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Effect of Organic and Inorganic Fertilizers on Soil Properties, Growth Yield, and Physiochemical Properties of Sunflower Seeds and Oils

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Abstract: Sunflower is the most important source of edible oil and fourth-largest oilseed crop in the world. The purpose of this study was to investigate the effect of using two organic fertilizers from various sources (compost coupled with biofertilizer (CCB), filter mud cake (FMC)) and comparing them to conventional inorganic fertilizers in their effect on the quality of sunflower seeds, sunflower oil, and soil properties. The data showed that the highest value of dry weight, plant height, disk dry weight in addition to chlorophyll content, and phenolic secondary metabolites in oil was measured after the application of inorganic fertilizer, while the use of organic fertilizer contributed to a substantial increase in the production yield of sunflower seeds, oil, and a high stalk yield compared with inorganic treatment. Oils produced from organic fertilizer (CCB and FMC) gave higher blue color values than inorganic ones and the most transparent oil was inorganic while the organic treatments produced darkest oils. The results for chemical composition of sunflower seeds showed nonsignificant differences for protein and ash among all treatments while a significant difference with regard to oil content was recorded, in which the FMC recorded the highest oil content followed by compost (CCB), and finally came the inorganic treatment. Organic fertilizers are a valuable source of organic material and nutrients essential for plants and can be safely used for soil, crops, and the environment.

Keywords: organic fertilizer; seed oils; *Helianthus annuus*; secondary metabolites

Citation: Alzamel, N.M.; Taha, E.M.M.; Bakr, A.A.A.; Loutfy, N. Effect of Organic and Inorganic Fertilizers on Soil Properties, Growth Yield, and Physiochemical Properties of Sunflower Seeds and Oils. *Sustainability* **2022**, *14*, 12928. https://doi.org/10.3390/su141912928

Academic Editors: Vito Michele Paradiso, Marta Igual Ramo and Ângela Fernandes

Received: 19 August 2022
Accepted: 5 October 2022
Published: 10 October 2022

1. Introduction

Oilseed crops have long been grown as a source of food for humans and raw materials for industry [1,2]. Oilseeds have increasingly been the subject of dietary claims in the past few decades owing to their content of phytochemical components beneficial for human health [3]. Among the three leading oilseed crops, that is, soybean, rapeseed, and sunflower, in the world today, sunflower has been documented as a major source of high-quality edible oil used for culinary purposes [4]. Owing to the continuous increase in the human population, the international oilseed market is dominated mainly by sunflowers and other oilseeds, so there is a need to intensify efforts to expand sunflower output to meet the demand for edible sunflower seeds, oil, and by-products [5]. The consumption rate of edible oil has been greatly increased in Egypt [6]. At present, Egypt consumes annually about 2.5 million tons of edible oils. The total quantity of oil produced in Egypt accounts for 2% only of the consumption requirements of edible oil. The remaining 98% is imported from abroad [7].

The nutritional quality of sunflower oil ranks among the best of vegetable oils in cultivation. The nutritional value of edible oils depends on the content and composition of other accompanying biologically active components such as phospholipids, sterols, and tocopherols in addition to the fatty acid composition of triacylglycerols [8].

The oilseed production in Egypt is still below current needs; consequently, improving oilseeds' productivity is essential to meet the sharp supply shortages of edible oils. Sunflower is adapted to different types of soils and climate conditions. Fertile soil, moderate rainfall, and viable seeds are the requirements for the good growth of sunflower. The adaptation of sunflower to different soil and climatic conditions has enhanced its cultivation as an oilseed plant throughout the world [9]. Sunflower is a highly exhaustive crop [10]. Poor soil fertility, incorrect plant population, lack of weed control, diseases, insect damage, bird depredation, late planting, and harvesting losses can cause low sunflower yields [11].

For years, producers have increased sunflower crop productivity by using fertilizers and these fertilizers have caused soil weakness, desertification, and even a decrease in vitality after years. The conventional agricultural practice of using chemical fertilizers for better crop yields and productivity adversely affects crop yield, physical and chemical properties of soil, microbial ecological imbalance, and water as a result of surface runoff [12]. Excessive nitrogen fertilization of sunflower not only causes environmental risk, but it may also affect the grain quality, decreasing its oil content or increasing the plant lodging, subsequently reducing the crop yield [13]. Therefore, producers have started to use organic fertilizers to improve the physical and chemical structure of soils. The use of organic fertilizers should be expanded to reduce environmental pollution and guarantee sustainable soils and reduce inorganic fertilizer use; especially as there are huge amounts of agriculture wastes produced every year in Egypt that could be effectively turned into organic fertilizer production [14]. The rated amount of agricultural wastes in Egypt ranges from 22 to 26 million dry tons per year and can cause numerous problems to rural areas in Egypt. Sugarcane is one of the top five crops producing the highest quantities of wastes in Egypt. This large amount of waste should be beneficially used rather than being burnt [15].

The benefits of using organic fertilizers have been underlined because of the high prices of commercial fertilizers and their bad effect on soil properties, groundwater, environment, and human health. Organic fertilizers also keep soil healthy and increase plant resistance to hard environmental conditions, and improve their properties [16].

Recently, great efforts have been made to use safe and natural materials to increase plant growth and productivity. Organic agricultural practices aim to enhance biodiversity, biological cycles, and soil biological activity to produce optimal natural systems that are socially, ecologically, and economically sustainable [17]. Organic farming is a technique that involves the use of organic and biological materials and avoids the use of synthetic substances, aiming to reduce soil and environmental pollution; thus, organic matter applications to soil are highly desired to reduce the cost and harms of chemicals. The use of these fertilizers at the appropriate ratio may be valuable in increasing crop yields and keeping soil healthy [18,19].

The use of poultry manure and filter mud cake recorded the highest levels of available N, P, and K in the soil without and with biofertilizer addition; microorganism activity also increases the decomposition of the organic waste, resulting in decreasing soil pH [20]. Compost (CCB) and filter mud cake (FMC) are examples of organic fertilizers that increase soil fertility, improve porosity, and promote healthy crop production.

