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RESEARCH ARTICLE

Effect of nano or/and normal application of N, P, and K fertilizers at different rates on growth, yield, and yield components of two squash hybrids
Part 1: Characteristics of flowering and yield

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Abstract

This study examined how two squash hybrids, Ola and Yara, responded to nano NPK fertilizers under the conditions of El-Minia Governorate, Middle Egypt, Egypt. Thirteen nutritional treatments were applied, including foliar application of nano NPK at 1000, 2000, and 3000 ppm either alone or combined with soil application of traditional NPK at 100%, 75%, 50%, and 25% of the recommended dose. The control treatment received 100% traditional NPK. Ola hybrid produced more male and female flowers, while Yara exhibited higher sex ratios. The results indicated that application of 3000 ppm nano NPK treatment significantly increased the number of female flowers and the Ola F1 hybrid plus 3000 ppm nano NPK interaction was the most effective. Ola produced longer fruits, whereas the Yara hybrid produced better fruit weights per plant and per fruit. The shape index was maximized by the combination of 50% NPK with Yara-1000 ppm nano NPK. Early and total fruit yield was significantly enhanced by the 3000 ppm nano NPK treatment, which outperformed the control by 8.4% and 3.5% for early yield and 6.5% and 5.1% for the total in the first and second seasons, respectively. Total soluble solids (TSS) exceeded the control in the average of all hybrids and seasons and was substantially equal (Ola) or increased (Yara) to the control with 2000 ppm nano NPK in the average of both seasons. Chlorophyll (Chl a, Chl b) and carotenoid levels showed no significant differences across hybrids, treatments, or interactions. In conclusion, foliar application of 3000 ppm nano NPK enhanced female flower production, early and total yield, as well as fruit quality in both hybrids, providing a cost-effective, environmentally safer alternative to traditional fertilizers for late summer squash cultivation.

Keywords: nano, fertilizers, squash

1. Introduction

Cucurbita pepo L. is a member of the Cucurbitaceae family (Lata and Lata, 2017). Tropical America is the birthplace of Squash growing. In particular, the southern United States and central Mexico (Filgueira, 2012), Squash was one of the primary foods consumed by Native Americans, particularly in central Mexico and the southern United States (Filgueira, 2012) and (Narke *et al.*, 2015). The plant is monoecious (Wang *et al.*, 2007). On a short stem, the fruit emerges from the base of the female flower (Schonbeck and Farmer, 2010). Because squash fruits are strong in carbohydrates, amino acids, vitamins, and minerals, it is very important nutritionally (Al-Mosali, 2007). Fertilizers play a vital role in increasing agricultural production, but excessive use of chemical fertilizers irreversibly damages the chemical ecology of soil and reduces the available area for crop production. Chemical fertilizers, therefore, inadvertently contribute to food insecurity in the long term by damaging fertile land. A very low percentage of fertilizer that reaches its target site have been found to be highly inefficient, using up approximately 40%, (Dijk and Meijerinck, 2014) due to

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leaching of chemicals, evaporation, drift, hydrolysis, run-off, and photolytic or microbial degradation. This decline in soil fertility with performance rates barely exceeding 30–40% over the past decades, including nitrogen (N) at 30–35%, phosphorus (P) at 18–20%, and potassium (K) at 35–40% (Subramanian *et al*., 2015). Agricultural practices that do not harm the planet must be implemented globally so that food production can be guaranteed for generations to come. One solution may come from Nano fertilizers, which do not rely on the heavy use of harmful chemicals. Switching from a conventional fertilizer to a Nano fertilizer could reduce the amount of chemicals used while simultaneously increasing crop yield. Nano fertilizers do this via various mechanisms, including increasing nutrient uptake, controlling the release of nutrients, and targeting nutrient delivery as well as distributed over a larger area of the soil, allowing for quick and simple absorption and long-term effectiveness maintenance (Nader and Danesh-Shahraki, 2013). Using a nano fertilizer can also reduce the environmental impact of agriculture. Its high solubility in comparison to its larger counterparts due to its huge surface area is the primary factor that sets this form of fertilizer apart from its ordinary counterpart (Derosa *et al*. 2010; Nair *et al*., 2010; Rameshaiah *et al.*,2015) and increasing the rate at which yields are produced (Rameshaia *et al*., 2015.). The goal of nanofertilizers is enhancing the nutrients uptake and efficiency of nutrients usage while minimizing the loss of nutrient via gaseous emissions and leaching along with preventing the risk of nutrient toxicity for food security, higher productivity, facilitate the site-targeted controlled delivery of nutrients, and enhance the economic turnouts by doing the sustainable farming processes as reported by (Iqbal, 2019).

The objective of this study was to evaluate the response of two squash hybrids to varying application rates of nano and/or conventional fertilizers. Flowering characteristics, yield, and yield components were assessed under the environmental conditions of El Minia Governorate, Middle Egypt.

2. Materials and Methods

The experiment was carried out during the two successive late summer seasons of 2022 and 2023 at the Experimental Farm, Faculty of Agriculture, El Minia University, El Minia Governorate, Middle Egypt, Egypt. The purpose of this experiment was to study the effect of foliar spray at three rates (as Nano) or /and soil fertilization with different concentrations of traditional NPK on the flowering characterícties, yield quantity and quality of the two hybrids of squash (*Cucurbita pepo L*.). Soil samples were taken randomly from the experimental field before planting at a depth of 0- 30 cm. for analysis according to Page (1982). The physical and chemical properties of the soil are shown in (Table 1).

The seeds of the two squash hybrids plants, namely the” Ola” F1 hybrid and the” Yara” F1 hybrid, The Yara hybrid seed were obtained from the company” NIAGARA” USA origin whereas, “ANTARIS” company for the Ola hybrid seed” Spain origin. The experimental field was plowed and finely tilled before ridge formation. The soil was then structured into rows and divided into plots. Each plot consisted of three rows, with each row measuring 3.5 m in length and 1 m in width, resulting in a total plot area of 10.5 m² (1/400 feddan). The spacing between plants within each row was 35 cm.Seeds were sown on August 31 in both seasons. Sowing was conducted on one side of each row, with one plant per hill.

Table 1. Analytical data of the studied soil before cultivation in the first and second seasons

Season	Sand %	Clay, %	Slit, %	Texture, %	pH value	Ec Mmhos/cm	Total $CaCO_3$	Organic matter	Total carbon	Available P ppm	Available K ppm	Total N%
First	13.1	52.4	34.5	Clay	8.45	1.38	6.50	2.00	1.16	4.00	310.0	0.10
Second	13.3	52.3	34.4	Clay	8.38	1.30	7.00	1.93	1.12	5.00	290.0	0.10

	Water soluble salts (1:5) me/100g soil							Micro-nutrients elements ppm			
	Na	K	Ca	Mg	Co_3	Hco_3	Cl	Fe	Mn	Zn	Cu
First	2.53	0.05	2.60	1.15	0.00	2.10	2.38	60.0	2.65	1.20	6.10
Second	2.44	0.05	2.55	1.30	0.00	2.00	2.45	61.0	2.57	1.37	5.52

