

Evaluation Caraway (*Carum Carvi*) Growth and Yield Component as Affected by Chemical, Organic and Biological Fertilizers

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Abstract

In order to evaluate the combination effect between chemical (NPK), organic (10, 15 and 20 ton/feddan) and biological fertilizers (effective microorganisms at 10, 15 and 20 kg/feddan) on growth and yield component characters of caraway (*Carum carvi* L.) plants a field experimental study was established. The experiment was simple in complete randomized block design in four replicates through winter season of 2023/2024 at Ghasala Farm, Faculty of Agriculture, Zagazig University, Egypt. Fertilized caraway plants with N60P33.75K20 + 10ton compost/ feddan recorded the tallest plants with significant difference with the other fertilizers types under study. Utilizing 10 or 20-ton compost plus 20 or 10 effective microorganisms (EM), respectively or 20-ton compost alone significantly increased number of branches per plant. The heaviest herb fresh and dry weights as well as longest root length of caraway were obtained with 10-ton compost + 20 kg EM/feddan in comparison with the other combinations under study. The highest roots fresh and dry weights per plant were produced when caraway plants fertilized by 15-ton compost + 15 kg EM/feddan. In general, the highest fruit yield per plant and per feddan were noticed with the combination between 20-ton compost + 10 kg EM/feddan with significant difference with the other treatments under study.

Keywords: Caraway, NPK, compost, Effective microorganisms, growth, yield

1. Introduction

Caraway (*Carum carvi* L.), belonging to the Apiaceae (Umbelliferae) family, is one of the oldest medicinal and aromatic plants cultivated across temperate and Mediterranean regions (Dyduch *et al.*, 2006). Prized primarily for its essential oil, caraway seeds (mericarps) contain significant concentrations of active volatile compounds, predominantly carvone and limonene, which account for its distinct aroma and therapeutic efficacy (Sedláková *et al.*, 2003). Historically utilized in traditional medicine, modern phytochemical analyses have confirmed caraway's potent antimicrobial, antioxidant, antispasmodic, and carminative activities (Laribi *et al.*, 2010).

In Egypt, the cultivation of medicinal and aromatic plants (MAPs) represents a vital sector of the agricultural economy, contributing substantially to export revenue and local pharmaceutical industries (El-Gengaihi *et al.*, 2012). Caraway thrives under Egyptian climatic conditions, particularly in reclaimed lands and the Upper Egypt region, where environmental parameters such as solar radiation and soil composition optimize volatile oil yield and composition (Mahfouz and Sharaf-Eldin, 2007). Given the growing global demand for natural bioactive compounds, understanding the agronomy, bio-active profile, and economic impact of *Carum carvi* L. in Egypt is essential for optimizing crop yield and industrial applications.

Appropriate application of chemical, organic, and bio-fertilizers enhances the vegetative growth, biomass, and secondary metabolite accumulation in medicinal and aromatic plants (Mahmoud *et al.*, 2020). Furthermore, integrating these nutrient sources improves soil health and microbial activity while reducing environmental pollution associated with excessive mineral fertilization (El-Serafy *et al.*, 2023). Integrated nutrient

management significantly boosts seed yield, essential oil percentage, and active compound accumulation in aromatic plants compared to sole chemical inputs (**Hassan *et al.*, 2021**). Bio-fertilizers containing beneficial microbial strains (such as *Azotobacter* and *Bacillus* species) facilitate nutrient availability and enhance the biosynthesis of primary essential oil constituents in caraway (*Carum carvi* L.), notably carvone and limonene (**Al-Snafi, 2020**). Organic soil amendments improve soil structure and water retention, which helps caraway plants withstand abiotic stress and maintain high productivity in newly reclaimed soils (**Böhme *et al.*, 2022**). Mineral fertilizers deliver an immediate supply of essential macronutrients (NPK) required for critical growth stages like flowering, whereas organic and bio-fertilizers provide sustained nutrient release throughout the plant's life cycle (**Abedi *et al.*, 2020**).

This study aims to evaluate the impact of chemical, organic, and bio-fertilizers - applied individually or in integrated combinations - on caraway (*Carum carvi* L.) plants by assessing vegetative growth parameters (such as plant height, branch number, and dry weight), determining improvements in yield components and fruit productivity under different fertilization sources.

