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Response Caraway (*Carum carvi* L.) Plants to Humic Acid, Mycorrhizae Fungi and Azolla Extract

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Abstract

This investigation was carried out at Faculty of Agriculture Farm New Valley University (EL-Kharga), during two experimental seasons of 2021/2022 and 2022/2023 to explore the impact of the addition of humic acid at rats 100, 200, and 300 ml/l. plus, half of the recommended dose of NPK fertilizer and bio-fertilization (mycorrhizae and azolla), on plant growth, yield, components, and essential oil and chemical constituents of caraway (*Carum carvi* L.)plants. Results showed a significant increase in plant growth traits in terms of plant height, branch number, plant fresh and dry weight, yield i.e., umbel number per plant fruit yield per plant and feddan, as well as volatile oil production. Treating plants with humic acid at a higher concentration of 300 ml/l recorded the highest values of these studied parameters. Also, adding mycorrhizae fungi (MY) with azolla extract together effectively increased the traits under this study. All tide coefficients were significantly affected by the interaction coefficients. In this regard, most combined treatments significantly increased all traits under study. Then humic acid at a high concentration (300 ml/l) plus inoculation caraway plants with mixed mycorrhizae fungi and azola were the most effective treatments. The main constituents of volatile oil were also affected by humic acid and biofertilizer applications. The results of gas chromatographic analysis (GC/MS) of caraway oil revealed 15 compounds. When comparing the values of the chemical compounds of the volatile oil, it is noticed that the Carvone-D-Limonene-cis-Anethole compounds contain the highest percentages of volatile oil compounds compared to the other compounds.

Keywords: Caraway, humic acid, mycorrhizae fungi, azola extract

Introduction

Caraway (*Carum carvi*, L.; belonging Apiaceae family.) is one of the most significant aromatic plants grown in Upper Egypt, it is. The medication made from caraway fruits is used in both the food and pharmaceutical industries and needs to be handled and stored the same way. This medication is used in a variety of ways to treat digestive issues, as a tonic, as an antispasmodic, and as a carminative **(Muhammad *et al.*, 2014).** Carvone (52%) and limonene (45%) are the two main components of the 4-8% essential oil found in dried Cumin and caraway fruit **(Olle and Bender, 2010).** Flavonoids, sugars, organic acids, mineral salts, coumarin derivatives, and other chemicals are also found in caraway fruit, along with nitrogen compounds (25–35%), lipids (13-21%), fiber (13–19%), fatty oil (up to 22%), water (9–13%), and protein compounds (up to 25% **Kluszczyñska, 2002).** Caraway fruit, which mostly consists of the monoterpenes carvone and limonene, is an important source of monoterpenes. The seeds are traditionally used as a treatment for dyspepsia, intestinal colic, and antispasmodic issues. They also add a nice flavor to dishes and are used as a spice **(Lawless, 1992).**

Humic acid is an important component of brown humic substances and active components of soil organic matter humus that affect the physical quality and chemical content of soil. Also, humic substances typically consist of heterogeneous mixtures of converted biomolecules that exhibit a supramolecular structure that can be separated into smaller molecular components by sequential chemical fractionation **(Piccolo, 2002).** Humic acid has been proven to increase the production of aromatic seed crops both quantitatively and qualitatively. Humic acid is used as a natural fertilizer to increase the productivity and quality of medicinal and aromatic plants that are grown in a way that does not harm the environment as compared to chemical fertilizers. It also lowers production costs and environmental pollution without affecting yield) **Gomma and Youssef, 2008; Aćimović *et al.*, 2015; Awad, 2016; Mahmoud *et al.*, 2017; El-Banna and Fouda, 2018; Hassan, 2019).** Many studies have revealed that humic acid is known to be a plant growth promoter by improving crop quality and nutrient supply, promoting plant growth and development, and raising yield due to its critical role in physiological and metabolic processes **(Eyheraguibel *et al.*, 2008; Asik *et al.*, 2009)**.

