Journal of Horticultural Science & Ornamental Plants 12 (1): 17-26, 2020
ISSN 2079-2158

DOI: 10.5829/idosi.jhsop.2020.17.26

Effect of Humic Acid and Compound Fertilizer of Macro and Micro Elements on the Vegetative Growth, Seed Yield and Biochemical Constituents of *Moringa oleifera* Lam. Plants Grown in Sandy Soils

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Abstract: The present work aimed to study the different effects of added grounding for humic acid at 0, 3, 4 and 5 L/fed., compound fertilizer (some macro and micro elements) at 0, 80, 100, 120 Kg/fed. and their interaction treatments on the vegetative growth, seed yield, minerals and some active ingredients of *Moringa oleifera* Lam. plants grown in sandy soils at the Experimental Farm of Ismailia Agriculture Research Station, Ismailia Governorate, Egypt, during the two successive seasons of 2016 and 2017. The obtained data showed that the positive effects of humic acid and compound fertilizer as well as their interactions on all studied traits. The highest values of vegetative growth, seed yield and minerals content (in dry leaves and seeds) as well as active ingredients in dry leaves especially antioxidants were obtained with the interaction between the highest level of compound fertilizer (120kg/fed.) and humic acid (5L/fed.) with significant differences compared to all other treatments. The highest levels of both compound fertilizer (120kg/fed.) and humic acid (5L/fed.) were significantly superior in comparison with other levels of each factor, individually. These results were recorded in both seasons.

Key words: *Moringa oleifera* Lam. · Humic acid · Macro and micro elements · Active ingredients · Vitamin C · Phenols · Antioxidants

INTRODUCTION

Moringa is the sole genus of Moringaceae family. There are 14 known species of the genus *Moringa*, which grow in the tropics. *Moringa oleifera* Lam. is the most widely distributed the best known and the most utilized of the *Moringa* species. In some parts of the world *M. oleifera* is referred to as the 'drumstick tree' or the 'horseradish tree', whereas in others it is known as the kelor tree [1]. While in the Nile valley, the name of the tree is 'Shagara al Rauwaq', which means 'tree for purifying' [2]. *M. oleifera* is a highly valued plant, distributed in many countries of the tropics and subtropics. It is best known as an excellent source of nutrition and a natural energy booster [3]. *Moringa oleifera* has a lot of potential for the production of food products, medicinal products, water purification processes, renewable polymer products, animal and aquaculture feeds and even potential to be utilized in the production of other crops [4]. The leaves, fruits, flowers and immature pods of this tree are used as a highly nutritive vegetable in many countries, particularly in India, Pakistan, Philippines, Hawaii and many parts of Africa [5, 6]. Moringa leaves have been reported to be a rich source of â-carotene, protein, vitamin C, calcium and potassium and act as a good source of natural antioxidants; and thus enhance the shelf-life of fat-containing foods due to the presence of various types of antioxidant compounds such as ascorbic acid, flavonoids, phenolics and carotenoids [7, 8]. In the Philippines, it is known as 'mother's best friend' because of its utilization to increase woman's milk production and is sometimes prescribed for anemia [8, 9]. The seeds provide "ben oil" used in perfumery and light lubricants and the seeds are also used to purify water and removal of industrial pollutants [10, 11]. *M. oleifera* oil was found to have potential as an acceptable feedstock for biodiesel. The leaves made highly nutritious cattle feed and the roots are also a source of edible condiment. The tree's

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bark, roots, fruits, flowers, leaves, seeds and gum are also used medicinally [12]. Thus, Charoensin [13] revealed that the *M. oleifera* dichloromethane extract shows high antioxidant activity, potent cancer cell anti-proliferation.

Moringa prefers neutral to slightly acidic soils and grows best in well-drained loam to clay-loam, it tolerates clay soils but does not grow well if waterlogged [14].

Humic substances (HS) can have a beneficial effect on plant growth as measured in terms of increases in lengths, fresh and dry weights of shoots and roots, leaf chlorophyll concentration, number of lateral root initials and many other biological parameters. Therefore, it has been suggested that these compounds may have a fundamental influence not only on the overall soil fertility and conservation, but also on the physiology of plants [15]. Humic acids (HA) are the main fractions of humic substances and the most active components of soil and compost organic matter. Humic acids have been shown to stimulate plant growth and consequently yield by acting on mechanisms involved in cell respiration, photosynthesis, protein synthesis, water and nutrient uptake and enzyme activities [16, 17]. Humic acid is not a fertilizer as it does not directly provide nutrients to plants, but is a compliment to fertilizer. Its benefits include: addition of organic matter to organically-deficient soils, increase root vitality, improved nutrient uptake, increased chlorophyll synthesis, stimulate beneficial microbial activity and healthier plants and improved yields as indicated by Varanini and Pinton [15]. Humic acids chelate nutrient compounds, especially iron, to obtain a suitable form for plant utilization in soil, so the nutrient supply of plants is optimized. Best economic results of the humic application can be obtained in light and sandy soils poor in humus as well as on recultivation fields [18].

