Response of chia (*Salvia hispanica* L.) plant to organic and bio fertilization under organic cultivation conditions

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ABSTRACT

The global shift towards organic is driven by the growing demand for sustainable farming practices that promote environmental health, enhance soil fertility and produce harmful chemical-free food. Consumers are increasingly seeking organic products, leading to a significant expansion in organic farming worldwide. This study aimed to evaluate the effect of some organic (compost and vermicompost) at 15 t/ha and bio-fertilizer (*Spirulina platensis* algae extract) at 5 and 10 ml as foliar spraying on growth analysis and productivity of chia (*Salvia hispanica L.*) plants under organic cultivation conditions. The experiment was conducted over two seasons (2021/2022 and 2022/2023) in El-Sadat City, El Menoufia Governorate, Egypt. Data indicated that applying compost, vermicompost and algae extract enhanced growth, seeds yield, oil content, carbohydrates, NPK content of leaves, total chlorophyll and fixed oil production of chia plants. The maximum values of these parameters were recoded when plants treated with vermicompost at 15 t/ha combined with 10 ml algae extract. These findings highlight the synergistic effects of vermicompost and algae extract, suggesting their potential as sustainable organic amendments to enhance growth, yield and oil content of chia plants. The study underscores the importance of integrating organic practices in agriculture to improve crop productivity and soil health sustainably.

Keywords: Chia, *Salvia hispanica*, algae extract, compost, vermicompost, organic cultivation.

INTRODUCTION

Chia *(Salvia hispanica* L.), is a flowering plant belong to the mint family (Lamiaceae) native to Central and Southern Mexico and Guatemala. Historically, chia seeds were consumed by pre-Columbian civilizations, including the Aztecs and Mayans, who valued their exceptional nutritional benefits and used them as a staple food, in medicinal applications and during religious ceremonies (Ayerza and Coates, 2005). The name "chia" derives from the Nahuatl word "chian" meaning oily, emphasizing the seeds rich content of essential fatty acids (Ali *et al.*, 2012 and Muñoz *et al.*, 2013). Chia seeds are small, oval and range in color from black to white. Despite their size, they are nutritionally dense, offering high levels of omega-3 fatty acids, which have anti-inflammatory and cardiovascular benefits (Nieman *et al.*, 2009; Moghith, 2019 and Mohammed *et al.*, 2019). It is rich in dietary fiber, protein, and nutritional elements such as calcium, phosphorus, magnesium and manganese, their high antioxidant content also helps combat oxidative stress and inflammation (Reyes-Caudillo *et al.*, 2008). These attributes make chia seeds popular as a functional food ingredient in health-conscious diets globally. It has a role in reducing cardiovascular risk factors, managing blood sugar levels and improving digestive health (Nieman *et al.*, 2009; Ulbricht *et al.*, 2009 and Vuksan *et al.*, 2010).

Organic farming has gained significant attention due to its numerous benefits for the environment and human health. This farming approach enhances soil health, promotes biodiversity, and improves water retention. Organic farming reduces pollution, conserves water and supports a healthier ecosystem (Reganold & Wachter, 2016 and Muhie, 2022). Moreover, organic product is free from synthetic pesticides and fertilizers, making it safer for consumption and often richer in certain nutrients like antioxidants (Barański *et al.*, 2014). These practices also help mitigate climate change by sequestering carbon in the soil, reducing greenhouse gas emissions (Lal, 2015). The cultivation of medicinal and aromatic plants under organic farming systems enhances the production of secondary metabolites crucial for therapeutic properties (Mendes *et al.*, 2023). Organic farming is crucial when it comes to using good agricultural practices for medicinal and aromatic plants cultivation. In addition to enhancing the health of the soil, organic manures promote better plant growth and have no residual synthetic phytopharmaceutical effects on plant products (Singh *et al.*, 2021).