Mycorrhizae fungi boosts the plant uptake of immobile phosphate ions from the soil as well as N, P, K, Mg, and some micronutrients resulting in stimulating growth **(Smith *et al.*, 2011; Veresoglou *et al.*, 2011).** Mycorrhizae fungi are common in agricultural systems and are particularly important to organic agriculture because they can act as natural fertilizers, improving plant yield. Mycorrhizae fungi establish large hyphal networks in the soil and supply nutrients to plants in exchange for assimilating **(Van der Heijden *et al.*, 2008**). Mycorrhizae has multiple uses, including promoting plant growth by increasing the uptake of phosphorus (P) and other non-labile important minerals from the soil **(Smith and Read, 2008).** Additional advantages of mycorrhizae include reducing plant stress brought on by abiotic and biotic factors **(Evelin *et al.* 2009; Pozo *et al.* 2010);** and stabilizing soil aggregates **(Rillig 2004)** by creating tUpadhyaya,tein glomalin **(Wright and Upadhyaya , 1996).**

Azola is a type of floating fern that is a member of the Azollaceae family. It collaborates with the cyanobacterium Anabaena azola, which is found in the fern's leaf cavity, to fix nitrogen **(yousefzadeh *et al*., 2015).** Azolla In addition to being a good source of critical vitamins like vitamin A, vitamin B12, and beta-carotene, azolla is also a rich source of protein and essential amino acids. Minerals including calcium (Ca), nitrogen (N), phosphorus (P), potassium (K), iron (Fe), manganese (Mn), copper (Cu), and zinc (Zn) are also abundant in it. Azolla has a 25–35% protein content based on dry weight **(parashuramulu *et al.*, 2013).** Azola is essential to preserving and increasing soil fertility. Biofertilizer treatments result in a large rise in photosynthetic pigments, which may be attributed to nitrogen's function in the chloroplast's increased photosynthetic activity **(Hossain *et al*., 2001; Pereira *et al*., 2009).** Azolla also increases soil organic matter, enhances the physical and chemical characteristics of the soil, inhibits the growth of weeds and mosquitoes, and reduces ammonia volatilization, among other positive benefits

(Pabby *et al.*, 2004 and Awodun, 2008). Therefore, the aim of this study was to evaluate the influences of humic acid rate, mycorrhizae, azolla as well as their interaction on growth, fruit yield and chemical constituents of caraway (*Carum carvi*, L.) plants.

Materials and Methods

Description of the experiments site

A field experiment was carried out at the Faculty of Agriculture Farm, New Valley University (EL-Karga), during the two successive seasons of 2022/2023 and 2023/2024 to study the effect of humic acid at 100, 200, and 300 ml/l plus, half of the recommended dose of NPK fertilizer and bio-fertilization (mycorrhizae and azolla), on plant growth, fruit yield and volatile oil yield and chemical constituents of caraway (*Carum carvi* L.) plants.

Experimental soil analysis

Five randomly selected soil samples from the surface of the experimental soil prior to cultivation, (0-30 cm depth) to analyze the physical and chemical characteristics according to **Black (1965)** and **Page *et al.* (1982)**, respectively. Data of soil analysis is presented in Table 1.

Table (1): Soil physical and chemical analysis of the experimental soil during 2021/2022 and 2022/2023 seasons

Soil properties		Season	
		2021/2022	2022/2023
Physical analysis	Particle size distribution (%)		
	Coarse sand	5.74	5.46
	Fine sand	75.24	76.02
	Silt	13.25	12.90
	Clay	5.95	6.62
	Texture class	Loamy Sandy	Loamy Sandy
Chemical Analysis	EC. dsm^{-1} (1:1 ex.)	0.88	0.88
	pH (1:1 w/v)	7.92	7.92
	Organic matter (%)	0.75	0.84
	Saturation capacity (%)	49.27	27.85
	Available nutrients (mg/kg)		
	N	51.9	53.1
	P	6.33	6.77
	K	86.7	87.5

