.57	c	46.24	a-e	47.44	c	1.24	bc	1.12	c
	75	28.22	h	27.12	h	45.69	b-f	46.79	d	0.98	f	0.77	l
	50	36.34	ab	37.64	ab	46.79	a-d	47.79	c	0.20	j	0.19	r
	0	37.44	a	38.64	a	48.27	ab	49.17	b	0.66	ef	0.89	i
G-465	100	36.40	ab	37.50	ab	42.95	d-g	44.15	de	1.35	ab	1.15	c
	75	28.40	h	29.70	g	40.84	gh	39.64	f	0.19	j	0.39	o
	50	34.05	b-f	35.15	b	43.17	d-g	42.07	ef	1.18	cd	1.26	b
	0	37.68	a	38.88	a	50.24	A	51.44	a	0.49	g	0.72	l
G-770	100	34.30	b-f	33.20	c	38.87	H	39.97	ef	1.20	c	1.01	fg
	75	31.47	fg	32.67	d	42.52	d-h	43.62	e	0.57	f	0.35	op
	50	32.09	ef	30.89	f	40.44	g-h	39.24	ef	1.37	ab	1.25	b
	0	31.90	ef	33.10	c	45.58	b-f	46.48	d	0.58	f	0.79	k
G-775	100	31.38	ef	30.18	f	46.73	a-d	47.83	c	0.79	ef	0.57	m
	75	36.25	ab	37.45	ab	45.61	b-f	46.41	d	1.30	b	1.07	e
	50	29.08	gh	27.98	h	42.44	fgh	41.24	e	0.44	g	0.23	q
	0	34.71	a-e	33.41	c	47.98	abc	46.88	d	0.39	gh	0.22	r
G-880	100	27.19	h	28.39	gh	43.59	d-g	44.79	de	1.03	e	0.85	j
	75	32.87	def	31.67	e	46.24	a-e	47.24	c	1.39	a	1.49	a
	50	32.72	def	33.62	c	44.04	c-g	45.24	de	1.11	d	0.93	h
	0	31.56	fg	30.66	f	43.59	d-g	42.79	ef	1.12	d	0.90	i
G-990	100	27.92	h	29.02	g	49.00	ab	50.20	ab	0.92	f	0.75	l
	75	34.17	b-f	32.97	cd	34.44	I	35.64	h	0.68	ef	0.48	n
	50	32.10	ef	33.00	c	46.03	b-f	47.13	c	0.59	f	0.79	k
	0	27.25	h	28.05	gh	35.30	I	36.20	h	0.29	i	0.51	m
Giza-120	100	27.03	h	27.93	h	48.34	ab	49.54	b	1.00	e	1.22	bc
	75	22.24	i	21.04	i	43.88	c-g	43.08	f	0.27	i	0.30	p
	50	33.34	c-f	32.04	d	34.75	I	35.85	h	0.77	ef	0.99	gh
	0	35.49	a-d	34.39	bc	41.93	fgh	40.73	g	0.48	g	0.31	p
Significant		* *		* *		* *		* *		* *		* *	

*Means having the same letter within each column are not significantly differed at 0.05 level according to DMRT.

Table 8. Biological and stover yields after harvesting date (kg), seed and oil yields (t fad^{-1}) with and without hull as affected by the interaction between sunflower genotypes and different fertilizer treatments at 2021 and 2022 seasons.