A split-plot design within a completely randomized block design (CRBD) was implemented, with three replicates. The main plots were assigned to the two squash hybrids, while the sub-plots were designated for fertilizer treatments. Traditional fertilizers were applied to soil, whereas nano fertilizers were administered via foliar spray. The experiment included thirteen treatments (for each hybrid) as shown in Table 2 as soil addition or/and foliar spray fertilization. The sources of mineral fertilization were ammonium nitrate (33.5 % N), mono calcium superphosphate (15.5 % P_2O_5) and potassium sulphate (50 % K_2O) as sources of N, P and K with the recommended dose of NPK mineral fertilizer at a rate of 200, 150, 100 kg/feddan, respectively, soil addition as a control. This amount was reduced to 75%, 50% and 25%, soil addition with the foliar application of the nano-NPK treatments. Each rate of nitrogen fertilizer was divided into three equal doses of seven days intervals. After two weeks from planting, all the potassium sulphate and calcium superphosphate rates as well as one-third of N doses were applied as soil treatments. At the same time Nano fertilizers were applied once as foliar spray at three concentrations, *i.e.,* 1000, 2000 or 3000 ppm/L. All the other agricultural practices of squash production other

Table 2. Treatment concentration used in the current study as follows

Treatments	Nano Foliar spray	Soil addition
T1 (Control)	-	100 % NPK
T2	1000 ppm/L NPK	-
T3	1000 ppm/L NPK	75% NPK
T4	1000 ppm/L NPK	50% NPK
T5	1000 ppm/L NPK	25% NPK
T6	2000 ppm/L NPK	-
T7	2000 ppm/L NPK	75% NPK
T8	2000 ppm/L NPK	50% NPK
T9	2000 ppm/L NPK	25% NPK
T10	3000 ppm/L NPK	-
T11	3000 ppm/L NPK	75% NPK
T12	3000 ppm/L NPK	50% NPK
T13	3000 ppm/L NPK	25% NPK

than the applied treatments were done as recommended by the Egyptian Ministry of Agriculture. On the other hand, Synthesis and characterization of NPs-NPK nano-fertilizer (NPs-NPK NF) was performed according to Corradini *et al*. (2010) and was analyzed in Nanotechnology & Advanced Materials Central Laboratory (NAMCL), Agricultural Research Center (ARC), Giza, Egypt as follow:

N =7.5% , P_2O_5 = 9.5% , K_2O = 7.5%, Fe = 0.04%, Zn = 0.01% , Mn = 0.03% ,Mg = 0.07%, B = 0.01%, Mo = 0.35ppm, Cu = 2.45 ppm, S = 0.14% , Amino Acid = 0.03% .

Data were recorded for the following parameters:

A-Flowering characteristics

Fifteen plants from each treatment (five plants from each replicate) were labeled from the appearance of the first flower for ten days to record the following characteristics:

1- Average number of male lowers/plant.

2 - Average number of female flowers/plant

3-Average sex ratio $= \frac{\text{No.of Male flowers/plant}}{\text{No.of Femal flower/plant}}$

B- Fruit characters

1- Number of fruits/plant.
2- Fruits weight/plant (g)
3- Average weight /fruit (g)
4- Average diameter (cm)/fruit
5- Average length (cm)/fruit
6- Shape index for fruit according to (Buyanov and Voronyuk 1985)

C- chemical analysis

1- Total soluble solids content (TSS %): It was estimated by hand refractometer and the reading was corrected by laboratory temperature at the measurement, according to **Ibrahim (2010).**

2- Photosynthetic pigments determination: After seven weeks from planting, leaf samples (0.5 g) were collected and extracted using methanol alcohol in accordance to Moran (1982) to ascertain the contents of photosynthetic pigments, specifically: chlorophyll a and b, and carotenoids (mg/g FW), using a spectrophotometer set to wavelengths of 656, 665, and 452.5 nm, respectively. The results were then computed using the following formulas. Equations:

a - Chl. A = (16.5 × E 665) – (8.3 × E 656) 0.5/1000

b - Chl. B = (33.3 × E 656) – (12.5 × E 665) 0.5/1000

c - Carotenoids = (4.2 × E 452.5) – (0.264 × Chl. A) – (0.496 × Chl. B) 0.5/1000

D- Early and Total yield

Data were recorded for yield and its components as follow:

After five weeks from sowing, five plants from each replicate were labeled for recording the following parameters:

1-Early yield (ton/fed) started on the six of Oct. in both seasons and calculated as the sum of the yield of the first four pickings.

2-Total yield (ton/fed) were calculated as the sum of the total of all pickings which terminated on the eleventh of Nov in both seasons.

The collected data of this study was statistically analyzed using the MSTAT-C computer software program's design **(Bricker, 1991)**, and an analysis of variance was performed to verify the results. **Gomez and Gomez (1984)** provide examples of how the differences between the means of the various treatment combinations were compared. The comparisons were made using the Duncan Multiple Test according to Duncan **(1955)**.

3. **Result**

3.1. Flowering characteristics

Data presented in Table (3) indicate that a significant effect on the number of male and female flowers was obtained, in both seasons. The Ola hybrid showed a significantly higher No. of mean values of male (13.20 and 16.34) and female (11.22 and 11.98) flowers as compared with Yara hybrid, in both seasons. On the other hand, the Yara hybrid showed the most significant increases in sex ratio (2.56 and 2.33) in the first and second seasons, respectively. Regarding the various treatments, 3000 ppm nano NPK resulted in the most significant increase of male (13.2 and 16.15) and female flowers (9.150 and 10.05) in the first and second seasons, respectively, whereas, the sex ratio showed significant increases with (1000 ppm nano NPK plus 25% NPK) in the first season while the rate of (1000 ppm nano NPK) resulted in the most significant increases in the second season, respectively. Significant increases were obtained on the highest No. of male flowers as compared with control treatment, in the first season. Whereas, insignificant differences on the highest No. of female flowers and that obtained from control treatment, in both seasons. The values of sex ratio showed significant increases in the highest values as compared with control treatments, in both seasons Concerning the various interactions, the interaction of Ola and 3000 ppm nano NPK showed the most significant value, in No. of male flowers (14.50) in the first season, whereas the highest No. of females (12.80 and 13.30) in both seasons, at the same time, the interaction of Ola and (3000ppm nano NPK) + 75% resulted in the highest No. of male flowers (17.60), in the second season. Whereas, the interaction of Yara and (1000ppm nano NPK) +25% significantly showed the most significant increases in sex ratio (3.086 and 2.566), in the first and second seasons, respectively.

3.2. Fruits number /plant, average fruit weight (gm), and fruit yield /plant(kg)

Data presented in Table (4) indicate that there is a significant effect on the number of fruits per plant, in both seasons, In the first season, the Ola hybrid showed a significantly higher value (13.07) on the average number of fruits per plant compared to the Yara hybrid, while, in the second season the reverse was obtained where the Yara hybrid showed a significantly higher value (15.00) as compared with Ola hybrid. On the other hand, there are insignificant effects were obtained between Yara and Ola hybrids on average fruit weight, in both seasons. Also, data in Table (5) indicated that the average yield/plant between the Yara and Ola hybrids was insignificant in the first season, while the results in the second season showed that the Yara hybrid had a insignificantly higher value (1.36 kg) per/ Plant. Regarding the various treatments, insignificant effect was gained on average weight per fruit, in both seasons, whereas a significant effect was obtained on the average number of fruits /plant and average yield (kg)/ plant, in both seasons. The treatments of (3000 ppm nano NPK) in the first and second seasons resulted in the most significant increases in the average number of fruits/ plants i.e.: (15.00 and 16.17), respectively. At the same time, the results on the average fruit yield /plant(kg) were significant, in both seasons where the treatment of 3000 ppm nano NPK

Table 3. Effect of nano or/and normal fertilizer on the average number of male and female flowers, and sex ratio/plant in both hybrids of squash plants in both seasons