In concern the effect of humic acid, the growth and nutrient uptake of teak (*Tectona grandis* L. f.), a tropical hardwood, was studied at two soil types in Nigeria by Fagbenro and Agboola [19], they recorded that plant parameters and uptake tended to increase with increasing amounts of HA. Also, El-Sayed [20] using humic acid on aggizy olive and found that the highest level gave an increment of leaf mineral content of N, P, K, Fe, Zn and Mn. Bakry *et al.* [21] reported that humic acid caused significant increase in the growth characters, increased chlorophyll a and b, carotenoids, consequently total pigments, total carbohydrates, phenol and free amino acids content of shoots as well as yield components in flax plant.

Compound fertilizer contains multiple nutrients in each individual granule, this differs from a blend of fertilizers mixed together to achieve a desired average nutrient composition. This difference allows compound fertilizer to be spread so that each granule delivers a mixture of nutrients as it dissolves in the soil and eliminates the potential for segregation of nutrient sources during transport or application. A uniform distribution of micronutrients throughout the root zone can be achieved when included in compound fertilizers. However, when a consideration is made of all the factors involved with nutrient handling and use, compound fertilizers may offer considerable advantages [22].

Fertilization has an important role in growth, flowering, fruit and seed yields as well as biochemical constituents of plants. In this concern, Anamayi *et al.* [23] concluded that vegetative growth and nutrients content of *Moringa oleifera* were best when supported by 5g/plant of NPK (15:15:15) which is significant as compared to the other treatment (3g/plant). Also, Fagbenro *et al.* [24] revealed that application of NPK 15:15:15 fertilizer had highly significant effects on height growth and dry-matter yield of *Moringa oleifera*. Similar results were reported by Makinde, [25] and Sarwar *et al.* [26], the highest fertilizer rate was best supported the vegetative growth parameters and produced the highest quantity of protein in *Moringa* leaves. Attia *et al.* [27] found that the yield components of *Moringa* trees increased with increasing of NPK fertilizers rates. Also Sabra [28] illustrated that increasing NPK rate gave increments in total antioxidants activity, vitamin C, phenols and amino acids contents as well as N, P, K and Ca percent at *Moringa* seedlings. Mazrou and El-Sebay [29] reported that the vegetative growth parameters and l-ascorbic acid (vitamin C) content in the leaves of *Moringa* gradually increased with increasing urea rate. Moreover, Hammam [30] on Senna (*Cassia acutifolia* D.) found that all NPK treatments increased the sennosides yield in leaves/plant compared with control.

Khater and Abd El-Azim [31] revealed that the combination of chemical fertilizers at 75% of the recommended dose of NPK with humic acid at 4 kg/fed. recorded a significant increase in plant height, number of branches, fresh and dry weights/plant, seed yield as well as total protein and mucilage contents in *Plantago psyllium* when compared to other treatments. The highest level 4 kg/fed. from humic acid was the best when compared to the two other levels. On the same way, Jamal *et al.* [32] suggest that application of 90kg P_2O_5/ha reinforced with HA (500g/ha) may be considered as an optimum dosage for achieving optimum yield of wheat crop.

The application of humic acid in conjunction with compound fertilizer in *Moringa* plants has not been discussed so far. Therefore, this work aims to investigate the effects of humic acid, compound fertilizer and their interaction treatments on vegetative growth, seed yield components, minerals and some active ingredients (Total phenols, carotenoids, vitamin C as antioxidants and total free amino acids) of *Moringa oleifera* Lam. under sandy soil conditions.

MATERIALS AND METHODS

This work was carried out at the Experimental Farm of Ismailia Agriculture Research Station, Ismailia Governorate, Egypt, during the two successive seasons of 2016 and 2017. The experimental soil was sandy soil and its physical and chemical properties are shown in Table (1).

Moring Oleifera Lam. trees were grown at the Experimental Farm of Ismailia Agriculture Research Station, Ismailia Governorate from 2013, with 2.5 m between the rows and 2 m between the plants within the row (840 tree/ feddan). The plants were pruned at the end of 2013 by cut the growing tip area (about 20cm.) to stimulate lateral branching. The experimental unit area 20 m^2 (2.5 × 8 m) and the whole experiment has 48 plots for each season. The age of treated plant groups was 4 and 5 years at the first and second seasons, respectively.

Humic acid (Hemogreen) was obtained from Soil, Water and Environment Research Institute, ARC, Egypt.

Compound fertilizer (TURO fort) was used; its macro and micro elements percentages are shown in Table (2).

Factorial experiment was conducted in split plot design with three replicates and included 16 treatments. Four levels of humic acid at the whole plots and four rates of compound fertilizer (TURO fort) in the split plots.

Humic acid (HA) treatments were HA_0= 0; HA_1= 3; HA_2= 4; HA_3= 5 L/fed.