G.	Nano NPK%	Biological yield (kg)		Stover yield (kg)		Seed yield (t fad^{-1})		Oil yield with hull (t fad^{-1})		Oil yield without hull (t fad^{-1})	
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
G-245	100	1.88 bc	2.32 b	0.41 bc	0.50 d	0.86	1.53 abc	27.82 cd	51.36 b	39.87 bcd	72.58 ab
	75	1.79 c	2.22 bc	0.37 bc	0.46 g	0.96	1.37 a-g	27.20 cd	37.07 g	39.83 bcd	63.96 bc
	50	1.88 bc	2.31 b	0.66 a	0.81 a	0.84	1.40 a-g	30.00 bcd	52.70 ab	39.53 bcd	66.91 b
	0	1.48 e	1.91 d	0.28 d	0.37 j	0.68	1.37 a-g	25.36 cd	52.82 ab	32.81 be	67.22 b
G-465	100	1.41 ef	1.83 e	0.34 c	0.44 i	1.12	1.27 c-g	40.74 ab	47.51 d	47.90 abc	55.94 de
	٧٥	1.48 e	1.71 f	28.0 d	0.33 k	0.88	1.30 b-g	24.72 cd	38.61 f	35.79 cde	53.51 e
	50	1.49 e	1.92 d	0.35 c	0.45 g	0.88	1.47 a-e	30.11 bcd	51.57 b	38.05 bc	61.72 c
	0	1.26 f	1.69 f	0.32 d	0.42 d	0.69	1.37 a-g	26.30 cd	53.15 a	34.94 cd	70.32 ab
G-770	100	1.25 f	1.63 f	0.25 e	0.34 n	0.95	1.10 hi	32.57 bcd	36.52 gh	36.74 bc	43.97 h
	75	0.85 h	1.28 i	0.21 f	0.32 n	0.99	1.17 f-h	31.25 bcd	38.13 f	41.81bcd	50.90 e
	50	2.20 a	2.46 b	0.30 d	0.37 j	1.01	1.20 e-h	32.18 bcd	37.07 g	40.81 bcd	47.09 g
	0	1.12 g	1.55 g	0.27 e	0.36 g	0.71	1.00 i	22.60 d	33.10 i	32.29 d	46.48 gh
G-775	100	1.13 g	1.56 g	0.25 e	0.35 j	0.92	1.33 a-g	29.09 bcd	40.14 ef	43.28 bcd	63.61 bc
	75	1.48 e	1.90 de	0.35 bc	0.45 e	0.95	1.40 a-g	34.67 abc	52.43 ab	43.69 bcd	64.97 bc
	50	1.47 e	1.91 de	0.36 bc	0.47 e	1.00	1.50 a-d	28.96 bcd	41.97 e	42.21 bcd	61.86 c
	0	1.52 d	1.96 d	0.37 bc	0.47 b	0.84	1.43 a-e	29.03 bcd	47.88 d	40.00 bcd	67.18 b
G-880	100	1.80 c	2.22 bc	0.40 c	0.49 b	0.98	1.43 a-e	26.68 cd	40.68 ef	42.80 bcd	64.18 bc
	75	0.74 j	1.16 j	0.18 g	0.30 n	0.99	1.13 gh	32.38 bcd	35.88 g	40.22 bcd	53.52 e
	50	0.74 j	1.17 j	0.20 w	0.32 n	1.37	1.23 d-h	44.83 a	41.45 ef	60.65 a	55.78 de
	0	1.12 g	1.55 g	0.23 f	0.32 n	0.78	1.17 f-h	24.53 cd	35.78 h	33.85 de	49.94 f
G-990	100	1.52 d	1.95 d	0.37 bc	0.47 e	1.06	1.17 f-h	29.46 bcd	33.87 i	52.30 ab	58.58 c
	75	0.85 i	1.28 i	0.23 q	0.35 i	0.95	1.30 b-g	32.51 bcd	42.86 e	32.76 de	46.33 g
	50	1.04 h	1.47 h	0.23 f	0.33 n	1.00	1.23 d-h	32.01 bcd	40.69 ef	45.77 abc	58.11 c
	0	1.02 h	1.45 h	0.25 f	0.35 l	0.83	1.30 b-g	22.44 d	36.47 g	29.12 e	47.06 g
Giza-120	100	1.68 cd	2.12 c	0.38 bc	0.48 c	1.14	1.60 a	30.60 bcd	44.69 de	54.68 ab	79.26 a
	75	1.57 d	2.01 c	0.35 c	0.45 d	1.08	1.50 a-d	23.85 d	31.56 ij	47.04 abc	64.62 bc
	50	2.19 a	2.52 a	0.44 b	0.53 c	1.11	1.57 ab	37.00 ab	50.21 bc	38.44 bcd	56.18 d
	0	1.75 c	2.18 d	0.41 bc	0.51 c	0.97	1.43 a-e	34.27 abc	49.28 c	40.47 bcd	58.37 c
Significant		* *	* *	*	*	N.S	*	*	*	*	*

*Means having the same letter within each column are not significantly differed at 0.05 level according to DMRT**.**

3. Total phenols (mg g^{-1}).

Study total phenols content is important to increasing the plant's ability stressful condition, especially, drought. Results in Table 7 shows that Total phenols content as affected by the interaction between sunflower genotypes and different fertilizer treatments in 2021 and 2022 seasons., G-880 genotype with using 75 % Nano NPK gave the highest values 1.39 & 1.49 mg g^{-1}, at 2021 and 2022 seasons. These results corroborate the study, whereas, nano fertilizer enhanced total phenols in plant as reported by **Rico *et al.* (2014)** and in peanut

El-Metwally *et al.* (2018). In Zaghloul date palm **AbdEl-Rahman and Abd-El-karim (2022)** and in onion **Salama *et al.* (2024).**

Table 9. Macro elements in stem after harvesting (kg fad^{-1}) as affected by interaction between genotypes and different fertilizer treatments at 2021and 2022seasons.

