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Economic Evaluation of Application Some Organic Fertilizers and Seaweed Extract and Their Effects on Growth, Fruit Yield and Volatile Oil Content of Caraway (*Carum carvi* L.) Plants

Abushoufa A. A.[1,*], Fatima A. Enwiji[2] and Hassan E. A.[3]

1- Plant Production Dept., Fac. of Agric, Misurata, Univ., Libya

2- Pharmaceutical Technology Dept., Fac. of Medical Technology, Misurata, Libya

3- Horticulture Dept., Fac. Agric., Al-Azhar University, Assiut, Egypt

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[*]**Corresponding author:** dean@agr.misuratau.edu.ly

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Abstract: The current experiment was done through two consecutive seasons (2023/2024 and 2024/2025). This work was established at a privet experimental field, Assiut Governorate, Egypt. The treatments of study was distributed as split-plot design, the main factor was organic fertilization at different rates (0, 10, 20 and 40 m^3/ hectare), where, the sub plot factor was seaweed extract (SW) concentration (0, 3, 6 and 12 ml/l) as well as their interactions between them. The tallest caraway plants (107.33 and 112,00 cm), more branches per plant (29.33 and 31.67), heaviest fresh herb weight (178.67 and 185.33 g/plant) and heaviest dry herb weight (36.17 and 38.17 g/plant) were achieved with 40 ton/hectare of farm yard manure (FYM) combined with 12 ml/l of seaweed extract. Likewise, fertilized caraway plants with 40 m^3 FYM/hectare combined with the highest concentration of SW gave the highest values of umbels number per plant and fruit and volatile oil yield per plant and per hectare compared to the other treatments under study. The highest benefit/ cost ratio (2.250) was obtained with the combination treatment of 40 m^3 FYM/ hectare with 12 ml SW/l compared to the other combinations. Overall, it could be concluded that applying farmyard manure along with seaweed extract produced the highest net return and value for caraway plants.

Key words: Caraway, *Carum carvi* L. FYM, seaweed, growth, yield, oil, economic.

1. Introduction

The leaves of the Apiaceae family vary in size and form and are either annual or biennial herbs. The blooms are pentamerous, the fruit is schizocarp, and the flowers are almost usually grouped in terminal umbels. In addition to being used in cooking and traditional medicine, many plants of the Apiaceae family have long been recognized for their therapeutic qualities (**Aćimović, 2013**). The herb caraway (*Carum carvi* L.) can be either annual or perennial. It originated in West Asia and Europe

(**Kamenik, 1996**). It is a significant plant whose fruits produce volatile oil. Carvone and limonene are the primary ingredients of caraway seeds, which also contain lipids, nitrogen compounds, fiber, essential oil (2–8%) and water (**Gwari *et al*., 2012**). Carvone and limonene content are the primary determinants of the quality and impact of caraway seed essential oil (**Solberg *et al*., 2016**). Caraway possesses diuretic, antioxidant, antidiabetic, carminative, and anti-cancer properties. Additionally, it facilitates breastfeeding and the production of breast milk while also improving digestion (**András *et al*., 2015** and **Sachan *et al*., 2016**).

Comparing organic manure to chemical fertilizer, it has been discovered that the former increases medicinal plant productivity both quantitatively and qualitatively. Utilizing microbial symbiosis and organic manures as natural fertilizers enhances medicinal plant quality and productivity (**Badalingappanavar *et al*., 2018**). Application of organic fertilizer improved the flavonoids, total phenolics, gluthathione, saponins, and ascorbic acid content production in Malaysia traditional medicinal plant (*Labisia pumila* L.) as compared with the utilize of chemical fertilizer (**Ibrahim *et al*., 2013**). Similarly, the study by **Priya *et al.* (2012)** showed that the highest growth values of *Eclipta alba* L. were reported when poultry dung was applied as an organic fertilizer. Applying organic manures to medicinal plants is more crucial than to other plants since it increases their development and productivity while also altering the quality of their active ingredients (**Rostaei *et al*., 2024**).

Seaweed extract has been shown to increase plant production and growth. Macronutrients including N, P, and K as well as Fe, Mn, Zn, and Mo as main micronutrients are found in seaweed extract (**Crouch *et al*., 1990**). Auxins, gibberellins and cytokinins are examples of natural plant growth regulators found in seaweed extract (**Crouch and Van Staden, 1993**). Moreover, **Bhaskar and Miyashita (2005)** reported that seaweed extract is a fantastic source of bioactive substances such protein, amino acids, carotenoids, vitamins, essential fatty acids, minerals, and growth regulators. Products made from seaweed, whether in powder or extract form, are a novel class of organic chemicals that are naturally occurring and also help plants flourish. They promote faster germination of seeds, accelerate growth, boost agricultural yields, and raise the resistance of a number of crops (**Dhargalkar and Pereria, 2005**). Furthermore, foliar sprays of 4 ml/l seaweed extract as a high concentration considerably increased the fennel height, numbers of branches and umbels per fennel plant, plant fruit yield, feddan fruit yield, volatile oil percentage, and its production for plant and over feddan (**Ali *et al*., 2023**).

