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EVALUATION OF APPLICATION METHODS OF MICRONUTRIENTS (FOLIAR SPRAY, SEED COATING AND SEED SOAKING) ON MAIZE WITH OR WITHOUT COMPOST

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ABSTRACT

Two field experiments were conducted on maize (*Zea mays* L. c.v Trible hybrid 310) grown on a newly reclaimed saline clay soil in private farm, Khaled Iben El-Walied, Sahl El-Hussinia, Sharkia Governorate, Egypt, (32°00/00// to 32° 15/00// N Latitude and 30° 50/00// to 31° 15/00// E Longitude) in seasons 2014 and 2015. Three micronutrient application methods *i.e.*, foliar spray, seed coating and seed soaking) were evaluated. The nutrients were Fe, Mn and Zn mixed in one solution. Rates of the mixture application were 5.0, 10.0 and 15.0 kg ha^{-1}, respectively. Nutrients application was done solely or in combination with compost, 24 Mg ha^{-1}. Available N, P, K, Fe, Mn and Zn at harvest were increased due to the above mentioned treatments, salinity and pH were decreased. Micronutrients in combination with compost increased N, P, K, Fe, Mn and Zn uptake by grains. The highest positive response of yield and nutrients uptake by grains was by application of compost in combination with foliar spray of micronutrients followed by seed coating with micronutrients + compost. Highest N contents and protein yield 674 kg ha^{-1} was obtained by foliar spray with 15 kg nutrient mix ha^{-1}+ compost.

Key words: Maize, foliar spray, coating, soaking, micronutrients (Fe, Mn and Zn), clay loam soil.

INTRODUCTION

Maize (*Zea mays* L.) is an important cereal crop in the world and Egypt and plays a fundamental role and used in human and animal feeding in Egypt (Harris *et al.,* 2007). Total maize grain yield production, in 2010 was 7 million Mg produced from an area of 920 thousand hectares (El-Gedwy *et al.*, 2012). Its grain is used for manufacturing many products as glucose syrup, starch, corn flakes, oil, lactic acid, gluten. Maize grains contain 72% starch, 10% protein, 4.8% oil, 8.5% fiber, 3% sugar and 1% ash (Zafar-ul-Hye *et al.,* 2014). Yield potential of maize is extremely affected by abiotic stress like salinity, drought, extreme temperature, flooding and extreme irradiation *etc.* (Lawlor and Cornic, 2002; Akram *et al.*, 2010). Salinity causes numerous physiological and biochemical changes in plants which ultimately reduce yields (Hussain *et al.,* 2013).

Micronutrient deficiency is widespread in plants, animal and humans, (Malakouti, 2008). Micronutrients are required in small amounts and affect photosynthesis, and the other vital processes such as respiration, protein synthesis and reproduction. Many investigators in Egypt reported positive response of many field crops to micronutrient application (Potarzycki and Grzebisz, 2009; Seadh *et al.,* 2009; Kanwal *et al.*, 2010; Zeidan *et al.*, 2010; Salem and El-Gizawy, 2012; Siam *et al.,* 2012). Iron is a constituent of many enzymes involved in metabolism and manganese has an essential role in amino acid synthesis by activating of some enzymes particularly decarboxylases and dehydrogenases. Zinc plays an important role in activiting enzymes as superoxide dismutase,

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carbonic anhydrase and RNA polymerase) and a cofactor of enzymes, (RÖmheld and Marchner, 2006).

High salinity affects soils in about 900 thousand ha in Egypt. Most of the saline soils in Egypt are in northern-central Nile Delta. The southern part of El-Hussinia plain, El-Sharkia Governorate, Egypt covering an area of 14160 ha (El-Bordiny and El-Dewiny, 2008).

The current work aimed at evaluating the combined effect of micronutrients applied in different methods solely or in combination with compost on maize.

MATERIALS AND METHODS

Two field experiments were conducted on maize plants (*Zea mays* L. c.v Trible hybrid 310) grown on a newly reclaimed saline clay soil in Khaled Iben El-Walied village, Sahl El-Hussinia, Sharkia Governorate, Egypt, (32° 00/00// to 32° 15/00// N Latitude and 30° 50/00// to 31° 15/00// E Longitude) during the two seasons of 2014 and 2015 to study the response to application of Fe, Mn and Zn (as a mixture) applied by 3 different methods (foliar, seed coating and seed soaking) at different mixture rates of 5, 10 and 15 kg ha^{-1} solely with or without compost, 24 Mg ha^{-1}. The soil texture was clay (Table 1). At the end of experiment soil and plant samples were taken for analyses using methods cited by Chapman and Pratt (1961), Page *et al.* (1982) and Jackson (1958).

The compost was analyzed, organic matter and nutrients according to methods of Brunner and Wasmer (1978). The obtained results are recorded in Table 2.

Treatments and Experimental Design

Factorial experiment in randomized complete block design with three replicates was done as follows: (1) method of nutrient application (2) rates of application and (3) compost application. The numbers of treatment combinations were 18 (3 methods × 3 rates × 2 compost application. Compost was prepared according to the method of Nasef *et al.* (2009) crop residues (rice straw, maize stover and faba bean straw). The recommended N, P and K rates were applied to all plots; the rates were 100, 211 and 168 kg ha^{-1}, respectively. N was in the form of urea (460 g N kg^{-1}), P was as calcium superphosphate (68g P kg^{-1}) and K was as potassium sulphate (400 g kg^{-1}). The P fertilizer was broadcasted before ploughing; the N was applied in three splits, 20% before sowing, 40% before the second irrigation (30 days after sowing "DAS") and 40% before the third irrigation, (45 DAS). The K was applied in two equal splits after 30 and 45 DAS. Plot area was 50 m^2 (5x10m) having 14 ridges each of 5 m in length and 0.7 m in width, two plants $hill^{-1}$ and 20 cm between hills. Fe, Mn and Zn were in forms of $FeSO_4$, $MnSO_4$ and $ZnSO_4$ having Fe, Mn and Zn mixture of 120 g kg^{-1} and applied at three rates *i.e.*, 5, 10 and 15 kg ha^{-1}. The application methods were foliar spray; seed coating and seed soaking into nutrient solution. Foliar spray was applied 40 DAS at a rate of 1000 l ha^{-1}, seed coating was done by mixing the amount of fertilizer salt needed per plot with a sticky material and the appropriate weight of seeds so as to make cating of the fertilizer around the seeds. Soaking was done by dissolving the proper amount of fertilizer in water, then soaking the proper amount of seeds into the solution for 12 hr., following soaking. Solution remaining after soaking was sprayed over the soil of the soaking treatments.