* This analysis was carried out by the Soil, Water and Environment Laboratory, Faculty of Agriculture, Assiut University, Egypt

Experimental design and tested treatments

Fruits of caraway (*Carum carvi* L.) plants were obtained from the Department of Medicinal and Aromatic Plants Research at the Horticultural Research Institute (Agricultural Research Center, Dokki, Giza). The fruits were sown on November 4 during 2022, and 2023 in both seasons. The fruits were planted in plots with dimensions (3 x 3 m) that were prepared in the experimental field such that each plot contained three rows. The row spacing within each plot was 60 cm. Each plot contains 72 plants, planted in four rows, with 60 cm between rows, and 30 cm between plants in each row.

The recommended NPK fertilization consists of ammonium nitrate (33.5%), calcium superphosphate (15.5%), and potassium sulfate (48%), at rates of 150, 200, and 37.5 kg/feddan, respectively. Ammonium nitrate was divided into two equal doses (one two weeks after planting the seeds, and the other after 4 weeks), while calcium superphosphate and potassium sulfate were mixed in the soil one day before planting.

Humic acid was added to plants three times: at sowing, after 30 and 60 days following cultivation at rates of 100-200-300 ml/l in both seasons.

Vesicular arbuscular mycorrhizae (VAM) fungi that contained 3 effective strains representing *Glomus etunicatum*, *Glomus intraradices*, and *Glomus fasciculatum*, VAM fungi were used for soil inoculation. The VAM inoculation was applied to sowing hills at a rate of 5 ml/hill. The amount contained about 200 VAM spores/pot.

Azola and mycorrhizae were added two times: the first dose was before sowing but the second dose was applied alone at the soil subsurface near the plant roots after30 days for transplantation.

Humic acid, mycorrhizae and azola were obtained from the Microbiology Department, Soils, Water and Environment, Research Institute (ARC), Giza.

Volatile oils isolate

Fruits were collected from each treatment during both seasons and weighed for EO extraction; then 100 g from each repeat of all transactions Hydro distillation (HD) for 3 hours using a Clevenger type Apparatus **(Clevenger 1928).** EO content was calculated as relative percentage (v/w). In addition, the total EO where ml/100 plants were calculated using dry weight. The extracted EOs were collected from A. abrotanum during the two seasons of each treatment and dried Anhydrous Sodium Sulfate for chemical determination voters.

Statistical analysis

All obtained data were tabulated and statistically analyzed as described to **MSTATE-C (1986).** Means were compared using L.S.D. at 5% as shown by **Mead *and Drasgow.* (1993).**

Results and discussion

Growth parameters

The data recorded in Table 2 shows that the effects of different rates of humic acid and half the recommended dose of NPK on plant height, number of branches per plant and plant dry weight (g/plant) of caraway (*Carum carvi* L.) plants were significantly affected compared to untreated plants in both seasons of 2021/2022 and 2022/2023. However, better growth was the result of the treatment with humic acid at 300 ml/ l, followed by, half recommended dose of NPK. Generally, growth parameters were increased gradually with increasing humic acid rates. These results are consistent with those reported by **Omar *et al.* (2020), Almarie Ahmed *et al*. (2019), Awad (2016) and Souzan *et al*. (2006),** who reported that caraway plants responded well to humic acid compared to the untreated plants.

The superior plant growth by adding humic acid is attributed to its vital role in providing the plant with the macro- and micro-nutrients necessary to enhance the plant's metabolism and development. It can directly improve plant growth by accelerating photosynthesis and increasing water and nutrient absorption and plant productivity **(Panda, 2006)**. Furthermore, organic compounds are expected to raise chlorophyll levels in green plants, assisting in chlorosis resistance and photosynthesis **(Nardi *et al*., 2002)**. Humic acid can provide protection against some toxic growth-inhibiting substances introduced in the soil**.**

From data presented in Table 2, inoculation of plants with azola (AZ) and mycorrhizae (MY) alone or together significantly increased plant growth compared to unfertilized in both seasons. The best values of these parameters were obtained from double inoculation caraway plants with azola and mycorrhizae.

