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Impact of Humic Acid, Phosphorus and Zinc on Productivity and Active Constituents of Hot Pepper Grown in Sandy Soil

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Abstract: Two field experiments were implemented in a greenhouse under drip irrigation conditions during two growing seasons 2019/2020 and 2020/2021, at the Experimental Farm of South Tahrir- Horticulture Research Station, Beheira Governorate. The study aims to investigate the effect of different doses of humic acid (HA), phosphorous (P) and chelated Zinc (Zn) on the improvement of the chemical soil properties, P-induced zinc relations as well as vegetative growth, fruit yield and quality of the Hot pepper plants. Two HA rates (0 and 6 Kg fed^{-1}.), three rates of P (0, 50 and 100 kg H_3PO_4 fed^{-1}) and/or three rates of Zn (0, 4 and 6 Kg Zn fed^{-1}) were applied through the drip irrigation system (fertigation). The HA applications significantly increased the soil contents of available N, P, K and Zn. Plant vegetative growth was maximized with the application of HA_6 +Zn_6 +P_{100}. Also, fruit yield and quality were superior with the same application. The maximum fruit contents of vitamin C, Capsaicin and Dihydrocapsaicin were 116.67 mg/100g, 23.96 and 3.22 mg/g DW, respectively. Moreover, the application of HA, P and Zn, significantly increased the fruit contents of NPK and Zn. Positive correlations between the fruit yield and both soil available phosphorous and zinc were observed. Where the correlations coefficient was 0.74 and 0.96, respectively, as a mean value for the two examined seasons.

Key words: Humic acid · Fertigation · Hot pepper · Fruit quality · Capsaicin · Dihydrocapsaicin

INTRODUCTION

Chilli (*Capsicum annum var. accuminatum* L. Cv. Omega) occupies an important position among the traditional vegetable crops due to its multifarious use in local fresh consumption, food processing and exportation [1, 2]. The investment of Hot peppers could be increased because it is greatly used in nutrition as well as their pharmacological properties. Peppers contain great metabolites such as phenolics, flavonoids, vitamin C, & E, carotenoids and alkaloids. Where these constituents are antioxidants and play a great role in human health [3]. Capsaicinoids and carotenoids increase antioxidant and anticancer activities. Flavonoids act as anti-inflammatory, antioxidants, antiallergic, as well as antibacterial [4-7]. Capsaicinoids are responsible for the pepper fruit´s pungency and productivity. [8]. Capsaicin (8-methyl-N-vanillyl-trans-6-nonenamide) and dihydrocapsaicin are the major capsaicinoids in peppers, where they are constituting about ~71% of the total capsaicinoids in most of the pungent varieties. Capsaicin content in peppers is used to determine the fruit commercial quality [9, 10]. Capsaicin and other capsaicinoids group members have numerous pharmacological effects like its role in the gastrointestinal tract, the cardiovascular, analgesic, antidiabetic, hypolipidemic and antitumor agent and respiratory system, the sensory and thermoregulation systems [11, 12].

Chilli is planted under drip irrigation in different soil types. So, a need for information about good fertilization practices, especially nutrients that have direct effects on production, is required [13]. Among the mineral nutrients in Egyptian soils, phosphorous plays an important role in fertilization programs. In high pH soils (Egyptian soils), phosphorous is less available due to fixation as insoluble phosphates form of iron, aluminum and calcium. P-induced deficiencies were observed in field corn, sweet corn and tomatoes. A result of an experiment on red kidney beans conducted in a greenhouse proved that P-induced Zn deficiencies as a result of P fertilization. Zinc uptake was decreased by P fertilization and increased by zinc fertilization. On the other side, phosphorous

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uptake was decreased by zinc fertilization and increased by phosphorus fertilization. When both Zn and P were applied, the absorption of both P and Zn was decreased [14]. Another study reported that Zinc concentration was significantly enhanced in the lower and middle leaves that received no supplemental P fertilizer compared with those plots that did [15].

Phosphorus is essential for the general health and growth of all plants. Phosphorus plays a vital role in plant growth that is associated with stimulated root development, increased stalk and stem strength, improved flower formation and seed production, more uniform and earlier crop maturity, increased nitrogen N-fixing capacity of legumes, improved crop quality and increased resistance to the plant diseases [16]. Adding 80 kg P_2O_5 ha^{-1} gave the highest plant height and most of the pepper growth parameters increased with increasing phosphorus application levels [17]. In another study, adding 60 kg P_2O_5 ha^{-1} resulted in the highest fruit and seeds yield of hot pepper through the two growing seasons, while, the agronomic efficiency was improved at 60 or 20 kg P_2O_5 ha^{-1} in both growing seasons. The fruit proximate composition, minerals and vitamin C contents increased to the highest values at 60 kg P_2O_5 ha^{-1} [18]. While, under agro-climatic conditions of Rawalakot, Pakistan, the maximum plant characteristics were observed when applied 100 kg ha^{-1} P and 120 kg ha^{-1} K for pepper plants [19].

Zinc is known to have an important role either as a metal component of enzymes or as a functional, structural and regulatory factor of a huge number of enzymes [20]. The pollen tube growth was induced by Zinc because of its role in the synthesis of tryptophan which considers an auxin precursor biosynthesis [21]. The foliar application of chelated Zn at rates of 50 and 100 mg/kg significantly increased all studied growth parameters, as well as the leaves content of N, P, K, Zn, photosynthetic pigments, total free amino acids, total sugars and crude protein concentrations. In addition, Zn application increased the chemical composition of minerals and some bio-constituents (total soluble solids, vitamin C and carbohydrates) in sweet pepper fruits [22].

Humic acids (HA) are a fraction of the Humic substances (HS) and contains aromatic and polyaromatic nuclei, linked together through aliphatic chains involving a wide range of functional groups, which allow them to have various functions in the soil-plant relationship [23-26]. HS has been widely recognized as a plant growth promoter that can be used as a growth regulator to control hormone levels and improve plant growth and like auxins in their mode of action [27, 28]. The HS plays a vital role in soils due to their oxygenated functional groups they enhance soil cation retention processes which increase soil water and nutrients holding capacity [29, 30]. There were significant differences between treated and un-treated pepper plants in plant height, number of branches per plant, leaf area, fruit weight, numbers of fruits per plant, fruit size, specific gravity and yield per plant as a result of humic acid. Also, the implementation of the foliar spraying method plays a considerable role in improving the growth characters and yield of vegetable crops through increasing the uptake and efficiency of plant nutrients [31-33]. Other studies attributed the effect of humic acid on enhancing yields to its ability to influence the uptake of essential nutrients, which encourage growth and fruit yield [34, 35]. On the other side, [36] reported that there were no significant differences between all humic treatments and control on fruit length, fruit diameter, TSS and nitrate content of pepper fruits.

The informed effects of HA on soil physiochemical properties include stabilization of soil structure [37]. There were no effects of HA on onion yield through three years of examined field. While, an enhancement of storage life was reported in the 1st year [38]. On the other hand, other results reported that HA did not affect field production of either onions or mustard greens, respectively [39]. Humic acid application may play a good role in increasing the ability of nutrients and decreasing the antagonism between them which may force the productivity of crops.

So, the current investigation aims to investigate the effect of different doses of humic acid (HA), phosphors (P) and chelated Zinc (Zn) and their interaction on chemical soil proprieties, P-induced zinc relations as well as vegetative growth, fruit yield and quality of the Hot pepper plants.

MATERIALS AND METHODS

Two field experiments were implemented in a greenhouse under drip irrigation conditions during two growing seasons 2019/2020 and 2020/2021 at The Experimental Farm of South Tahrir-Horticulture Research Station, Beheira. The experimental soil characterizations were determined for the both examined seasons. Total carbonate was measured by calcimeter [40]. The particle size distribution (sand, silt and clay) was measured by the method of FAO [41]. The electrical conductivity (E.C) was determined in a saturated soil water extract, while, the

Table 1: Main physical and chemical properties of the experimental soil during the two growing seasons

	Particle size distributions (%)							Available nutrients (mg/kg)					
Growth season	Sandy	Silt	Clay	Texture	O.M%	CaCO3	PH	N	P	K	Fe	Zn	Mn
2019	95.50	3.2	2.8	Sandy	0.44	1.18	7.8	40.21	2.79	19.75	3.12	0.85	1.00
2020	94.00	3.00	3.00	Sandy	0.46	1.16	8.2	30.78	3.85	19.95	3.10	0.77	1.01

soil pH was measured in suspension mixture consisted of 1:2.5 soil to water by pH- Meter [42]. The main physical and chemical characterizations of the soil are presented in Table (1).