Treatment	No. Of mal flowers						No. Of female flowers.						Sex ratio					
	2022			2023			2022			2023			2022			2023		
	Yara	Ola	Mean	Yara	Ola	Mean	Yara	Ola	Mean	Yara	Ola	Mean	Yara	Ola	Mean	Yara	Ola	Mean
T1	12.30 def	13.70 bc	10.80 e	13.70 lm	17.20 c	15.45 abc	5.300 fg	12.60 ab	8.950 a	6.200 k	13.00 bc	9.600 ab	2.321 fg	1.087 lm	1.704 b	2.210 ef	1.323 jk	1.766 d
T2	9.90 m	11.70fgh	10.80e	12.80 q	15.20ij	14.00 c	3.40 i	9.20 e	6.30 f	5.10 p	9.87 i	7.485 d	2.912 c	1.272 i	2.092 a	2.510 ab	1.536 g	2.023 a
T3	10.56jkl	12.50 d	11.53de	13.10 p	15.60 h	14.35 bc	3.800 ghi	9.800 de	6.800 def	5.600 mn	10.80 g	8.200 bcd	2.763 d	1.276 i	2.020 ab	2.340 c	1.445 hi	1.892 bc
T4	10.57jkl	12.40 de	11.49 de	13.40 o	15.30 i	14.35 bc	3.600 hi	9.600 e	6.600 ef	5.500 no	10.60 g	8.050 bcd	2.973 b	1.292 i	2.132 a	2.437 b	1.443 hi	1.940 ab
T5	10.80ijkl	12.10 def	11.45 de	13.60 mn	15.10 j	14.35 bc	3.500 hi	9.293 e	6.397 f	5.300 op	10.30 h	7.800 cd	3.086 a	1.301 i	2.194 a	2.566 a	1.466 gh	2.016 a
T6	11.15 hij	13.90 b	12.52 abc	13.80 l	16.30 ef	15.05 abc	4.500 fghi	11.00 cd	7.750 cd	6.200 k	12.50% ef	9.350 abc	2.533 e	1.264 i	1.898 ab	2.226 ef	1.304 jk	1.765 d
T7	10.96 ijk	13.70 bc	12.33 a bcd	13.20 p	16.40 e	14.80 abc	4.300 fghi	11.40 abc	7.850 bcd	5.900 l	12.80 cd	9.350 abc	2.489 e	1.202 j	1.845 ab	2.237 def	1.281 k	1.759 d
T8	10.47klm	13.30 bc	11.88bcd	12.70 q	16.21 f	14.45 bc	4.100 fghi	11.20 bc	7.650 cde	5.400 no	12.40 ef	8.900 abcd	2.537 e	1.189 j	1.863 ab	2.352 c	1.307 jk	1.829 cd
T9	10.20lm	13.10 c	11.65 cde	12.30 r	16.00 g	14.15 bc	4.240 fghi	11.28 bc	7.760 cd	5.300 op	12.30 f	8.800 abcd	2.526 e	1.180 jk	1.853 ab	2.321 c	1.301 jk	1.811 cd
T10	11.99defg	14.50 a	13.2 a	14.90 k	17.40 b	16.15 a	5.500 f	12.80 a	9.150 a	6.800 j	13.30 a	10.05 a	2.328 f	1.133 kl	1.730 b	2.191 f	1.308 jk	1.750 d
T11	12.37de	13.82 b	13.10 a	13.50% no	17.60 a	15.55 ab	5.400 f	12.70 ab	9.050 a	5.867 l	13.10 ab	9.483 ab	2.260 h	1.094 lm	1.677 b	2.313 cd	1.343 jk	1.828 cd
T12	11.80efg	13.60 bc	12.40 abcd	13.20 p	17.20 c	15.20 abc	5.200 fg	12.60 ab	8.900 ab	5.800 lm	12.57 de	9.183 abc	2.270 gh	1.079 lm	1.674 b	2.276 cde	1.369 ij	1.822 cd
T13	11.40ghi	13.40 bc	13.00 a	12.80 q	17.00 d	14.90 abc	5.000 fgh	12.50 ab	8.750 abc	5.500 no	12.30 f	8.900 abcd	2.281 fgh	1.072 m	1.676 b	2.327 c	1.382 ij	1.855 bcd
Mean	11.11b	13.20a		13.30 b	16.34a		4.44 b	11.22a		5.72 b	11.98 a		2.56 a	1.18 b		2.33 a	1.37 b	

T1: Control (Soil addition 100 % NPK), T2: Spray 1000ppm nano NPK, T3: Spray 1000ppm nano+soil addition 75 % NPK, T4: Spray 1000ppm nano+soil addition 50 % NPK, T5: Spray 1000ppm nano+soil addition 25 % NPK, T6: Spray 2000 ppm nano, T7: Spray 2000 ppm nano +soil addition 75 % NPK, T8: Spray 2000 ppm nano +soil addition 50 % NPK, T9: Spray 2000 ppm nano +soil addition 25 % NPK, T10: Spray 3000 ppm nano, T 11: Spray 3000 ppm nano +soil addition 75 % NPK, T12: Spray 3000 ppm nano+soil addition 50 % NPK and T13: Spray 3000 ppm nano+soil addition 25 % NPK. Values within each column followed by the same letter are not significantly different at the 5% level resulted in the most significant increases (1.296 and 1.383 kg) in the first and second seasons, respectively A comparison between the highest values of the average fruits number /plant and average fruit yield /plant(kg)showed significant increases as compared with control treatment in the first season. In the meantime, insignificant differences on the average fruit weight (gm) between the highest values and the control treatment were obtained, in both seasons. Concerning the various interactions, between the hybrids and the different treatments, a significant effect was obtained, in both seasons. The interaction between Ola and (3000 ppm nano NPK) showed the highest value and followed by Yara and (3000 ppm nano NPK) i.e: (15.33 and 14.67), with insignificant differences between their values in the number of fruits in the first season. In the second season, data showed that the highest values were obtained from the interactions of Yara +(3000 ppm nano NPK)and Ola+(3000 ppm nano NPK) with the mean values of (17.00 and 15.33) on a number of fruits, respectively. Also, data on the average weight/ per /fruit indicated that the interaction of Yara and (1000 ppm nano NPK) +75% showed the highest value (110.4 g followed by the Ola and (3000 ppm nano NPK)+75% (104.8 gm) in the first season, with insignificant differences between their mean values. In the second season, the interaction between Ola and (3000 ppm nano NPK) +75% showed the highest average fruit weight (g) followed by Yara and (2000 ppm nano NPK) +50% with values of (103.44 and 99.03 g) with insignificant differences between their mean values.... Among the various interactions. On average yield per plant, Ola hybrid and (3000 ppm nano NPK) showed the most significant increases followed by Yara hybrid and (3000 ppm nano NPK) with values of (1.299 and 1.293 gm) in the first season. Whereas, in the second season Yara +3000 ppm nano NPK surpassed Ola and (3000 ppm nano NPK)with values of (1.483 and 1.312gm) respectively. However, insignificant differences were obtained between the mean values of all the mentioned interactions.