Compound fertilizer (CF) treatments were CF_0= 0; CF_1= 80; CF_2= 100; CF_3= 120 Kg/fed. Both of humic acid and compound fertilizer were added to the soil in the root area, divided at 10 times during the season from February until June, the first dose was applied at 1st February each season and the other doses were applied at 15 days intervals in both seasons.

Data Recorded:

Vegetative Growth Parameters: Plant height (cm), number of branches per plant, number of leaves per plant, fresh and dry weights of 10 leaves (collected from the same site on branches per all plants) were recorded at 15th August in both seasons.

Table 1: The physical and chemical properties of the used soil.

		Physical properties		
Sand (%)	Silt (%)	Clay (%)	Texture	---
91.70	7.00	1.30	Sandy	---
		Chemical properties		
Salt analysis		Anions (meq/l)		
EC dSm^{-1}	pH	Cl^-	$HCO_3^-+CO_3^{2-}$	SO_4^{2-}
0.15	7.82	0.46	0.28	0.35
		Cations (meq/l)		---
Ca^{2+}	Mg^{2+}	Na^+	K^+	---
0.42	0.25	0.34	0.08	---
Available elements			Total nitrogen (g/kg)	Organic matter (OM) (%)
Nitrogen (mg/kg)	Phosphorus (mg/kg)	Potassium (mg/kg)	0.20	0.23
11.00	13.40	41.20	---	---

Table 2: Chemical constituents of the used compound fertilizer (TURO fort).

Macro nutrients %		Micro nutrients %	
Nitrogen (N)	20 %	Iron (Fe- EDTA)	0.10 %
Phosphorus (P_2O5) Soluble in water	20 %	Copper (Cu- EDTA)	0.05 %
Potassium (K_2O) Soluble in water	20 %	Manganese (Mn- EDTA)	0.05 %
---	---	Zinc (Zn- EDTA)	0.05 %
---	---	Boron (B)	0.01 %
---	---	Molybdenum (Mo)	0.001 %
---	---	Sulfur (S)	1.00 %
---	---	Chelating agent	1.24 %

Seed Yield Components: Seeds were collected after harvesting the mature pods from July until October, then seed weight (g)/plant, seed yield (kg)/feddan were calculated at the end of each season by multiplying seed weight (g)/plant by plant number/feddan (840 tree).

Chemical Contents in Dry Leaves and Seeds: N, K, Ca percentages and P content (mg/100g d.w.) were determined in the dry leaves and seeds according to A.O.A.C. [33]. Total protein percentage in both dry leaves and seeds was calculated by multiplying N percentage with a conversion factor (6.25) according to A.O.A.C. [34]. Also, the content of vitamin C (mg/100g d.w.), total carotenoids (mg/100g d.w.), total phenols (mg/100g d.w.) and total free amino acids (mg/100g d.w.) in dry leaves were determined according to A.O.A.C. [33].

Statistically Analysis: The factorial experiments were arranged in split plot design in three replicates and the collected data were computed and statistically analyzed with analysis of variance according to Mead *et al.* [35] using SPSS (V. 22) program and the differences between the means of treatments were tested by L.S.D test at 0.05 level.

RESULTS AND DISCUSSION

Vegetative Growth Parameters: The results presented in Table (3), show that humic acid levels significantly increased plant height, branch number and leaf number, as well as fresh and dry weights of leaves. By increasing level of humic acid all trails were significantly increased. The highest level (5 L/fed.) was superior in this respect during the two seasons. These results are in harmony with those reported by Khater and Abd El-Azim [31] on plantago plant.

From the data recorded in Table (3), it can be concluded that vegetative growth parameters were significantly increased by increasing the compound fertilizer rates in the two seasons. The highest rate (120 Kg/fed.) gave the highest values of all studied trails. Moreover, all rates (80, 100 and 120 Kg/fed.) of compound fertilizer were superior compared to control (zero). These results are in line with those stated by Anamayi *et al*. [23]; Fagbenro *et al.* [24]; Makinde [25] and Sarwar *et al.* [26] on *Moringa oleifera*.

Regarding the interaction between humic acid and compound fertilizer levels, data in Table (3) revealed that all interaction treatments gave significant increases in plant height, the number of branches and the number of leaves as well as fresh and dry weights of leaves in *Moringa* plants during the two seasons compared to the control. The highest level of compound fertilization (120Kg/fed.) with the highest rate of humic acid (5L/fed.) significantly produced the highest values of recorded parameters in both seasons. Similar results were found by Khater and Abd El-Azim [31] on plantago plant.

Improving the vegetative growth by using organic material may be due to that it amendment of the soil, increasing the availability and uptake of the nutrients (macro and micro), besides increasing the water holding capacity of the soil. Also, humic acids have been shown to stimulate plant growth and consequently yield by acting on mechanisms involved in: cell respiration, photosynthesis, protein synthesis, water and nutrient uptake, enzyme activities [16, 17].

