Effect of spraying nano NPK fertilizer on the yield of canola varieties and their fatty acid content

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Abstract

During the 2024–2025 winter season, a field experiment was conducted in two locations in the Al-Rashidiya area and the Wana sub-district, in silty loam and sandy loam soils, respectively. To study the effect of Nano NPK fertilizer on the yield of three canola varieties and their content of fatty acids. Three Nano NPK fertilizer treatments (0, 2.5, and 5 g/L) and three canola cultivars (Serw, Raja, and Reandy) were used in the study. The Experiment was done in a split-plot design in compliance with the Randomized Complete Block Design having 3 replications. The main plots were assigned nano-NPK treatments whereas varieties were the subplots. It was found out that the concentration of the Nano fertilizer (5 g/L) performed remarkably better in seed yield, seed oil content, oil yield, oleic acid, linoleic acid, linolenic acid, palmitic acid, and stearic acid, at the two experimental sites. The Serw variety performed highly in seed yield, seed oil content, oil yield, and palmitic acid and stearic acid at the Wana site, oleic acid and linoleic acid at the Al-Rashidiya site, and linolenic acid, palmitic acid and stearic acid at the Al-Rashidiya site. The interaction between the 5 g/L concentration of Nano fertilizer and the Serw variety outperformed in seed yield at both experiment locations and in oil yield at the Al-Rashidiya location. Results show that nano-NPK fertilizer techniques can be adapted to aquatic plant and algal development systems, even though the experiment was conducted on a terrestrial oilseed crop. Applications of nano-fertilizers have been shown to improve nutrient uptake and fatty acid profiles, potentially leading to new nano-nutrient formulations that enhance oil quality and biomass productivity in aquatic organisms.

Keywords: Yield, Oil, Fatty acids, Nano NPK fertilizer, Canola, Aquatic plant, Algal system

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Introduction

After becoming the second-most-important oil crop after soybeans in less than 20 years, canola is regarded as a crucial oilseed crop and a significant source of the world's vegetable oils. Around 33.8 million hectares are thought to have been planted with it globally, yielding roughly 66.5 million tons, or an average yield of 1.9 tons per hectare (Hurley, 2010). Its cultivation in Iraq remains restricted to experimental purposes (Faisal, Abdullah and Hzaa, 2024).

The high oil content of its seeds can reach 50% in some types. The meal of canola seed is regarded as a rich protein source; thus, it is utilized in animal nutrition, since it raises the level of milk and meat production. To expand the cultivation of this crop, it is necessary to seriously consider researching its cultivation methods under various environmental conditions, as a valuable oil crop that will be important for future agricultural investment (Begna and Angadi, 2016; Rashid, 2003).

Agricultural sector is plagued by various issues including climate change, increased pressure on agricultural products, and degradation of the farms, among others that demand agriculture transformation to proceed and achieve economic and agricultural stability. Therefore, the importance of the implementation of nanotechnology that makes it possible to create modern mechanisms that can detect and address many agricultural problems (Al-Juheishy and Ghazal, 2023).

Nanoparticles have numerous benefits in the growth and productivity of numerous crops due to their specific features, including the prevention of the adverse consequences of the climate change on the productivity and the employment of less fertilizer. They also strive to detect illnesses when they are at an early infection stage (Waleed, 2023).

Due to their simple absorption and cell penetration, which enables them maximize the necessary application and efficiency in the body, nano fertilizers are viewed as a potential replacement of traditional fertilizers. Given their small size and the ability of nanoparticles to penetrate the cell walls and bind to protein carriers, they enhance an increased flow of nanomaterials between cells (Grover, Singh and Venkateswarlu, 2012; Boghori and Tabatabai, 2017).

Utilizing NPK fertilizer, which supplies nitrogen, phosphorus, and potassium in the proper ratio, improves the canola crop's development and yield. This contributes to improving crop quality and increasing its quantity, as well as supporting the integration of metabolic activities within the plant, which enhances agricultural efficiency and improves the sustainability of production (Hasan *et al*., 2013).

As well as their capacity to adjust to various environmental situations, varieties are thought to be among the most significant elements that directly impact growth, production, and quality attributes. According to numerous scientific studies, the interplay of genetic structures, environmental factors, and balanced nutrition management greatly influences both quantity and quality of output (Al-Jobury and Al-Juheieshy, 2024).

The results obtained by (Al-Jobury and Al-Juheieshy, 2024) in their study of two NPK fertilizer treatments (Traditional, Nano) showed that the Nano NPK fertilizer treatment significantly outperformed the traditional treatment in seed yield, seed oil content, and oil yield. Results from (Soliman, 2025; Hasan and Hussien, 2025) on three nano NPK fertilizer treatments (1, 3, and 5 ml/L) showed that the 5 ml/L treatment significantly outperformed the others in seed yield, seed oil content, and productivity.

(Liersch, Bocianowski and Bartkowiak-Broda, 2013) In the execution of an experiment, where the canola varieties were utilized (Kaszub, Kronos, Lisek, Lubusz, Pomorzanin, Samourai), the existence of significant differences among the varieties in the content of the oil in the seeds, the oleic acid, linoleic acid, linolenic acid, palmitic acid, stearic acid, and fatty acids was observed. (Mohammed, 2018). In the process of experimenting with three canola varieties (Pactol, Srew, Sputnick), it was discovered that the Pactol variety performed significantly higher in the content of oil in the seeds, yield of oil, oleic acid, and palmitic acid, the Srew variety performed significantly high in seed yield and the Sputnick variety performed significantly high in oleic acid, linoleic acid, linolenic acid and stearic acid. (Abdulkhaleq *et al.*, 2018). In the research process of examining an experiment on three canola varieties (Serw, Hybrid, and Reandy), the researchers discovered that there was a great difference between the varieties in terms of yielding seeds and oil content. Findings of (Hama, 2021) in his research of the three types of canola (Serw, Hybrid, and Reandy) revealed that Serw variety slightly outdid in the oleic, linoleic and linolenic acids and the Reandy slightly outdid in the oil yield and stearic acid. In his research on the three types of canola of varieties (Serw, Hybrid, and Reandy), he noted that the Serw variety had the most oil content on the seeds whereas Reandy was more successful on the seed yield.

The study will identify the right quantity of NPK fertilizer, the right type of canola variety that yields maximum productivity, and quantitative and qualitative estimation of fatty acids.