In recent years, there has been a renewed interest in the composition of oils containing fatty acids and other minor compounds and the factors that affect the accumulation of fatty acids during seed development, but there is little detailed research documenting the effect of organic fertilizers on sunflower oil quality and oil fatty acid composition and their relationships in Egypt.

There is an urgent need to increase the amount of oilseeds produced in Egypt, especially healthy sunflower oil. The high prices of inorganic fertilizers and their negative impact on the environment, as well as the benefits of using organic fertilizers for the quality of plants, oils, and soil, and the need to solve the problem of the accumulating amount of agricultural waste, have led to the idea of using agricultural wastes as an organic fertilizer. Production efficiency can be improved via use of alternative organic fertilizers, the decrease in production expenses, as well as the production of oil of better quality and the decrease in wastes. Therefore, this study aimed at elucidating the effect of organic fertilizer on the production of sunflower seeds, the nutritional quality of sunflower oil, and soil health.

2. Materials and Methods

2.1. Experiment Design

A pot experiment was carried out at the Faculty of Science, South Valley University, in Egypt. The experiment was carried out to investigate the effect of two organic fertilizer additions (compost combined with biofertilizers and filter mud cake) on soil properties, plant growth, and yield of sunflower (*Helianthus annuus* L) plants, as well as oil production and oil characteristics. The pot experiment was set up with a completely randomized design, with plastic plant pots 45 cm in height and 30 cm in diameter, each with a drainage aperture in the bottom. Each pot was filled with 10 kg of sieved soil that had been filtered through a 2 mm sieve. The experiment used three treatments (inorganic fertilizers, compost coupled with biofertilizer (CCB), and filter mud cake (FMC)), four replicates, and each organic treatment was applied at a rate of 30 ton/fed (300 G/pot) as a source of nitrogen and using rock phosphate (31% P_2O_5) and feldspar (10% K_2O) as recommended. A month before seeding, organic fertilizers were added and thoroughly mixed with the soil, and water was added (for saturation) three days before planting. Five sunflower seeds were then sown in each pot.

Inorganic fertilizers treatment used recommended doses of NPK inorganic fertilizers in the form of ammonium nitrate 33.5% N (100 kg/fed) in two doses, the first at cultivation and the second at the flowering buds stage, and superphosphate 15.5% P_2O_5 at a rate of 100 kg/fed, added in one dose in each pot during preparing for planting, and potassium sulfate 48% K_2O (50 kg/fed), added with the first addition of ammonium nitrate fertilizer.

The residual agricultural operations were carried out equally and as needed for all treatments. At the end of the cultivated season, the plants were harvested from each pot, washed with deionized water, cut into small pieces with a sharp knife, and oven-dried at 70 °C for 48 h before being weighed. Plant samples from each pot were milled and saved for chemical analysis.

Furthermore, soil samples were collected from each pot after harvest, air-dried, crushed with a wooden roller, sieved to pass through a 2 mm sieve, and stored for analysis. Table 1 shows the physical and chemical properties of soil. The following plant growth characteristics were studied: plant height (cm), disk fresh and dry weight, disk diameter, weight of 100 seeds, seed yield and oil percentage, and plant nitrogen content. All samples were calculated based on the number of plants harvested from each pot.

Samples were taken at random between the 15th and 90th day after flowering in 15-day intervals by picking 10–20 flower heads at random and removing the whole seeds by hand; then, the collected sunflower seeds were transferred to the Department of Food Science and Technology), Faculty of Agriculture, South Valley University for determination of physical characteristics of sunflower seeds, extraction of sunflower oil, and determination of the extracted oil properties.

2.2. Applied Organic Manure and Bacterial

Filter mud cake (FMC) was made from organic waste from the Qus Sugarcane factory. Compost coupled with biofertilizer (CCB) was produced from experimental farm residues (derived from plant residues, cow and chicken manure) at the Faculty of Agriculture at Qena, South Valley University and contained both nitrogen fixers (*Azotobacter chroococcum* and *Azospirillum lipoferum*) and phosphate dissolving bacteria (*Paenibacillus polymyxa;* previously *Bacillus polymyxa*). Nitrogen fixers *Azotobacter chroococcum* and nitrogen fixer *Azospirillum lipoferum* were locally isolated as previously described by [21]. Phosphate dissolving bacteria (PDB)*: Paenibacillus polymyxa*; *Bacillus polymyxa* were locally isolated as described by [22].

Table 1. Physical and chemical properties for experimental soil.

Property	Value
Particle size distribution:	
% sand	40.7 ± 0.502
% silt	28.9 ± 0.187
% clay	30.4 ± 0.415
Texture class	Clay loam
Soil pH (1:1) in water	7.98 ± 0.038
ECe (dS/m)	3.01 ± 0.029
Calcium carbonates (%)	8.02 ± 0.038
CEC (cmol/kg)	17.5 ± 0.217
Organic carbon (g/Kg)	14 ± 0.048
Available nitrogen (mg/kg)	19.43 ± 0.392
Available −P (mg/kg)	11.2 ± 0.043
Available −K (mg/kg)	201 ± 1.871

Data are expressed as means ± SD (n = 4).

Dry pulverized, neutralized, and sterilized moss peat was used as carrier for preparing inoculants. Mixed biofertilizer inoculant was prepared by mixing an equal ratio of *Azospirillum lipoferum* inoculant (6×10^6 cfu/gm), *Azotobacter chroococcum* inoculant (4.4×10^6 cfu/gm), and PDB inoculant (3×10^8 cfu/gm) just before use for seed inoculation at the rate of 10% of the seed weight and was thoroughly mixed until the seeds were uniformly surface-coated using 20% Arabic gum solution as adhesive.

2.3. Analytical Methods for Soil, Plant, and Organic Fertilizers

The pipette method was used to determine the particle size distribution of soil according to [23]. The Walkley–Black wet combustion method [24] was used to determine soil organic matter in soil and organic wastes, and soil organic matter was then calculated.

A Collins volumetric calcimeter was used to determine the total calcium carbonate content [23]. Soil electrical conductivity (EC) of soil samples was measured in a 1:10 water extract (soil:water ratio) using EC meters [23], and soil pH was measured in a 1:1 water suspension using pH meters [25].