The increase in the growth of *Moringa oleifera* plants using compound fertilization may be due to the direct or indirect role of its macro and micro nutrients in plant anabolism through activating the photosynthetic processes and cell division, cell enlargement as well as the accumulation of their metabolites in plant organs, resulting in more plant materials.

Seed Yield Components: Seed weight (g)/ plant and seed yield (kg)/ fed. were affected with application of humic acid as shown in Table (4), by increasing humic level, seed yields were significantly increased. The highest yields of seed per plant and per feddan were obtained with application of the highest level of humic acid (5L/fed.) at both seasons as, 360.92, 486.42 g/plant and 303.17, 408.59 Kg/fed., respectively. Similar results were recorded by Attia *et al.* [27] on *Moringa* and Khater and Abd El-Azim [31] on plantago plant.

Data illustrated in Table (4), reveal that compound fertilizer has a positive effect on seed weight (g)/plant and seed yield (kg)/fed. The highest level of compound fertilization (120 Kg/fed.) gave a significant increase of seed yield components in comparison with the other levels; it recorded 428.17, 576.67 g/plant and 359.66, 484.40 Kg/fed. in the two seasons, respectively. Moreover, all levels were significantly superior compared by control (zero Kg/fed.). These results agree with those found by Attia *et al.* [27] on *Moringa*, Khater and Abd El-Azim [31] on plantago and Jamal *et al.* [32] on wheat.

As shown in Table (4), the interaction treatment between the highest levels of humic and fertilization gave the highest yield per plant and feddan of moringa seed as 450.67, 621.00 g/plant and 378.56, 521.64 Kg/fed. for first and second seasons, respectively. These results were in concert with those obtained by Khater and Abd El-Azim [31] on plantago and Jamal *et al.* [32] on wheat.

Table 3: Effect of humic acid (HA), compound fertilizer (CF) and their interaction on some vegetative growth parameters of *Moringa oleifera* Lam. during 2016 and 2017 seasons.

Compound fertilizer	CF_0	CF_1	CF_2	CF_3	M_{HA}	CF_0	CF_1	CF_2	CF_3	M_{HA}
Humic acid	First season 2016					Second season 2017				
					Plant height (cm)					
HA_0	224.11	233.22	248.33	252.67	239.58	291.00	321.33	344.44	361.44	329.55
HA_1	232.00	243.00	254.00	261.67	247.67	303.89	315.67	350.00	385.89	338.86
HA_2	240.22	249.00	262.33	272.11	255.92	310.89	337.33	369.33	394.55	353.03
HA_3	243.00	252.67	269.11	275.00	259.94	324.44	352.56	395.22	407.22	369.86
M_{CF}	234.83	244.47	258.44	265.36		307.56	331.72	364.75	387.28	
LSD at 5%	HA= 1.83 CF= 1.32 Inter.=2.64					HA= 5.08 CF= 3.62 Inter.= 7.24				
					Branch number/plant					
HA_0	5.67	8.00	9.22	9.00	7.97	6.22	8.00	9.44	10.00	8.42
HA_1	5.78	8.33	9.67	10.67	8.61	6.33	8.72	9.89	11.17	9.03
HA_2	6.67	9.00	10.39	11.33	9.35	6.89	9.89	11.67	12.00	10.11
HA_3	8.00	9.67	10.22	12.00	9.97	8.00	10.00	11.78	13.55	10.83
M_{CF}	6.53	8.75	9.87	10.75		6.86	9.15	10.69	11.68	
LSD at 5%	HA= 0.77 CF= 0.43 Inter.= 0.86					HA= 0.49 CF= 0.41 Inter.= 0.81				
					Leaf number/plant					
HA_0	40.00	59.33	70.67	84.33	63.58	43.00	72.00	78.67	89.00	70.67
HA_1	43.67	68.67	81.33	92.00	71.42	51.00	77.67	88.67	96.00	78.33
HA_2	53.00	76.67	90.67	101.00	80.33	57.67	82.33	97.33	102.33	84.92
HA_3	59.00	83.67	98.67	110.33	87.92	61.67	89.33	102.00	112.67	91.42
M_{CF}	48.92	72.08	85.33	96.92		53.33	80.33	91.67	100.00	
LSD at 5%	HA= 4.00 CF= 2.45 Inter.= 4.90					HA= 4.08 CF= 2.5 Inter.= 5.01				
					Fresh weight of 10 leaves (g)/plant					
HA_0	34.15	38.21	42.16	43.25	39.44	36.72	41.10	46.44	45.08	42.34
HA_1	39.49	46.80	49.79	54.36	47.61	41.91	48.18	48.65	52.37	47.78
HA_2	42.32	48.18	53.14	59.36	50.75	43.71	50.01	55.04	57.52	51.57
HA_3	45.83	50.52	57.77	60.97	53.77	44.52	52.02	57.43	60.61	53.64
M_{CF}	40.45	45.93	50.72	54.49		41.72	47.83	51.89	53.90	
LSD at 5%	HA= 1.67 CF= 1.26 Inter.= 2.51					HA= 1.57 CF= 1.40 Inter.= 2.81				
					Dry weight of 10 leaves (g)/plant					
HA_0	9.85	11.68	13.66	14.96	12.54	11.76	12.76	13.84	13.81	13.04
HA_1	11.51	13.96	15.12	16.97	14.39	12.76	14.21	14.87	17.24	14.77
HA_2	12.44	13.84	16.07	16.95	14.82	13.25	14.28	15.38	17.47	15.10
HA_3	13.16	14.02	17.38	17.84	15.60	13.56	14.75	16.64	18.14	15.77
M_{CF}	11.74	13.37	15.56	16.68		12.83	14.00	15.18	16.67	
LSD at 5%	HA= 0.35 CF= 0.16 Inter.= 0.31					HA= 0.33 CF= 0.29 Inter.= 0.59				