Genotypes	Nano NPK %	Stem											
		Nitrogen				Phosphorus				Potassium			
		2021		2022		2021		2022		2021		2022	
G-245	100	7.60	h	10.71	t	3.49	c	1.89	e-h	65.89	bc	61.53	i
	75	12.22	e	15.33	i	1.48	e	3.08	b-g	67.82	bc	64.46	gh
	50	19.28	d	16.17	h	4.29	b	2.79	b-g	51.50	e	49.14	k
	0	23.04	b	19.95	d	5.32	ab	3.72	a-d	60.74	d	65.10	gh
G-465	100	28.36	a	26.25	a	6.63	a	4.83	a	78.49	b	74.13	ef
	75	22.19	b	25.20	b	4.86	b	3.36	a-f	68.19	bc	64.89	gh
	50	7.71	h	10.82	s	1.47	e	3.07	a-f	67.04	bc	64.68	gh
	0	20.20	c	22.26	c	5.82	ab	4.22	abc	68.72	bc	71.40	f
G-770	100	21.78	c	18.69	g	2.04	d	3.64	a-d	97.39	a	93.03	a
	75	10.33	f	13.44	m	2.73	d	4.13	abc	70.83	bc	67.20	g
	50	5.38	i	8.40	x	1.32	e	2.92	b-g	49.77	f	46.41	k
	0	7.16	h	9.24	w	3.24	c	1.84	fg	36.17	g	40.53	m
G-775	100	8.06	h	11.13	r	3.49	c	2.09	d-h	59.09	d	61.95	h
	75	17.05	d	19.11	f	4.59	b	3.29	a-f	57.38	de	61.74	i
	50	11.65	e	14.70	k	4.25	b	2.95	b-g	56.49	de	59.85	j
	0	17.63	d	19.74	e	4.26	b	3.06	b-g	86.68	ab	82.32	bc
G-880	100	15.71	de	12.60	o	5.11	ab	3.51	a-f	63.00	c	59.64	j
	75	16.00	de	19.11	f	5.81	ab	4.41	ab	79.38	b	76.02	de
	50	13.45	e	11.34	q	2.39	d	3.99	abc	35.82	g	40.11	m
	0	17.56	d	18.69	g	4.05	b	2.45	c-g	63.09	c	66.36	gh
G-990	100	11.96	ef	9.87	v	4.60	b	3.00	b-g	34.40	g	37.38	n
	75	8.23	g	5.12	j	5.16	ab	3.86	a-d	49.35	f	45.99	kl
	50	15.29	de	12.18	p	4.26	b	2.16	d-h	88.99	ab	84.63	b
	0	8.39	g	10.50	u	2.56	d	1.26	h	83.11	b	78.75	cd
Giza-120	100	15.92	de	12.81	n	2.14	de	1.54	gh	51.25	e	47.67	k
	75	9.72	f	12.81	n	5.24	ab	3.64	a-e	46.62	fg	43.26	lm
	50	15.99	de	13.88	l	3.59	c	3.50	a-e	52.33	e	49.77	k
	0	11.33	ef	13.44	m	0.93	f	2.53	c-h	64.21	c	66.57	g
Significant		**		**		*		**		**		**	

* Means having the same letter within each column are not significantly differed at 0.05 level according to DMRT.

Table 10. Macro elements in leaves after harvesting (kg fad^{-1}) as affected by interaction between genotypes and different fertilizer treatments at 2021and 2022seasons.

Genotypes	Nano NPK %	Leaves											
		Nitrogen				Phosphorus				Potassium			
		2021		2022		2021		2022		2021		2022	
G-245	100	40.49	ab	37.38	abc	4.21	b	3.15	bcd	56.32	cd	51.66	gh
	75	38.67	ab	36.11	a-d	4.18	b	3.15	bcd	52.80	d	49.56	hi
	50	41.96	a	38.85	a	5.05	ab	3.99	ab	47.58	e	51.24	gh
	0	37.63	abc	35.49	a-f	1.71	e	2.73	c-f	59.91	c	55.65	fg
G-465	100	30.86	de	32.97	a-f	2.05	de	2.52	c-f	38.88	h	34.65	l
	75	36.64	b	35.49	a-f	2.65	d	2.73	c-f	48.79	e	45.57	j
	50	36.37	b	33.81	a-f	2.89	d	2.31	c-f	36.69	h	39.90	k
	0	27.97	e	31.08	a-f	2.95	d	2.52	c-g	44.85	f	48.09	i
G-770	100	42.17	a	39.06	a	4.01	b	3.57	abc	83.20	a	78.54	a
	75	24.73	g	26.88	f	3.21	c	2.94	bcd	47.96	e	45.57	j
	50	33.14	c	31.29	a-f	2.16	de	1.47	g	48.80	e	46.41	j
	0	27.82	e	30.66	a-f	3.97	bc	3.57	abc	40.85	g	38.46	k
G-775	100	24.32	g	26.88	f	2.59	d	2.10	d-h	47.96	e	45.57	j
	75	24.73	g	26.88	f	2.76	de	2.10	d-h	38.09	h	35.70	k
	50	35.64	b	32.55	a-f	3.02	c	2.89	cd	51.69	d	48.30	i
	0	33.20	c	36.45	a-d	2.89	d	2.10	d-h	60.81	bc	63.00	d
G-880	100	39.56	ab	36.54	a-d	6.01	a	4.41	a	71.54	ab	69.06	b
	75	35.24	b	33.60	a-f	3.11	c	2.10	d-h	69.97	b	65.31	bcd
	50	26.85	f	27.51	ef	3.32	c	2.31	d-h	36.16	h	31.50	m
	0	34.67	c	38.23	ab	2.28	de	1.26	h	58.42	cd	53.76	gh
G-990	100	27.61	e	29.61	b-f	5.26	a	4.20	a	42.25	g	37.59	k
	75	26.57	f	28.15	d	2.71	d	1.68	fg	56.11	cd	51.45	gh
	50	26.14	f	27.09	f	2.90	d	1.89	ef	69.13	b	64.47	cd
	0	29.86	de	31.71	a-f	3.12	c	2.10	d-h	62.25	bc	58.59	ef
Giza-120	100	32.41	d	29.40	c-f	3.34	c	2.31	d-h	63.98	bc	61.32	de
	75	31.89	d	29.82	b-f	1.88	e	0.84	i	43.72	g	39.06	k
	50	35.24	b	33.39	a-f	3.29	c	2.31	d-h	72.33	ab	68.67	bcd
	0	30.73	de	27.72	ef	3.21	c	2.31	d-h	62.83	bc	58.17	ef
Significant		*		*		*		* *		* *		* *	

* Means having the same letter within each column are not significantly differed at 0.05 level according to DMRT.

