Scientific J. Flowers & Ornamental Plants
www.ssfop.com/journal
ISSN: 2356-7864 **doi: 10.21608/sjfop.2023.198497.1019**

INFLUENCE OF ZINC AND HUMIC ACID ON GROWTH, YIELD AND ESSENTIAL OIL PERCENTAGE OF FENNEL (*FOENICULUM VULGARE* MILL.) PLANTS

Osama H. Tawfik

Department of Horticulture, Faculty of Agriculture, Al-Azhar University, Assiut Branch, Egypt

Scientific J. Flowers & Ornamental Plants, 9(4):397-407 (2022).

Received:
2/12/2022
Accepted:
26/12/2022

Corresponding author:
Osama H. Tawfik
osama393139@gmail.com

ABSTRACT: The current study was carried out to study the growth, yield and essential oil percentage of fennel as influenced by different concentrations of zinc and humic acid. The treatments were comprised of foliar application of zinc at three rates (0, 100 and 200 ppm) and soil drench of humic acid at four rates (0, 500, 750 and 1000 ppm), as well as their interactions. The results revealed that zinc treatment at 100 ppm significantly increased the number of branches/plant, number of umbels/plant, herb fresh and dry weights/plant, fruit yield/fed and essential oil %. However, raising zinc concentration to 200 ppm revealed a significant decrease in fruit yield/fed. Soil application of humic acid at the moderate level (750 ppm) scored the highest values compared to the other levels on all parameters except for plant height and herb fresh weight. The interaction effect was statistically significant on all examined parameters. In this connection, combined zinc treatment at 100 ppm and humic acid at 750 ppm proved superior in all measured parameters except for plant height. Thus, our study provides valuable information about the possibility of improving the growth and productivity of fennel plants using a combined treatment of zinc and humic acid.

Keywords: Fennel, zinc, humic acid, micronutrients, organic substances.

INTRODUCTION

Fennel (*Foeniculum vulgare* Mill.) plant is an annual aromatic herb that belongs to the Apiaceae family (Farrell, 1988 and Wichtl and Bissel, 1994). Fennel is a native of the Mediterranean and Asia Minor, and is now widely cultivated throughout the tropical and subtropical regions of the globe. Also, the plant is largely grown in South Europe and Egypt, especially in Middle Egypt Governorates (Minia and Assiut). It is mainly planted for its fruits, which contain carbohydrates at 42.3%, fiber at 18.5%, minerals at 13.4%, protein at 10% and essential oil at 0.7-6%, depending on genotypes or botanical types (Bhunia *et al.*, 2005).

The volatile oil is famous as a flavoring agent and carminative used in laxative preparations (Lawless, 1995). In addition, it has a high anti-inflammatory and antispasmodic impact on the smooth muscle in addition to being beneficial in controlling flatulent dyspepsia and colic in children (Mahfouz and Sharaf Eldin, 2007; Stary and Jirasck, 1975). Due to their therapeutic effects, fennel is considered an important medicinal and aromatic plant. It is used in traditional medicine as a sedative, diuretic, carminative, stimulant, expectorant, galactagogic, antispasmodic and emmenagogic (Charles *et al.*, 1993 and Chiej, 1984). Moreover, fruits are favorable for the food industry, condiments, culinary spices, bakery, tincture and infusion (Lawless, 1995).

It has been well-known for a long time that humic acid (HA) contributes greatly to soil fertility. It enhances crop growth and productivity by improving the physicochemical and biological properties of the soil (Canellas *et al*., 2015). Plants and soil can receive high doses of nutrients and trace elements from humic acid in an organic and natural manner. As well as improving micronutrient uptake, it interferes with calcium phosphate precipitation in order to increase cation exchange capacity and phosphorus availability in the soil (Jindo *et al*., 2012 and Trevisan *et al*., 2010). There are a variety of HA products available for soil and foliar application.

There is a considerable variation in the response of different crops to the treatment with HA. According to Rose *et al*. (2014), HA application increased plant biomass by varying degrees based on the crop genotype and environmental conditions. HA has been successfully applied to crops in a number of ways, with Halpern *et al*. (2015) and Canellas *et al*. (2015) citing many examples of improved horticultural crops in terms of yield and quality. Through their research, they were able to elucidate the effect of the dosage and time of application of HA on plant growth. It has been shown by Lyons and Genc (2016) and Olk *et al.* (2018) those commercial HA products are generally beneficial for plants but do not always work as expected, despite the fact that they often improve crop yields by alleviating different environmental stressors. It was shown by Waqas *et al.* (2014) that applying HA as a seed priming agent, foliar application and soil amendment considerably increased the number of pods per plant and the seed yield of mungbean plants, with no significant differences between different application methods on the biological attributes. There was no statistically significant difference between soil additions of 1, 2 or 3 kg of HA/ha with respect to pods/plant and grain yield. Another study conducted by Dawood *et al.* (2019) showed significant improvement in growth, yield and quality attributes of faba bean plants in response to the application of HA at 5 ml/l. Similar results were recorded on soybean yield and oil content, even though a reduction in the seed protein content was observed (Lenssen *et al*., 2019). When HA was applied to chickpea seeds (pre-sowing and pre-flowering) at 0, 60, 90, and 120 kg/h, it demonstrated a positive effect on chickpea growth based on the concentration of HA applied.

