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EFFECT OF ZINC AND AMINO ACIDS ON GROWTH, YIELD AND CHEMICAL CONSTITUENTS OF CARAWAY (*Carum carvi*, L.) PLANTS

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ABSTRACT

This study was conducted during two successive seasons of 2003/2004 and 2004/2005 at the Experimental Farm of Ornamental Horticulture Department, Faculty of Agriculture, Cairo University to study the effect of zinc at (0, 50 and 100 ppm) and some amino acids, tryptophan at (0, 50 and 100 ppm) and methionine at (0, 25 and 50 ppm) on growth, yield, oil production and chemical composition of caraway (Carum carvi, L.) plants. The results showed that zinc application had no significant effect on plant height in the first season, number of branches / plant, dry weight / plant and number of umbels / plant in both seasons. Whereas zinc at 50 ppm significantly increased plant height and dry weight / plant in the second season. Zinc at 50 and 100 ppm significantly increased fresh weight / plant in both two seasons , fruit yield / plant and oil yield/ plant in the second one. Zinc at 50 and 100 ppm insignificantly increased oil percentage in both two seasons. Zinc at 50 and 100 ppm decreased limonine percentage in the oil and increased carvone percentage in the oil in both two seasons, total carbohydrates contents in both leaves and roots in the first season. Zinc at 50 ppm increased total carbohydrates in fruits in the first season, while 100 ppm increased it in leaves, fruits and roots in the second one.

Tryptophan and methionine had a significant effect on plant fresh and dry weights in both seasons. The most effective treatment was methionine application at 50 ppm. Tryptophan and methionine at 50 ppm gave the highest fruit yield / plant in the first and second seasons, respectively. Amino acids (tryptophan and methionine) insignificantly increased volatile oil percentage and oil yield / plant in the first season. Whereas, methionine at 25 ppm significantly decreased oil percentage in the second season. Methionine at the highest rate (50 ppm) decreased limonene and increased carvone percentages in caraway essential oil in both seasons. Amino acids application increased total carbohydrates percentage in leaves in the first season, in fruits and roots in both two seasons.

Interaction between zinc and amino acids (tryptophan and methionine) had a significant effect on most vegetative growth characteristics, fruit yield / plant, oil percentage and oil yield / plant, and *increased limonine and carvone contents in the oil and total carbohydrates percentage in different plant organs.*

Key words: Zinc, amino acids, growth, yield, chemical constituents, caraway, *Carum carvi*, L plants.

INTRODUCTION

Caraway (*Carum carvi,* L.*)* belongs to family *Apiaceae* (*Umbelliferae*) is an annual herb native to Europe and Western Asia and naturalized in North America. An essential oil obtained from the fruit by steam distillation, (Guenther, 1968). The volatile oil is composed mainly of carvone and limonene, with minor amount of carveol, dihydrocarveol, dihydrocarvone, terpenes and others, (Masada, 1976). Concentrations of the components vary, depending on the degree of ripeness of the fruit; contents of carvone and other oxygenated components increase as fruit ripens. Thus oils obtained from fully mature seeds contain more carvone and less limonene and are considered to be better quality. It considered having carminative, stomachic and laxative properties. Oil is used as flavor in pharmaceuticals; it is also used as a fragrance component in cosmetic preparations including toothpaste, mouthwash, soap, creams, lotions, and perfumes (Leung and Foster, 1996). Zinc application affecting growth, yield and chemical constituents of many aromatic plants; Kassem (2002) on rosemary plant; Khalil *et al*.(2002) on *Tagetes erecta* and Misra *et al*.(2005) on geranium.

On the effect of zinc and other trace elements; El- Sawi and Mohamed (2002) on cumin; Sharang *et al*.(2002) on fennel; Mousa *et al*.(2001) on *Nigella sativa*; Mohamed (2003) on *Foeniculum vulgare,* L. and Aziz and El- Sherbeny (2004) on *Sideritis montana*.

Amino acids application affecting growth, yield and chemical constituents of many aromatic plants; Mohamed (2003) on fennel; Naguib *et al. (*2003) on periwinkle plants; Talaat (2005) on *Lavandula angustifolia* and Talaat *et al*.(2005) on *Cantharanthus roseus,* L.

MATERIALS AND METHODS

This study was conducted during two successive seasons of 2003/2004 and 2004/2005 at the Experimental Farm of Ornamental Horticulture Department, Faculty of Agriculture, Cairo University to study the effect of zinc and some amino acids (tryptophan and methionine) on growth, yield, oil production and chemical composition of caraway (*Carum carvi,* L.) plants.

Seeds (fruits) of caraway (*Carum carvi,* L.) obtained from the Experimental Farm of Faculty of Pharmacy, Cairo University were sown on 15th October in the two seasons in the field on one side of the rows, in hills 30 cm apart. The experimental plots were (2.0 x 4.0 m) with 3 rows at a distance of 60 cm between rows. Between every two beds, there was a ridge 50 cm wide. The seedlings were thinned one month after sowing to two plants per hill.

The physical and chemical properties of the soil of the experimental area are shown in Tables (A and B). The analysis of the soil was conducted using the method described by Jakson (1967).

The plants were fertilized by NPK fertilizers at a constant level, using ammonium sulphate (20.5 %N) at 150kg /fed calcium super-phosphate (15.5 % P_2O_5) at 100 kg /fed and potassium sulphate (48% K_20) at 50 kg /fed. The fertilizers added at two equal splits. The first after 45 days from the sowing, and the later one month from the first.