Table 4: Effect of humic acid (HA), compound fertilizer (CF) and their interaction on seed yield components of *Moringa oleifera* Lam. during 2016 and 2017 seasons.

Compound fertilizer	CF_0	CF_1	CF_2	CF_3	M_{HA}	CF_0	CF_1	CF_2	CF_3	M_{HA}
Humic acid	First season 2016					Second season 2017				
					Seed weight (g)/plant					
HA_0	204.67	273.33	325.67	397.33	300.25	316.33	357.00	432.67	518.67	405.92
HA_1	219.67	290.33	364.33	418.33	323.17	326.67	398.00	495.67	565.33	446.42
HA_2	239.33	316.00	381.67	446.33	345.83	343.67	422.00	508.67	601.67	469.00
HA_3	259.33	329.00	404.67	450.67	360.92	349.33	434.67	540.67	621.00	486.42
M_{CF}	230.75	302.17	369.08	428.17		333.75	402.92	494.42	576.67	
LSD at 5%	HA= 7.99 CF= 4.32 Inter.= 8.63					HA= 7.24 CF= 5.71 Inter.= 11.42				
					Seed yield (kg)/feddan					
HA_0	171.92	229.60	273.56	333.76	252.21	264.88	299.88	363.44	435.68	340.97
HA_1	184.52	243.88	306.04	351.40	271.46	274.40	334.32	416.36	474.88	374.99
HA_2	201.04	265.44	320.60	374.92	290.50	288.68	354.48	427.28	505.40	393.96
HA_3	217.84	276.36	339.92	378.56	303.17	293.44	365.12	454.16	521.64	408.59
M_{CF}	193.83	253.82	310.03	359.66		280.35	338.45	415.31	484.40	
LSD at 5%	HA= 6.71 CF= 3.62 Inter.= 7.25					HA= 6.08 CF= 4.80 Inter.= 9.59				

Table 5: Effect of humic acid (HA), compound fertilizer (CF) and their interaction on minerals and total protein percentage in dry leaves of *Moringa oleifera* Lam. during 2016 and 2017 seasons

Compound fertilizer	CF_0	CF_1	CF_2	CF_3	M_{HA}	CF_0	CF_1	CF_2	CF_3	M_{HA}
Humic acid	First season 2016					Second season 2017				
	Nitrogen percentage									
HA_0	3.49	3.74	4.15	4.34	3.93	3.60	3.80	4.21	4.35	3.99
HA_1	3.60	4.24	4.39	4.55	4.20	3.63	4.12	4.32	4.45	4.13
HA_2	3.79	4.33	4.48	4.62	4.31	3.72	4.20	4.39	4.58	4.22
HA_3	3.87	4.51	4.65	4.74	4.44	3.79	4.36	4.57	4.70	4.36
M_{CF}	3.69	4.21	4.42	4.56		3.69	4.12	4.37	4.52	
LSD at 5%	HA= 0.03 CF= 0.03 Inter.= 0.05					HA= 0.03 CF= 0.03 Inter.= 0.05				
	Phosphorus content (mg/100g d.w.)									
HA_0	300.00	315.00	330.00	330.33	321.17	301.33	315.67	333.00	348.33	324.58
HA_1	303.33	323.67	330.33	338.67	329.67	306.00	331.00	341.67	356.33	333.75
HA_2	308.67	330.33	330.33	351.00	338.75	310.00	335.67	354.33	368.33	342.08
HA_3	312.00	338.67	330.33	362.00	346.67	316.33	345.67	372.33	382.00	354.08
M_{CF}	306.00	326.92	345.42	357.92		308.42	332.00	350.33	363.75	
LSD at 5%	HA= 1.33 CF= 1.02 Inter.= 2.04					HA= 2.16 CF= 1.61 Inter.= 3.21				
	Potassium percentage									
HA_0	2.18	2.52	3.02	3.17	2.72	2.49	2.60	2.94	3.21	2.81
HA_1	2.25	2.78	3.17	3.28	2.87	2.53	2.73	3.14	3.40	2.95
HA_2	2.37	2.86	3.24	3.39	2.97	2.57	3.09	3.31	3.55	3.13
HA_3	2.46	2.96	3.35	3.45	3.05	2.63	3.32	3.52	3.57	3.26
M_{CF}	2.32	2.78	3.20	3.32		2.56	2.93	3.23	3.43	
LSD at 5%	HA= 0.04 CF= 0.03 Inter.= 0.05					HA= 0.04 CF= 0.04 Inter.= 0.07				
	Calcium percentage									
HA_0	2.33	2.59	3.05	3.19	2.79	2.61	2.74	2.88	3.19	2.85
HA_1	2.39	2.64	3.07	3.24	2.83	2.66	2.85	3.19	3.29	3.00
HA_2	2.42	2.89	3.15	3.25	2.93	2.76	3.01	3.26	3.32	3.09
HA_3	2.49	2.99	3.22	3.33	3.00	2.86	3.13	3.35	3.47	3.21
M_{CF}	2.41	2.78	3.12	3.25		2.73	2.93	3.17	3.32	
LSD at 5%	HA= 0.04 CF= 0.03 Inter.= 0.05					HA= 0.03 CF= 0.04 Inter.= 0.07				
	Total protein percentage									
HA_0	21.79	23.39	25.94	27.44	24.64	22.48	23.73	26.33	27.17	24.93
HA_1	22.52	26.48	27.46	28.44	26.22	22.71	25.73	27.00	27.81	25.81
HA_2	23.67	27.08	28.02	28.89	26.92	23.27	26.25	27.41	28.64	26.39
HA_3	24.21	28.21	29.08	29.60	27.77	23.71	27.27	28.56	29.35	27.22
M_{CF}	23.05	26.29	27.62	28.59		23.04	25.74	27.33	28.24	
LSD at 5%	HA= 0.21 CF= 0.17 Inter.= 0.34					HA= 0.14 CF= 0.16 Inter.= 1.70				