Crop Management Practices

Maize (Triple hybrid, 310 cv) was provided by Maize Department, Field Crop Institute. ARC. Seeding at a rate of 34 kg ha^{-1}, performed on 25th April for 2014 season and 20th for April 2015 season. Two to three seeds were sown per hill, and then 30 days after seeding plants were thinned to one plant per hill. The crop was irrigated with water of El-Salam Canal (Agricultural drainage water mixed with Nile water at a 1:1 ratio). Some chemical properties of the irrigation water as described are shown in Table 3.

To control soil salinity, water was applied immediately after sowing for 4 hours then excess water was drained. The same process was repeated in the second day. After that, irrigation water was added every 15 days until the end of the growing seasons. Agricultural practices for growing maize were carried out as recommended by the Ministry of Agriculture.

Table 1. Physical and chemical properties of the investigated soil

Property	Value	Property	Value
Particle size distribution (%)		**- Soluble ions (mmolc l^{-1})**	
- Clay	45.88	▪ **Na^+**	58.86
- Silt	23.31	▪ **K^+**	1.49
- Sand	30.81	▪ **Ca^{++}**	9.56
- Textural class	**Clay**	▪ **Mg^{++}**	13.00
- EC (dSm^{-1}) in soil paste extract	8.34	▪ **Cl^-**	37.06
- pH [Soil suspension 1:2.5]	8.04	▪ **HCO_3^-**	8.22
▪ **Organic matter (g kg^{-1})**	5.41	▪ **$SO_4^=$**	37.63
▪ **SAR**	17.20	▪ **$CaCO_3$ (g kg^{-1})**	64.9
▪		▪ **ESP**	21.03

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

N	P	K	Fe	Mn	Zn
35.27	3.89	175	2.40	3.15	0.61

Table 2. Chemical properties of the used compost

Moisture (%)	OM (%)	OC (%)	C/N (%)	Macronutrients (%)			Micronutrients (mg/kg)			pH	EC (dSm^{-1}) (1:10)
				N	P	K	Fe	Mn	Zn		
25-30	55.34	32.10	13.38	2.40	0.69	2.69	127.52	76.22	31.50	7.42	3.85

Table 3. Chemical analysis of irrigation water at El-Salam canal

pH	EC (dSm^{-1})	Macronutrients (mgl^{-1})				Micronutrients (mgl^{-1})		
		NO_3-N	NH_4-N	P	K	Fe	Mn	Zn
8.03	1.95	14.60	8.00	3.10	7.19	2.14	1.09	0.078

Measured Parameters

Plant height was measured after 75 days after seeding (average of 10 plants). During growth time the followings were recorded on 10 plants taken at random: ear weight, grain weight per ear, 100-grain weight, stover yield, and grain yield, (adjusted to 15% moisture content). Plant samples were washed with water then dried at 70°C for 48 hr. Then milled and analyzed for nutrients, digestion with mixture of concentrated H_2SO_4 and $HClO_4$ acids. N was determined by micro-kjeldahl according to AOAC (1990). While P was determined using ascorbic acid method and K was determined by a flame photometer (Chapman and Pratt, 1961). Fe, Mn and Zn were determined using the atomic absorption (model GBC 932). Protein content was calculated by multiplying grain N by 6.25 (FAO, 2003).

Statistical Analysis

Data (combined of the two seasons) were statistically analyzed according to MSTAT-C, Statistical Software Package according to Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Soil Properties After Harvest

Soil pH and EC

The data representing the effect of application of micronutrients and compost, on soil pH and EC are presented in Table 4. Values in combined data of the two studied seasons show that, soil pH was slightly decreased and ranged between 7.94-8.01 without compost and 7.92–8.00 with compost. The highest decrease in pH was observed when micronutrients added as foliar spray at the high rate in combination with compost. This is an indication of effect of microorganisms on decomposing organic matter releasing organic acids and producing several phytohormones such as indole acetic acid and cytokinins (El-Galad *et al.*, 2013). A decrease in pH was observed by Sarwar *et al.* (2010) upon applying organic manure. They observed production of organic acids (amino acids, glycine, cystein and humic acids) during mineralization of the organic manure.

Soil salinity decreased by the treatment. The lowest EC values of 4.89 and 3.94 dSm^{-1} occurred when the plants were sprayed with micronutrients at high rate, with decreases of 41.4% without compost and 43.2% with compost, lowering of soil pH by the compost and in turn encouraging must have enhanced the availability of plant nutrients, leading to a decrease in EC.

Clay domains are coated with the released active organic acids, and then forming coarse sizes of water stable aggregates would form upon decreasing EC leading to improved filteration and accelerating leaching of soluble salts (Ewees and Abdel-Hafeez, 2010). Improved aggregation by would increase water permeability and encourage downward movement of water carrying Na-salts out of the soils (Bassiony and Shaban, 2010 ; Rashed *et al.*, 2011).

Available N, P and K Macronutrients in the Soil After Harvest

Table 5 reveals that the application of micronutrients with different methods and rates in presence or absence of compost showed greater N, P and K contents than the contents at the start of the experiment. The treatment of the high foliar spray combined with compost gave the highest contents. The positive effect of compost is an indication of its mineralization (Bhandari *et al.*, 2002) and (Yadvinder *et al.*, 2004). Formation of organic acids during degradation of organic material as a function of the microbial activities which in turn produce chelating materials, leading to increased availability of elements in the rhizosphere (Wenhui *et al.*, 2010 ; Taha *et al.*, 2010).

Application of micronutrients at the high rate increased soil available N, P and K by averages 4.7, 15.9 and 8.0% over those given by the low application rate indicating a considerable positive effect of micronutrients on available P in particular. The foliar method of application showed the highest positive effect followed by the soaking method, then the coating method.