4. Yields

4.1. Biological, Stover (kg), seed and oil yields (t fad^{-1})

Seed yield considered the most important traits, it is an ultimate goal and facilitates the evaluation to check out the effectiveness of all treatments hence it should be, it is an absolute product, physiological and morphological processes occurring in plants during growth. As for the effect of the interaction among sunflower genotypes and different fertilizer treatments on Biological, Stover, seed and oil yields, results in Table 8 showed that had a high significant influence whereat, superiorities were recorded in Giza120 with 50 % Nano in biological yield (219 & 2.52 kg), and G-245 genotype was supreme to the other genotype in stover yield (0.66 & 0.81 kg) at both seasons. Against the lowest, the lightest weight of biological (0.74 & 1.16 kg) and stover (0.18 & 0.30 kg) yield were observed in G-880 genotype x 75 % Nano at 2021 and 2022 seasons. Regarding to seed yield t fad-1, Giza120 responded positively to with Nano application which gave the highest seed yield (1.60, 1.50& 1.57 t fad-1) with 100, 75 and 50 % NPK Nano followed by G-245 genotype. In concern oil yield, G-465 genotype x control gave superiority of oil yield with and without hull at 2022 season, followed by G- 245 genotype x control in oil yield with hull and without hull at 2022 season. Consequence, G-245 genotype was decrease 8.4 % compared of Giza120 with application 100% Nano NPK in non-hull oil yield the same season. Also in the same Table, G-465 genotype using 100% Nano was increased 70 % as compared to Giza120 x 75% Nano NPK interaction which considered the lowest value in hull oil yield in 2021 season. This might be due to the cause that foliar application of nano-NPK, which is regarded the biological pump for the plants to absorb nutrients, furthers the plant to absorb the nutrients efficiently and in turn enhance the photosynthesis rate Vadlamudi *et al.*. (2022; 2023). Similar significant effects were recorded by Abdel-Aziz *et al.* (2016) illustrated that nano fertilizer NPN excess yields in Wheat; in cotton Sohair et al. (2018); biological yield in Maize Alzreejawi and Al-Juthery (2020); Bapir and Mahmood (2022) and Vadlamudi *et al.* (2022, 2023) and Vadlamudi *et al.* (2023) implementing NPK Nano fertilizer in sunflower augment seed, biological, stalk yields kg ha^{-1} in sunflower.

5. Macro elements in plant.

5.1. Macro elements (kg fad^{-1}).

In the light results Data in Tables 9 and 10 indicated that high significant effect in the interaction between sunflower genotypes and different fertilizer treatments in macro elements percent in stem and leaves after harvesting date (kg fad^{-1}), results showed that G465 x 100% Nano NPK is supreme in nitrogen (28.36& 26.25kg fad^{-1}) and phosphorus (6.63 & 4.83 kg fad^{-1})content in stem after harvesting at both seasons, respectively. Also, G770 genotype x 100 % Nano gave superior on all studied genotypes where, gave the highest values in potassium content in stem (97.39 & 93.03kg fad^{-1}) and leaves (83.20 & 78.54 kg fad^{-1}) and nitrogen content in leaves (42.17 & 39.06 kg fad^{-1}) after harvesting at both seasons, respectively, In addition, implementation 100% Nano NPK x G880 genotype gave the highest percent phosphorus in leaves after harvesting date in 2021 and 2022 seasons. Similar significant effects were recorded by **Abdel-Aziz *et al.* (2016); Al-Juthery *et al.* (2018); Burhan and Hassan (2019)** in wheat statyed that applying Nano fertilizer NPK excess macro elements in plant; in leaf Lettuce **Nofal *et al.* (2021);** in Grapevines **Mohamed *et al.* (2022);** in gladiolus plant Rose Supremplant **Sarhan *et al.* (2022);** in Valencia orange **El-Shereif *et al.* (2023);** in Mahogany leaf **(Nofal *et al.* 2024)**, comparing with mineral fertilizers and **Salama *et al.* (2024)** in onion x Nano k**.**