Humic acid have been shown to stimulate plant growth and consequently yield by acting on mechanisms involved in: cell respiration, photosynthesis, protein synthesis, water and nutrient uptake, enzyme activities, then this is reflected in the seed yields [16, 17].

The positive effects of fertilization on seed yield components may be the reflection of its promotion of vegetative growth parameters and stimulation materials in the plant and then, on increasing the seed weight and yield.

The positive effect of the interaction between humic acid and compound fertilizer on growth and yield may result to the role of humic acid in amendment of the soil, increased the availability and uptake of the nutrients (macro and micro) of compound fertilizer, besides increasing the water holding capacity of the soil, which reflected on the metabolic processes activation and hence, increasing the vegetative growth and seed yields of plants.

Chemical Constituents of Leaves and Seeds:

Minerals and Total Protein in Leaves and Seeds: Data in Tables (5 and 6) demonstrated that minerals and protein contents in dry leaves and seeds were increased by increasing humic acid levels. The highest level of humic acid (5L/fed.) gave a significant increases in each of nitrogen, potassium, calcium percentages and phosphorus content as well as protein percentage in both dry leaves and seeds comparing to the other levels (0, 3 and 4L/fed.) in the two seasons. These results are in line with these are found by Fagbenro and Agboola [19] on teak seedlings and El-Sayed [20] on aggizy olive.

Table 6: Effect of humic acid (HA), compound fertilizer (CF) and their interaction on minerals and total protein percentage in dry seeds of *Moringa oleifera* Lam. during 2016 and 2017 seasons