Nano NPK nutrient delivery, absorption efficiency, and improvement of lipid biosynthesis are principles that are particularly relevant to aquatic plant and algae production systems, even though this study focused on a terrestrial oilseed crop. The use of nanofertilizers is gaining popularity in aquaculture as a means to increase nutrient availability in aquatic habitats, boost microalgae growth, and improve the fatty acid profiles of these organisms for use as biofuels, feed, or bioproducts. Regarding nutrient uptake methods, growth responses, and oil quality enhancement, the present results provide a useful foundation for modifying nano-NPK fertilizer strategies for use with aquatic plant and algal systems.

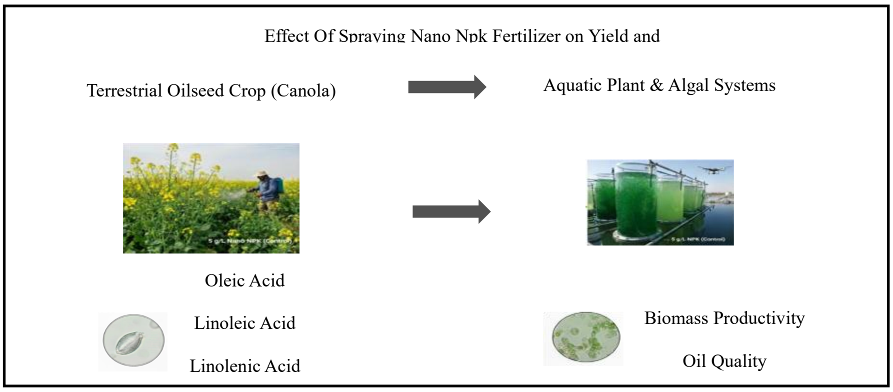


Figure 1: Impact of nano npk fertilizer on yield and fatty acid content in terrestrial oilseed crops and aquatic algal systems.

Figure 1 shows the effects of spraying nano NPK fertilizer on land oilseed (canola), as well as water plants and algae. The left picture depicts the treatment of the canola crop with a concentration of 5 g/L nano NPK fertilizer whereas the right image shows the treatment of aquatic plants and algae by the same fertilizer. The results of the observed outcomes are the increased content of Oleic acid, linoleic acid and linolenic acid in the oil seed crop and the enhanced biomass productivity and the quality of oil in the aquatic systems. This contrast shows the possible uses of nano NPK fertilizers on the land and on water, specifically, with the aim of increasing the yield and improving the nutrient content (Afify and El-Nwehy, 2023).

Materials and Methods

During the 2024–2025 winter season, a field experiment was conducted in two locations in the Al-Rashidiya area and the Wana sub-district, in silty loam and sandy loam soils for two places, respectively as shown in table 1, to study the effect of Nano NPK fertilizer on the yield of three canola varieties and their content of fatty acids. Three Nano NPK treatments (0, 2.5, and 5 g/L) and three canola cultivars (Serw, Raja, and Reandy) were used in the study. The Experiment was conducted using a split-plot approach in accordance with the Randomized Complete Block Design, with 3 replications. Nano-NPK treatments were assigned to the main plots, and varieties to the subplots.

The experiment was conducted on canola plants; however, the results regarding nutrient behavior and interactions between nanoparticles can help with the adaptation of nano-NPK application techniques for aquatic conditions in the future. Managed aquatic algae farms might benefit from using the same dosages and foliar/solution-based delivery methods.

Four rows, each measuring 2 meters in length, with a 40-cm gap between rows and a 10-cm gap between plants, made up the experimental unit. The two middle rows were used for readings, while the two outer rows were kept as guard rows. A distance of one meter separated the experimental units from one another, and the treatments were assigned to them at random, with a distance of 1.5 m between each replication by 1.5 m. The land of the experiment was plowed twice in perpendicular directions, then leveled and smoothed, and afterward, it was divided into experimental units. The planting was carried out on 20/11/2023. During the growth season, weeding was done twice, and when the plants were fully grown, the experiment was harvested.

Table 1: Lists a few of soil's chemical and physical characteristics at two locations.

physical characters	Al-Rashidiya	Wana District
Sand (%)	14.2	58.43
Silt (%)	53	23.07
Clay (%)	32.8	18.5
Texture	Silty loam	Sandy loam
	Chemical characters	
Available N (ppm)	140.6	57
Available P (ppm)	38	7.6
Available K (ppm)	20	105.5
E.C. (mmhos/cm)	1.7	0.13
pH	7.5	7.6

Studied Traits

1. **Seed yield (kg/ha):** Harvested the two middle rows of every experimental unit, and the area was then computed.
2. **Oil content in seeds (%):** A Soxhlet was used to calculate the seeds' oil content (AC, 1995).
3. **Oil yield:** Calculated as seed yield (kg/ ha) × Oil content in seeds (%).
4. **Determination of fatty acids:**

Esterification of Fat

Sample was prepared using a procedure approved by the (AC, 1995), which entails esterifying lipids by a reaction with methanolic potassium hydroxide. This solution was created by dissolving 11.2 g of potassium hydroxide in 100 mL of methanol. One gram of fat was then mixed with five milliliters of hexane and eight milliliters of methanolic potassium hydroxide. After a vigorous 30-second shake, the mixture was allowed to separate into two layers. After being removed from the hexane layer, the esterified fat was introduced into the apparatus.

The Sample's Chromatographic Analysis

A Shimadzu, Japan-made gas chromatography instrument (GC-2010) was used to investigate the fatty acid constituents. The apparatus had a capillary separation column of SE-30 type and a flame ionization detector (FID), measuring 30 m by 0.25 mm, according to the conditions mentioned in table 2.

Table 2: Conditions for analyzing fatty acids using gas chromatography.

Sequence	Name of paragraph	Temperature
1	Temperature of the injection area	280 C
2	Temperature of the detector	310 C
3	Temperature of the separation column	120 – 290 (10 C / MIN)
4	Rate of gas flow	100 Kpa

According to (Al-Rawi and Khalaf-Allah, 2000), comparison of means was done using the Duncan multiple range test at 1 percent and 5 percent probability level. The data of the studied features was analyzed with the help of statistical program (Berglund and Heeringa, 2014) to correspond to the experimental design.

Results and Discussion

Effect of Nano NPK Fertilizer

The findings in table 3 show that there are significant differences in the levels of nano NPK fertilizer in seed yield at both locations, Al-Rashidiya and Wana. The 5 g/L fertilizer level recorded the highest value for this trait, reaching 1303.61 and 1356.55 kg/ha at the two locations, respectively, while the 0 g/L level recorded the lowest value, at 1099.28 and 1145.75 kg/ha at the two locations, respectively. More dry matter accumulates in the seeds as a result of the increased surface area that nano fertilizers provide for various metabolic processes within the plant, which accelerates photosynthesis (Kalia, & Kaur,2019; Al-Jobury and Al-Juheieshy, 2024; Soliman, 2025) have also reported similar results.