2. Materials and Methods

A field experiment was done through the winter season of 2023/2024 at Ghasala Farm, Faculty of Agriculture, Zagazig University, Egypt. A simple design in complete randomized block with four replicates was established. Table 1 displays the physical and chemical characteristics of the soil that was used (averaged over two growing seasons) as described by **Chapman and Pratt (1978)**. In addition, Table 2 displays the physical and chemical characteristics of the compost that was previously used.

Table 1. Physical and chemical properties of experimental farm soil (average of two seasons)

Mechanical analysis									Soil texture		
Clay (%)		Silt (%)				sand (%)			Clayey		
56.50		18.91				24.59					
Chemical analysis											
pH	E C m.mohs/ cm	Soluble cations (meq. / l)				Soluble anions (meq. / l)			Available (ppm)		
		Mg ⁺⁺	Ca ⁺⁺	K ⁺	Na ⁺	Cl ⁻	HCO ₃ ⁻	SO ₄ ⁻⁻	N	P	K
7.84	0.93	2.5	3.5	1.3	0.8	1.5	0.5	5.0	0.04	8.30	0.2

Table 2. Physical and chemical properties of the vegetarian compost applied in the current study (average of two seasons)

pH	E C dS.m ⁻¹	Organic matter (%)	Organic carbon (%)	C:N ratio	M ³ weight (kg)	Humidity (%)	Total N (%)	Total P (%)	Total K (%)
7.60	2.25	19.52	11.32	1:20	770	23	0.57	0.36	0.23

The present experimental work involved studying the following treatments:

1. N 80 + P 45 + K 40 kg/ feddan (Control).
2. N 60 + P 33.75 + K 30 kg + 10 m³ compost/ feddan.
3. N 40 + P 22.5 + K 20 kg + 15 m³ compost / feddan.
4. N 20 + P 11.25 + K 10 kg + 20 m³ compost / feddan.

5. Compost at 10 ton + 20 kg effective microorganisms /feddan.
6. Compost at 15 ton + 15 kg effective microorganisms /feddan.
7. Compost at 20 ton + 10 kg effective microorganisms /feddan.
8. Compost at 20 ton.

The plot area was 4.5×11.20 m and it included sixteen ridges; each ridge was 70 cm apart and 4.5 meters in length. The fruits were sown in hills on one side of the ridge during 21st November, and hills spaced 30 cm, a part. The irrigation system was surface irrigation. All caraway plants received normal agricultural practices whenever they needed.

Ammonium nitrate (33.5 % N), calcium super phosphate (12 % P_2O_5) and potassium sulphate (51 % K_2O) were applied as soil drench at twenty-day intervals in the growing season. At the time of soil preparation, we added organic fertilizing with different rates of compost as soil application. Compost typically has a moisture content of 25-30%. Effective microorganisms were applied to the soil around the caraway seeds once before sowing.

The statistical layout of these experiments was simple experiment in randomized complete blocks design with four replicates.

The recorded data:

After 102 days from sowing date of caraway, a sample of 3 plants were randomly taken from each experimental unit and following growth traits were recorded:

A. Growth characters:

1. Plant height (cm);
2. Number of main branches per plant;
3. Fresh and dry weights of herb per plant (g);
4. Root fresh and dry weights per plant (g) and
5. Root length (cm).

At harvesting stage (after 152 days from sowing date) the yield components were determined as follow:

B. Yield components:

1. Fruit yield / plant (g);
2. Fruit yield per feddan (kg)

Statistical Analysis

Data of the present work were statically analyzed and the differences between the means of the treatments were considered significant when they were more than the least significant differences (L.S.D) at the 5% level by using computer program of Statistix Version 9 (**Analytical Software, 2008**).

3. Results and Discussion

1. Plant growth characters

1.1. Plant height (cm)

The plant height of *Carum carvi* was significantly influenced by the application of different fertilization treatments during the 2023/2024 season (Table 3). The maximum plant height (138.75 cm) was achieved with the application of $N_{60}P_{33.75}K_{30}$ + 10-ton compost/feddan, showing a significant superiority over all other

treatments. Conversely, the treatment of $N_{40}P_{22.50}K_{20}$ + 15-ton compost/feddan recorded the lowest plant height value (124.00 cm).

