Response of Chia Seed Plants to Some Growth Stimulants and their Effects on Growth, Yield and Oil content.

Reem, M. Abd-El Raouf and Rasha M. Ashour

Medicinal and aromatic plants Research Department, Horticulture Research Institute, Agriculture. Research. Center, Egypt.

ABSTRACT

The present investigation was conducted at the nursery of ornamental plants, faculty of agriculture, Minia university, during the two growing seasons of October, 2020/2021 and 2021/2022, to determine the effect of soil application of humic acid at (0, 100, 200 and 400 ppm) and foliar application of vitamin E at (0, 25, 50 and100 ppm) as well as the control treatment on growth and yield of chia (*Salvia hispanica*, L.) plants.

The obtained data revealed that all concentrations of humic acid significantly increased all studied parameters: vegetative growth [plant height, stem diameter, total number of branches, and leaves/plant, leaf area and herb fresh and dry weight), yield components (number of inflorescences /plant, seeds yield /plant, feddan and 1000 seed weight) fixed oil productivity [fixed oil percentage and yield]and chemical constituents [NPK concentrations and photosynthetic pigments) as compared with control treatment. In this study, humic acid at 400 ppm was the most effective in this concern. Also, the same results were obtained with the treatments of vitamin E at different concentrations for the previous studied characters. The best treatment was 50 ppm.

The best interaction treatment for the highest yield of the chia plant was obtained with the treatment of humic acid at a 400 ppm combined with vitamin E at a concentration of 50 ppm.

Keywords: Humic acid, vitamin E, Salvia hispanica, vitamin E, seeds yield

INTRODUCTION

Chia plant (*Salvia hispanica*, L.) belongs to Lamiaceae family. It is native to the north of Guatemala and Central Mexico (Ayerza, 2010). Chia is an annual herbaceous plant, cultivated in tropical to sub-tropical areas. Chia seeds have long been used by the Aztec tribes. It is a macro-thermal short day plant grows in the tropical areas located between 20° 55’ N to 25° 05’ S (Sorondo 2014), its life cycle absolutely depending on the cultivated area latitude (Coates 2011). The ideal temperature for chia growth and development is between 14 and 20°C (Ayerza 2010). They are important not only as food, but also for medicines and paints. The seeds contain minerals, carbohydrates, protein, oils (fixed and essential) and α-linolenic acid. Also, it has a high percentage of fibre, protein, Omega-3, Omega-6 and essential fatty acids (Ayerza, and Coates, 1999), vitamins (A, B, K, E, D) (Grancieri, et al. 2019), (Das, A 2018). It is gaining popularity in Africa because it is considered as a good nutritional and healthy food (Ayerza and Coates, 2002), source of polyphenolic antioxidants, amino acids and particularly lysine and antimicrobial activity (Ullah, et al. 2016), (Hrnčič et al. 2019).

Improvement plant growth in response to humic acid application appears not only to be related to the nutrient content of humic acid directly but also to interactions of humic acid with plant membrane transporters responsible for nutrient uptake and membrane associated signal transduction cascades which regulate growth and development (Canellas et al. 2015). Many author’s investigate the role of humic acid on medicinal plants (Jamali et al.

2015), (Mahsa et al. 2015), (Taghipour et al. 2017), (Hassan 2019), (Karimian et al. 2019), (Abou El-Ghait et al. 2021), (Prasanna et al. 2021a and b), (Massoud et al. 2022) and (Mirzapour et al. 2022).

Tocopherols are chemically lipophilic compounds/antioxidants well known as vitamin E family. Tocopherols play an important role in plant growth, phytohormonal balance, signal transduction, senescence and abscission, as well as in many other metabolic processes (Niki and Abe, 2019 and Sadiq et al. 2019). Many studies concluded that exogenous application of vitamin E had improved plant growth and productivity such as Soltani et al., 2012 on Calendula; Abdou et al., 2019a and b on cumin; Ayyat et al. (2021) on black cumin and Mohamed et al. (2022) on fennel.

Therefore, the aim of this study was to evaluate the effect of humic acid and vitamin E treatments on growth and productivity of chia plants.

MATERIALS AND METHODS

The current study was conducted at the nursery of ornamental plants, Faculty of Agriculture, Minia University during the two successive seasons of 2020/2021 and 2021/2022

Plants material:

Seeds of chia plant were obtained from Sekam Company, Egypt.

Layout of the investigation:

The randomized complete block design in a split-plot design with three replicates was used. The main plots (A) included four levels of humic acid, while, the sub-plots (B) involved four levels of vitamin E. Therefore, the study including 16 interaction treatments (A x B). The physical and chemical analyses of the used soil are listed in Table (1). Seeds of chia were sown at the Mid of October (15th October), during both seasons. Seeds were directly sown in hills at the rate of 5 seeds/hill with 50 cm between hills (thinned to2 plants/hill, after complete germination) and 50 cm between rows. The unit area plot was 10 m2 (2 m x 5 m) containing 60 plant.

Table (1): Physical and chemical properties of the used soil before planting of chia during 2020/2021 and 2021/2022 seasons.