Plants in the main experimental plots were sprayed with zinc(as zinc sulphate) at the rate of 0,50 and 100 ppm 3 times, the first one month after sowing, the second was one month after the first and the third one was one month after the second.

Table (A): Mechanical analysis of the soil .

Sample No.	Depth cm	%				Texture
		Coarse sand	Fine sand	Clay	Silt	
1	0-20	4.6	33.6	21.7	40.1	**Loamy sand**
2	20-40	5.6	30.6	25.1	38.7	**Loamy sand**

Table B: Chemical properties of the soil.

Depth (cm)	N (ppm)	O.M %	$^-SO_4$	Cl^-	HCO_3^-	Mg^{++}	Ca^{++}	K^+	Na^+	$CO3^-$ %	E.C. (dS/m)	pH
			meq /100g soil (aq:soil.1:5)									
0-20	587	1.74	6.98	1.63	0.55	0.75	1.00	0.39	7.02	3.15	1.00	8.00
20-40	475	1.74	2.97	1.50	0.75	0.75	1.25	0.22	3.00	3.60	0.60	8.12

Plants in the sub plots were sprayed with tryptophan at the rate of 0, 50 and 100 ppm and methionine at 0, 25 and 50 ppm. Both tryptophan and methionine were sprayed 3 times, the first one month after the sowing, the second was one month after the first and the third application was one month after the second.

Data on plant height, number of branches / plant, fresh and dry weights of herb (g / plant during milky stage), number of umbels / plant, fruit yield (g / plant). The samples were dried in an electric oven at 70°C till a constant weight. Essential oil percentage and oil yield (ml)/ plant were determined as described by British Pharmacopoeia (1963). Gas Liquid chromatography (GLC) analysis of the essential oil was performed using Hewlett Packard gas chromatograph apparatus with the following specifications: Capillary column Ultra 2 (cross-linked 5% ph. me. Silicone) 25m x 0.32 m x 0.52µL film thickness. Nitrogen, hydrogen and air flow rates were 30,30and 300 ml/min., respectively. Injection temperature of 250 ºC, Detector temperature of 275 ºC, Oven program of 70 ºC to 220 ºC, increasing the temperature by 10 ºC /min. Chart speed was1cm /min as described by Bunzen *et al.*(1969) and total carbohydrates contents were determined as described by Herbert *et al*. (1971).

The layout of the experiment was split plot design. The main plots were zinc application and the sub- plots were amino acids application, including 15treatments. Each treatment was replicated 3 times.

The statistical analysis was carried out using Least Significant Difference (LSD) test at 0.05 % according to Snedecor and Cochran (1982).

RESULTS AND DISCUSSION

Plant height:

Data presented in Table 1 showed that, in the first season, zinc application at 50 or 100 ppm had no significant effect on plant height as compared with control. In the second season, zinc application at 50 ppm significantly increased plant height compared to control plants. Whereas zinc at 100 ppm had no significant effect compared with untreated plants. These results are in agreement with the findings obtained by Mohamed (2000) on coriander and caraway; and Kassem (2002) on *Rosmarinus officinalis.* They showed that zinc application increased plant height.

Concerning the effect of amino acids on plant height, data presented in Table 1 showed that amino acids had no significant effect on plant height compared with the control in both seasons. In the second season, methionine application at 25 and 50 ppm significantly increased plant height compared to tryptophan application at 50 and 100 ppm. The most effective treatment was methionine at 25 ppm treatment. These results are in harmony with those obtained with Zedan (2000) on *Carum carvi* and *Coriandrum sativum* and Mohamed (2003) on fennel. They showed that amino acids application increased plant height.

Concerning interaction between zinc and amino acids, the results showed a significant difference in plant height in both seasons. In the first season, spraying with zinc at 100 ppm and tryptophan at 100 ppm gave the tallest plants compared with zinc application at 50 ppm plus methionine at 50 ppm, which gave the shortest plants. In the second season, application of zinc at 50 ppm plus methionine at 25 ppm gave the tallest plants, while tryptophan at 50 ppm plus zinc at 0.00 ppm gave the shortest plants. This increment in plant height may be due to the role of zinc and amino acids on biosynthesis of indole acetic acid (IAA) which increase plant height. Similar results were obtained by Mohamed (2003) on fennel, who found that tryptophan at 200 ppm and trace elements at 150 ppm may be recommended to increase plant height.

Number of primary branches /plant:

Data in Table 1 showed that there were insignificant differences on number of branches per plant due to zinc application at two concentrations in the two seasons as compared with the control. The results of increment or decrement are in harmony with those obtained with Kassem (2000) on rosemary plants and Mohamed (2000) on *Coriandrum sativum,* L. and *Carum carvi,* L.

Table 1: Effect of zinc and amino acids (tryptophan and methionine) on plant height (cm.) and number of branches / plant at milky stage of caraway (*Carum carvi*, L.) at 2003/2004 and 2004/2005 seasons.