Nano fertilizer levels also differed significantly in oil content in seeds at both experimental sites. The 5 g/L fertilizer level gave highest oil content values of 35.90% & 36.46%, whereas control treatment given lowest values of 30.57% & 31.32% at the two sites, respectively. Superiority of the 5 g/L nano fertilizer treatment may likewise be due to the larger surface area it provides for various metabolic activities inside plant, leading to an increased photosynthetic rate and greater deposition of dry matter in the seeds. These outcomes align with those of these outcomes align with those of (Al-Jobury and Al-Juheieshy, 2024; Soliman, 2025).

Levels of nano fertilizer had a significant impact on oil yield at both locations. 5 g/L fertilizer level produced the highest oil yield values, reaching 468.16 and 494.63 kg/ha, nevertheless control treatment given lowest values, at 336.38 and 359.43 kg/ha at the two sites, respectively. This is because 5 g/L nano NPK fertilizer treatment outperformed the others in terms of seed yield and oil content in seeds (Table 4), which ultimately led to higher total oil yield. The results presented by (Al-Jobury and Al-Juheieshy, 2024; Soliman, 2025) are in agreement with these findings.

Table 3 also shows significant differences among nano fertilizer levels in oleic acid content at both experimental sites. The 5 g/L level recorded the highest oleic acid values, at 35.90% & 36.46%, while control treatment given lowest values, at 21.35% & 19.09% for the two sites, respectively. The increase in cellular energy enhances chlorophyll production, which in turn promotes photosynthesis, followed by an intensification of nitrogen assimilation within the cell, resulting in the highest possible oleic acid content.

Significant variations in the quantities of nano fertilizer in the linoleic acid content at both experimental sites are shown by the results in table 3. The highest values, 35.84% and 33.06%, were recorded at the 5 g/L level, while the lowest values, 28.96% and 27.07%, were observed in the control treatment, at the two sites, respectively.

Significant differences were also found among nano fertilizer levels in linolenic acid content at both sites. The

5 g/L level given highest values, 2.77% and 2.43%, while control treatment given lowest values, 1.43% and 1.32%, respectively.

Palmitic acid concentration at both sites was significantly impacted by nano fertilizer treatments as well. The 5 g/L level produced values of 13.57% and 12.36%, while the 0 g/L level recorded the lowest values, 6.81% and 6.09%, for the two sites, respectively.

Similarly, significant differences were observed in stearic acid content at both sites. The highest values, 5.76% and 3.27%, were recorded at the 5 g/L level, while control treatment given lowest values, 1.90% and 1.27%, respectively.

Table 3: Effect of nano NPK fertilizer on yield, oil and fatty acid concentration.

Nano NPK Fertilizer (g/l)	Seed yield (kg/ha)	Oil content in seeds (%)	Oil yield (kg/ha)	Oleic acid (%)	Linoleic acid (%)	Linolenic acid (%)	Palmitic acid (%)	Stearic acid (%)
				Al-Rashidiya				
0	1099.28c	30.53c	336.38c	21.35c	28.96c	1.43c	6.81c	1.90c
2.5	1229.72b	34.08b	419.115b	24.74b	32.59b	2.12b	10.22b	3.52b
5	1303.61a	35.90a	468.16a	28.015a	35.84a	2.77a	13.57a	5.76a
				Wana				
0	1145.75c	31.32c	359.43c	19.09c	27.07c	1.32c	6.09c	1.27c
2.5	1284.42b	34.87b	447.98b	22.59b	30.15b	1.87b	9.14b	2.03b
5	1356.55a	36.46a	494.63a	24.61a	33.06a	2.43a	12.36a	3.27a

Significant differences exist between values in the same column that are followed by different letters.

Effect of Cultivars

Significant variations in seed yield between cultivars at both experimental sites are shown in table 4. Cultivar Serw recorded highest values, 1244.17 and 1291.63 cm, while the cultivar Reandy recorded the lowest values, 1179.04 and 1238.09 cm, respectively. This may be attributed to the ability of *Serw* to make maximum use of the environmental conditions surrounding its growth, performing better than the other cultivars. This enhanced its photosynthetic activity, causing the seeds, the sink, to accumulate more nutrients, which in turn causes the weight of the seeds to increase. The results shown (Mohammed, 2018; Abdulkhaleq *et al*., 2018; Hama, 2021) by agree with these findings.

Cultivars also had a significant impact on oil content in seeds at both experimental sites. Serw cultivar recorded highest oil content, 34.27% and 34.96%, and did not differ significantly from the Raja cultivar, which recorded 33.44% and 34.07%. In the meantime, Reandy cultivar registered the lowest oil content, 32.81 and 33.62 percent, respectively. The difference in oil content of the seeds among the cultivars could be attributed to the fact that the environment favors better cultivar as compared to the others and also the difference in genetic composition of the cultivars in their oil content of seeds. These findings are similar, according to (Liersch, Bocianowski and Bartkowiak-Broda, 2013; Mohammed, 2018; Abdulkhaleq *et al*., 2018; Hama, 2021).

Diversity of cultivars increased the yield of oil at the two sites tremendously. The Serw cultivar had the greatest values, 427.38 and 452.78 kg/ha whereas the Reandy cultivar had the lowest values, 389.53 kg/ha at the Al-Rashidiya site. The Raja cultivar registered the lowest value in the Wana site with a value of 430.25 kg/ha. It is possible that the superiority of Serw was because of its high yield in seed and oil content table 3 which eventually led to oil yield. These findings are in consensus with the results produced by (Mohammed, 2018; Hama, 2021).

Cultivar differences also resulted in a great difference in oleic acid content at Al-Rashidiya site. The highest value was registered under plants of Raja cultivar, which were 26.21, and by plants of Serw, and Reandy, the lowest values were 23.59 and 24.44 respectively. This can be attributed to the powerful effect of growth conditions, climate, and the length of the growing season on the proportion of unsaturated to saturated fatty acids in seed oil. (Mohammed, 2018; Hama, 2021) have all reported similar outcomes.

Cultivar differences also resulted in a significant increase in linoleic acid at Al-Rashidiya site. Plants of the Raja cultivar recorded the highest value, 33.59%, while Serw recorded the lowest value, 31.20%, which did not differ significantly from Reandy at 32.60%. This may be attributed to genetic differences among cultivars. (Mohammed, 2018; Hama, 2021) all found similar results.