Soil characters	Values		Soil characters	Values	
	2020/2021	2021/2022		2020/2021	2021/2022
Physical properties:			**Exchangeable nutrients:**		
Sand (%)	27.88	26.70	**Ca^{++} (mg/100 g soil)**	28.11	28.93
Silt (%)	29.87	30.64	**Mg^{++} (mg/100 g soil)**	4.55	4.75
Clay (%)	42.25	42.66	**Na^{+} (mg/100 g soil)**	2.79	2.73
Soil type	Clay loam	Clay loam	**K^{+} (mg/100 g soil)**	2.96	2.75
Chemical properties:			**DTPA-Extractable nutrients:**		
pH (1:2.5 paste)	7.89	7.83	**Fe (ppm)**	7.91	7.79
E.C. (dS/m)	1.13	1.11	**Cu (ppm)**	1.80	1.75
O.M. %	1.25	1.30	**Zn (ppm)**	2.45	2.46
$CaCO_3$ %	2.05	2.06	**Mn (ppm)**	7.68	7.82

Treatments:

Main plot treatments (A):

Four concentrations of humic acid, namely, 0, 100, 200 and 400 ppm /L. Humic acid (Humic King product of Egyptian Spain company, Egypt), were applied as soil drench, three times starting from 25th November with one month intervals, in both seasons.

Sub-plot treatments (B):

Four levels of vitamin E, namely, 0, 25, 50 and 100 ppm (supplied from Sigma company) were sprayed 3 times on the same schedule of humic acid.

All treatments other agricultural practices were carried out as usual for chia cultivation.

Harvesting time:

At the end of the experiments. (first week of April in both seasons), the plants were harvested after the appearance symptoms of physiological maturity by cutting the vegetative growth (aerial parts),10cm above the ground.

Data recorded:

Morphological parameters: plant height (cm), stem diameter (mm), number of branches, and leaves/plant, leaf area (cm2) and herb fresh and dry weights/plant (g).

Yield characteristics: number of inflorescences/plant, seeds weight/plant (g), seeds yield/feddan (kg) and seed index, weight of 1000 seeds (gm)

Fixed oil productivity: fixed oil (%), fixed oil yield/plant (ml) and fixed oil /fed (L).

Chemical composition: photosynthetic pigments [chlorophyll a, b &carotenoids] (mg/g f. w.) and NPK (%).

Laboratory analysis:

1. Photosynthetic pigments determination:

Chlorophyll a, b and carotenoids contents were colorimetrically determined in the chia leaves samples (mg/g fresh weight) after three weeks of the last treatment in both seasons, according to the method of Fadl and Sari El-Deen (1978). Fresh samples of leaves (0.5 g) were homogenized with acetone (85 % v/v) in the presence of little amount of $Ca2CO3$ and silica quartz, then filtered through centered glass funnel (G4), the residue was washed several times with acetone until the filtrate became colorless, the combined extract was completed to a known volume (10 ml), a portion of this extract was taken for the colorimetric determination of pigments using the following equations:

Chlorophyll a = (9.784 x E 662) – (0.99 x E 644) = mg/g f.wt.

Chlorophyll b = (21.426 x E 644) – (4.65 x E 662) = mg/g f.wt.

Carotenoids = (4.695 x E 440.5) – 0.268 (E 662 - E 644) = mg/g f.wt.

Where: E the optical density of given wave length.

2. Nitrogen, phosphorus and potassium determination (%):

Samples of chia herbs were taken randomly from each replicate for every treatment and washed several times with tab water then followed by distilled water. The herbs were oven dried at 70 ^{o} C till constant weight. The dried samples were ground in plant mill to fine powder and sieved to pass through a 0.5 mm screen. The dried and ground matter was mixed thoroughly and a sub sample was taken and analyzed for nitrogen, phosphorus and potassium. A 0.2 g of fine powder was taken and digested by a mixture of hydrogen peroxide (H_2O_2) and sulphoric acid (H_2SO_4) (ratio of 4:10) using the Digestor (Buchi, speed digestor, model: K - 425 Digestion unit). The clear digestion was complete quantively to 100 ml volumetric flask. In this solution, nitrogen, phosphorus and potassium contents were determined according to the methods described by ICARDA (2013).

3. Fixed oil determination (%):

Fixed oil percentage in the seed was estimated according to A.O.A.C (1980). The fixed oil was extracted from the seed samples using a Soxhlet apparatus, 2.0 g of each sample was taken and put in a thimble (Whatman), where the extraction chamber filled with separately 4 samples, after grinding rough with the addition of 250 ml of the solvent (Hexane) and filled the device for 4 hours. Then the fixed oil percentage was calculated as a difference between the sample weight before and after extraction process.

Fixed oil % = [(Sample weight before extraction "2g" - sample weight after extraction/ sample weight before extraction "2 g") x 100

Also, the fixed oil %, yield/plant and fixed oil/fed. were calculated., according to plant density

Statistical analysis

The obtained data are statistically analyzed by using MSTAT–C (1986). Differences between means were determined using the Least Significant Difference (L.S.D.0.05) test.

RESULTS

1. Vegetative Characteristics:

The data presented in Tables (2 and 3) clearly show that all concentrations of humic acid led to a significant increase in all vegetative growth parameters as compared to untreated plants in both seasons. Also, the increase in above mentioned parameters was in parallel with the increase in humic acid concentration. So, the highest concentration (400 ppm) was significantly superior than that of 200 ppm concentration, except with the total number of branches, number of leaves and herb fresh and dry weights/plant, in both seasons.

The improvement role of humic acid was emphasized by Hanafy et al. (2018) on marjoram; Mohamed and Ghatas (2020), Abou El-Ghait et al. (2021) and Prasanna et al. (2021a and b) on chia plant; Massoud et al. (2022) on basil; Mirzapour et al. (2022) on thyme; and Ghaderimokri et al. (2022) on fennel.