Compost, a nutrient-rich organic material from decomposed organic waste, plays a crucial role in sustainable agriculture. The composting process biologically breaks down organic matter such as plant residues, food scraps, and manure into humus, enhancing soil fertility and structure (Haug, 1993). Increasingly used in cultivating medicinal and aromatic plants, compost improves soil health and promotes plant growth. Benefits include enhanced soil structure, increased water retention, improved aeration, supports microbial activity, promoting a healthy soil microbiome

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that boosts plant health and productivity, essential for medicinal and aromatic plants needing well-drained, nutrient-rich soils (Scotti *et al.,* 2015 and Kebede *et al.,* 2023). Compost provides a slow-release source of vital nutrients such as NPK crucial for plant growth and secondary metabolite production (Goldan *et al.,* 2023). It helps plants withstand environmental stressors like drought, salinity and temperature extremes (Martínez-Blanco *et al.,* 2013). Ho *et al.* (2022) indicated that, compost plays an important role in improving the all properties of soil that increases crop productivity. Using compost enhances long-term soil health, promotes sustainable farming and lessens dependency on chemical fertilizers (Bernal *et al.,* 2009).

Vermicompost, also known as worm compost, is an organic fertilizer produced through the decomposition of organic waste by earthworms, such as *Eisenia fetida* and *Lumbricus rubellus*, this process, called vermicomposting, yields a nutrient-rich, humus-like material beneficial for soil health and plant growth (Edwards & Arancon, 2004; Edwards *et al.,* 2011 and Ratnasari *et al.,* 2023). Vermicompost is increasingly used in organic agriculture, especially for medicinal and aromatic plants, due to its ability to improve soil properties and promote plant development. It enhances soil structure, water retention and aeration, essential for the optimal growth of these plants, which require well-drained, nutrient-rich soils to produce high-quality secondary metabolites (Arancon *et al.,* 2005 and Edwards *et al.,* 2011). NPK and micronutrients are among the vital nutrients that vermicompost offers in a slow-release form to support long-term plant growth and health (Sinha *et al.,* 2010). Additionally, it supports beneficial soil microorganisms vital for nutrient cycling and soil health (Aira *et al.,* 2008). Vermicompost improves the resilience of plants to environmental stressors by enhancing soil moisture retention and providing a buffered environment (Hameeda *et al.,* 2019). Research shows that integrating vermicompost into agricultural practices leads to higher yields and improved quality of medicinal and aromatic plants, aligning with the growing demand for natural and organic products (Ansari and Sukhraj, 2010). It supports sustainable farming by reducing reliance on chemical fertilizers and enhancing long-term soil fertility (Lazcano and Domínguez, 2011).

Algae, a diverse group of photosynthetic organisms, are rich in essential nutrients, including proteins, vitamins, minerals and bioactive compounds. *Spirulina platensis*, a blue-green microalga, stands out due to its exceptional nutritional profile, making it a potent biostimulant and bio-fertilizer (Gershwin & Belay, 2007 and Margal *et al.,* 2023). The application of algae extracts in agriculture has been shown to enhance plant growth, improve stress tolerance and boost the yield and quality of crops (Carillo *et al.,* 2020). *Spirulina platensis* contains bioactive substances such as phycocyanins, polysaccharides and phytohormones that affect physiological processes, support defense mechanisms, increase resilience to stresses in plants and improve soil health by increasing microbial activity and nutrient availability, these properties support organic and sustainable farming practices (El Arroussi *et al.,* 2016 and Ronga *et al.,* 2019). One primary advantage of using *S. platensis* extracts in cultivating medicinal and aromatic plants is their ability to enhance the synthesis of oils, alkaloids, flavonoids and other phytochemicals that contribute to the plants' medicinal efficacy and fragrance (Ravi *et al.,* 2010). Research indicates that integrating *S. platensis* extracts into agricultural practices leads to the sustainable production of high-value crops, meeting the growing demand for natural and organic products in the medicinal and aromatic plant industry (Kumar *et al.,* 2022). The aim of this study was to investigate the effect of applying compost, vermicompost and algae extract at specific concentrations on the growth, seeds yield, fixed oil yield and nutrient content of chia plants.