Compound fertilizer	CF_0	CF_1	CF_2	CF_3	M_{HA}	CF_0	CF_1	CF_2	CF_3	M_{HA}
Humic acid	First season 2016					Second season 2017				
					Nitrogen percentage					
HA_0	3.48	3.70	4.06	4.35	3.90	3.45	3.69	3.88	4.11	3.78
HA_1	3.54	3.89	4.49	4.67	4.14	3.53	3.86	4.12	4.27	3.94
HA_2	3.65	4.15	4.55	4.81	4.29	3.66	4.08	4.47	4.63	4.21
HA_3	3.76	4.45	4.75	4.98	4.49	3.72	4.30	4.55	4.70	4.32
M_{CF}	3.61	4.05	4.46	4.70		3.59	3.98	4.25	4.43	
LSD at 5%	HA= 0.03 CF= 0.03 Inter.= 0.05					HA= 0.03 CF= 0.04 Inter.= 0.07				
					Phosphorus content (mg/100g d.w.)					
HA_0	209.33	226.33	239.33	255.33	232.58	218.33	232.67	248.67	264.67	241.08
HA_1	218.33	239.33	261.00	301.33	255.00	228.33	248.67	267.67	307.00	262.92
HA_2	228.33	254.67	290.67	321.33	273.75	233.00	260.33	297.67	325.33	279.08
HA_3	235.00	283.33	317.67	346.00	295.50	241.33	290.00	321.00	349.00	300.33
M_{CF}	222.75	250.92	277.17	306.00		230.25	257.92	283.75	311.50	
LSD at 5%	HA= 1.70 CF= 1.29 Inter.= 2.59					HA= 2.53 CF= 1.94 Inter.= 3.89				
					Potassium percentage					
HA_0	2.72	2.85	3.11	3.22	2.98	2.88	3.08	3.16	3.24	3.09
HA_1	2.73	2.91	3.20	3.41	3.06	2.95	3.16	3.24	3.40	3.19
HA_2	2.80	3.08	3.30	3.53	3.18	3.07	3.34	3.47	3.66	3.38
HA_3	2.88	3.19	3.49	3.61	3.29	3.11	3.47	3.67	3.76	3.50
M_{CF}	2.78	3.01	3.27	3.44		3.00	3.26	3.38	3.51	
LSD at 5%	HA= 0.04 CF= 0.03 Inter.= 0.05					HA= 0.03 CF= 0.04 Inter.= 0.07				
					Calcium percentage					
HA_0	0.86	1.02	1.23	1.47	1.14	1.11	1.21	1.57	1.72	1.40
HA_1	0.93	1.11	1.36	1.56	1.24	1.15	1.37	1.71	1.88	1.53
HA_2	1.00	1.23	1.48	1.69	1.35	1.23	1.53	1.82	1.93	1.63
HA_3	1.08	1.32	1.67	1.74	1.45	1.28	1.62	1.90	1.99	1.70
M_{CF}	0.97	1.17	1.44	1.61		1.19	1.43	1.75	1.88	
LSD at 5%	HA= 0.04 CF= 0.03 Inter.= 0.05					HA= 0.03 CF= 0.03 Inter.= 0.05				
					Total protein percentage					
HA_0	21.77	23.10	25.35	27.21	24.36	21.54	23.04	24.27	25.71	23.64
HA_1	22.10	24.29	28.04	29.19	25.90	22.06	24.10	25.73	26.71	24.65
HA_2	22.81	25.92	28.44	30.08	26.81	22.88	25.52	27.92	28.92	26.31
HA_3	23.48	27.83	29.71	31.13	28.04	23.25	26.87	28.44	29.37	26.98
M_{CF}	22.54	25.29	27.88	29.40		22.43	24.88	26.59	27.68	
LSD at 5%	HA= 0.22 CF= 0.15 Inter.= 0.30					HA= 0.23 CF= 0.23 Inter.= 0.46				

Compound fertilizer rates at 80, 100, 120 Kg/fed. gave a significant increase in nitrogen, potassium, calcium percentages and phosphorus content as well as protein percentage in both dry leaves and seeds in comparison to control in both seasons as clear in Tables (5, 6). The highest rate (120 Kg/fed.) was more effective in this way compared to the other rates. A Similar trend was recorded by Anamayi *et al*. [23]; Makinde [25]; Sarwar *et al*. [26] and Sabra [28] on Moringa oleifera by using NPK fertilizers.

Interaction treatments between humic acid levels and compound fertilizer rates had a significant effect on minerals and protein contents in both dry leaves and seeds as shown in Tables (5, 6). The highest values of nitrogen, potassium, calcium percentages and phosphorus content as well as protein percentage were obtained from the interaction treatment between 5L/fed. of humic acid and 120Kg/fed. of compound fertilizer with significant differences. These results were true for dry leaves and seeds during both seasons. The increase in total protein by the interaction was recorded by Khater and Abd El-Azim [31] in Plantago seeds.

Some Active Ingredients in Dry Leaves: Data regarding the active ingredients in dry leaves during the two seasons were recorded in Table (7). It is clear that total phenols, carotenoids, vitamin C and total free amino acids contents were increased by increasing humic acid levels in the two seasons. Treatments with 3, 4 and 5L/fed. levels gave significant increase in this respect, in comparison

Table 7: Effect of humic acid (HA), compound fertilizer (CF) and their interaction on some active ingredients content in dry leaves of *Moringa oleifera* Lam. during 2016 and 2017 seasons