5.2. Macro elements use efficiency in plants (kg kg^{-1})

Overall NUE in plant is a function of capacity of soil to supply adequate levels in nutrients and ability of plant to acquire, transport in roots and remobilize to other parts of the plant. The evaluation of NPK use efficiency is useful to differentiate plant genotypes for their ability to absorb and utilize nutrients for maximum yields, whereby, Tables 11 and 12 showed that interaction between sunflower genotypes and different fertilizer treatments, where, G-770 genotype x 50 % Nano gave the highest weight in nitrogen use efficiency in stem at both seasons and surpassed in phosphorus use efficiency content in stem at 2021 season. Regarding to the highest weight potassium use efficiency in stem and leaves were recorded in G-880 genotype x 50% Nano at both studied seasons. These results confirmed with those obtained by **Mustafa and Zaied (2019); El-Salhy(2021)** whose stated that application Nano fertilizer makes nutrients greater available to plant through leads to regulate the release of nutrients from fertilizers and therefore result in enhance nutrient use efficiency and reduce in nutrient doses **and AbdEl-Aziem *et al.* (2020)** whose, illustrated that Nano fertilizer NPK gave the maximum values in nitrogen, phosphorus and potassium use efficiency in potato.

Table 11: Macro elements use efficiency in stem after harvesting (kg kg^{-1}) as affected by the interaction between genotypes and different fertilizer treatments at 2021and 2022seasons.

Genotypes	Nano NPK %	Stem											
		Nitrogen				Phosphorus				Potassium			
		2021		2022		2021		2022		2021		2022	
G-245	100	113.55	ab	143.04	a	247.28	e	911.80	a	13.10	fg	24.87	cd
	75	78.56	d	89.87	fgh	649.97	ab	364.54	fgh	14.15	f	21.30	de
	50	43.72	g	84.91	gh	196.37	f	594.40	bc	16.37	e	27.97	bc
	0	29.51	i	67.77	ij	127.89	h	306.49	hi	11.20	g	20.83	de
G-465	100	39.60	h	47.20	ij	169.38	g	245.86	j	14.31	f	16.73	ij
	75	39.66	h	51.31	k	180.96	fg	513.38	bcd	12.91	fg	19.91	ef
	50	114.14	ab	130.85	ab	597.42	b	394.20	efg	13.13	fg	22.22	de
	0	34.16	h	62.26	ij	118.62	i	367.79	fg	10.04	h	19.42	ef
G-770	100	43.62	g	59.60	ij	465.69	c	337.39	fg	9.75	i	11.97	l
	75	95.55	b	87.59	fgh	361.54	d	258.69	i	13.93	fg	17.51	gh
	50	187.73	a	141.01	ab	763.42	a	483.43	cd	20.29	c	25.59	cd
	0	99.16	b	107.81	de	219.34	ef	460.72	de	19.63	d	24.77	cd
G-775	100	114.52	ab	119.52	cd	264.70	e	574.42	bc	15.62	ef	21.48	de
	75	55.89	f	72.86	h	207.63	ef	462.89	de	16.61	e	22.57	de
	50	85.58	c	101.20	ef	234.59	ef	628.11	b	17.65	e	24.87	cd
	0	47.65	g	72.29	hi	197.04	f	415.31	ef	9.69	i	17.31	gh
G-880	100	62.38	e	115.51	cd	191.67	f	407.75	ef	15.56	ef	24.51	cd
	75	61.88	e	58.67	ij	170.40	gh	232.06	j	12.47	fg	14.78	jk
	50	101.86	b	107.58	de	573.22	b	341.58	fg	38.25	a	30.34	ab
	0	44.25	g	63.65	ij	191.85	f	629.18	b	12.32	fg	17.93	gh
G-990	100	88.88	c	118.52	cd	231.24	ef	327.46	gh	30.90	ab	31.27	ab
	75	115.43	ab	85.11	gh	184.11	g	322.48	gh	19.25	d	27.97	bc
	50	65.40	de	103.15	de	234.74	ef	997.69	a	11.24	g	14.84	jk
	0	98.57	b	122.67	bc	323.43	d	1024.11	a	9.95	i	16.38	jk
Giza-120	100	71.61	d	124.31	abc	532.71	bc	949.25	a	22.24	b	33.35	a
	75	111.11	ab	117.00	cd	205.99	ef	324.65	gh	23.17	b	34.82	a
	50	69.62	de	112.48	cd	309.77	d	530.38	bcd	21.27	bc	31.38	ab
	0	85.35	c	106.60	de	639.78	ab	619.68	bc	15.06	ef	21.56	de
Significant		*		* *		* *		*		* *		*	

* Means having the same letter within each column are not significantly differed at 0.05 level according to (DMRT).

Table 12. Macro elements use efficiency in leaves after harvesting (kg kg^{-1}) as affected by the interaction between genotypes and different fertilizer treatments at 2021and 2022seasons.