Several plants suffer from zinc shortages, which is well recognized as an important micronutrient (Ojeda-Barrios *et al*., 2014). A number of enzymes are dependent upon it for their activity, including dehydrogenase, isomerase, aldolase, transphosphorylase, as well as RNA and DNA polymerase. Additionally, it is necessary for the synthesis of tryptophan, the preservation of cell structure, the division of cells, and photosynthesis. In several proteins, it serves as a cofactor, increasing the synthesis of proteins (Marschner, 2012). It has been demonstrated by numerous studies that zinc nutrition highly influences the number of umbels and fruit yield of many aromatic crops that belong to the Apiaceae family. A positive correlation was found between the number of umbels and fruit production with the foliar application of zinc elements with specific sources. According to Diab (2007), foliar Zn-EDTA application resulted in the highest fruit yields for caraway, fennel, coriander, cumin and khella (El-Sawi and Mohamed, 2002; Akbari *et al*., 2013; Eid, 1983 and El-Sherbeny and Abou-Zied, 1986; Said AlAhl and Omer, 2009 and Besher and Mohamed, 1984).

The main objective of the current study is to determine the best treatment for enhancing the growth characteristics, yield, and essential oil percentage of fennel plants by evaluating the effects of different concentrations of zinc and humic acid and their interactions.

MATERIALS AND METHODS

A two-year experimental trial was carried out at the experimental farm of the Faculty of Agriculture, Al-Azhar University, Assiut Branch, Egypt, during 2020/2021 and 2021/2022. As shown in Table (1), the soil physical and chemical properties of the soil

Table 1. An overview of the physicochemical characteristics of the soil.

Particle size distribution (%)			Texture grade	pH (1:2.5) soil suspension	EC. dS/m (1:5) soil extract	Total $CaCO_3$ (%)	Organic matter (%)	Soluble ions (meq/l, soil paste)								Total N (%)	Total P (%)	Total K (%)
								Anions				Cations						
Sand	Silt	clay						Cl^-	$CO_3^{=}$	HCO_3^-	$SO_4^{=}$	Ca^{++}	Mg^{++}	Na^+	K^+			
22.3	26.2	51.5	Clay	8.71	1.03	1.97	0.97	3.32	-	4.94	3.05	5.40	0.52	1.30	3.89	0.70	0.21	0.41

are presented. The study was performed in a 3 × 4 two-way factorial experiment laid out in a split-plot design with three replications. There were 15 plants in each experimental unit. The two substances used were zinc at 14% chelated with EDTA and humic acid. A total of three zinc treatments (0, 100 and 200 ppm) were randomly assigned to the main plots (A), while four humic acid treatments (0, 500, 750 and 1000 ppm) were assigned to the subplots (B). Fennel seeds used in the two experimental seasons were obtained from the Department of Medicinal and Aromatic Plants, Horticulture Research Institute, Agriculture Research Center, Giza, Egypt. The seeds of fennel were sown on 15th Nov. in both seasons. The dimension of the experimental plot was 1.25 × 1.80 m with three rows 60 cm apart. On one side of the row, the seeds were planted on hills spaced 25 cm apart. A total of 45 plants were used in each experimental unit, divided into three replicates for each treatment. It was thinned to a single plant or hill after 40 days after the sowing date. Three foliar applications of zinc were applied starting 45 days after planting, followed by two applications with 15-day intervals. The zinc treatments were applied simultaneously with three applications of humic acid soil additions (200 ml around the base of the plants). The rest of the agricultural practices were performed as usual. For each growing season, the following parameters were recorded: plant height (cm), number of branches (g), herb fresh weight (g), herb dry weight (g), umbel number (g), fruit yield (ton/fed.) and essential oil (%). Statistix 8.1 (Analytical Software, 2008) was used to analyze the data obtained using ANOVA and means were compared using the LSD test, as per Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Plant height:

Data presented in Table (2) showed nonsignificant effects of plant height due to applying the different zinc levels in both seasons. It could be mentioned that the highest zinc level (200 ppm) achieved the highest results (157.30 and 157.15 cm) against the control (155.20 and 155.85 cm) in the first and second seasons, respectively. With regard to humic acid, a significant increment in plant height was noticed due to applying any of the humic acid concentrations in both seasons except for the highest level (1000 ppm) in the first season only. However, supplying the plants with humic acid at the lowest level (500 ppm) generated the tallest plants (160.53 and 160.93 cm) in comparison with the other levels and the untreated control plants (151.73 and 151.47 cm) in the first and second seasons, respectively. It could also be noticed that all combined treatments significantly increased plant height over the control ones in the two seasons. The highest value of this trait was observed by supplying zinc at 200 ppm combined with humic acid at 500 ppm in both seasons.