Plant Source and Transplanting: Plantlets of hot pepper (*Capsicum annumvar accu minotum* L.) omega cultivar were obtained from local nurseries. Plantlets were treated with Anti-fungi (1 ml^{-1} Brificor N^{+} g^{-1} Ridomil gold) for 30 minutes. Transplanting was carried out on 15th and 20th October 2019 and 2020, respectively. It took place in rows 0.80 m width and 20m along with 0.25m spacing between plants.

Source of Nutrient Treatments: Humic acid is a commercial product containing 80 % HA and 10% potassium. The perspective phosphors (P) source was phosphoric acid (85% H_3PO_4), while chelated Zinc EDTA 13% was used as Zinc (Zn) source.

The Experimental Layout: It was split-split plot design with three replications. Humic acid (HA) was arranged in the main plots while phosphorous applications were in the sub-plot and Zinc in the sub-sub plot resulting in 18 treatments. Each sub-sub-plot was a row of 10 m long and 0.80m width. Two humic acid application rates of 0.0 and 6.0 kg fed^{-1}, three phosphors levels 0, 50 and 100 kg phosphoric acid fed^{-1} and three zinc levels 0, 4 and 6 Kg chelated Zinc EDTA fed^{-1}). All fertilizer treatments were added through a water drip system (fertigation, during the two growing seasons). The humic acid was applied once a week, Phosphorus was added three times per week and zinc was applied twice per month.

Farm Fertilization Regime and Harvesting: During the entire growing season, nitrogen fertilizers were also added through the drip irrigation system four times per week. At a rate of 350 kg ammonium nitrate (33.5% N) per fed for each season. Also, potassium at a rate of 120 kg K_2O fed^{-1} as soluble potassium (48%/k_2O) was added according to the recommendation of the Horticulture Research Institute. Harvesting was started on the 1st February and extended to the 29th June in the first season. Whereas; in the second season, it was started on 25th Jan and extended to the 29th June.

Recorded Data

Experimental Soil Analysis: During the growing seasons, samples from the root zone area (0-60 cm depth) were collected for soil chemical analyses for each replicate. The amount of available N in soil was determined by Kjeldahl method, the amount of available phosphorus in soil was extracted by 0.5 N $NaHCO_3$ pH 8.5 as described by Olsen and Dean [43] and the concentration of P was measured colourimetrically using the ascorbic acid method according to Olsen and Dean [43]. Also, the amount of available K was extracted with neutral normal NH_4-Acetate and measured by flame photometer [44]. The amount of soil organic matter was determined by Walkley- Black method and calculated as follows: O. M (%) = (O.C % x 1.72) [45].

Plant Parameters: Five random plant samples were tagged in each plot and were used for recording the observations. The recorded data were based on characters assessing plant growth. Average plant weight (kg), plant height (cm), number of side branches/plant were recorded. Also, plant content of N, P and K was determined in dry leaves (oven-dried at 70°C for 48 hrs). Where 0.3 g of each leaves sample was digested using H_2O_2 [46]. Total nitrogen was determined using micro kjeldahl method [47]. Phosphorus content was determined colourmetrically using spectrophotometer at 650 nm [48]. Potassium was measured using a flame photometer [49].

Fruit Yield and Quality: Average fresh weight of 10 fruits (g), fruit yield (ton/fed.) and seed yield/plant (g) were recorded. Fruits content of vitamin C (ascorbic acid) was determined using 2, 4 dinitrophenylhydrazine reagent with spectrophotometer at 540 nm according to Kumar and Tata [50]. Data were expressed as mg/100g fresh weight. Capsaicin fruit content was extracted with Soxlet apparatus. About 0.800 g of dry fruit material was soaked in 100 mL 70% ethanol and was incubated for 5 hours at

80 ± 2°C [12]. Extracted Capsaicin content was determined by spectrophotometric measurement through the blue colour component. The latter was formed from the reduction of phosphomolybdic acid to lower acids of molybdenum according to the description of Ademoyegun *et al.* [51]. The content of capsaicin was calculated using the standard curve. Capsaicin was expressed as mg/100g of dry fruit [52, 53].

Experimental Data Analysis: Data were statistically analyzed according to co-stat software, 1085. Means were compared using the Least Significance Difference (L.S.D.) test at 0.05 level of probability.

RESULTS AND DISCUSSION

Soil Content of Available NPK and Organic Matter

Available Nitrogen (N) in the Experimental Soil: Data presented in Table (2) revealed that application of humic acid significantly increased the amount of available N in the tested soil compared with non-treated soil, whereas available nitrogen increased from 83.65 mg/kg to 101.69 mg/kg for HA_0 and HA_6, respectively. The same trend was found for the second growing season. This is may be attributed to the effect of humic acid application on increasing soil exchange capacity, which may lead nitrogen to be more retained in treated soil. On the other

Table 2: Effect of humic acid, phosphorous and chelated Zn on the amount of available N and P in the experimental soil cultivated with omega cultivar

		Soil available N (mg/kg)							
		1st season				2nd season			
Treatments	Zinc (kg fed^{-1})	Phosphorous levels (kg fed^{-1})							
		P_0	P_{50}	P_{100}	Mean	P_0	P_{50}	P_{100}	Mean
HA_0	Zn_0	90.41	80.52	81.50	84.14	76.21	74.5	79.1	76.60
	Zn_4	88.52	89.90	76.20	84.87	77.7	70.2	75.27	74.39
	Zn_6	83.21	78.30	84.29	81.93	79.2	77.16	71.15	75.84
Mean		87.38	82.91	80.66	83.65	77.70	73.95	75.17	75.61
HA_6	Zn_0	98.78	104.52	97.90	100.40	124.1	121.3	99.32	114.91
	Zn_4	106.42	99.00	98.75	101.39	117.72	102.86	93.3	104.63
	Zn_6	101.98	100.54	102.54	101.69	85.66	80.33	88.2	84.73
Mean		102.39	101.35	99.73	101.16	109.16	101.50	93.61	101.42
Phosphorous x Zinc	Zn_0	94.60	92.52	89.70	92.27	100.16	97.90	89.21	95.76
	Zn_4	97.47	94.45	87.48	93.13	97.71	86.53	84.29	89.51
	Zn_6	92.60	89.42	93.42	91.81	82.43	78.75	79.68	80.28
Mean		94.89	92.13	90.20	92.40	93.43	87.73	84.39	88.52
		LSD at 0.05 level							
HA (A)		17.51	A x B	NS	A	25.81	AxB	NS	
Phosphorous (B)		NS	AxC	NS	B	NS	AxC	NS	
Zinc (C)		NS	BxC	NS	C	NS	BxC	NS	
AxBxC		NS			AxBxC	NS			
		Soil available P (mg/kg)							
	Zinc (kg fed^{-1})	P_0	P_{50}	P_{100}	Mean	P_0	P_{50}	P_{100}	Mean
HA_0	Zn_0	8.97	9.3	9.98	9.42	9.35	10.22	12.04	10.54
	Zn_4	8.14	9.22	10.12	9.16	9.2	9.45	11.02	9.89
	Zn_6	8.25	9.87	10.01	9.38	8.89	9.85	11.52	10.09
Mean		8.45	9.46	10.04	9.32	9.15	9.84	11.53	10.17
HA_6	Zn_0	13.01	13.49	14.47	13.65	13.46	14.72	17.34	15.17
	Zn_4	11.80	13.37	14.67	13.28	13.25	13.61	15.87	14.24
	Zn_6	11.96	14.31	14.51	13.60	12.80	14.18	16.59	14.52
Mean		12.26	13.72	14.55	13.51	13.17	14.17	16.60	14.64
Phosphorous x Zinc	Zn_0	10.99	11.39	12.23	11.54	11.41	12.47	14.69	12.85
	Zn_4	9.97	11.29	12.40	11.22	11.22	11.53	13.44	12.07
	Zn_6	10.11	12.09	12.26	11.49	10.85	12.02	14.05	12.31
Mean		10.36	11.59	12.29	11.41	11.16	12.00	14.06	12.41
		LSD at 0.05 level							
HA (A)		3.19	A x B	5.10	A	3.48	AxB	6.45	
Phosphorous (B)		1.90	AxC	NS	B	2.70	AxC	NS	
Zinc (C)		NS	BxC	NS	C	NS	BxC	NS	
AxBxC		NS			AxBxC	NS			