Dried plant material or an organic fertilizer sample of 0.2 g was digested using 10 mL of a mixture of 7:3 ratios of H_2SO_4 to $HClO_4$ and then analyzed for nitrogen by micro-Kjeldahl, and phosphorus was determined colorimetrically using chlorostannous-phosphomolybdic acid by spectrophotometer and K by flame photometer, as described by [23].

The micro-Kjeldahl method was used to estimate available nitrogen using the 1% K_2SO_4 method described in [23]. Available phosphorus was extracted using the $NaHCo_3$ method buffered at pH 8.5 according to [26] and measured by spectrophotometer using the phosphomolybdic acid method. Available potassium was extracted with 1 N ammonium acetate at pH 7.0 and determined using flame photometer [23]. Total nitrogen was determined using the micro-Kjeldahl method as described by [23].

Tables 1 and 2 show the physical and chemical properties of experimental soil, as well as the chemical properties of organic fertilizers.

Table 2. Physical and chemical characteristics of organic fertilizers.

Property	Compost Coupled with Biofertilizer	Filter Mud Cake
pH (1:1) in water	7.12	6.5
EC (1:10) (dS/m)	2.85	5.5
Organic carbon%	15.1	38.1
N%	0.9	2.4
P%	0.69	2.6
K%	1.49	0.35
C/N ratio	16.78	15.88

2.4. Physical Characteristic of Sunflower Seeds

2.4.1. Seed Mass Properties

A digital balance with an accuracy of 0.01 g was used to measure the mass of a single seed as well as the weight of 100 seeds. From the bulk sample, 300 seeds were chosen at random and divided into three bins, with 100 seeds placed in each bin. The bin weight was determined, and the seed weight was multiplied by 100.

2.4.2. Seed Density

A circular metallic container with a volume of 500 mL and a height of 150 mm was chosen to measure the bulk density of the sunflower seeds. The seeds were placed in the container. The container's contents were then weighed. The bulk density was calculated using the seed mass and container volume [27,28].

2.4.3. Seed Dimensional Properties

Bulk samples were selected quite randomly from sunflower heads. The length, width, thickness, and mass of each individual seed were measured. All the physical properties were measured for 50 seeds. A digital caliper with an accuracy of 0.01 mm for dimensional measurements was used.

2.4.4. Hull Content and Free Hull Percentage

After manually hulling 50 seeds, the percentage hull content (HC) of the seed was calculated. Samples of 10 g of seed were mechanically hulled in a laboratory huller based on a centrifuge effect, with a disk turning at 3800 rpm. The detailed process was described by [29]. The percentage of mechanically extracted free hulls (FH) was calculated from weight of free hulls/weight of the sample before hulling $\times$ 100.

2.5. Sunflower Oil Extraction

The whole seeds were removed by hand from sunflower heads. From a portion of 800 g seeds, a sample of 200 g was obtained by quartering. Hulls were manually removed, and hull and kernel were weighed separately. Specified portions of the air-dried kernel were taken for lipid extraction. A 50 g portion of kernels was subjected to cold extraction [29] with n-hexan, and the solvent was mixed with samples and kept overnight under refrigeration after a brief agitation under vortexing. The solvent was partly removed in a rotary vacuum evaporator, the residue was quantitatively transferred in a pre-weighed glass vessel, and the rest of the solvent was removed under a stream of nitrogen. The obtained oil was kept in the refrigerator until the next analysis.

2.6. Chemical Composition of Sunflower Seeds

The method suggested by [30] was followed to analyze the nutrient composition of different sunflower seeds. Carbohydrate content was estimated by the difference of the other components using the formula: carbohydrate content = 100 − (% protein + % oil + % ash) [31].

2.7. Sunflower Seed Oil Characteristics

The extracted sunflower oil was subjected to the following measurements.

2.7.1. Fatty Acid Composition (FAMEs)

Fatty acid methyl esters (FAMEs) were prepared, using the procedure described by [32].

2.7.2. Phenolic Compounds in Sunflower Oil

The amount of total phenolic compounds of sunflower oil was measured colorimetrically at 725 nm by a modified Folin–Ciocalteau method.

2.7.3. Tocopherol Content of Sunflower Oil

Sample preparation to extract seed tocopherol and analysis of (α-, β and γ-, tocopherol contents using gas chromatography flame ionization detector (GC-FID) technique were done according to the method described by [33].

2.7.4. Chlorophyll Content of Sunflower Oil

A 600 mg sample of sunflower oil was fully dissolved in 2 mL cyclohexane. Chlorophyll was determined spectrophotometry following the method of [34].

2.7.5. Oil Color

The oil color was determined by measuring the transparency at 455 nm (UV–vis spectrophotometer) against carbon tetrachloride as the blank as done by [35].

2.8. Statistical Analysis

The data were statistically analyzed according to the design of the experiment and the mean of the treatments was calculated using the least significant difference test at a probability level of 0.05.

3. Results

3.1. Effect of Organic Waste and Biofertilizer Additions on Soil Properties

The results shown in Table 3 indicate a significant difference between treatments in pH values, and among the treatments compost (CCB) had the lowest pH value. Soil buffering is considered to be an important aspect of soil health, as it assures reasonable stability in soil pH (preventing large fluctuations) and influences the amount of chemicals (lime or sulfur) needed to change the soil pH. The results in the same table refer to a significant difference between treatments for electrical conductivity values (EC), and the highest value for EC was recorded for compost (CCB) treatment.

Table 3. Chemical properties of soil after planting.

Treatments	Soil pH	Soil EC	$CaCO_3$ (%)
Inorganic	7.87 ± 0.025 a	3.98 ± 0.04 c	7.97 ± 0.031 a
CCB	7.70 ± 0.015 c	4.77 ± 0.05 a	7.78 ± 0.022 b
FMC	7.75 ± 0.030 b	4.12 ± 0.09 b	7.81 ± 0.015 b

Values not followed by the same letter are significantly different at $p < 0.05$. Data are expressed as means ± SD (n = 4).

Both organic applications showed significant difference from inorganic treatment compared with soil analysis before planting. A limited effect of organic fertilizers' addition was observed on the calcium carbonate content of the studied soil.