1.2. Number of branches per plant

The number of branches per plant varied significantly depending on the fertilization regime applied (Table 3). The treatment of 10-ton Compost + 20 kg EM/feddan yielded the highest number of branches (15.50), which did not show significant differences compared to 15-ton Compost + 15 kg EM/feddan and 20-ton Compost/feddan. On the other hand, the mineral fertilizer control ($N_{80}P_{45}K_{40}$ feddan) recorded the lowest number of branches (10.75).

Table 3. Influence of different fertilizer types on plant height (cm) and number of branches/plant of *Carum carvi* during 2023/2024 season

Fertilization type	Plant height (cm)	Number of branches / plant
$N_{80} P_{45} K_{40}$ / feddan	128.75cd	10.75 d
$N_{60} P_{33.75} K_{30}$ + 10 ton compost / feddan	138.75 a	12.00cd
$N_{40} P_{22.50} K_{20}$ + 15 ton compost / feddan	124.00 e	12.00cd
$N_{20} P_{11.25} K_{10}$ + 20 ton compost / feddan	134.50 b	14.25ab
10 ton Compost + 20 kg EM* / feddan	135.00 b	15.50 a
15 ton Compost + 15 kg EM / feddan	128.75cd	15.25 a
20 ton Compost + 10 kg EM / feddan	128.00 d	13.25bc
20 ton Compost / feddan	131.25 c	14.75 a

* EM = Effective microorganisms

Means having the same letter (s) within the same column are not significantly different according to Duncan's multiple range test at 5% level of probability.

1.3. Plant fresh weight (g)

The fresh weight of caraway plants was highly responsive to organic, bio, and mineral fertilizer combinations (Table 4). The application of 10-ton Compost + 20 kg EM/feddan produced the highest plant fresh weight (558.47 g), which significantly outperformed all other treatments. In contrast, the lowest plant fresh weight (379.72 g) was observed when plants were fertilized solely with 20-ton Compost/feddan.

1.4. Plant dry weight (g)

Plant dry weight followed a highly similar statistical trend to that of the fresh weight (Table 4). The highest significant value (85.95 g) was recorded with the treatment of 10-ton compost + 20 kg EM/feddan. Meanwhile, the sole organic treatment of 20-ton compost/feddan led to the lowest dry accumulation, yielding only 54.78 g per plant.

1.5. Root Fresh Weight per Plant (g)

Root growth parameters responded positively to organic fertilization supplemented with bio-fertilization (EM). The highest root fresh weight (35.90 g) was obtained when applying 15-ton compost + 15 kg EM/feddan, which statistically was comparable to the 20-ton compost + 10 kg EM/feddan treatment (Table 5). On the contrary, the purely chemical treatment of $N_{80}P_{45}K_{40}$ /feddan resulted in the lowest root fresh weight (19.98 g).

Table 4. Influence of different fertilizer types on plant fresh and dry weights (g) of *Carum carvi* during 2023/2024 season

Fertilization type	Plant fresh weight (g)	Plant dry weight (g)
N₈₀ P₄₅ K₄₀ / feddan	394.50 e	69.55 e
N₆₀ P_{33.75} K₃₀+ 10 ton compost / feddan	453.15 d	72.50 d
N₄₀ P_{22.50} K₂₀+ 15 ton compost / feddan	450.80 d	72.65cd
N₂₀ P_{11.25} K₁₀+ 20 ton compost / feddan	494.68 c	78.63 b
10 ton Compost + 20 kg EM* / feddan	558.47 a	85.95 a
15 ton Compost + 15 kg EM / feddan	532.42 b	79.63 b
20 ton Compost + 10 kg EM / feddan	505.25 c	74.68 c
20 ton Compost / feddan	379.72 f	54.78 f

* EM = Effective microorganisms

Means having the same letter (s) within the same column are not significantly different according to Duncan's multiple range test at 5% level of probability.

1.6. Root Dry Weight per Plant (g)

The dry weight of the roots was significantly affected by the different organic and bio-fertilizer combinations (Table 5). The highest root dry weights were observed in treatments containing higher ratios of compost with EM, peaking at 6.77 g and 6.64 g under 15-ton Compost + 15 kg EM/feddan and 20-ton Compost + 10 kg EM/feddan, respectively. Conversely, chemical fertilization (N₈₀P₄₅K₄₀/feddan) and lower compost ratios gave the lowest values, staying below 4.70 g.