Bio-fertilization systems can raise the fertility of the soil, increase the availability and uptake of nutrients in the soil, and increase crop productivity. This biosystem's microorganisms fix nitrogen, dissolve phosphate and potassium from the soil, create chemicals that encourage plant growth, and shield the plant from diseases and biotic and abiotic stresses **(Mącik *et al.*, 2020; Viji *et al*., 2021; Shalaby *et al.*, 2022).**

The results under discussion in Table 2 show that with the combination of the two factors under the conditions of this study, it was significant in both seasons. Accordingly, the highest values of plant height were obtained using humic acid at concentration of 300 ml/l. Combined treatment of azola and mycorrhizae was superior to the rest of the overlapping treatments in this study in both seasons.

Table (2): Impact of humic acid rates, azolla (AZ) and mycorrhizae (MY) on growth parameters of caraway (*Carum carvi* L.) during 2022/2023 and 2023/2024 seasons

Humic acid HM (A)	2020/2021 season					2021/2022 season				
	Azola AZ and Mycorrhizae MY (B)									
	Control	AZ	MY	AZ+MY	Mean (A)	Control	AZ	MY	AZ+MY	Mean (A)
	Plant height (cm)									
Control	82.22	86.55	93.22	98.44	90.10	86.22	92.44	97.88	104.3	95.21
NPK $_{HR}$	104.17	118.7	124.4	129.16	119.11	110.2	124.4	128.8	132.6	124.02
HM (100)	93.66	104.55	108.44	114.3	105.23	94.99	109.09	114.3	120.2	109.6
HM (200)	100.52	105.5	109.86	114.77	107.66	105.2	110.53	116.2	120.03	112.99
HM (300)	108.3	132.3	135.6	137.43	128.40	115.4	136.96	140.33	142.4	133.77
Mean (B)	97.77	109.52	114.30	118.82		102.40	114.68	119.51	123.91	
L.S.D at$_{5\%}$	A: 0.56	B :0.39		AB :0.89		A :0.37	B: 0.49	AB: 1.11		
	Number of branches									
Control	24.00	28.00	33.00	37.00	30.41	27.00	31.00	36.00	41.00	33.83
NPK $_{HR}$	42.00	55.00	58.00	62.00	54.33	45.00	48.00	64.00	67.00	58.41
HM (100)	29.00	38.00	41.00	45.00	38.33	33.00	43.00	45.00	48.00	42.41
HM (200)	37.00	48.00	50.00	52.00	46.75	42.00	59.00	51.00	55.00	49.5
HM (300)	47.00	66.00	69.00	72.00	63.41	48.00	69.00	72.00	75.00	65.91
Mean (B)	35.00	46.93	50.26	53.6		39.00	50.06	53.86	57.13	
L.S.D at$_{5\%}$	A: 0.34	B: 0.43		AB: 0.96		A: 0.43	B:0.38	AB :85		
	Plant dry weight (g)									
Control	51.96	55.69	58.64	62.27	57.14	56.74	60.37	63.73	68.11	62.23
NPK $_{HR}$	65.62	89.96	94.19	98.16	86.98	73.12	95.78	98.53	103.75	92.79
HM (100)	55.70	65.67	70.44	74.00	66.45	61.12	72.35	75.88	79.70	72.26
HM (200)	61.18	77.72	82.18	86.01	76.77	66.63	83.57	86.95	92.09	82.31
HM (300)	70.74	103.27	109.67	115.98	99.91	78.77	109.86	114.36	119.91	105.72
Mean (B)	61.04	78.46	83.02	87.28		67.28	84.39	87.89	92.71	
L.S.D at$_{5\%}$	A: 0.63	B: 0.34		AB: 0.77		A: 0.58	B:0.51	AB :1.141		