As for vitamin E concentration treatments, data listed in Tables (2 and 3) clear that all treatments of alpha tocopherol significantly increased the above mentioned parameters, except, in the case of stem diameter under the dose of at 100 ppm, in both seasons. It is noticed that vitamin E at 50 ppm was superior to the other two treatments of 25 or 100 ppm in all cases.

The results of the effect of vitamin E on the vegetative growth parameters are in a similar pattern with those obtained by Soltani et al., 2012 on Calendula, Abdou et al., 2019a on cumin; Ayyat et al., 2021 on black cumin and Mohamed et al. (2022) on fennel.

The interaction effect between humic acid and alpha tocopherol treatments was significant for vegetative growth parameters in both seasons. The highest values for chia plant height were due to the application humic acid at 400 ppm in combination with vitamin E at 50 or 100 ppm, in both seasons. While, the best interaction treatment for stem diameter was humic acid at 400 ppm in combination with vitamin E at 50 ppm. Moreover, the superior interaction treatment overall were humic acid at 400 or 200 ppm in combination with vitamin E at 50 ppm for total number of branches/plant, number of leaves/plant, leaf area and herb fresh and dry weights.

Table (2): Effect of humic acid and vitamin E and their interactions on some vegetative growth parameters of chia plant in the two growing seasons (2020/2021 and 2021/2022).

Vitamin E	Humic acid (ppm) (A)

concentrations (ppm) (B)	0.0	100	200	400	Mean (B)	0.0	100	200	400	Mean (B)
	The 1st season (2020/2021)					The 2nd season (2021/2022)				
Plant height (cm)										
Control (Without)	53.67	58.00	76.00	84.00	**67.92**	64.40	69.60	91.20	100.80	**81.50**
Vit. E at 25 ppm	64.00	66.70	85.00	89.30	**76.25**	77.44	80.71	102.85	108.05	**92.26**
Vit. E at 50 ppm	72.40	73.70	88.80	102.70	**84.40**	88.33	89.91	108.34	125.29	**102.97**
Vit. E at 100 ppm	65.00	69.00	73.30	101.30	**77.15**	78.00	82.80	87.96	121.56	**92.58**
Mean (A)	**63.77**	**66.85**	**80.78**	**94.33**		**77.04**	**80.76**	**97.59**	**113.93**	
L.S.D. at 5 %	**A: 3.01**		**B: 1.80**		**AB: 3.60**	**A: 3.55**		**B: 1.94**		**AB: 3.88**
Stem diameter (mm)										
Control (Without)	2.81	3.22	3.54	3.75	**3.33**	2.89	3.30	3.62	3.88	**3.42**
Vit. E at 25 ppm	3.02	3.43	3.64	3.85	**3.49**	3.11	3.52	3.75	3.96	**3.59**
Vit. E at 50 ppm	3.21	3.62	4.13	4.52	**3.87**	3.32	3.74	4.22	4.62	**3.98**
Vit. E at 100 ppm	3.00	3.34	3.55	3.77	**3.42**	3.07	3.44	3.68	3.81	**3.50**
Mean (A)	**3.01**	**3.40**	**3.72**	**3.97**		**3.10**	**3.50**	**3.82**	**4.07**	
L.S.D. at 5 %	**A: 0.22**		**B: 0.16**		**AB: 0.32**	**A: 0.25**		**B: 0.17**		**AB: 0.34**
Total number of branches										
Control (Without)	21.24	31.64	36.16	37.52	**31.64**	23.78	35.44	40.50	42.04	**35.44**
Vit. E at 25 ppm	27.12	33.00	43.84	45.20	**37.29**	31.19	37.97	50.44	51.98	**42.89**
Vit. E at 50 ppm	40.68	45.20	48.82	49.72	**46.10**	48.82	54.24	58.58	59.66	**55.32**
Vit. E at 100 ppm	36.16	43.39	44.30	45.20	**42.26**	40.86	49.04	50.04	51.08	**47.75**
Mean (A)	**31.30**	**38.31**	**43.28**	**44.41**		**36.16**	**44.17**	**49.89**	**51.19**	
L.S.D. at 5 %	**A: 3.66**		**B: 1.92**		**AB: 3.84**	**A: 3.85**		**B: 2.01**		**AB: 4.02**
Number of leaves/plant										
Control (Without)	51.70	77.00	88.00	91.30	**77.00**	54.80	81.62	93.28	96.78	**81.62**
Vit. E at 25 ppm	68.40	83.22	110.58	114.00	**94.05**	75.24	91.54	121.64	125.40	**103.46**
Vit. E at 50 ppm	106.20	118.00	127.44	129.80	**120.36**	144.43	160.48	173.32	176.53	**163.69**
Vit. E at 100 ppm	92.00	110.40	112.70	115.00	**107.53**	100.28	120.34	122.84	125.35	**117.20**
Mean (A)	**79.58**	**97.16**	**109.68**	**112.53**		**93.69**	**113.49**	**127.77**	**131.01**	
L.S.D. at 5 %	**A: 5.11**		**B: 3.04**		**AB: 6.08**	**A: 6.18**		**B: 3.10**		**AB: 6.20**

Table (3): Effect of humic acid and vitamin E and their interactions on some vegetative growth parameters of chia plant in the two growing seasons (2020/2021 and 2021/2022).