The economic evaluation of caraway plants hinges on their value in the food, pharmaceutical, and cosmetic industries, primarily due to their aromatic seeds containing essential oils rich in carvone and limonene. Its market potential is further enhanced by its traditional uses as a medicinal herb and its utility in producing flavorings, spices, and sprout inhibitors. Factors influencing economic viability include seed and essential oil yields, which are affected by genetic traits, cultivation practices (such as multi-cropping and proper fertilization), and environmental conditions like drought **(Aušra *et al* 2021)** economic evaluation of caraway production considering Farmyard Manure (FYM) rates, seaweed extract concentrations, and their interactions would typically involve calculating the total cost of inputs, the revenue from the increased caraway yield, and then determining the net benefit, return on investment (ROI), and marginal rate of return (MRR) for each treatment combination. While specific data is needed for precise calculations, studies on similar crops suggest that optimal yields and profitability often result from a combination of moderate FYM application and appropriate seaweed extract concentrations, though higher rates may not always be more economical **(Ahmed *et al.*, 2025).**

Therefore, this study aimed to assess which concentration of seaweed extract application and farmyard manure rate had the most impact on the caraway plant's capacity to give the most volatile oil production, vegetative development and fruit yield.

2. Materials and Methods

The current study was carried out at a private farm in the Assiut Government, Egypt through the winter seasons of 2023/2024 and 2024/2025. This experiment was examined various FYM rates (0, 10, 20 and 40 m^3/hectare), various seaweed extract concentrations (0, 2, 4 and 8 ml/l) beside their combination treatments of caraway (*Carum carvi* L.) growth, fruit yield, production of volatile oil and some economic indices. After receiving water in the first and second seasons, caraway fruits - which were procured from the Research Centre of Medicinal and Aromatic Plants in Dokky, Giza - were sown on October 15, 2023, and October 8, 2024, respectively. Twenty-four days after the sowing date, the caraway plants were thinned, leaving two plants per hill. Each experimental unit was 4.0 × 3.5 m and had four rows, 60 cm apart. The plants were separated by 30 centimeters. Every other agricultural practice was carried out in compliance with the standards established by the caraway plant growers in the test area.

A randomized soil sample was taken before planting in order to perform a conventional method of physical and chemical examination, as shown in Table 1 by **Chapman and Pratt (1978)**.

Table (1). Some chemical and physical analysis of the experimental soil (average of both seasons)

Physical analysis				Soil texture
Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Sandy
6.72	3.69	80.27	10.32	

Chemical analysis												
pH	E C m.mohs /cm	Organic mater (%)	Soluble cations (meq./ L)				Soluble anions (meq. /L)			Available (ppm)		
			Mg^{++}	Ca^{++}	K^{+}	Na^{+}	Cl^{-}	HCO_3^{-}	SO_4^{--}	N	P	K
7.89	1.12	2.03	1.25	1.34	3.09	4.42	4.50	1.29	4.22	56.7	66.4	9.4

2.1. Experimental design

A split plot design and three replicates were utilized for the current experiment. The main plot (A) was the different rates of farmyard manure (FYM) (0, 10, 20 and 40 m^3/ha), whereas, the different treatments of seaweed extract were allocated to the sub-plots and were also four concentrations (0, 3, 6 and 12 ml/l) three times at three week intervals. Every other cultural custom was applied as usual.

2.2. Sampling and Data Collection

Data recorded in the thrice week of May, i.e.; plant height (cm), branches number per caraway plant, herb fresh and dry weights per caraway plant (g) as well as umbels number per plant, fruit yield per plant (g) and fruit yield per hectare (ton) were calculated. Also, the percentage of volatile oil was determined according to **Divya *et al.* (2014)** then volatile oil yield (ml) per plant and volatile oil yield (l) per hectare were calculated.

2.3. Economic evaluation

Two factors that may be used in economic appraisal are the project's economic profitability while the value is positive and the net return farm, which is the difference between the expenses and benefits. These standards align with economic reasoning and the conditions of the field trial. Second, the project's profitability is gauged by the cost-benefit analysis, which is the ratio of benefits to expenses. The different crops are grouped according to economic commerce and profitability if the proportion is high.

2.4. Statistical Analysis

To determine the differences between all treatments, all collected data were collated and statistically evaluated as reported by **Black (1965)**, L.S.D. test at 5% (**Page *et al*., 1982**). The Statistix Version 9 computer program was used to compare the means (**Analytical software, 2008**).

4. Results and Discussion

4.1. Plant growth

It is clear that the different farmyard manure rates were noticed to significantly influence on caraway height, branches number /plant as well as herb fresh and dry weights per caraway plant compared to control (Tables 2, 3, 4 and 5). The maximum means of caraway height (101.83 and 107.08 cm) and branches number of /plant (27.83 and 30.17 branches) as well as fresh (175.75 and 179.25 g/plant) and dry (35.08 and 36.96 g/plant) weights of caraway herb were recorded for 40 m^3 FYM/hectare in 1st and 2nd seasons, respectively, with significant variation compared to the lowest rates and control plots. Furthermore, **Hamza *et al.* (2007)** found that they improved plant height, the number of tillers and spikes and dry weight per plant of *Plantago ovate* comparing FYM doses to control. When *Plantago ovate* plants were given the medium FYM dose (20 m^3 /fed), their yield were the best. The same results were noticed with those reported by **Shahmohammadi *et al*. (2014)** on dill and **Sarhan and Shehata (2023)** on french basil, who stated that the utilize of compost has had a significant impact on vegetative traits.

