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Impact of some organic nutrients and salicylic acid on growth and oil quality of black cumin (*Nigella sativa* L.) plants

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Abstract

The purpose of this study was to investigate the impacts of manure (FYM) and salicylic acid (SA) application on growth (plant height, branches number /plant, fresh weight of /plant and dry weight of /plant), yield (number of capsules /plant, seed yield/plant and /hic.), oil production (fixed and volatile oil %) and the fixed and volatile oil content of black cumin plants were investigated during 2021/2022 and 2022/2023.Four levels of FYM including 0, 20, 30 and 40 M^3/hectare in main plots, while SA four levels were assigned in sub-plots at [0 (distilled water), 200, 400 and 600 ppm] SA as well as their interactions. The results demonstrated that the use of FYM and salicylic acid significantly improved the growth parameters, seed yield and oil extraction. Regarding this concern, the highest results were recorded through the addition of a high level of FYM (40 m^3/hectare) along with foliar spray of salicylic acid SA (600 ppm) in comparison to the control during two growing seasons. The usage of organic fertilizer and biostimulant applications also had an impact on the primary ingredients, according to GC-MS analysis of the volatile and fixed oil. When plants were sprayed with 400 ppm of salicylic acid and a higher standard organic fertilizer (40 M3/ha), the proportions of key components were generally greater than those of untreated plants. Based on this, can explain that the black seed plant and its production of seeds and oils can be used in many diverse applications and uses, the most important of which are various pharmaceutical industries, flavor, cosmetics and nutritional supplements.

Keywords: Manure (FYM), salicylic acid and productivity, *Nigella sativa* L.

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1. Introduction

The annual herbaceous flowering plant *Nigella sativa* L., sometimes called black cumin or black seed, belongs to the Ranunculaceae family and is well-known for its many uses in conventional medicine and food. Southern Europe, North Africa and southwest Asia are the native locations of black cumin seed. It is also found in the Middle East Mediterranean region, Syria, northern India, Iran, Turkey, Egypt, Saudi Arabia and Pakistan [1]. Black cumin, among various medicinal plants, has been widely recognised as one of the most nutrient-rich herbs in the world. Research has been conducted to verify the traditional usage of a little seed of this species. According to [2], the biological activities of the majority of medicinal plant families are always brought on by the presence of naturally occurring bioactive substances like tannins, terpenoids, steroids, flavonoids, phenols, and alkaloids. In accordance with [3], black cumin seeds are an important source of dietary protein (19.8%), lipids (37.0%), and carbohydrates (30.0%). Further research results verify the content and structure of black cumin seeds. The biological properties and antioxidant activities have been impacted by polysaccharides [4]. Thymoquinone, thymol, tocopherol, transretinol, and selenium are among the beneficial compounds found in black cumin's fixed and essential oil [5]. Numerous experts have conducted extensive research on *N. sativa* and its anti-inflammatory, anti-microbial, analgesic, immunomodulatory, and antidiabetic effects [6]. The food processing, nutraceutical, cosmetics and pharmaceutical sectors have all employed black seed, oil, microcapsules, and their constituent parts as multifunctional additives. Thymoquinone, a significant component of black cumin seed and oil, has phenolic components that provide it anti- diabetic, -oxidant, -microbial, -cancer, -inflammatory, and -viral characteristics. According to numerous clinical and experimental researches, black seeds and their byproducts can lower the risk of metabolic disorders, diabetes, hypertension, asthma, oxidative stress, polycystic ovarian syndrome, cardiovascular illnesses, chronic cancer, and skin conditions [7].

Organic fertilisers are essential for preserving soil structure, preserving water, minimising soil erosion, and halting the depletion of renewable resources. Additionally, it sustains a robust and varied biological system and encourages the development of advantageous soil organisms [8,9]. In the study by [10], organic fertilizers can enhance the long-term sustainability of agricultural ecosystems in addition to providing nutrients to plants. An alternative to artificial fertilisers, the organic manures utilised are inexpensive and sustainable sources of plant nutrition. According to [11], it can therefore be presumed to be an additional efficient, secure, and economical substitute supply of fertilizers for the crops. By adding organic matter to the soil, Farmyard Manure (FYM) improves its qualities and raises the productivity and fertility of the soil in a sustainable manner [12]. Additionally, FYM serves as a soil conditioner. By reducing the bulk density of the soil and enhancing its organic matter and water-holding capacity, it improved the soil's qualities and attributes and maintained the soil's fertility [11].