Vitamin E concentrations (ppm) (B)	Humic acid (ppm) (A)									
	0.0	100	200	400	Mean (B)	0.0	100	200	400	Mean (B)
	The 1st season (2020/2021)					The 2nd season (2021/2022)				
Leaf area (cm^2)										
Control (Without)	6.40	7.04	7.74	8.51	**7.42**	6.50	7.14	7.91	8.88	**7.61**
Vit. E at 25 ppm	7.98	8.86	9.84	10.94	**9.41**	8.09	8.95	10.08	11.36	**9.62**
Vit. E at 50 ppm	8.02	9.92	10.93	11.05	**9.98**	8.15	10.05	11.09	11.38	**10.17**
Vit. E at 100 ppm	7.73	8.50	9.35	10.39	**8.99**	7.95	8.88	10.00	11.12	**9.49**
Mean (A)	**7.53**	**8.58**	**9.47**	**10.22**		**7.67**	**8.76**	**9.77**	**10.69**	
L.S.D. at 5 %	**A:0.51**		**B: 0.22**		**AB: 0.44**	**A: 0.55**		**B: 0.25**		**AB: 0.50**
Herb fresh weight/plant (g)										
Control (Without)	261.40	389.46	445.20	462.10	**389.54**	290.21	432.62	494.51	513.43	**432.69**
Vit. E at 25 ppm	333.77	406.20	539.76	556.68	**459.10**	380.64	463.50	615.87	634.83	**523.71**
Vit. E at 50 ppm	500.65	556.37	601.07	612.35	**567.61**	595.80	662.11	715.26	728.63	**675.45**
Vit. E at 100 ppm	445.02	534.09	545.42	556.68	**520.30**	498.66	598.63	610.99	623.84	**583.03**
Mean (A)	**385.21**	**471.53**	**532.86**	**546.95**		**441.33**	**539.21**	**609.16**	**625.18**	
L.S.D. at 5 %	**A: 14.45**		**B: 5.64**		**AB: 11.28**	**A: 16.51**		**B: 6.69**		**AB: 13.38**
Herb dry weight/plant (g)										
Control (Without)	66.40	98.92	113.08	117.37	**98.94**	73.71	109.89	125.61	130.41	**109.90**
Vit. E at 25 ppm	84.78	103.17	137.10	141.40	**116.61**	96.68	117.73	156.43	161.25	**133.02**
Vit. E at 50 ppm	125.66	141.32	155.68	157.99	**145.16**	136.09	153.04	168.58	171.07	**157.20**
Vit. E at 100 ppm	111.70	135.66	141.26	143.62	**133.06**	113.90	138.37	144.01	146.46	**135.68**
Mean (A)	**97.13**	**119.77**	**136.78**	**140.09**		**111.28**	**136.96**	**156.38**	**160.15**	
L.S.D. at 5 %	**A: 5.33**		**B: 2.05**		**AB: 4.10**	**A: 6.01**		**B: 2.24**		**AB: 4.48**

2. Yield characteristics:

Data recorded in Table (4) clear that yield characteristics [number of inflorescences/plant, seeds weight/plant (g), seeds yield/feddan (kg) and weight of 1000 seeds weight (g)] were significantly increased by all concentration treatments of humic acid aganist the control one, in both seasons. Ascending increased in previos four characters with the increase in humic concentrations. So, the greatest number of inflorescences/plant (43.52 in the first season and 49.65 in the second one) and the heaviest seed yield/fed. (224.22g in the first season and 228.63g in the second one)

over the control were obtained from the highest humic acid concentration (400 ppm).

Humic acid is essential for plant growth and productivity as reported by Al-Dalain et al. (2013) on thyme; Mostafa (2015) on fenugreek; Ariafar and Forouzandeh (2017) on black cumin; Mohamed and Ghatas (2020), Abou El-Ghait et al. (2021) and Prasanna et al. (2021a and b) on chia plant; Massoud et al. (2022) on basil; Aly et al. (2022) on anise; and Ghaderimokri et al. (2022) on fennel.

Regarding the impact of vitamin E concentration treatments, data presented in Table (4) reveal that all above mentioned parameters of yield were significantly increased due to all treatments of alpha tocopherol in both seasons. It could be noticed that vitamin E at 50 ppm was superior followed by100 ppm, and the 25 ppm in all cases.

Similar results were obtained by Abdou et al. (2019a) on cumin, Ayyat et al. (2021) on black cumin and Mohamed et al. (2022) on fennel.

The interaction effect between humic acid and vitamin E treatments was significant for the number of inflorescences/plant, seeds weight/plant, seeds yield/feddan and 1000 seeds weight. The highest values for all yield components of chia were resulted from soil application with 400 or 200 ppm of humic acid in combination with vitamin E at 50 ppm, in both seasons.

Table (4): Effect of humic acid and vitamin E and their interactions on some yield components of chia plant in the two growing seasons (2020/2021 and 2021/2022).