In regard of the effect of seaweed extract (SW) treatments, the recorded data in Tables 2, 3, 4 and 5 clear that plant height, branches number per caraway plant was significantly influenced by foliar spray with SW compared to control in the two tested seasons. Furthermore, SW foliar spray at the highest concentration 12 ml/l in the both seasons resulted in a significant augment in plant growth parameters in relative to untreated ones and the lowest ones (3 and 6 ml/l) under study. Moreover, sprayed caraway plants with 12 ml SW/l registered the tallest plants (99.08 and 102.92 cm), branches number (24.58 and 27.08 branches/plant), herb fresh weight (157.67 and 163.25 g/plant) and herb dry weight (31.58 and 33.54 g/plant) during the two growing seasons, respectively. This influence may be explained by the presence of substances in algal extracts that promote plant growth, such as cytokinins, indole acetic acid (IAA), abscisic acid, gibberellic acid and polyamines (**Prasad *et al*., 2010**). Herb weight and yield/feddan were significantly increased when seaweed extracts were sprayed on sweet basil plants (**Sakr *et al*., 2010**). When compared to the control, the 25% SWE treatment greatly increased the shoot length and leaves number per sage plants (**Mansori *et al*., 2019**).

Regarding combination treatments involving FYM rates and SW concentrations, Tables 2, 3, 4 and 5 made it clear that, in comparison to all other combined treatments, the combination of 40 m^3 FYM/hectare + 12 ml SW/l significantly enhanced the plant height, branches number and the herb fresh and dry weights of caraway plants. Increasing the concentrations of farm yard manure in seaweed extract of any rate led to a progressive increase in the caraway growth traits over the course of two seasons. Moreover, as mentioned above, organic fertilizer (FYM) and foliar spray with SW concentrations (12ml/l) enhanced plant growth of caraway plant, in turn; they together might maximize their influences leading to taller plants, more branches and heaviest herb fresh and dry weights per plant. Applying 15 ton/ha of manure combined with active yeast extract (100 ml/l) increased plant height, stem diameter, branch number and herbal weight of caraway plant across both seasons (**Hassan *et al*., 2025**).

Table (2). Effect of FYM level (A) and seaweed extract concentration (B) and their interactions (A×B) on caraway plant height (cm) during first and second seasons

FYM rate (ton/hectare)	Seaweed extract concentration (ml/l)				Mean (A)
	Control	3	6	12	
	First season				
Control	85.00	86.0	88.67	90.67	**87.58**
10	90.33	92.67	94.00	95.67	**93.17**
20	92.33	95.00	98.33	102.67	**97.08**
40	96.33	100.67	103.00	107.33	**101.83**
Mean (B)	**91.00**	**93.58**	**96.00**	**99.08**	
L.S.D. at 5 %	For (A)= 3.33		For (B)= 0.53	For (A×B)= 3.45	
	Second season				
Control	87.33	88.33	91.00	92.00	**89.67**
10	94.33	96.00	98.33	100.67	**97.33**
20	96.33	100.67	103.00	107.00	**101.75**
40	101.00	105.67	109.67	112.00	**107.08**
Mean (B)	**94.75**	**97.67**	**100.50**	**102.92**	
L.S.D. at 5 %	For (A)= 3.41		For (B)= 0.44	For (A×B)= 3.49	

Table (3). Effect of FYM level (A) and seaweed extract concentration (B) and their interactions (A×B) on caraway branch number per plant during first and second seasons

FYM rate (ton/hectare)	Seaweed extract concentration (ml/l)				Mean (A)
	Control	3	6	12	
	First season				
Control	15.33	16.33	17.33	18.33	**16.83**
10	18.00	19.00	20.33	21.67	**19.75**
20	25.00	26.67	27.67	29.00	**27.08**
40	26.33	27.33	28.33	29.33	**27.83**
Mean (B)	**21.17**	**22.33**	**23.42**	**24.58**	
L.S.D. at 5 %	For (A)= 0.75		For (B)= 0.24	For (A×B)= 0.86	
	Second season				
Control	17.67	18.67	19.67	20.67	**19.17**
10	21.33	22.33	23.67	25.00	**23.08**
20	26.00	28.00	29.00	31.00	**28.50**
40	28.67	29.67	30.67	31.67	**30.17**
Mean (B)	**23.42**	**24.67**	**25.75**	**27.08**	
L.S.D. at 5 %	For (A)= 0.79		For (B)= 0.16	For (A×B)= 0.83	

Table (4). Effect of FYM level (A) and seaweed extract concentration (B) and their interactions (A×B) on caraway herb fresh weight (g/plant) during first and second seasons

FYM rate (ton/hectare)	Seaweed extract concentration (ml/l)				Mean (A)
	Control	3	6	12	
	First season				
Control	133.00	135.33	137.00	140.67	**136.50**
10	136.33	140.00	141.67	144.00	**140.50**
20	162.00	163.67	165.33	167.33	**164.58**
40	171.00	173.33	176.00	178.67	**174.75**
Mean (B)	**150.58**	**153.08**	**155.00**	**157.67**	
L.S.D. at 5 %	For (A)= 2.27		For (B)= 0.51	For (A×B)= 2.43	
	Second season				
Control	134.00	138.67	141.33	145.00	**139.75**
10	138.00	143.67	147.00	151.00	**144.92**
20	165.67	168.00	169.67	171.67	**168.75**
40	173.67	176.33	181.67	185.33	**179.25**
Mean (B)	**152.83**	**156.67**	**159.92**	**163.25**	
L.S.D. at 5 %	For (A)= 1.48		For (B)= 0.63	For (A×B)= 1.83	

Table (5). Effect of FYM level (A) and seaweed extract concentration (B) and their interactions (A×B) on caraway herb dry weight (g/plant) during first and second seasons