At Al-Rashidiya location alone, results in table 4 show significant variations in linolenic acid content between cultivars. Plants of the Raja cultivar recorded highest value, 2.34%, while Serw and Reandy recorded lowest values, 1.89% and 2.09%, respectively. The cultivars' genetic differencescould be the cause of this. (Mohammed, 2018; Hama, 2021) have all reported similar outcomes.

Cultivars also caused a significant increase in palmitic acid at both experimental sites. At Al-Rashidiya site, the Raja cultivar recorded the highest value, 11.44%, while Serw and Reandy recorded the lowest values, 9.14% and 10.02%, respectively. In the Wana site, Raja plants showed the lowest value of 10.11%, followed by Reandy with 9.13%, and Serw had the lowest overall value of 8.14%. The results show that the fatty acid profile is largely controlled by genetic factors as well as by multiple environmental factors, specifically highlighting overwhelming roles played by water availability, the availability of nutrients (NPK), and the growing period. According to (Mohammed, 2018), the results are in agreement.

Significant differences in stearic acid concentration between cultivars at both sites are also evident from the results in table 4. Raja cultivar given highest values, 4.37% and 1.87%, while Significant differences in stearic acid concentration between cultivars at both sites are also evident from the results in table 4. recorded the lowest values, 3.08% and 2.55%, respectively, which did not differ significantly from *Reandy*, recording 3.73% and 2.15%. This difference may be attributed to genetic variation among cultivars. According to (Mohammed, 2018; Hama, 2021), these results are Similar.

Table 4: Effect of varieties on yield, oil and fatty acid concentration.

Varieties	Seed yield (kg/ha)	Oil content in seeds (%)	Oil yield (kg/ha)	Oleic acid (%)	Linoleic acid (%)	Linolenic acid (%)	Palmitic acid (%)	Stearic acid (%)
Al-Rashidiya								
Serw	1244.17a	34.27a	427.38a	23.59b	31.20b	1.89b	9.14b	3.08b
Raja	1209.41b	33.44ab	406.79b	26.21a	33.59a	2.34a	11.44a	4.37a
Reandy	1179.04c	32.81b	389.53c	24.44b	32.60ab	2.09b	10.02b	3.73ab
Wana								
Serw	1291.63a	34.96a	452.78a	22.22a	31.07a	2.05a	10.11a	2.55a
Raja	1257.00b	34.07ab	430.25b	21.54a	28.94a	1.70a	8.14b	1.87b
Reandy	1238.09c	33.62b	419.00b	22.54a	30.27a	1.88a	9.33a	2.15ab

Significant differences exist between values in the same column that are followed by different letters.

Interaction Effect between Nano-fertilizer and Cultivars

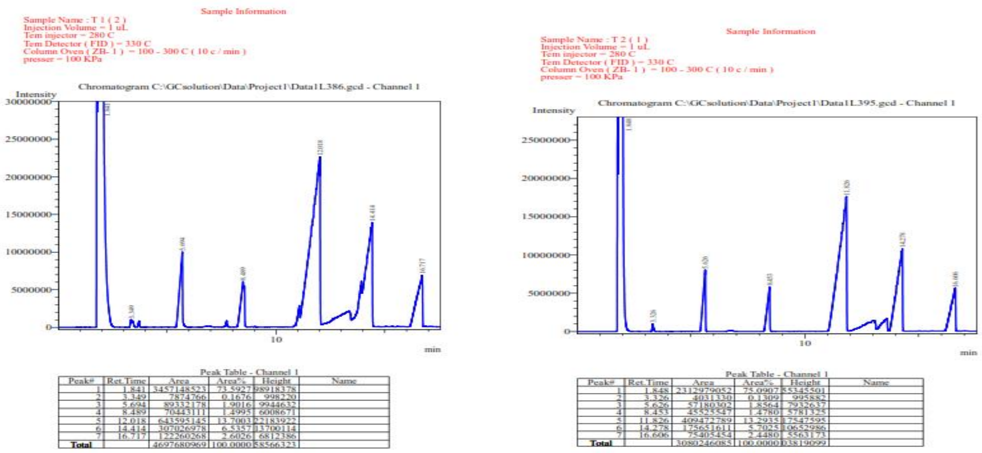
Table 5: Interaction effect between nano NPK fertilizer and varieties on yield, oil, and fatty acid concentration.

Nano NPK Fertilizer (g/l)	Varieties	Seed yield (kg/ha)	Oil content in seeds (%)	Oil yield (kg/ha)	Oleic acid (%)	Linoleic acid (%)	Linolenic acid (%)	Palmitic acid (%)	Stearic acid (%)
Al-Rashidiya									
0	Serw	1162.25g	32.47a	377.42d	20.15a	27.49a	1.23a	5.81a	1.26a
	Raja	1086.19h	30.15a	327.50e	22.66a	30.15a	1.66a	7.89a	2.55a
	Reandy	1049.41i	28.99a	304.23e	21.25a	29.25a	1.40a	6.74a	1.89a
2.5	Serw	1250.85d	33.97a	424.94c	23.65a	31.55a	1.89a	8.97a	3.00a
	Raja	1233.16e	34.16a	421.29c	25.99a	33.65a	2.36a	11.45a	4.01a
	Reandy	1205.15f	34.12a	411.24c	24.59a	32.58a	2.11a	10.25a	3.56a
5	Serw	1319.40a	36.36a	479.77a	26.98a	34.56a	2.55a	12.66a	4.99a
	Raja	1308.89b	36.03a	417.60ab	29.99a	36.99a	3.00a	14.99a	6.56a
	Reandy	1282.55c	35.33a	453.12b	27.49a	35.98a	2.78a	13.08a	5.74a
Wana									
0	Serw	1195.f	32.94a	394.02a	20.11a	28.55a	1.50a	7.15a	1.56a
	Raja	1141.58g	32.09a	355.00a	18.09a	25.19a	1.12a	5.01a	1.01a
	Reandy	1100.02h	29.93a	329.27a	19.08a	27.49a	1.36a	6.11a	1.25a
2.5	Serw	1310.00c	34.96a	458.01a	23.58a	31.12a	2.00	10.12a	2.10a
	Raja	1279.01d	34.52a	441.57a	21.55a	29.09a	1.73a	8.08a	1.88a
	Reandy	1264.26e	35.14a	444.36a	22.66a	30.25a	1.88a	9.22a	2.12a
5	Serw	1369.23a	36.98a	506.33a	22.99a	33.55a	2.66a	1308a	4.00a
	Raja	1350.42b	36.59a	494.20a	24.98a	32.56a	2.25a	11.35a	2.74a
	Reandy	1349.99b	35.80a	483.38a	25.88a	33.08a	2.40a	12.66a	3.08a

Significant differences exist between values in the same column that are followed by different letters.