3.2. Effect of Organic Waste and Biofertilizer Additions on Sunflower Plant Parameters

Inorganic treatment had the highest dry weight (41.0 g) with a significant effect compared to compost (CCB) and FMC treatments, followed by compost (CCB) treatment, (28.6 g) while the lowest effect was of FMC treatment with a mean 21.9 g (Table 3). The results revealed that all manure treatments, whether combined with or without (BF), led to a significant increase in sunflower dry weight.

Disk dry weight was 288.6, 175.5, and 121.3 g for inorganic, compost (CCB), and FMC, respectively.

The results in the same table show that compost (CCB) treatment scored the highest seed yield (8.963), highest oil yield (3.988), and highest stalk yield (11.795), followed by filter mud cake (7.387, 3.625, and 10.01, respectively), while inorganic treatment recorded the lowest values (6.60, 2.626, and 9.390, respectively).

The results in Table 4 indicate that FMC treatment showed a significant effect compared with compost (CCB) and inorganic treatment in the nitrogen percentage of leaves but there was no difference in nitrogen content of kernels. The results in the same table show a nonsignificant effect between treatments for potassium content of leaves but there was a significant difference for potassium kernel content of organic treatments compared with inorganic treatment.

3.3. Effects of Organic Waste and Biofertilizer Additions on Physical and Chemical Characteristics of Sunflower Seeds

Sunflower being an oilseed crop is considered a heavy feeder of nutrients. Among the various factors affecting the growth and yield of sunflower, nutrient management practices play a vital role. The dimensional properties of sunflower seeds' length (L), width (W), and thickness (T), and mass (m) of each seed (50 seeds) of the three treatments as well as the physical properties (100 seed weight, hull content, free hull, and bulk density) are presented in Table 5. Filter mud cake treatment produced the lowest dimensional properties of the seed in terms of weight and diameter, but they had nonsignificant differences compared with compost (CCB) in terms of length and width. The bulk density was 317.00, 312.00, and 301.50 for inorganic, compost (CCB), and FMC, respectively (Table 5). The inorganic and compost (CCB) samples also showed significant differences in bulk density compared to FMC samples, and the seed dimensions affected the value of the bulk density of the seeds. The growth and development of plants were increased by increasing the nitrogen application and decreased by decreasing the nitrogen rate.

Sunflower seeds for all treatments showed good seed weight (100 seed weight), recording 6.2585 g, 5.7265 g, and 5.6605 g for inorganic, compost (CCB), and FMC samples, respectively. At the same time, there were no significant differences among treatments with regard to 100 seed weight, and no differences were recorded for hull content, while a significant difference was found for the free hull values: the highest free hull percentage recorded was for compost (CCB) (67.65%), followed by FMC treatment (63.76%), while inorganic treatment recorded only 58.28% free hull percentage.

In the same table, inorganic treatment seeds show the best results in terms of seed dimensions compared to both compost (CCB) and FMC. In addition, the dimension characteristics of compost (CCB) treatment and seed were comparable with those of the inorganic treatment and there were no significant differences between inorganic treatment and compost (CCB) in relation to weight and width, while significant differences were recorded for both length and diameter.

The chemical composition of sunflower seeds (moisture, ash, oil, and protein) is presented in Table 6. The results show nonsignificant differences for protein and ash among all treatments. Ash content varied between 3.63% and 3.80% while protein percentage ranged from 17.71% to 18.20%. The results in the same table show a significant difference with regard to oil content, with FMC recording the highest oil percentage (44.20%,) while compost (CCB) recorded 41.15%, and finally came the inorganic sample with an oil percentage of 39.80%.

Table 4. Effects of organic waste and biofertilizer additions on sunflower plant parameters.

Treatments	Fresh W	Dry Weight g	Plant Hight cm	Disk Fresh Weight g	Disk Dry Weight g	Disk Diameter	Stalk Yield g/Pot	Oil Yield g/Pot	Seed Yield g/Pot	% N		K ppm	
										Leaves	Kernels	Leaves	Kernels
Inorganic	96.8 ± 7.99 a	41.0 ± 5.43 a	341.8 ± 11.01 a	392.5 ± 15.60 a	288.6 ± 12.91 a	20.3 ± 2 a	9.390 ± 0.34 c	2.626 ± 0.07 c	6.60 ± 0.16 c	0.9 ± 0.007 b	0.2 ± 0.006 a	225.3 ± 7.57 a	36.8 ± 6.36 b
CCB	64.9 ± 5.38 b	28.6 ± 4.63 b	314.3 ± 7.02 b	266.0 ± 15.60 b	175.5 ± 20.88 b	20.5 ± 2.08 a	11.795 ± 0.56 a	3.988 ± 0.15 a	8.963 ± 0.21 a	0.8 ± 0.062 b	0.2 ± 0.017 a	230.2 ± 10.31 a	43.1 ± 0.835 a
FMC	48.5 ± 6.49 c	21.9 ± 2.81 c	306.8 ± 6.02 b	226.7 ± 15.60 c	121.3 ± 10.49 c	19.9 ± 0.76 a	10.01 ± 0.42 b	3.625 ± 0.11 b	7.387 ± 0.34 b	1.0 ± 0.055 a	0.2 ± 0.013 a	212.9 ± 9.92 a	43.7 ± 1.02 a

Values not followed by the same letter are significantly different at $p < 0.05$. Data are expressed as means ± SD (n = 4).

Table 5. Physical characteristics of sunflower seeds.

Treatments	100 Seeds Weight g	Hull Content %	Free Hull %	Bulk Density	Dimensional Properties of Sunflower Seeds			
					Length L/mm	Width W/mm	Thickness T/mm	Mass M/g
Inorganic	6.26 ± 0.156 a	33.71 ± 1.05 a	58.28 ± 0.885 c	317.00 ± 1 a	0.9580 ± 0.056 a	0.3700 ±0.078 a	0.1740 ± 0.043 a	0.0732 ± 0.013 a
CCB	5.73 ± 0.092 a	28.93 ± 1.57 a	67.65 ± 0.951 a	312.00 ± 1 a	0.8790 ± 0.063 b	0.3600 ± 0.041 a	0.1470 ±0.042 b	0.0712 ± 0.011 a
FMC	5.66 ± 0.16 a	30.33 ± 1.06 a	63.77 ± 0.615 b	301.50 ± 1.1 b	0.9080 ± 0.092 b	0.3150 ± 0.058 b	0.0980 ± 0.031 c	0.0597 ± 0.010 b

Values not followed by the same letter are significantly different at $p < 0.05$. Data are expressed as means ± SD (n = 50 for dimensional properties of sunflower seeds measurements and n = 4 for physical characteristics of sunflower seeds assay).