Table 3: Effect of humic acid, phosphorous and chelated Zn on the amount of available K and Zn in the experimental soil cultivated with omega cultivar

					Soil available K (mg/kg)				
		1st season				2nd season			
Treatments	Zinc (kg fed^{-1})				Phosphorous levels (kg fed^{-1})				
		P_0	P_{50}	P_{100}	Mean	P_0	P_{50}	P_{100}	Mean
HA_0	Zn_0	73.41	71.20	68.27	70.96	70.25	70.74	75.28	72.09
	Zn_4	70.20	69.20	67.18	68.86	75.22	70.23	65.20	70.22
	Zn_6	72.14	64.10	73.10	69.78	65.74	72.48	69.98	69.40
Mean		71.92	68.17	69.52	69.87	70.40	71.15	70.15	70.57
HA_6	Zn_0	79.98	79.20	70.25	76.48	73.76	74.28	79.04	75.69
	Zn_4	70.25	69.69	60.20	66.71	78.98	73.74	68.46	73.73
	Zn_6	81.20	82.00	75.22	79.47	69.03	76.10	73.48	72.87
Mean		77.14	76.96	68.56	74.22	73.92	74.71	73.66	74.10
Phosphorous x Zinc	Zn_0	76.70	75.20	69.26	73.72	72.01	72.51	77.16	73.89
	Zn_4	70.23	69.45	63.69	67.79	77.10	71.99	66.83	71.97
	Zn_6	76.67	73.05	74.16	74.63	67.38	74.29	71.73	71.14
Mean		74.53	72.57	69.04	72.04	72.16	72.93	71.91	72.33
					LSD at 0.05 level				
HA (A)		4.35	A x B	NS	A	3.53	AxB	NS	
Phosphorous (B)		NS	AxC	NS	B	NS	AxC	NS	
Zinc (C)		NS	BxC	NS	C	NS	BxC	NS	
AxBxC				AxBxC					
					Soil available Zn (mg/kg)				
	Zinc (kg fed^{-1})	P_0	P_{50}	P_{100}	Mean	P_0	P_{50}	P_{100}	Mean
HA_0	Zn_0	0.81	0.79	0.75	0.78	0.85	0.83	0.79	0.82
	Zn_4	1.10	1.30	1.05	1.15	1.16	1.37	1.10	1.21
	Zn_6	1.60	1.80	1.95	1.78	1.68	1.89	2.05	1.87
Mean		1.17	1.30	1.25	1.24	1.23	1.36	1.31	1.30
HA_6	Zn_0	0.83	0.87	0.89	0.86	0.94	0.91	0.87	0.90
	Zn_4	1.16	1.43	1.21	1.27	1.27	1.50	1.21	1.33
	Zn_6	2.15	1.98	1.76	1.96	1.85	2.08	2.25	2.06
Mean		1.38	1.43	1.29	1.36	1.35	1.50	1.44	1.43
Phosphorous x Zinc	Zn_0	0.82	0.83	0.82	0.82	0.89	0.87	0.83	0.86
	Zn_4	1.13	1.37	1.13	1.21	1.21	1.43	1.16	1.27
	Zn_6	1.88	1.89	1.86	1.87	1.76	1.98	2.15	1.97
Mean		1.28	1.36	1.27	1.30	1.29	1.43	1.38	1.37
					LSD at 0.05 level				
HA (A)		0.12	A x B	NS	A	0.12	AxB	NS	
Phosphorous (B)		NS	AxC	1.19	B	NS	AxC	1.22	
Zinc (C)		1.02	BxC	NS	C	1.08	BxC	NS	
AxBxC		NS			AxBxC	NS			

side, there was no significant effect due to phosphorous and chelated zinc application on the amount of available nitrogen in the soil. All interaction effects between the studied variables were insignificant. These results came in harmony with those obtained by Gumu and Seker [54].

Available Potassium (K) in the Experimental Soil: Data in Table (3) show that application of humic acid significantly increased the amount of available K in the treated soils compared with untreated ones, it's clear that soil available K increased from 69.87 mg/kg at HA_0 to 74.22 mg/kg at HA_6 for the first growing season and from 70.57 mg/kg at HA_0 to 74.10 mg/kg at HA_6 for the second growing season. Also, data in Table (3) indicated that there were no significant effects of the application of phosphoric acid and zinc chelated fertilization on the amount of available K in the soil, the same trends were observed for the effects of interaction between humic acid, phosphoric acid and chelated zinc applications. These results were supported by the results of Mindari *et al*. [55, 56].

Table 4: Effect of humic acid, phosphorous and chelated Zn on the amount of organic matter in the experimental soil cultivated with omega cultivar

		Soil organic matter content (%)							
		1st season				2nd season			
Treatments	Zinc (kg fed^{-1})	Phosphorous levels (kg fed^{-1})							
		P_0	P_{50}	P_{100}	Mean	P_0	P_{50}	P_{100}	Mean
HA_0	Zn_0	0.49	0.51	0.55	0.52	0.49	0.58	0.53	0.53
	Zn_4	0.50	0.52	0.56	0.53	0.51	0.53	0.57	0.54
	Zn_6	0.58	0.54	0.50	0.54	0.56	0.51	0.50	0.52
Mean		0.52	0.52	0.54	0.53	0.52	0.54	0.53	0.53
HA_6	Zn_0	0.62	0.74	0.66	0.67	0.71	0.76	0.64	0.70
	Zn_4	0.60	0.65	0.67	0.64	0.69	0.77	0.70	0.72
	Zn_6	0.70	0.68	0.60	0.66	0.74	0.61	0.60	0.65
Mean		0.64	0.69	0.64	0.66	0.71	0.71	0.65	0.69
Phosphorous x Zinc	Zn_0	0.56	0.63	0.61	0.60	0.60	0.67	0.59	0.62
	Zn_4	0.55	0.59	0.62	0.58	0.60	0.65	0.64	0.63
	Zn_6	0.64	0.61	0.55	0.60	0.65	0.56	0.55	0.59
Mean		0.58	0.61	0.59	0.59	0.62	0.63	0.59	0.61
		LSD at 0.05 level							
HA (A)		0.12	A x B	NS	A	0.14	AxB	NS	
Phosphorous (B)		NS	AxC	NS	B	NS	AxC	NS	
Zinc (C)		NS	BxC	NS	C	NS	BxC	NS	
AxBxC		NS			AxBxC	NS			

Available Phosphorus (P) in the Experimental Soil: Humic acid application significantly increased the amount of available P in the soil compared with untreated soils (Table 2). Whereas, the relative increase in soil available P due to humic acid application was 45 and 44 % for the first and second growing seasons, respectively. Concerning the application of phosphoric acid as a great source of mineral phosphorous nutrients, results revealed that it significantly maximized the amount of available phosphorous for plants in the fertilized soils when compared with unfertilized ones. Where, the available P in soil increased from 10.36 mg/kg to 11.59 and 12.29 mg/kg for P_0, P_{50} and P_{100}, respectively, for the first growing season and from 11.16 mg/kg to 12 and 14.06 mg/kg for P_0, P_{50} and P_{100}, respectively, for the second growing season. On the other side, Zinc chelated application had no significant effect on the amount of available P in the soil during the two growing seasons. The interaction effect between humic acid, phosphorous and zinc application cleared no significant effect on the amount of available P in the soil, except for the interaction between humic acid and phosphorous application.

Available Zinc in the Experimental Soil: Results in Table (3) show that increasing the amount of humic acid application significantly enhanced the amount of available zinc in the treated soil compared with the control soil, whereas available zinc increased from 1.24 mg/kg at HA_0 to 1.36 mg/kg at HA_6 and from 1.30 mg/kg at HA_0 to 1.43 mg/kg at HA_6 for the first and second season respectively. On the other hand, phosphorous application had no significant effect on the amount of available Zn in the soil. The increase in available Zn in the treated soil may be due to that humic acid applications increase the availability of micronutrients in the soil and play as a chelating agent for zinc which enters the soil as chelated zinc. There was no significant interaction effect between the tested variable except for the interaction between humic acid application and zinc chelated application where the amount of available Zn increased from 0.75 mg/kg at $HA_0P_{100}Zn_0$ to 2.15 mg/kg at $HA_6P_0Zn_6$ and from 0.79 mg/kg at $HA_0P_{100}Zn_0$ to2.25 mg/kg at $HA_6P_{100}Zn_6$ for the first and second growing season, respectively.