Number of branches/plant:

The data presented in Table (3) showed that the application of zinc at 100 ppm was the best in increasing the number of branches/plant in comparison with the other levels in both seasons. This treatment

Table 2. Effect of humic acid (HA) and zinc (Zn) application on plant height (cm) of fennel plant during 2020/2021 and 2021/2022 seasons.

HA (ppm)		Zn (ppm) First season 0	100	200	Mean	Second season 0	100	200	Mean
0		145.20	150.80	159.20	151.73	146.20	150.20	158.00	151.47
500		155.80	162.60	163.20	160.53	156.60	161.80	164.40	160.93
750		157.60	157.80	155.80	157.07	157.80	158.60	154.60	157.00
1000		162.20	152.80	151.00	155.33	162.80	153.80	151.60	156.07
Mean		155.20	156.00	157.30		155.85	156.10	157.15	
LSD (0.05)	Zn		NS				NS		
	HA		3.95				2.00		
	Zn × HA		6.84				3.46		

NS denotes nonsignificant differences using ANOVA

Table 3. Effect of humic acid (HA) and zinc (Zn) application on the number of branches of fennel plant during 2020/2021 and 2021/2022 seasons.

HA (ppm)		Zn (ppm) First season 0	100	200	Mean	Second season 0	100	200	Mean
0		8.20	9.20	9.80	9.07	8.40	9.40	9.60	9.13
500		9.20	10.00	9.40	9.53	9.20	10.20	9.60	9.67
750		9.60	11.00	9.20	9.93	9.80	11.00	9.40	10.07
1000		10.00	9.80	9.20	9.67	9.80	9.80	9.40	9.67
Mean		9.25	10.00	9.40		9.30	10.10	9.50	
LSD (0.05)	Zn		0.29				0.30		
	HA		0.39				0.28		
	Zn × HA		0.67				0.49		

generated 10.00 and 10.10 branches/plant compared to 9.25 and 9.30 attained from untreated plants (control) in the first and second seasons, respectively. Number of branches was also improved due to the application of humic acid at any level, where applying the moderate level (750 ppm) gave the highest results (9.93 and 10.07) in both seasons, respectively. As for the interaction effect, all combined treatments significantly increased the number of branches compared to untreated ones. The combination of zinc (100 ppm) and humic acid (750 ppm) produced the highest number of branches/plant (11.00 and 11.00) in both seasons, respectively.

Number of umbels/plant:

Number of umbels per plant was significantly affected by the application of zinc with evident superiority of the highest level (100 ppm), as shown in Table (4). The increment reached 53.25 and 54.20 against 49.75 and 50.05 of the control means. Likewise, the different humic acid levels caused a significant improvement in the umbels number/plant. The highest value was attained by the moderate level (52.93 and 53.13) compared with the control plants (47.47 and 47.40) in both seasons, respectively. The interactions between zinc and humic acid levels also showed an apparent significant increase in the number of umbels compared with untreated plants. The highest values were detected in the plants supplied with the lowest zinc level (100 ppm) combined with the medium humic acid level (750 ppm) recorded (56.80 and 57.40 umbel/plant) compared with the control plants (42.40 and 42.20) in the two seasons, respectively.

Herb fresh weight:

Data presented in Table (5) show that zinc at 100 ppm significantly increased fresh weight of fennel plants in the two growing seasons. The fresh weight of the plants treated with 100 ppm zinc reached 639.65 and 647.65 g compared with 582.40 and 588.10 g of the control in both seasons,

Table 4. Effect of humic acid (HA) and zinc (Zn) application on number of umbels of fennel plant during 2020/2021 and 2021/2022 seasons.

HA (ppm)		Zn (ppm)							
		First season				Second season			
		0	100	200	Mean	0	100	200	Mean
0		42.40	48.80	51.20	47.47	42.20	49.20	50.80	47.40
500		48.60	53.20	49.80	50.53	48.40	54.60	49.80	50.93
750		52.20	56.80	49.80	52.93	53.20	57.40	48.80	53.13
1000		55.80	54.20	47.80	52.60	56.40	55.60	47.00	53.00
Mean		49.75	53.25	49.65		50.05	54.20	49.10	
LSD (0.05)	Zn	1.99				1.06			
	HA	1.73				0.99			
	Zn × HA	3.00				1.73			

Table 5. Effect of humic acid (HA) and zinc (Zn) application on fresh weight (g/plant) of fennel plant during 2020/2021 and 2021/2022 seasons.

HA (ppm)		Zn (ppm)							
		First season				Second season			
		0	100	200	Mean	0	100	200	Mean
0		435.20	551.20	591.20	525.87	441.20	560.60	598.20	533.33
500		575.20	657.40	651.20	627.93	579.80	666.40	567.60	604.60
750		636.60	685.20	582.60	634.80	642.80	692.20	588.40	641.13
1000		682.60	664.80	580.80	642.73	688.60	671.40	587.60	649.20
Mean		582.40	639.65	601.45		588.10	647.65	585.45	
LSD (0.05)	Zn	25.20				10.94			
	HA	29.70				12.12			
	Zn × HA	51.44				20.99			

respectively. However, a gradual increase was detected due to the elevated levels of humic acid in the two seasons. Using the highest humic acid level (1000 ppm) generated the highest herb fresh weight (642.73 and 649.20 g) in both seasons, respectively. The interactions also revealed a significant increment in herb fresh weight. The heaviest fresh weight was induced by the combined treatment of zinc at 100 ppm + humic acid at 750 ppm (685.20 and 692.20 g) against the untreated plants (435.20 and 441.20 g) in both seasons, respectively.

