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Mutual Effect among Some Organic Substances and Micronutrients on Maize (*Zea mays* l.) Grown on Sandy Soil

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TWO FIELD experiments were conducted at a farm in Ismailia Governorate, Egypt during two successive summer seasons of 2011 and 2012. The response of maize grains (Triple hybride 310) grown on a sandy loam soil to different organic amendments, *i.e.*, compost (CO) and humic acid (HA) at different rates and foliar spraying with micronutrients (mixture of Fe, Mn and Zn) on growth characters, productivity and nutrients in plant were assessed. The obtained results reveal CO and HA enhanced the growth and yield productivity of maize as well as nutrient contents and uptake. CO effectively augmented these parameters in comparison with HA application. Foliar spray with micronutrients in combination with CO or HA substantially elevated these parameters. N, P, K, Fe, Mn and Zn uptake by grains; significantly increased by application of the treatments. The highest response of maize productivity and nutrients uptake by grains were achieved by application of CO in combination with foliar spray of micronutrients followed by HA + foliar spray of micronutrients for the two growing seasons. Highest values of protein content and protein yield (205 g kg^{-1} and 1114 kg ha^{-1}), respectively were at the first season and (218 g kg^{-1} and 1185 kg ha^{-1}) at the second one were obtained due to the application of HA at the rate of 36 kg ha^{-1} + foliar spray with micronutrients.

Keywords: Foliar spray, Compost, Humic acid, Micronutrients (Fe, Mn and Zn), Maize, Sand soil

Maize (*Zea mays* L.) is an important cereal crop in the world and has economic value in livestock. It is considered as one of the two important cereal crops in Egypt and plays a fundamental role in human and animal feeding (Harris *et al.*, 2007). Increasing maize production is one of the most important goals of the Egyptian government to meet human and animal demands.

Micronutrient deficiency is widespread in plants, animal and humans, especially in many arid countries, due to high pH, low organic matter, drought, high bicarbonate contents in irrigation water and imbalanced application of fertilizers (Malakouti, 2008). Micronutrients are required in small amounts and they affect directly or indirectly photosynthesis, vital processes in plant such as respiration, protein synthesis, reproduction phase. In this connection, many investigators in Egypt reported positive response of different field crops to micronutrient fertilization (Seadh, *et al.* 2009; Potarzycki & Grzebisz, 2009; Zeidan, *et al.* 2010; Kanwal, *et al.*, 2010, Salem & El-Gizawy, 2012 and Siam, *et al.*, 2012). Iron is a constituent of many enzymes involved in the nutritional metabolism of plant. Manganese has an essential role in amino acid synthesis by activating a number of enzymes particularly decarboxylases and dehydrogenases of the tricarboxylic acid cycle. Zinc plays an important role as a metal component of enzymes (superoxide dismutase, carbonic anhydrase and RNA polymerase) or as a functional, structural or regular cofactor of a large number of enzymes, (Römheld and Marchner, 2006).

Humic acid (HA) is one of the main organic fertilizers, which is an important component of humic substances. Humic acid is produced by the chemical and biological decomposition of organic material. Humic acid is a vital component of soil organic matter which improves the plant growth. It enhances soil fertility and improves its physical and chemical properties such as permeability, aggregation, water holding capacity, ion transport and availability through pH buffering (Tan, 2003). Turan *et al*. (2011) reported that humic acid had positive impacts on nutrient content and uptake in maize plants.

Compost is as a low cost organic fertilizers and soil amendment (Francis and Daniel, 2004). When applied to soils, it positively affects the structure, porosity, water holding capacity, nutrient contents and organic matter all of which improve plant growth and crop yield (Rajaa & Saadi, 2011 and Gosling *et al.*, 2006).

The current study aims at assessing compost and humic acid applications through the soil and micronutrients through foliar spray on improving maize yield and its components as well as grain quality and nutrients content.

Materials and Methods

Two field experiments were conducted on a sandy soil using maize (*Zea mays* cv. Triple hybrid 310) in two growing seasons of 2011 and 2012, at a farm in Ismailia Governorate, Egypt. Treatments involved application of compost (CO) and humic acid (HA) through the soil and foliar spray with some micronutrients (Fe+Mn+Zn). Table 1 shows properties of soil of the experiment (0 – 30 cm). The experimental design was split-split design within completely randomized block design with three replicates. There were 3 factors; Factor 1 "main plots" concerned foliar spray (F) with micronutrients and involved 2 treatments of no-spray and spray. Factor 2 " sub plots" concerned organic source (S) of compost (CO) and humic acid (HA). Factor 3 " sub-sub plots" concerned the rate (R) of organic application of none (R0), low (R1), medium (R2) and high (R3) rates. The foliar spray was done using commercial EDTA material containing 120g Fe, 120g Mn and 120g Zn kg^{-1}. Spray solution rate was 950 L ha^{-1} applied three times (20 days after seeding, then 15 and 30 days afterwards). The low, medium and high rates of organic materials were 12, 24 and 36 Mg ha^{-1}, respectively for compost; and 12, 24 and 36 kg ha^{-1}, respectively for humic acid. Tables 2 and 3 show properties of the organic materials used in the experiment. Therefore there were 16 treatments which represent 2 (foliar-treatments) X 2 (organic sources) X 4 (organic rates).