Vitamin E concentrations (ppm) (B)	Humic acid concentrations (ppm) (A)									
	0.0	100	200	400	Mean (B)	0.0	100	200	400	Mean (B)
	The 1st season (2020/2021)					The 2nd season (2021/2022)				
	Number of inflorescences/plant									
Control (Without)	20.18	30.37	35.08	36.77	**30.60**	22.12	33.67	38.88	40.78	**33.86**
Vit. E at 25 ppm	25.76	31.68	42.52	44.30	**36.07**	29.01	36.07	48.42	50.42	**40.98**
Vit. E at 50 ppm	38.65	43.39	47.36	48.73	**44.53**	45.40	51.53	56.24	57.87	**52.76**
Vit. E at 100 ppm	34.35	41.65	42.97	44.30	**40.82**	38.00	46.59	48.04	49.55	**45.54**
Mean (A)	**29.74**	**36.78**	**41.98**	**43.52**		**33.63**	**41.96**	**47.89**	**49.65**	
L.S.D. at 5 %	**A: 1.54**		**B: 0.69**		**AB: 1.38**	**A: 1.76**		**B: 0.83**		**AB: 1.66**
	Seeds weight /plant (g)									
Control (Without)	3.12	5.13	7.14	8.15	**5.89**	3.15	5.34	7.35	8.31	**6.04**
Vit. E at 25 ppm	5.12	6.14	7.15	8.17	**6.65**	5.17	6.39	7.36	8.33	**6.81**
Vit. E at 50 ppm	7.15	8.16	9.17	10.16	**8.66**	7.22	8.49	9.45	10.36	**8.88**
Vit. E at 100 ppm	6.11	7.10	8.11	9.11	**7.61**	6.17	7.38	8.35	9.29	**7.80**
Mean (A)	**5.38**	**6.63**	**7.89**	**8.90**		**5.43**	**6.90**	**8.13**	**9.08**	
L.S.D. at 5 %	**A: 0.91**		**B: 0.50**		**AB: 1.0**	**A: 0.93**		**B: 0.46**		**AB: 0.92**
	Seeds yield/feddan (kg)									
Control (Without)	78.62	129.28	179.93	205.38	**148.30**	79.38	134.57	185.22	209.41	**152.15**
Vit. E at 25 ppm	129.02	154.73	180.18	205.88	**167.45**	130.28	161.03	185.47	209.92	**171.68**
Vit. E at 50 ppm	180.18	205.63	231.08	256.03	**218.23**	181.94	213.95	238.14	261.07	**223.78**
Vit. E at 100 ppm	153.97	178.92	204.37	229.57	**191.71**	155.48	185.98	210.42	234.11	**196.50**
Mean (A)	**135.45**	**167.14**	**198.89**	**224.22**		**136.77**	**173.88**	**204.81**	**228.63**	
L.S.D. at 5 %	**A: 22.33**		**B: 12.48**		**AB: 24.96**	**A: 23.45**		**B: 12.55**		**AB: 25.10**
	Weight of 1000 seeds (g)									
Control (Without)	1.03	1.09	1.14	1.18	**1.11**	1.04	1.09	1.14	1.18	**1.11**
Vit. E at 25 ppm	1.06	1.12	1.17	1.21	**1.14**	1.08	1.13	1.18	1.22	**1.15**
Vit. E at 50 ppm	1.10	1.16	1.20	1.24	**1.18**	1.12	1.17	1.21	1.26	**1.19**
Vit. E at 100 ppm	1.07	1.13	1.17	1.21	**1.15**	1.09	1.14	1.19	1.23	**1.16**
Mean (A)	**1.07**	**1.13**	**1.17**	**1.21**		**1.08**	**1.13**	**1.18**	**1.22**	
L.S.D. at 5 %	**A: 0.03**		**B: 0.02**		**AB: 0.04**	**A: 0.04**		**B: 0.02**		**AB: 0.04**

3. Fixed oil productivity:

The fixed oil parameters including fixed oil percentage, oil yield/plant and oil yield/ feddan for all spraying treatments during two seasons are shown in Table (5) Available results show the significant influence of humic acid treatments on the investigated traits. Humic acid concentration at 400 ppm was superior to other used treatments as it gave 30.80%, 2.75 ml/plant and 69.3 l/fed. in the first season, respectively, and 31.03%, 2.826 ml/plant and 71.209 L/fed. in the second one, respectively

Humic acid is a promising natural resource to improve crop production as mentioned by Aiyafar et al. (2015) and Ariafar and Forouzandeh (2017) on black cumin; Mostafa (2015) and Zulfiqar et al. (2019) on fenugreek, Mohamed and Ghatas (2020) and Abou El-Ghait et al. (2021) on chia plant,

Concerning the impact of vitamin E on oil productivity, data presented in Table (5) showed that all used treatments of alpha tocopherol significantly augmented fixed oil productivity facing the control in both seasons, gave Vitamin E at 50 ppm. the highest values (28.07 and 28.32%, 2.472 and 2.558 ml, and 62.282 and 64.462 l for fixed oil (%), yield/plant and /fed. in the first and second seasons, respectively.

Similar results were obtained by Ayyat et al. (2021) on black cumin.

The interaction effect between humic acid and vitamin E treatments was significant for fixed oil (%), yield/plant and /fed. The highest values were produced from soil application with 400 ppm of humic acid in combination with vitamin E at 50 ppm, followed by 100 ppm, in both seasons.

Table (5): Effect of humic acid and vitamin E and their interactions on fixed oil productivity of chia plant in the two growing seasons (2020/2021 and 2021/2022).