Genotypes	Nano NPK %	Leaves											
		Nitrogen				Phosphorus				Potassium			
		2021		2022		2021		2022		2021		2022	
G-245	100	21.31	g	40.92	c	204.99	f	486.28	ef	15.32	de	29.62	c
	75	24.83	e	42.68	cd	229.67	ef	437.597	ef	18.18	cd	27.78	cd
	50	20.09	h	35.41	fg	166.93	gh	344.47	g	17.72	cd	26.82	cd
	0	18.07	i	38.31	ef	397.66	c	495.19	ef	11.35	f	24.42	cde
G-465	100	36.39	b	37.75	ef	547.80	ab	491.84	ef	28.88	a	35.90	ab
	75	24.02	e	36.45	ef	332.08	cd	473.73	ef	18.04	cd	28.36	cd
	50	24.20	e	42.24	bc	304.50	cd	618.23	bc	23.98	b	36.16	ab
	0	24.67	e	44.70	abc	233.90	e	550.34	cd	15.38	de	28.89	cd
G-770	100	22.53	f	28.58	j	236.91	e	311.92	gh	11.42	f	14.18	i
	75	39.91	ab	43.83	bc	307.48	d	400.27	f	20.58	c	25.84	cde
	50	30.48	d	38.07	ef	467.59	b	806.36	ab	20.70	c	25.60	cde
	0	25.52	e	32.67	h	178.84	g	279.12	h	17.38	d	25.91	cde
G-775	100	37.95	ab	49.47	abc	356.37	cd	651.43	bc	19.25	cd	29.22	cd
	75	38.54	ab	51.98	ab	345.29	cd	752.27	ab	25.02	ab	39.05	a
	50	27.97	de	45.80	abc	330.13	cd	387.13	f	19.29	cd	30.80	bc
	0	25.30	e	38.99	cd	290.66	de	472.74	ef	13.81	ef	22.62	d
G-880	100	24.77	e	39.88	cd	163.06	gh	330.51	g	13.70	ef	21.02	fg
	75	28.09	d	33.39	g	318.33	cd	606.67	bc	14.15	e	17.19	h
	50	51.04	a	44.98	abc	412.65	bc	529.15	de	37.89	a	39.12	a
	0	22.41	f	31.15	i	340.79	c	945.26	a	13.30	ef	22.13	d
G-990	100	38.50	ab	39.50	de	202.09	f	289.10	h	25.16	ab	31.10	bc
	75	35.75	b	45.73	abc	350.55	c	765.92	abc	16.93	d	25.05	cd
	50	38.26	ab	46.65	abc	344.83	c	668.07	bc	14.47	e	19.49	g
	0	27.70	de	40.56	cd	265.06	de	538.62	cd	13.29	ef	21.94	ef
Giza-120	100	35.17	b	54.93	a	341.32	c	602.09	bc	17.82	d	26.04	cd
	75	33.87	bc	50.66	abc	574.47	a	527.53	de	24.70	ab	38.34	a
	50	31.58	c	46.86	abc	338.30	c	674.90	bc	15.39	de	22.73	d
	0	31.47	c	52.02	ab	301.25	cd	619.87	bc	15.39	de	24.61	cd
Significant		*		*		*		* *		* *		* *	

* Means having the same letter within each column are not significantly differed at 0.05 level according to DMRT.

Table 13. Soil chemical properties of the experimental site as affected by sunflower genotypes and different fertilizer treatments at 2021 and 2022 seasons.

Genotypes	Nano NPK%	Chemical analyses of soil											
		pH (1:2.5)				Electrical conductivity (dsm^{-1})				Organic matter (%)			
		2021		2022		2021		2022		2021		2022	
G-245	100	8.12	cd	8.11	c-f	2.33	b	2.45	cd	1.10	bc	1.16	c
	75	8.14	c	8.17	a-e	2.45	ab	2.57	b	2.92	a	3.01	a
	50	8.17	b	8.22	abc	2.31	bc	2.33	f	0.68	de	0.77	f
	0	8.01	h	8.02	fg	2.36	b	2.41	de	2.51	b	2.60	b
G-465	100	8.00	i	8.01	g	2.32	bc	2.36	ef	0.51	g	0.60	l
	75	8.21	ab	8.21	abc	2.52	a	2.65	a	0.81	c	0.89	d
	50	8.13	c	8.14	b-f	2.31	bc	2.35	f	0.27	k	0.31	q
	0	8.11	d	8.12	b-f	2.21	d	2.26	j	0.64	de	0.73	g
G-770	100	8.17	b	8.19	a-d	2.24	cd	2.26	j	0.42	h	0.51	o
	75	8.11	d	8.12	b-f	2.22	cd	2.24	l	0.43	h	0.51	o
	50	8.20	b	8.22	abc	2.19	d	2.30	f	0.82	c	0.91	d
	0	8.16	b	8.17	a-e	2.36	b	2.47	c	0.32	j	0.41	p
G-775	100	8.13	c	8.14	b-f	2.20	cd	2.31	f	0.63	de	0.72	g
	75	8.16	bc	8.17	a-e	2.23	cd	2.34	f	0.58	f	0.67	j
	50	8.17	b	8.18	a-d	2.20	cd	2.31	f	0.74	d	0.83	e
	0	8.13	c	8.14	b-f	2.35	b	2.46	cd	0.60	e	0.69	h-k
G-880	100	8.26	a	8.28	a	2.15	d	2.26	j	0.47	h	0.53	n
	75	8.14	c	8.16	a-e	2.22	cd	2.31	f	0.49	h	0.58	mn
	50	8.14	c	8.15	b-e	2.26	c	2.35	f	0.65	de	0.74	gh
	0	8.21	ab	8.22	abc	2.23	cd	2.25	kl	1.07	bc	1.16	c
G-990	100	8.09	e	8.11	c-f	2.48	ab	2.53	b	0.67	de	0.68	i
	75	8.03	f	8.05	efg	2.44	ab	2.53	j	0.39	i	0.45	p
	50	8.13	c	8.15	b-e	2.17	d	2.26	i	0.13	l	0.14	s
	0	8.21	ab	8.24	abc	2.21	cd	2.27	f	0.56	f	0.65	kl
Giza-120	100	8.19	b	8.22	abc	2.24	cd	2.39	g	0.13	l	0.15	s
	75	8.12	cd	8.08	d-g	2.34	b	2.30	f	0.73	c	0.82	ef
	50	8.14	c	8.19	a-d	2.20	cd	2.25	j	0.21	k	0.25	r
	0	8.11	d	8.13	b-f	2.22	cd	2.29	h	0.39	i	0.44	p
Significant		**		**		*		**		**		**	