Table 6. Chemical composition of sunflower seeds.

Gross Chemical Composition of Sunflower Seeds (%)					
Treatments	**Moisture**	**Ash**	**Fat**	**Protein**	**Carbohydrates**
Inorganic	3.04 ± 0.005 a	3.63 ± 0.03 a	39.80 ± 0.77 b	18.20 ± 0.23 a	38.37 ± 0.65 a
Compost (CCB)	2.47 ± 0.05 b	3.80 ±0.11 a	41.15 ± 0.35 ab	18.09 ± 0.22 a	36. 96 ± 0.72 b
FMC	2.33 ±0.09 b	3.70 ±0.11 a	44.20 ± 0.75 a	17.71 ± 0.35 a	34.39 ± 0.55 c

Values not followed by the same letter are significantly different at $p < 0.05$. Data are expressed as means ± SD (n = 4).

The results in the same table show a significant difference with regard to oil content, with the FMC sample recording the highest oil percentage (44.20%), while compost (CCB) recorded 41.15%, and finally came the inorganic sample with an oil percentage of 39.80%. The carbohydrate content varied from 34.39% to 38.37%, so there was a significant difference in carbohydrate content between treatments.

3.4. Sunflower Seed Oil Characteristics

3.4.1. Phenolic Compounds in Sunflower Oil

There is a scarcity of data on the effect of nitrogen form on the production of secondary metabolites in plants. Plants can absorb nitrogen (N) either as inorganic ions (NH^{4+} or NO^{3-}) or as organic nitrogen.

The results of phenolic content tests in Table 7 show total phenolic content of sunflower oil was significantly influenced by fertilizer source. The phenolic content of inorganic samples was 36.06 mg/100 g while it was 32.73 mg/100 g and 30.62 mg/100 g for both compost (CCB) and FMC samples, respectively. It was observed that the application of organic fertilizer decreased the production of total phenolics in sunflower seeds.

Table 7. Chemical composition of sunflower seed oils.

Sunflower Seed Oil Characteristics					
Treatments	**Phenolic Compounds (mg/100 g)**	**Chlorophyll (mg/Kg)**	**Transparency (%)**	**Alpha α-Tocopherol**	**Gamma γ-Tocopherol**
Inorganic	36.06 ± 0.345 a	1.36 ±0.047 a	26.06 ± 0.62 b	485.69 ±3.83 b	10.09 ±0.24 b
CCB	32.73 ±0.843 b	0.13 ±0.008 b	36.38 ±0.38 a	558.09 ±3.54 a	13.24 ±0.07 a
FMC	30.62 ±0.202 b	0.06 ±0.001 b	36.41 ±0.14 a	500.21 ±2.03 b	14.00 ±0.22 a

Values not followed by the same letter are significantly different at $p < 0.05$. Data are expressed as means ± SD (n = 4).

3.4.2. Tocopherol and Chlorophyll Content

In addition to fatty acids, tocopherol and other constituents such as phenolic compounds, carotenoids, and chlorophyll are important metabolites that should be studied expansively in oilseed to characterize seed oil and its relation to nitrogen fertilizers. Knowledge of the response of tocopherol in sunflower oilseed to nitrogen fertilizer sources and application rates is wanting. In the present study, nitrogen sources significantly affected α-, and γ-, Toc contents. The results in Table 7 show α- and γ- tocopherol contents of compost

(CCB) samples were the highest with 558.09 and 13.24, followed by FMC (500.21 and 14.00), while inorganic samples showed the lowest α- and γ- tocopherol contents (485.69 and 10.09). The results indicate that compost (CCB) fertilizer as a source of nitrogen yielded more seed α- α- and γ- tocopherol compared with the inorganic and FMC fertilizers; additionally, α-α- and γ- tocopherol content of compost (CCB) treatment increased significantly compared to both inorganic and FMC fertilizers, while a nonsignificant difference was recorded for γ-, α- and γ- tocopherol contents of compost (CCB) and FMC samples. The chlorophyll content of samples is shown in the same table, where the inorganic sample shows the highest content (1.36) and both compost (CCB) and FMC show low chlorophyll content (0.13 and 0.06), respectively.

3.4.3. Changes of Sunflower Oil Color

Sensory characteristics and oil appearance give oils a vital sensory role in food products. They are the main factors that influence their acceptability, desirable use, and market value (Figure 1).

Inorganic fertilizer   Compost coupled with biofertilizer (CCB)   Filter mud cake organic fertilizer (FMC)

Figure 1. Sunflower oils produced under different nitrogen fertilizers.

In this study, oil color was determined by measuring transparency at 455 nm (Table 7). Statistical analysis of the results of transparency measurements indicates the existence of significant differences between samples. The values of the investigated samples' transparency broadly varied, ranging from 26.06% for the most transparent oil (inorganic) to 36.41% for the darkest oil (FMC). In our study, oils produced from compost (CCB) and FMC gave higher blue values than inorganic.

3.4.4. Fatty Acid Profile of Sunflower Seed Oils under Different Nitrogen Sources

The changes in the fatty acid profile of sunflower attributable to different nitrogen source fertilization have been poorly investigated. In the present study, sunflower hybrids responded differentially to varying nitrogen sources in terms of fatty acid composition (Table 8); the unsaturated fatty acid content of sunflower oil in addition to stearic acid (C18:0) unsaturated fatty acid was significantly related to the nitrogen source.