Experimental Soil Organic Matters Content: The small increase in the organic matter content, the big changes in soil properties, where, organic matter plays a vital role in the improvement of the soil chemical and physical properties. Table (4) indicates that application of humic acid at rate of 6 kg/fed significantly augmented the amount of soil organic matters, where it increased from 0.53 % at HA_0 to 0.66% at HA_6 for the first growing season and from 0.53 % at HA_0 to 0.69 % at HA_6 for the second growing season. Phosphoric acid and zincchelated application didn't have any significant effect on the amount of organic matter in the soil during

Table 5: Effect of Humic acid, phosphorous and chelated Zn application on plant growth characters of omega cultivar for the two growing seasons

		Average plant weight (kg)							
		1st season				2nd season			
Treatments	Zinc (kg fed^{-1})	Phosphorous levels (kg fed^{-1})							
		P_0	P_{50}	P_{100}	Mean	P_0	P_{50}	P_{100}	Mean
HA_0	Zn_0	1.76	1.78	1.81	1.78	1.75	1.64	1.78	1.72
	Zn_4	1.78	1.89	1.96	1.88	1.76	1.88	1.94	1.86
	Zn_6	1.92	2.14	2.42	2.16	1.9	2.13	2.42	2.15
Mean		1.82	1.94	2.06	1.94	1.80	1.88	2.05	1.91
HA_6	Zn_0	1.87	1.89	1.92	1.89	1.84	1.72	1.87	1.81
	Zn_4	1.89	2.00	2.08	1.99	1.85	1.97	2.04	1.95
	Zn_6	2.04	2.27	2.57	2.29	2.00	2.24	2.54	2.26
Mean		1.93	2.05	2.19	2.06	1.89	1.98	2.15	2.01
Phosphorous x Zinc	Zn_0	1.81	1.83	1.86	1.84	1.79	1.68	1.82	1.77
	Zn_4	1.83	1.95	2.02	1.93	1.80	1.93	1.99	1.91
	Zn_6	1.98	2.20	2.49	2.22	1.95	2.18	2.48	2.20
Mean		1.87	1.99	2.13	2.00	1.85	1.93	2.10	1.96
		LSD at 0.05 level							
HA (A)		0.12	A x B	0.36	A	0.11	AxB	0.32	
Phosphorous (B)		0.26	AxC	0.52	B	0.23	AxC	0.50	
Zinc (C)		0.40	BxC	NS	C	0.68	BxC	NS	
AxBxC		NS			AxBxC	NS			
		Plant height (cm)							
	Zinc (kg fed^{-1})	P_0	P_{50}	P_{100}	Mean	P_0	P_{50}	P_{100}	Mean
HA_0	Zn_0	70.67	76.23	81.53	76.14	68.63	74.48	79.07	74.06
	Zn_4	89.91	94.61	100.03	94.85	87.66	91.36	98.17	92.40
	Zn_6	91.2	98.21	117.25	102.22	100.3	108.4	117.58	108.76
Mean		83.93	89.68	99.60	91.07	85.53	91.41	98.27	91.74
HA_6	Zn_0	89.78	78.63	84.02	84.14	88.2	80.33	85.66	84.73
	Zn_4	91.33	99.04	113.54	101.30	93.3	102.86	117.72	104.63
	Zn_6	97.96	118.3	126.19	114.15	99.32	121.3	124.1	114.91
Mean		93.02	98.66	107.92	99.87	93.61	101.50	109.16	101.42
Phosphorous x Zinc	Zn_0	80.23	77.43	82.78	80.14	78.42	77.41	82.37	79.40
	Zn_4	90.62	96.83	106.79	98.08	90.48	97.11	107.95	98.51
	Zn_6	94.58	108.26	121.72	108.19	99.81	114.85	120.84	111.83
Mean		88.48	94.17	103.76	95.47	89.57	96.46	103.72	
		LSD at 0.05 level							
HA (A)		8.5	A x B	23.04	A	9.60	AxB	41.85	
Phosphorous (B)		15.0	AxC	38. 1	B	13.15	AxC	25.23	
Zinc (C)		27.04	BxC	NS	C	38.30	BxC	NS	
AxBxC		NS		AxBxC	NS				
		Numbers of side branches/plant							
	Zinc (kg fed^{-1})	P_0	P_{50}	P_{100}	Mean	P_0	P_{50}	P_0	Mean
HA_0	Zn_0	8.80	9.90	10.00	9.57	7.72	8.70	8.91	8.44
	Zn_4	8.10	11.90	13.60	11.20	7.52	10.56	12.45	10.18
	Zn_6	12.20	14.50	16.20	14.30	11.04	13.68	14.78	13.17
Mean		9.70	12.10	13.27	11.69	8.76	10.98	12.05	10.60
HA_6	Zn_0	9.90	10.00	11.10	10.33	8.75	8.92	9.97	9.21
	Zn_4	9.10	12.70	14.40	12.07	8.49	11.94	13.49	11.31
	Zn_6	13.40	15.60	16.30	15.10	12.29	14.81	15.19	14.10
Mean		10.80	12.77	13.93	12.50	9.84	11.89	12.88	11.54
Phosphorous x Zinc	Zn_0	9.35	9.95	10.55	9.95	8.24	8.81	9.44	8.83
	Zn_4	8.60	12.30	14.00	11.63	8.01	11.25	12.97	10.74
	Zn_6	12.80	15.05	16.25	14.70	11.67	14.25	14.99	13.63
Mean		10.25	12.43	13.60	12.09	9.30	11.44	12.47	11.07
		LSD at 0.05 level							
HA (A)		0.82	A x B	4.33	A	0.91	AxB	4.22	
Phosphorous (B)		3.31	AxC	5.03	B	3.15	AxC	5.64	
Zinc (C)		4.65	BxC	NS	C	5.50	BxC	NS	
AxBxC		NS		AxBxC	NS				

the two growing seasons. Also, there were no significant effects of the interaction between the tested variables on the amount of organic matters in the soil during the two growing seasons. These results support the previous obtained results of Jan [57] and Gumu and Seker, [54].

Vegetative Growth Characters: Results in Table (5) clear that the average plant weight of omega cultivar was significantly affected by the humic acid application, HA6 increased average plant weight to 2.06 or 2.01kg, for 1st or 2nd seasons, respectively. Also, phosphorus application maximized the average plant weight, P_{100} (100kg fed^{-1}) significantly enhanced plant weight (2.06 and 2.05kg) for 1st and 2nd seasons, respectively. Also, the high dose of Zn (Zn_6) significantly improved the average plant weight for the two growth seasons (2.29 and 2.48 kg). Anyway, the interaction between applications cleared no significant difference except for interaction between HA and P which cleared significant differences. The HA_6+ P_{100}+Zn_6 application produced the highest average plant weight 2.49kg in the 1st season and 2.48kg for the 2nd season. Concerning the plant height, the three examined applications significantly affected plant height individually, application with HA_6 increased plant height more than HA_0 (99.87 and 91.07, in 1st season and 101.42 and 91.74cm, in 2nd season, respectively). Increasing the P dose led to enhanced plant height from 83.93 for P_0 to 89.68cm for P_{50} and 99.60cm for P_{100} in the 1st season and the same trend was observed in the 2nd one. Also, Zn dose appeared a significant effect on plant height, where Zn_6 produced the significantly highest plants (102.22 and 108.76cm, for 1st and 2nd seasons, respectively). The interaction between HA and either P or Zn cleared significant positive effects on plant height, where the presence of HA improved the effects of P and Zn more than the absence of HA. The interaction between the three applications showed no significant differences between their effects on plant height, although the highest plant height was obtained with the treatment of HA_6+ P_{100}+ Zn_6 (126.19 and 124.1cm, for 1st and 2nd seasons, respectively).