Compound fertilizer	CF_0	CF_1	CF_2	CF_3	M_{HA}	CF_0	CF_1	CF_2	CF_3	M_{HA}
Humic acid	First season 2016					Second season 2017				
	Total phenols (mg/100g d.w.)									
HA_0	111.97	120.75	124.55	130.17	121.86	117.44	120.14	125.02	132.16	123.69
HA_1	112.31	121.98	130.06	132.99	124.33	117.73	122.65	130.91	135.36	126.66
HA_2	113.55	124.75	133.25	137.06	127.15	118.05	124.02	136.03	139.87	129.49
HA_3	115.07	134.32	136.85	138.46	131.17	119.02	130.35	139.35	141.03	132.44
M_{CF}	113.23	125.45	131.18	134.67		118.06	124.29	132.83	137.10	
LSD at 5%	HA= 0.34 CF= 0.24 Inter.= 0.49					HA= 0.08 CF= 0.05 Inter.= 0.09				
	Carotenoids (mg/100g d.w.)									
HA_0	12.82	14.00	19.20	19.94	16.49	14.62	17.01	19.02	19.70	17.59
HA_1	13.16	17.92	19.85	21.05	18.00	15.01	19.13	20.11	20.59	18.71
HA_2	14.10	19.51	20.71	21.95	19.07	16.00	20.17	21.29	21.97	19.86
HA_3	15.85	20.85	22.71	22.63	20.40	16.61	21.25	22.58	23.07	20.88
M_{CF}	13.98	18.07	20.51	21.39		15.56	19.39	20.75	21.33	
LSD at 5%	HA= 0.12 CF= 0.10 Inter.= 0.19					HA= 0.13 CF= 0.10 Inter.= 0.21				
	Vitamin C (mg/100g d.w.)									
HA_0	18.70	18.93	21.73	23.18	20.64	19.74	19.89	21.30	22.19	20.78
HA_1	19.17	20.24	22.57	23.43	21.35	19.77	20.94	21.82	22.51	21.26
HA_2	20.07	21.32	22.79	23.82	22.00	20.02	21.80	22.18	23.01	21.75
HA_3	20.19	21.52	23.21	23.96	22.22	20.44	21.95	23.06	23.29	22.18
M_{CF}	19.53	20.50	22.58	23.60		19.99	21.15	22.09	22.75	
LSD at 5%	HA= 0.04 CF= 0.03 Inter.= 0.05					HA= 0.08 CF= 0.05 Inter.= 0.09				
	Total free amino acids (mg/100g d.w.)									
HA_0	22.37	23.61	24.91	25.55	24.11	23.41	24.46	25.93	26.91	25.18
HA_1	22.87	24.59	25.79	26.65	24.98	24.08	25.45	26.50	27.76	25.95
HA_2	23.55	24.97	26.55	27.78	25.71	24.45	26.14	27.36	28.18	26.53
HA_3	24.45	25.69	27.61	28.26	26.50	24.74	26.55	28.00	28.86	27.04
M_{CF}	23.31	24.71	26.22	27.06		24.17	25.65	26.95	27.93	
LSD at 5%	HA= 0.03 CF= 0.03 Inter.= 0.05					HA= 0.03 CF= 0.03 Inter.= 0.05				

with control (0 L/fed.). The highest level (5 L/fed.) was superior significantly compared to the other levels. It gave the highest content of total phenols as 131.17 and 132.44 mg/100g d.w., carotenoids as 20.40 and 20.88 mg/100g d.w., vitamin C as 22.22 and 22.18 mg/100g d.w. and free amino acids as 26.5 and 27.04 mg/100g d.w., for the first and second seasons, respectively. These results were in accordance with those obtained on phenols, carotenoids and free amino acids in flax plant by Fagbenro and Agboola [19] and mucilage in Plantago plant by Khater and Abd El-Azim [31].

All active ingredients under study were significantly affected by the application of compound fertilizer compared to control as clear at Table (7). Total phenols, carotenoids, vitamin C and total free amino acids were significantly increased by increasing compound fertilizer rate. The highest contents of these components were recorded by application the highest rate (120 Kg/fed.) of compound fertilizer. It gave 134.67 and 137.10; 21.39 and 21.33; 23.60 and 22.75; 27.06 and 27.93 mg/100g d.w. of total phenols, carotenoids, vitamin C and total free amino acids for the two seasons, respectively. However, a similar increase in total antioxidants activity, vitamin C, phenols and amino acid contents in *Moringa* leaves was found by Sabra [28] and in vitamin C by Mazrou and El-Sebay [29] with NPK fertilizers.

The results tabulated in Table (7) reveal that the interaction treatment between humic acid at 5 L/fed. and compound fertilizer at 120 Kg/fed. recorded the highest values of total phenols, carotenoids, vitamin C and total free amino acids contents in dry leaves of *Moringa oleifera* with significant differences during the two seasons. Moreover, the contents of these components were significantly increased by increasing humic acid and compound fertilizer levels under each level of the other factor. These results are in harmony with those reported by Khater and Abd El-Azim [31] on mucilage content in *Plantago Psyllium* seeds.

Such increase in the content of minerals, protein and active components in the plant organs might be due to the effect of organic compound (humic acid) on soil fertility, water holding capacity and enhancing the availability, absorption and translocation of the elements (which included in used compound fertilizer) from the root system to the leaves and activation of the active processes. This effect led to high photosynthesis and metabolic efficiency and then more growth, uptake, accumulation of nutrients, carbohydrates and proteins as well as plant products such as active ingredients.

CONCLUSION

From the obtained results it could be concluded that there are significant effects of both humic acid and compound fertilizer and their interaction treatments on vegetative growth, seed yield components and active ingredients of *Moringa oleifera* plants. Therefore, it is recommended to use humic acid at 5 L/fed. and compound fertilizer at 120 Kg/ fed. to increase the yields of dry leaves and seeds as well as active ingredients (Total phenols, carotenoids, vitamin C as antioxidants and total free amino acids) of *Moringa oleifera* plants under sandy soil conditions.

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