MY= Mycorrhiza, AZ= Azolla and HM = Humic acid

Yield parameters

The data recorded in Table (3) show the effect of humic acid rates and half the recommended dose of NPK fertilization treatments during the two growing seasons on the number of umbels per plant, fruit yield per plant and feddan of caraway (*Carum carvi* L.) plants were statistically significant. From the results obtained, it was noticed that with increasing humic acid concentration from 100-300 ml/l, the number of umbels per plant, fruit yield per plant, and feddan were significantly increased compared with the control. Therefore, the higher values of number of umbels per plant, fruit yield per plant and feddan were observed when plants treated with high rate of humic acid (300ml/l). These results are consistent with those reported by **El-Banna and Fouda (2018), Omar *et al*. (2020), Suzan *et al.* (2006),** who reported that caraway plants responded well to humic acid. Also, humic acid promotes vegetative development by making nutrients available to plants, which results in a rise in the fennel number of umbels on each plant (**Kandil *et al.*, 2002)**.

In this regard, **Abdel-Razzak (2010)** found that humic acid contains plant hormone-like material (cytokinins) which possibly leads to keeping a nutrient balance that in turn enhances growth and yield.

From data presented in Table 3, azola (AZ) and mycorrhiza (MY) inoculation alone or together significantly increased umbel number per plant, fruit yield per plant and feddan of caraway compared to unfertilized plants in both seasons. The best values of fruit yield/plant (g) were obtained from double inoculation of azolla and mycorrhizae fungi. Biofertilizers also improved the fruit yield attributes and this improvement is a logical result because of the positive effects of HA in the growth. Similar results have been documented by **Akhani *et al.* (2012), Hassan *et al.* (2012) and Ali and Hassan (2014)** Biofertilizers increase photosynthetic efficiency and photosynthate translocation. Toward the growth of seeds and flowers. And furthermore, soil mobilization caused by microorganisms bonded soluble minerals to the plants during their growth phase, which produces improved nutrition for the crop, resulting in a greater yield being produced **(Abdel-Azieza *et al*., 2013)**.

The interaction between fertilization with humic acid at a rate of 300ml/l and inoculation with mycorrhizae and azolla was the most effective as it was higher in the number of umbels per plant, fruit yield per plant and feddan compared to the control in both seasons.

Table (3): Effect of humic acid rates, azolla (AZ) and mycorrhizae (MY) on yield parameters of caraway (*Carum carvi*) during 2022/2023 and 2023/2024 seasons