3.3. Average length (cm), average diameter (cm), and shape index/fruit

Data present in Table (5) indicated that insignificant effects were obtained between Yara and Ola hybrids on average length, diameter, and shape index per fruit, in both seasons. Regarding the various treatments, a significant effect was obtained on average length per fruit, in both seasons. The treatments of (1000 ppm nano NPK) +75% in the first season and (3000 ppm nano NPK)+75% in the second season resulted in the most significant increases in the average length of fruit i.e.: (11.08 and 11.28cm), respectively. Whereas, the results on the average diameter of fruits which obtained from the treatment of (3000 ppm nano NPK) showed significant increases with a value of (3.450 cm) in the first season. The treatment of (1000 ppm nano NPK) +50 % showed the most significant increases on shape index i.e.: (3.337), in the first season. In comparison between the highest values of the three parameters in this table, insignificant differences were obtained as compared with the values obtained from control treatment, in both seasons. Although, the values obtained from the control were slightly lower as compared with the highest values in these characters, in both seasons. Concerning the various interactions, between the hybrids and the different treatments, a significant effect was obtained, in both seasons. The interaction of Yara and (1000 ppm nano NPK) +75% showed the highest value, in average fruit length followed by the Ola and (2000 ppm nano NPK) +75% (11.23 and 11.06 cm) with insignificant differences between their mean values in the first season. While the interaction of Yara and

Table 4. Effect of nano or/and normal fertilizer on average number of fruit/plant and average weight (gm) /fruit and average yield of fruit /plant (kg) in both hybrids of squash plants in both seasons

Treatment	Fruits number /plant						Average fruit weight (g)						fruit yield /plant (kg)					
	2022			2023			2022			2023			2022			2023		
	Yara	Ola	Mean	Yara	Ola	Mean	Yara	Ola	Mean	Yara	Ola	Mean	Yara	Ola	Mean	Yara	Ola	Mean
T1	13.33 abcde	11.67 ef	2.50 bcd	15.00 abcd	13.33 cdef	4.17 ab	3.51 bc	97.19 abc	5.35 a	3.57 abc	95.21 abc	94.39 a	1.237 bcde	1.197 defg	1.217 b	1.393 bc	1.259 ghij	1.326 abcd
T2	11.00 fg	12.33 cdef	11.67 cd	14.67 abcd	13.67 bcdef	14.17 ab	96.19 bc	90.43 bc	93.31 a	87.78 bc	88.69 abc	88.24 a	1.053 mno	1.109 jklm	1.081 d	1.286 fgh	1.202 jklm	1.244 ef
T3	9.333 g	12.00 def	10.67 d	13.67 bcdef	11.67 f	12.67 b	110.4 a	89.89 bc	100.2 a	92.36 abc	99.54 ab	95.95 a	1.028 o	1.074 lmno	1.051 d	1.261 ghij	1.159 m	1.210 f
T4	11.00 fg	12.33 cdef	11.67 cd	13.33 cdef	14.00 bcdef	13.67 b	95.56 bc	88.60 c	92.08 a	97.28 abc	84.46 bc	90.87 a	1.046 no	1.087 klmno	1.066 d	1.269 ghi	1.179 lm	1.224 f
T5	12.33 cdef	13.00 bcdef	12.67 bcd	13.67 bcdef	13.67 bcdef	13.67 b	86.13 c	90.79 bc	88.46 a	93.91 abc	87.12 bc	90.51 a	1.056 mno	1.098 jklmn	1.077 d	1.273 fgh	1.185 klm	1.229 f
T6	13.33 abcde	14.00 abcd	13.67 abc	15.33 abc	14.33 bcde	14.83 ab	86.62 c	85.66 c	86.14 a	89.83 abc	89.51 abc	89.67 a	1.153 ghij	1.195 defg	1.174 c	1.376 cd	1.273 fgh	1.324 abcd
T7	12.00 def	13.00 bcdef	12.50 bcd	16.00 ab	12.67 def	14.33 ab	93.42 bc	89.24 c	91.33 a	83.35 c	95.59 abc	89.47 a	1.116 ijkl	1.156 ghij	1.136 c	1.330 def	1.209 ijklm	1.270 def
T8	11.67 ef	13.00 bcdef	12.33 bcd	13.67 bcdef	14.33 bcde	14.00 ab	98.00 abc	90.23 bc	94.11 a	99.03 abc	86.73 bc	92.88 a	1.130 hijkl	1.169 fghi	1.150 c	1.347 cde	1.238 hijk	1.292 cde
T9	12.33 cdef	14.00 abcd	13.17 abc	15.33 abc	14.00 bcdef	14.67 ab	92.57 bc	84.59 c	88.58 a	88.72 abc	89.36 abc	89.04 a	1.140 ghijk	1.180 efgh	1.160 c	1.355 cde	1.249 hij	1.302 bcde
T10	14.67 ab	15.33 a	15.00 a	17.00 a	15.33 abc	16.17 a	91.54 bc	85.20 c	88.37 a	87.40 bc	86.09 bc	86.75 a	1.293 ab	1.299 a	1.296 a	1.483 a	1.312 efg	1.383 a
T11	13.67 abcde	12.00 def	12.83 bcd	16.00 ab	12.00 ef	14.00 ab	89.63 bc	104.8 ab	97.23 a	89.88 abc	103.4 a	96.65 a	1.224 cdef	1.25%3 abcd	1.238 b	1.435 ab	1.236 hijkl	1.335 abc
T12	14.33 abc	13.67 abcde	14.00 ab	15.67 abc	13.67 bcdef	14.67 ab	86.80 c	92.98 bc	89.89 a	92.91 abc	93.05 abc	92.98 a	1.239 bcde	1.260 abc	1.249 b	1.454 a	1.266 ghi	1.360 ab
T13	13.33 abcde	13.67 abcde	13.50 abc	15.67 abc	14.00 bcdef	14.83 ab	93.69 bc	94.75 bc	94.22 a	93.91 abc	92.29 abc	93.10 a	1.243 abcd	1.276 abc	1.260 ab	1.466 a	1.278 fgh	1.372 a
Mean	12.48 b	13.07 a		15.00 a	13.50 b		93.39a	91.10 a		91.53a	91.62a		1.15 a	1.18 a		1.36 a	1.23 b	

T1: Control (Soil addition 100 % NPK), T2: Spray 1000ppm nano NPK, T3: Spray 1000ppm nano+soil addition 75 % NPK, T4: Spray 1000ppm nano+soil addition 50 % NPK, T5: Spray 1000ppm nano+soil addition 25 % NPK, T6: Spray 2000 ppm nano, T7: Spray 2000 ppm nano +soil addition 75 % NPK, T8: Spray 2000 ppm nano +soil addition 50 % NPK, T9: Spray 2000 ppm nano +soil addition 25 % NPK, T10: Spray 3000 ppm nano, T 11: Spray 3000 ppm nano +soil addition 75 % NPK, T12: Spray 3000 ppm nano+soil addition 50 % NPK and T13: Spray 3000 ppm nano+soil addition 25 % NPK. Values within each column followed by the same letter are not significantly different at the 5% level.

(2000 ppm nano NPK) +75% or (3000 ppm nano NPK)+75% resulted in the highest values (11.35cm) followed by Ola hybrid and (3000ppm nano NPK) +75% i.e:(11.22 cm) with insignificant differences between their mean values, in the second season. At the same time, the interaction of Ola with (3000 ppm nano NPK)+75% showed the highest average diameter of fruit (3.50 cm) followed by Yara+ (1000 ppm nano NPK)+75% resulting in a value of (3.483 cm) with insignificant differences between their mean values in the first season. Meanwhile, on the contrary, the interaction of Yara and (3000 ppm nano NPK) resulted in the highest value (3.49) with insignificant differences with the interaction of Ola +(3000 ppm nano NPK) +75% with the value of (3.48 cm) in the second season. The interactions of both hybrids and the various treatments on shape index showed significant effects in both seasons. The most significant increases were obtained from Yara and (1000 ppm nano NPK) +50% with a value of (3.450%) and Ola +(1000 ppm nano NPK)+25% with a value of (3.237) in the first season, respectively. Also, in the second season, Yara +(2000 ppm nano NPK) +25% resulted in a shape index with a value of (3.320), and Ola +(3000 ppm nano NPK) +75% showed a value of (3.293).