According to table 5, there was a noteworthy interaction between nano-fertilizer treatments and cultivars in seed yield at both the Al-Rashidiya and Wana sites, as well as in oil yield at the Al-Rashidiya site. Plants fertilized with the 5.0 g/L level combined with the Serw cultivar recorded the highest seed yields (1319.40 and 1369.23 kg/ha) at the two sites, respectively, and the highest oil yield (479.77 kg/ha) at Al-Rashidiya. In contrast, unfertilized plants of the Readny cultivar recorded the lowest seed yields (1049.41 and 1100.02 kg/ha) at the two sites, respectively, and the lowest oil yield (304.23 kg/ha) at Al-Rashidiya.

The figures 2 to 10 below show the analysis of fatty acid extract samples from rapeseed oil using GC (gas chromatography) for oleic acid, linoleic acid, linolenic acid, palmitic acid and stearic acid compounds at both Al-Rashidiya and Wana sites, as illustrated in figures 2–10 (Stepien, Wojtkowiak and Pietrzak-Fiecko, 2017).



Sample Information

Sample Name : T 1 (2)
Injection Volume = 1 uL
Tem injector = 280 C
Tem Detector (FID) = 330 C
Column Oven (ZB- 1) = 100 - 300 C (10 c / min)
presser = 100 KPa

Chromatogram C:\GCsolution\Data\Project1\Data1L386.gcd - Channel 1

Peak Table - Channel 1

Peak#	Ret.Time	Area	Area%	Height	Name
1	1.841	3457148523	73.5927	98918378	
2	3.349	7874766	0.1676	998220	
3	5.694	89332178	1.9016	9944632	
4	8.489	70443111	1.4995	6008671	
5	12.018	643595145	13.7003	22183922	
6	14.414	307026978	6.5357	13700114	
7	16.717	122260268	2.6026	6812386	
Total		4697680969	100.0000	58566323	

Sample Information

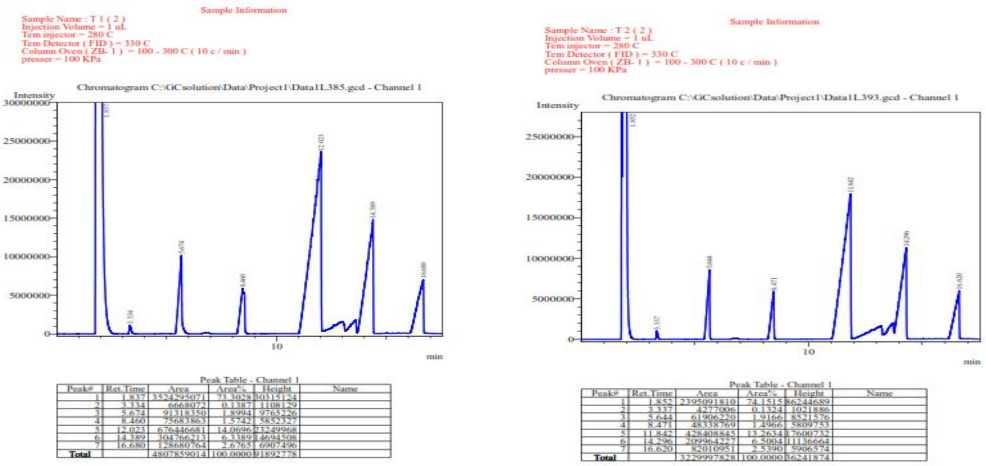
Sample Name : T 2 (1)
Injection Volume = 1 uL
Tem injector = 280 C
Tem Detector (FID) = 330 C
Column Oven (ZB- 1) = 100 - 300 C (10 c / min)
presser = 100 KPa

Chromatogram C:\GCsolution\Data\Project1\Data1L395.gcd - Channel 1

Peak Table - Channel 1

Peak#	Ret.Time	Area	Area%	Height	Name
1	1.848	2312979052	75.0907	55345501	
2	3.326	4031330	0.1309	995882	
3	5.626	57180302	1.8564	7932637	
4	8.453	45525547	1.4780	5781325	
5	11.826	409472789	13.2935	17547595	
6	14.278	175651611	5.7025	10652986	
7	16.606	75405454	2.4480	5563173	
Total		3080246085	100.0000	038190099	

Figure 2: Fatty acids curve at 0 g NPK nano/l with serw variety for al-rashidiya (T1) and wana (T2) locations.



Sample Information

Sample Name : T 1 (2)
Injection Volume = 1 uL
Tem injector = 280 C
Tem Detector (FID) = 330 C
Column Oven (ZB- 1) = 100 - 300 C (10 c / min)
presser = 100 KPa

Chromatogram C:\GCsolution\Data\Project1\Data1L385.gcd - Channel 1

Peak Table - Channel 1

Peak#	Ret.Time	Area	Area%	Height	Name
1	1.837	3524295071	73.3028	30315124	
2	3.334	6668072	0.1387	1108129	
3	5.674	91318350	1.8994	9765226	
4	8.460	75683863	1.5742	5852327	
5	12.023	676446681	14.0696	23249968	
6	14.389	304766213	6.3389	14694508	
7	16.680	128680764	2.6765	6907496	
Total		4807859014	100.0000	91892778	

Sample Information

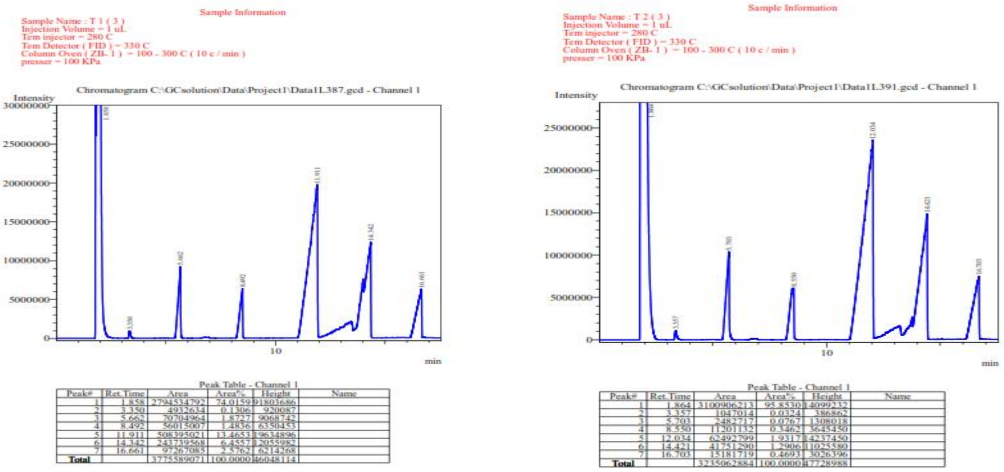
Sample Name : T 2 (2)
Injection Volume = 1 uL
Tem injector = 280 C
Tem Detector (FID) = 330 C
Column Oven (ZB- 1) = 100 - 300 C (10 c / min)
presser = 100 KPa