Humic acid HM	2022/2023 season					2023/2024 season				
	Treatment									
	Control	AZ	MY	AZ+MY	Mean (A)	Control	AZ	MY	AZ+MY	Mean (A)
	Number of umbels/ plants									
Control	51.33	56.00	59.00	61.66	57.00	56.33	60.00	62.33	64.33	60.75
NPK HR	61.66	68.00	70.00	73.00	63.33	57.66	65.66	67.33	68.66	64.83
HM (100)	55.00	63.66	64.66	66.00	68.16	66.00	70.00	72.00	75.00	70.75
HM (200)	65.00	76.00	78.33	81.00	75.03	68.00	79.00	82.00	85.00	78.5
HM (300)	70.00	84.33	87.00	92.00	83.33	74.00	87.00	90.66	97.33	87.25
Mean (B)	60.6	69.6	71.8	74.73		64.4	72.33	74.86	78.06	
L.S.D at5%	A: 0.41		B: 0.30	AB: 68		A: 0.71	B: 0.31		AB: 0.70	
	fruit yield/plant (g)									
Control	22.18	23.48	25.61	29.73	25.25	23.46	25.16	26.18	28.12	25.73
NPK HR	29.79	39.01	42.92	47.17	39.72	32.18	43.26	47.26	51.16	43.46
HM (100)	25.61	27.90	28.79	31.01	28.33	29.15	29.93	30.78	36.43	31.57
HM (200)	37.61	51.59	55.69	59.61	51.13	44.42	54.76	58.78	62.35	55.08
HM (300)	43.50	62.78	64.8	67.24	59.58	52.95	65.24	67.73	71.80	64.43
Mean (B)	31.74	40.95	43.56	46.95		36.43	43.67	46.15	49.97	
L.S.D at5%	A: 1.93		B: 1.43	AB: 3.17		A: 1.19	B: 0.68		AB: 1. 52	
	fruit yield/fed (kg)									
Control	656.13	688.92	760.60	787.03	723.17	695	730.96	774.63	806.4	751.75
NPK HR	1002.7	1310.7	1442.3	1584.9	1335.1	1021	1350.3	1466.5	1620.1	1364.4
HM (100)	834.87	874.7	935.45	968.89	903.48	847.26	881.16	948.03	976.06	913.13
HM (200)	1145.7	1678.3	1720.2	1759.1	1575.8	1167.5	1685.2	1736.4	1772.1	1590.3
HM (300)	1176.3	1786.5	1837.2	1882.8	1670.7	1218.8	1804.7	1855.1	1888.3	1691.7
Mean (B)	963.16	1267.8	1339.1	1396.5		989.91	1290.4	1356.1	1412.6	
L.S.D at5%	A: 19.11		B:8.55	AB: 28.70		A: 23. 09	B: 10.32		AB: 25. 33	

Volatile oil production

Obtained data in Table (4) revealed that volatile oil percentage, volatile oil yield per plant and feddan of caraway (*Carum carvi* L.) Plants were significantly influenced by humic acid and half-recommended dose of NPK fertilization treatments in the two growing seasons. The results showed that fertilizing plants with humic acid at all concentrations besides a half-recommended dose of NPK led to an increase significant in volatile oil percentage in both seasons. These results are consistent with those reported by **Omar *et al*. (2020) and Hassan (2019),** who reported that caraway plants responded well to humic acid compared to mineral fertilizers and not treated with humic acid.

Concerning the effect of mycorrhizae fungi (MY) and azola extract (AZ) treatments, data in Table (4) showed that volatile oil percentage, volatile oil yield per plant and feddan of caraway plants were significantly increased in comparison with untreated ones in the two consecutive seasons. Besides, volatile oil percentage, volatile oil yield per plant and feddan were increased when plants received AZ plus MY.

According to the interaction effects between humic acid and mycorrhizae fungi (MY) and azola extract (AZ) treatments; it had a significant effect on the volatile oil percentage, volatile oil yield per plant and feddan in both seasons. Data indicated that the most effective treatments were obtained due to the high rate of humic acid (300 ml/l) in combination with mixed of AZ and MY compared to control treatments during two growing seasons, as shown in Table (4). Promotive effect of mycorrhizae fungi on growth and production might be attributed to the increase in soil available nitrogen, as a result of fixing the atmospheric nitrogen and consequently increasing the formation of metabolites which encourage the growth **(Sperenat, 1997).**

Table (4): Effect of humic acid rates, azola (AZ) and mycorrhizae (MY) on oil production of caraway (*Carum carvi*) during 2022/2023 and 2023/2024 seasons