There was a significant difference among different nitrogen treatments regarding oleic, linoleic, and stearic acid concentration. Oleic acid concentrations responded negatively to compost (CCB) nitrogen application compared to inorganic, while inorganic samples had the highest oleic content (58.83%) followed by FMC and compost (CCB), which had oleic acid concentrations of 58. 58% and 54.78%, respectively.

Table 8. Fatty acid profile of sunflower seed oils.

Fatty Acids \ Treatments	Inorganic	CCB	FMC
C14:0	0.055 ± 0.023 a	0.045 ± 0.022 a	0.045 ± 0.015 a
C16:0	5.70 ± 0.584 a	5.59 ± 0.030 a	5.34 ± 0.682 a
C16:1	0.15 ± 0.0 a	0.14 ± 0.021 a	0.13 ± 0.025 a
C17:0	0.04 ± 0.012 a	0.03 ± 0.009 ab	0.025 ± 0.017 b
C17:1	0.035 ± 0.006 a	0.030 ± 0.00 a	0.030 ± 0.010 a
C18:0	2.82 ± 0.02 a	2.53 ± 0.025 b	2.86 ± 0.020 a
C18:1	58.83 ± 0.015 a	54.78 ± 0.015 c	58.58 ± 0.020 b
C18:2	31.56 ± 0.032 b	35.64 ± 0.025 a	31.59 ± 0.010 b
C18:3	0.05 ± 0.02 a	0.03 ± 0.010 a	0.03 ± 0.010 a
C20:0	0.21 ± 0.02 a	0.19 ± 0.030 a	0.21 ± 0.050 a
C20:1	0.20 ± 0.015 a	0.14 ± 0.031 a	0.17 ± 0.040 a
C22:0	0.71 ± 0.021 a	0.04 ± 0.017 b	0.58 ± 0.145 a
C16:0 + C18.0 + C18.1 + C22.0/(C18:2 + C18:3)	2.16	1.76	2.13

Values not followed by the same letter are significantly different at $p < 0.05$. Data are expressed as means ± SD (n = 4).

4. Discussion

The addition of organic wastes decreased the soil pH [36,37]. Soil pH value was slightly decreased in the soils that were treated with organic wastes, which may be due to the accumulation of acidic organic materials [38]. This also may be attributed to the organic matter buffering property that met any changes in soil pH.

Badawi (2003) [39] reported that electrical conductivity values (EC) increased by application of composted plant residues and the increment attributes to the release of soluble salts of composted materials during their decomposition.

Khalil et al. (2004) [40] studied the effect of farmyard manure (FYM) and chicken manure (CM) individually and/or together combined with or without a biofertilizer (BF), *Azospirillum brasilense* or *Bacillus megatherium phosphaticum*, on wheat grown in sandy, calcareous, and clay soils. The results revealed that all manure treatments, whether combined with or without BF, led to a significant increase in wheat dry weight.

Inorganic treatment plants that received a recommended dose of chemical fertilizer had high plant height (341.8) with a significant effect compared with other organic treatments, which had no significant effects on plant height (306.8) (Table 4). This may be attributed to chemical fertilizers' ready solubility compared with organic fertilizer, where nitrogen plays a role in building up amino acids that are necessary for growth as it enters the composition of protein. This promotes cell division, which leads to increase in the activity of GAs inside plant tissues, and produces increasing cell elongation [41].

Compost (CCB) treatment recorded the second highest level of disk dry weight after inorganic treatment. This significant difference between treatments may be due to more nutrient solubility in mineral form in inorganic treatment than other treatments, which increased plant nutrient uptake. This also may be due to compost coupled with biofertilizer (CCB), which enhanced plant nutrients' uptake. These results are similar to those of [42], while a nonsignificant effect on head diameter was observed in all treatments. These results were compatible with those of [43]. The produced organic acids, such as acetate, lactate, oxalate, tartrate, succinate, citrate, gluconate, etc., during the composting process by the microbes might have caused the increase in the availability of nutrients, especially phosphorus. The availability of carbon and other nutrients is increased during composting because of the mineralization of nutrients present, which increases the microbial population and finally the organic acid production [44]. The existence of different organic acids in the composted resources accelerates the RP breakdown by quick dissolving reaction to the right.

Due to the low pH during the composting process, an increase in CO_2 production appeared. The produced CO_2 aids in carbonic acid production in the presence of water, consequently increasing the available phosphorus in the soil and from RP [45].

CCB and FMC organic fertilizers used in this study could have increased the availability of carbon and energy to N-fixing bacteria, which increases the population of bacteria.

In the present study, the addition of phosphate-solubilizing bacteria might have increased P availability. Moreover, the organic material used in the present study delivered micro and macronutrients which provide better root growth and nodulation. Previous studies have described similar results [46,47].

Organic fertilizers are useful; however, the presence of additional phosphorus with phosphate-solubilizing bacteria may enhance the crop yields in the same way as inorganic fertilizers [48].

Compost has some advantages for use as an organic fertilizer because it is a source of organic carbon that microbes require to enhance their growth promotion activities under drought stress [49], and it is also a source of available nutrients and natural vitamins, antibiotics, and hormones. As a result, it improves plant nutrient uptake, soil biological and chemical properties, and water holding capacity. The disadvantages of compost include the long time it takes to mature (3–5 months), and poor compost with low nutrients will be produced when poor materials are used for production, and fair can occur as a result of volatilized gaseous substances. Finally, extending the storage period reduces the nutritional content and value of the compost.

On the other hand, filter mud cake has some benefits, such as being a good source of essential nutrients. The addition of FMC to soil increases WHC and improves water and nutrient movement within the soil. Egypt produces a large amount of FMC due to the abundance of sugarcane factories in Upper Egypt. FMC availability is related to the presence of a sugarcane crop.

Compost (CCB) treatment produced high seed yield, high oil yield, and high stalk yield. The high production yield of sunflower crop treated with compost (CCB) may be due to nutrient availability caused by compost (CCB) decomposition and weak acids that are located in compost (CCB); also $CO_{2,}$ which results from decomposition, plays a major role in pH decreasing, which allows plants to absorb more nutrients. Moreover, microorganisms that are located in compost (CCB) or native microorganisms in soil enhance nutrient availability. The physical structure of the soil improves using vermicompost, which increases the organic carbon, N, P, Zn, K, Ca, and Mn availability in the soil [50]. Some soils do not have sufficient nutrients for sunflower growth or high seed and high oil yields. To solve this problem, organic compound fertilizers should be applied.