3.4. Average early yield (ton/fed) and average total yield (ton/fed)

Data present in Table (6) indicated that insignificant effect was obtained between Yara and Ola hybrids on average early yield, in both seasons. Whereas, the total yield showed significant differences between the two hybrids in the second season only. However, the total yield showed values of (13.63 and 12.34) ton / fed. with Yara and Ola hybrids, respectively. Regarding the various treatments, a significant effect was obtained between the various treatments, in both seasons. The treatments of (3000ppm nano NPK) in the first and second seasons resulted in the most significant increases on the average early yield i.e.: (3.87 and 3.87 tons/fed) in the first and second seasons, respectively. Also, the results on the average total yield (ton/fed) were significant, in both seasons where the treatment of (3000ppm nano NPK) resulted in the most significant increases with values of (12.96 and 13.93 ton/fed) in the first and second seasons, respectively. A comparison between the highest values of early yield and that obtained from the control treatment, which showed lower values with significant differences between their mean values, in the second season. Significant increases in the highest values of the total yield as compared with that obtained from control, in both seasons. Concerning the various interactions, between the hybrids and the different treatments, a significant effect was obtained, in both seasons. The interaction of Ola and (3000 ppm nano NPK) showed the highest value (3.91 ton/fed), in the early yield in the first season ,Whereas, in the second season, the results showed that the interaction between the Yara and Ola hybrids with treatment (3000 ppm nano NPK) was significant although the differences between their mean values were insignificant At the same time, the interaction of Yara and Ola with (3000ppm nano NPK) showed the highest significant average total yield (12.93 and 12.99 ton/fed) with insignificant differences between their mean values, in the first season. On the contrary, the interaction of Yara and (3000 ppm nano NPK) resulted in the highest significant value of the average total yield in comparison with the interaction of Ola + (3000 ppm nano NPK) i.e: (14.83 and13.12 ton/fed) in the second season. A comparison between the early obtained from nano (3000 ppm nano NPK) treatment and that which obtained from the control treatment

Table 5. Effect of nano or/and normal fertilizer on average length (cm), average diameter (cm) and shape index/fruit in both hybrids of squash plants in both seasons

Treatment	Average Length of fruit (cm)						Average Diameter of fruit (cm)						Shape indexes					
	2022			2023			2022			2023			2022			2023		
	Yara	Ola	Mean	Yara	Ola	Mean	Yara	Ola	Mean	Yara	Ola	Mean	Yara	Ola	Mean	Yara	Ola	Mean
T1	10.58 efg	10.90 bcd	10.74 ab	10.83 ghij	11.10 cd	10.96 abc	3.370 bcdef	3.370 bcdef	3.370 abcd	3.380 abcd	3.377 abcd	3.378 a	3.137 c	3.233 abc	3.185 abc	3.207 fg	3.287 cd	3.247 a
T2	10.90 bcd	10.60 efg	10.75 ab	10.53 l	10.62 kl	10.57 d	3.233 ghi	3.327 defgh	3.280 cde	3.347 bcd	3.330 cde	3.338 a	3.377 ab	3.187 bc	3.282 ab	3.147 h	3.190 gh	3.168 a
T3	11.23 a	10.94 bcd	11.08 a	10.97 defg	10.88 efgh	10.93 bc	3.483 ab	3.357 cdefg	3.420 ab	3.387 abcd	3.343 bcd	3.365 a	3.227 abc	2.923 d	3.075 c	3.240 cdefg	3.253 cdef	3.247 a
T4	11.04 ab	10.61 efg	10.82 ab	10.84 fghi	10.81 hij	10.82 bcd	3.200 i	3.293 efghi	3.247 de	3.327 cde	3.370 abcd	3.348 a	3.450 % a	3.223 abc	3.337 a	3.260 cdef	3.210 efg	3.235 a
T5	10.52 g	10.52 g	10.52 b	10.80 hij	10.72 ijk	10.76 cd	3.233 ghi	3.250 fghi	3.242 e	3.303 cdef	3.327 cde	3.315 a	3.253 abc	3.237 abc	3.245 abc	3.270 cde	3.227 defg	3.248 a
T6	10.55 fg	10.85 bcde	10.70 ab	11.00 def	10.84 fghi	10.92 bcd	3.320 defghi	3.400 abcde	3.360 abcde	3.407 abcd	3.370 abcd	3.388 a	3.177 bc	3.190 bc	3.183 abc	3.230 defg	3.217 efg	3.223 a
T7	10.83 bcdef	11.06 ab	10.95 ab	11.28 ab	11.03 de	11.15 ab	3.330 defgh	3.470 abc	3.400 abc	3.200 ef	3.417 abc	3.308 a	3.25%3 abc	3.187 bc	3.220 abc	3.527 a	3.230 defg	3.378 a
T8	11.02 abc	10.79 bcdefg	10.90 ab	11.34 a	10.95 defgh	11.15 ab	3.320 defghi	3.330 defgh	3.325 abcde	3.183 f	3.400 abcd	3.292 a	3.320 abc	3.243 abc	3.282 ab	3.567 a	3.217 efg	3.392 a
T9	10.83 bcdef	10.74 cdefg	10.78 ab	10.68 jk	10.90 efgh	10.79 cd	3.200 i	3.300 efghi	3.250 de	3.270 def	3.380 abcd	3.325 a	3.383 ab	3.25%7 abc	3.320 a	3.270 cde	3.227 defg	3.248 a
T10	10.58 efg	10.91 bcd	10.75 % ab	11.18 bc	10.96 defgh	11.07 abc	3.440 abcd	3.460 abc	3.450 a	3.490 a	3.427 abc	3.458 a	3.083 cd	3.153 bc	3.118 bc	3.203 fgh	3.200 fgh	3.202 a
T11	10.67 defg	11.03 ab	10.85 ab	11.35 a	11.22 abc	11.28 a	3.360 cdef	3.50%0 a	3.430 a	3.347 bcd	3.480 ab	3.413 a	3.173 bc	3.153 bc	3.163 abc	3.390 b	3.223 efg	3.307 a
T12	10.68 defg	10.82 bcdef	10.75 % ab	10.94 defgh	11.08 cd	11.01 abc	3.250 fghi	3.357 cdefg	3.303 bcde	3.440 abc	3.400 abcd	3.420 a	3.287 abc	3.223 abc	3.255 abc	3.180 gh	3.260 cdef	3.220 a
T13	10.65 defg	10.72 defg	10.68 ab	10.81 ghij	11.00 def	10.90 bcd	3.210 hi	3.313 efghi	3.262 de	3.350 bcd	3.340 bcd	3.345 a	3.320 abc	3.227 abc	3.273 abc	3.227 defg	3.293 c	3.260 a
Mean	10.78 a	10.81 a		10.97 a	10.93 a		3.30 a	3.36 a		3.34 a	3.38 a		3.26 a	3.18 a		3.28 a	3.23 a	

T1: Control (Soil addition 100 % NPK), T2: Spray 1000ppm nano NPK, T3: Spray 1000ppm nano+soil addition 75 % NPK, T4: Spray 1000ppm nano+soil addition 50 % NPK, T5: Spray 1000ppm nano+soil addition 25 % NPK, T6: Spray 2000 ppm nano, T7: Spray 2000 ppm nano +soil addition 75 % NPK, T8: Spray 2000 ppm nano +soil addition 50 % NPK, T9: Spray 2000 ppm nano +soil addition 25 % NPK, T10: Spray 3000 ppm nano, T 11: Spray 3000 ppm nano +soil addition 75 % NPK, T12: Spray 3000 ppm nano+soil addition 50 % NPK and T13: Spray 3000 ppm nano+soil addition 25 % NPK. Values within each column followed by the same letter are not significantly different at the 5% level.