Humic acid HM	2022/2023 season					2023/2024 season				
	Treatment									
	Control	AZ	MY	AZ+MY	Mean (A)	Control	AZ	MY	AZ+MY	Mean (A)
	Volatile oil percentage									
Control	1.456	1.496	1.536	1.573	1.515	1.503	1.546	1.586	1.633	1.567
NPK $_{HR}$	1.59	1.853	1.893	1.933	1.817	1.64	1.916	1.956	1.996	1.877
HM (100)	1.496	1.616	1.653	1.693	1.615	1.543	1.673	1.713	1.753	1.670
HM (200)	1.54	1.736	1.773	1.816	1.716	1.583	1.7933	1.836	1.876	1.772
HM (300)	1.64	1.973	2.016	2.063	1.923	1.700	2.03	2.073	2.116	1.981
Mean (B)	1.544	1.735	1.774	1.816		1.594	1.793	1.833	1.875	
L.S.D at$_{5\%}$	A: 0.003		B:0.002		AB: 0.005	A: 0.004	B: 0.002		AB: 0.005	
	volatile oil yield /plant (ml)									
Control	0.309	0.368	0.439	0.500	0.404	0.356	0.427	0.503	0.580	0.466
NPK $_{HR}$	0.693	1.179	1.280	1.377	1.132	0.765	1.278	1.380	1.484	1.227
HM (100)	0.523	0.630	0.709	0.798	0.665	0.592	0.723	0.810	0.897	0.755
HM (200)	0.606	0.896	0.987	1.079	0.892	0.679	0.982	1.079	1.176	0.979
HM (300)	0.797	1.471	1.585	1.676	1.382	0.906	1.581	1.683	1.760	1.482
Mean (B)	0.586	0.909	1.000	1.086		0.659	0.998	1.091	1.179	
L.S.D at$_{5\%}$	A: 0.013		B:0.004		AB: 0.010	A: 0.007	B: 0.004		AB: 0.010	
	Volatile oil yield/fed. (L)									
Control	10.39	12.37	14.75	16.79	13.57	11.95	14.36	16.92	19.49	15.68
NPK $_{HR}$	23.30	39.62	43.00	46.28	38.05	25.72	42.95	46.36	49.88	41.22
HM (100)	17.58	21.18	23.84	26.83	22.35	19.89	24.31	27.22	30.14	25.39
HM (200)	20.38	30.11	33.18	36.26	29.98	22.83	32.99	36.26	39.51	32.9
HM (300)	26.78	49.43	53.25	56.31	46.44	30.43	53.11	56.56	59.13	49.81
Mean (B)	19.68	30.54	33.60	36.49		22.16	33.54	36.66	39.63	
L.S.D at$_{5\%}$	A: 0.361	B: 0.161		AB: 0.454		A: 0.263		B:0.149	AB: 0.334	

Volatile oil Components

The results of gas chromatographic analysis (GC/MS) of caraway oil obtained from the study proved that it consists of (15) compounds. When comparing the values of the chemical compounds of the oil, we notice that the Carvone-D-Limonene-cis-Anethole compounds contain the highest percentages of volatile oil compounds compared to the other compounds. The highest average for the Carvone compound (75.49) was recorded in control, followed by treatment Humic acid at 200 + (Az + MY) which recorded (65.48), followed by humic acid at 300 ml/l + (Az + MY) which reached (65.07), while the highest average was for compound D. - Limonene (33.93) in treatment humic acid at 100 ml/l + (Az + MY), followed by humic acid at 300 ml/l + (Az + MY), which recorded (32.78), which had the highest percentages for the compound. cis-Anethole (1.29) in the control, while the highest percentage of Cuminaldehyde (2.31) is in Treatment in the control. This indicates a clear effect of the treatments in increasing the proportions of some of the main compounds of caraway oil. The treatments also have a clear effect on some compounds, and this is consistent with the findings of **(Mahfouz and Sharaf-Eldin, 2007 and Masada *et al*. 2007)** where they found an increase in the percentage of oil and the proportions of essential oil components through fertilization. This is due to the integration between the two types of fertilization and its impact on the provision of all elements. Nutrient elements for the plant, and this result is consistent with what the researcher **(Mahfouz and Sharaf-Eldin,2007)** said that fertilization leads to an increase in the compounds found in the caraway plant.