1.7. Longest Root Length (cm)

Root penetration and length were significantly stimulated by the combined application of compost and effective microorganisms (Table 5). The treatment of 10-ton compost + 20 kg EM/feddan produced the longest roots, reaching a maximum value of 29.50 cm. Conversely, the shortest length of root (19.00 cm) was recorded under the standard chemical fertilizer treatment (N₈₀P₄₅K₄₀/feddan).

Table 5. Influence of different fertilizer types on roots fresh and dry weights /plant (g) of *Carum carvi* during 2023/2024 season

Fertilization type	Root fresh weight per plant (g)	Root dry weight per plant (g)	Longest root length (cm)
N₈₀ P₄₅ K₄₀ / feddan	19.98 g	4.52 d	19.00 e
N₆₀ P_{33.75} K₃₀+ 10 ton compost / feddan	21.73 f	4.69 d	21.25 d
N₄₀ P_{22.50} K₂₀+ 15 ton compost / feddan	22.75 e	4.49 d	25.00bc
N₂₀ P_{11.25} K₁₀+ 20 ton compost / feddan	29.03 c	5.73bc	24.50 c
10 ton Compost + 20 kg EM* / feddan	29.28 c	5.81 b	29.50 a
15 ton Compost + 15 kg EM / feddan	35.90 a	6.77 a	26.50 b
20 ton Compost + 10 kg EM / feddan	35.18 b	6.64 a	26.50 b
20 ton Compost / feddan	27.78 d	5.51 c	26.50 b

* EM = Effective microorganisms

Means having the same letter (s) within the same column are not significantly different according to Duncan's multiple range test at 5% level of probability.

In addition, EM contains a mixture of beneficial photosynthetic bacteria, lactic acid bacteria, and yeasts. These microorganisms accelerate the mineralization and decomposition of organic matter (compost), releasing essential plant nutrients such as nitrogen (N), phosphorus (P) and potassium (K) in highly bioavailable forms. In the same time, beneficial microbes synthesize plant-growth-promoting substances, including auxins (indole-3-acetic acid), gibberellins, and cytokinins. These phytohormones stimulate cellular division and elongation, directly promoting root elongation and lateral branching. Moreover, compost improves soil physical properties—such as water-holding capacity, aeration, and bulk density. This creates an optimal rhizosphere (root zone) environment that allows the roots to penetrate deeper and absorb water and nutrients more efficiently.

Furthermore, **Hellal *et al.* (2011)** on dill (*Anethum graveolens*) demonstrated that bio-fertilizers combined with organic manures dramatically improve plant height and branching by enhancing nutrient uptake. Also, **He *et al.* (2020)** reported that integrating organic compost with bio-inoculants significantly improves vegetative growth and root architecture compared to chemical fertilizers alone due to enhanced soil microbial activity.

2. Fruit yield components

2.1. Fruit yield per plant (g)

Fruit yield per plant was highly sensitive to the nature of the nutrition treatments applied (Table 6). The maximum fruit yield (62.65 g) was significantly achieved under 20-ton Compost + 10 kg EM/feddan, closely followed by 15-ton compost + 15 kg EM/feddan treatment (60.78 g). On the other hand, the control treatment of standard chemical fertilization (N₈₀P₄₅K₄₀/feddan) showed the lowest productivity, yielding only 36.62 g of fruits per plant.

Table 6. Influence of different fertilizer types on fruit yield per plant (g) and per feddan (kg) of *Carum carvi* during 2023/2024 season

Fertilization type	Fruit yield per plant (g)	Fruit yield per feddan (kg)
N ₈₀ P ₄₅ K ₄₀ / feddan	36.62 h	732.5 h
N ₆₀ P _{33.75} K ₃₀ + 10 ton compost / feddan	44.13 e	882.5 e
N ₄₀ P _{22.50} K ₂₀ + 15 ton compost / feddan	51.40 c	1027.9c
N ₂₀ P _{11.25} K ₁₀ + 20 ton compost / feddan	40.90 f	818.0 f
10 ton Compost + 20 kg EM* / feddan	50.80 d	1016.0d
15 ton Compost + 15 kg EM / feddan	60.78 b	1215.5b
20 ton Compost + 10 kg EM / feddan	62.65 a	1253.0a
20 ton Compost / feddan	40.25 g	805.0 g

* EM = Effective microorganisms

Means having the same letter (s) within the same column are not significantly different according to Duncan's multiple range test at 5% level of probability.