Results in Table (5) state that the number of side branches/plant was significantly enhanced by the presence of HA_6 as well as P and Zn doses, number of side branches increased from 11.69 to 12.50 side branch/plant as a result of HA presence in the first season, the same response was recorded for the second season. A positive relationship was recorded between number of side branches and the dose of either P or Zn in the two examined seasons. The interaction cleared a significant effect between HA and P and between HA and Zn, the highest number of side branches/plant was recorded in the presence of HA_6+ P_{100}+Zn_6 (16.30 and 15.19 side branch/plant, for 1st and 2nd season, respectively). The enhancing effect of applied HA on plant growth may be attributed to its beneficial effects on improving soil fertility, increasing availability of nutrients as well as decreasing the harmful effect of stresses through various mechanisms. These results agree with those reported by Ibrahim *et al*. [35].

Also, the increase in plant growth due to Zn application may be attributed to its beneficial effects on enhancing the meristematic activity for producing more tissues and organs via its role in cell division and elongation. Results came in line with Unlu *et al*. [58] who stated that the positive effect of phosphorus application refers to the role of phosphorous in enhancing functions of enzymes required for the vital processes and growth. Results were supported with Mahmud *et al*. [17] who reported that adding phosphorus gave the highest plant height (79.45 cm) and most of the pepper growth parameters increased with increasing phosphorus application levels. Also, the obtained results are in the same line with those reported by Motesharezade *et al*. [21] who attributed the enhancement of vegetative growth to the role of Zn in the activation of meristematic division via its important role in cell division through its role in syntheses of tryptophan and Indole Acetic Acid (IAA).

Fruit Yield and Quality:

Fruit Yield Components: Results presented in Table (6) indicated that the average fresh weight of 10 fruits was significantly maximized by humic acid application, the highest average fresh weight of 10 fruits was obtained from application with HA_6 (770.0 g) compared with HA_0 (647.1 g) in 1st season, the same results were recorded for the 2nd season (694.7 and 658.3 g, for HA_6 and HA_0, respectively). Also phosphorus application significantly affected the average fresh weight of 10 fruits, application with P_{100} (100 kg P_20_5 fed^{-1}) gave the maximum significant average fresh weight of 10 fruits for the two experimental seasons (727.9 and 738.1 g, respectively), compared with P_0 which produced the lowest fresh weight in 1st and 2nd seasons (560.3 and 572.6 g, respectively). Zn application significantly enhanced the average fresh weight of 10 fruits, Zn_6 possessed the highest values of fruits weight through the 1st and 2nd seasons (725.2 and 735.0 g, respectively) compared with control and other Zn applications. The interaction between humic acid and phosphorus treatments in both growing seasons showed significant effects on average weight of 10 fruits, while there was no significant difference of the effect of either

Table 6: Effect of humic acid, phosphorous and chelated Zn application on fruit yield components of omega cultivar for the two growing seasons

		Average fresh weight of 10 fruits (g)							
		1st season				2nd season			
Treatments	Zinc (kg fed^{-1})	Phosphorous levels (kg fed^{-1})							
		P_0	P_{50}	P_{100}	Mean	P_0	P_{50}	P_{100}	Mean
HA_0	Zn_0	438.4	542.1	596.1	525.5	448.8	552.2	606.4	535.8
	Zn_4	591.4	689.4	791.4	690.7	608.1	702.8	801.4	704.1
	Zn_6	651.1	728.1	796.3	725.2	660.9	737.8	806.4	735.0
Mean		560.3	653.2	727.9	647.1	572.6	664..3	738.1	658.3
HA_6	Zn_0	560.3	653.2	727.9	647.1	572.6	664.3	738.1	658.3
	Zn_4	487.1	553.4	608.4	549.6	496.1	686.7	618.6	600.5
	Zn_6	616.	704.4	794.4	704.9	626.7	713.2	804.4	714.8
Mean		761.8	750.7	797.4	770.0	738.3	760.7	807.4	694.7
Phosphorous x Zinc	Zn_0	462.8	547.8	602.3	537.6	472.5	619.5	612.5	568.1
	Zn_4	603.7	696.9	792.9	697.8	617.4	708.0	802.9	709.4
	Zn_6	706.5	739.4	796.9	747.6	699.6	749.3	806.9	751.9
Mean		591.0	661.4	730.7	661.0	596.5	692.2	740.8	676.5
		LSD at 0.05 level							
HA (A)		8.0	A x B	4.13	A	9.0	AxB	42.2	
Phosphorous (B)		33.0	AxC	5.50	B	32.6	AxC	56.0	
Zinc (C)		40.5	BxC	NS	C	54.5	BxC	NS	
AxBxC		NS			AxBxC	NS			
		Fruit yield (Ton fed^{-1})							
	Zinc (kg fed^{-1})	P_0	P_{50}	P_{100}	Mean	P_0	P_{50}	P_{100}	Mean
HA_0	Zn_0	17.03	17.48	17.93	17.48	16.95	17.36	17.7	17.34
	Zn_4	17.35	18.15	19.03	18.18	17.18	18.22	19.16	18.19
	Zn_6	18.7	20.95	22.38	20.68	18.97	20.57	21.22	20.25
Mean		17.69	18.86	19.78	18.78	17.70	18.72	19.36	18.59
HA_6	Zn_0	17.88	18.35	18.83	18.35	17.80	18.23	18.59	18.20
	Zn_4	18.22	19.06	19.98	19.09	18.04	19.13	20.12	19.10
	Zn_6	19.64	22.00	23.50	21.71	19.92	21.60	22.28	21.27
Mean		18.58	19.80	20.77	19.72	18.59	19.65	20.33	19.52
Phosphorous x Zinc	Zn_0	17.46	17.92	18.38	17.92	17.37	17.79	18.14	17.77
	Zn_4	17.78	18.60	19.51	18.63	17.61	18.68	19.64	18.64
	Zn_6	19.17	21.47	22.94	21.19	19.44	21.08	21.75	20.76
Mean		18.14	19.33	20.27	19.25	18.14	19.18	19.84	19.06
		LSD at 0.05 level							
HA (A)	0.94	A x B	3.08	A	0.93	AxB	2.63		
Phosphorous (B)	2.14	AxC	4.23	B	1.70	AxC	3.93		
Zinc (C)	3.28	BxC	NS	C	2.99	BxC	NS		
AxBxC	NS			AxBxC	NS				
		Seed yield/plant (g)							
	Zinc (kg fed^{-1})	P_0	P_{50}	P_{100}	Mean	P_0	P_{50}	P_{100}	Mean
HA_0	Zn_0	28.83	36.21	40.21	35.08	29.98	33.7	37.34	33.67
	Zn_4	29.47	38.27	44.5	37.41	30.65	34.64	43	36.1
	Zn_6	33.47	40.64	47.24	40.45	36.68	50.73	52.51	46.64
Mean		30.59	38.37	43.98	37.65	32.44	39.69	44.28	38.80
HA_6	Zn_0	27.47	36.4	45.65	36.51	28.85	38.2	38.74	35.26
	Zn_4	30.52	34.88	44.37	36.59	32.1	36.5	44.2	37.60
	Zn_6	36.57	42.15	51.51	43.41	37.4	45.2	54.85	45.82
Mean		31.52	37.81	47.18	38.84	32.78	39.97	45.93	39.56
Phosphorous x Zinc	Zn_0	28.15	36.305	42.93	35.8	29.415	35.95	38.04	34.47
	Zn_4	29.995	36.575	44.435	37	31.375	35.57	43.6	36.85
	Zn_6	35.02	41.4	49.38	41.93	37.04	47.965	53.68	46.23
Mean		31.06	38.09	45.58	38.24	32.61	39.83	45.11	39.18
		LSD at 0.05 level							
HA (A)		1.19	A x B	16.59	A	0.76	AxB	13.49	
Phosphorous (B)		14.52	AxC	8.33	B	12.50	AxC	12.15	
Zinc (C)		6.13	BxC	NS	C	11.76	BxC	NS	
AxBxC		NS			AxBxC	NS			