Herb dry weight:

Foliar treatment of zinc at 100 ppm attained a significant increment in herb dry weight (177.30 and 179.50 g) in both seasons, respectively (Table, 6). Similar improvement in the dry weight was noticed in humic acid-treated plants, with obvious superiority to the higher levels (750 and 1000 ppm), producing heavier dry weights in the first season (177.60 and 178.13 g) and in the second season (179.87 and 179.67 g, respectively). The combined effect between the two examined factors exerted significant differences in herb dry weight in the two growing seasons. Obviously, all combined treatments significantly improved herb dry weight, where the combined treatment of zinc at 100 ppm and humic acid at 750 ppm produced the heaviest plants (189.80 and 193.60 g) in both seasons, respectively.

Fruit yield:

An increment in fruit yield was recorded due to applying zinc at 100 ppm, with a significant increase compared to the other zinc levels in both seasons, as it elevated the yield to 1.719 and 1.785 ton/fed compared with 1.577 and 1.667 ton/fed in control plants, in both seasons, respectively (Table, 7). Fruit yield showed a significant decrease with the highest level of zinc (200 ppm), recorded the lowest yield (1.489 and 1.501 ton/fed in both seasons, respectively). All humic acid levels registered a significant increase in fruit yield, where utilizing the moderate level (750 ppm) recorded the highest values (1.660 and 1.698 ton/fed) against that in the untreated plants (1.435

Table 6. Effect of humic acid (HA) and zinc (Zn) application on dry weight (g/plant) of fennel plant during 2020/2021 and 2021/2022 seasons.

HA (ppm)		Zn (ppm)							
		First season				Second season			
		0	100	200	Mean	0	100	200	Mean
0		142.40	165.80	170.20	159.47	145.20	169.20	173.80	162.73
500		166.60	176.80	166.20	169.87	169.80	178.60	167.80	172.07
750		175.20	189.80	167.80	177.60	175.80	193.60	170.20	179.87
1000		188.80	176.80	168.80	178.13	192.20	176.60	170.20	179.67
Mean		168.25	177.30	168.25		170.75	179.50	170.50	
LSD (0.05)	**Zn**	5.27				7.00			
	HA	7.67				7.54			
	Zn × HA	13.29				13.05			

Table 7. Effect of humic acid (HA) and zinc (Zn) application on fruit yield (ton/fed) of fennel plant during 2020/2021 and 2021/2022 seasons.

HA (ppm)		Zn (ppm)							
		First season				Second season			
		0	100	200	Mean	0	100	200	Mean
0		1.360	1.392	1.552	1.435	1.568	1.573	1.595	1.579
500		1.616	1.787	1.493	1.632	1.648	1.808	1.504	1.653
750		1.627	1.883	1.472	1.660	1.680	1.925	1.488	1.698
1000		1.707	1.813	1.440	1.653	1.771	1.835	1.419	1.675
Mean		1.577	1.719	1.489		1.667	1.785	1.501	
LSD (0.05)	**Zn**	0.169				0.067			
	HA	0.059				0.038			
	Zn × HA	0.101				0.065			

and 1.579 ton/fed) in both seasons, respectively. The interaction treatments resulted in a significant increase in fruit yield in most cases compared with that gained from control plants in the two experimental trials. Applying zinc at 100 ppm in combination with humic acid at 750 ppm gave the highest yield (1.883 and 1.925 ton/fed) in both seasons, respectively.

Essential oil percentage:

The data in Table (8) presented an improvement in essential oil percentage in plants treated with zinc at 100 ppm in both seasons. It raised the values to 1.80 and 1.81% compared with 1.71 and 1.67% in control plants, respectively. In response to humic acid treatments, it was evident that all levels significantly increased essential oil content. Applying humic acid at 750 ppm has proved superior in elevating the values (1.86 and 1.83%) compared with all other humic acid levels in both seasons, respectively (Table, 8). Also, all combined treatments improved the percentage of essential oil compared to untreated ones. The plants supplied with zinc at 100 ppm in combination with humic acid at 750 ppm were superior in producing the highest percentage (1.95 and 1.90%) of essential oil in the two seasons, respectively.