A phenolic plant hormone (salicylic acid) is regulates numerous physiological processes relevant to plant development and growth [13]. Salicylic acid plays a role in a number of processes, including thermogenesis, environmental stress tolerance, and DNA damage/repair, the production of fruits, seed germination, and more, according to many researches [14]. Since SA effectively promotes the growth and manufacture of bioactive substances, it is a common elicitor molecule in aromatic and medicinal plants [15]. As stated by [16,17], these include transpiration, photosynthesis, stomatal control, protein and chlorophyll synthesis, the activity of enzymes, and the absorption of nutrients. Due to its classification as "a substance generally recognised as safe" by the Food and Drug Administration (FDA), salicylic acid might be used in commercial medicinal species cultivation targeted at the phytomedicine market [18]. Regard to the necessity for organic fertilization in medicinal plants and the important role of *Nigella sativa* L. for both economic and medical purposes, this experiment was carried out to determine how the plant response to farmyard manure (FYM) as organic manure and salicylic acid.

2. Materials and Methods

The experimental work was carried out on a private farm in Kharga city, New Valley Governorate, Egypt, during two successive seasons 2021/2022 and 2022/2023 To investigate that the black cumin (*Nigella sativa* L.), plant responds by organic fertilization and some antioxidants, namely salicylic acid, as well as their interactions. Three replications of the experiment were set up in split plots, with the main plots containing farmyard manure (FYM) as organic fertilizer levels and the sub-plots taking salicylic acid concentrations into consideration. black cumin seeds were obtained from Medicinal and Aromatic Plants Department, Agricultural Research Center, Giza, Egypt. In addition, some farmyard manure (FYM) was collected from the farm at New Valley University, Egypt. The Gomhoria Company in Egypt provided the ascorbic acid and salicylic acid that were used. [19] and [20] Methods were used for investigating the physical and chemical characteristics of five selected at random soil samples collected from the experimental soil's surface before growing, ranging in depth from 0 to 30 cm. The results of the soil analysis are listed in Table 1.

The FYM manure used in this investigation obtained from the farm at New Valley University. Using the suggested analytical techniques, the amount of nutrition was established; the results are listed in Table (2).

Table 1: The experimental soil physical and chemical analysis during 2021/2022 and 2022/2023 seasons

Soil properties		Seasons	
		1st season	2nd season
Physical analysis	Particle distribution (%)		
	Coarse sand	5.75	5.22
	Fine sand	74.85	73.95
	Silt	15.20	16.10
	Clay	5.20	4.73
	Texture class	Sandy	Sandy
Chemical analysis	EC. Dsm-1(1:1 ex.)	0.89	0.91
	pH (1:1 w/v)	8.15	8.50
	Organic matter	0.81	0.86
	saturation capacity	26.62	26.95
	Meq/100g soil		
	Mg	0.43	0.48
	K	0.04	0.06
	Ca	0.62	0.69
	Cl	0.27	0.33
	Na	0.07	0.08
	HCO_3	0.31	0.39

Table 2: Chemical properties of farmyard manure FYM (Average both seasons)

Component	EC.dsm-1	pH (1:2 w/v)	C/N%	Mg (PPM)	Mn (PPM)	Zn (PPM)	Fe (PPM)	N%	P %	K %
Percentage	8.9	8.6	19	690	385	1680	1710	2.4	4.5	1.4

2.1. Experimental design

Three replications and a split plot design were used for the experiment. The main plot was farmyard manure (FYM) rates (FYM0= 0, FYM1=20, FYM2=30, FYM3=40 m3/ha. The plants were foliar sprayed with salicylic acid at concentrations (SA0=0, SA1=200, SA2=400, SA3=600 three times at two week intervals starting January10th of the two experimental seasons. The black cumin was sowed on 10^{th} November of two seasons. Experimental unit was 3.0 × 2.5 m contained 3 rows and 60 cm apart. All other standard farming practices were followed. Plant height (cm), branches number /plants, fresh and dry weight of plants (g), capsules number/plant, seed yield/plant (g) and /ha (kg). The percentage of fixed oil, were all recorded during the first week of May. Furthermore, volatile oil percentage was recorded. Then the different components of both fixed and volatile oil were measured by GC Mass.