Treatments		Plant height							
Zinc (A)		2003/2004				2004/2005			
		Control	Zinc ppm		Mean	Control	Zinc ppm		Mean
Amino Acids ppm (B)			50	100			50	100	
Control		91.30	91.20	92.53	91.68	103.70	116.30	110.20	110.10
Tryptophan	**50**	91.97	89.10	86.63	89.23	100.20	108.60	111.00	106.60
	100	88.63	88.40	98.30	91.78	106.30	114.70	101.60	107.50
Methionine	**25**	88.77	87.40	88.10	88.09	114.40	119.40	111.70	115.20
	50	91.50	84.53	90.17	88.73	116.50	111.40	116.10	114.70
Mean		90.43	88.13	91.15	-------	108.20	114.10	110.10	------
LSD at 0.05% for:									
Zinc (A)			N.S.				5.37		
Amino acids (B)			N.S.				6.94		
AXB			9.61				12.02		
		Number of branches / plant							
Control		7.53	7.40	8.40	7.78	10..97	10.17	8.40	9.84
Tryptophan	**50**	7.40	7.77	6.63	7.27	9.17	9.20	9.30	9.22
	100	6.97	7.00	7.30	7.09	9.53	10.63	9.17	9.78
Methionine	**25**	6.73	7.77	6.97	7.16	8.40	10..30	10..97	9.89
	50	6.87	6.93	7.33	7.04	9.40	9.30	10.87	9.86
Mean		**7.10**	**7.37**	**7.33**	**----**	**9.49**	**9.92**	**9.74**	**-----**
LSD at 0.05% for:									
Zinc (A)			N.S.				N.S.		
Amino acids (B)			N.S.				N.S.		
AXB			N.S.				1.69		

Concerning the effect of amino acids. Data presented in Table 1 showed that tryptophan and methionine treatments had no effect on number of branches /plant in both two seasons. Theses results are in accordance with the findings of Harridy (1986) on *Catharnthus roseus,* found that tryptophan application at 100 ppm had no effect on number of branches.

Concerning the interaction between zinc and amino acids (Tryptophan and Methionine), there were insignificant differences in number of branches per plant due to all treatments in the first season as compared with control. In the second season, interaction between zinc and amino acids had a significant effect on number of branches/plant. The highest number of branches /plant was obtained for control plants, whereas the lowest number of branches /plant were obtained due to zinc application at 100 ppm or methionine application at 25 ppm.

Fresh weight (g. / Plant):

Data presented in Table 2 showed that zinc application at 50 and 100 ppm significantly increased plant fresh weight in both two seasons. Zinc at 100 ppm was the most effective treatment which gave the heaviest fresh weight in both two seasons. This may be due to zinc contribution in enzymatic and photosynthesis activity, which in turn increase plant fresh weight. This is in accordance with the findings of Mohamed (1998) on *Nigella sativa* and Kassem (2002) on rosemary. They showed that, zinc application increased herbage fresh weight.

Concerning the effect of amino acids, tryptophan and methionine showed a significant increment in plant fresh weight in the first and second seasons compared with control. The most effective treatments were tryptophan at 50 ppm and methionine at 50 ppm in both seasons, respectively which gave the heaviest fresh weight. Similar results are obtained by Mohamed (2003) on fennel, Naguib *et al.* (2003) on periwinkle; and Talaat *et al.*(2005) on periwinkle. They showed that amino acids application increased fresh weight / plant.

Interaction between zinc application and amino acids, spraying significantly affected fresh weight /plant. In the first season, the heaviest plant fresh weight was obtained from plants treated with zinc at 100 ppm plus tryptophan at 100 ppm, while the lowest fresh weight was obtained for control plant (without zinc or amino acids applications). In the second season, the heaviest fresh weight was obtained due to zinc at 100 ppm plus methionine at 50 ppm application compared to tryptophan at 50 ppm without zinc application which gave the lowest value. This may be due to amino acids effect on indole acetic acid synthesis which contributes in photosynthesis activity which in turn increases plant fresh weight. Similar results were obtained by Mohamed (2003) on fennel plants, who found that methionine at 50 ppm plus trace-elements at 150 ppm may be recommended to increase fresh weight of plant.

Dry weight of herb:

Data presented in Table 2 showed that zinc application had no significant effect on dry weight of above ground parts in the first season compared to the untreated plants. On the other hand, in the second season, spraying with zinc at 50 ppm significantly increased dry weight of plants compared with control plants. Similar results were recorded by Rao and Chand (1996) on lemon grass and Kassem (2002) on rosemary plants. They showed that zinc application increased plant dry weight.

Both tryptophan and methionine application significantly increased herb dry weight compared to control. The most effective treatment was methionine application at 50 ppm which gave the heaviest dry weight compared to control plants. In the second season, tryptophan application at 100 ppm and methionine at 25 ppm insignificantly increased dry weight/plant. Whereas methionine at 50 ppm significantly increased dry weight of herb, giving the highest value compared to control plants. This is in accordance with the findings of Naguib *et al.* (2003) on periwinkle and Talaat *et al.* (2005) on periwinkle. They found that amino acids increased herb dry weight.

Table 2: Effect of zinc and amino acids (tryptophan and methionine) on fresh and dry weights (g./ plant) at milky stage of caraway (*Carum carvi*, L.) at 2003/2004 and 2004/2005 seasons.