Available Fe, Mn and Zn Micronutrients in the Soil After Harvest

Table 6 shows that available Fe, Mn and Zn followed the same trend of that observed for macronutrients. Application of micronutrients at

Table 4. Soil pH and EC after harvest as affected by treatments

Micronutrient addition		pH		EC		
		Compost application (C)				
Method (M)	Rate (R)	Without	With	Without	With	Mean
Coating	5 kg ha^{-1}	8.01	8.00	7.52	5.64	6.58
	10 kg ha^{-1}	8.00	7.97	6.14	4.23	5.19
	15 kg ha^{-1}	7.98	7.95	5.82	4.01	4.92
Mean		--	--	6.49	4.63	5.56
Soaking	5 kg ha^{-1}	8.01	8.00	7.33	6.33	6.83
	10 kg ha^{-1}	7.99	7.97	5.92	5.12	5.52
	15 kg ha^{-1}	7.98	7.93	5.26	4.10	4.68
Mean		--	--	6.17	5.18	5.68
Foliar	5 kg ha^{-1}	7.99	7.97	6.23	5.96	6.10
	10 kg ha^{-1}	7.97	7.95	5.12	5.10	5.11
	15 kg ha^{-1}	7.94	7.92	4.89	3.94	4.42
Mean		--	--	5.41	5.00	5.21
Grand mean for compost		--	--	6.02 a	4.94 b	
Grand mean for rate				5 kg: 6.50 a	10 kg: 5.27 b	15 kg: 4.67 c
F-test		-----		M: NS	R: **	C: **
				M×R: NS		M×C : *
				R×C: NS	M×R×C: NS	

* Values for control were, 8.04 and 8.01 with and without compost respectively, for pH 8.34 and 6.94 dsm^{-1}for EC with and without compost, respectively.

* Different lower case letters indicate statistically significant differences between treatments (P≤ 0.05).

Table 5. Available macronutrient contents (mg kg^{-1}) in soil after harvest

Micronutrient addition		Available macronutrients (mg kg^{-1})								
		N			P			K		
		Compost application (C)								
Method (M)	Rate (R)	Without	With	Mean	Without	With	Mean	Without	With	Mean
Coating	5 kg ha^{-1}	38.1	40.2	39.2	4.10	4.18	4.14	195	197	196
	10 kg ha^{-1}	38.7	41.0	39.9	4.52	4.66	4.59	198	203	201
	15 kg ha^{-1}	40.2	41.2	40.7	4.95	4.99	4.97	201	207	204
Mean		39.0	40.8	39.9 c	4.52	4.61	4.57	198	202	200 b
Soaking	5 kg ha^{-1}	38.9	41.0	40.0	4.08	4.16	4.12	198	203	201
	10 kg ha^{-1}	40.2	41.6	40.9	4.15	4.89	4.52	203	215	209
	15 kg ha^{-1}	42.5	42.3	42.4	4.20	5.02	4.61	208	220	214
Mean		40.5	41.6	41.1 b	4.14	4.69	4.42	203	213	208 b
Foliar	5 kg ha^{-1}	41.1	42.2	41.7	4.15	4.39	4.27	199	213	206
	10 kg ha^{-1}	41.9	43.7	42.8	4.36	4.95	4.66	209	226	218
	15 kg ha^{-1}	43.0	44.0	43.5	4.85	5.05	4.95	218	248	233
Mean		42.0	43.3	42.6 a	4.45	4.80	4.63	209	229	219 a
Grand mean for (C)		40.5	41.9		4.37	4.70		203 b	215 a	
Grand mean for (R)		5 kg: 40.3 c	10 kg: 41.2 b	15 kg: 42.2 a	5 kg: 4.18 b	10 kg: 4.59 a	15 kg: 4.84 a	5 kg: 201 b	10 kg: 209 ab	15 kg: 217 a
F-test		M: **	R: **	C: NS	M: NS	R: **	C: NS	M: **	R: **	C: **
		M×R: NS	M×C: **		M×R: NS	M×C: NS		M×R: NS	M×C: NS	
		R×C: NS	M×R×C: NS		R×C: NS	M×R×C: NS		R×C: NS	M×R×C: NS	

* Values for control were, 35.6 and 39.2 for N; 3.97 and 4.02 for P as well as 192 and 194 for K under without or with compost, respectively.

* Different lower case letters indicate statistically significant differences between treatments (P≤ 0.05).

Table 6. Available micronutrient contents (mg kg^{-1}) in soil after harvest

Micronutrient addition		Available macronutrients (mg kg^{-1})								
		Fe			Mn			Zn		
		Compost application (C)								
Method (M)	**Rate (R)**	**Without**	**With**	**Mean**	**Without**	**With**	**Mean**	**Without**	**With**	**Mean**
Coating	**5 kg ha^{-1}**	3.03	3.34	3.19	1.42	1.66	1.54	0.69	0.78	0.74
	10 kg ha^{-1}	3.12	3.45	3.29	1.44	1.78	1.61	0.71	0.83	0.77
	15 kg ha^{-1}	3.22	3.52	3.37	1.68	1.82	1.75	0.76	0.85	0.81
Mean		3.12	3.44	3.28 b	1.51	1.75	1.63	0.72	0.82	0.77
Soaking	**5 kg ha^{-1}**	3.14	3.44	3.29	1.55	1.75	1.65	0.72	0.86	0.79
	10 kg ha^{-1}	3.18	3.69	3.44	1.69	1.85	1.77	0.75	0.89	0.82
	15 kg ha^{-1}	3.33	3.72	3.53	1.75	1.88	1.82	0.78	0.92	0.85
Mean		3.22	3.62	3.42 b	1.66	1.83	1.75	0.75	0.89	0.82
Foliar	**5 kg ha^{-1}**	3.85	3.48	3.67	1.89	1.79	1.84	0.78	0.88	0.83
	10 kg ha^{-1}	3.94	3.74	3.84	1.96	1.89	1.93	0.82	0.96	0.89
	15 kg ha^{-1}	3.98	3.83	3.91	1.99	1.93	1.96	0.86	0.98	0.92
Mean		3.92	3.68	3.81 a	1.95	1.87	1.91	0.82	0.94	0.88
Grand mean for (C)		3.42	3.58		1.71	1.82		0.76	0.88	
Grand mean for (R)		5 kg: 3.38	10 kg: 3.52	15 kg: 3.60	5 kg: 1.68	10 kg: 1.77	15 kg: 1.84	5 kg: 0.79	10 kg: 0.83	15 kg: 0.86
F-test		M: *	R: NS	C: NS	M: NS	R: NS	C: NS	M: NS	R: NS	C: NS
		M×R: NS		M×C: NS	M×R: NS		M×C: NS	M×R: NS		M×C: NS
		R×C: NS		M×R×C: NS	R×C: NS		M×R×C: NS	R×C: NS		M×R×C: NS

* Values for control were, 2.96 and 3.21 for Fe; 1.38 and 1.52 for Mn as well as 0.68 and 0.72 for Zn under without or with compost, respectively.