TABLE 1. Physical and chemical properties of the soil of the experiment.

Property	Value	Property	Value
Particle size distribution		EC (dSm^{-1}) in soil paste extract	1.47
Clay %	13.14	Soluble ions (mmolc L^{-1})	
Silt %	5.39	Na^+	7.06
Fine sand %	70.88	K^+	0.88
Coarse sand %	10.59	Ca^{++}	4.66
Textural class	Sandy Loam*	Mg^{++}	2.10
pH [Soil suspension 1:2.5]	7.89	Cl^-	6.85
Organic matter (g kg^{-1})	5.51	HCO_3^-	1.58
$CaCO_3$ (g kg^{-1})	12.4	$SO_4^=$	6.27

Available macro and micronutrients (mg kg^{-1} soil)

N	P	K	Fe	Mn	Zn	
30.9	2.81	110	3.71	1.20	0.65	

* (1) Extractants of available nutrients: NH_4HCO_3-DTPA (P, K, Fe, Mn and Zn), KCl (N)
(2) Texture according to the international soil texture triangle.

TABLE 2. Humic acid analysis (plant sources).

Density g cm^{-3}	pH	Total macronutrients (g kg^{-1})			Humic acid (g L^{-1})	Fulfic acid (g L^{-1})	O.C g kg^{-1}	C/N ratio	O.M (g kg^{-1})	Total micronutrients (mg kg^{-1})		
		N	P	K						Fe	Mn	Zn
1.43	7.79	24.1	5.51	76.3	22.9	0.54	430	17.8	741	425	250	97.7

TABLE 3. Chemical properties of compost.

Moisture content (%)	EC dS m^{-1} 1:10	pH 1:2.5	O.C (g kg^{-1})	O.M	C/N ratio	Total macro-nutrients			Total micro- nutrients		
						N	P	K	Fe	Mn	Zn
						(g kg^{-1})			(mg kg^{-1})		
21	4.15	7.47	350	603	18.5	18.9	9.11	18.8	241	130	33.1

Compost manure was prepared (Nasef *et al.,* 2009) using 5 Mg (megagram; 1 Mg = 10^6 g) of some crop residues (rice straw, maize stover and faba bean straw), air dried and piled into 5 – 10 layers, each about 50-cm thick, An amount of 300 kg/weight of farmyard manure was added to each pile to enhance microorganism activity. Piles were moistened with a sufficient quantity of water (about 60%). Every 21 days the piles were turned over until well decomposed as described by Nasef *et al.* (2009). After 63 days the compost was well decomposed and ready for use. The CO manure was mixed thoroughly with the soil one month before sowing. The final product was chemically analyzed according to Brunner and Wasmer (1978).

All plots of the experiment were fertilized with the recommended rates of NPK as follows: 120 kg N ha^{-1} as ammonium sulphate, (206 g N kg^{-1}) in three equal splits: immediately before seeding as a starter then 40 and 60 days after seeding. Phosphorus was added at 31 kg P ha^{-1} as calcium superphosphate (67.6 g P kg^{-1}) during seedbed preparation and potassium was added at 198 kg K ha^{-1} as potassium sulphate (400 g K kg^{-1}) in two equal splits 30 and 45 days after seeding. Agricultural practices for growing maize were carried out as recommended by the Ministry of Agriculture. The area of each plot was 20 m^2 (4 X 5 m) and included 8 rows 50 cm apart, two plants $hill^{-1}$ and 15 cm between hills.

Grain characters and calculations

Maize grains were recorded for each plot after harvesting and the following agronomic characters were estimated; weight of ear (g), weight of grain ear^{-1} (g), 100-grain weight (g) and grain yield (Mg ha^{-1}).

Methods of analysis

Samples of maize grains were oven dried at 70^o C and digested using H_2SO_4 and $HClO_4$ mixture to determine nutrient contents. Plant analysis was done according to Chapman & Pratt (1961) and AOAC (1990). Soil analysis was done according to Black *et al.* (1965). Crude protein in maize grains was calculated by multiplying total N-content by 6.25.

Grain protein yield (kg ha^{-1}) = protein content (g kg^{-1}) x grains yield (Mg ha^{-1}).

Statistical analysis

Results were statistically analyzed using COSTATC software. The ANOVA test was used to determine significance of ($p \leq 0.01$ or $p \leq 0.05$) treatment effect and Duncan Multiple Range Test was used to determine significance of the difference between individual means (Duncan, 1955).

Results and Discussion

Growth components and grain yield of maize

Data presented in Table 4 reveal that the weight of ear, weight of grain ear^{-1}, 100-grain weight and grain yield of maize increased due to soil application.