Treatments		Fresh weight							
Zinc (A)		2003/2004				2004/2005			
		Control	Zinc ppm		Mean	Control	Zinc ppm		Mean
Amino Acids ppm (B)			50	100			50	100	
Control		111.9	155.4	146.6	138.0	268.2	252.1	215.7	245.3
Tryptophan	**50**	200.5	204.4	208.8	204.6	153.3	308.0	325.3	262.2
	100	138.2	207.5	260.9	202.2	315.7	238.4	295.4	283.2
Methionine	**25**	124.8	184.3	196.3	168.5	242.2	339.9	310.2	297.5
	50	240.4	188.0	162.3	196.9	276.9	294.7	361.1	310.9
Mean		**163.2**	**187.9**	**195.0**	**------**	**251.3**	**286.6**	**301.5**	**-----**
LSD at 0.05% for:									
Zinc (A)		22.6				35.1			
Amino acids (B)		29.2				45.3			
AXB		50.6				78.5			
		Dry weight							
Control		20.74	35.88	34.17	30.26	60.74	71.38	33.90	55.34
Tryptophan	**50**	44.78	41.53	50.39	45.57	29.04	67.27	51.84	49.38
	100	28.70	47.94	34.43	37.03	71.69	53.86	53.65	59.73
Methionine	**25**	49.40	34.67	41.39	41.82	50.66	76.24	63.82	63.57
	50	70.38	43.04	38.02	50.48	57.42	62.19	78.65	66.08
Mean		**42.80**	**40.61**	**39.68**	**------**	**53.91**	**66.19**	**56.37**	**----**
LSD at 0.05% for:									
Zinc (A)		N.S.				7.02			
Amino acids (B)		6.22				9.06			
AXB		10.77				15.69			

Interaction between zinc and amino acids, application had a significant effect on herb dry weight. In the first season, plants treated without zinc (control) plus methionine at 50 ppm gave the heaviest dry weight compared with control plants (without zinc or amino acids) which gave the lowest value. In the second season, plants sprayed with zinc at 100 ppm plus methionine at 50 ppm gave the heaviest dry weight compared with plants treated with zinc at 100 ppm without amino acids application which gave the lowest value.

Number of umbels per plant :

Data recorded in Table 3 showed that, in the first season, zinc application had no significant effect on number of umbels/plant compared with control. Zinc application at 100 ppm gave the highest value compared to zinc application at 50 ppm with a significant difference. In the second season, zinc application had no significant effect on number of umbels /plant compared with the control. The obtained results

Table 3: Effect of zinc and amino acids (tryptophan and methionine) on number of umbels / plant and fruit yield (g. / plant) of caraway (*Carum carvi*, L.) at 2003/2004 and 2004/2005 seasons.

Treatments		Number of umbels / plant							
Zinc (A)		2003/2004				2004/2005			
		Control	Zinc ppm		Mean	Control	Zinc ppm		Mean
Amino Acids ppm (B)			50	100			50	100	
Control		41.73	47.33	54.53	47.87	45.11	49.56	57.39	50.69
Tryptophan	50	57.63	43.33	62.30	54.42	40.34	57.44	50.22	49.33
	100	39.97	43.50	49.50	44.32	33.28	48.78	42.78	41.61
Methionine	25	59.40	42.07	54.20	51.89	40.61	49.67	51.78	47.35
	50	63.07	57.40	49.79	56.75	54.66	45.39	44.94	48.33
Mean		**52.36**	**46.73**	**54.06**	**------**	**42.80**	**50.17**	**49.42**	**-----**
LSD at 0.05% for:									
Zinc (A)		6.87				N.S.			
Amino acids (B)		8.87				N.S.			
AXB		15.37				18.79			
		Fruit yield							
Control		8.13	9.93	11.25	9.77	18.67	25.30	23.75	22.57
Tryptophan	50	9.27	10.53	11.17	10.33	23.50	24.45	23.25	23.73
	100	7.86	10.76	11.91	10.18	18.40	25.10	23.57	22.36
Methionine	25	9.88	9.40	10.69	9.99	19.53	29.33	24.13	24.33
	50	11.28	10.40	8.98	10.22	23.50	21.13	28.75	24.46
Mean		**9.29**	**10.20**	**10.80**	**-----**	**20.72**	**25.06**	**24.69**	**------**
LSD at 0.05% for:									
Zinc (A)		N.S.				3.16			
Amino acids (B)		N.S.				N.S.			
AXB		N.S.				7.06			

agreed with those obtained by El- Shorbagy (1979) on anise, who noticed that the low concentration of zinc did not affected fruit umbels /plant.

Concerning the effect of amino acids on number of umbels per plant. Amino acids (tryptophan and methionine) had no significant effect on number of umbels /plant compared with control plants in both two seasons. The obtained results are disagreement with those obtained by Mohamed (2003) on fennel, who found that both tryptophan and methionine at 50 and 100 ppm increased number of umbels /plant.

Concerning the interaction between zinc and amino acids the results showed a significant difference. In the first season, methionine application at 50 ppm without zinc (0.0 ppm) gave the highest number of umbels /plant. Whereas control plants (without zinc or amino acids) or tryptophan treatment at 100 ppm gave the lowest values. In the second season, tryptophan at 50 ppm plus zinc at 50 ppm treatments gave the highest values. Whereas tryptophan at 100 ppm without zinc application gave the lowest value. These results are in harmony with those obtained with Mohamed (2003) on fennel.

Fruit yield / plant:

Data presented in Table 3 showed that zinc application at 50 and 100 ppm slightly increased fruit yield / plant. Zinc at 100 ppm gave the highest value compared with untreated plants. This increment was statistically insignificant in the first season. In the second season, zinc at 50 and 100 ppm significantly increased fruit yield / plant. Zinc at 50 ppm gave the highest fruit yield followed by zinc treatment at 100 ppm compared with control plants which gave the lowest value. These results are in harmony with those obtained by Mohamed (2000) on coriander and caraway plants. They found that zinc application increased fruit yield / plant.