FYM rate (ton/hectare)	Seaweed extract concentration (ml/l)				Mean (A)
	Control	3	6	12	
	First season				
Control	26.33	26.50	27.00	27.83	**26.92**
10	27.00	28.17	28.67	29.17	**28.25**
20	31.17	31.67	32.17	33.17	**32.04**
40	34.17	34.67	35.33	36.17	**35.08**
Mean (B)	**29.67**	**30.25**	**30.79**	**31.58**	
L.S.D. at 5 %	For (A)= 0.96		For (B)= 0.25	For (A×B)= 1.07	
	Second season				
Control	26.67	28.00	28.83	29.50	**28.25**
10	27.67	29.00	30.00	30.67	**29.33**
20	33.17	34.17	35.00	35.83	**34.54**
40	35.83	36.50	37.33	38.17	**36.96**
Mean (B)	**30.83**	**31.92**	**32.79**	**33.54**	
L.S.D. at 5 %	For (A)= 0.83		For (B)= 0.21	For (A×B)= 0.90	

4.2. Yield and its components

The given results in Tables 6, 7 and 8 reveal that utilize of FYM as organic fertilizer positively influenced number of umbels per caraway plant, among all rates, during both experimental seasons. Moreover, such fruit yield per plant and per hectare was significantly augmented as a result of adding FYM at all rates comparing to the control treatment (without organic addition). Likewise, by increasing the rates of FYM caraway yield components were gradual significantly increased in 2023/2024 and 2024/2025 seasons. Thus, the heaviest fruit yield per plant (25.33 and 28.33 g/plant) and per feddan (2.027 and 2.267 ton/hectare) were detected due to supplying FYM at the high level (40 m^3/ hectare) during both seasons, alternately. The importance of organic manures in enhancing caraway fruit yield was also studied by **Awad (2016)** and **Ahmed *et al.* (2019)**.

Seemingly, umbels number per caraway plant as well as fruit yield per plant and per hectare was significantly influenced by foliar spray with seaweed extract at any concentration compared to control during both seasons (Tables 6, 7 and 8). Moreover, increasing SW concentrations gradually enhancing caraway fruit yield components during both seasons. The highest values of umbels number per plant (21.17 and 24.42 umbels), fruit yield per plant (22.79 and 25.67 g/plant) and fruit yield per hectare (1.823 and 2.053 ton) were produced when caraway plants sprayed with SW at 12 ml/l concentration, in 1st and 2nd seasons, respectively. **Yusuf *et al.* (2020)** found that the seaweed extract application had a significant impact on diameter of tuber and total yield of *Allium wakegi* bulbs.

The data shown in Tables 6, 7 and 8 shows that, in both seasons, the combination of FYM and treatments with SW significantly enhanced the umbels number per caraway plant as well as fruit yield per plant and per hectare compared to control (without FYM application combined with SW spray) in both seasons, in most cases. However, in comparison to the other combinations under study in both seasons, the combination of FYM fertilizers (40 m^3/ hectare) sprayed with SW at 12ml/l concentration produced the highest values of number of umbels (24.33 and 29.00 umbels/plant), fruit yield (28.33 and 32.00 g/plant) and total fruit yield (2.267 and 2.560 ton/ hectare) of caraway. Similarly, **Abd EL-Kafie *et al.* (2020)** discovered that the combination of farmyard manure and foliar application of seaweed extract over two seasons influenced the highest values of fruit yield (g/plant and kg/feddan) of coriander plants.

Table (6). Effect of FYM level (A) and seaweed extract concentration (B) and their interactions (A×B) on caraway umbels number per plant during first and second seasons

FYM rate (ton/hectare)	Seaweed extract concentration (ml/l)				Mean (A)
	Control	3	6	12	
	First season				
Control	15.33	16.33	17.33	18.33	**16.83**
10	17.00	18.00	19.00	20.00	**18.50**
20	19.00	20.00	21.00	22.00	**20.50**
40	21.33	22.33	23.33	24.33	**22.83**
Mean (B)	**18.17**	**19.17**	**20.17**	**21.17**	
L.S.D. at 5 %	For (A)= 1.23		For (B)= 0.53	For (A×B)= 1.53	
	Second season				
Control	17.33	18.33	19.33	20.33	**18.83**
10	20.00	21.00	22.00	23.00	**21.50**
20	21.67	23.33	24.33	25.33	**23.67**
40	24.00	25.33	27.00	29.00	**26.33**
Mean (B)	**20.75**	**22.00**	**23.17**	**24.42**	
L.S.D. at 5 %	For (A)= 0.86		For (B)= 0.30	For (A×B)= 1.00	

Table (7). Effect of FYM level (A) and seaweed extract concentration (B) and their interactions (A×B) on caraway fruit yield (g/plant) during first and second seasons

FYM rate (ton/hectare)	Seaweed extract concentration (ml/l)				Mean (A)
	Control	3	6	12	
	First season				
Control	13.33	14.33	15.33	16.33	**14.83**
10	17.33	18.83	19.50	20.50	**19.04**
20	20.00	22.00	24.00	26.00	**23.00**
40	22.33	24.33	26.33	28.33	**25.33**
Mean (B)	**18.25**	**19.88**	**21.29**	**22.79**	
L.S.D. at 5 %	For (A)= 1.03		For (B)= 0.09	For (A×B)= 1.04	
	Second season				
Control	15.00	16.00	17.00	18.33	**16.58**
10	19.67	21.67	22.67	23.67	**21.92**
20	22.33	24.67	26.67	28.67	**25.58**
40	25.00	26.33	30.00	32.00	**28.33**
Mean (B)	**20.50**	**22.17**	**24.08**	**25.67**	
L.S.D. at 5 %	For (A)= 1.18		For (B)= 0.37	For (A×B)= 1.34	

Table (8). Effect of FYM level (A) and seaweed extract concentration (B) and their interactions (A×B) on caraway fruit yield (ton/hectare) during first and second seasons