Vitamin E concentrations (ppm) (B)	Humic acid concentrations (ppm) (A)									
	0.0	100	200	400	Mean (B)	0.0	100	200	400	Mean (B)
	The 1st season (2020/2021)					The 2nd season (2021/2022)				
	Fixed oil (%)									
Control (Without)	18.34	24.63	26.85	28.81	**24.66**	18.47	24.80	27.04	29.01	**24.83**
Vit. E at 25 ppm	20.15	25.22	28.36	30.41	**26.04**	20.31	25.42	28.59	30.65	**26.24**
Vit. E at 50 ppm	22.29	27.68	29.88	32.41	**28.07**	22.49	27.93	30.15	32.70	**28.32**
Vit. E at 100 ppm	21.19	26.71	28.66	31.55	**27.03**	21.34	26.90	28.86	31.77	**27.22**
Mean (A)	**20.49**	**26.06**	**28.44**	**30.80**		**20.65**	**26.26**	**28.66**	**31.03**	
L.S.D. at 5 %	**A: 1.36**		**B: 1.21**		**AB: 2.42**	**A: 1.75**		**B: 0.88**		**AB: 1.76**
	Fixed oil yield/plant (ml)									
Control (Without)	0.572	1.264	1.917	2.348	**1.525**	0.582	1.324	1.987	2.411	**1.576**
Vit. E at 25 ppm	1.032	1.549	2.028	2.485	**1.774**	1.050	1.624	2.104	2.553	**1.833**
Vit. E at 50 ppm	1.594	2.259	2.740	3.293	**2.472**	1.624	2.371	2.849	3.388	**2.558**
Vit. E at 100 ppm	1.295	1.896	2.324	2.874	**2.097**	1.317	1.985	2.410	2.951	**2.166**
Mean (A)	**1.123**	**1.742**	**2.252**	**2.750**		**1.143**	**1.826**	**2.338**	**2.826**	
L.S.D. at 5 %	**A: 0.421**		**B: 0.271**		**AB: 0.542**	**A: 0.451**		**B: 0.292**		**AB: 0.584**
	Fixed oil yield/feddan (L)									
Control (Without)	14.414	31.853	48.308	59.170	**38.436**	14.666	33.365	50.072	60.757	**39.715**
Vit. E at 25 ppm	26.006	39.035	51.106	62.622	**44.692**	26.460	40.925	53.021	64.336	**46.185**
Vit. E at 50 ppm	40.169	56.927	69.048	82.984	**62.282**	40.925	59.749	71.795	85.378	**64.462**
Vit. E at 100 ppm	32.634	47.779	58.565	72.425	**52.851**	33.188	50.022	60.732	74.365	**54.577**
Mean (A)	**28.306**	**43.898**	**56.757**	**69.300**		**28.810**	**46.015**	**58.905**	**71.209**	
L.S.D. at 5 %	**A: 7.660**		**B: 5.330**		**AB: 10.660**	**A: 8.110**		**B: 5.512**		**AB: 11.024**

4. Chemical composition:

4.1. Photosynthetic pigments (mg/g f.w.):

Data presented in Table (6) demonstrate that all concentrations of humic acid significantly increased the content of chlorophyll a, b and carotenoids in both seasons as compared with the control treatment. The high contents were obtained with humic acid concentration at 400 ppm.

Humic acid is a promising natural resource to improve crop production as mentioned by El-Khateeb et al. (2017) on marjoram and Abou El Salehein et al. (2021) on basil Mohamed and Ghatas (2020) on chia plant,

Regarding the effect of vitamin E, Data illustrated in Table (6) reveal that all used concentrations of vitamin E resulted in significant increase in these parameters (chlorophyll a, b and carotenoids) facing the control in both seasons, with superiority for the meddle concentration of vitamin E at 50 ppm.

The positive role of vitamin E in enhancement the pigments was emphasized by Ismail (2008) and Ayyat et al. (2021) on black cumin, Soltani et al. (2012) on Calendula, Abdou et al. (2019 b) on cumin.

The interaction effect of humic acid and vitamin E treatments was significant for chlorophyll a, b and carotenoids in both seasons. The highest values were produced from the soil application with 400 ppm of humic acid in combination with vitamin E at 50 ppm, followed by 200 ppm of humic acid with 50 ppm, in both seasons.

Table (6): Effect of humic acid and vitamin E and their interactions on photosynthetic pigments of chia plant in the two growing seasons (2020/2021 and 2021/2022).

Vitamin E concentrations (ppm) (B)	Humic acid concentrations (ppm) (A)									
	0.0	100	200	400	Mean (B)	0.0	100	200	400	Mean (B)
	The 1st season (2020/2021)					The 2nd season (2021/2022)				
Chlorophyll a (mg/g f. w.)										
Control (Without)	2.418	2.845	2.879	2.899	**2.760**	2.431	2.863	2.892	2.914	**2.775**
Vit. E at 25 ppm	2.858	2.897	2.928	2.949	**2.908**	2.876	2.914	2.943	2.962	**2.924**
Vit. E at 50 ppm	2.997	3.037	3.068	3.080	**3.046**	3.013	3.054	3.085	3.096	**3.062**
Vit. E at 100 ppm	2.867	2.918	2.931	2.920	**2.909**	2.882	2.933	2.943	2.936	**2.924**
Mean (A)	**2.785**	**2.924**	**2.952**	**2.962**		**2.801**	**2.941**	**2.966**	**2.977**	
L.S.D. at 5 %	**A: 0.022**		**B: 0.011**		**AB: 0.022**	**A: 0.025**		**B: 0.013**		**AB: 0.026**
Chlorophyll b (mg/g f. w.)										
Control (Without)	0.786	0.928	0.940	0.951	**0.901**	0.79	0.934	0.944	0.958	**0.907**
Vit. E at 25 ppm	0.933	0.946	0.956	0.968	**0.951**	0.939	0.951	0.961	0.975	**0.957**
Vit. E at 50 ppm	0.979	0.992	1.003	1.012	**0.997**	0.984	0.998	1.008	1.019	**1.002**
Vit. E at 100 ppm	0.936	0.953	0.957	0.958	**0.951**	0.941	0.958	0.961	0.966	**0.957**
Mean (A)	**0.909**	**0.955**	**0.964**	**0.972**		**0.914**	**0.960**	**0.969**	**0.980**	
L.S.D. at 5 %	**A: 0.008**		**B: 0.005**		**AB: 0.010**	**A: 0.009**		**B: 0.006**		**AB: 0.012**
Carotenoids (mg/g f. w.)										
Control (Without)	0.826	0.968	0.980	0.986	**0.940**	0.830	0.974	0.984	0.999	**0.947**
Vit. E at 25 ppm	0.973	0.986	0.996	1.003	**0.990**	0.979	0.991	1.001	1.015	**0.997**
Vit. E at 50 ppm	1.019	1.032	1.043	1.047	**1.035**	1.024	1.038	1.048	1.060	**1.043**
Vit. E at 100 ppm	0.976	0.993	0.997	0.993	**0.990**	0.981	0.998	1.001	1.007	**0.997**
Mean (A)	**0.949**	**0.995**	**1.004**	**1.007**		**0.954**	**1.000**	**1.009**	**1.020**	
L.S.D. at 5 %	**A: 0.008**		**B: 0.003**		**AB: 0.006**	**A: 0.009**		**B: 0.007**		**AB: 0.014**