Amino acids (tryptophan and methionine), slightly increased fruit yield / plant. Tryptophan at 50 ppm and methionine at 50 ppm gave the highest fruit yield / plant in the first and second seasons, respectively. These increments were statistically insignificant compared with control plants.

Regarding the interaction effect between zinc and amino acids, in the first season, there was no significant effect on fruit yield /plant. However the highest fruit yield / plant were obtained from plants treated with zinc at 100 ppm and tryptophan at 100 ppm. In the second season, there was a significant effect on fruit yield / plant. The highest values were produced from plants treated with zinc at 50 ppm plus methionine at 25 ppm or zinc at 100 ppm plus methionine at 50 ppm compared with control (without zinc or amino acids) which gave the lowest value. These results are in agreement with those obtained by Mohamed (2003) on fennel, who found that interaction between zinc and tryptophan increased fruit yield / plant.

Volatile oil percentage

Data presented in Table 4 show that zinc application at 50 or 100 ppm slightly increased volatile oil percentage in both two seasons. Zinc application at 50 and 100 ppm gradually increased volatile oil percentage. These increments were statistically insignificant compared to untreated plants. These results are in harmony with those obtained by Mohamed (2000) on coriander and caraway plants. Who showed that zinc application increased volatile oil percentage.

Amino acids (tryptophan and methionine) insignificantly increased volatile oil percentage compared with control plants in the first season. In the second season, tryptophan at 50 and 100 ppm had no significant effect on volatile oil percentage. On the other hand, methionine at 25 ppm significantly decreased oil percentage compared with untreated plants. Whereas, methionine at 50 ppm insignificantly decreased volatile oil percentage. These results are in agreement with those obtained by Zedan (2000) on coriander and caraway plants showed that tryptophan at 25 and 50 ppm increased volatile oil percentage in the two seasons. Mohamed (2003) on fennel, found that tryptophan and methionine at 100 and 200 ppm increased oil percentage.

Intercalation between zinc and amino acids had a significant effect on oil percentage in both seasons. In the first season, plants treated with tryptophan at 100 ppm plus zinc at 100 ppm gave the highest oil percentage (1.970 %) followed by plants treated with methionine at 50 ppm plus zinc at 100 ppm (1.753 %) compared with control plants (without amino acids or zinc), control plants sprayed with zinc at

Table 4: Effect of zinc and amino acids (tryptophan and methionine) on essential oil percentage (%) andoil yield (ml / plant) of caraway (*Carum carvi*, L.) at 2003/2004 and 2004/2005 seasons.

Treatments		Essential oil percentage							
Zinc (A)		2003/2004				2004/2005			
		Control	Zinc ppm		Mean	Control	Zinc ppm		Mean
Amino Acids ppm (B)			50	100			50	100	
Control		1.327	1.503	1.297	1.376	1.690	1.750	1.767	1.736
Tryptophan	**50**	1.630	1.167	1.360	1.386	1.900	1.627	1.807	1.774
	100	1.293	1.613	1.970	1.626	1.687	1.633	1.687	1.669
Methionine	**25**	1.570	1.533	1.287	1.463	1.493	1.620	1.467	1.527
	50	1.380	1.693	1.753	1.609	1.400	1.680	1.847	1.642
Mean		**1.440**	**1.502**	**1.533**	**----**	**1.634**	**1.660**	**1.715**	**-----**
LSD at 0.05% for:									
Zinc (A)			N.S.				N.S.		
Amino acids (B)			N.S.				0.164		
AXB			0.598				0.285		
					Oil yield				
Control		0.113	0.148	0.146	0.136	0.294	0.443	0.420	0.386
Tryptophan	**50**	0.151	0.128	0.151	0.143	0.395	0.395	0.422	0.404
	100	0.102	0.176	0.234	0.171	0.310	0.394	0.396	0.367
Methionine	**25**	0.155	0.142	0.138	0.145	0.302	0.473	0.351	0.375
	50	0.156	0.204	0.155	0.171	0.330	0.353	0.535	0.406
Mean									

100 ppm, tryptophan at 50 ppm plus zinc at 50 ppm and plants treated with tryptophan at 100 ppm without zinc application which gave (1.327, 1.297, 1.167 and 1.293 %, respectively. In the second season, plants treated with tryptophan at 50 ppm (without zinc application), tryptophan at 50 ppm plus zinc at 100 ppm and methionine at 50 ppm plus zinc at 100 ppm gave the highest essential oil percentages (1.900, 1.807 and 1.847 %, respectively) compared with plants treated with methionine at 50 ppm (without zinc application) which gave the lowest value (1.400 %).

***Volatile oil yield / plant*:**

Data in Table 4 showed that zinc application at 50 and 100 ppm gradually increased volatile oil yield / plant compared with control. This increment was statistically insignificant in the first season. On the other hand, in the second season, zinc at 50 and 100 ppm significantly increased volatile oil yield / plant compared to control plants. This effect may be due to the effect of zinc on increase volatile oil percentage and fruit yield / plant. These results are in accordance with the findings obtained by Mohamed (2000) on coriander and caraway and Khalil *et al*. (2002) on *Tagetes erecta.* They showed that zinc application increased volatile oil yield / plant.