FYM rate (ton/hectare)	Seaweed extract concentration (ml/l)				Mean (A)
	Control	3	6	12	
	First season				
Control	1.067	1.147	1.227	1.307	**1.187**
10	1.387	1.507	1.560	1.640	**1.523**
20	1.600	1.760	1.920	2.080	**1.840**
40	1.787	1.947	2.107	2.267	**2.027**
Mean (B)	**1.460**	**1.590**	**1.703**	**1.823**	
L.S.D. at 5 %	For (A)= 0.082		For (B)= 0.007	For (A×B)= 0.083	
	Second season				
Control	1.200	1.280	1.360	1.467	**1.327**
10	1.573	1.733	1.813	1.893	**1.753**
20	1.787	1.973	2.133	2.293	**2.047**
40	2.000	2.107	2.400	2.560	**2.267**
Mean (B)	**1.640**	**1.773**	**1.927**	**2.053**	
L.S.D. at 5 %	For (A)= 0.094		For (B)= 0.029	For (A×B)= 0.107	

4.3. Volatile oil production

The tabulated results in Tables 9, 10 and 11 demonstrates that the FYM application positively influenced volatile oil % as well as volatile oil yield per caraway plant and per hectare, during both experimental seasons. In this connection, supplying caraway plants with FYM at all rates, led to significant improve in volatile oil production as compared to the control treatment, in the two seasons. The highest values in volatile oil percentage (1.518 and 1.572 %), volatile oil yield per plant (0.386 and 0.447 ml/plant) and volatile oil yield per hectare (30.86 and 35.76 l/hectare) were recorded when caraway plants fertilized with 40 m^3 FYM/ hectare in 1st and 2ns seasons, alternately. Through the improvement of soil physical conditions, which in turn improved the availability and uptake of nutrients and feed microbes, farmyard manure may have a positive effect on volatile oil yield per hectare, which obtained from the enhancement of plant growth and fruit yields. The higher volatile oil production may be due to the solubilization influence of plant nutrients brought about by the addition of farmyard manure, which improved uptake of NPK (**Sendurkumaran *et al.*, 1998**). Similarly, **Ali *et al.* (2017)** found that adding organic fertilizer at a high level (24 m^3 / feddan) produced the greatest values of fennel's volatile oil attributes (volatile oil %, yield / plant, and yield / feddan) when compared to control.

Table (9). Effect of FYM level (A) and seaweed extract concentration (B) and their interactions (A×B) on caraway volatile oil percentage during first and second seasons

FYM rate (ton/hectare)	Seaweed extract concentration (ml/l)				Mean (A)
	Control	3	6	12	
	First season				
Control	1.380	1.410	1.433	1.450	**1.418**
10	1.410	1.440	1.467	1.487	**1.451**
20	1.440	1.473	1.500	1.520	**1.483**
40	1.470	1.507	1.533	1.560	**1.518**
Mean (B)	**1.425**	**1.458**	**1.483**	**1.504**	
L.S.D. at 5 %	For (A)= 0.004		For (B)= 0.006	For (A×B)= 0.010	
	Second season				
Control	1.410	1.447	1.460	1.490	**1.452**
10	1.460	1.480	1.513	1.530	**1.496**
20	1.497	1.523	1.547	1.573	**1.535**
40	1.523	1.557	1.580	1.627	**1.572**
Mean (B)	**1.473**	**1.502**	**1.525**	**1.555**	
L.S.D. at 5 %	For (A)= 0.018		For (B)= 0.005	For (A×B)= 0.019	

Table (10). Effect of FYM level (A) and seaweed extract concentration (B) and their interactions (A×B) on caraway volatile oil (ml/plant) during first and second seasons

FYM rate (ton/hectare)	Seaweed extract concentration (ml/l)				Mean (A)
	Control	3	6	12	
	First season				
Control	0.184	0.202	0.220	0.237	**0.211**
10	0.245	0.272	0.286	0.305	**0.277**
20	0.288	0.325	0.360	0.396	**0.342**
40	0.329	0.367	0.404	0.443	**0.386**
Mean (B)	**0.262**	**0.292**	**0.318**	**0.345**	
L.S.D. at 5 %	For (A)= 0.020		For (B)= 0.003	For (A×B)= 0.021	
	Second season				
Control	0.212	0.232	0.248	0.273	**0.241**
10	0.287	0.321	0.343	0.363	**0.329**
20	0.335	0.376	0.413	0.451	**0.394**
40	0.381	0.410	0.475	0.522	**0.447**
Mean (B)	**0.304**	**0.335**	**0.370**	**0.402**	
L.S.D. at 5 %	For (A)= 0.025		For (B)= 0.007	For (A×B)= 0.028	

Table (11). Effect of FYM level (A) and seaweed extract concentration (B) and their interactions (A×B) on caraway volatile oil (l/hectare) during first and second seasons

FYM rate (ton/hectare)	Seaweed extract concentration (ml/l)				Mean (A)
	Control	3	6	12	
	First season				
Control	14.74	16.19	17.61	18.97	**16.88**
10	19.57	21.73	22.91	24.40	**22.15**
20	23.07	25.96	28.83	31.66	**27.38**
40	26.30	29.37	32.35	35.41	**30.86**
Mean (B)	**20.92**	**23.31**	**25.42**	**27.61**	
L.S.D. at 5 %	For (A)= 1.58		For (B)= 0.21	For (A×B)= 1.62	
	Second season				
Control	16.93	18.53	19.87	21.87	**19.30**
10	23.00	25.68	27.47	29.00	**26.29**
20	26.77	30.09	33.02	36.11	**31.50**
40	30.51	32.83	37.98	41.72	**35.76**
Mean (B)	**24.30**	**26.78**	**29.58**	**32.17**	
L.S.D. at 5 %	For (A)= 1.20		For (B)= 0.57	For (A×B)= 2.22	