the interaction between P and Zn applications or between all application treatments (HA, P or Zn) on average fruit weight. The positive effects of phosphorus and Zn application may be attributed to the important role of phosphorus in functions of enzymes which are required for the plant vital processes and growth. Additional results of Alabi and Ayodele [18] proved that adding H_3PO_4 resulted in the highest fruit and seeds yield of hot pepper through the two growing seasons. Concerning the effect of fertigation on the fruit yield/fed., humic acid application significantly affected the fruit yield fed^{-1}., HA_6 significantly improved fruit yield fed^{-1} for 1st and 2nd seasons (19.72 and 19.52 ton fed^{-1}., respectively) compared to HA_0 (18.78 and 18.59ton fed^{-1}., respectively). Also, P application significantly increased the fruit yield/fed, P_{100} (100kg fed^{-1}) produced the highest fruit yield/fed followed by $P_{50}$and P_0(17.69, 18.86and 19.78ton fed^{-1}, respectively) for the 1st season, the same trend was recorded for the 2nd season. Also, Zn application showed significant effects on fruit yield/fed with increasing the Zn application dose, Zn_6 maximized the fruit yield/fed to 20.68ton/fed., in the 1st season and 20.25ton/fed. in the 2nd season. The interaction between HA and P cleared significant effects on fruit yield fed^{-1}, while, the interaction between P and Zn or between the three applications did not significantly affect fruit yield fed^{-1}. Regarding the effect of Humic acid application on the seed yield/plant, HA_6 significantly improved the seed yield/plant for the 1st and 2nd seasons (38.84 and 39.65g/plant, respectively) compared with untreated plants (37.65 and 38.80g/plant, respectively). P_{100} significantly promoted the seed yield/plant for both seasons which ranged from 43.98 to 44.28g/plant for the 1st and 2nd seasons, respectively. Also, Zn_6 significantly maximized the seed yield/plant, which ranged from 40.45 to 46.64 g/plant for 1st and 2nd seasons, respectively. The interaction results of HA and P showed significant effects on seed yield/plant. Although, there were no significant differences between the effects of interaction among the three applications, the seed yield/plant was the highest value when plants were applied with HA_6+ P_{100}+Zn_6 for 1st and 2nd seasons (49.38 and 53.68 g/plant, respectively). A significant increase on all studied fruit pepper yield and its components as compared to the unfertilized treatments during the two growing seasons was observed. The positive effects of fertilizer applications may be attributed to their effects on the soil exchange in the case of humic acid or may be attributed to the effects of Phosphorus on cell division, growth enzymatic systems, or may result from the effect of Zn as a co-factor for multi number of enzymes and its important roles in metabolism process. The results are supported by previous studies which showed that HA able to reduce the harmful effect of a biotic stresses on plants [58-60]. The positive effect of phosphorus application may be attributed to the important role of phosphorus in functions of enzymes which are required for the plant vital processes and growth. Also, the positive results of phosphorous may be attributed to the potentiality of P-fertilization, to secure the phosphorous requirements, which were resulted in improving vegetative growth and flowering traits resulting in increasing yield and its components. The results also, are similar with those found by Abdellatif *et al*. [61]; Sing and Jain [2]; Hunde [62] and Khanal *et al*. [63] who stated that pepper production significantly affected by the balanced phosphorus level. They added that the requirements of P varied according to soil conditions.

Fruit Yield Quality:

Fruit Content of Vitamin C: Table (7) indicated that humic acid application significantly positive enhanced the content of vitamin C in chili plants, where it increased from 90.98 mg/100g at HA_0 to 94.36 mg/100g at HA_6 and from 93.55 mg/100g at HA_0 to 96.02 mg/100g at HA_6 during the first and second growing seasons, respectively. Also, results cleared that the content of vitamin C significantly augmented with increasing phosphorous application rates where it increased from 83.91 to 100.41 mg/100g for P_0 and P_{100}, respectively, for the first growing season and from 85.39 to 101.87 mg/100g for P_0 and P_{100}, respectively, for the second growing season. Also, Table (7) showed that, there were significant relationship between chelated zinc application and the content of vitamin C in chili plants, where it increased from 85.63 to 103.69 mg/100g for Zn_0 and Zn_6, respectively, during first season and increased from 87.24 to 105.34 mg/100g for Zn_0 and Zn_6, respectively, during second season. Regarding the effect of the interactions, increases in the content of vitamin C are affected by interaction between HA x P, HA x Zn and P x Zn. Anyway, the highest vitamin C content was obtained from HA with P_{100} and Zn_6, which were 115.27 and 116.67 mg/100g, for the first and second seasons, respectively. Results were supported by Abdellatif *et al*. [61] who stated that HA application had the least impact on fruit number per plant and on vitamin C and total soluble solids (TSS) concentration as compared with control.

Table 7: Effect of humic acid, phosphorous and chelated Zn application on vitamin C content of omega cultivar fruits for the two growing seasons

Treatments	Zinc (kg fed⁻¹)	Vitamin C (mg/100g) 1st season				2nd season			
		Phosphorous levels (kg fed⁻¹)							
		P_0	P_{50}	P_{100}	Mean	P_0	P_{50}	P_{100}	Mean
HA_0	Zn_0	78.43	85.67	90.20	84.77	79.93	86.80	91.6	86.11
	Zn_4	78.67	87.70	95.70	87.36	79.63	99.53	97.10	92.09
	Zn_6	92.40	99.03	111.00	100.81	93.73	101.23	112.43	102.46
Mean		83.17	90.80	98.97	90.98	84.43	95.85	100.38	93.55
HA_6	Zn_0	79.57	87.63	92.27	86.49	80.77	90.61	93.70	88.36
	Zn_4	80.67	91.33	98	90.00	82.47	92.33	99.70	91.50
	Zn_6	93.73	110.73	115.27	106.58	95.8	112.17	116.67	108.21
Mean		84.66	96.56	101.85	94.36	86.35	98.37	103.36	96.02
Phosphorous	Zn_0	79.00	86.65	91.24	85.63	80.35	88.71	92.65	87.24
x Zinc	Zn_4	79.67	89.52	96.85	88.68	81.05	95.93	98.40	91.79
	Zn_6	93.07	104.88	113.14	103.69	94.77	106.70	114.55	105.34
Mean		83.91	93.68	100.41	92.67	85.39	97.11	101.87	94.79
					LSD at 0.05 level				
HA (A)		3.28	A x B	18.58	A	2.45	AxB	18.90	
Phosphorous (B)		16.41	AxC	21.80	B	16.38	AxC	22.15	
Zinc (C)		18.17	BxC	34.10	C	22.90	BxC	27.20	
AxBxC		NS			AxBxC	NS			

Fruit Content of Capsaicinoids: Results in Table (8) show that humic acid application significantly increased the fruit content of Capsaicin and dihydrocapsaicin in both examined seasons. Also, increasing the application dose of either Phosphorous or Zinc resulted in maximized fruit content of Capsaicin and dihydrocapsaicin. The interaction between all examined factors cleared significant difference. Finally, the maximum fruit content of both Capsaicin and dihydrocapsaicin was obtained from the HA_6 + Zn_6 + P_{100} in the first season (23.33 and 3.10 mg/g DW, respectively) and in the second season (23.96 and 3.22 mg/g DW, respectively). The enhanced effects of the examined fertilization may be attributed to their effects on the soil exchange in the case of humic acid or may be attributed to the effects of Phosphorus on cell division, growth enzymatic systems, or may result from the effect of Zn as a co-factor for multi number of enzymes and its important roles in metabolism process. All these reasons may augment plants to produce high yield of both Capsaicin and dihydrocapsaicin. Results are supported by the previous finding of Abdellatif *et al.* [61]; Sing and Jain [2] and Khanal *et al*. [63] who reported that chili yield components and quality affected by nutrients concentration and soil conditions.

Minerals Plant Content

Nitrogen Percentage in Plants (N%): Results in Table (9) revealed that there was a significant increase in the nitrogen uptake by plant as a result of humic acid application, where the plant nitrogen content was enhanced from 3.27 % to 3.90% and from 3.36 % to 4.03 % for unapplied and applied plants during the first and second growing seasons, respectively. Also, data indicated that there were significant effects especially between the highest rates of phosphorous applications and the control. Plant nitrogen content significantly increased with increasing chelated zinc application rates. Increasing nitrogen content in plants due to application of phosphorus and zinc may be due to the enhancement of plant growth especially roots which increased its ability to uptake nitrogen and translocate it to other plant parts. Table (9) showed that there were no significant effects of the interaction between the studied variables on plant nitrogen content. These results supported the finding of Singh *et al*. [64]; Çelik *et al*. [65]; Khaled and Fawy [66] and Mindari *et al*. [55] where they reported that humic acid improves nutrients uptake by plants and enhance the plant minerals content.