Chromatogram C:\GCsolution\Data\Project1\Data1L393.gcd - Channel 1

Peak Table - Channel 1

Peak#	Ret.Time	Area	Area%	Height	Name
1	1.852	2395091810	74.1515	86244689	
2	3.337	4277006	0.1324	1021886	
3	5.644	61906220	1.9166	8521576	
4	8.471	48338769	1.4966	5809753	
5	11.842	428408845	13.2634	17600732	
6	14.296	209964227	6.5004	11136664	
7	16.620	82010951	2.5390	5906574	
Total		3229997828	100.0000	36241874	

Figure 3: Fatty acids curve at 0 g/L with raja variety for al-rashidiya (T1) and wana (T2) locations.



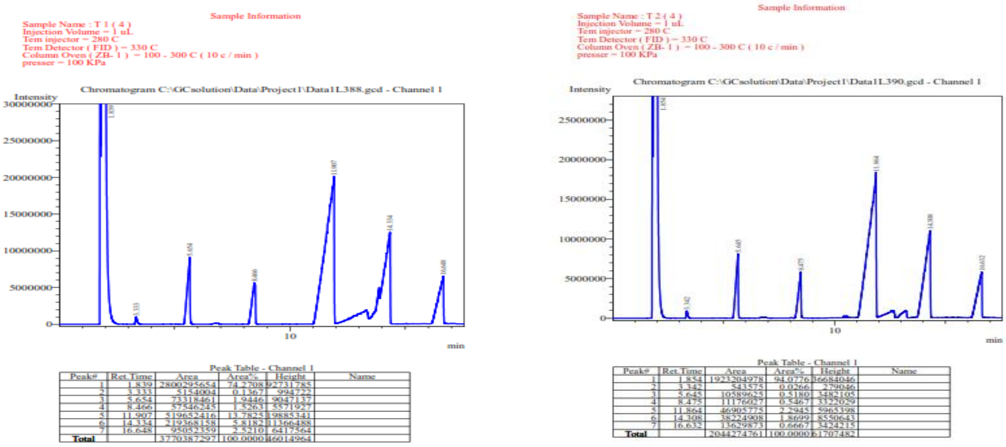
Peak Table - Channel 1

Peak#	Ret.Time	Area	Area%	Height	Name
1	1.858	2794534792	74.0159	91803686	
2	3.350	4932634	0.1306	920087	
3	5.662	70704964	1.8727	9068742	
4	8.492	56015007	1.4836	6350453	
5	11.911	508395021	13.4653	19634896	
6	14.342	243739568	6.4557	12055982	
7	16.661	97267085	2.5762	6214268	
Total		3775589071	100.0000	146048114	

Peak Table - Channel 1

Peak#	Ret.Time	Area	Area%	Height	Name
1	1.864	3100906213	95.8530	14099232	
2	3.357	1047014	0.0324	386862	
3	5.703	2482717	0.0767	1308018	
4	8.550	11201132	0.3462	3645450	
5	12.034	62492799	1.9317	14237450	
6	14.421	41751290	1.2906	11025580	
7	16.703	15181719	0.4693	3026396	
Total		3235062884	100.0000	47728988	

Figure 4: Fatty acids curve at 0 g NPK nano/l with reamdy variety for al-rashidiya (T1) and wana (T2) locations.



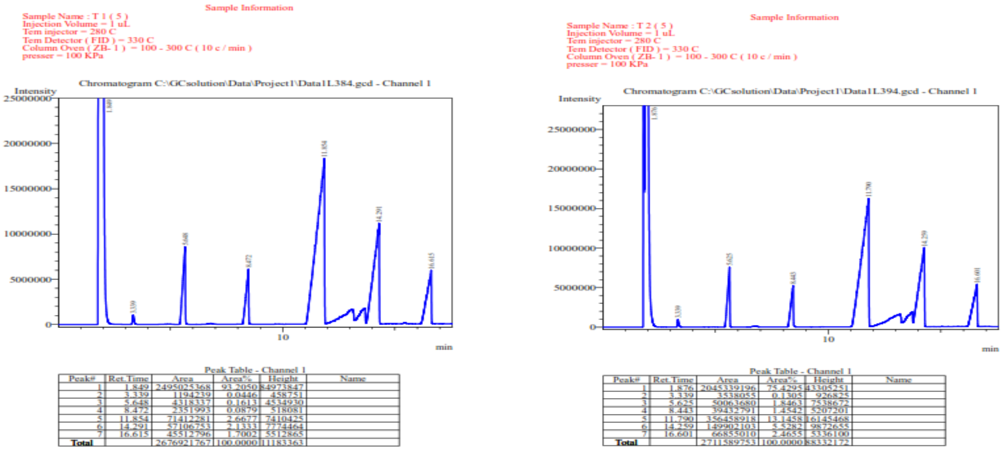
Peak Table - Channel 1

Peak#	Ret.Time	Area	Area%	Height	Name
1	1.839	2800295654	74.2708	92731785	
2	3.333	5154004	0.1367	994722	
3	5.654	73318461	1.9446	9047137	
4	8.466	57546245	1.5263	5571927	
5	11.907	519652416	13.7825	19885341	
6	14.334	219368158	5.8182	11366488	
7	16.648	95052359	2.5210	6417564	
Total		3770387297	100.0000	146014964	

Peak Table - Channel 1

Peak#	Ret.Time	Area	Area%	Height	Name
1	1.854	1923204978	94.0776	36684046	
2	3.342	543575	0.0266	279046	
3	5.645	10589625	0.5180	3482105	
4	8.475	11176027	0.5467	3322029	
5	11.864	46905775	2.2945	5965398	
6	14.308	38224908	1.8699	8550643	
7	16.632	13629873	0.6667	3424215	
Total		2044274761	100.0000	61707482	

Figure 5: Fatty acids curve at 2.5 g NPK nano/l with serw variety for al-rashidiya (T1) and wana (T2) locations.