* Different lower case letters indicate statistically significant differences between treatments (P≤ 0.05).

different rates in presence or absence of compost caused higher contents of Fe, Mn and Zn compared with the contents at start of the experiment (Table 1). Increased application of micronutrients was accompanied by increased contents of available micronutrients. The high rate of micronutrient application showed more available Fe, Mn and Zn by average of 6.5, 9.5 and 8.9%, respectively over contents of the low application rate. The effect was marked with Fe in particular. El-Galad *et al.* (2013) reported that application of compost was effective in increasing the release of Fe, Mn and Zn into the growing media. The highest available Fe of 3.98 mg kg^{-1} and Mn of 1.99 mg kg^{-1} and Zn of 0.98 mg kg^{-1} was obtained by the highest foliar spray rate with compost.

There was a superiority of the foliar spray than the coating or soaking methods in increasing available Fe, Mn and Zn. Application of compost enhanced the availability of micronutrients in soil especially Zn while, for Fe and Mn, coating and soaking had a positive effect. Decomposition of organic matter from compost as well as the soil (Ewees and Abdel-Hafeez, 2010). The average positive effect of the addition rates of micronutrients on available Fe, Mn and Zn could be arranged in the following order: high rate > medium rate > low rate.

Growth and Yield Productivity of Maize

The effects of micronutrients and compost treatments on plant height, ear weight and grain weight/ ear are given in Table 7. The effects show increased values with the increase in the rate of micronutrient application. The highest values of 219 cm, 268 g and 262 g for plant height, ear weight and grain weight per ear, respectively (increases of 17, 12 and 12%, respectively) were recorded in the plants treated with foliar spray combined with compost. The lowest respective values of 182 cm, 238 g and 234 g were obtained by plants receiving the low coating method uncombined with compost.

Table 7. Some yield attributes of maize as affected by treatments

Micronutrient addition		Plant height (cm)			Weight of ear (g)			Grain weight/ear (g)		
		Compost application (C)								
Method (M)	Rate (R)	Without	With	Mean	Without	With	Mean	Without	With	Mean
Coating	5 kg ha^{-1}	182	195	189	238	246	242	234	240	237
	10 kg ha^{-1}	185	199	192	243	252	248	240	247	244
	15 kg ha^{-1}	188	203	196	248	258	253	246	254	250
Mean		185	199	192 b	243	252	248 b	240	247	244
Soaking	5 kg ha^{-1}	186	197	192	245	255	250	239	250	245
	10 kg ha^{-1}	191	204	198	254	258	256	250	253	252
	15 kg ha^{-1}	197	212	205	259	263	261	254	258	256
Mean		191	204	198 b	253	259	256 ab	248	254	251
Foliar	5 kg ha^{-1}	194	201	198	248	259	254	243	254	249
	10 kg ha^{-1}	198	214	206	257	264	261	253	259	256
	15 kg ha^{-1}	206	219	213	263	268	266	260	262	261
Mean		199	211	205 a	256	264	260 a	252	258	255
Grand mean for (C)		192 b	205 a		251 b	258 a		247	253	
Grand mean for (R)		5 kg: 193 b	10 kg: 199 ab	15 kg: 204 a	5 kg: 249 b	10 kg: 255 ab	15 kg: 260 a	5 kg: 243	10 kg: 250	15 kg: 256
F-test		M: **	R: **	C: **	M: *	R: *	C: *	M: NS	R: NS	C: NS
		M×R: NS	M×C: NS		M×R: NS	M×C: NS		M×R: NS	M×C: NS	
		R×C: NS	M×R×C: NS		R×C: NS	M×R×C: NS		R×C: NS	M×R×C: NS	

* Values for control were, 175 and 187 for plant height; 231 and 239 for weight of ear as well as 225 and 234 for grain weight per ear under without or with compost, respectively.

* Different lower case letters indicate statistically significant differences between treatments (P≤ 0.05).

The beneficial effect of compost on maize growth is a demonstration of the improvement which must have occurred to the conditions; lowering pH and forming organic matter in the root rhizosphere enhancing nutrient by roots (Helmy and Shaban, 2008).

Application of micronutrients showed that the foliar spray gave the highest values while the coating method gave the lowest values. The high rate of application showed the highest values followed by the medium rate then low rate.

100-Grain Weight, Stover and Grain Yields

The data of 100-grain weight, stover and grain yield of maize plants are presented in Table 8. The obtained results show increases due to application of micronutrients at different methods and rates as well as compost addition.

As for 100-grain weight, foliar spray gave highest values with or without compost. Foliar application with micronutrients was reported by (Hythum and Nasser, 2012) to be more effective than the other methods. The positive response to compost reflects it improvement of the nutritional status of maize plants which in turn was positively reflected on the grain yield (Shaban *et al.,* 2011). The highest value of 32.4 g for 100-grain weight was recorded for the plants treated with foliar spray at high rate combined with compost giving an increase of 23.7% over the control. Increasing the rates of micronutrients, significantly increased 100-grain weight of maize and could be arranged in an ascending order, as follow: 15 kg ha^{-1} > 10 kg ha^{-1} > 5 kg ha^{-1}.