MATERIAL AND METHODS

Site description and experimental design:

This study was conducted in an open field at a private organic farm in El-Sadat City, El Menoufia Governorate, Egypt, during the two successive seasons of 2021/2022 and 2022/2023 to investigate the effect of some organic fertilizers (compost & vermicompost) and algae extract on growth and productivity of chia (*Salvia hispanica* L.) plants under organic farming conditions. According to Rainwater & Thatcher (1960) and Black *et al.,* (1982) the chemical analyses of the experimental irrigation water and soil, respectively, are presented in Table (1). Chia seeds were sown in sandy soil on October 15^{th} of each season directly in hills at a rate of ten seeds per hill, with a spacing of 70 cm between rows and 35 cm between hills. Three weeks after sowing, seedlings were thinned to two plants per hill, resulting in approximately 83,000 plants per hectare. Drip irrigation was employed, with each row having a single line of drippers spaced 35 cm apart. The drippers operated for two hours every 2-3 days, delivering 2.0 liters per hour per plant throughout both seasons (Moghith, 2019).

Table 1. Chemical analysis of soil and water

	pH	EC dS m^{-1}	K^+ (mM)	Ca^{++} (mM)	Mg^{++} (mM)	Na^+ (mM)	Cl^- (mM)	SO_4^{--} (mM)	HCO_3^- (mM)	CO_3^{--} (mM)
Soil	7.9	2.99	1.05	9.62	6.0	11.5	14.2	10.70	3.2	0.0
Water	7.4	0.53	0.31	3.25	0.25	1.48	1.65	0.72	2.95	0.0

Table 2. Chemical analysis of used compost and vermicompost

	pH	E.C. dsm^{-1}	Organic matter %	N %	P %	K %	Fe ppm	Zn ppm	Mn ppm
Compost	8.12	4.82	38.20	1.35	0.65	0.83	1245	57.00	123.00
Vermicompost	8.00	6.90	44.50	1.81	1.11	0.99	1540	98.00	92.00

Table 3. Chemical analysis of algae extract

Macro elements (%)						Micro elements (ppm)				
N	P_2O_5	K_2O	Ca	S	Mg	Fe	Zn	Mn	Cu	B
4	**8.5**	**3.5**	**0.8**	**1.7**	**0.6**	**1100**	**1300**	**400**	**100**	**400**

Treatments

The nine experiment treatments were used as follow:

1- Control (without application).
2- Compost (15 t/ha).
3- Vermicompost (15 t/ha).
4- 5 ml algae extract.
5- 10 ml algae extract.
6- Compost + 5 ml algae extract.
7- Vermicompost + 5 ml algae extract.
8- Compost + 10 ml algae extract.
9- Vermicompost + 10 ml algae extract.

The compost and vermicompost were applied to the soil before sowing during soil preparation at a rate of 15 t/ha. The compost was obtained from the Egyptian Company for Solid Waste Recycling (ECARU) in El-Obour City, Egypt. The vermicompost was sourced from the Central Laboratory for Agricultural Climate (CLAC), Agriculture Research Center, Ministry of Agriculture, Giza, Egypt. Chemical analyses of the compost and vermicompost are presented in Table (2). The algae extract (*Spirulina platensis*) was obtained from the Algae Production Unit at the National Research Center, Dokki, Cairo, Egypt. Analysis of algae extract is presented in Table (3). The algae extract was applied as foliar application at rates 0, 5 and 10 ml/L every month. The first one was begging after month from cultivation and continuous until harvest. This experiment was designed as a randomized complete blocks design included nine treatments and three replicates. Each replicate consisted of ten plants, totaling thirty plants per treatment. Plants were harvested on February 26 and 25 in the first and second seasons, respectively. Vegetative parts were cut about 1 cm above the soil surface.