The highest values were achieved by the addition of CO, (R3) in combination with foliar spray. Such increases were 12.4, 6.42, 24.0 and 126% for weight of ear, weight of grain ear^{-1}, 100-grain weight and grain yield, respectively at 2011 season and 13.1, 9.09, 38.0 and 124% for weight of ear, weight of grain ear^{-1}, 100-grain weight and grain yield, respectively at 2012 season.

TABLE 4. Yield components and grain yield, (Mg ha^{-1}) of maize as affected by organic sources and foliar spray with micronutrient.

Organic source (S)	Addition rate, (R)	Foliar spray, (F)											
		Without spray (F)	With spray	Mean	Without spray	With spray	Mean	Without spray	With spray	Mean	Without spray	With spray	Mean
		Weight of ear (g)			Weight of grain ear^{-1} (g)			100-grain weight (g)			Grain yield (Mg ha^{-1})		
2011													
CO (Mg ha^{-1})	**R0 (None)**	241	253	247	218	225	222	25.8	30.1	28.0	2.43	2.57	2.50
	R1(12)	252	262	257	220	227	224	27.6	30.9	29.3	2.58	5.77	4.18
	R2 (24)	259	266	263	224	230	227	28.9	31.6	30.3	2.73	5.35	4.04
	R3 (36)	266	271	269	227	232	230	30.0	32.0	31.0	3.35	5.50	4.43
	Mean	255	263	259 a	222	229	226 a	28.1	31.2	29.7a	2.77	4.80	3.79
HA (kg ha^{-1})	**R0 (None)**	233	248	241	213	220	217	23.9	27.9	25.9	2.43	2.50	2.47
	R1 (12)	235	253	244	217	221	219	25.2	29.2	27.2	2.49	5.15	3.82
	R2 (24)	244	255	250	221	227	224	26.2	30.0	28.1	2.82	5.35	4.09
	R3 (36)	253	265	259	225	230	228	28.3	31.0	29.7	2.87	5.43	4.15
	Mean	241	255	248 b	219	224	222 b	25.9	29.5	27.7b	2.65	4.61	3.63
Mean of spray		248b	259a		221b	227a		27.0b	30.4a		2.71b	4.71a	
Means of rate		R0	244 d		R0	219 d		R0	26.9 d		R0	2.48 c	
		R1	251 c		R1	221 c		R1	28.2 c		R1	4.00 b	
		R2	256 b		R2	226 b		R2	29.2 b		R2	4.06 ab	
		R3	264 a		R3	229 a		R3	30.3 a		R3	4.29 a	
2012													
CO (Mg ha^{-1})	**R0 (None)**	244	259	252	220	230	225	27.6	32.2	29.9	2.47	2.59	2.53
	R1(12)	257	267	262	224	235	230	28.4	33.5	31.0	2.60	5.83	4.22
	R2 (24)	262	272	267	227	238	233	30.3	36.8	33.6	2.78	5.41	4.10
	R3 (36)	264	276	270	229	240	235	31.9	38.1	35.0	3.36	5.54	4.45
	Mean	257	269	263a	225	236	231	29.6	35.2	32.4a	2.80	4.85	3.83
HA (kg ha^{-1})	**R0 (None)**	237	254	246	216	225	221	24.3	28.6	26.5	2.47	2.53	2.50
	R1 (12)	240	258	249	219	229	224	25.5	31.9	28.7	2.52	5.18	3.85
	R2 (24)	247	261	254	224	233	229	27.6	32.1	29.9	2.83	5.38	4.11
	R3 (36)	256	263	260	229	236	233	28.2	32.4	30.3	2.86	5.44	4.15
	Mean	245	259	252b	222	231	227	26.4	31.3	28.9b	2.67	4.63	3.65
Mean of spray		251b	264a		224b	234a		28.0b	33.3a		2.74b	4.74a	
Means of rate		R0	249 c		R0	223 c		R0	28.2 c		R0	2.52 b	
		R1	256 b		R1	227 bc		R1	29.8 bc		R1	4.03 a	
		R2	261 ab		R2	231 ab		R2	31.7 ab		R2	4.10 a	
		R3	265 a		R3	234 a		R3	32.7 a		R3	4.30 a	

The values followed by a different letters are significantly different at $p \leq 0.05$ of CO and HA solely or in combination with micronutrients foliar spray; in both seasons.

The compost contained rather high contents of nutrients, which must have released for plant uptake. In addition, the compost improves soil physicochemical, hydrological and biological characteristics, which facilitates nutrient uptake by crops (Hegazi, 2004). The beneficial effects of HA on plant growth could be related to improved plant metabolism. Eyheraguibl *et al.* (2008) reported that HA can directly act as a substrate or nutrient source for crops. In addition, Trevisan *et al.* (2010) attributed the growth stimulation effect of HA on plant growth to their interaction with physiological and metabolic processes; stimulating nutrient uptake and cell permeability, and the regulating mechanisms involved in plant growth stimulation. The results also indicate that application of CO surpassed HA in improving crop growth.