Phosphorus Contents in Plants (P%): Table (9) shows that there were no significant effects on plant phosphorous content as a result of application of humic acids to the soil. Application of different rates of phosphoric acid as a source of P significantly increased the amount of phosphorous in chili plants whereas plant P content increased from 0.46 % at control plants to

Table 8: Effect of humic acid, phosphorous and chelated Zn application on Omega cultivar Fruit content of Capsaicin and Dihydrocapsaicin for the two growing seasons

		Fruit content of Capsaicin (mg/g DW)							
		1[st] season				2[nd] season			
Treatments	Zinc (kg fed^{-1})	Phosphorous levels (kg fed^{-1})							
		P_0	P_{50}	P_{100}	Mean	P_0	P_{50}	P_{100}	Mean
HA_0	Zn_0	18.00	18.33.	18.96	18.43	18.50	18.66	19.00	18.72
	Zn_4	18.33	18.50	19.00	18.61	19.00	19.33	19.88	19.40
	Zn_6	18.50	18..88	19.33	18.90	19.80	20.00	20.66	20.15
Mean		18.28	18.57	19.10	18.65	19.10	19.33	19.85	19.43
HA_6	Zn_0	19.00	20.33	21.33	20.22	19.88	20.40	21.66	20.65
	Zn_4	19.93	21.60	22.66	21.40	20.66	21.96	21.33	21.32
	Zn_6	21.50	22.25	23.33	22.36	21.66	22.50	23.96	22.71
Mean		20.14	21.40	22.44	21.33	20.73	21.62	22.32	21.56
Phosphorous x Zinc	Zn_0	18.50	19.50	19.66	19.22	19.10	20.33	20.96	20.13
	Zn_4	19.66	19.88	20.00	19.85	20.33	21.33	23.66	21.77
	Zn_6	20.96	21.00	22.00	21.32	21.33	21.60	22.10	21.68
Mean		19.71	20.13	20.55	20.13	20.25	21.09	22.24	21.19
					LSD at 0.05 level				
HA (A)		1.33	AxB	1.99	A	1.36	AxB	1.96	
Phosphorous (B)		1.86	AxC	1.40	B	1.54	AxC	1.87	
Zinc (C)		1.16	BxC	2.36	C	1.32	BxC	2.10	
AxBxC		AxBxC	2.96		AxBxC	2.33			
		Fruit content of Dihydrocapsaicin (mg/g DW)							
	Zinc (kg fed^{-1})	P_0	P_{50}	P_{100}	Mean	P_0	P_{50}	P_{100}	Mean
HA_0	Zn_0	2.20	2.24	2.23	2.22	2.32	2.35	2.39	2.35
	Zn_4	2.33	2.36	2.40	2.36	2.42	2.46	2.49	2.46
	Zn_6	2.60	2.66	2.73	2.66	2.63	2.65	2.76	2.68
Mean		2.38	2.42	2.45	2.42	2.46	2.49	2.55	2.50
HA_6	Zn_0	2.60	2.62	2.66	2.63	2.65	2.68	2.86	2.73
	Zn_4	2.65	2.79	2.96	2.80	2.73	2.85	2.93	2.84
	Zn_6	2.85	2.91	3.10	2.95	2.89	2.96	3.22	3.02
Mean		2.70	2.77	2.91	2.79	2.76	2.83	3.00	2.86
Phosphorous x Zinc	Zn_0	2.36	2.56	2..64	2.52	2.43	2.67	2.76	2.62
	Zn_4	2.54	2.69	2.81	2.68	2.62	2.72	2.85	2.73
	Zn_6	2.63	2.79	2.93	2.78	2.67	2.81	2.90	2.79
Mean		2.51	2.68	2.79	2.66	2.57	2.73	2.84	2.71
					LSD at 0.05 level				
HA (A)		0.30	AxB	0.36	A	0.33	AxB	NS	
Phosphorous (B)		0.25	AxC	0.40	B	0.14	AxC	0.22	
Zinc (C)		0.30	BxC	0.43	C	0.16	BxC	0.46	
AxBxC		0.46			AxBxC	0.52			

0.58 and 0.61% at P_{50} and P_{100}, respectively for the first growing season and from 0.43 at control plants to 0.61 and 0.64 at P_{50} and P_{100}, respectively for the second growing season. Other researchers found that there was a high relation between phosphorous and zinc in plant [18]. Application of different rates of chelated zinc significantly increased the amount of P uptake by omega cultivar plant as indicated in Table (9), whereas plant P content increased from 0.33 at the control plants to 0.61 and 0.71% for Zn_4 and Zn_6 treatments, respectively for the first growing season and from 0.34 at control plants to 0.61% and 0.73 % for Zn_4 and Zn_6 treatments, respectively for the second growing season. There were no significant interaction effects between humic acid, phosphorous and chelated zinc application on the amount of phosphorous content in chili plants under the certain condition. These results agree with that found by Singh *et al*. [64]; Khaled and Fawy [66] and Atiyeh *et al*. [67].

Table 9: Effect of humic acid, phosphorous and chelated Zn application on the nitrogen and phosphorous content of omega cultivar plants during the two growing seasons

		Plant N content (%)							
		1st season				2nd season			
Treatments	Zinc (kg fed^{-1})	Phosphorous levels (kg fed^{-1})							
		P_0	P_{50}	P_{100}	Mean	P_0	P_{50}	P_{100}	Mean
HA_0	Zn_0	2.44	2.61	2.88	2.64	2.51	2.64	3.01	2.72
	Zn_4	2.95	3.23	3.95	3.38	3.01	3.41	3.96	3.46
	Zn_6	3.24	3.96	4.18	3.79	3.48	3.97	4.21	3.89
Mean		2.88	3.27	3.67	3.27	3.00	3.34	3.73	3.36
HA_6	Zn_0	2.5	2.64	2.94	2.69	2.55	2.69	3.18	2.81
	Zn_4	2.99	3.49	3.99	3.49	3.03	3.7	3.99	3.57
	Zn_6	3.45	3.99	4.26	3.90	3.64	3.99	4.45	4.03
Mean		2.98	3.37	3.73	3.36	3.07	3.46	3.87	3.47
Phosphorus x Zinc	Zn_0	2.47	2.63	2.91	2.67	2.53	2.67	3.10	2.76
	Zn_4	2.97	3.36	3.97	3.43	3.02	3.56	3.98	3.52
	Zn_6	3.35	3.98	4.22	3.85	3.56	3.98	4.33	3.96
Mean		2.93	3.32	3.70	3.32	3.04	3.40	3.80	3.41
		LSD at 0.05 level							
HA (A)		0.08	A x B	NS	A	0.10	AxB	NS	
Phosphorous (B)		0.75	AxC	NS	B	0.76	AxC	NS	
Zinc (C)		NS	BxC	NS	C	NS	BxC	NS	
AxBxC		NS			AxBxC	NS			
		Plant P content (%)							
	Zinc (kg fed^{-1})	P_0	P_{50}	P_{100}	Mean	P_0	P_{50}	P_{100}	Mean
HA_0	Zn_0	0.54	0.76	0.79	0.70	0.56	0.79	0.8	0.72
	Zn_4	0.46	0.62	0.69	0.59	0.46	0.64	0.7	0.60
	Zn_6	0.41	0.42	0.45	0.43	0.41	0.46	0.51	0.46
Mean		0.40	0.47	0.60	0.64	0.57	0.48	0.63	0.67
HA_6	Zn_0	0.56	0.79	0.82	0.72	0.58	0.81	0.83	0.74
	Zn_4	0.66	0.7	0.57	0.64	0.47	0.68	0.73	0.63
	Zn_6	0.47	0.54	0.55	0.52	0.45	0.57	0.61	0.54
Mean		0.53	0.56	0.68	0.65	0.63	0.50	0.69	0.72
Phosphorus x Zinc	Zn_0	0.55	0.78	0.81	0.71	0.57	0.80	0.82	0.73
	Zn_4	0.56	0.66	0.63	0.62	0.47	0.66	0.72	0.61
	Zn_6	0.44	0.48	0.50	0.47	0.43	0.52	0.56	0.50
Mean		0.46	0.52	0.64	0.65	0.60	0.49	0.66	0.70
		LSD at 0.05 level							
HA (A)		0.06	A x B	0.17	A	0.04	AxB	0.23	
Phosphorous (B)		0.12	AxC	NS	B	0.21	AxC	NS	
Zinc (C)		0.23	BxC	NS	C	NS	BxC	NS	
AxBxC		NS			AxBxC	NS			

Potassium and Zinc Content in Chili Plants: Data in Table (10) revealed that soil application of humic acid significantly increased the content of potassium in omega cultivar plants whereas plant k increased from 3.03 % at HA_0 to 3.51% at HA_6 and from 3.04% at HA_0 to 3.54 % at HA_6 for the first and second growing season respectively. Phosphorous and chelated zinc applications had no significant effects on the amount of K in chili plants. Also, there was no significance of the content of K in chili plants as affected by the interaction between the examined variables. Table (10) also, showed that Zn content (mg/100gm) significantly increased as a result of increasing application rates of humic acid, phosphorous and chelated Zn fertilization. With respect to the effect of interaction among the three examined variables (humic acid, phosphorous and zinc rates), there were significant effects of interaction only for the HA x P, HA x Zn, P x Zn for the two growing seasons. These results are supported by the published results of Singh *et al*. [32] and Khaled and Fawy [66] who stated that balanced nutrition affected plant growth, yield and soil physical and chemical characterizations.