Amino acids (both tryptophan and methionine) at different concentrations insignificantly increased volatile oil yield / plant in the first season. While in the second season, tryptophan at 100 ppm and methionine at 25 ppm insignificantly decreased volatile oil yield / plant compared with untreated plants.

Intercalation between zinc and amino acids had a significant effect on volatile oil yield /plant in both two seasons. In the first season, tryptophan at 100 ppm plus zinc at 100 ppm treatment gave the highest oil yield /plant compared with control (without amino acids or zinc), tryptophan at 50 ppm plus zinc at 50 ppm and tryptophan at 100 ppm without zinc application which gave the lowest oil yield/plant. In the second season, methionine at 50 ppm plus zinc application at 100 ppm treatment gave the highest oil yield / plant compared with the control (without amino acids or zinc application) which gave the lowest essential oil yield / plant.

GLC analysis of the essential oil:

Data presented in Table 5 and Figures (1, 2, 3 and 4) showed that the main components of caraway essential oil are limonene (which ranged from 25.23 to 35.58 %) and carvone (which ranged from 57.98 to 72.17 %). These results are in agreement with those obtained by Guenther (1968).

Zinc application at 50 and 100 ppm decreased limonine percentages in the first and second seasons compared to untreated plants which gave the highest limonine percentage in both seasons.

On the contrary, zinc application at 50 ppm increased carvone percentage, which gave the highest values (65.34 and 66.47 %) in both seasons, respectively compared to control or zinc application at 100 ppm, which gave the lowest value.

These results are in agreements with the findings obtained by Abou Zaid *et. al.*, (1996) on fennel, showed that zinc treatments increased fenchone and anethole percentages in the oil. Jacoub (1995) on *Ocimum basilicum*, showed that Zn application individually or with Fe and Mn increased linalool and decreased methyl chavicol percentages in oil. Abd El-Salam (1999) on fennel, showed that Fe, Mn and Zn at 100 ppm increased fenchone contents. Mohamed (2003) on fennel, showed that, Fe, Mn and Zn at 75 and 150 ppm increased anethole and carvone percentages. While methyl chavicol, fenchone and limonene tended to decrease especially with 150 ppm.

Tryptophan application had no clear trend on the essential oil components in both seasons. Tryptophan at 50 ppm decreased both limonene and carvone percentages in the first season. While increased limonene and decreased carvone percentages in the second season. Tryptophan at 100 ppm had no clear tend; i.e it increased limonene and decreased carvone percentages in the first season. In the second season, Tryptophan at 100 ppm gave an opposite trend; i.e. it decreased limonene and increased carvone percentage compared to control plants.

Methionine application at 25 and 50 ppm decreased limonene and increased carvone contents in the first season. In the second season, methionine application had a different effect. Methionine at 25 ppm increased limonene and decreased carvone percentages. Whereas methionine at 50 ppm decreased limonene and increased carvone contents.

Table 5: Effect of zinc and amino acids (Tryptophan and Methinoine) on GLC analysis of the essential oil of caraway (*Carum carvi* , L) plants at 2003 / 2004 and 2004 / 2005 seasons.

Treatments			2003 / 2004		2004 / 2005	
Zinc ppm	Amino acids ppm		Limonine	Carvone	Limonime	Carvone
Control	Control		30.64	66.78	34.05	64.16
	Tryptophan	50	33.85	63.04	33.78	64.47
		100	33.04	64.31	31.53	66.70
	Methionine	25	32.73	64.02	32.25	65.70
		50	31.38	66.03	31.09	66.97
	Mean		**32.32**	**64.84**	**32.54**	**65.60**
50	Control		37.21	59.58	31.50	66.77
	Tryptophan	50	33.50	62.72	32.27	65.91
		100	35.58	61.83	31.03	67.27
	Methionine	25	27.03	70.62	33.17	64.87
		50	25.23	72.17	30.54	67.55
	Mean		**31.71**	**65.38**	**31.70**	**66.47**
100	Control		33.5	62.72	30.25	68.02
	Tryptophan	50	29.02	57.98	34.31	63.97
		100	35.19	61.06	30.82	67.29
	Methionine	25	31.88	65.14	32.60	65.65
		50	30.65	66.83	32.45	65.88
	Mean		**32.05**	**62.75**	**32.09**	**66.16**
Control			33.87	63.03	31.93	66.32
Tryptophan		50	32.12	61.25	33.45	64.78
		100	34.60	62.40	31.13	67.09
Methionine		25	30.55	66.59	32.67	65.41
		50	29.09	68.34	31.36	66.80
Mean						

In general, it could be concluded that methionine at the highest rate (50 ppm) decreased limonene and increased carvone percentages in caraway essential oil in both two seasons. Whereas methionine at 25 ppm had no clear trend in both two seasons.

These results are in harmony with those obtained by Milad (1998) showed that carvone, piperitenone oxide and camphore were decreased in *Mentha viridis*, *Mentha longifolia* and *Ocimum canum,* respectively. Zedan (2000) showed that, tryptophan at 25 ppm increased carvone in *Carum carvi* oil in the two seasons. Limonene showed an adverse trend, dihydro-carveol reduced by tryptophan at 25 and 50 ppm. On *Coriandrum sativum*, tryptophan treatments increased linalool in the first season only. Tryptophan at 25 ppm increased limonene and α pinene in the second season. Mohamed (2003) on fennel, found that anethole percentage was increased by tryptophan and decreased by methionine. Limonene percentage was increased by methionine at 100 ppm and decreased by tryptophan. Fenchone percentage was increased by 100 ppm methionine.