Regarding stover and grain yields of maize, foliar spray gave the highest values when combined with compost. These results are in harmony with those which obtained by Potarzycki and Grzebisz (2009) as well as Hythum and Nasser (2012). Bakry *et al.* (2009) applied micronutrients to maize grown on a sandy

Table 8. 100-grain weight and maize yields as affected by treatments

Micronutrient addition		100-grain weight (g)			Stover yield (ton ha^{-1})			Grain yield (ton ha^{-1})		
		Compost application (C)								
Method (M)	**Rate (R)**	**Without**	**With**	**Mean**	**Without**	**With**	**Mean**	**Without**	**With**	**Mean**
	5 kg ha^{-1}	26.6	27.7	27.2	5.46	5.86	5.66	4.73	5.58	5.15
Coating	**10 kg ha^{-1}**	27.4	28.9	28.2	5.58	6.09	5.83	5.04	5.80	5.44
	15 kg ha^{-1}	28.1	29.6	28.9	5.63	6.20	5.92	5.21	5.95	5.58
Mean		27.4	28.8	28.1 b	1.96	5.55	6.06	5.80	16.42	5.78
	5 kg ha^{-1}	27.1	28.9	28.0	5.52	6.06	5.79	4.78	5.63	5.21
Soaking	**10 kg ha^{-1}**	27.7	29.3	28.5	5.89	6.31	6.10	5.24	6.09	5.66
	15 kg ha^{-1}	28.3	30.0	29.2	6.03	6.43	6.23	5.61	6.20	5.92
Mean		27.7	29.4	28.6 b	2.05	5.80	6.26	6.03	17.07	5.97
	5 kg ha^{-1}	28.1	29.9	29.0	5.86	6.45	6.16	5.01	6.03	5.52
Foliar	**10 kg ha^{-1}**	28.9	31.3	30.1	6.17	6.54	6.36	5.63	6.45	6.06
	15 kg ha^{-1}	29.0	32.4	30.7	6.37	6.94	6.65	5.86	6.51	6.20
Mean		28.6	31.2	29.9 a	2.17	6.14	6.65	6.40	18.12	6.34
Grand mean for (C)		27.9 b	29.8 a		2.06 b	5.83 b	6.31 a	9.87 b	6.03 a	
Grand mean for (R)		5 kg: 28.1 c	10 kg: 28.9 b	15 kg: 29.6 a	5 kg: 2.07	10 kg: 4.93	15 kg: 5.12	5 kg 5.02	10 kg: 2.02	15 kg: 2.08
F-test		M: **	R: **	C: **	M: NS	R: NS	C: *	M: NS	R: NS	C: **
		M×R: NS	M×C: NS		M×R: NS	M×C: NS		M×R: NS	M×C: NS	
		R×C: NS	M×R×C: NS		R×C: NS	M×R×C: NS		R×C: NS	M×R×C: NS	

* Values for control were, 25.1 and 26.2 g for 100-grain weight; 4.45 and 4.69 ton ha^{-1} for stover yield as well as 3.78 and 4.28 ton ha^{-1} for grain yield under without or with compost, respectively.
* Different lower case letters indicate statistically significant differences between treatments ($P \leq 0.05$).

soil and obtained increased physiological and yield of maize. The marked increase in maize yield exhibited by foliar application of micronutrients may be attributed to their crucial roles in many biochemical and physiological processes; photosynthesis, respiration, enzyme activity or involving in growing meristem, maintaining high meristematic activity in the cells of the growing parts, (Siam *et al.*, 2006). Also, addition of such nutrients as foliar application could compensate the soil micronutrients deficiency prevailing in the studied saline soil, thus resulted in an improvement in the nutritive status of maize plants which reflected on the performance of the physiological processes. The obtained results are in accordance with those reported by El-Fouly *et al.* (2011), Salem and El-Gizawy (2012) and Siam *et al.* (2012).

Treatment of maize with foliar spray at the high rate combined with compost gave 24.4% average increase in stover yield and 27.8% increase in grain yield.

Grain Protein Content and Grain Protein Yield

Results presented in Table 9 show that the protein content in maize grains increased by application of micronutrients particularly using foliar spray, the effect of rates of micronutrients and compost addition was insignificant. Zeidan *et al.* (2010) pointed out that foliar application of Fe, Mn and Zn significantly increased protein content of wheat plants. Also, such beneficial effect of compost was actually reflected on increasing maize grain yield and its quality due to the applied organic manure decreased the loss of soil moisture, enhanced soil water retention and the drought resistance of grown plants as well as increased the ability rate of leaves for photosynthetic process, increased the grain filling intensity, and consequently increased the grain weight. These findings are in harmony with those obtained by, Abd El-Hady *et al.* (2006).

Table 9. Protein content (%) and protein yield (kg ha^{-1}) of maize grains

Micronutrient addition		Protein content			Protein yield		
		Compost application (C)					
Method (M)	**Rate (R)**	**Without**	**With**	**Mean**	**Without**	**With**	**Mean**
	5 kg ha^{-1}	8.06	8.31	8.19	321.44	390.48	357.15
Coating	**10 kg ha^{-1}**	8.44	8.50	8.47	357.15	414.29	385.72
	15 kg ha^{-1}	9.13	8.63	8.88	400.01	430.96	416.68
Mean		8.54	8.48	8.52 b	359.53	359.53	411.91 b
	5 kg ha^{-1}	7.44	7.63	7.54	300.01	361.91	330.95
Soaking	**10 kg ha^{-1}**	7.69	7.81	7.75	338.10	400.01	369.06
	15 kg ha^{-1}	7.88	8.06	7.97	371.44	421.44	397.63
Mean		7.67	7.83	7.77 b	335.72	335.72	395.25 b
	5 kg ha^{-1}	11.1	11.6	11.4	466.68	588.11	528.58
Foliar	**10 kg ha^{-1}**	11.4	11.9	11.7	540.49	645.25	592.87
	15 kg ha^{-1}	11.8	12.2	12.0	580.96	669.06	626.20
Mean		11.4	11.9	11.7 a	409.05 b	528.58	633.35 a
Grand mean for (C)		9.22	9.40		172 b	409.05 b	
Grand mean for (R)		5 kg: 9.02	10 kg: 9.29	15 kg: 9.62	5 kg: 170	10 kg: 189	15 kg: 201
F-test		M: **	R: NS	C: NS	M: **	R: NS	C: **
		M×R: NS	M×C: NS		M×R: NS	M×C: NS	
		R×C: NS	M×R×C: NS		R×C: NS	M×R×C: NS	

* Values for control were, 7.81 and 8.06% for protein content and 295.24 and 345.25 kg ha^{-1} for protein yield under without or with compost, respectively.

* Different lower case letters indicate statistically significant differences between treatments (P≤ 0.05).

Concerning protein content and protein yield, foliar spray was superior to the other methods while, coating was slightly higher than soaking. The highest protein content of 12.2% and protein yield of 674 kg ha^{-1} were recorded in the plants treated with the high foliar spray with compost. The increase percentage over the control was 38.9% for protein content and 93.8% for protein yield.