The main effects of foliar spray with micronutrients increased the growth parameters and grain yield for the two growing seasons. This reflects the positive role in many biochemical and physiological processes such as; photosynthesis, respiration, enzyme activity. Application micronutrients as foliar spray could compensate soil micronutrient deficiency in sandy soils, (Marschner, 1995). The obtained results are in accordance with those reported by Salem & El-Gizawy (2012) and Siam *et al.* (2012).

The average increases achieved by compost were 9.47% for ear yield, 9.47%, 6.39% for weight of grain ear^{-1}, 24.3% for 100-grain weight and 97.1% for grain yield. Application of HA recorded average increases of 9.36%,6.05%, 26.1% and 88.6% for weight of ear, weight of grain ear^{-1}, 100-grain weight and grain yield, respectively. These results are in agreement with those obtained by Yassen *et al.* (2010) and Nrabet *et al.* (2012).

The main effect of organic amendments rate of application, results show progressive increase in ear weight, weight of grain ear^{-1} and 100-grain weight with progressive increase in rates in 2011. In 2012 the pattern was: R3 ≥ R2 ≥ R1 > none. Regarding the grain yield, results followed the pattern: R3 ≥ R2 ≥ R1 > none in 2011 and R3 = R2 = R1 in 2012.

Grain protein content and protein yield

Grain protein content and grain protein yield increased as affected by the treatments of CO, HA solely and/or combined with foliar spray. The highest values of protein content (205 and 218 g kg^{-1}) were obtained due to the treatment HA (R3) + foliar spray with (Fe+Mn+Zn) in 2011 and 2012 seasons representing increase percentage of 54.2% and 61.5%, respectively.

Gad El-Hak *et al.* (2012) found that foliar application of humic acid increased protein content in peas. Abd El-Latif *et al.* (2010) stated that N uptake in wheat grains and straw increased by compost addition. Moreover, Yassen *et al.* (2010) reported that spraying wheat with Fe, Mn and Zn individually or in combinations resulted in marked increase in protein content.

As the rate of applying CO or HA increased, the increase is progressed. This reflects the positive effect of organic fertilization in increasing metabolic processes and physiological activities necessary for more plant organs formation, more dry matter accumulation and enhancing the grain hilling rate, which finally increase the amount of protein in grain. These results are in accordance with those reported by Abbas *et al.* (2011).

Regarding the grain protein yield, results followed a trend similar to that of protein content and followed a pattern of: CO > HA and foliar spray > no foliar spray, and R3 > R2 > R1 > none for amendment rates. This promoting effect could be attributed to the integrated effect of highly humified organic materials enhancing nitrogen fixing bacteria on increasing available nutrients (Ewees and Abdel Hafeez, 2010). The highest values of protein yield (1114 and 1185 kg ha^{-1}) were obtained due to the same treatment which resulted in the highest protein content in the two growing seasons, respectively.

Effect on nutrient uptake

Tables 5 and 6 show the uptake of N, P and K and Tables 7 and 8 show the uptake of Fe, Mn and Zn.

N, P and K uptake by grains

The obtained results in Tables 5 and 6 confirm that the uptake of N, P and K by grains increased due to foliar spray and also due to addition of CO and HA. Addition of CO increased the uptake of N, P and K by grains than HA treatment in season 1. In season 2 N as well as K uptake was higher by CO than HA, but P-uptake was higher for HA than CO. El-Shahawy (2013) noted that application of compost to sandy soil increased N, P and K uptake by peanuts.

The main effect of organic amendment rate, concerning N, P and K uptake at both seasons followed the order of: R3 > R2 > R1 > none for compost and humic acid amendments.

Regarding the micronutrients effects, the results show that foliar spraying with Fe+Mn+Zn significantly enhanced N, P and K uptake and this trend was found true at the two growing seasons of 2011 and 2012.

The highest values for N and P uptake by maize grains were 178 and 33.8 kg ha^{-1}, respectively at first season as well as 189 and 31.6 kg ha^{-1}, respectively at second season; occurred with HS, (R3) + (Fe+Mn+Zn) treatment. Highest K-uptake (115 kg ha^{-1}) was obtained by CO, (R3) + foliar spray with (Fe+Mn+Zn) in season 1 and (119 kg ha^{-1}) assigned for HS, (R3) + foliar spray treatment in season 2. HA may contain growth promoting substances, resulting in more nutrient absorption (Janaína *et al.,* 2011). The beneficial responses of increased N, P and K resulted from adding compost may be due to release of the abundand macronutrients in the compost. In this concern, Eida *et al.* (2008) indicated that application of compost could enrich soil with large quantities of organic forms of macronutrients which slowly released in the mineral forms by soil microorganisms beside, its beneficial effect on the physical and chemical properties of the soil. Foliar application of micronutrients must have enhanced nutrient uptake by maize grains. El-Sowfy and Osman (2009) reported that microutrients applied through foliar spray cause positive effects on biosynthesis of auxin which promote rooting process and consequently, increase mineral absorption and translocation in plants.