2.2. Volatile and Fixed oil %

The hydro distillation process used to extract volatile oils from seeds is described in the [21] using the equation that follows:

volatile oil content = oil content in the

measuring ÷ tube sample weight ^{x} 100

The extraction apparatus was filled with 50 g of ground materials right before distillation. In addition to the oil output per plant and fed, the percentage of volatile oil was computed. After drying the volatile oil with anhydrous sodium sulphate, it was kept cool and dark until GC-MS analysis. The Organisation of Official Agricultural Chemists indicates that the Soxhlet apparatus with petroleum ether (BP 40-60 ° C) was used to calculate fixed oil instead [22]. The fixed oil content of black cumin seeds was determined using the AOCS method. The samples were ground at 70 °C to make powder. In a Soxhlet device, 10 grammes of the substance were added to 300 millilitres of diethyl ether after a 24-hour separating. After six hours, the oil was turned to recover the aimed solvent. After separation, the oil was kept in amber glass vials so that its chemical makeup could be determined. Gas chromatography mass spectrometry (GCMS), as explained by [23], was used to analyse black cumin fixed oil. The following equation was applied:

Seed fixed oil % = [Weight of oil / Weight of sample] ×100

− % seed moisture.

2.3. GC and GC–MS conditions

2.3.1. Gas chromatography-mass spectrometry (GC – MS) analysis

The samples in this study were analyzed using gas chromatography (Agilent 8890 GC System), an HP-5MS fused silica capillary column (30 m, 0.25 mm i.d., 0.25 mm film thickness), and a mass spectrometer (Agilent 5977B GC/MSD). Initially, the oven temperature was kept at 50°C. It was then programmed to rise from 50°C to 220°C at a pace of 5°C per minute, then from 220°C to 280°C at a rate of 20°C per minute. Finally, it was held at 280°C for 5 minutes. At a flow rate of 1.0 mL/min, helium was employed as the carrier gas. A 1:50 split ratio was used to inject 1 µL of the essential oil solution into the GC after it had been dissolved in 30 µL of diethyl ether (30 µL essential oil / mL diethyl ether). 230 °C was the injection temperature. The electron impact mode (EI) mass spectra were acquired at 70 eV and scanned in the 39–500 amu m/z range. By comparing the isolated peaks with information from the National Institute of Standards and Technology's (NIST) library of mass spectra, they were recognized.

2.4. Statistical analysis

According to [24], all collected data were statistically examined, and [25] used the LSD test at 5% to compare the means.

3. Results

3.1. Growth parameters

The presented results in Table (3) cleared that vegetative growth parameters [plant height (cm), branches number, herb fresh weight (g) and herb dry weight (g)] of black cumin plants had positively responded to the application of FAM as organic fertilization, during the two growing seasons. Obviously, the addition of FAM at all levels (20, 30 and 40 M^3/hectare), in both seasons, resulted in a significant increase in vegetative growth parameters, except for the low level of FAM (20 M^3/hectare), in both seasons, in relative to the check treatment. Obviously, high rate (40 M^3 / hectare) gave the greatest values of growth traits were obtained under in both seasons. In the first and second seasons, the main increases in percentages of plant height, branches number and fresh and dry weights of herb were 32.85 and 37.96, 54.95 and 52.54, 25.32 and 29.94, 35.42 and 29.58 percent, respectively, more than the control.

Numerous researchers reached similar conclusions, which led to the current study showing that organic manures increased vegetative growth parameters, including, [26,27,28,29,30] on black cumin (*Nigella sativa*) and [31] on borage (*Borago officinalis* L.)

With respect to stimulant substances treatments, data in Table (3) indicated that foliar spray of salicylic acid treatments at all concentrations (200, 400 and 600 ppm) caused a significant augmentation in all growth traits (plant height, branches number as well as fresh and dry herb weights). except for the low level of salicylic acid (200 ppm), in the two seasons regarding herb fresh weight and herb dry weight, in relative to the check treatment. Apparently, the best values were produced when adding the high concentration of salicylic acid (600 ppm), Numerically, the above mentioned superior treatment augmented vegetative growth parameters by 29.47 %, 38.87 %, 51.36 %, 34.76 %, 23.43 %, 17.76 %, 38.36 % and by 34.62 % over control, in both seasons, respectively.