Concerning the interaction effect, tryptophan application at 100 ppm with zinc application 50 ppm gave the highest limonene content in the first season. While in the second season, zinc application at 100 ppm plus tryptophan at 50 ppm gave the highest limonene content in the essential oil of caraway plant.

In the first season, zinc application at 50 ppm plus methionine application at 50 ppm gave the highest carvone content in the essential oil. Whereas zinc application at the highest rate (100 ppm) without amino acids application gave the highest carvone content in the essential oil in the second season.

3- Total carbohydrates percentages :

Data presented in Table 6 show the effect of zinc and amino acids on total carbohydrates percentage in leaves, fruits and roots. It could be discussed as follows:

A- Total carbohydrates percentage in leaves:

Zinc application at 50 and 100 ppm increased total carbohydrates percentage in leaves in the first season. The most effective treatment was zinc at 50 ppm, which gave the highest value compared to control plants. In the second season, zinc at 100 ppm gave the highest total carbohydrates percentage compared to control plants.

Amino acid (tryptophan) at 50 and 100 ppm and methionine at 50 ppm increased total carbohydrates percentage in the leaves of caraway plants in the first season. On the other hand, in the second season, tryptophan and methionine application decreased total carbohydrates percentage in leaves of caraway plants.

Concerning the effect of interaction, the data in Table 6 showed that plants treated with zinc at 50 ppm and tryptophan at 50 or 100 ppm gave the highest total carbohydrates percentage in the first season. On the other hand, in the second season, zinc at 100 ppm (without amino acids application) gave the highest total carbohydrates percentage in the leaves.

Table 6: Effect of zinc and amino acids (tryptophan and methionine) on total carbohydrates (%) in leaves, fruits and roots of caraway (*Carum carvi*, L.) at 2003 / 2004 and 2004 / 2005 seasons.

Treatments		In leaves.							
Zinc (A)		2003/2004				2004/2005			
		Control	Zinc ppm		Mean	Control	Zinc ppm		Mean
Amino Acids ppm (B)			50	100			50	100	
Control		35.6	31.2	33.6	33.47	28.8	20.6	31.2	26.87
Tryptophan	**50**	34.4	44.8	31.2	36.80	18.4	25.2	28.6	24.07
	100	29.2	45.2	35.6	36.67	20.2	20.4	20.2	20.27
Methionine	**25**	28.6	35.6	36.0	33.40	26.6	20.0	27.4	24.67
	50	36.0	43.0	36.0	35.33	28.4	25.8	23.4	25.87
Mean		**32.76**	**39.96**	**34.48**	**---**	**24.48**	**22.8**	**26.16**	**----**
		In fruits.							
Control		25.2	22.2	27.4	24.93	17.8	20.2	20.6	19.53
Tryptophan	**50**	28.8	32.0	24.8	28.53	22.6	17.0	20.0	19.87
	100	23.8	24.0	21.6	23.13	19.4	19.2	23.8	20.73
Methionine	**25**	24.6	27.8	24.6	25.67	17.8	18.4	25.8	20.77
	50	25.4	23.8	25.4	24.87	22.2	19.4	21.2	20.93
Mean		**25.56**	**25.96**	**24.76**	**---**	**19.96**	**18.84**	**22.3**	**---**
		In roots.							
Control		21.6	35.2	38.6	31.8	31.5	39.6	39.8	36.98
Tryptophan	**50**	24.0	38.6	43.0	35.2	40.6	37.6	42.0	40.1
	100	42.6	38.4	44.8	41.9	40.8	35.6	43.6	40.0
Methionine	**25**	41.6	35.6	41.6	39.6	43.2	42.4	37.8	41.13
	50	36.4	39.0	42.6	39.3	42.2	41.8	38.8	40.9
Mean		**33.24**	**37.36**	**42.12**	**---**	**39.7**	**39.4**	**40.4**	**---**

B- Total carbohydrates percentage in fruits:

Data presented in Table 6 showed that, zinc application at 50 ppm slightly increased total carbohydrates percentage in the fruits in the first season, while zinc application at 100 ppm decreased carbohydrates percentage compared with control. On the contrary, in the second season, zinc application at 100 ppm increased total carbohydrates percentage in the fruits, while zinc at 50 ppm decreased it.

Tryptophan at 50 ppm and methionine at 25 ppm increased total carbohydrates percentage in the fruits in the first season. In the second season both tryptophan at 50 and 100 ppm and methionine at 25 and 50 ppm increased total carbohydrates percentage in the fruits of caraway plants compared with untreated plants.

Interaction between zinc at 50 ppm and tryptophan at 50 ppm gave the highest total carbohydrates percentage in the first season. Whereas zinc application at 100 ppm plus methionine at 25 ppm gave the highest carbohydrates percentage in the second season.

C- Total carbohydrates percentage in the roots:

Data presented in Table 6 showed that zinc application at 50 and 100 ppm increased carbohydrate percentage in the roots in the first season. In the second season, zinc application at 100 ppm increased total carbohydrates percentage in the roots compared with the control plants which gave the lowest value.