TABLE 5. N and protein content as well as N-uptake and protein yield of maize grains as affected by organic sources and foliar spray with micronutrient.

Organic source (S)	**Addition rate, (R)**	**Foliar spray, (F)**											
		Without spray (F)	With spray	**Mean**	Without spray	With spray	**Mean**	Without spray	With spray	**Mean**	Without spray	With spray	**Mean**
		N content (g kg^{-1})			N-uptake (kg ha^{-1})			Protein content g kg^{-1}			Protein yield kg ha^{-1}		
2011													
CO (Mg ha^{-1})	**R0 (None)**	21.4	23.8	22.6	52.1	60.9	56.5	134	149	142	325	381	353
	R1(12)	23.0	27.8	25.4	59.6	161	110	144	174	159	373	1006	690
	R2 (24)	24.4	29.6	27.0	66.6	158	112	153	185	169	416	989	703
	R3 (36)	25.6	31.8	28.7	85.3	175	130	160	198	179	533	1092	813
	Mean	23.6	28.2	25.9	65.9	139	102	148	176	162	412	867	640
HA (kg ha^{-1})	**R0 (None)**	21.4	24.2	22.8	52.0	60.1	56.1	133	151	142	325	376	351
	R1 (12)	22.4	27.2	24.8	55.8	140	98.0	140	170	155	349	876	613
	R2 (24)	23.8	29.4	26.6	67.1	157	112	148	184	166	420	983	702
	R3 (36)	26.0	32.8	29.4	74.7	178	126	163	205	184	467	1114	791
	Mean	23.4	28.4	25.9	62.4	134	98.1	146	177	162	390	838	614
Mean of spray		23.5b	28.3a		64.2b	137a		147b	177a		401b	853a	
Mean of rates		R0	22.7 d		R0	56.3 d		R0	142 d		R0	352 d	
		R1	25.1 c		R1	104 c		R1	157 c		R1	652 c	
		R2	26.8 b		R2	112 b		R2	168 b		R2	703 b	
		R3	29.1 a		R3	128 a		R3	182 a		R3	802 a	
2012													
CO (Mg ha^{-1})	**R0 (None)**	21.6	24.0	22.8	53.4	61.4	57.4	135	150	143	333	384	359
	R1(12)	23.3	28.0	25.7	60.6	164	112	145	175	160	379	1026	703
	R2 (24)	24.6	29.6	27.1	68.6	160	114	154	185	170	429	1001	715
	R3 (36)	25.7	31.7	28.7	85.8	175	130	160	198	179	537	1094	816
	Mean	23.8	28.3	26.1	67.1	140	104	149	177	163	420	876	648
HA (kg ha^{-1})	**R0 (None)**	21.5	24.4	23.0	53.4	61.2	57.3	135	152	144	334	383	359
	R1 (12)	22.7	28.3	25.5	57.2	147	102	142	177	160	358	922	640
	R2 (24)	23.9	30.5	27.2	67.9	164	116	150	191	171	425	1023	724
	R3 (36)	26.2	34.8	30.5	75.0	189	132	164	218	191	468	1185	827
	Mean	23.6	29.5	26.6	63.4	140	102	147	184	166	396	878	637
Mean of spray		23.7b	28.9a		65.3b	140a		148b	181a		408b	877a	
Mean of rates		R0	22.9 c		R0	57.4 c		R0	143 c		R0	359 c	
		R1	25.6 bc		R1	107 b		R1	160 bc		R1	671 b	
		R2	27.2 ab		R2	115 b		R2	170 ab		R2	720 b	
		R3	29.6 a		R3	131 a		R3	185 a		R3	821 a	

TABLE 6. P and K content and uptake of maize grains as affected by organic sources and foliar spray with micronutrient