The increases in vegetative growth parameters about by the use of stimulant substances in this study were further demonstrated by [32,33,37] on black cumin (*Nigella sativa* L.), [35] on cumin and [36,37] on coriander, (*Coriandrum sativum*),

Regarding the combined effect of FAM and salicylic acid treatments, the results showed that over the two growth seasons, the interaction had a significant impact on the fresh and dry herb weights (g), plant height (cm), and branch count of black cumin plants. It was evident that, throughout the course of the two seasons, the majority of combination treatments considerably raised vegetative growth indices when compared to untreated plants. Moreover, the most effective treatments in increasing such trait were resulted when the addition of FAM at the high level (40 M^3/hectare) with the high concentration of salicylic acid treatment (600 ppm), followed by the high level of FAM at (40 M^3 / hectare) with the moderate concentration of salicylic acid treatment (400 ppm), followed by the addition of FAM at the moderate level (30 M^3/hectare) with the high concentration of salicylic acid treatment (600 ppm), in comparison with those given by other combination treatments, in both seasons, as clearly claimed in Table (3).

Table 3: Effect of farmyard manure FAM and salicylic acid SA treatments on vegetative growth parameters of black cumin plants during two seasons

Organic manure		Vegetative growth parameters							
		Plant height (cm)		Branches Number / plant		Total fresh weight /plant (g)		Total dry weight /plant (g)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control		47.67	49.05	6.46	7.08	75.16	79.02	15.16	17.48
FAM 1		50.19	53.75	6.93	7.85	78.69	84.96	16.59	18.61
FAM 2		57.25	60.68	8.28	9.28	87.79	95.07	18.86	20.36
FAM 3		63.33	67.67	10.01	10.80	94.19	102.68	20.53	22.65
L.S.D. at 5 %		A:3.02	A:6.56	A:1.17	A:1.36	A: 5.29	A: 6.78	A:1.65	A:1.34
Effect of salicylic acid concentration (ppm)									
Control		47.50	48.50	6.25	7.48	75.75	83.68	15.20	17.04
SA1		53.28	55.83	7.59	8.45	80.10	87.50	16.21	18.40
SA2		56.17	59.47	8.38	8.99	86.48	92.00	18.71	20.72
SA 3		61.50	67.35	9.46	10.08	93.50	98.54	21.03	22.94
L.S.D. at 5 %		B:4.52	B:6.58	B: 0.99	B:0.90	B: 4.63	B: 4.07	B:2.16	B:2.11
Effect of combination between farmyard manure and amino acids									
Control	Control	41.67	40.67	5.50	6.03	66.24	71.34	12.67	15.00
	SA1	46.00	46.67	6.00	6.95	70.58	76.74	13.54	16.59
	SA2	48.00	50.20	6.60	7.18	78.33	80.67	16.09	18.23
	SA 3	55.00	58.67	7.75	8.15	85.50	87.33	18.33	20.10
FAM 1	Control	43.33	43.33	5.70	6.68	71.08	79.17	14.25	16.47
	SA1	48.10	50.67	6.50	7.62	75.67	82.33	15.12	17.60
	SA2	51.33	56.67	7.20	8.03	80.50	85.67	17.55	19.29
	SA 3	58.00	64.33	8.30	9.05	87.50	92.67	19.45	21.07
FAM 2	Control	50.67	53.33	6.00	8.17	79.83	89.33	16.46	17.47
	SA1	56.00	58.67	8.20	9.00	84.00	91.43	17.47	19.10
	SA2	58.33	60.33	9.03	9.43	90.33	96.33	19.70	21.17
	SA 3	64.00	70.40	9.87	10.53	97.00	103.17	21.80	23.70
FAM 3	Control	54.33	56.67	7.80	9.05	85.83	94.90	17.42	19.20
	SA1	63.00	67.33	9.67	10.23	90.17	99.50	18.70	20.30
	SA2	67.00	70.67	10.67	11.32	96.77	105.33	21.50	24.20
	SA 3	69.00	76.00	11.92	12.58	104.00	111.00	24.52	26.89
L.S.D. at 5 %		AB:9.03	AB:13.15	AB:1.98	AB:1.81	AB:9.26	AB:8.15	AB:4.32	AB:4.22

3.2. Yield components

The listed data in Table (4) emphasized that the examined traits [capsules number/plant, seed yield/plant (g) and /ha. (kg)] of black cumin were positively responded to adding FAM at all levels (20, 30 and 40 M^3/hectare), as organic fertilization during the two experimental seasons compared to unfertilized plants, except for low one in both seasons. Clearly, the highest values of capsules number/plant, seed yield/plant (g) and seed yield/ha. (kg) were obtained due to the use of FAM at the high level (40 M3/hectare) as ranged capsules number/plant by 14.20 and by 13.67 %, for seed yield/plant (g/plant) by 24.63 and by 25.70 % and for seed yield/ha. (kg) by 24.67 and by 25.75 % over control, during both seasons, respectively.