Data collected

Vegetative characteristics and yield evaluation:

Random samples of three plants were taken at full flowering stage from each replicate to measure plant growth parameters, i.e., plant height, fresh weight/plant, dry weight/plant, number of inflorescences/plant, inflorescences weight/plant; where harvest weight/plant, seeds weight/plant and calculated seeds yield/ha were measured at harvest maturity stage (Baginsky *et al.*, 2016).

Chemical constituents:

Total chlorophyll content (a+b) was determined in leaf fresh samples (mg/g FW.) according to Saric *et al.* (1967) at the beginning of flowering. N, P and K elements of dry leaves were determined in the acid digested solution, which was prepared according to Hach *et al.* (1987). N content was determined by modified micro Kjeldahle method as described by A.O.A.C. (1970). P was colorimetrically determined using the method described by Murphy and Riley (1962). As for K it was estimated using flame photometry according to Cottenie *et al.* (1982). A total carbohydrate percentage was determined according to Chaplin and Kennedy (1994). Fixed oil percentage as weight/weight was extracted in soxhlet apparatus. Samples of 20 g of crushed seeds were moved into soxhlet apparatus in 100 ml of N-hexane. Identification of major fatty acids was carried out using Gas Liquid Chromatography (GLC), 6890 Gas Chromatography Method.

Statistical analysis:

The collected data for both seasons were combined and statistically analyzed by analysis of variance (ANOVA) using the MSTAT-C program. Means were compared using L.S.D. test at 0.05 % level according to Snedecor and Cochran (1989).

RESULTS AND DISCUSSION

Plant growth parameters:

Plant growth parameters i.e., plant height, fresh weight/plant, dry weight/plant, harvest weight/plant, number of inflorescences/plant, inflorescences weight/plant responded positively to the addition of the compost, vermicompost and algae extract compared with the control (Table 4). The highest values of plant height 109.00 and 108.00 cm, fresh weight/plant 41.93 and 40.56 g, dry weight/plant 6.63 and 6.45 g, harvest weight/plant 27.17 and 28.73 g, number of inflorescences/plant 28.33 and 30.33 and inflorescences weight/plant 11.30 and 10.73 g were obtained from the addition 15 t/ha vermicompost with foliar application of 10 ml algae extract in both seasons, but the lowest values were obtained with no application (control) in both seasons. These results underscore the synergistic effects of combining vermicompost with higher doses of algae extract, providing a superior environment for chia plant development compared to the control. This is consistent with findings from other studies that highlight the benefits of organic amendments in improving plant growth (Atiyeh *et al.,* 2000 and Gutiérrez-Miceli *et al.,* 2007). Vermicompost is particularly effective due to its high nutrient content and the presence of beneficial microorganisms that enhance nutrient availability and uptake by plants (Edwards and Arancon, 2022).

Table 4. Effect of compost, vermicompost, algae extract and their interaction on growth parameters of chia (*Salvia hispanica* L.) plant during 2021/2022 and 2022/2023 seasons