Organic source (S)	Addition rate, (R)	Foliar spray, (F)											
		Without spray (F)	With spray	**Mean**	Without spray	With spray	**Mean**	Without spray	With spray	**Mean**	Without spray	With spray	**Mean**
		P content (g kg^{-1})			**P-uptake (kg ha^{-1})**			**K content (g kg^{-1})**			**K-uptake (kg ha^{-1})**		
2011													
CO (Mg ha^{-1})	**R0 (None)**	3.43	3.77	3.60	8.37	9.70	9.03	16.0	17.3	16.7	39.0	44.4	41.7
	R1(12)	3.83	4.61	4.22	9.91	26.6	18.2	16.6	18.5	17.6	42.9	107	74.9
	R2 (24)	4.52	5.23	4.88	12.4	28.0	20.2	17.5	19.6	18.6	48.0	105	76.6
	R3 (36)	4.60	5.94	5.27	15.4	32.7	24.0	17.9	20.8	19.4	59.8	115	87.3
	Mean	4.10	4.89	4.50	11.5	24.3	17.9	17.0	19.1	18.1b	47.4	92.8	70.1
HA (kg ha^{-1})	**R0 (None)**	3.53	3.86	3.70	8.65	9.66	9.16	16.9	18.1	17.5	41.1	45.2	43.2
	R1 (12)	3.90	4.79	4.35	9.75	24.8	17.3	17.3	19.1	18.2	43.0	98.6	70.8
	R2 (24)	4.27	4.98	4.63	12.1	26.6	19.4	17.7	19.5	18.6	50.1	104	77.2
	R3 (36)	4.79	6.22	5.51	13.8	33.8	23.8	19.2	21.2	20.2	55.1	96.2	85.1
	Mean	4.12	4.96	4.54	11.1	23.7	17.4	17.8	19.5	18.6a	47.3	90.7	69.1
Mean of spray		4.11b	4.93a		11.3b	24.0a		17.4b	19.3a		47.4b	91.8a	
Mean of rates		R0	3.65 d		R0	9.10 d		R0	17.1 d		R0	42.4 c	
		R1	4.28 c		R1	17.7 c		R1	17.9 c		R1	72.9 b	
		R2	4.75 b		R2	19.8 b		R2	18.6 b		R2	76.9 b	
		R3	5.39 a		R3	23.9 a		R3	19.8 a		R3	86.2 a	
2012													
CO (Mg ha^{-1})	**R0 (None)**	3.93	4.17	4.05	9.71	10.9	10.4	16.5	17.7	17.1	40.5	45.7	43.1
	R1(12)	4.13	4.51	4.32	10.7	26.3	18.5	17.1	19.1	18.1	44.6	112	78.3
	R2 (24)	4.32	4.93	4.63	12.1	26.6	19.4	17.3	19.9	18.6	48.3	108	78.2
	R3 (36)	4.90	5.34	5.12	16.3	29.6	23.0	18.5	20.6	19.6	61.9	114	88.0
	Mean	4.32	4.74	4.53	12.2	23.4	17.8	17.4	19.3	18.4b	48.8	94.9	71.9
HA (kg ha^{-1})	**R0 (None)**	3.93	4.16	4.05	9.76	10.5	10.1	16.6	18.3	17.5	41.2	46.4	43.8
	R1 (12)	4.20	5.19	4.70	10.8	26.8	18.8	17.6	19.6	18.6	44.6	102	73.3
	R2 (24)	4.77	5.28	5.03	13.7	28.3	21.0	18.3	20.3	19.3	52.1	109	80.6
	R3 (36)	4.99	5.82	5.41	14.3	31.6	23.0	19.4	21.9	20.7	55.4	119	87.2
	Mean	4.47	5.11	4.79	12.2	24.3	18.3	18.0	20.0	19.0a	48.3	94.1	71.2
Mean of spray		4.40b	4.93a		12.2b	23.9a		17.7b	19.7a		48.6b	94.5a	
Mean of rates		R0	4.05 c		R0	10.2 c		R0	17.3 c		R0	43.5 c	
		R1	4.51 b		R1	18.7 b		R1	18.4 b		R1	75.8 b	
		R2	4.83 ab		R2	20.2 b		R2	19.0 b		R2	79.4 b	
		R3	5.26 a		R3	23.0 a		R3	20.1 a		R3	87.6 a	

Fe, Mn and Zn uptake by gains

Data in Tables 7 and 8 display Fe, Mn and Zn uptake by maize grains. Compost (CO) and humic acid (HA) increased the uptake of Fe, Mn and Zn and compost application was generally more effective than humic acid in elevating the uptake of these nutrients. Increases due to applying CO (averaged over the three rates) were 64.0, 103 and 98.0 concerning uptake of Fe, Mn and Zn, respectively in first season. Comparable increases due to applying HA were 58.7, 102 and 92.2%, respectively. Comparable respective increases for the second season were 74.1, 84.5 and 72.9% for CO and 67.0, 85.6 and 68.9% for HA. Sener *et al.* (2009) found that humic acids enhance the absorbance capacity of nutrients of the roots by having carboxylic and phenolic groups and increasing H^+-ATPase activity in the root cells cause increasing in Fe, Mn and Zn uptake.

As for amendments application rates, data indicate that Fe, Mn and Zn uptake by maize grains significantly increased by increasing the application rate. This trend was found true for the two seasons of 2011 and 2012.Response of Fe, Mn and Zn uptake by grains due to foliar application of (Fe+Mn+Zn), was positive. Average increases in Fe, Mn and Zn uptake due to foliar spray were 108, 98 and 119% in 2011 and 69, 128 and 88% in 2012, respectively .