4.2. Nitrogen, phosphorus and potassium (%):

The effect of humic acid and vitamin E treatments on contents of N, P and K in dry herb of chia plants is shown in Table (7). This experiment demonstrated that all humic acid treatments significantly improved the contents of N, P and K % (d. w.) in dry herb in both seasons comparing with the control treatment. The high contents were obtained with humic acid concentration at 400 ppm.

Humic acid is a promising natural resource to improve crop production as mentioned by El-Khateeb et al. (2017) on marjoram and Abou El Salehein et al. (2021) on basil; Mohamed and Ghatas (2020) and Abou El-Ghait et al. (2021) on chia plant.

In respect to the effect of vitamin E treatments, as illustrated in Table (7), all used concentrations of vitamin E significantly succeeded in increasing the percentages of N, P and K facing the control in both seasons. The high values of N, P and K were produced by the concentration of 50 ppm.

The positive role of vitamin E in enhancement the pigments was obtained by Ismail (2008) and Ayyat et al. (2021) on black cumin, Abdou et al. (2019 b) on cumin.

The interaction effect between humic acid and vitamin E treatments was significant for N, P and K % in both seasons. The highest values were obtained from the combination of soil application of 400 ppm of humic acid + vitamin E at 50 ppm, in both seasons.

Table (7): Effect of humic acid and vitamin E and their interactions on N, P and K % in dried herb of chia plant in the two growing seasons (2020/2021 and 2021/2022).

Vitamin E concentrations (ppm) (B)	Humic acid concentrations (ppm) (A)									
	0.0	100	200	400	Mean (B)	0.0	100	200	400	Mean (B)
	The 1st season (2020/2021)					The 2nd season (2021/2022)				
	Nitrogen (%)									
Control (Without)	1.65	1.69	1.74	1.80	**1.72**	1.70	1.74	1.79	1.85	**1.77**
Vit. E at 25 ppm	1.92	1.96	2.01	2.07	**1.99**	2.02	2.06	2.11	2.17	**2.09**
Vit. E at 50 ppm	2.03	2.08	2.12	2.18	**2.10**	2.21	2.27	2.31	2.38	**2.29**
Vit. E at 100 ppm	1.94	1.99	2.03	2.09	**2.01**	2.08	2.13	2.17	2.24	**2.15**
Mean (A)	**1.89**	**1.93**	**1.98**	**2.04**		**2.00**	**2.05**	**2.10**	**2.16**	
L.S.D. at 5 %	**A: 0.04**		**B: 0.02**		**AB: 0.04**	**A: 0.05**		**B: 0.03**		**AB: 0.06**
	Phosphorus (%)									
Control (Without)	0.214	0.220	0.224	0.230	**0.222**	0.220	0.227	0.231	0.237	**0.229**
Vit. E at 25 ppm	0.236	0.242	0.248	0.246	**0.243**	0.248	0.254	0.260	0.258	**0.255**
Vit. E at 50 ppm	0.245	0.251	0.256	0.262	**0.254**	0.267	0.274	0.279	0.286	**0.276**
Vit. E at 100 ppm	0.238	0.243	0.249	0.254	**0.246**	0.255	0.260	0.266	0.272	**0.263**
Mean (A)	**0.233**	**0.239**	**0.244**	**0.248**		**0.247**	**0.254**	**0.259**	**0.263**	
L.S.D. at 5 %	**A: 0.004**		**B: 0.002**		**AB: 0.004**	**A: 0.004**		**B: 0.003**		**AB: 0.006**
	Potassium (%)									
Control (Without)	1.57	1.62	1.67	1.73	**1.65**	1.62	1.67	1.72	1.78	**1.70**
Vit. E at 25 ppm	1.69	1.73	1.79	1.85	**1.77**	1.77	1.82	1.88	1.94	**1.85**
Vit. E at 50 ppm	1.78	1.83	1.88	1.94	**1.86**	1.94	1.99	2.05	2.11	**2.02**
Vit. E at 100 ppm	1.71	1.75	1.81	1.86	**1.78**	1.83	1.87	1.94	1.99	**1.91**
Mean (A)	**1.69**	**1.73**	**1.79**	**1.85**		**1.79**	**1.84**	**1.90**	**1.96**	
L.S.D. at 5 %	**A: 0.03**		**B: 0.02**		**AB: 0.04**	**A: 0.05**		**B: 0.02**		**AB: 0.04**