Kimana et al. (2018) [51] reported that applying organic fertilizers had a positive effect on the oil content of sunflower. The use of vermicompost alone or in combination with other organic or mineral fertilizers was effective in increasing the growth and yield of numerous plants [52,53].

On the other hand, [54] reported that the application of organomineral fertilizers increased sunflower yield and the related quality parameters and increased essential plant nutrients such as nitrogen, phosphorus, and potassium as well.

Kiniry et al. (1989) [55] and Malik et al. (1999) [56] evaluated different nitrogen application rates and sources on sunflower hybrids and found a positive response for stem height, yield, and diameter of the head and growth components but not on number of seeds. The abundant supply of nitrogen is important for increasing all the metabolic processes accountable for rapid growth and high crop production [57–59]. El-Aref et al. (2011) [60] indicated that FMC application to sunflower plants showed a significant effect on the seed index and this index increased by increasing the rate of FMC application. In the same study, they also showed that the application of FMC to the sunflower plants showed a significant impact on seed weight/plant and they attributed the increase in this characteristic to the increase in the shelling percentage and seed index.

The deficiency of nitrogen fertilizer at the earliest phases of growth, especially at the vegetative stage, causes a decrease in the number of leaves and also retards the growth of leaves [61]. Among the different nutrients influencing crop growth, N, P, and K are most critical. Nitrogen, phosphorus, and potassium management significantly affect achene oil contents. Sunflower needs a higher amount of nutrients during the first 40 and 60 days, which matches with flowering and seed setting stages. Nitrogen is an essential component of proteins and chlorophyll and it is physiologically important in plant metabolism. This means the amount of applied nitrogen from a different source in this study was adequate for optimal sunflower growth. The shortage of nitrogen has a large effect on the vegetative (leaves) and reproductive (florets and seed) stages of sunflower.

In this study, after applying organic fertilizers the improvement in plant response in terms of growth parameters can possibly be attributed to the proliferation of mineralization and absorption of nutrients which later translated into superior plant growth to control plants. Organic fertilizers could enhance the agronomic properties of sunflower by increasing nutrient accessibility in the form of N, P, and K in the soil environment. The increase in sunflower growth and yield was possibly caused by improved leaf area, chlorophyll density, and subsequently biomass production, causing more photoassimilation and eventually converting into higher grain yield [62]. Organic materials are able to keep nutrients in soils and improve the soil structure and fertility [63]. Similar results were also confirmed in [64], which states that the application of farmyard manure not only increases the soil health but also provides crops with different types of required nutrients. It was previously reported that yield parameters of a potato crop improved by significantly by increasing the quantities of organic manure [65]. Naveed et al. (2021) [66] concluded that the use of organic waste in agriculture acts as a soil improver and biostimulator to promote crop growth and helps to reduce the amount of agricultural wastes as well.

Ditta et al. (2015) [47] suggested that rock phosphate-enriched organic fertilizer and compost had a strong effect on lentil growth and yield compared with chemical phosphate fertilizer.

Montemurro and Giorgio (2005) [67] reported a negative correlation between seed yield and oil content, showing better seed production was related to lower oil content. The availability of sulfur improved the sulfur-containing coenzyme level, which is involved in fatty acids synthesis. With an increase in zinc content the availability and uptake of major nutrients increases; also boron content improves the sugar translocation and micronutrients involved in activation of more than 300 enzymes in plant systems [68]. Different forms of nutrient uptake under different tillage practices [69] may affect the coenzyme functioning of micronutrients and hence oil production in the plant. In this study, the amount of oil, particularly unsaturated fatty acids, was very much influenced by the organic nitrogen source during the period of oil accumulation and seed maturity. These were probable reasons for significant increase in oil content under different organic nitrogen sources application for fertigated plants receiving equal amounts of nitrogen. Montagu and Goh (1990) [70] observed that application of high NH^{4+} and low NO^{3-} levels improved fruit quality.

The phenolic compound content of both organically grown sunflower (compost (CCB) and FMC) treatments was lower than that in sunflower grown using inorganic fertilizers (inorganic). That is clear evidence that the nitrogen source affects the amount of formed phenolic compounds in sunflower: according to the C/N balance hypothesis, when nitrogen is readily available, plants will mainly make compounds with high nitrogen content such as proteins. When nitrogen availability is restricted, metabolism changes more towards carbon-containing compounds (e.g., starch, cellulose) and non-N-containing secondary metabolites such as phenolics and terpenoids [71].

The results support the hypothesis that the release of nutrients from various fertilizers varies according to the type of nitrogen. The relative variances in the release of nutrients from different fertilizers could lead to various C/N ratios in plants and this in sequence could lead to a difference in secondary metabolite production [71]. These results suggest that the usage of inorganic fertilizers can enhance the production of plant secondary metabolites in sunflower. Organic fertilizer contains nitrogen bound to organic material that is slowly released.

The third step of the mechanism of nitrogen uptake and assimilation in plants is assimilation of inorganic nitrogen into organic nitrogen [72], which means that the nitrogen from organic sources assimilates faster than that from inorganic source. In plants, tocopherol is found mostly in plastids, specifically in the chloroplast, [73], and nitrogen is a major component of chlorophyll and amino acids [73]. Chlorophyll and tocopherol are localized in the same plant tissues and may be linked because nitrogen may improve photosynthetic activity. Moreover, the function of tocopherol is highly related to maintaining the integrity and regular photosynthetic functions of the cell membrane system [74,75].