The highest uptake of Fe was achieved by CO (R1) in combination with (Fe+Mn+Zn) foliar spray. For Mn-uptake, the highest increase was due to HA application (R3) under foliar spray with (Fe+Mn+Zn). Highest increases of Zn-uptake at the two growing seasons (223% and 162%, respectively) were obtained under the application treatments of CO (R3) and CO (R1), respectively when sprayed with (Fe+Mn+Zn).

Conclusion

The obtained results clearly show that the application of compost manure at rate of 36 Mg $ha^{-1}$and humic acid at rate of 36 kg ha^{-1} with foliar application of a mixture solution of (Fe+Mn+Zn) could give the highest growth and produce the highest grains yield of maize plants grown in sandy soil, having ample contents of macro and micronutrients and compost was more effective than humic acid under the conditions of sand soil.

TABLE 7. Fe and Mn content and uptake of maize grains as affected by organic sources and foliar spray with micronutrient .

Organic source, (S)	Addition rate, (R)	Foliar spray, (F)											
		Without spray (F)	With spray	**Mean**	Without spray	With spray	**Mean**	Without spray	With spray	**Mean**	Without spray	With spray	**Mean**
		Fe content ($mg\ kg^{-1}$)			**Fe-uptake ($g\ ha^{-1}$)**			**Mn content ($mg\ kg^{-1}$)**			**Mn-uptake ($g\ ha^{-1}$)**		
2011													
CO ($Mg\ ha^{-1}$)	**R0 (None)**	69.8	82.9	76.4	170	213	192	37.6	40.6	39.1	91.5	104	97.9
	R1(12)	71.0	88.0	79.5	183	509	346	40.9	47.8	44.4	105	276	191
	R2 (24)	72.1	89.2	80.7	197	479	338	44.0	48.2	46.1	120	258	189
	R3 (36)	72.9	91.3	82.1	244	502	373	45.9	50.5	48.2	154	278	216
	Mean	71.5	87.8	79.7 a	198	426	312 a	42.1	46.8	44.5 b	118	229	174
HA ($kg\ ha^{-1}$)	**R0 (None)**	70.4	72.0	71.2	171	180	176	38.2	40.7	39.5	92.9	102	97.5
	R1 (12)	71.3	84.0	77.7	177	433	305	41.5	48.9	45.2	103	252	178
	R2 (24)	72.5	86.1	79.3	205	460	333	44.7	52.4	48.6	126	280	203
	R3 (36)	73.4	87.0	80.2	211	472	342	47.3	53.6	50.5	136	291	214
	Mean	71.9	82.3	77.1 b	191	386	289 b	42.9	48.9	45.9 a	114	231	173
Mean of spray		71.7b	85.1a		195b	406a		42.5b	47.9		116b	230a	
Mean of rates		R0	73.8 c		R0	184 c		R0	39.3 d		R0	97.6 d	
		R1	78.6 b		R1	326 b		R1	44.8 c		R1	184 c	
		R2	80.0 ab		R2	335 ab		R2	47.3 b		R2	196 b	
		R3	81.2 a		R3	357 a		R3	49.3 a		R3	215 a	
2012													
CO ($Mg\ ha^{-1}$)	**R0 (None)**	71.2	81.3	**76.3**	176	211	**194**	41.9	49.5	**45.7**	103	129	**116**
	R1(12)	72.7	82.2	**77.5**	189	481	**335**	43.2	48.9	**46.1**	112	286	**199**
	R2 (24)	73.0	82.4	**77.7**	203	447	**325**	42.2	56.4	**49.3**	118	305	**212**
	R3 (36)	73.7	82.6	**78.2**	248	458	**353**	43.6	57.0	**50.3**	146	316	**231**
	Mean	**72.7**	**82.1**	**77.4**	**204**	**399**	**302a**	**42.7**	**52.9**	**47.8**	**120**	**259**	**190**
HA ($kg\ ha^{-1}$)	**R0 (None)**	70.4	80.6	**75.5**	174	204	**189**	40.5	47.4	**44.0**	99.5	119	**109**
	R1 (12)	72.5	80.7	**76.6**	183	419	**301**	41.7	58.5	**50.1**	105	302	**204**
	R2 (24)	72.6	81.2	**76.9**	206	436	**321**	41.5	52.0	**46.8**	118	279	**199**
	R3 (36)	72.0	81.4	76.7	206	443	325	42.9	52.2	47.6	123	284	204
	Mean	71.9	81.0	76.5	192	376	284b	41.7	52.5	47.1	111	246	179
Mean of spray		72.3b	81.6a		198b	388a		42.2b	52.7		116b	253a	
Mean of rates		R0	75.9 b		R0	191 b		R0	44.8 b		R0	113 b	
		R1	77.0 a		R1	318 a		R1	48.1 a		R1	201 a	
		R2	77.3 a		R2	323 a		R2	48.0 a		R2	205 a	
		R3	77.4 a		R3	339 a		R3	48.9 a		R3	217 a	

TABLE 8. Zn content and uptake of maize grains as affected by organic sources and foliar spray with micronutrient.