In agreement with the findings of an increase in yield components in the present research as a result of applying organic fertilization, it was discussed by [26,27,28,29,30,38,39] on black cumin (*Nigella sativa*), [31] on borage (*Borago officinalis* L.) and [40,41] on cumin.

Concerning application of salicylic acid treatments, the given data in Table (4) cleared that total capsules number /plant, seed yield/plant (g) and seed yield/ha. (kg) of black cumin had positively impacted by the use of examined stimulant, during both seasons. Apparently, treated plants with all concentrations of SA resulted a significant increase in number of capsules /plant, seed yield/plant (g) and seed yield/ha. (kg), except for the lowest one (200 ppm) in both seasons, comparing to control. Greatest values of such aspects were obtained by utilizing the high concentration treatment, mostly, then those observed by other treatments, during the two consecutive seasons. Clearly, treating black cumin plants with the SA high level (600 ppm) proved to be more effective in augmenting, such traits reached 31.05, 13.83, 34.94, 20.42, 34.92 and 20.43 % over un-inoculated plants, during the two experimental seasons, respectively

Table 4: Effect of farmyard manure FAM and salicylic acid SA treatments on yield components of black cumin plants during two seasons

Organic manure		Yield components					
		Capsules number/plant		Seed yield/ plant (g)		Seed yield/ Hectare (ton)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Control		63.53	65.17	16.93	18.29	1.625	1.755
FAM 1		65.50	66.75	17.95	19.33	1.723	1.856
FAM 2		69.08	70.17	19.40	21.12	1.863	2.027
FAM 3		72.55	74.08	21.10	22.99	2.026	2.207
L.S.D. at 5 %		A: 3.16	A: 2.24	A:1.27	A:1.63	A: 0.122	A: 0.156
Effect of salicylic acid concentration (ppm))							
Control		63.69	65.08	16.23	18.71	1.558	1.796
SA1		66.00	67.08	17.43	19.57	1.673	1.878
SA2		68.97	69.92	19.83	20.92	1.903	2.008
SA 3		72.00	74.08	21.90	22.53	2.102	2.163
L.S.D. at 5 %		B: 2.70	B: 2.13	B:1.64	B:1.20		
Effect of combination between farmyard manure and amino acids							
Control	Control	60.10	61.67	14.30	16.65	1.373	1.598
	SA1	62.67	64.33	15.00	17.35	1.440	1.666
	SA2	63.67	65.33	17.90	19.01	1.718	1.825
	SA 3	67.67	69.33	20.50	20.13	1.968	1.933
FAM 1	Control	62.67	63.67	15.50	17.02	1.488	1.634
	SA1	63.67	65.00	16.50	18.73	1.584	1.798
	SA2	66.67	67.33	18.70	19.67	1.795	1.888
	SA 3	69.00	71.00	21.10	21.91	2.026	2.103
FAM 2	Control	64.00	66.00	16.91	19.40	1.623	1.862
	SA1	67.67	67.67	18.10	20.18	1.738	1.938
	SA2	71.33	71.00	20.60	21.48	1.978	2.062
	SA 3	73.33	76.00	22.00	23.40	2.112	2.246
FAM 3	Control	68.00	69.00	18.21	21.77	1.748	2.090
	SA1	70.00	71.33	20.10	22.00	1.930	2.112
	SA2	74.20	76.00	22.10	23.50	2.122	2.256
	SA 3	78.00	80.00	24.00	24.67	2.304	2.369
L.S.D. at 5 %		AB: 5.39	AB: 4.26	AB:3.28	AB: 2.40	AB:0.315	AB: 0.231

The addition of salicylic acid in this study increased the yield components, which was also explained by [32,33,34] on black cumin (*Nigella sativa* L.), [35] on cumin, [42,43,36] on coriander (*Coriandrum sativum*).

As a result, during the two growing seasons, there was a substantial impact from the interaction between the two parameters on the features of black cumin (capsules number per plant, seed production per plant (g), and seed yield per hectare (Table 4). It could be noticed that the application of the most combined treatments led to a significant augment in yield components, as compared to control, during both seasons. Moreover, the addition of FAM at the high level (40 M3/hectare) with the high level of salicylic acid (600 ppm) then the high level of FAM at (40 M^3 / hectare) with the moderate concentration of salicylic acid treatment (400 ppm), were the most effective treatments in elevating yield components, in comparison with those proved by other combination ones, during the two successive seasons.