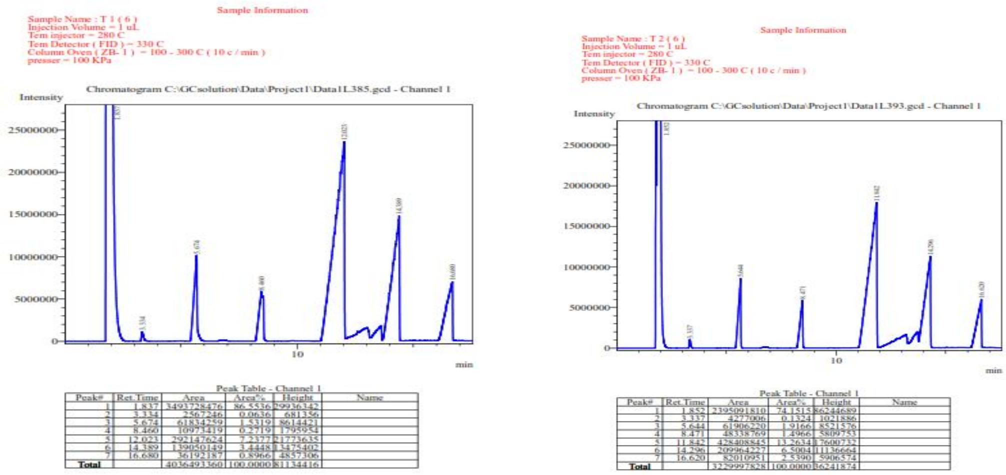
Peak Table - Channel 1

Peak#	Ret.Time	Area	Area%	Height	Name
1	1.849	2495025368	93.2050	84973847	
2	3.339	1194239	0.0446	458751	
3	5.648	4318337	0.1613	4534930	
4	8.472	2351993	0.0879	518081	
5	11.854	71412281	2.6677	7410425	
6	14.291	57106753	2.1333	7774464	
7	16.615	45512796	1.7002	5512865	
Total		2676921767	100.0000	111183363	

Peak Table - Channel 1

Peak#	Ret.Time	Area	Area%	Height	Name
1	1.876	2045339196	75.4295	43305251	
2	3.339	3538055	0.1305	926825	
3	5.625	50063680	1.8463	7538672	
4	8.443	39432791	1.4542	5207201	
5	11.790	356458918	13.1458	16145468	
6	14.259	149902103	5.5282	9872655	
7	16.601	66855010	2.4655	5336100	
Total		2711589753	100.0000	88332172	

Figure 6: Fatty acids curve at 2.5 g NPK nano/l with raja variety for al-rashidiya (T1) and wana (T2) locations.



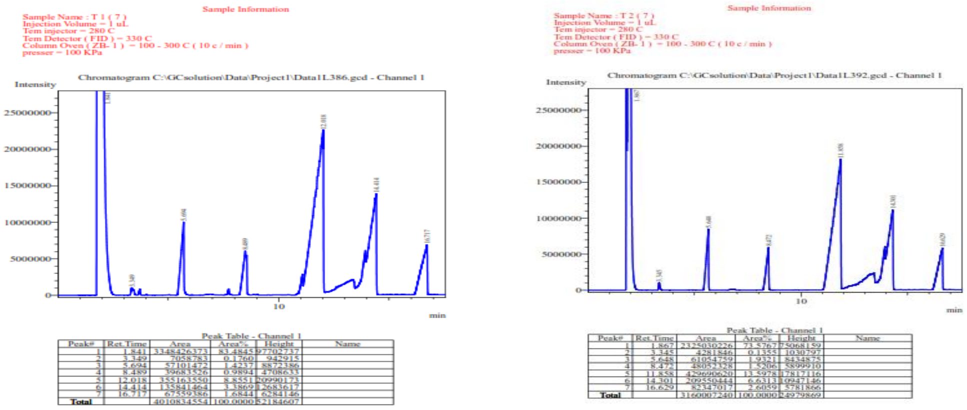
Peak Table - Channel 1

Peak#	Ret.Time	Area	Area%	Height	Name
1	1.837	3493728476	86.5536	29936342	
2	3.334	2567246	0.0636	681356	
3	5.674	61834259	1.5319	8614421	
4	8.460	10973419	0.2719	1795954	
5	12.023	292147624	7.2377	21773635	
6	14.389	139050149	3.4448	13475402	
7	16.680	36192187	0.8966	4857306	
Total		4036493360	100.0000	81134416	

Peak Table - Channel 1

Peak#	Ret.Time	Area	Area%	Height	Name
1	1.852	2395091810	74.1515	86244689	
2	3.337	4277006	0.1324	1021886	
3	5.644	61906220	1.9166	8521576	
4	8.471	48338769	1.4966	5809753	
5	11.842	428408845	13.2634	17600732	
6	14.296	209964227	6.5004	11136664	
7	16.620	82010951	2.5390	5906574	
Total		3229997828	100.0000	36241874	

Figure 7: Fatty acids curve at 2.5 g NPK nano/l with reandy variety for al-rashidiya (T1) and wana (T2) locations.



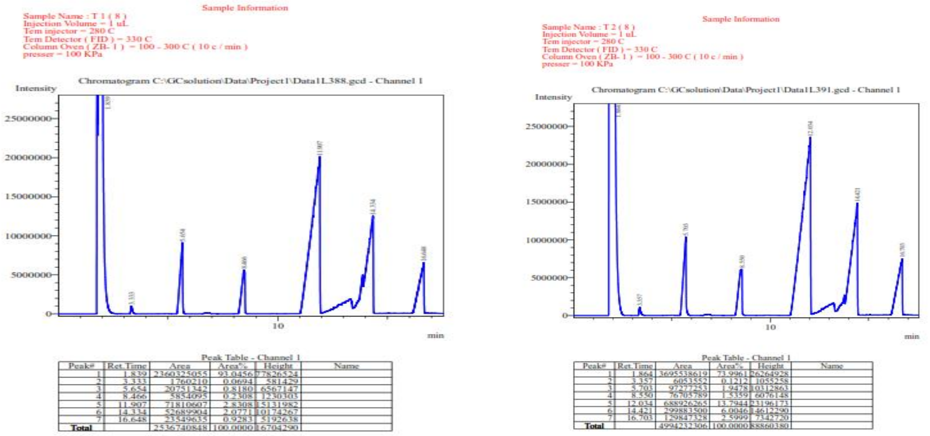
Peak Table - Channel 1

Peak#	Ret.Time	Area	Area%	Height	Name
1	1.841	3348426373	83.4845	97702737	
2	3.349	7058783	0.1760	942915	
3	5.694	57101472	1.4237	8872386	
4	8.489	39683526	0.9894	4708633	
5	12.018	355163550	8.8551	20990173	
6	14.414	135841464	3.3869	12683617	
7	16.717	67559386	1.6844	6284146	
Total		4010834554	100.0000	52184607	