DISCUION

Humic acid caused an increase in activity of root growth parameters such as auxins, which in turn is reflected in the improvement of growth of plant during all stages, and leaf pigments (Hassan, 2019; Karimian et al., 2019; Abou El-Ghait et al., 2021; Prasanna et al., 2021a and b; Massoud et al. 2022 and Mirzapour et al. 2022). The increase in the leaf content of total chlorophyll, which is a biochemical characteristic, is due to the role of humic acid in increasing the permeability of the cell wall of root cells and increasing the absorption of elements such as magnesium, which play an important role in the construction of the chlorophyll molecule (Mohammed et al.1982)

The significant increase in most of vegetative traits such as plant height, leaf weight, vegetative growth and root weight may be due to the important role of humic acid in improving soil texture, facilitating the availability of nutrients to the plant and increasing the soil's ability to retain water (Fliessbach et al. 2000).

The increase in seed yield in this study may be attributed to the availability of nutrients by the addition of humic acid.

The significant increase in the percentage of fixed oil in response to humic acid application was discussed by (Zahra et al.1984) who indicated that the main component of humic acid is potassium and this element is important for the effectiveness of 60 types of enzymes and it affects the metabolism of nitrogen and carbohydrates and the formation of fats.

Also, vitamin E plays an important role in plant growth, phytohormonal balance, increasing chlorophylls and plant productivity (Desel et al. 2007 and Arrom and Munné-Bosch, 2010).the application of α-tocopherol led to increase in seed yield. So the response to α-tocopherol is mainly due to its on protein synthesis and delaying senescence or might be related to increase in photosynthetic products. (Sadak et al. 2010). Tocopherols are believed to protect chloroplast membranes from photooxidation and provide an optimal environment for the photosynthetic machinery (Munne-Bosch and Algere, 2002).

The highest increase in vegetative growth parameters are in harmony with that reported by (Abdou et al. 2019a) who showed that the application of alpha tocopherol improved vegetative growth and increased the number of flowers and seeds, which is reflected positively on the seed yield.

On the other hand, the increment in the weight and size of the vegetative growth resulting from the use of humic acid can be attributed to the availability of nutrients due to the use of humic acid which lead to a larger photosynthesis. The results of our study are in agreement with (Soliman, 2011).

In general, it could be summarized that the beneficial roles of humic acid and vitamin E were responsible for improving the different physiological processes, stimulating various vegetative growth, reflecting the good production of chia plant.

CONCLUSION

The obtained results showed that spraying chia plants with vitamin E and by adding humic acid to the ground that caused a significant increase in the vegetative growth, yield characteristics, oil productivity, Photosynthetic pigments as well as N, P and K contents compared to untreated plants. The highest values of all studied parameters were obtained by humic acid at 400 ppm combined with vitamin E at 50 ppm. Therefore, we recommended that spraying chia plants with 400 ppm humic acid and 50 ppm vitamin E can be used for obtaining higher vegetative growth, yield and quantity of fixed oil.

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استجابة نباتات بذور الشيا لبعض منشطات النمو وتأثيرها على النمو والمحصول ومحتوى الزيت

ريم محمد الحسيني ورشا محمد عاشور
قسم النباتات الطبية والعطرية – معهد بحوث البساتين - مركز البحوث الزراعية.

تم إجراء هذا الدراسه في مشتل نباتات الزينة بكلية الزراعة جامعة المنيا خلال موسمي زراعة أكتوبر (2021/2020) و (2022/2021) ، لدراسة تأثير الأضافه الأرضية لحامض الهيوميك بتركيز (100، 200 و 400 جزء في المليون) والرش الورقي لفيتامين E بتركيز (25، 50 و 100 جزء في المليون) وعلى نمو وإنتاجية نباتات الشيا (*Salvia hispanica* L.).

اوضحت النتائج التي تم الحصول عليها أن جميع تركيزات حمض الهيوميك (100 و200 و400 جزء في المليون) أدت إلى زيادة معنوية فى جميع الصفات المدروسة للنمو الخضري (أرتفاع النبات، قطر الساق، عدد الأفرع والأوراق/النبات، مساحة الورقة والوزن الطازج والجاف ومكونات المحصول (عدد النورات، وزن البذور، محصول البذور كجم/فدان، وزن 1000 بذرة، إنتاجية الزيت الثابت (زيت ثابت٪، محصول زيت ثابت مل/ نبات ولتر/فدان) وكذلك المكونات الكيميائية (صبغات التمثيل الضوئي ومحتوى النيتروجين والفوسفور والبوتاسيوم) مقارنة بالكنترول. وكان لإضافة حمض الهيوميك بتركيز 400 جزء في المليون أكثر فعالية في تحسين النمو. أيضا، تم الحصول على نفس النتائج مع معاملات فيتامين E بتركيز 25 و50 و100 جزء في المليون للصفات المدروسة؛ وكان أفضل تركيز 50 جزء في المليون؛ كانت أفضل معاملة تفاعل للحصول علي أعلى إنتاجية لنبات الشيا هي المعاملة الأرضيه لحمض الهيوميك بتركيز 400 جزء في المليون مع رش فيتامين هـ بتركيز 50 جزء في المليون.