DISCUSSION

Based on the results of this study, Zn and HA significantly increased fennel growth and productivity. As a result of the treatment of zinc at a concentration of 100 ppm, the total number of branches increased significantly, which was accompanied by an augment in the number of umbels and herb fresh and dry weights. The improvement of the growth characteristics of fennel has resulted in a significant improvement in fruit yield and essential oil content. The same results were observed when humic acid was applied at a moderate level (750 ppm) to fennel plants as a soil application. All measurements involving the interaction between the two treatments showed superior results with the exception of the plant height. Several authors have reported positive effects of HA on fennel growth, including

Table 8. Effect of humic acid (HA) and zinc (Zn) application on essential oil % of fennel plant during 2020/2021 and 2021/2022 seasons.

HA (ppm)		Zn (ppm)							
		First season				Second season			
		0	100	200	Mean	0	100	200	Mean
0		1.45	1.58	1.68	1.57	1.40	1.63	1.70	1.58
500		1.60	1.80	1.70	1.70	1.65	1.88	1.70	1.74
750		1.88	1.95	1.75	1.86	1.80	1.90	1.78	1.83
1000		1.90	1.85	1.70	1.82	1.83	1.83	1.75	1.80
Mean		1.71	1.80	1.71		1.67	1.81	1.73	
LSD (0.05)	**Zn**	0.08				0.08			
	HA	0.10				0.07			
	Zn × HA	0.18				0.12			

Machiani *et al*. (2019), Akbari and Gholami (2016), Mostafa (2015) and Sharaf-El-Deen *et al*. (2012). Heydarnejadiyan *et al.* (2020) have also studied the response of fennel to the application of Zn. According to their findings, fennel growth, seed yield, and essential oil percentage were improved under drought conditions. The results of several other studies were similar, including those reported by Harisha *et al.* (2017), Choudhary *et al.* (2015), Kumawat *et al.* (2015), and Gour *et al.* (2011).

There is evidence that soil application of HA promotes plant growth by accelerating photosynthesis, increasing water and nutrient uptake, and increasing yield (Panda, 2006). In addition, organic materials are thought to increase chlorophyll levels in green plants, thereby helping to overcome chlorosis and enhance photosynthesis (Nardi *et al*., 2002). According to Arun (2002), organic substances are capable of protecting plants against growth-inhibiting substances that may be introduced into the soil. Numerous authors have reported that HA has direct beneficial effects on plant growth. These include Ahmadian *et al.* (2011), Khoshghalb *et al.* (2017), and Hassan and Fahmy (2020). The beneficial effects of HA may also be due to the indirect effects of HA on soil structure, fertility, and uptake of micronutrients due to soil cation-exchange capacity enhancement (Kisić *et al*., 2019). By interfering with calcium phosphate precipitation, HA also improves phosphorus availability (Trevisan *et al*., 2010; Jindo *et al*., 2012) and enhances microbial diversity and activity (Kisić *et al*., 2019). Due to their vital role in providing nutrients for plant metabolism, these effects directly influence the growth and flowering characteristics of plants. There are numerous horticultural crops where the growth and yield have improved through the application of HA, including mung bean (Waqas *et al*., 2015) and Halpern *et al*., 2015), faba bean (Dawood *et al*., 2019), soybean (Lenssen *et al*., 2019), chickpea (Kahraman, 2017).

Multiple studies have demonstrated that Zn has an essential contribution to the growth and productivity of many medicinal crops of the Apiaceae family, confirming the vital role of Zn nutrition in enhancing the number of umbels and fruit yields of fennel, coriander, cumin and khella (Diab, 2007; Eid, 1983 and El-Sherbeny and Abou-Zied, 1986; Said AlAhl and Omer, 2009; El-Sawi and Mohamed, 2002; Akbari *et al*., 2013 and Besher and Mohamed, 1984). According to their findings, foliar application of zinc element with specific sources was positively correlated with the number of umbels and fruit production. Several plants suffer from zinc deficiencies due to a shortage of this vital micronutrient (Ojeda-Barrios et al., 2014). A number of enzymes are dependent on Zn for their function; these include dehydrogenases, isomerases, aldolases, transphosphorylases, and RNA and DNA polymerases. In addition, it participates in the production of tryptophan, the preservation of cell structure, the proliferation of cells, and the process of photosynthesis. In several proteins, it functions as a cofactor, which increases protein synthesis (Marschner, 2012).

In several publications, Ghaderimokri *et al*. (2022), Machiani *et al*. (2019), Akbari and Gholami (2016), Mostafa (2015) and Sharaf-El-Deen *et al*. (2012) reported an increase in fennel oil yield due to the application of zinc or humic acid. It was found that the increase in oil yield was correlated with an improvement in vegetative growth and seed yield. As a result of enhancing plant growth and metabolism, the combination of zinc and humic acid produced higher essential oil content than the other treatments, as compared to the other treatments. As part of regulating essential oil production, particular attention has been paid to the plant's physiological and biochemical aspects. Moreover, the same combination significantly improved flowerhead yield per unit area. Nutritional quality significantly influences plant performance, especially in terms of its physiological mechanisms for producing essential oils. Numerous researchers have endorsed these ideas, including Jimayu (2017), Mahmoud *et al*. (2017), Acimovic *et al*. (2015 a & b), Ahmadian *et al*. (2011), Singh *et al*. (2011) and Sangwan (2001).