Table 10: Effect of humic acid, phosphorous and chelated Zn application on potassium and zinc content in omega cultivar plants during the two growing seasons

Treatments	Zinc (kg fed^{-1})	Plant K content (%) 1st season, Phosphorous levels (kg fed^{-1}) P$_0$	P$_{50}$	P$_{100}$	Mean	2nd season P$_0$	P$_{50}$	P$_{100}$	Mean
HA$_0$	Zn$_0$	2.91	2.98	2.98	2.96	2.9	2.85	2.83	2.86
	Zn$_4$	2.92	3.02	3.1	3.01	2.85	3	3.08	2.98
	Zn$_6$	3.02	3.14	3.23	3.13	3	3.18	3.66	3.28
Mean		2.95	3.05	3.10	3.03	2.92	3.01	3.19	3.04
HA$_6$	Zn$_0$	3.22	3.45	3.5	3.39	3.1	3.22	3.43	3.25
	Zn$_4$	3.46	3.53	3.6	3.53	3.48	3.55	3.67	3.57
	Zn$_6$	3.45	3.48	3.9	3.61	3.74	3.8	3.84	3.79
Mean		3.38	3.49	3.67	3.51	3.44	3.52	3.65	3.54
Phosphorous x Zinc	Zn$_0$	3.07	3.22	3.24	3.17	3.00	3.04	3.13	3.06
	Zn$_4$	3.19	3.28	3.35	3.27	3.17	3.28	3.38	3.27
	Zn$_6$	3.24	3.31	3.57	3.37	3.37	3.49	3.75	3.54
Mean		3.16	3.27	3.39	3.27	3.18	3.27	3.42	3.29
					LSD at 0.05 level				
HA (A)		0.48	A x B	NS	A	0.50	AxB	NS	
Phosphorous (B)		0.22	AxC	NS	B	0.24	AxC	NS	
Zinc (C)		0.20	BxC	NS	C	0.48	BxC	NS	
AxBxC		NS			AxBxC	NS			

	Zinc (kg fed^{-1})	Plant Zn content, mg/100g P$_0$	P$_{50}$	P$_{100}$	Mean	P$_0$	P$_{50}$	P$_{100}$	Mean
HA$_0$	Zn$_0$	0.13	0.19	0.24	0.19	0.14	0.21	0.25	0.20
	Zn$_4$	0.15	0.21	0.26	0.21	0.18	0.22	0.28	0.23
	Zn$_6$	0.21	0.22	0.29	0.24	0.22	0.23	0.30	0.25
Mean		0.16	0.21	0.26	0.21	0.18	0.22	0.28	0.22
HA$_6$	Zn$_0$	0.15	0.21	0.27	0.21	0.15	0.23	0.28	0.22
	Zn$_4$	0.19	0.23	0.28	0.23	0.19	0.24	0.30	0.24
	Zn$_6$	0.22	0.25	0.32	0.26	0.22	0.26	0.33	0.27
Mean		0.18	0.23	0.29	0.23	0.19	0.24	0.30	0.24
Phosphorous x Zinc	Zn$_0$	0.14	0.20	0.26	0.20	0.14	0.22	0.26	0.21
	Zn$_4$	0.17	0.22	0.27	0.22	0.18	0.23	0.29	0.23
	Zn$_6$	0.21	0.24	0.30	0.25	0.22	0.24	0.31	0.26
Mean		0.17	0.22	0.28	0.22	0.18	0.23	0.29	0.23
					LSD at 0.05 level				
HA (A)		0.02	A x B	NS	A	0.02	AxB	NS	
Phosphorous (B)		0.10	AxC	NS	B	0.11	AxC	NS	
Zinc (C)		0.04	BxC	NS	C	0.05	BxC	NS	
AxBxC		NS			AxBxC	NS			

Relationship Between Both Available Phosphorus or Available Zinc and Chili Yield: Considering the relationship between available P in the soil and chili yield, Fig. (1) indicate that there was a positive relation between soil available phosphorous and the chili yield, where correlation coefficient was 0.74 as a mean value for the two growing seasons. Also, there were a positive correlation between soil available zinc and the chili yield, where correlation coefficient was 0.96 as a mean value for the two growing seasons as presented in Fig. (2). It also clear that chili yield was more correlated to available zinc than available phosphorous in the soil.

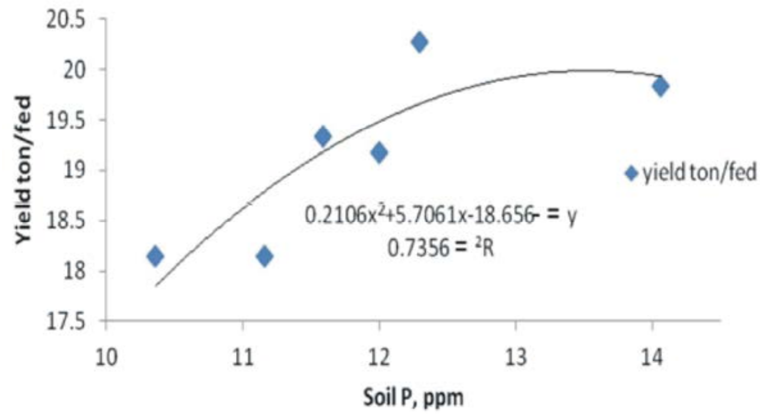

Fig. 1: Relation between soil available P (ppm) and chili yield (ton fed^{-1}) for the two growing seasons

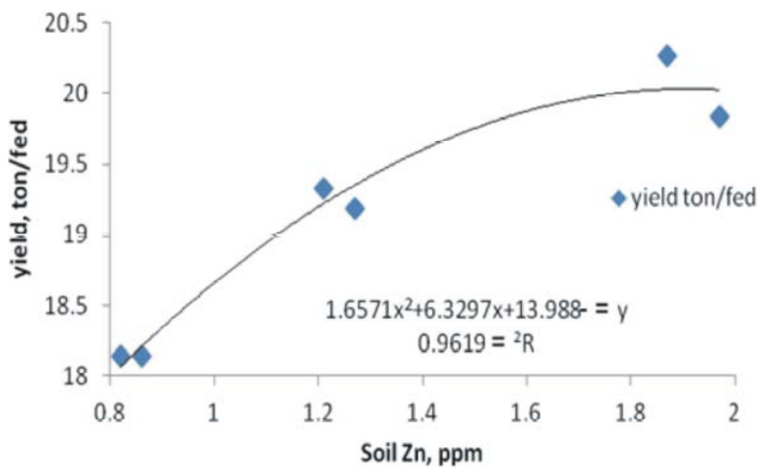

Fig. 2: Relation between soil available Zn (ppm) and chili yield (ton fed^{-1}) for the two growing seasons

CONCLUSION

In conclusion, under sandy soil conditions at El-Tahrir region, chili plants should be supplied with 6 kg humic acid + 100 kg H_3PO_4+ 6 kg chelated Zn. Where this application results in improving the soil´s physical and chemical characteristics, as well as the achievement of the highest chili growth, yield (21.19 ton/fed) and fruit content of Capsaicin and dihydrocapsaicin (23.96 and 3.22 mg/g DW, respectively) without high risk of P-induced Zn deficiencies. The enhanced effects of the examined fertilization may be attributed to their effects on the soil exchange in the case of humic acid or may be attributed to the effects of Phosphorus on cell division, growth enzymatic systems, or may result from the effect of Zn as a co-factor for a multi number of enzymes and its important roles in metabolism process. All these reasons may augment plants to produce a high yield of both Capsaicin and dihydrocapsaicin.

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