* Means having the same letter within each column are not significantly differed at 0.05 level according to DMRT.

Table 14. Macro elements content in soil after harvesting (ppm) as affected by interaction between genotypes and different fertilizer treatments at 2021and 2022seasons.

G	Nano NPK %	Macro elements in soil (ppm)											
		Nitrogen				Phosphorus				Potassium			
		2021		2022		2021		2022		2021		2022	
G-245	100	26.79	e	29.40	i	5.37	bc	6.70	a-e	31.67	cd	34.00	hi
	75	23.99	ef	26.60	kl	6.07	ab	7.40	a-d	25.71	e	28.00	kl
	50	25.49	ef	28.00	jkl	3.27	e	4.60	e	27.68	d	30.00	jk
	0	24.18	ef	26.60	kl	2.97	f	4.30	e	11.69	j	14.00	p
G-465	100	23.39	f	25.90	l	5.29	bc	6.30	a-e	39.71	bc	42.00	de
	75	25.45	ef	28.00	jkl	4.07	d	5.40	cde	21.72	g	24.00	m
	50	24.03	ef	26.60	kl	6.58	ab	7.60	abc	17.73	i	20.00	o
	0	33.14	c	35.70	ef	7.46	a	8.50	ab	35.74	c	38.00	f
G-770	100	32.44	c	35.00	f	5.21	bc	6.30	a-e	33.75	cd	36.00	gh
	75	26.09	ef	28.70	ijk	6.49	ab	7.60	abc	27.77	d	30.00	jk
	50	25.39	ef	28.00	jkl	5.18	bc	6.30	a-e	47.75	b	50.00	c
	0	36.59	b	39.20	cd	4.07	d	5.20	cde	29.64	d	32.00	ij
G-775	100	37.99	b	40.60	bc	4.74	c	5.90	b-e	49.73	b	52.00	c
	75	32.39	c	35.00	f	7.33	ab	8.50	ab	71.74	ab	74.00	b
	50	42.26	a	44.80	a	6.02	ab	7.20	a-e	39.71	bc	42.00	de
	0	30.99	cd	33.60	fg	5.17	bc	6.50	a-e	23.78	f	26.00	lm
G-880	100	28.20	d	30.80	hi	5.37	b	6.70	a-e	19.67	h	22.00	no
	75	29.58	d	32.20	gh	6.37	ab	7.70	abc	31.77	cd	34.00	hi
	50	21.21	f	23.80	m	5.67	b	7.00	a-e	41.66	bc	44.00	d
	0	34.75	bc	37.30	de	5.50	b	6.70	a-e	27.67	d	30.00	jk
G-990	100	38.03	ab	40.60	bc	3.78	d	5.00	cde	29.69	d	32.00	ij
	75	39.44	ab	42.00	b	7.87	a	9.10	a	33.67	cd	36.00	gh
	50	32.46	c	35.00	ef	4.16	c	5.40	cde	47.67	b	50.00	c
	0	28.27	d	30.80	hi	5.75	b	7.00	a-e	37.67	bc	40.00	ef
Giza-120	100	25.48	ef	28.00	jkl	5.44	bc	6.70	a-e	29.67	d	32.00	i
	75	38.01	ab	40.60	bc	5.43	bc	6.70	a-e	35.67	c	38.00	f
	50	26.79	e	29.40	ij	3.32	e	4.60	de	39.82	bc	42.00	de
	0	32.39	c	35.00	ef	5.01	bc	6.30	a-e	89.79	a	92.12	a
Significant		* *		* *		*		*		* *		* *	

* Means having the same letter within each column are not significantly differed at 0.05 level according to DMRT.

Table 15. Macro elements use efficiency in soil after harvesting (%) as affected by interaction between genotypes and different fertilizer treatments at 2021and 2022seasons.