Macronutrients Content and Uptake by Maize Grains

Data in Tables 10 and 11 illustrate that content and uptake of N, P and K in maize grains were affected significantly by application methods of micronutrients for macronutrients content while, significantly affected by application methods for micronutrients and compost addition for N, P and K uptake by grains. Concerning N-content and uptake, spraying gave the highest values with significant differences with soaking and coating methods which were similar in effect. As for P and K-contents and uptake, foliar spray and coating methods are equally effective and both were superior to coating method. On the other hand, addition of compost had a significant effect in increasing N, P and K uptake by maize grains. The role of micronutrients in increasing concentrations of macro and micronutrients in maize grains is mainly due to the vital physiological roles in plant cells which promote the uptake of plant nutrients (Abd El-Hady, 2007).

A glance on data is clear that the mixed foliar application of micronutrients (Fe + Mn + Zn) jointly with compost application gave the highest values of all studied nutrients content and uptake in maize grains as compared to control. It is well known that, during the decomposition of organic matter, macro and micronutrients are incorporated into the soil matrix, allowing the soil to act as a reservoir of these nutrients.

Table 10. N, P and K contents (%) of maize grains as affected by treatments

Micronutrient addition		N-content			P-content			K-content		
		Compost application (C)								
Method (M)	Rate (R)	Without	With	Mean	Without	With	Mean	Without	With	Mean
Coating	5 kg ha^{-1}	1.29	1.33	1.31	0.31	0.40	0.36	2.19	2.22	2.21
	10 kg ha^{-1}	1.35	1.36	1.36	0.36	0.43	0.40	2.24	2.30	2.27
	15 kg ha^{-1}	1.46	1.38	1.42	0.39	0.46	0.43	2.26	2.34	2.30
Mean		1.37	1.36	1.36 b	0.35	0.43	0.39 a	2.23	2.29	2.26 ab
Soaking	5 kg ha^{-1}	1.19	1.22	1.21	0.23	0.24	0.24	2.10	2.12	2.11
	10 kg ha^{-1}	1.23	1.25	1.24	0.27	0.28	0.28	2.13	2.15	2.14
	15 kg ha^{-1}	1.26	1.29	1.28	0.29	0.32	0.31	2.16	2.19	2.18
Mean		1.23	1.25	1.24 b	0.26	0.28	0.27b	2.13	2.15	2.14 b
Foliar	5 kg ha^{-1}	1.78	1.85	1.82	0.39	0.35	0.37	2.26	2.33	2.30
	10 kg ha^{-1}	1.82	1.91	1.87	0.43	0.41	0.42	2.29	2.36	2.33
	15 kg ha^{-1}	1.89	1.95	1.92	0.47	0.48	0.48	2.33	2.42	2.38
Mean		1.83	1.90	1.87 a	0.43	0.41	0.42 a	2.29	2.37	2.33 a
Grand mean for (C)		1.47	1.50		0.35	0.37		2.22	2.27	
Grand mean for (R)		5 kg: 1.44	10 kg: 1.49	15 kg: 1.54	5 kg: 0.32 b	10 kg: 0.36ab	15 kg: 0.40 a	5 kg: 2.20	10 kg: 2.25	15 kg: 2.28
F-test		M: **	R: NS	C: NS	M: **	R: *	C: NS	M: *	R: NS	C: NS
		M×R: NS	M×C: NS		M×R: NS	M×C: NS		M×R: NS	M×C: NS	
		R×C: NS	M×R×C: NS		R×C: NS	M×R×C: NS		R×C: NS	M×R×C: NS	

* Values for control were, 1.25 and 1.29% for N-content; 0.25 and 0.37% for P-content as well as 2.14 and 2.16% for K- content under with or without compost, respectively.

* Different lower case letters indicate statistically significant differences between treatments ($P \leq 0.05$).

Table 11. N, P and K uptake (kg ha^{-1}) by maize grains as affected by treatments

Micronutrient addition		N-uptake			P-uptake			K-uptake		
		Compost application (C)								
Method (M)	Rate (R)	Without	With	Mean	Without	With	Mean	Without	With	Mean
Coating	5 kg ha^{-1}	51.19	62.38	56.91	12.33	18.76	15.55	87.14	104.05	95.72
	10 kg ha^{-1}	57.14	66.43	61.91	15.26	21.00	18.14	95.00	112.38	103.81
	15 kg ha^{-1}	64.05	69.05	66.67	17.10	23.00	20.05	99.05	116.91	108.10
Mean		57.38	65.95	61.91b	14.91	20.93	17.93a	93.81	111.19	102.62
Soaking	5 kg ha^{-1}	47.86	57.86	52.86	9.26	11.38	10.33	84.53	100.48	92.62
	10 kg ha^{-1}	54.29	64.05	59.29	11.91	14.33	13.12	93.81	110.00	101.91
	15 kg ha^{-1}	59.29	67.38	63.33	13.67	16.69	15.19	101.91	114.29	108.10
Mean		53.81	63.10	58.57 b	11.62	14.14	12.88 b	93.34	108.34	100.95
Foliar	5 kg ha^{-1}	75.00	93.81	84.53	16.43	17.76	17.10	95.24	118.10	106.67
	10 kg ha^{-1}	86.19	103.57	95.00	20.38	22.26	21.33	108.57	128.10	118.34
	15 kg ha^{-1}	93.10	106.91	100.00	23.17	26.19	24.76	114.76	132.62	123.81
Mean		84.76	101.43	93.34 a	20.00	22.07	21.05 a	106.19	126.19	116.19
Grand mean for (C)		65.24	76.91		15.50	19.05		97.86	115.24	
Grand mean for (R)		5 kg: 64.76	10 kg: 71.91	15 kg: 76.67	5 kg: 14.33 b	10 kg: 17.52 ab	15 kg: 19.98 a	5 kg: 64.76	10 kg: 71.91	15 kg: 76.67
F-test		M: **	R :NS	C: **	M: **	R: *	C: *	M: NS	R: NS	C: **
		M×R: NS	M×C: NS		M×R: NS	M×C: NS		M×R: NS	M×C: NS	
		R×C: NS	M×R×C: NS		R×C: NS	M×R×C: NS		R×C: NS	M×R×C: NS	

* Values for control were 47.38 and 55.24 kg ha^{-1}for N-uptake; 9.48 and 15.86 kg ha^{-1}for P-uptake as well as 80.95 and 92.62 kg ha^{-1}for K-uptake under with or without compost, respectively.