3.3. Oil percentages

The illustrated data in Table (5) showed that fixed oil % and volatile oil % of black cumin plants had positively responded to the use of FAM, during both seasons. Clearly, such parameters were significantly improved, in the two seasons; as a result of applying FAM at all levels, except for low one (20, M^3/hectare) in both seasons, in relative to control. Obviously, with increasing the compost levels, parameter was gradually significantly augmented, during both seasons. The highest fixed oil % and volatile oil % were given by the application of FAM at the high level (40 m³/ hectare) reached 16.98 %, 18.26 %, 33.14% and 21.39 % over control, during both seasons, respectively.

Table 5: Effect of farmyard manure FAM and salicylic acid SA treatments on oil percentage of black cumin plants during both seasons

Organic manure		Oil production			
		Fixed oil %		Volatile oil %	
		1st season	2nd season	1st season	2nd season
Control		21.97	23.33	0.175	0.201
FAM 1		23.04	24.11	0.185	0.213
FAM 2		24.47	25.85	0.207	0.227
FAM 3		25.70	27.59	0.233	0.244
L.S.D. at 5 %		A: 1.17	A: 1.27	A:0.020	A:0.013
Effect of salicylic acid concentration (ppm))					
Control		22.45	23.68	0.185	0.205
SA1		23.02	24.57	0.194	0.218
SA2		24.30	25.76	0.205	0.224
SA 3		25.41	26.88	0.216	0.237
L.S.D. at 5 %		B: 0.99	B: 1.08	B:0.010	B:0.011
Effect of combination between farmyard manure and amino acids					
Control	Control	20.33	22.01	0.160	0.187
	SA1	21.00	22.80	0.170	0.197
	SA2	22.70	23.67	0.180	0.200
	SA 3	23.83	24.85	0.188	0.220
FAM 1	Control	21.67	22.91	0.170	0.198
	SA1	22.00	23.42	0.180	0.208
	SA2	23.29	24.79	0.190	0.218
	SA 3	25.20	25.32	0.200	0.228
FAM 2	Control	23.35	24.15	0.193	0.210
	SA1	24.07	25.27	0.198	0.223
	SA2	24.88	26.40	0.213	0.233
	SA 3	25.58	27.60	0.223	0.240
FAM 3	Control	24.43	25.65	0.217	0.227
	SA1	25.00	26.80	0.227	0.243
	SA2	26.33	28.17	0.237	0.245
	SA 3	27.02	29.75	0.253	0.261
L.S.D. at 5 %		AB: 1.98	AB: 2.16	AB: 0.021	AB: 0.021

In connection with the results about the oil percentages this study achieved by using organic manures, it was additionally released by [26,27,28,29,30,38,39] on black cumin (*Nigella sativa*), [31] on borage (*Borago officinalis* L.), [44] on (*Ocimum bailicum* L.), [45] on peppermint (*Mentha piperita* L.) and [37] on *Coriandrum sativum* L.

As for the influence of SA treatments, the data indicated that foliar spray with salicylic acid, in both seasons, resulted a significant augment in fixed oil % and volatile oil % of black cumin plants. It is obvious that treating the plants with SA at all levels resulted a significant increase in fixed oil %, except for the low one (200 ppm), as compared to control, in both seasons. Similarly, volatile oil %, was significantly augmented as a result of adding SA at all levels, in the two seasons, except for the low one (200 ppm), in the first season, in relative to control. Apparently, applying the high level of SA (600 ppm) resulted higher values of fixed oil % and volatile oil % than those given by control, mostly during the two seasons. The higher values were observed when adding the SA at (600 ppm) as ranged 13.18%, 13.51%, 16.76% and 15.61% in both seasons, respectively, above plants that were not treated as clearly shown in Table (5).