Table 6. Effect of nano or/and normal fertilizer on early yield (ton/fed) and total yield (ton/fed)/ in both hybrids of squash plants in both seasons

Treatment	Early yield						Total yield					
	2022			2023			2022			2023		
	Yara	Ola	Mean	Yara	Ola	Mean	Yara	Ola	Mean	Yara	Ola	Mean
T1	3.52 abcdefgh	3.63 abcdef	3.57 abc	3.72 bcde	3.76 abc	3.74 bc	12.37 de	11.97 f	12.17 d	13.93 d	12.59 ij	13.26 c
T2	3.16 ijk	3.56 abcdefg	3.36 bc	3.43 ijk	3.39jkl	3.41 f	10.52 p	11.09 lm	10.81 h	12.86 h	12.02 lm	12.44 f
T3	3.09 jk	3.37 efghij	3.23 c	3.23 mn	3.18 n	3.21 h	10.28 q	10.74 o	10.51 i	12.61 ij	11.59 o	12.10 h
T4	3.25 ghijk	3.44 cdefghi	3.35 bc	3.33 klm	3.26 lmn	3.29 g	10.46 p	10.87 no	10.66 hi	12.69 hij	11.79 n	12.24 gh
T5	3.35 k	3.53 abcdefg	3.44 c	3.39 jkl	3.31 klmn	3.35 fg	10.56 p	10.98 mn	10.77 h	12.73 hi	11.85 mn	12.29 fg
T6	3.50 bcdefgh	3.78 abcdef	3.64 abc	3.72 bcde	3.66 bcdefg	3.69 bc	11.53 hi	11.95 f	11.74 e	13.76 d	12.73 hi	13.25 c
T7	3.20 hijk	3.49 cdefgh	3.34 bc	3.53 ghi	3.54 fghi	3.54 e	11.16 kl	11.56 hi	11.36 g	13.30 f	12.09 l	12.70 e
T8	3.31 fghijk	3.58 abcdef	3.45 abc	3.60 defgh	3.59 efgh	3.60 de	11.30 jk	11.69 gh	11.49 fg	13.47 ef	12.38 k	12.93 d
T9	3.39 defghij	3.65 abcdefg	3.52 abc	3.68 bcdef	3.65 bcdefgh	3.66 cd	11.40 ij	11.80 fg	1.60 ef	3.55 e	2.49 jk	13.02 d
T10	3.84 ab	3.91 a	3.87 a	3.87 a	3.87 a	3.87 a	12.93 a	12.99 a	12.96 a	14.83 a	3.12 g	13.93 a
T11	3.59 abcdef	3.65 abcde	3.62 abc	3.52 hij	3.65 bcdefgh	3.58 de	12.24 e	12.53 cd	12.38 c	14.35 c	12.36 k	13.36 c
T12	3.62 abcdef	3.72 abcd	3.67 abc	3.63 cdefgh	3.72 bcde	3.68 c	12.39 de	12.60 bc	12.49 bc	14.54 b	12.66 ij	13.60 b
T13	3.71 abcd	3.76 abc	3.74 ab	3.74 abcd	3.79 ab	3.76 b	12.43 cd	12.76 b	12.60 b	14.66 ab	12.78 hi	13.72 b
Mean	3.424 a	3.621 a		3.569 a	3.567a		11.51a	11.81a		13.63a	12.34b	

T1: Control (Soil addition 100 % NPK), T2: Spray 1000ppm nano NPK, T3: Spray 1000ppm nano+soil addition 75 % NPK, T4: Spray 1000ppm nano+soil addition 50 % NPK, T5: Spray 1000ppm nano+soil addition 25 % NPK, T6: Spray 2000 ppm nano, T7: Spray 2000 ppm nano +soil addition 75 % NPK, T8: Spray 2000 ppm nano +soil addition 50 % NPK, T9: Spray 2000 ppm nano +soil addition 25 % NPK, T10: Spray 3000 ppm nano, T 11: Spray 3000 ppm nano +soil addition 75 % NPK, T12: Spray 3000 ppm nano+soil addition 50 % NPK and T13: Spray 3000 ppm nano+soil addition 25 % NPK. Values within each column followed by the same letter are not significantly different at the 5% level.

(received 100% normal NPK) indicated higher in the range of 8.4 % and 3.5% for nano in the first and second season, respectively. On the other hand, the total yield with nano(3000 ppm nano NPK) treatment and control treatment showed higher total yield with nano (3000 ppm nano NPK) in the range of 6.5% and 5.1% in the first and second seasons, respectively. Although amount of nanomaterials and the cost of application for nano is more lower and more safe than that of control traditional fertilizer. In the meantime, most of the obtained characters in squash fruits showed that the presence of nano in any interactions enhanced their quality in most of its parameters.

3.5. Average total soluble solids (TSS), average Carotenoids, and average Chlorophyll a and Chlorophyll b

According to the data in Table (7), there was a significant variation in total soluble solids between the Yara and Ola hybrids during the first season. In this regard, Ola hybrid outperformed Yara. However, in the second season, a minor rise was achieved with Ola, with negligible differences when compared to the Yara hybrid. In relation to the various treatments, a noteworthy impact on TSS in fruits was seen across both seasons. In the first season, (2000 ppm nano NPK) demonstrated the most notable and cost-effective increases among the other treatments. In contrast, during the second

Table 7. Effect of nano or/and normal fertilizer on total soluble solids and average Carotenoids in both hybrids of squash plants in both seasons