* Different lower case letters indicate statistically significant differences between treatments ($P \leq 0.05$).

These nutrients will be released to become available for uptake by plants. Otherwise, humus which is the final component of organic matter decomposition accumulates in the environmental systems to increase moisture retention and nutrient supply potentials of soils (Suganya and Sivasamy, 2006).

The highest N, P and K uptake by maize grains which were 101.43, 22.07 and 126.19 kg ha^{-1}, were given by the high foliar spray, respectively; assigned for foliar spray in presence of compost. The lowest comparable values were 55.24, 15.86 and 92.62 kg ha^{-1} respectively, were given by the non-treated plants.

Micronutrients Content and Uptake by Maize Grains

Values of Fe, Mn and Zn uptake by maize grains as affected by application of micronutrients and/or compost were shown in Tables 12 and 13. The content and uptake of Fe, Mn and Zn followed a pattern similar to that shown by the macronutrient where they increased significantly by the addition of the aforementioned fertilization treatments under with or without addition of compost. Foliar of micronutrients at 15 kg ha^{-1} in presence of compost treatment was most effective on increasing content and uptake of Fe, Mn and Zn as compared to the other treatments. The percentages response of Fe, Mn and Zn content and uptake by maize grains over the control were 28.7%, 20.5% and 34.3% as well as 64.3%, 53.2% and 71.5%, respectively due to the addition treatment of, foliar spray of micronutrients at 15 kg ha^{-1} + compost. These findings are in agreement with those reported by Siam *et al*. (2012) who reported that the application of micronutrients as mixture treatment used as foliar application registered highest content and uptake of micronutrients in maize plant as compared with the other methods. Khalil *et al.* (2013) reported that foliar spraying of (Fe + Mn + Zn) in combination with compost significantly increased Fe, Mn, Zn and Cu content and uptake by maize grains.

The beneficial responses of increased Fe, Mn and Zn resulted from adding compost may be attributed to the role of organic sources in improving these micronutrients availability which was likely attributed to several reasons: *i*) Releasing of these nutrients through microbial decomposition of organic matter ; *ii*) Enhancing the chelation of metal ions by fulvic acid, organic legends and/or other organic function groups which may promote the mobility of metal from solid to liquid phase in the soil environment; *iii*) Lowering the redox statues of iron and manganese, leading to reduction of higher Fe^{3+} and Mn^{4+} to Fe^{2+} and Mn^{2+} and / or transformation of insoluble chelated forms into more soluble ions. The obtained results are supported by Bakry *et al.* (2009) and Shaban *et al.* (2011). The response of maize plants to Fe, Mn and Zn may be due to the important role of these elements in enzymes activation and hormones regulation, in metabolism of carbohydrate, proteins and auxins and also in multiple processes, development, division and differentiation of cells. In addition, Fe is characteristics for its ability to undergo oxidation-reduction reaction and to form a component of chlorophyll. Zn also plays an essential role in the synthetase and metabolism of tryptophan. Mn influences directly the indole acetic acid balance in plants, responsible for plant height (RÖmheld and Marchner, 2006).

Moreover, the superior effect of the mixture treatment may be due to the suitable balance between the aforementioned micronutrients, which enable the plants to grow well and to absorb more quantities of macro and micronutrients.

The statistical data in Tables 12 and 13 indicate that foliar spray showed significant superiority regarding Fe, Mn, Zn-contents and Fe-uptake values by maize grains comparing with coating and soaking methods. Also, coating, though was slightly superior to soaking, such superiority was statistically significant for Fe and Zn-content. Spray and soaking were equally effective and both were superior to coating regarding Mn-uptake while, spraying method was superior to the other methods.

Table 12. Fe, Mn and Zn contents (mg kg^{-1}) of maize grains as affected by treatments

Micronutrient addition		Fe-content			Mn-content			Zn-content		
		Compost application (C)								
Method (M)	Rate (R)	Without	With	Mean	Without	With	Mean	Without	With	Mean
Coating	5 kg ha^{-1}	98.3	113	106	80.2	84.6	82.4	24.6	25.4	25.0
	10 kg ha^{-1}	105	121	113	84.6	86.1	85.4	24.9	25.9	25.4
	15 kg ha^{-1}	111	127	119	88.3	89.1	88.7	25.0	26.2	25.6
Mean		105	120	113 b	84.4	86.6	85.5 c	24.8	25.8	25.3 b
Soaking	5 kg ha^{-1}	88.3	90.1	89.2	75.3	76.5	75.9	18.8	23.1	21.0
	10 kg ha^{-1}	92.4	93.2	92.8	79.3	80.2	79.8	22.2	22.9	22.6
	15 kg ha^{-1}	93.5	98.7	96.1	83.1	84.4	83.8	24.6	24.9	24.8
Mean		91.4	94.0	92.7 c	79.2	80.4	79.8 b	21.9	23.6	22.8 c
Foliar	5 kg ha^{-1}	116	118	117	85.6	88.3	87.0	25.7	26.0	25.9
	10 kg ha^{-1}	122	123	123	89.5	91.2	90.4	28.3	28.7	28.5
	15 kg ha^{-1}	128	130	129	92.1	95.4	93.8	28.8	29.0	28.9
Mean		122	124	123 a	89.1	91.6	90.4 a	27.6	27.9	27.8 a
Grand mean for (C)		106 b	113 a		84.2 b	86.2 a		24.8 b	25.8 a	
Grand mean for (R)		5 kg: 104 c	10 kg: 109 b	15 kg: 115 a	5 kg: 81.8 c	10 kg: 85.2 b	15 kg: 88.7 a	5 kg: 23.9 c	10 kg: 25.5 b	15 kg: 26.4 a
F-test		M: **	R: **	C: **	M: **	R: **	C: **	M: **	R: **	C: **
		M×R: **		M×C: **	M×R: NS		M×C: NS	M×R: **		M×C: NS
		R×C: NS		M×R×C: NS	R×C: NS		M×R×C: NS	R×C: NS		M×R×C: *

* Values for control were 92.5 and 101 mg kg^{-1} for Fe-content; 78.6 and 79.2 mg kg^{-1} for Mn-content as well as 20.6 and 21.6 mg kg^{-1} for Zn-content under with or without compost, respectively.