2.2. Fruit yield per feddan (kg)

The total productivity of caraway fruits per feddan mirrored the trends observed in individual plant yields (Table 6). The highest crop yield per feddan (1253.0 kg) was achieved under the biological and organic mixture of 20-ton compost + 10 kg EM/feddan. In contrast, the conventional mineral fertilizer application (N₈₀P₄₅K₄₀/feddan) resulted in the lowest land productivity, recording only 732.5 kg/feddan.

Adding organic matter alone is insufficient if microbial decomposition rates are low. Without adequate EM inoculants, compost decomposes slowly, and temporary microbial nitrogen immobilization may occur (**El-Gendy *et al.*, 2017**). High microbial activity driven by sufficient EM application is essential to convert bound organic nutrients into plant-available inorganic forms (NH₄⁺, NO₃⁻, H₂PO₄⁻).

Effective Microorganisms (EM) act as a potent biocatalyst. EM contains beneficial strains—including lactic acid bacteria, nitrogen-fixing bacteria, photosynthetic bacteria, and yeasts—that accelerate the mineralization and humification process of organic compost (Hellal *et al.*, 2018; Ahmad *et al.*, 2020). This symbiotic interaction promotes the gradual release of key macro- and micronutrients (N, P, K, Fe and Zn) throughout critical physiological stages (blooming and seed setting). Furthermore, EM secretes endogenous plant growth regulators (such as auxins, gibberellins, and cytokinins) that enhance root architecture and photosynthetic translocation toward fruit umbels (Hassan *et al.*, 2023).

This trend demonstrates the efficacy of integrated nutrient management. Small starter doses of mineral NPK provide immediate nutrient availability during early vegetative establishment, while the bulky organic compost increases soil cation exchange capacity, improves moisture retention, reduces leaching losses, and provides sustained nutrient availability (Bistgani *et al.*, 2017; Sharaf-Eldin *et al.*, 2021). This balanced nutritional supply prevents vegetative overgrowth while maximizing reproductive performance.

4. Conclusion

Based on the experimental results, applying 20 tons of compost + 10 kg of EM (Effective Microorganisms) per feddan is strongly recommended to achieve optimal growth and productivity in *Carum carvi* (caraway). This organic treatment outperformed all other fertilization rates, producing the highest fruit yield, maximum branch count, and superior biomass accumulation. Overall, replacing conventional chemical fertilizers (N₈₀ P₄₅ K₄₀) with compost enriched with bio-inoculants significantly enhances crop yield, root development and eco-friendly farming practices.