G	Nano NPK	Macro elements use efficiency in soil %									
		Nitrogen				Phosphorus		Potassium			
		2021		2022		2021	2022	2021		2022	
G-245	100	6.31	l	16.67	h	19.64	21.90	45.40	d	41.38	hi
	75	5.08	m	5.55	j	5.67	7.93	55.67	c	51.72	ef
	50	11.15	g	11.11	i	35.61	37.87	52.28	c	48.27	fg
	0	5.05	m	5.55	j	39.54	41.80	79.84	a	75.86	a
G-465	100	7.18	k	5.16	j	12.61	14.87	31.53	f	27.59	lm
	75	9.15	i	11.11	i	24.77	27.03	62.55	bc	58.62	cd
	50	6.03	l	5.80	j	18.73	20.99	69.43	b	65.46	b
	0	31.51	d	41.67	de	22.33	24.59	38.38	e	34.48	jk
G-770	100	28.73	d	38.89	def	12.79	15.05	41.81	de	37.93	ij
	75	8.56	j	13.89	i	14.59	16.85	52.12	c	48.28	fg
	50	8.96	j	11.11	i	13.60	15.86	17.67	i	13.79	n
	0	45.20	bc	55.55	bc	27.47	29.73	48.90	d	44.83	gh
G-775	100	50.75	b	61.11	b	21.16	23.42	14.26	j	10.35	n
	75	28.53	d	38.89	def	22.33	24.59	23.96	h	27.59	lm
	50	67.70	a	77.78	a	6.30	8.56	31.53	f	27.58	lm
	0	22.98	e	33.33	efg	9.91	12.17	59.00	bc	55.17	de
G-880	100	11.90	g	22.22	g	9.18	11.44	66.09	bc	62.07	bc
	75	17.38	e	27.78	f	11.62	13.88	45.22	d	40.38	h
	50	15.83	ef	5.56	j	22.24	24.50	28.17	g	24.14	m
	0	37.90	c	48.02	cd	9.72	11.98	52.29	c	48.28	fg
G-990	100	50.91	b	61.11	b	30.17	32.43	48.81	d	44.83	gh
	75	56.51	ab	66.67	b	20.71	22.97	41.95	de	37.93	i
	50	28.81	d	38.88	def	24.77	27.03	17.81	h	13.79	n
	0	12.18	f	22.22	g	14.95	17.21	35.05	ef	31.03	kl
Giza-120	100	10.25	h	11.11	i	14.32	16.58	48.84	d	44.83	gh
	75	50.83	b	61.11	b	10.72	12.98	38.50	e	34.48	jk
	50	9.31	i	16.67	h	37.84	37.84	31.34	f	27.59	lm
	0	28.53	d	38.89	f-h	14.93	14.93	54.81	c	58.62	cd
Significant		*		*		N. S.		* *		* *	

* Means having the same letter within each column are not significantly differed at 0.05 level according to DMRT.

6. Soil analyses.

6.1. Chemical analyses of soil site.

Nano-fertilizers are highly efficient in supplying plants with nutrients and have physical properties. Table 13 shows that there were high significant in the interaction between sunflower genotypes and different fertilizer treatments on soil chemical properties of the experimental site after harvesting date during two studied seasons. The highest percent organic matter (2.92 and 3.01%) were found in G-

245 genotype x75 % Nano NPK in soil depth 30 cm after harvesting date in both seasons. Also, the highest percent (2.52 and 2.65 dsm^{-1}) of electrical conductivity in soil analyses from the same depth after harvesting date were recorded in G-465 genotype x 75 % Nano NPK followed by G- 245 genotype x75 % Nano NPK at both respective seasons but the lowest electricity conductivity were recorded in G-880 genotype x 100% Nano and gave the highest values pH percent in soil analyses after harvesting date at 2021 and 2022 seasons. The opposite trend was obtained by **Vadlamudi (2023)** who mentioned that there were non-significant in pH and organic matter in soil .

6.2. Macro elements content in soil (ppm).

Table 14 shows that high significant effect of macro elements in soil analyses from 0 to 30 cm after harvesting date among sunflower genotypes and different fertilizer treatments. Regarding to nitrogen element percent in soil after harvesting, the highest percent were reported in G-775 genotypes x 50 % Nano NPK at both studied seasons followed by G-990 genotype x 75 % Nano NPK. Respecting potassium content in the soil were observed in Giza-102 x control is supreme at the first and second seasons. Respecting to phosphorus, G-990 genotype x 75 % Nano NPK gave the maximum percent of phosphorus content in the soil from the same depth after harvesting date followed by G-775 genotype x75 % Nano and G- 465 genotypes x control at both studied seasons. The same trend was obtained by **Vadlamudi (2023)**.

6.3. Macro elements use efficiency in soil (%).

Use of Nano-fertilizers is one the potential option available for enhancing the nutrient use efficiency and increasing crop yields and also minimize its accumulation in the soil. Data in Table 15 shows the interaction between sunflower genotypes and different fertilizer treatments in macro elements use efficiency in soil after harvesting date at 2021 and 2022 seasons. G-775 genotype x Nano 50 % NPK gave the highest percent (67.70 and 77.78 %) of nitrogen use efficiency followed by G-990genotype with 75 % Nano NPK. Also, G-245 genotype gave superiority of percent potassium use efficiency in the soil after harvesting date (79.84 & 75.68 %) with control 0 NPK. These results confirmed with those obtained by **Vadlamudi (2023)**.

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