* Different lower case letters indicate statistically significant differences between treatments (P≤ 0.05).

Table 13. Fe, Mn and Zn uptake (g ha^{-1}) by maize grains as affected by treatments

Micronutrient addition		Fe-uptake			Mn-uptake			Zn-uptake		
		Compost application (C)								
Method (M)	Rate (R)	Without	With	Mean	Without	With	Mean	Without	With	Mean
Coating	5 kg ha^{-1}	390.48	530.96	461.91	319.05	397.63	359.53	97.86	119.05	108.57
	10 kg ha^{-1}	445.25	590.49	519.06	359.53	421.44	390.48	105.48	126.43	115.95
	15 kg ha^{-1}	485.72	635.73	561.92	385.72	445.25	416.68	109.53	130.96	120.00
Mean		440.49	585.73	511.92 b	354.77	421.44	388.10 a	104.29	125.48	114.76 b
Soaking	5 kg ha^{-1}	354.77	426.20	390.48	302.39	361.91	333.34	75.72	109.53	92.62
	10 kg ha^{-1}	407.15	476.20	442.87	350.01	409.53	380.96	97.86	117.15	107.62
	15 kg ha^{-1}	440.49	514.30	478.58	392.87	440.49	416.68	115.95	129.76	122.86
Mean		400.01	471.44	438.10 c	347.63	404.77	376.20 b	96.43	118.81	107.38 b
Foliar	5 kg ha^{-1}	488.11	597.63	542.87	361.91	447.63	404.77	108.34	131.91	120.24
	10 kg ha^{-1}	578.58	666.68	623.82	423.82	495.25	459.53	134.05	155.72	145.00
	15 kg ha^{-1}	630.97	711.92	671.44	454.77	521.44	488.11	141.91	158.81	150.48
Mean		566.68	659.54	614.30a	414.29	488.11	450.01a	128.10	148.81	138.57 a
Grand mean for (C)		469.06	571.44		371.44	438.10		109.53	130.96	
Grand mean for (R)		5 kg: 464.30 b	10 kg: 528.58 a	15 kg: 569.06a	5 kg: 364.29b	10 kg: 409.53 b	15 kg: 440.49a	5 kg: 107.15 b	10 kg: 122.86 a	15 kg: 131.19 a
F-test		M: **	R: **	C: **	M: **	R: **	C: **	M: **	R: **	C: **
		M×R: NS		M×C: NS	M×R: NS		M×C: NS	M×R: NS		M×C: NS
		R×C: NS		M×R×C: NS	R×C: NS		M×R×C: NS	R×C: NS		M×R×C: NS

* Values for control were 350 and 433 g kg^{-1} for Fe-uptake; 297 and 340 g kg^{-1} for Mn-uptake as well as 78.09 and 92.62 g kg^{-1} for Zn-uptake under with or without compost, respectively.

* Different lower case letters indicate statistically significant differences between treatments (P≤ 0.05).

Conclusion

Based on the results obtained, it might be concluded that application of compost in combination with foliar application of micronutrients (Fe+Mn+Zn) had the highest effect on all quantities of yield characteristics. Foliar application of micronutrients could be useful for improving the nutrient status, physiological performance of maize plants which led to an increase in concentration and uptake of macro and micronutrients by grains under saline soil conditions. These desirable effects could be consequences of their influences on improving the mineral nutrition status and physiological performance of maize plants that assisted them to tolerate the unfavorable saline conditions, characterized this area.

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تأثير بعض طرق الإضافة المختلفة (الرش ، التغليف و النقع) للعناصر الصغرى بمعدلات مختلفة على إنتاجية الذرة في وجود أو غياب الكمبوست

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أجريت تجربتان حقليتان بحقل خاص لأراضي ملحية (طينية) حديثة الاستصلاح بمنطقة خالد بن الوليد – سهل الحسينية - بمحافظة الشرقية - مصر خلال موسمي صيف متتاليين لعامي ٢٠١٤ و ٢٠١٥ لدراسة تأثير بعض طرق الإضافة (الرش، تغليف الحبوب و نقع الحبوب) للعناصر الصغرى (حديد + منجنيز + زنك) خلطت مع محلول بمعدلات مختلفة هي ٥.٠ ، ١٠.٠ و ١٥.٠ كجم/هكتار بمفردها أو في وجود الكمبوست معها والذي أضيف بمعدل ٢٤ ميجاجرام/ هكتار على إنتاجية وجودة محصول الذرة صنف (هجين ثلاثي ٣١٠) وكذلك محتوي الحبوب من بعض العناصر الكبرى والصغرى والكمية الممتصة منها وامتدت الدراسة لتحليل بعض الخواص الطبيعية والكيميائية بالتربة بعد الحصاد وذلك قياسا بمعاملة المقارنة (سمدت بعناصر ن ، فو و بو بالمعدلات الموصي بها فقط)، أكدت النتائج المتحصل عليها زيادة محتوى العناصر الكبرى والصغرى الميسرة في حين انخفضت قيم الحموضة والملوحة بالتربة بعد إنتهاء التجربة وذلك نتيجة إضافة المعاملات تحت الدراسة، أوضحت النتائج المتحصل عليها أيضاً أن استخدام كلاً من الكمبوست والعناصر الصغرى أدت إلى تحفيز النمو وتحسين إنتاجية حبوب الذرة وكذلك محتواها من الكمية الممتصة من بعض العناصر الغذائية الكبرى والصغرى خاصة في وجودهما معاً، تفوقت طريقة إضافة العناصر الصغرى من خلال الرش علي النباتات خاصة في وجود الكمبوست على باقي طرق الإضافة (النقع والتغليف) وأدت إلي زيادة وتحسين جميع القياسات والصفات تحت الدراسة، كما أدت نفس المعاملة إلي زيادة المحتوي والكمية الممتصة من العناصر الكبرى (ن ، فو و بو) والعناصر الصغرى (حديد ، منجنيز وزنك) بواسطة الحبوب، ثم تلتها معاملة التغليف لحبوب الذرة بالعناصر الصغرى مع إضافة الكمبوست، أعلى قيم لمحتوى ومحصول البروتين (١٢.٢% و ٢٨١ كجم/فدان) على التوالي تم التحصل عليها نتيجة المعاملة الرش بالعناصر الصغرى في وجود الكمبوست.

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