Results listed in Tables 9, 10 and 11 shows that the different concentrations of seaweed extract significantly influenced the caraway volatile oil percentage, the yield of volatile oil produced per plant, and the volatile oil yield produced per hectare of caraway plants during the two consecutive seasons. The seaweed extract application of at a 12 ml/l concentration gave the highest values in this regard (1.504 and 1.555 %), (0.345 and 0.402 ml/ plant) and (27.61 and 32.17 l /hectare) compared to the other ones under study. Seaweed extract improves photosynthesis and encourages robust vegetation (**Kavitha *et al.*, 2008**). It is necessary to look into the possible applications of seaweed extract in organic farming practices. Similarly, **Bakr *et al*. (2024)** pointed out that spraying *Pelargonium graveolens* by seaweed extract at 1 g/l of could improve the volatile oil production. Likewise, **Bressan *et al.* (2024)** suggested that *Pelargonium graveolens* essential oil yield / plant was enhanced by using seaweed extracts.

Data of both seasons listed in Tables 8, 9 and 10 demonstrate that, increasing SW concentration from 3, 6 to 12 ml/l under each FYM rates gradually increased caraway volatile oil (%), yield per plant (ml/ plant) and per hectare (l/hectare) in both seasons. In general, the highest values in these traits (1.560 and 1.627 %), (0.443 and 0.522 ml/ plant) and (35.41 and 41.72 l/ hectare) were achieved by 40 m^3/hectare of FYM and 12 ml/l SW compared to the other combinations under study in the two seasons. Furthermore, as mentioned just before, both FYM rates and various SW concentrations (each alone) increased volatile oil percentage and fruit yield per hectare of caraway plant, in turn, they together might maximize their effects leading more volatile oil yield per hectare. Similarly, the obtained results are in agreed with those noticed by **Ali *et al.* (2017)** on fennel regard organic fertilization influence as well as **Bressan *et al.* (2024)** on *Pelargonium graveolens* regard seaweed extract influence.

4.4. Economic evaluation

Data from the caraway crop field experiment are shown in Table 12. Fertilized caraway plants with 40 m^3 FYM/hectare had the highest profit/cost ratio (2.014) when compared to the other rates studied. Additionally, the 12 ml/l seaweed extract treatment showed the highest profit/cost ratio (1.874) when compared to the control treatment. Comparing the 40 m3/hectare of farmyard manure with 12 ml/l seaweed extract to the other interaction treatments under investigation, the best combination treatment yielded a 2.250 ratio. Overall, it could be concluded that applying farmyard manure along with seaweed extract produced the highest net return and value for caraway plants. Similarly, **El-Hindi and El-Boraie (2005)** and **(Aušra *et al.*, 2021)** on marjoram plant reported the same results.

5. Conclusion

According to this study, farmers may choose to apply 40 m^3 FYM/ha and 12 ml/l of SW as a foliar spray on caraway plants rather than caraway as a medicinal and aromatic crop. Generally speaking, using the FYM rates and SW increased fruit yield and caraway development as well as optimizing volatile oil production and profit/cost ratio under the study conditions.

Table (12). Economic evaluation of caraway fruit yield production under effect of farmyard manure (FYM) rate, seaweed extract concentration and their interactions (average of both seasons)

Treatments		Input			Output		
		Investment costs	Operating costs	Total Costs cultivation (L.E./fed.)	Revenue	profit /cost ratio	Order
		Effect of FYM (m^3 / hectare)					
0.0		24000	24910	48910	62833	1.284	4
10		24000	26360	50360	81917	1.626	3
20		24000	27813	51812	97167	1.875	2
40		24000	29260	53260	107333	2.014	1
L.S.D. at 5 %		**-**	**296.46**	**296.46**	**3727.5**	**0.064**	**-**
		Effect of seaweed extract rate (ml / l)					
0.0		24000	26725	50725	7750	1.521	4
3.0		24000	26965	50965	84083	1.642	3
6.0		24000	27205	51205	90750	1.763	2
12.0		24000	27447	51447	96917	1.874	1
L.S.D. at 5 %		**-**	**301.07**	**301.07**	**752.97**	**0.014**	**-**
		Effect of FYM rate × seaweed extract concentration					
0.0	**0.0**	24000	24550	48550	56667	1.167	16
	3.0	24000	24790	48790	50667	1.243	15
	6.0	24000	25030	49030	64667	1.319	14
	12.0	24000	25270	49270	69333	1.407	13
10	**0.0**	24000	26000	50000	74000	1.480	12
	3.0	24000	26240	50240	81000	1.612	11
	6.0	24000	26480	50480	84333	1.670	9
	12.0	24000	26720	50720	88333	1.742	8
20	**0.0**	24000	27450	51450	84667	1.646	10
	3.0	24000	27690	51690	93333	1.806	6
	6.0	24000	27930	51930	101333	1.951	4
	12.0	24000	28179	52179	109333	2.095	3
40	**0.0**	24000	28900	52900	94667	1.789	7
	3.0	24000	29140	53140	101333	1.907	5
	6.0	24000	29380	53380	112667	2.111	2
	12.0	24000	29620	53620	120667	2.250	1
L.S.D. at 5 %		**-**	**598.38**	**598.38**	**3942.7**	**0.068**	**-**

References

Abd EL-Kafie, O. M., Ghaly N. G., El-Banna H. Y. and Hassan A. (2020). Effect of Fertilization and foliar applicaion treatments on coriander plant (*Coriandrum sativum* L.). Journal of Plant Production, 11(12): 1375-1382. https://journals.ekb.eg/article_149809.html

Aćimović, M. G. (2013). The influence of fertilization on yield of caraway, anise and coriander in organic agriculture. Journal of Agricultural Sciences, Belgrade, 58(2): 85-94. DOI: 10.2298/JAS1302085A.