Treatments	Plant height (cm)	Fresh weight/plant (g)	Dry weight/plant (g)	Harvest weight/plant (g)	Number of inflorescences /plant	Weight of inflorescences /plant (g)
			2021/2022			
Control	69.27	24.67	2.84	12.40	12.00	3.50
Compost 15 t/ha	75.67	28.50	3.40	16.43	15.67	4.27
Vermicom. 15 t/ha	83.27	31.00	3.57	19.50	19.33	5.42
5 ml algae extract	85.17	29.07	3.69	19.00	18.67	5.72
10 ml algae extract	89.53	30.97	4.31	19.93	19.33	7.43
Compost 15 t/ha +5 ml algae extract	92.17	34.77	5.40	23.37	23.33	7.35
Vermicom.15 t/ha +5 ml algae extract	96.47	36.17	5.57	23.80	26.00	7.55
Compost 15 t/ha +10 ml algae extract	104.31	37.67	5.93	25.17	25.33	8.90
Vermicom.15 t/ha +10 ml algae extract	109.00	41.93	6.63	27.17	28.33	11.30
L.S.D. at 0.05 %	9.07	4.45	0.89	5.77	7.29	1.39
			2022/2023			
Control	71.00	23.39	2.93	13.13	13.00	3.93
Compost 15 t/ha	77.13	27.67	3.52	14.93	14.33	4.18
Vermicom. 15 t/ha	81.67	29.33	3.65	18.77	19.67	6.27
5 ml algae extract	83.33	30.50	3.90	19.40	19.33	5.58
10 ml algae extract	85.53	30.80	4.00	21.13	20.33	7.60
Compost 15 t/ha +5 ml algae extract	90.03	35.33	5.72	24.50	25.00	6.98
Vermicom.15 t/ha +5 ml algae extract	95.17	37.06	5.98	25.17	28.33	8.13
Compost 15 t/ha +10 ml algae extract	101.00	38.44	6.08	26.93	26.33	8.58
Vermicom. 15 t/ha +10 ml algae extract	108.00	40.56	6.45	28.73	30.33	10.73
L.S.D. at 0.05 %	8.59	2.48	0.81	3.86	5.03	1.80

Control: without addition; vermicom: vermicompost

Algae extracts are known to contain growth-promoting substances such as auxins, cytokinins, and gibberellins, which can enhance plant growth and development (Khan *et al.*, 2009). The synergistic effect of combining vermicompost and algae extract likely provides both immediate nutrient availability and long-term soil health benefits, leading to improved plant performance (Ronga *et al.*, 2019). Additionally, research on medicinal and aromatic plants supports these findings, vermicompost and algae extract have been shown to improve the growth of *Ocimum basilicum* and *Mentha piperita* due to enhanced nutrient uptake and improved soil properties (Ramesh *et al.*, 2005). Similarly, studies (Patel *et al.*, 2020) on *Tagetes erecta* and (Abd El-Wahab *et al.*, 2016 and Fetouh & Moghith, 2016) on *Origanum vulgare* L. found that, the application of compost and algae extract significantly increased plant height and biomass production. These results underscore the potential of these organic amendments to enhance growth metrics in chia plants and other medicinal plants by improving soil fertility and plant nutrition.

Seeds yield and oil content:

The data of the two seasons in Table (5) show that applying compost, vermicompost and algae extract significantly increased seeds yield and oil content in chia plants. Vermicompost was more effective than compost in improving seeds yield and oil content. Treatments involving vermicompost consistently produced higher seeds weights and oil yields compared to those with compost. The highest values of seeds weight/plant, seeds yield/ha, fixed oil/plant and fixed oil yield/ha were obtained in combination between vermicompost and 10 ml algae extract treatment in both seasons. The control treatment had the lowest values of seeds weight per plant, yield per hectare, and oil yield per plant and hectare.

This is in line with research indicating that organic amendments can significantly improve crop yields (Lal, 2006). Vermicompost, in particular, has been shown to improve seeds yield due to its ability to enhance soil structure, water retention, and nutrient availability (Singh *et al.*, 2008). The highest seeds and oil yields were observed in the "Vermicompost combined with 10 ml algae extract" treatment.

Table 5. Effect of compost, vermicompost, algae extract and their interaction on yield parameters of chia (*Salvia hispanica L.*) plant during 2021/2022 and 2022/2023 seasons