Thus, the current study shows the efficient conversion of compost (CCB) nitrogen into ammonium is more advantageous than both FMC and inorganic nitrogen in terms of regulating physiological processes in leaves to achieve higher production of tocopherol molecules in plastids. The characterization of chlorophyll-derived phytol and phytyl phosphate kinase from Arabidopsis [76,77], has shown that the prenyl moiety of tocopherol biosynthesis is derived from free phytol in seeds, indicating that phytol is recycled during chlorophyll breakdown [78–80]. Thus, the best plant growth caused by high nitrogen results initially in high photoassimilation storage in photosynthetic tissues and then in efficient translocation to seeds. Though our results refer to insights into the effects of nitrogen sources on seed tocopherol in sunflower oil, our results propose a possible interaction between tocopherol and chlorophyll contents in plastids, and between tocopherol and nitrogen fertilizer sources. This observation may explain the significant increase in tocopherol content of seeds from compost (CCB)-treated plants compared with those plants treated with inorganic nitrogen or from FMC nitrogen in the current study.

Moreover, the presence of dissolved constituents and other unfinished products could promote color in oils. Based on vegetable oil sensory studies, a positive relationship is found between the transparency of oils and sensory color marks [81]. Oils produced from compost (CCB) and FMC gave higher blue values than those produced with inorganic fertilizer. This might be due to the presence of carotenoids and other red pigments.

The bud and flowering stages are a sensitive period for crops related to fertilizers and the environment. So, the influence of soil nutrient status on crude fat and fatty acid composition of crude oil from sunflower seeds was greater [82].

Boydak et al. (2010) [83] observed a decrease in oleic fatty acid content with increased nitrogen application. Oleic acid content was negatively correlated with both linoleic acid and palmitic acid. Li et al. (2017) [82] showed that no fertilizer or low nitrogen fertilizer application rates would raise the content of unsaturated fatty acid of sunflower seed oils. Temperature and genotype during oil formation had a major effect on the oleic and linoleic acids proportions, whereas the effect of nitrogen supply was small and depended on nitrogen application timing [84].

The present study assumed the oil content and fatty acid composition response to the nitrogen source of sunflower seeds may occur through direct effects of nitrogen supply on the enzymes of lipid synthesis during the seed-filling period. Wolswinkel (1987) [85] stated that fatty acids are synthesized in the fertilized ovule and not translocated from other organs, such as leaves, where the early nitrogen supply could have influenced synthetic processes. Another report on fatty acid synthesis in sunflower seeds [86] proposed that the activation or synthesis of oleoyl-CoA desaturase is genetically programmed and that environmental factors could interact with this program activation. Steer and Seiler (1990) [84] suggested that the early nitrogen supply rates could modify the genetic programmed activation that later is expressed as different desaturase activities in the developing seed.

The results are difficult to interpret in terms of our current knowledge of lipid biosynthesis. Nitrogen sources may affect the rate of fatty acid complex hydrolysis or their transport from the proplastid to the cytosolic compartment. The relationship between the proplastid and cytosol components may be expressed in sunflower by the fraction

(C16:0 + C18:0 + C22:0 + C24:0 + C18:1)/(C18:2 + C18:3). A low value means a relatively high flux of fatty acids into the cytosolic compartment. Our results in the same table below show that compost (CCB) treatment gives the lowest value of 1.76, suggesting an enhancement at this transport step for this treatment.

Stumpf (1980) [87] studied the evidence for the place of fatty acids synthesis in cells of leaves or seeds and proposed a scheme whereby the steps up to C18: l acid occur in proplastids and the desaturation of C18:l to C18:2 and C18:3 acids take place in the cytosol, associated with the endoplasmic reticulum. Thus, the proportions of fatty acids may be controlled not only by enzyme activity but also by a transport step from one organelle to another. The nitrogen source could affect this transport step.

5. Conclusions

Based on the obtained results, it can be concluded that using organic fertilizers from different sources is an effective method for producing sunflower seeds and oil with high quality compared with that produced by conventional inorganic fertilizers. Organic fertilizers can be considered a valuable source of organic matter and nutrients for plants. The results of studies of soil properties showed that the addition of organic wastes decreased the soil pH, and increased the electrical conductivity values (EC). Both organic applications showed significant difference from inorganic treatment compared with soil analysis before planting. The inorganic treatment produced the highest dry weight, plant height, and disk dry weight with a significant effect compared with other organic treatments. A high production yield of sunflower was also recorded for organic treatments with high seed yield, high oil yield, and high stalk yield, while inorganic treatment recorded the lowest values. Regarding the physical and chemical characteristics of sunflower seeds, there were no significant differences among treatments with regard to 100 seed weight and hull content, while a significant difference was found for the free hull. Inorganic treatment seeds had the best results in terms of seed dimensions compared to both compost (CCB) and FMC treatment seeds. The inorganic fertilizer also produced higher chlorophyll content and phenolic secondary metabolites than organic fertilizers. In contrast, it was found that organic fertilizers enhance the production of tocopherol. In the present study, sunflower hybrids responded differentially to varying nitrogen sources in terms of fatty acid composition. There was a significant difference among different nitrogen treatments regarding oleic, linoleic, and stearic acid concentration. Oleic acid concentrations responded negatively to compost (CCB) nitrogen application compared to inorganic fertilizer application. Agricultural wastes can be well utilized in the production of good and cheap organic fertilizers that can be easily used to increase the productivity of one of the most important oilseed crops in Egypt, sunflower, subsequently contributing to solving the problem of the shortage of produced oils in Egypt, in addition to solving the problem of safe disposal of agricultural wastes.

Author Contributions: Conceptualization, A.A.A.B., E.M.M.T. and N.L.; methodology, A.A.A.B., E.M.M.T. and N.L.; software, A.A.A.B.; E.M.M.T. and N.L.; statistical analysis, A.A.A.B., E.M.M.T., N.M.A. and N.L; investigation, A.A.A.B., E.M.M.T., N.L. and N.M.A.; funding acquisition, N.M.A.; data curation, A.A.A.B., E.M.M.T. and N.L.; writing—original draft preparation, A.A.A.B., E.M.M.T and N.L.; writing—review and editing, A.A.A.B., E.M.M.T. and N.L. All authors have read and agreed to the published version of the manuscript.

Funding: There is no financial funding from any governmental or non-governmental entity.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The datasets generated and/or analyzed during the current study are available from the corresponding authors upon reasonable request.

Acknowledgments: The author would like to thank the Deanship of Scientific Research at Shaqra University for supporting this work.

Conflicts of Interest: The authors have no conflicts of interest.

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