Consistent with the results showing that salicylic acid improved seed yield, those obtained by [32,33,34] on black cumin (*Nigella sativa* L.), [46] on (*Achillea millefolium* L.), [47] on (*Thymbra spicata* L.), [35] on cumin [42,37] on coriander, (*Coriandrum sativum*),

It is evident from the given data that the fixed oil % and volatile oil % of black cumin plants were positively influenced by the interaction treatments between the two factors, during the two successive seasons. It seems that applying most combined treatments caused a significant increase in fixed oil % and volatile oil %, for the two seasons, as compared to untreated plants. Apparently, the most effective treatments in augmenting the oil yield were detected resulting from the addition of FAM at the high level (40 m^3/ hectare) in combination with salicylic acid at (600 ppm), followed by the high level of FAM at (40 M^3 / hectare) with the moderate concentration of salicylic acid treatment (400 ppm), also the high level (40 m^3/ hectare) of such manure + the lowest value of salicylic acid treatment (200 ppm), in comparison with those revealed by other ones, during the two experimental seasons, as listed in Table (5).

3.4. Fixed oils compositions

Myristic, palmitic, stearic, oleic, linoleic, arachidic and linolenic acids were the primary fatty acids identified by the results of the GC-MS analysis of fixed oil (Table 6). Of the preceding components, oleic acid had the largest percentage, followed by arachidic and stearic acids. In comparison to the untreated control, the foliar application of SA and the treatment of farmyard manure, particularly the high concentration of farmyard manure with medium SA concentration, enhanced the amount of previous fatty acids in the fixed oil.

Table 6: The interaction effect of some manure FAM and salicylic acid SA treatments on Fixed oil ingredients of black cumin plants during the 2022/2023 season

Fatty acids	Percentage of ingredients				
	Control	FAM 2+ SA2	FAM 2 + SA3	FAM 3+ SA2	FAM 3 + SA3
Myristic acid (C14:0)	0.37	1.41	1.13	0.27	0.18
Palmitoleic acid (C16:1)	---	---	0.89	---	0.29
Palmitic acid (C16:0)	11.12	12. 71	12.14	13.11	12.57
Heptadecanoic acid (C17:0)	----	1.61	---	---	0.84
Stearic acid (C18:0)	1.24	3.07	1.12	2.92	2.47
Cis-10-Heptadecanoic acid (C17:1)	0.26	0. 78	0.38	---	0.32
Oleic acid (C18:1c)	19.61	21. 91	20.04	22. 44	22.58
Linoleic acid (C18:2c)	51.77	53.96	53.44	56. 89	56.29
Linolelaidic acid (C18:2t)	---	---	1.15	---	0.07
Elaidic acid (C18:1t)	---	---	0.83	0.88	1.13
Arachidic acid (C20:0)	3.22	4.73	4.34	3.21	2.98
γ- Linolenic acid (C18:3)	----	----	4. 55	0.25	0.27

3.5. Essential oils components

Essential oils derived from *Nigella sativa* seeds had twenty-one components, which made up all of the components and belonged to two main chemical groups. Sesquiterpenes (SH) were 19.04–17.53 percent, whereas monoterpene hydrocarbons (MH) made up the majority (80.96–91.54 percent) as presented in Table 7. The primary components identified by GC/MS in Nigella sativa essential oil seeds were p-cymene (30.68 - 34.87%) γ-Terpinene (4.73% - 13.61%), β-Thujene (9.94% -13.87%), trans-4-methoxy thujane (1.54%–7.48%), longifolene (5.45% - 5.94%), carvacrol (3.34–6.50%), and d-limonene (3.26 - 7.24%). Furthermore, the addition of FAM 2 + SA3 produced the highest levels of the primary components from treatment, with p-Cymene values of 34.87%. Monoterpenes and sesquiterpenes are the two chemical groupings that include all detected components. They produced the greatest value of SCH (19.04%) and the largest proportion of MH values (91%).

Table 7: The interaction effect of some farmyard manure FAM and salicylic acid SA treatments on essential oils components of black cumin plants during 2022/2023 season