CONCLUSION

Based on the results of the current study, Zn and HA significantly improved the growth and productivity of fennel. Applying zinc at 100 ppm significantly enhanced the number of branches, number of umbels, and herb fresh and dry weights per plant. Improvement of fennel growth characteristics was accompanied by an improvement in fruit yield/fed and essential oil %. Similar results were recorded for fennel plants supplemented with humic acid at the moderate level (750 ppm) as soil application. The interaction between both treatments showed superior results with regard to all measured parameters except for plant height.

REFERENCES

Acimovic, M.G.; Dolijanovic, Z.K.; Oljaca, S.I.; Kovacevic, D.D. and Oljaca, M.V. (2015 a). Effect of organic and mineral fertilizers on essential oil content in caraway, anise and coriander fruits. Acta Sci. Pol. Hort. Cultus, 14(1):95-103.

Acimovic, M.G.; Vladimir, F.; Jovana, S.; Mirjana, C. and Lana, D. (2015 b). The influence of environmental conditions on *Carum carvi* L. seed quality. Ratar. Povit., 52(3):91-96.

Ahmadian, A.; Ghanbari, A.; Siahsar, B.; Haydari, M.; Ramroodi, M. and Mousavinik, S.M. (2011). Study of chamomile’s yield and its components under drought stress and organic and inorganic fertilizers using and their residue. J. Microbiol. & Antimicrob., 3(2):23-28.

Akbari, G.A.; Amirinejad, M.; Baghizadeh, A.; Allahdadi, I. and Shahbazi, M. (2013). Effect of Zn and Fe foliar application on yield, yield components and some physiological traits of cumin (*Cuminum cyminum*) in dry farming. Inter. J. Agron. & Plant Production, 4(12):3231-3237.

Akbari, I. and Gholami, A. (2016). Evaluation of mycorrhizal fungi, vermicompost and humic acid on essence yield and root colonization of fennel. Iranian Journal of Field Crops Research, 13(4):840-853.

Arun, K.S. (2002). A Handbook of Organic Farming. Pub. Agrobios, India, 669 p.

Besher, G.A. and Mohamed, M.A. (1984). Effect of foliar spray with zinc on the growth and active constituents of *Ammi majus* and *Ammi visnaga* plants. Zagazig J. Agric. Res., 11(2):111-129.

Bhunia, S.R.; Chauhan, R.P.S. and Yadav, B.S. (2005). Effect of nitrogen and water use, moisture-extraction pattern, nutrient uptake and yield of fennel (*Foeniculum vulgare*). Indian J. Agron., 50:73-76.

Canellas, L.P.; Olivares, F.L.; Aguiar, N.O.; Jones, D.L.; Nebbioso, A.; Mazzei, P. and Piccolo, A. (2015). Humic and fulvic acids as biostimulants in horticulture. Sci Hortic., 196:15–27.

Charles, D.J.; Morales, M.R. and Simon, J.E. (1993). Essential oil content and chemical composition of finocchlo fennel. In: Janick, J. and Simon, J.E. (eds), New Crops**,** Wiley, New York, USA, pp. 570-573.

Chjej, R. (1984). The Macdonald Encyclopedia of Medicinal Plants. MacDonald & Co., London, UK, 447 p.

Choudhary, H.D.; Sharma, S.R.; Jat, R.S. and Jat, G.A.J. (2015). Effect of soil and foliar application of zinc and iron on yield, quality and economics of fennel. Annals of Plant and Soil Research, 17(2):200-203.

Dawood, M.G.; Abdel-Baky, Y.R. and El-Awadi, M.E.S. (2019). Enhancement quality and quantity of faba bean plants grown under sandy soil conditions by nicotinamide and/or humic acid application. Bull Natl Res Cent., 43:1-8 https://doi.org/10.1186/s42269-019-0067-0

Diab, S.A.A. (2007). Effect of Spraying with Zinc and Some Amino Acids on Growth, Yield, Oil Production and Plant Constituents of Caraway (*Carum carvi* L.) Plants. M.Sc. Thesis, Fac. Agric., Cairo Univ., Egypt, 112 p.

Eid, M.I. (1983). Studies of Some Factors Affecting The Seed Production of Some Umbelliferae Plants. M.Sc. Thesis, Fac. Agric., Ain Shams Univ., Egypt, 120 p.

El-Sawi, S.A. and Mohamed, M.A. (2002). Cumin herb as a new source of essential oils and its response to foliar spray with some microelements. J. Food Chemistry, 77:75-80.

El-Sherbeny, S.E. and Abou-Zied, E.N. (1986). Preliminary study on effect of foliar microelement on growth and chemical constituents in *Foeniculum capillicum*. Bull. Nat. Res. Cent., 26(7):69-74.

Farrell, K.T. (1988). Spices, Condiments and Seasonings. Springer Science & Business Media, 428 p.