Peak Table - Channel 1

Peak#	Ret.Time	Area	Area%	Height	Name
1	1.867	2325030226	73.5767	75068159	
2	3.345	4281846	0.1355	1030797	
3	5.648	61054759	1.9321	8434875	
4	8.472	48052328	1.5206	5899910	
5	11.858	429690620	13.5978	17817116	
6	14.301	209550444	6.6313	10947146	
7	16.629	82347017	2.6059	5781866	
Total		3160007240	100.0000	24979869	

Figure 8: Fatty acids curve at 5 g NPK nano/l with serw variety for al-rashidiya (T1) and wana (T2) locations.



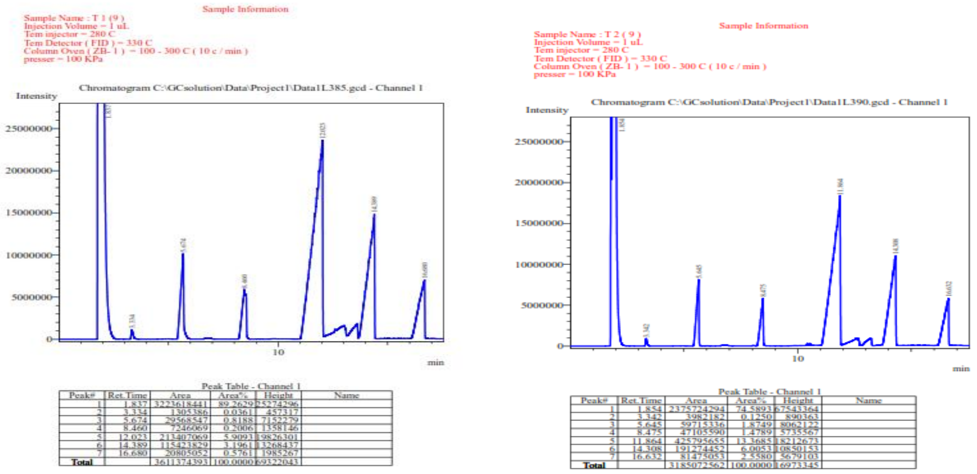
Peak Table - Channel 1

Peak#	Ret.Time	Area	Area%	Height	Name
1	1.839	2360325055	93.0456	77826524	
2	3.333	1760210	0.0694	581429	
3	5.654	20751342	0.8180	6567147	
4	8.466	5854095	0.2308	1230303	
5	11.907	71810607	2.8308	15131982	
6	14.334	52689904	2.0771	10174267	
7	16.648	23549635	0.9283	5192638	
Total		2536740848	100.0000	16704290	

Peak Table - Channel 1

Peak#	Ret.Time	Area	Area%	Height	Name
1	1.864	3695538619	73.9961	26264928	
2	3.357	6053552	0.1212	1055258	
3	5.703	97277253	1.9478	10312863	
4	8.550	76705789	1.5359	6076148	
5	12.034	688926265	13.7944	23196173	
6	14.421	299883500	6.0046	14612290	
7	16.703	129847328	2.5999	7342720	
Total		4994232306	100.0000	88860380	

Figure 9: Fatty acids curve at 5 g NPK nano/l with raja variety for al-rashidiya (T1) and wana (T2) locations.



Sample Information
Sample Name : T 1 (9)
Injection Volume = 1 uL
Tem injector = 280 C
Tem Detector (FID) = 330 C
Column Oven (ZB- 1) = 100 - 300 C (10 c / min)
presser = 100 KPa

Chromatogram C:\GCsolution\Data\Project1\Data1L385.gcd - Channel 1

Peak Table - Channel 1

Peak#	Ret.Time	Area	Area%	Height	Name
1	1.837	3223618441	89.2629	25274296	
2	3.334	1305386	0.0361	457317	
3	5.674	29568547	0.8188	7152279	
4	8.460	7246069	0.2006	1358146	
5	12.023	213407069	5.9093	19826301	
6	14.389	115423829	3.1961	13268437	
7	16.680	20805052	0.5761	1985267	
Total		3611374393	100.0000	69322043	

Sample Information
Sample Name : T 2 (9)
Injection Volume = 1 uL
Tem injector = 280 C
Tem Detector (FID) = 330 C
Column Oven (ZB- 1) = 100 - 300 C (10 c / min)
presser = 100 KPa

Chromatogram C:\GCsolution\Data\Project1\Data1L390.gcd - Channel 1

Peak Table - Channel 1

Peak#	Ret.Time	Area	Area%	Height	Name
1	1.854	2375724294	74.5893	67543364	
2	3.342	3982182	0.1250	890363	
3	5.645	59715336	1.8749	8062122	
4	8.475	47105590	1.4789	5735567	
5	11.864	425795655	13.3685	18212673	
6	14.308	191274452	6.0053	10850153	
7	16.632	81475053	2.5580	5679103	
Total		3185072562	100.0000	116973345	

Figure 10: Fatty acids curve at 5 g NPK nano/l with reandy variety for al-rashidiya (T1) and wana (T2) locations.

Relevance of Findings to Aquatic Plant and Algal Growth Systems

Consistent with processes documented in aquatic environments, nano NPK treatments improved nutrient absorption, seed productivity, and fatty acid content. The algal and aquatic macrophyte cells are able to absorb nutrients more efficiently, produce more chlorophyll, and store more lipids when exposed to nano-sized fertilizers because of their large surface area and good water mobility. Hence, future studies on the use of nano fertilizers in the growth of aquatic plants and algae can be informed by the response patterns shown in this work, especially the rise in oleic, linoleic, and linolenic acids. Based on these results, it seems that aquaculture species that are used to make biofuels and feed could benefit from controlled nano NPK supplementation in terms of biomass production and oil quality.

Conclusion

From this experiment, it can be concluded that the optimal nano-fertilizer level is 5 g/L to achieve the highest productivity and improve fatty acid composition in rapeseed seeds. Furthermore, cultivating the Serw cultivar increased productivity in both quantity and quality. Improved fatty acid composition and nutrient-use efficiency are of equal importance in aquatic plant or algae growth systems, and the nutrient-response patterns shown in this study may provide a basis for adapting nano NPK fertilizer technology to these systems.

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