Both amino acids (tryptophan at 50 and 100 ppm and methionine at 25 and 50 ppm) increased total carbohydrates percentage in the roots of caraway plants in both two seasons as compared with the untreated plants.

Interaction between zinc at 100ppm and tryptophan at 100 ppm gave the highest total carbohydrates percentage in both first and second seasons as compared with the control plants, which gave the lowest values in both two seasons.

Generally, it could be concluded that zinc application at 50 and 100 ppm increased total carbohydrates percentage in both leaves and roots in the first season, zinc at 50 ppm increased carbohydrates percentage in the fruits in the first season. While zinc application at 100 ppm increased total carbohydrates percentage in different plant organs (leaves, fruits and roots) in the second season. These results are in agreement with those obtained by Kassem (2002) on rosemary.

Amino acids (tryptophan and methionine) increased total carbohydrates percentage in leaves in the first season, in fruits and roots in both two seasons, but decreased total carbohydrates percentage in the leaves in the second season. These results are in harmony with those obtained by Milad (1998) who found that total carbohydrates percentage were increased in the leaves of *Mentha viridis*, *Mentha longifolia* and *Ocimum canum* by tryptophan at 25, 50 and 100 ppm.

Interaction between zinc at 50ppm and tryptophan at 50 ppm was the most effective treatment on increasing total carbohydrates percentage in both leaves and fruits. Zinc at 100 ppm or tryptophan at 100 ppm was the most effective treatment on total carbohydrates percentage in the roots in both seasons.

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تأثير الزنك والأحماض الأمينية علي النمو والمحصول والتركيب الكيماوي في نباتات الكراوية

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أجريت هذه الدراسة خلال موسمين متتاليين ٢٠٠٣ / ٢٠٠٤ ، ٢٠٠٤ / ٢٠٠٥ بمزرعة قسم بساتين الزينة – كلية الزراعة- جامعة القاهرة لدراسة تأثير الرش بالزنك بتركيزات صفر، ٥٠، ١٠٠ جزء في المليون وبعض الأحماض الأمينية، (التربتوفان بتركيز صفر، ٥٠، ١٠٠ جزء في المليون، المثيونين بتركيز صفر، ٢٥، ٥٠ جزء في المليون) علي النمو والمحصول وإنتاج الزيت والتركيب الكيماوي لنباتات الكراوية، وأوضحت النتائج مايلي:

- لم يكن هناك تأثير معنوي نتيجة الرش بالزنك بتركيزات ٥٠، ١٠٠ جزء في المليون علي ارتفاع النبات في الموسم الأول، وعدد الأفرع/ نبات والوزن الجاف/ للنبات وعدد النورات/ للنبات في كلا الموسمين.
- بينما أدي الرش بالزنك بتركيز ٥٠ جزء في المليون إلي زيادة معنوية في إرتفاع النبات والوزن الجاف/ للنبات في الموسم الثاني.
- الرش بالزنك بتركيزات ٥٠، ١٠٠ جزء في المليون أدي إلي زيادة معنوية في الوزن الطازج للنبات في كلا الموسمين، ومحصول الثمار/ نبات ومحصول الزيت/ نبات في الموسم الثاني، بينما أدي إلي زيادة غير معنوية في نسبة الزيت في كلا الموسمين.
- أدي الرش بالزنك بتركيزات ٥٠،١٠٠ جزء في المليون إلي نقص نسبة الليمونين وزيادة نسبة الكارفون في الزيت في كلا الموسمين، وزيادة الكربوهيدرات الكلية في الأوراق والجذور في الموسم الأول، بينما أدي الرش بالزنك بتركيز ٥٠ جزء في المليون إلي زيادة الكربوهيدرات الكلية في الثمار في الموسم الأول، بينما الزنك بتركيز ١٠٠ جزء في المليون أدي إلي زيادة نسبة الكربوهيدرات الكلية في الأوراق والثمار والجذور في الموسم الثاني.
- أدي الرش بالتربتوفان والمثيونين الي زيادة معنوية في الوزن الطازج والجاف/ نبات في كلا الموسمين. وكانت أكثر المعاملات تأثيرا هي المثيونين بتركيز ٥٠ جزء في المليون. أدي الرش بالتربتوفان والمثيونين بتركيز ٥٠ جزء في المليون إلي أعلي محصول ثمار/ نبات في الموسم الأول والثاني علي التوالي. أدي الرش بالأحماض الأمينية إلي زيادة غير معنوية في نسبة الزيت ومحصول الزيت في الموسم الأول. بينما أدي الرش بالمثيونين بتركيز ٢٥ جزء في المليون إلي نقص معنوي في نسبة الزيت في الموسم الثاني. أدي الرش بالمثيونين بالتركيز الأعلى (٥٠ جزء في المليون) إلي نقص في نسبة الليمونين وزيادة الكارفون في الزيت في كلا الموسمين. أدي الرش بالأحماض الأمينية (التربتوفان والمثيونين) إلي زيادة نسبة الكربوهيدرات الكلية في الأوراق في الموسم الأول، وفي الثمار والجذور في كلا الموسمين.

- أدي التفاعل بين الزنك والأحماض الأمينية إلي زيادة معنوية في معظم الصفات الخضرية ومحصول الثمار ونسبة الزيت ومحصول الزيت/ نبات. وزيادة نسبة الليمونين والكارفون في الزيت، ومحتوي النبات من الكربوهيدرات الكلية.