No	Compound	RT	Treatments			
			Control	FAM 2 + SA3	FAM 3+ SA2	FAM 3 + SA3
1	β-Thujene	6.199	9. 94	13. 87	11. 92	12. 44
2	α-Pinene	6.365	3. 67	3. 59	3. 45	3. 41
3	α-Terpinene	8.453	2. 38	2. 39	2. 05	2. 59
4	β-Pinene	7.429	2. 69	4. 06	3. 67	3. 66
5	Sabinene	7.337	2. 24	2. 08	1. 39	1. 84
6	p-Cymene	8.705	32. 18	34. 87	30. 68	33. 29
7	D-Limonene	8.785	4. 32	5. 15	7. 24	3. 26
8	γ-Terpinene	9.609	11. 39	4. 73	10. 72	13. 61
9	cis-4-methoxy thujane	9.805	2. 89	2. 32	2. 05	0. 24
10	trans-4-methoxy thujane	12.18	7. 47	7. 48	5. 04	1. 54
11	Terpinen-4-ol	13.395	0. 44	1. 57	0. 94	0. 63
12	Cosmen-2-ol	13.22	0. 86	0. 36	0. 86	7. 45
13	(-)-Carvone	14.828	0. 49	1. 27	4. 62	1. 34
14	β-Cyclocitral	12.977	1. 93	1. 21	0. 80	1. 02
15	Carvacrol	16.407	4. 38	3. 34	6. 50	3. 59
16	Thymoquinone	15.235	3. 44	2. 58	0. 41	0. 97
17	α-Longipinene	17.69	2. 12	2. 28	0. 2	1. 42
18	Longifolene	19.153	5. 48	5. 45	5. 94	5. 54
19	Hydrothymoquinone	22.85	0. 72	0. 91	2. 64	0. 64
20	Apiol	24.395	0. 87	0. 44	0. 79	1. 50
21	Ledol	33.373	2.06	-	-	–
Sesquiterpene hydrocarbons			20.04	18.47	13.72	9.50
Monoterpene hydrocarbons			79.92	81.48	86.23	90.48
Total identified compounds			99.96	99.95	99.95	99.98

4. Discussion

Considering the results, the following points could be discussed: Increases in plant height, branches number/plant, fresh weight of /plant, dry weight of /plant, number of capsules /plant, seed yield/plant and /hic., fixed oil % and volatile oil % of black cumin plants by adding FYM as organic manure may be explained by the beneficial biological and physiological functions of organic manures, which have been detailed by several of authors, such as [48] indicated that organic fertilizers contains microorganisms like *Azotobacter* and *Azospirillium* that can fix nitrogen and release the phytohormones such as IAA, GA, and cytokinins that may enhance dry matter, growth, and nutrient absorption. According to research by [49]. The main source of nutrients like N, P, and S is organic manures, which additionally contain high amounts of B and Mo. According to [50], applying organic manure enhanced the microbial activity in the root zone. Enhancing microbial biomass requires the use of organic manures [51]. Additionally, organic manure has been shown by [52] to be a beneficial substitute for mineral fertilisers that help improve soil structure. Applying salicylic acid to fennel may have improved its growth, fruit production, and oil production because of its beneficial biological and physiological functions [53]. According to [54], salicylic acid has been classified as a plant hormone. It regulates the metabolism of plants [55]. [56]. According to [57], the increase in plant essential oils may be caused by salicylic acid -stimulated vegetative growth, the number of leaf oil glands, the amount of carbohydrates, as well as the positive impact of salicylic acid on metabolism and the activities of the enzymes involved in the biosynthesis of mono- or sesqueterpenes. Promoting flowering, delaying senescence, and increasing the rate of cell metabolism, it may be necessary for and/or play a significant function as a coenzyme. Additionally, it has a strong defence against a variety of plant pathogens, including parasitic plants, nematodes, fungus, and bacteria [58]. Salicylic acid influences ethylene production, stomatal movement, and retains the effect of ABA on leaf abscission, as demonstrated by [56]. Salicylic acid attaches itself to a protein-like receptor on the plasma membrane of the cell. A series of translocable intracellular signals are stimulated by this salicylic acid-receptor interactions, causing the plant to mount various defence mechanisms [59, 60]. This effect is explained by the SA's accessibility inside the plant, which enhances signals and facilitates complex regulatory activities by interacting with many physiological and biochemical events. [61].

Due to its numerous applications in a variety of industries, including flavoring, medicines, cosmetics, and nutraceuticals, the market for *N. sativa* products is anticipated to grow rapidly [62].

5. Conclusion

The results of this study show that when fertilizer was applied at a high level (40 m³/hectare), the maximum values of the characteristics under study (growth traits, yield, oil production and its components) were listed. When compared to untreated plants, foliar spraying with AS at 600 ppm also boosted the quantities of main components. The usage of organic fertilizer and biostimulant applications also had an impact on the primary ingredients, according to GC-MS analysis of the volatile and fixed oil. In comparison to control, plants sprayed with AS at 600 ppm and given a higher standard organic fertilizer (40 m³/ hectare) often produced larger amounts of the active components.

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