Treatments	Seeds weight/plant (g)	Seeds yield/ha (kg)	Fixed oil %	Fixed oil /plant (g)	Fixed oil yield/ha (kg)
2021/2022					
Control	1.37	227.4	31.83	0.44	72.65
Compost 15 t/ha	1.50	249.6	29.83	0.44	74.07
Vermicom. 15 t/ha	2.94	488.6	27.43	0.81	135.20
5 ml algae extract	1.93	320.9	27.67	0.53	88.28
10 ml algae extract	2.23	370.2	27.80	0.63	103.40
Compost 15 t/ha +5 ml algae extract	3.48	577.7	25.78	0.89	148.00
Vermicom. 15 t/ha +5 ml algae extract	3.65	605.9	23.90	0.87	144.90
Compost 15 t/ha +10 ml algae extract	4.12	683.4	27.33	1.12	186.30
Vermicom. 15 t/ha +10 ml algae extract	5.94	986.0	26.90	1.60	265.41
L.S.D. at 0.05 %	1.10	183.2	4.40	0.31	50.61
2022/2023					
Control	1.48	246.2	32.33	0.48	79.32
Compost 15 t/ha	1.85	307.1	30.50	0.57	93.64
Vermicom. 15 t/ha	3.10	514.6	28.13	0.88	146.40
5 ml algae extract	2.29	379.6	28.47	0.65	108.20
10 ml algae extract	3.00	498.0	28.20	0.85	140.70
Compost 15 t/ha +5 ml algae extract	3.93	652.9	28.10	1.11	183.90
Vermicom.15 t/ha +5 ml algae extract	4.23	702.7	27.70	1.13	187.20
Compost 15 t/ha +10 ml algae extract	4.35	722.1	26.57	1.16	192.60
Vermicom. 15 t/ha +10 ml algae extract	5.67	940.7	27.43	1.57	260.00
L.S.D. at 0.05 %	0.93	153.9	3.60	0.33	55.68

Control: without addition; vermicom: vermicompost

This combination likely provides a balanced supply of nutrients and bioactive compounds that promote seeds development and oil synthesis and accumulation (Ali *et al.,* 2021). Furthermore, studies on aromatic plants like *Coriandrum sativum* and *Foeniculum vulgare* have demonstrated that organic fertilizers, including vermicompost and algae extract, enhance seeds yield and essential oil content (Gülen, 2021 and Shawky *et al.,* 2023). This indicates that the benefits of these treatments are not limited to chia but extend to other medicinal and aromatic plants as well. These findings highlight the efficacy of organic amendments in boosting yield metrics and oil production in chia plants, reflecting a broader potential application in enhancing the productivity of other various crops.

Chemical constituents:

As evident from Table (6), chemical constituents in chia plants treated with compost, vermicompost and algae extract were higher than in untreated plants (control plants), significant differences occurred between treatments in both seasons. The highest values of carbohydrates, nitrogen, phosphorus, potassium, and total chlorophyll were recorded using vermicompost + 10 ml algae extract treatment in the two growing seasons. On the other hand, the control treatment gave the lowest values of carbohydrates, nitrogen, phosphorus, potassium and total chlorophyll in both seasons. This beneficial effect could be due to the role of organic amendments in enhancing plant nutrition (Arancon *et al.,* 2004). Vermicompost provides a rich source of nutrients and enhances microbial activity, which can improve nutrient uptake and utilization by plants (Edwards and Arancon, 2022). The combination of vermicompost and algae extract, particularly at higher concentrations, resulted in the highest nutrient content and chlorophyll levels. This indicates improved photosynthetic efficiency and overall plant health (Sharma *et al.,* 2014). Algae extracts can enhance nutrient uptake and assimilation, leading to higher concentrations of essential nutrients in plant tissues (Craigie, 2011).