References

- [1] Abedi, F., Razavi, B. M. and Hosseinzadeh, H. (2020). A review on phytochemistry and pharmacological properties of *Carum carvi* L. *Phytotherapy Research*, 34 (10): 2428–2445.
- [2] Ahmad, M., Zaheer, Z. and Ismail, M. (2020). Role of effective microorganisms (EM) and compost in enhancing nutrient uptake and crop yield of medicinal plants. *Journal of Plant Nutrition*, 43(8): 1145–1158.
- [3] Al-Snafi, A. E. (2020). Medical importance of *Carum carvi* - A review. *Indo American Journal of Pharmaceutical Sciences*, 7(2): 101–112.
- [4] Analytical Software (2008). Statistix Version 9, Analytical Software, Tallahassee, Florida, USA.
- [5] Bistgani, Z. E., Siadat, S. A., Bakhshandeh, A. and Pirbalouti, A. G. (2017). Interactive effects of organic and chemical fertilizers on growth, yield, and essential oil of Apiaceae family plants. *Industrial Crops and Products*, 108: 241–247.
- [6] Böhme, M. H., Pinker, I. and Abdel-Mawgoud, A. M. (2022). Bio-active compounds and production potential of Apiaceae family crops in arid environments. *Journal of Applied Research on Medicinal and Aromatic Plants*, 28: 1-17.
- [7] Chapman, D. H. and Pratt, R. F. (1978). *Methods of Analysis for Soils, Plants and Waters*. Div. Agric. Sci. Univ. of California USA pp16-38.
- [8] Dyduch, J., Najda, A. and Brzozowski, P. (2006). Study on the chemical composition of essential oil from caraway (*Carum carvi* L.) fruits. *Annales Umcs, Medicina Veterinaria*, 60(1): 62–67.
- [9] El-Gendy, A. G., Hendawy, S. F., Omer, E. A. and Hussein, M. S. (2017). Impact of organic and bio-fertilizers on yield and essential oil composition of caraway (*Carum carvi* L.). *Journal of Applied Research on Medicinal and Aromatic Plants*, 6: 12–19.
- [10] El-Gengaihi, S. E., Wahba, H. E. and Ibrahim, M. E. (2012). Growth, yield and essential oil content of caraway (*Carum carvi* L.) plants as affected by bio-fertilizers and organic manures. *Journal of Applied Sciences Research*, 8(8): 4160–4167.
- [11] El-Serafy, R. S., El-Sheshtawy, A. A. and Hashim, A. M. (2023). Integrated nutrient management impacts on growth, yield, and essential oil composition of *Carum carvi* L. under stress conditions. *Egyptian Journal of Agronomy*, 45(1)L 45–59.

- [12] **Hassan, E. A., El-Ghadban, E. A. E. and Mohamed, H. F. (2023).** Sustainable bio-organic fertilization practices for enhancing productivity and oil quality of *Carum carvi* L. *Egyptian Journal of Agronomy*, 45(2): 175–188.
- [13] **Hassan, F. A., Mazrou, R. M. and El-Kady, M. A. (2021).** Impact of nano-nitrogen and organic bio-fertilizers on caraway (*Carum carvi* L.) productivity and essential oil constituents in reclaimed soils. *Industrial Crops and Products*, 168: 1-14.
- [14] **He, X., Liu, J., Jiang, J., Wang, Y. and Zhang, Y. (2020).** Integrating organic compost with bio-inoculants enhances plant growth, root architecture, and soil microbial activity: A comparative study with chemical fertilizers. *Applied Soil Ecology*, 150, Article 103476.
- [15] **Hellal, F. A., Mahfouz, S. A. and Hassan, F. A. (2018).** Response of *Carum carvi* L. plants to organic fertilizers and effective microorganisms (EM) under sandy soil conditions. *Bulletin of the National Research Centre*, 42(1), 105.
- [16] **Hellal, F. A., Mahfouz, S. A. and Hassan, F. A. S. (2011).** Partial substitution of mineral fertilizers by bio-fertilizers for improving growth, yield and essential oil content of dill (*Anethum graveolens* L.). *Journal of Applied Sciences Research*, 7(12): 1950–1957.
- [17] **Laribi, B., Bettaieb, I., Kouki, K., Sahli, A., Mougou, A. and Marzouk, B. (2010).** Water deficit effects on caraway (*Carum carvi* L.) growth, essential oil yield and composition. *Industrial Crops and Products*, 31(1): 34–42.
- [18] **Mahfouz, S. A. and Sharaf-Eldin, M. A. (2007).** Effect of biofertilizers on growth, yield and essential oil content of caraway (*Carum carvi* L.) plant. *Journal of Applied Sciences Research*, 3(7): 558–566.
- [19] **Mahmoud, A. W. M., Esmail, S. E. A. and Abdel-Gawad, A. M. (2020).** Response of Apiaceae plants to integrated fertilization regimes under Egyptian condition. *Asian Journal of Plant Sciences*, 19(4): 312–321.
- [20] **Sedláková, K., Kocourková, B., Lojková, L. and Kubáň, V. (2003).** Determination of essential oil content in caraway (*Carum carvi* L.) seeds by hydrodistillation and supercritical fluid extraction. *Plant, Soil and Environment*, 49(6): 237–242.
- [21] **Sharaf-Eldin, M. A., El-Sawi, S. A. and El-Kashoury, A. (2021).** Integrated nutrient management improving yield and secondary metabolites in aromatic crops. *Scientia Horticulturae*, 285: 1-18.