Ghaderimokri, L.; Rezaei-Chiyaneh, E.; Ghiyasi, M.; Gheshlaghi, M.; Battaglia, M.L. and Siddique, K.H. (2022). Application of humic acid and biofertilizers changes oil and phenolic compounds of fennel and fenugreek in intercropping systems. Scientific Reports, 12(1):5946.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research (2nd ed.). John Wiley and Sons Inc, USA, 680 p.

Gour, S.L.; Yadav, K.K. and Singh, S.D. (2011). Effect of zinc and iron on growth and yield of fennel crop. Environment and Ecology, 29(3B):1502-1505.

Halpern, M.; Bar-Tal, A.; Olek, M.; Minz, D.; Muller, T. and Yermiyahu, U. (2015). The use of biostimulants for enhancing nutrient uptake. Adv. Agron., 130:141-174.

Harisha, C.B.; Diwakar, Y.; Aishwath, O.P.; Singh, R. and Asangi, H. (2017). Soil fertility and micronutrient uptake by fennel (*Foeniculum vulgare* Mill.) as influenced by micronutrients fertilization. Environment & Ecology, 35(1B):514-518.

Hassan, H.M. and Fahmy, A.A. (2020). Effect of foliar spray with proline and humic acid on productivity and essential oil content of chamomile plant under different rates of organic fertilizers in sandy soil. J. Plant Production, Mansoura Univ., 11(1):71-77.

Heydarnejadiyan, H.; Maleki, A. and Babaei, F. (2020). The effect of zinc and salicylic acid application on grain yield, essential oil and phytochemical properties of fennel plants under drought stress. Journal of Essential Oil Bearing Plants, 23(6):1371-1385.

Jimayu, G. (2017). Review of effects of organic and chemical fertilizers on chamomile (*Matricaria chamomilla* L.) production. J. Agric. Sci. and Res., 5(6):453-460.

Jindo, K.; Martim, S.A.; Navarro, E.C.; Aguiar, N.O. and Canellas, L.P. (2012). Root growth promotion by humic acids from composted and non-composted urban organic wastes. Plant Soil, 353:209-220.

Kahraman, A. (2017). Effect of humic acid applications on the yield components in chickpea. J. Agric. Faculty of Gaziosmanpasa Univ., 34:218-222.

Khoshghalb, H.; Babaei, M. and Najafabadi, M.Y. (2017). How different concentrations of humic acid, zinc, nitrogen on boron influence quantitative and qualitative yield of German chamomile (*Matricaria chamomilla* L.)?. J. Appl. Environ. Biol. Sci., 7(11):53-59.

Kisić, I.; Kovać, M. and Ivanec, J. (2019). Effects of organic fertilization on soil properties and chamomile flower yield. Org. Agric., 9:345-355.

Kumawat, S.K.; Yadav, B.L. and Kumawat, S.R. (2015). Response of fennel (*Foeniculum vulgare* Mill.) to phosphorus and zinc fertilization in a loamy sand soil. Journal of Spices and Aromatic Crops, 24(1):23-27.

Lawless, J. (1995): The Illustrated Encyclopedia of Essential Oils: The Complete Guide to The Use of Oils in Aromatherapy and Herbalism. Element Books Ltd., UK, 256 p.

Lenssen, A.W.; Olk, D.C. and Dinnes, D.L. (2019). Application of a formulated humic product can increase soybean yield. Crop, Forage and Turfgrass Management, 5(1):1-6.

Lyons, G. and Genc, Y. (2016). Commercial humates in agriculture: Real substance or smoke and mirrors? A review. Agron 6:1-8. https://doi.org/10.3390/agronomy6040050

Machiani, M.A.; Rezaei-Chiyaneh, E.; Javanmard, A.; Maggi, F. and Morshedloo, M.R. (2019). Evaluation of common bean (*Phaseolus vulgaris* L.) seed yield and quali-quantitative production of the essential oils from fennel (*Foeniculum vulgare* Mill.) and dragonhead (*Dracocephalum moldavica* L.) in intercropping system under humic acid application. Journal of Cleaner Production, 235:112-122.

Mahfouz, S.A. and Sharaf-Eldin, M.A. (2007). Effect of mineral vs. biofertilizer on growth, yield, and essential oil content of fennel [*Foeniculum vulgare* Mill.]. International Agrophysics, 21(4):361-366.

Mahmoud, A.M.; El-Attar, A.B. and Mahmoud, A. (2017). Economic evaluation of nano and organic fertilizers as an alternative source to chemical fertilizers on *Carum carvi* L. plants yield and components. Agric. (Pol'nohospodárstvo), 63(1):33-49.

Marschner, P. (2012). Marschner's Mineral Nutrition of Higher Plants, 3rd Ed. Academic Press, Elsevier, London, UK, 672 p.

Mostafa, G.G. (2015). Improving the growth of fennel plant grown under salinity stress using some biostimulants. Am. J. Plant Physiol, 10(2):77-83.

Nardi, S.; Pizzeghello, D.; Muscolo, A. and Vianello, A. (2002). Physiological effects of humic substances on higher plants. Soil Biol. & Biochem., 34:1527-1536.