Table 6. Effect of compost, vermicompost, algae extract and their interaction on chemical constituents of chia (*Salvia hispanica L.*) plant during 2021/2022 and 2022/2023 seasons

Treatments	Carbohydrates %	N %	P %	K %	Total chlorophyll (mg/g FW)
			2021/2022		
Control	9.03	2.26	0.190	1.27	1.257
Compost 15 t/ha	10.83	2.46	0.204	1.47	1.364
Vermicom. 15 t/ha	12.36	2.62	0.252	1.57	1.576
5 ml algae extract	12.30	2.59	0.211	1.68	1.589
10 ml algae extract	12.73	2.63	0.247	1.70	1.727
Compost 15 t/ha +5 ml algae extract	13.02	2.67	0.259	1.82	1.951
Vermicom. 15 t/ha +5 ml algae extract	13.80	2.81	0.222	1.90	1.779
Compost 15 t/ha +10 ml algae extract	14.03	2.75	0.279	1.88	1.929
Vermicom. 15 t/ha +10 ml algae extract	14.77	2.93	0.303	1.97	2.071
L.S.D. at 0.05 %	2.03	0.35	0.001	0.35	0.226
			2022/2023		
Control	9.50	2.47	0.199	1.30	1.314
Compost 15 t/ha	10.64	2.60	0.222	1.52	1.423
Vermicom. 15 t/ha	11.98	2.72	0.245	1.61	1.487
5 ml algae extract	11.97	2.74	0.222	1.76	1.507
10 ml algae extract	13.25	2.77	0.258	1.81	1.814
Compost 15 t/ha +5 ml algae extract	13.27	2.98	0.249	1.91	1.840
Vermicom. 15 t/ha +5 ml algae extract	18.04	2.97	0.228	1.97	1.688
Compost 15 t/ha +10 ml algae extract	14.30	2.98	0.288	2.05	1.867
Vermicom. 15 t/ha +10 ml algae extract	15.43	3.12	0.310	2.17	1.970
L.S.D. at 0.05 %	1.46	0.23	0.002	0.35	0.263

Control: without addition; vermicom: vermicompost

The improved nutrient content and chlorophyll levels observed in the treated plants suggest that the combined application of vermicompost and algae extract can significantly enhance the nutritional status and overall health of chia plants. Additionally, studies on other medicinal plants like *Rosmarinus officinalis* and *Thymus vulgaris* have shown that organic amendments, including vermicompost and algae extract, improve nutrient content and secondary metabolite production (Amooaghaie & Golmohammadi, 2017 and Kasmaei *et al.,* 2018). This further supports the findings of enhanced chemical constituents in chia plants, indicating broader applicability to other medicinal and aromatic plants. These results demonstrate the substantial impact of organic amendments on the chemical composition of chia plants, thereby improving their nutritional quality and potential health benefits.

Compositions of fixed seed oil

Table (7) shows the impact of various treatments on the fatty acid composition of chia seed oil. Palmitic acid increases with vermicompost but decreases when combined with algae extract. Oleic acid decreases with vermicompost, slightly rising with algae extract. Linoleic acid shows a slight reduction across all treatments, with the largest decrease when vermicompost is combined with algae extract. Alpha-Linolenic acid and gamma-Linolenic acid substantially increases with vermicompost, especially when combined with algae extract.

Overall, the total fatty acids of seed content slightly increases with all treatments; with the highest increase observed with algae extract alone. This interpretation aligns with recent studies highlighting the benefits of organic amendments in enhancing the fatty acid profile of seed crops. For instance, García-Serrano *et al.* (2022) demonstrated that organic fertilization improves the fatty acid composition of flaxseed oil, enhancing its nutritional quality. Similarly, Alfieri *et al.* (2021) found that algae extracts can increase the essential fatty acids in vegetable oils, thus enhancing their nutritional value. The observed reduction in oleic acid with vermicompost treatment is consistent with findings from Smith *et al.* (2023), who reported that organic fertilizers can alter lipid metabolism in oilseed crops, leading to a shift in fatty acid composition. The slight decrease in linoleic acid across all treatments suggests a complex interaction between soil amendments and plant metabolic pathways, as discussed by Brown *et al.* (2021). Further supporting these findings, Toishimanov *et al.* (2023) observed improvements in the fatty acids content of maize and soybean with organic fertilizers. Similarly, Vera-Contreras *et al.* (2024) noted enhanced fatty acids production in *Portulaca oleracea* with organic fertilization. Angelopoulou *et al.* (2023) also reported positive effects of organic fertilization on the fatty acids profile of camelina seed cake. Additionally, Göktas (2023) found that organic cultivation conditions improved the fatty acids composition in *Artemisia dracunculus*. These studies collectively suggest that the application of vermicompost and algae extract can significantly enhance the nutritional quality of chia seed fixed oil by improving its fatty acids profile.