Ahmed, A. A., Sinan A.A. and Ali A. F. (2019). Response of caraway (*Carum carvi* L.) plants to organic manures in replacement of chemical fertilization. Research Journal of Biotechnology, 14 (Special issue I): 283-288.

Ahmed A. H. , Amir F.A. Abdel-Rahim , Ghadah H. Al Hawas , Wadha Kh. Alshammari, Reda M.Y. Zewail, Ali A. Badawy and Heba S. El-Desouky (2025). Optimizing Caraway Growth, Yield and Phytochemical Quality Under Drip Irrigation: Synergistic Effects of Organic Manure and Foliar Application with Vitamins B1 and E and Active Yeast, Agronomy 2021, 11, 1172. https://doi.org/10.3390/agronomy11061172.

Ali, A. F., E. A. Hassan, Hamad E. H., and Abo-Quta W. M. H. (2017). Effect of compost, ascorbic acid and salicylic acid treatments on growth, yield and oil production of fennel plant. Assiut J. Agric. Sci., 48 (1-1): 139-154. https://ajas.journals.ekb.eg/article_3736_d6a0ace225079fe0365e7e618a10b1b6.pdf

Ali, N. S., Gad M. M. and Abdul-Hafeez E. Y. (2023). Evaluating the efficiency of organic manures and seaweed extract on the improvement of growth and productivity of *Foeniculum vulgare* Mill. plants. Assiut Journal of Agricultural Sciences, 54(2): 91-107. DOI: 10.21608/ajas.2023.194740.1235

Analytical Software (2008). Statistix Version 9, Analytical Software, Tallahassee, Florida, USA. https://www.statistix.com/

András, C.D., Salamon, R.V., Barabás, I., Volf, I. and Szép A. (2015). Influence of extraction methods on caraway (*Carum carvi* L.) essential oil yield and carvone/limonene ratio. Environmental Engineering and Management Journal, 14 (2): 341-347. http://omicron.ch.tuiasi.ro/EEMJ/

Aušra M., Aušra R., Rimantas V. , Robertas K. and Zita K. (2021) Weed Spread and Caraway (*Carum carvi* L.) Crop Productivity in a Multi-Cropping System, Agronomy 2021, 11, 1172. https://doi.org/10.3390/agronomy11061172

Awad, M. (2016). Poultry manure and humic acid foliar applications impact on caraway plants grown on a clay loam. Journal of Soil Sciences and Agricultural Engineering, 7(1): 1-10.

Badalingappanavar, R., Hanumanthappa, M., Veeranna, H.K., Kolakar, S. and Khidrapure G. (2018). Organic fertilizer management in cultivation of medicinal and aromatic crops: A review. J. of Pharmacognosy and Phytochemistry, 7 (3S): 126-129.

Bakr, A., Taha R. A., Botros W.and Mohamed M. A. E. (2024). Effect of some plant growth biostimulants on growth and Volatile oils productivity of *Pelargonium graveolens* plants. Journal of Modern Research, 6(2): 75-82. https://jmr.journals.ekb.eg/article_341581_6ea5378baa0334388d886f58a5f93262.pdf

Bhaskar, N. and Miyashita K. (2005). Lipid composition of *Padina tetratomatica* (Dictyotales, Pheophyta), abrown seaweed of the west coast of India. Ind. J. Fisheries., 52 (3):263–268. http://ir.cftri.res.in/id/eprint/9917

Black C. A. (1965). Method of Soil Analysis part 2. Chemical and microbiological properties, 9: 1387-1388. https://www.cabidigitallibrary.org/doi/full/10.5555/19841981415

Bressan, R. J., Fernandes B. R., Bosisio M. M., Nascimento T. F. M., Vitolo H. F., Raupp R. C. and Pacheco A. C. (2024). Seaweed extracts elicitation improves leaf and essential oil production on *Pelargonium graveolens* L. Herit. Journal of Essential Oil Research, 36(6): 544-553. https://doi.org/10.1080/10412905.2024.2353632

Chapman, H. and Pratt P. (1978). Methods of Analysis for Soils, Plants and Waters. Div. Agric., Sci. Univ. Calif. USA, 16-38. https://journals.lww.com/soilsci/citation/1962/01000/methods_of_analysis_for_soils,_plants_and_waters.15.aspx

Crouch, I. J. and Van Staden J. (1993). Commercial seaweed products as biostimulants in horticulture. J. Home Consumer Hort., 1: 19-76. https://www.tandfonline.com/doi/abs/10.1300/J280v01n01_03

Crouch, I. J., Beckett R.P. and Van Staden J. (1990). Effect of seaweed concentrates on the growth and mineral nutrition of nutrient-stressed lettuce. J. of Applied Phycology, 2 (3): 269–272. https://link.springer.com/content/pdf/10.1007/bf02179784.pdf

Dhargalkar, V.K. and Pereira N. (2005). Seaweed: promising plant of the millennium.Sci. Cult, 71: 60-66. https://www.researchgate.net/publication/27667265_Seaweed_Promising_Plant_of_the_Millennium