Table (5): Effect of humic acid rates, azola (AZ) and mycorrhiza (MY) on volatile oil components of caraway (*Carum carvi* L.) during 2022/2023 and 2023/2024 seasons

No	Component	R T	Treatments				
			Control	NPK HR	Humic 100 (Az+My)	Humic 200 (Az+My)	Humic 300 (Az+My)
1	β-Myrcene	7.7	---	---	0.4	0.34	0.33
2	p-Cymene	8.615	0.36	0.33	---	---	---
3	D-Limonene	8.731	16.99	17.02	33.93	31.63	32.78
4	trans-Chrysanthenyl acetate	11.283	---	0.22	0.23	---	---
5	Limonene oxide	11.763	---	---	0.27	0.25	---
6	cis-Anethole	13.455	1.29	1.07	0.41	0.41	---
7	trans-Dihydrocarvone	13.657	0.43	0.40	0.38	0.34	0.29
8	trans-Carveol	14.073	0.41	0.44	0.72	0.71	0.59
9	Dihydrocarveol	14.367	---	0.27	0.32	---	---
10	cis-Carveol	14.46	---	---	0.35	0.35	---
11	Cuminaldehyde	14.645	2.31	2.52	---	---	0.52
12	Carvone	14.841	75.49	74.45	62.5	65.48	65.07
13	Perillaldehyde	15.574	0.48	--	0.47	0.48	0.42
14	γ-Terpinen-7-al	16.008	1.02	1.09	---	---	---
15	β-Copaene	20.957	1.21	2.18	---	---	---
Number of identified compounds			10	11	11	9	7
Total % of identified compounds			99.99	99.99	99.98	99.99	100

Conclusion

The results of the current experiment found that the combination of humic acid at concentration of 300 ml/l plus mycorrhizae fungi (MY) and Azola extract (AZ) treatments combination mixed of AZ and MY improve the plant growth, yield components and volatile oil production and component of caraway (*Carum carvi* L.) plants.

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استجابة نباتات الكراوية لحمض الهيوميك وفطريات الميكورهيزا ومستخلص الازولا

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الملخص العربي

أجري هذا البحث بمزرعة كلية الزراعة جامعة الوادي الجديد (الخارجة) خلال موسمين متتاليين (2022/2021 و2023/2022) لدراسة تأثير إضافة معدلات مختلفة من (حامض الهيوميك 100، والتسميد الحيويNPK ، و300 مللي/لتر) بالإضافة إلى نصف الجرعة الموصى بها من سماد (200 الميكوريزا والأزولا) على نمو النبات ومحصوله والزيت العطري ومكوناته لنبات الكراوية NPK .

أوضحت النتائج

أن هناك زيادة معنوية في صفات نمو النبات (ارتفاع النبات وعدد الأفرع ووزن النبات الطازج والجاف) والمحصول معبراً عنه بعدد النورات لكل نبات ومحصول الثمار/ النبات والفدان وكذلك إنتاج الزيت العطري.

ولوحظ مع معاملة النباتات بتركيز حامض الهيوميك العالي (300 مللي/لتر) سجلت أعلى القيم لتلك الصفات المدروسة. بالإضافة إلى ذلك فإن إضافة فطريات الميكوريزا مع مستخلص الأزولا أدى إلى زيادة الصفات تحت هذه الدراسة معنوياً .

وفي هذا الصدد، أدت معظم معاملات التفاعل إلى زيادة معنوية في جميع الصفات قيد الدراسة. وكان لاستخدام حامض الهيوميك بتركيز عالي (300 مللي/ لتر) بالإضافة إلى تلقيح نباتات الكراوية بخليط من الفطريات الجذرية والأزولا تأثير معنوي لتلك الصفات. كما تأثرت المكونات الرئيسية للزيت العطري باستخدام حامض الهيوميك والأسمدة الحيوية. من نتائج التحليل الكروماتوغرافي الغازي (GC/MS) لزيت الكراوية

الكلمات الدالة: - نبات الكراوية – الهيوميك اسد – فطريات الميكورايزا- مستخلص الازولا.