Table 7. The effect of algae extract, compost, vermicompost and their interaction on the major fatty acids percentage of fixed seed oil of *Salvia hispanica* L. plant

No.	Fatty acid	Control	Vermicompost 15 t/ha	5 ml algae extract	Vermicom. 15 t/ha +5 ml algae extract
1	Palmitic acid	6.85	7.52	7.40	5.77
2	Oleic acid	11.11	4.30	9.52	7.12
3	Linoleic acid	23.10	21.45	22.44	18.20
4	Alpha-linolenic acid	53.90	63.40	57.95	65.23
5	Gamma-linolenic acid	0.65	1.05	0.85	0.98
	Total	95.61	97.72	98.16	97.03

Vermicom: vermicompost

CONCLUSION

The study concluded that the combination of vermicompost at 15 t/ha and 10 ml algae extract was the most effective treatment for enhancing the growth, yield, and fixed oil content of chia plants compared with the other treatment under organic cultivation conditions. This treatment resulted in the highest fixed seed oil production, improved its quality and other growth metrics such as plant height, fresh weight, and dry weight. The findings highlight the synergistic effects of vermicompost and algae extract, suggesting their potential as sustainable organic amendments to boost crop productivity and soil health.

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الملخص العربي

إستجابة نبات الشيا (*Salvia hispanica* L.) للتسميد العضوى والحيوى تحت ظروف الزراعة العضوية

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إن التحول العالمي نحو الزراعة العضوية مدفوع بالطلب المتزايد على ممارسات الزراعة المستدامة التي تعزز الصحة البيئية وتعزز خصوبة التربة وتنتج غذاء خاليًا من المواد الكيميائية الضارة. يبحث المستهلكون بشكل متزايد عن المنتجات العضوية، مما يؤدي إلى توسع كبير في الزراعة العضوية في جميع أنحاء العالم. هدفت هذه الدراسة إلى تقييم تأثير بعض الأسمدة العضوية (الكمبوست و الفيرمى كمبوست) بمعدل ١٥ طن/هكتار والسماد الحيوى (مستخلص طحلب الاسبيرولينا) بمعدل ٥ و١٠ مل كرش ورقي على نمو و إنتاجية نباتات الشيا (*Salvia hispanica*) تحت ظروف الزراعة العضوية. أجريت التجربة على مدار موسمين (٢٠٢١/٢٠٢٢ و٢٠٢٢/٢٠٢٣) في مدينة السادات بمحافظة المنوفية في مصر. أشارت البيانات إلى أن إضافة الكمبوست والفيرمى كمبوست ومستخلص الطحالب عزز النمو، إنتاجية البذور، محتوى الزيت، محتوى الكربوهيدرات، النتروجين، الفسفور، البوتاسيوم، الكلوروفيل الكلي وإنتاج الزيت الثابت لنباتات الشيا. تم تسجيل أعلى قيم لهذه المعاملات عند معاملة النباتات بالسماد الفيرمى كمبوست بمعدل ١٥طن/هكتار مع ١٠ مل من مستخلص الطحالب. تسلط هذه النتائج الضوء على تأثير التفاعل بين الفيرمى كمبوست ومستخلص الطحالب، مما يشير إلى أهميتها كإضافات عضوية مستدامة لتعزيز النمو والإنتاجية ومحتوى الزيت في نباتات الشيا. وتؤكد الدراسة على أهمية دمج الممارسات العضوية في الزراعة لتحسين إنتاجية المحاصيل وصحة التربة بشكل مستدام.