Treatment	Total soluble solids (TSS)						Carotenoids					
	2022			2023			2022			2023		
	Yara	Ola	Mean	Yara	Ola	Mean	Yara	Ola	Mean	Yara	Ola	Mean
T1	4.750 h	5.700 abc	5.23 ab	4.80 bcdefg	5.06 a	4.93 a	0.06667a	0.06667a	0.06667a	0.06667a	0.08000a	0.07333 a
T2	4.520 i	5.250 f	4.89 ab	4.407 jk	4.600 ghij	4.503 de	0.06000 a	0.08000 a	0.07000 a	0.07000 a	0.06667 a	0.06833 a
T3	4.150 j	4.970 gh	4.560 b	4.080 m	4.430 ijk	4.255 f	0.07000 a	0.07000 a	0.07000 a	0.07667 a	0.07667 a	0.07667 a
T4	4.350 ij	5.230 f	4.790 ab	4.167 lm	4.750 defgh	4.458 ef	0.07667 a	0.06000 a	0.06833 a	0.08000 a	0.09667 a	0.08833 a
T5	4.500 i	5.380 ef	4.940 ab	4.330 kl	4.830 bcdefg	4.580 cde	0.08333 a	0.06667 a	0.07500 a	0.08667 a	0.07667 a	0.08167 a
T6	5.000 g	5.750 ab	5.375 a	4.750 defgh	5.000 abc	4.875 ab	0.08000 a	0.05333 a	0.06667 a	0.05333 a	0.07000 a	0.06167 a
T7	5.317 ef	4.810 gh	5.063 ab	4.550 hij	4.790 bcdefg	4.670 bcde	0.09667 a	0.06000 a	0.07833 a	0.07000 a	0.07333 a	0.07167 a
T8	4.800 gh	5.330 ef	5.065 ab	4.620 fghij	4.850 abcdef	4.735 abcd	0.07667 a	0.06333 a	0.07000 a	0.07000 a	0.07000 a	0.07000 a
T9	4.900 gh	5.500 cde	5.200 ab	4.720 defgh	4.900 abcde	4.810 abc	0.06333 a	0.07000 a	0.06667 a	0.06667 a	0.06500 a	0.08833 a
T10	4.800 gh	5.923 a	5.362 a	4.850 abcdef	4.867 abcde	4.858 ab	0.06333 a	0.06000 a	0.06167 a	0.07000 a	0.08333 a	0.07667 a
T11	4.500 i	5.450 def	4.975 ab	4.630 fghi	4.880 abcde	4.755 abc	0.05000 a	0.06333 a	0.05667 a	0.08333 a	0.07000 a	0.07667 a
T12	4.750 h	5.650 bcd	5.200 ab	4.700 efgh	4.950 abcd	4.825 ab	0.06667 a	0.05667 a	0.06167 a	0.07000 a	0.06667 a	0.06833 a
T13	4.88 gh	5.75 ab	5.315 a	4.780 cdefg	5.020 ab	4.900 ab	0.07000 a	0.06667 a	0.06833 a	0.05667 a	0.07333 a	0.06500 a
Mean	4.709 b	5.438 a		4.568 a	4.841 a		0.07 a	0.06 b		0.07 b	0.08 a	

T1: Control (Soil addition 100 % NPK), T2: Spray 1000ppm nano NPK, T3: Spray 1000ppm nano+soil addition 75 % NPK, T4: Spray 1000ppm nano+soil addition 50 % NPK, T5: Spray 1000ppm nano+soil addition 25 % NPK, T6: Spray 2000 ppm nano, T7: Spray 2000 ppm nano +soil addition 75 % NPK, T8: Spray 2000 ppm nano +soil addition 50 % NPK, T9: Spray 2000 ppm nano +soil addition 25 % NPK, T10: Spray 3000 ppm nano, T 11: Spray 3000 ppm nano +soil addition 75 % NPK, T12: Spray 3000 ppm nano+soil addition 50 % NPK and T13: Spray 3000 ppm nano+soil addition 25 % NPK. Values within each column followed by the same letter are not significantly different at the 5% level.

season, the control treatment exhibited the most notable increases. In all seasons, there was a notable impact on the diverse interactions between the hybrids and the various treatments. In the first season, the interaction between Ola and (3000 ppm nano NPK) had the highest value (5.923) among all soluble solids. According to the results, the Ola hybrid's interaction with the control treatment exhibited the most increases in the second season, specifically at (5.060). Data presented in Table (7) indicate a significant effect between the two hybrids on the carotenoids, where the Yara hybrid surpassed the Ola hybrid in this character in the first season. In the meantime, the reverse was obtained in the second season Among the various treatments and different interactions, insignificant effects were obtained on this parameter, in both seasons.

According to the data in Table (8), there were insignificant effects between Yara and Ola hybrids, all used treatments, and the interactions between hybrids and various treatments on chlorophyll a and chlorophyll b, in both seasons.

4. Discussion

There will be higher pressure on global agricultural systems to provide food security for the growing world population with environmental security in the coming years. The chemical fertilizers lead to the loss of nutrients from agricultural fields via leaching and gaseous emissions that create environmental pollution and climate change. Iqbal (2019) demonstrated that Farmers applied commercial fertilizers to crop plants for optimum plant growth that maintain the balanced distribution of the three primary macronutrients i .e: nitrogen (N), phosphorous (P), and potassium (K). Inefficient fertilizer management leads to environmental pollution, climate change, and economic consequences. Modern profit-oriented farming systems have been reported the utilization efficiency of nitrogenous fertilizers is only 45–50%, and for phosphorous fertilizers is only 10–25 %, and potassium (K) at 35–40% (Subramanian *et al*., 2015). Where, approximately half of the applied nitrogen fertilizer lost from agricultural fields to air, water, and other processes that lead to a negative impact on the environment, like N-oxides release into the atmosphere and lead global warming, and nitrate leached into marine ecosystem.Also, Shang *et al*. (2019) indicated that It has been reported that only 27 kg NPK ha−1 was needed for one ton of grain production in 1970, whereas in 2008 it had increased rapidly to 109 kg of NPK ha−1 to gain the same amount of production. Iqbal (2019) stated that commonly, the utilization efficacy of mineral or chemical fertilizers has remained below 30%.

New advanced nano-engineering is used to boost sustainable crop production while reducing chemical fertilization's negative impacts on the environment. Liu *et al*. (2009). studied the nano-biotechnology application to increase vegetable production. The carbon with 5 to 50% nm used as the Nano-fertilizer on eggplant, leek crops, radish, tomatoes, cabbage, and peppers. The results exhibited promoted the crops' growth with better quality and increased the yield 20% to 40%. However, nano-carbon could act as non-toxic materials in vegetable production. Shujuan *et al*. (2011) demonstrated the usage of nano-hydroquinone and nano-tea-polyphenols in nitrogen fertilizer in order to enhance the production, the number of nutrients (N,P,K) absorption, nitrogen fertilizer use efficiency, and leaf chlorophyll content of cabbage, where nano-preparation with 4% tea-polyphenols acted as the best effective treatment among other treatments. However, nano-preparation could enhance crop yields and improve fertilizer efficiency. Siddiqui *et al*. (2014) experimented with the effects of nano

Table 8. Effect of nano or/and normal fertilizer on average Chlorophyll a and Chlorophyll b in both hybrids of squash plants in both seasons