Organic source (S)	Addition rate, (R)	Foliar spray, (F)						Foliar spray, (F)					
		Without spray (F)	With spray	**Mean**	Without spray	With spray	**Mean**	Without spray	With spray	**Mean**	Without spray	With spray	**Mean**
		Zn content (mg kg^{-1})			**Zn-uptake (g ha^{-1})**			**Zn content (mg kg^{-1})**			**Zn-uptake (g ha^{-1})**		
		2011						**2012**					
CO (Mg ha^{-1})	**R0 (None)**	30.8	34.4	32.6	74.9	88.8	81.9	30.2	32.5	31.4	73.4	83.5	78.5
	R1(12)	31.8	39.2	35.5	82.1	226	154	30.5	33.2	31.9	68.7	192	130
	R2 (24)	32.5	41.6	37.1	88.6	223	156	31.4	33.7	32.6	85.7	180	133
	R3 (36)	33.6	44.0	38.8	112	242	177	31.4	34.4	32.9	105	189	147
	Mean	32.2	39.8	36.0b	89.5	195	142	30.9	33.4	32.2	83.2	161	122a
HA (kg ha^{-1})	**R0 (None)**	31.0	34.5	32.8	75.4	86.4	80.9	30.5	31.4	31.0	74.1	78.5	76.3
	R1 (12)	32.0	41.1	36.6	79.6	212	146	30.9	32.0	31.5	76.9	165	121
	R2 (24)	32.8	42.0	37.4	92.5	224	158	31.1	32.4	31.8	87.7	173	130
	R3 (36)	33.9	44.3	39.1	97.4	241	169	31.2	32.8	32.0	89.4	178	134
	Mean	32.4	40.5	36.5a	86.2	191	139	30.9	32.1	31.5	82.0	149	115b
Mean of spray		32.3 b	40.2a		87.9 b	193 a		30.9b	32.8		82.6b	155a	
Mean of rates		R0	32.7 d		R0	81.4 c		R0	31.2		R0	77.4 b	
		R1	36.0 c		R1	150 b		R1	31.7		R1	126 a	
		R2	37.2 b		R2	157 b		R2	32.2		R2	132 a	
		R3	39.0 a		R3	173 a		R3	32.5		R3	141 a	

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التأثير المتبادل بين بعض المواد العضوية و المغذيات الدقيقة على الذرة المنزرعة في الأرض الرملية

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أجريت تجربتان حقليتان بحقل تجريبي بمحافظة الإسماعيلية مصر خلال موسمي صيف متتاليين لعامي 2011 و 2012. تم دراسة أستجابة نباتات الذرة صنف (هجين ثلاثي 310) النامي تحت ظروف الأراضي الرملية الطميية للإضافات العضوية المختلفة المتمثلة في الكمبوست و حامض الهيوميك بمعدلات مختلفة في حالة الرش الورقي ببعض العناصر الصغري (مخلوط من الحديد و المنجنيز والزنك) أو عدم الرش بها على إنتاجية الحبوب ومحتواها من بعض العناصر الغذائية الكبري و الصغرى. أكدت النتائج المتحصل عليها أن إضافة كلٍّ من الكمبوست و حامض الهيوميك ادت إلى تحفيز النمو وتحسين إنتاجية حبوب الذرة وكذلك محتواها و الكمية الممتصة من بعض العناصر الغذائية الكبرى والصغرى. تفوق الكمبوست المضاف مقارنة بإضافة حامض الهيوميك على زيادة وتحسين جميع القياسات والصفات تحت الدراسة. كما أدى الرش الورقي بالعناصر الصغري (حديد ، منجنيز و زنك) بالتداخل مع إضافة الكمبوست وحامض الهيوميك إلي إعطاء أعلي أستجابة لجميع القياسات و الصفات تحت الدراسة. و أيضاً أظهرت النتائج المتحصل عليها زيادة الكمية الممتصة من العناصر الكبرى (ن ، فو و بو) ومحتوى العناصر الصغرى (حديد ، منجنيز و زنك) معنوياً نتيجة إضافة تلك المعاملات. أعطت المعاملة بالكمبوست المصاحبة للرش الورقي بالعناصر الصغرى أعلى إستجابة لإنتاجية الذرة و أيضاً الكمية الممتصة من العناصر الغذائية السابقة ثم معاملة الذرة بالهيوميك مع الرش الورقي بالعناصر الصغري وذلك خلال موسمى النمو. أعلى قيم لمحتوى و محصول البروتين تم التحصل عليها نتيجة المعاملة بحامض الهيوميك بمعدل 36 كيلوجرام هكتار$^{-1}$ مع الرش بالعناصر الصغرى خلال موسمى الزراعة حيث كانت القيم (205 جم كجم$^{-1}$ و 1114 كجم هكتار$^{-1}$) على التوالى في موسم 2011 و (218 جم كجم$^{-1}$ و 1185 كجم هكتار$^{-1}$) على التوالى فى موسم 2012.