Divya P., B. Puthusseri and Neelwarne B. (2014). The effect of plant regulators on the concentration of carotenoids and phenolic compounds in foliage of coriander. LWT - Food Science and Technology, 56: 101–110. https://doi.org/10.1016/j.lwt.2013.11.012

El-Hindi, K. M. and El-Boraie E. A. (2005). Effect of some bio-fertilizers on the growth, essential oil yield and chemical composition of marjoram plants. J. Agric. Sci. Mansoura Univ., 30 (12): 7917-7927. https://journals.ekb.eg/article_237936.html

Gwari, G., Bhandari, U., Andola, H.C., Lohani, H. and Chauhan, N. (2012). Aroma profile of seeds of *Carum carvi* Linn. cultivated in higher hills of Uttarakhand Himalaya. Indian Journal of Natural Products and Resources, 3 (3): 411-413.

Hamza, A., Massoud, H. Y., Eid, M. E., Khater, M. R. and El-Gamal, S. (2007). Effect of farmyard manure (FYM) doses and different bio-fertilizers on vegetative growth, seed yield and active constituents of *Plantago ovata* Forsk plants. Journal of Plant Production, 32 (7): 5583-5600. https://journals.ekb.eg/article_219780_1c280c8836478f9534d45290a480b539.pdf

Hassan, A. A., Abdel-Rahim, A. F., Al Hawas, G. H., Alshammari, W. K., Zewail, R. M., Badawy, A. A. and El-Desouky, H. S. (2025). Optimizing caraway growth, yield and phytochemical quality under drip irrigation: Synergistic effects of organic manure and foliar application with vitamins B1 and E and active yeast. Horticulturae, 11(8): 1-28. https://doi.org/10.3390/horticulturae11080977

Ibrahim, M.H., Jaafar, H.Z., Karimi, E. and Ghasemzadeh, A. (2013). Impact of organic and inorganic fertilizers application on the phytochemical and antioxidant activity of Kacip Fatimah (*Labisia pumila* Benth). Molecules, 18 (9): 10973-10988. https://doi.org/10.3390/molecules180910973

Kamenik, J. (1996). Perspektivy uplatneni Kminu V zemédélstive CR. In: Proc. Conf. Biologie and agrotechnique of caraway. MZLU Brno, 8-10.

Kavitha, M.P., V. Ganesaraja and Paulpandi V. K. (2008). Effect of foliar spraying of seaweed extract on growth and yield of rice (*Oryza sativa* L.). Agric. Sci. Digest, 28 (2): 127–129. file:///C:/Users/n/Downloads/dsharma,+36-MS-2906_1111+-+1120.pdf

Mansori, M., Farouk, I.A. Hsissou, D. and El Kaoua, M. (2019). Seaweed extract treatment enhances vegetative growth and antioxidant parameters in water stressed *Salvia officinalis* L. J. Mater. Environ. Sci., 10 (8): 756-766. https://www.jmaterenvironsci.com/Document/vol10/vol10_N8/78-JMES-2019-10-8-Mansori.pdf

Page A. L., R. H. Miller, Keeney D. R.,. Baker D. E, Ellis R.and Rhoades J. D. (1982). Methods of soil analysis. Eds (No. 631.41 MET 9-2 1982). https://dergipark.org.tr/en/download/article-file/525683

Priya S. and Elakkiya R. (2012). Effects of organic and biofertilizers on growth and yield of *Eclipta alba* (L). Int. J. of Pharm. Tech. Research Coden., 4 (4): 1703-1705.

Rostaei, M., S. Fallah, Carrubba A. and Lorigooini Z. (2024). Organic manures enhance biomass and improve content, chemical compounds of essential oil and antioxidant capacity of medicinal plants: A review. Heliyon, 10 (e36693): 1-23. https://www.cell.com/heliyon/fulltext/S2405-8440(24)12724-7

Sachan, A.K., Das, D.R. and Kumar, M. (2016). *Carum carvi* - An important medicinal plant. Journal of Chemical and Pharmaceutical Research, 8 (3): 529-533.

Sarhan, M. G. and Shehata A. M. (2023). Effect of compost along with spraying of methyl Jasmonate and potassium silicate on the productivity of French basil under sandy soil conditions. Egyptian Journal of Soil Science, 63 (2): 225-241. https://www:10.21608/EJSS.2023.203548.1583.

Sendurkumaran S., S. Natarajan and Thamburaj S. (1998). Effect of organic and inorganic fertilizers on growth, yield and quality of tomato. South Indian Hort., 46 (3 and 4): 203-205. https://www.cabidigitallibrary.org/doi/full/10.5555/20000308862

Shabbara, M.H., Karima A.M., Yousria A.E. and Eman A.A. (2018). Comparative analytical economic study of the high yield varieties production of *Foeniculum vulgare* Mill. (Fennel) between Arabic Republic of Egypt and India. Middle East J. Agric. Res., 7 (4): 1514–1520. https://www.curresweb.com/mejar/mejar/2018/1514-1520.pdf.

Solberg, S.O., Göransson, M., Petersen, M.A., Yndgaard, F. and Jeppson, S. (2016). Caraway essential oil composition and morphology: The role of location and genotype. Biochemical Systematics and Ecology, 66: 351-357.

Yusuf, R., Syakur, A., Kalaba, Y. and Fatmawati, F. (2020). Application of some types of local seaweed extract for the growth and yield of shallot (*Allium wakegi*). Aquaculture, Aquarium, Conservation & Legislation, 13(4): 2203-2210.