Treatment	Chlorophyll a						Chlorophyll b					
	2022			2023			2022			2023		
	Yara	Ola	Mean	Yara	Ola	Mean	Yara	Ola	Mean	Yara	Ola	Mean
T1	0.03667 a	0.03100 a	0.03383 a	0.04033 a	0.02933 a	0.03483 a	0.01000 a	0.01133 a	0.01067 a	0.05333 a	0.07667 a	0.06500 a
T2	0.03167 a	0.03033 a	0.03100 a	0.04067 a	0.03000 a	0.03533 a	0.01067 a	0.01133 a	0.01100 a	0.06667 a	0.08000 a	0.07333 a
T3	0.02867 a	0.03200 a	0.03033 a	0.03467 a	0.02867 a	0.03167 a	0.01167 a	0.01123 a	0.01145 a	0.06000 a	0.08000 a	0.07000 a
T4	0.03100 a	0.03100 a	0.03100 a	0.04167 a	0.04467 a	0.0432 a	0.01100 a	0.01100 a	0.01100 a	0.06667 a	0.08000 a	0.07333 a
T5	0.02867 a	0.03200 a	0.03033 a	0.03467 a	0.02867 a	0.03167 a	0.01100 a	0.01133 a	0.01117 a	0.09000 a	0.08333 a	0.08667 a
T6	0.03100 a	0.03100 a	0.03100 a	0.03233 a	0.03200 a	0.03217 a	0.01067 a	0.01067 a	0.01067 a	0.07000 a	0.08667 a	0.07833 a
T7	0.03133 a	0.03133 a	0.03133 a	0.03433 a	0.03100 a	0.03267 a	0.01200 a	0.01100 a	0.01150 a	0.09000 a	0.08333 a	0.08667 a
T8	0.03200 a	0.03100 a	0.03150 a	0.03633 a	0.03167 a	0.03400 a	0.01167 a	0.01133 a	0.01150 a	0.06333 a	0.08333 a	0.07333 a
T9	0.03200 a	0.03100 a	0.03150 a	0.04067 a	0.03067 a	0.03567 a	0.01300 a	0.01100 a	0.01200 a	0.07667 a	0.08333 a	0.08000 a
T10	0.03267 a	0.03100 a	0.03183 a	0.04133 a	0.03067 a	0.03600 a	0.01067 a	0.01067 a	0.01067 a	0.09333 a	0.09333 a	0.09333 a
T11	0.03400 a	0.03200 a	0.03300 a	0.03600 a	0.03500 a	0.03550 a 0.	0.01100 a	0.01167 a	0.01133 a	0.08667 a	0.09000 a	0.08833 a
T12	0.03300 a	0.03100 a	0.03200 a	0.03767 a	0.03200 a	0.03483 a	0.01167 a	0.01100 a	0.01133 a	0.06000 a	0.07667 a	0.06833 a
T13	0.03133 a	0.03100 a	0.03117 a	0.03800 a	0.02867 a	0.03333 a	0.01100 a	0.01133 a	0.01117 a	0.07333 a	0.07333 a	0.07333 a
Mean	0.03367 a	0.03100 a		0.04000 a	0.02767 a		0.011 a	0.011 a		0.07 b	0.08 a	

T1: Control (Soil addition 100 % NPK), T2: Spray 1000ppm nano NPK, T3: Spray 1000ppm nano+soil addition 75 % NPK, T4: Spray 1000ppm nano+soil addition 50 % NPK, T5: Spray 1000ppm nano+soil addition 25 % NPK, T6: Spray 2000 ppm nano, T7: Spray 2000 ppm nano +soil addition 75 % NPK, T8: Spray 2000 ppm nano +soil addition 50 % NPK, T9: Spray 2000 ppm nano +soil addition 25 % NPK, T10: Spray 3000 ppm nano, T 11: Spray 3000 ppm nano +soil addition 75 % NPK, T12: Spray 3000 ppm nano+soil addition 50 % NPK and T13: Spray 3000 ppm nano+soil addition 25 % NPK. Values within each column followed by the same letter are not significantly different at the 5% level.

silicon dioxide ($nSiO_2$ with 12 nm size) on the tomato (*Lycopersicum esculentum* Mill., cv. Super Strain B) to seed germination. The results exhibited the increment characteristics of seed germination, which showed improved percent seed germination, seed germination index, seed vigor index, mean germination time, seedling fresh, and dry weight. This proposed fertilizer provides an alternative source for conventional fertilizer system that may enhance sustainable agriculture via increase effectiveness for the growth and yield of crops. Mastronardi *et al.* (2015) indicated that there are a lot of research that exist for enhancing agricultural productivity via the use of nanotechnology. Nanomaterials can enhance the release profiles, interaction, and efficient uptake of plant nutrients for crop fertilization due to their small size, large surface area nature, catalytic reactivity, and shape, which also increase the environmental and economic benefits. fertilizers with nano-size can deliver required plant nutrition and enhance the sustainability of crop production without compromising the yield of the crop. Iqbal ((2019) reported that the ultimate goal of synthesizing and assess of nanofertilizers is enhancing the nutrients uptake and efficiency of nutrients usage while minimizing the loss of nutrient via gaseous emissions and leaching along with preventing the risk of nutrient toxicity for food security, higher productivity, facilitate the site-targeted controlled delivery of nutrients, and enhance the economic turnouts by doing the sustainable farming processes . In addition, the plant leaves also have stomatal openings and nanopores that easily uptake nanomaterial and penetrate deep inside leaves, facilitating the higher nutrient use efficiency (NUE). The plasmodesmata facilitate cell-to-cell transport within a plant that is nanosized (50%–60 nm) channels and are between cells. Fertilizers with nanoscale effectively transport and release nutrients to various transport channels and plant surfaces through plasmodesmata due to their small size. Mastronardi (2015) Indicated that nano-fertilizers enhance productivity (6–17%) and the nutritional quality of field plants via higher NUE and lesser nutrient losses. Also, the nanoscale used as fertilizer to provide antimicrobial properties or pest resistance. Some fertilizers are encapsulated by nanoscale films or keep in nanoscale pores or spaces within a host material. They are worked as a medium for nutrient adsorption and fertilizers able to protect from decomposition by microbes, heat, and sunlight within the nanosized interlayer space, and reducing fertilizer loss. Abdel-Aziz *et al*. (2016) researched the chitosan-NPK fertilizer application (chitosan nanoparticles loaded with the nitrogen, phosphorus, and potassium) for wheat plants via foliar uptake. The chitosan-NPK fertilizer exhibited easy application on leaf surfaces, easy transmission to stomata via gas uptake, and prevent direct interaction with soil systems. The experiments with wheat plants showed an increment in crop index, harvest index, and mobilization index of the determined wheat yield variables on sandy soil with nano chitosan-NPK fertilizer over normal fertilized NPK. Further, nano fertilizer also reduced the period of the life cycle of wheat plants than normal-fertilizer with the ratio of 23.5%. However, nano-fertilizers accelerate plant growth and productivity in order to increase the efficiency of agricultural practice and fertilizer usage. Different agronomic practices can be implemented to increase productivity in squashes (*Cucurbita spp*.), although they do not always give the same results. They depend on environmental factors such as temperature, environmental humidity, water quality as well as nutrients availability in the soil, which among other variables influence the precocity of maturation, the culinary quality and the fruit preservation capacity. It is clear from the results obtained from this experiment, that the fluctuant in data was high from season to the another which may be as result of the huge changes in the environmental conditions particular the change in the climate to higher temperatures during summer, and lower cold temperatures during winter Also, these differences may depend on the genetically differed between the two hybrids and the reaction for this genetically differed with all environmental conditions. These genetic differences between the two hybrids may be a result of a switch on and off for some genes whose role is controlled by biotic and abiotic stress conditions on plant growth. Many researches demonstrated the influence that the gene exerts on physiological processes by controlling the mechanism of synthesis of enzymes . Therefore, it could be concluded that spraying the two hybrids Yara and Ola of squash plants once after two weeks from sowing with nano NPK at the concentration of 3000 ppm had stimulated the female flowers, six ratio, early yield, and total yield with better fruits quality of the two squash hybrids grown on the late summer season than that obtained from soil application of traditional NPK. However, more studies are needed on nano NPK with higher rates, the number of foliar applications, and the proper plant age for application Also, the researchers should be responsible for the risks and limitations of nano fertilizer usage in order to take full advantage of nano fertilizers for sustainable crop production under changing climate while reducing the risk of causing environmental pollution.

Declarations

Authors' Contributions
All authors are contributed in this research

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Data Availability Statement
Data presented in this study are available on fair request from the respective author.

Ethics Approval and Consent to Participate
Not applicable

Consent for Publication
Not applicable.

Conflicts of Interest
The authors disclosed no conflict of interest.

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