Ojeda-Barrios, D.L.; Perea-Portillo, E.; Hernández-Rodríguez, O.A.; Ávila-Quezada, G.; Abadía, J. and Lombardini, L. (2014). Foliar fertilization with zinc in pecan trees. HortScience, 49(5):562-6.

Olk, D.C.; Dinnes, D.L.; Rene Scoresby, J.; Callaway, C.R. and Darlington, J.W. (2018). Humic products in agriculture: Potential benefits and research challenges: A review. J. of Soils and Sediments, 18:2881–2891.

Panda, S.C. (2006). Soil Management and Organic Farming. Agrobios (India), 462 p.

Rose, M.T.; Patti, A.F.; Little, K.R.; Brown, A.L.; Jackson, W.R. and Cavagnaro, T.R.

(2014). A meta-analysis and review of plant growth response to humic substances: practical implications for agriculture. Adv. Agron., 124:37–89.

Said-AlAhl, H.A.H. and Omer, E.A. (2009). Effect of spraying with zinc and/or iron on growth and chemical composition of coriander (*Coriandrum sativum* L.) harvested at three stages of development. J. Medicinal Food Plants, 1(2):30-46.

Sangwan, N.S.; Farooqi, A.H.A.; Shabih, F. and Sangwan, R.S. (2001). Regulation of essential oil production in plants. Plant Growth Regul., 34:3-21.

Sharaf-El-Deen, M.N.; Massoud, H.Y. and Ahmed, M.A. (2012). Effect of humic acid and fertilizers types on vegetative growth, fruit yield, essential oil quality of fennel (*Foeniculum Vulgare* Mill.) plants. Journal of Plant Production, 3(2):201-215.

Singh, O.; Khanam, Z.; Misra, N. and Srivastava, M.K. (2011). Chamomile (*Marticaria chamomilla* L.): An overview. Pharm. Rev., 5(9):82-95.

Stary, F. and Jirasck, V. (1975). Herbs, A Concise Guide in Colour Herbs. Hamlyn, London, New York, Sydney, Torento, 240 p.

Trevisan, S.; Francioso, O.; Quaggiotti, S. and Nardi, S. (2010). Humic substances biological activity at the plant-soil interface: From environmental aspects to molecular factors. Plant Signal Behav., 5:635–643.

Waqas, M.; Ahmad, B.; Arif, M.; Munsif, F.; Khan, A.L.; Amin, M.; Kang, S.M.; Kim, Y.H. and Lee, I.J. (2014). Evaluation of humic acid application methods for yield and yield components of mungbean. Amer. J. of Plant Sci., 5:2269-2276.

Wichtl, M. and Bissel, N.G. **(**1994**).** Herbal Drugs and Phytopharmaceuticals. Med. Pharm Scientific Publ. Stuttgart, 566 p.

تأثير الزنك وحمض الهيوميك على النمو والمحصول ونسبة الزيت الطيار لنباتات الشمر

أسامة حشمت توفيق

قسم البساتين، كلية الزراعة، جامعة الأزهر، فرع أسيوط، مصر

تم إجراء البحث الحالي في المزرعة البحثية بكلية الزراعة جامعة الأزهر، أسيوط، مصر، خلال الموسمين المتتابعين ٢٠٢٠/٢٠٢١ و ٢٠٢١/٢٠٢٢، وذلك بهدف دراسة استجابة النمو والمحصول ونسبة الزيت العطري لنبات الشمر للمعاملة بمستويات مختلفة من الزنك وحمض الهيوميك. اشتملت المعاملات على ثلاثة مستويات من الزنك في صورة رش ورقي (٠ ، ١٠٠ و ٢٠٠ جزء في المليون)، وأربعة مستويات من حمض الهيوميك في صورة إضافة أرضية (٠ ، ٥٠٠، ٧٥٠ و ١٠٠٠ جزء في المليون)، بالإضافة إلى المعاملات المشتركة بين جميع المستويات. أوضحت النتائج أن معاملة النباتات بالزنك بمعدل ١٠٠ جزء في المليون أدت إلى زيادة معنوية في عدد الأفرع/نبات، عدد النورات/نبات، الوزن الطازج والجاف/نبات، محصول الثمار/فدان والنسبة المئوية للزيت العطري. في حين أدى استخدام الزنك بمعدل ٢٠٠ جزء في المليون إلى انخفاض معنوي في محصول الثمار/فدان. سجلت المعاملة بالإضافة الأرضية لحمض الهيوميك بالمستوى المتوسط (٧٥٠ جزء في المليون) أعلى القيم مقارنة بالمستويات الأخرى في جميع الصفات باستثناء ارتفاع النبات ووزن الأعشاب الطازج. كان لمعاملات التفاعل تأثير معنوي على جميع الصفات النباتية والمحصولية التي تم تسجيلها، حيث حققت المعاملة المشتركة بين الزنك عند ١٠٠ جزء في المليون وحمض الهيوميك عند ٧٥٠ جزء في المليون أعلى القيم في جميع الصفات المدروسة باستثناء ارتفاع النبات.