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Importance of Micronutrients, Organic Manure and Biofertilizer for Improving Maize Yield and its Components Grown in Desert Sandy Soil

Mohamed A.A. Bakry, Yasser R.A. Soliman and Samir A.M. Moussa

Soils, Water and Environment Institute, Agriculture Research Center, Giza, Egypt.

Abstract: A field experiment was carried out on a desert sandy soil at Ismailia Agric. Res. Station during the summer season of 2008 to evaluate the importance of some treatments, *i.e.* foliar spray with both micronutrients (MN) and humic acid (HA) as well as chicken manure (CM) as soil application and seed inoculation with Rhizobactrin (RI) used either in solely or combined treatments on maize (*Zea. mays L*., cv. single cross 10 hybrid) yield and its components. The effect of the applied treatments on grain contents of some macro- and micronutrients would be a matter of concern in this study. Results indicate that the experimental soil is dominated by the sand fraction, which is poorer in the nutrient bearing minerals as well as it is not partially capable to retain neither soil moisture nor nutrients for both growing plants and organisms. The studied soil could be classified as "Typic Torripsamments, siliceous, hyperthermic" and it is evaluated as a marginally suitable class, with both soil texture and gypsum as effective limitations for soil productivity. Maize yield and its components showed a positively responded to all the applied treatments, either solely added or together, however, they recorded significant increases in maize vegetative growth characters (*i.e.,* plant height, dry weight of leaves/plant and leaf contents of chlorophyll a & b); ear characters and grain yield (*i.e.,* ear length, ear diameter, ear weight, raw number/ear, grain number/raw and grain yield/plot) and grain quality parameters (*i.e.,* weight of 100 grain, crude protein content % as well as macro- & micro-nutrient contents of N, P, K, Fe, Mn, Zn and Cu), with superiority to the combined treatment of (MN+CM+RI). That was true, since the triple combined treatment of (MN+CM+RI) showed a positively effect due to enrich macro and micronutrients as well as organic and bio substances that are essential to plant growth and activating the bio-chemical processes in plants, which lead to improve the grain yield and its quality under the prevailing conditions of the experimental soil.

Key words: Desert sandy soil, micronutrients, maize, chicken manure, humic acid and seed inoculation.

INTRODUCTION

Undoubtedly, the markedly decrease in the productivity of the desert sandy soils is mainly due to low contents of organic and inorganic colloids, which represent the main factors for widespread occurrence of some micronutrients deficiency in the different desert regions of the world. This is mainly due to the main mechanical or mineral constituent of sandy soils is the sand fraction (quartz), which is poorer in the nutrient bearing minerals as well as it is not partially capable to retain neither water nor nutrients for growing plants. Accordingly, the productivity of the different crops tends to decrease markedly[28,19]. Hence, such soils required a proper and justified fertilization policy particularly with regard to micronutrients, where their deficiencies in the majority of Egyptian soils occur. In addition, soil management practices of sandy soils are usually carried out through addition of natural or chemical soil amendments that have become one of the most important practices for improving physical, chemical and biological properties as well as fertility status of these soils.

The beneficial effects of organic manures or bio-fertilizers as well as micronutrients for increasing the productivity of desert sandy soils as a result of increasing the bio-available micronutrients (*i.e,* Fe, Mn, Zn and Cu) and cation exchange capacity[23]. Also, such beneficial effects positively reflected on soil organic matter content as well as the dry weight and the plant contents of Fe, Mn, Zn and Cu at the vegetative and elongation stages of maize[1]. In addition[4]. found that applying organic manure to sandy soils plays an important role for improving soil media throughout modifying the pore size distribution, and consequently the majority of soil physical properties, *i.e.,* bulk density, moisture constants, hydraulic conductivity, water consumptive use and water use efficiency.

In general, the micronutrient contents may become a limiting factor in crop production in sandy soils; however[22]. reported that supplying micronutrients to plants as foliar spray is of great importance in case of

Corresponding Author: Mohamed Bakry, Soils, Water and Environ. Institute, Agric. Res. Center, Giza, Egypt.

sandy soils to an increase in crop production. In this respect[21] pointed out that the micronutrients (Fe, Mn and Zn) enhanced the crop yield because of their essential roles concerned with some bio-processes. Such findings are confirmed by[13]. who found that application of Fe- and Zn-EDTA to soil enhance the vegetative growth of plants, and in turn increased the maize yield.

In Egypt, maize is one of the most important cereal crops, whether a great attention has been paid to increase its total production, particularly in the newly reclaimed desert area through the agronomic practices such as application of bio, organic and/or mineral fertilization. This is emphasized by the findings outlined by[21] for the applied micronutrients (Fe, Mn and Zn) and[16] for the application of specific bacteria strains or micro fauna, which enhancing nutrients availability, and in turn encouraging the vegetative growth and increasing crop yields, even over that of chemically fertilized systems. Also[32] stated that efficiency of effective microorganisms attributed to its role on accelerating the mineralization processes of organic and help nutrient release, and in turn enhance utility values of organic matter content in soil.

This study aimed to evaluate the integrated effect of applied either micronutrients or humic acid as foliar spray in combination with organic manure as soil application and specific effective microorganisms on maize yield and its components at both vegetative growth and harvest stages.

MATERIALS AND METHODS

To achieve the aforementioned objectives, a field experiment was carried out on a sandy soils at Ismailia Agric. Res. Station during the summer season of 2008 cultivated with maize plants (*Zea. mays L*., cv. single cross 10 hybrid). The surface soil sample (0-30 cm) of the experimental area was subjected to the different lab analysis to determine some physical and chemical properties as well as nutrients status according to the standard methods undertaken by[5,25]. and the results obtained are illustrated in Table (1).

It is noteworthy to mention that the obtained data of the studied macro and micronutrients in the experimental sandy soil, Table (2), are lying at the low levels according to the critical levels of available plant nutrients outlined by[17,25]. That is true, since the investigated soil is dominated by sand fraction which show siliceous in nature and poorer in the nutrient bearing minerals as well as it is not partially capable to retain nutrients or moisture for grown plants.

The applied treatment of micronutrients (MN) was used as foliar spray on maize plants as either solely or together with another ones in a solution attains 500 mg of Fe, Mn, Zn and Cu/L, all micronutrients were applied in sulphate form and added two times as foliar spraying on maize plants, *i.e.,* 30 and 60 days after sowing with a rate of 200 L/fed in each time. Humic acid was applied with a concentration of 50 mg K-humate/L, and it was sprayed on the plants at rate of 400 L/fed three times once every month starting from sowing. Organic manure was added in form of chicken manure at a rate of 8 ton/fed, and its chemical analysis is presented in Table (3).

Seed inoculation was carried out before sowing, where maize seeds were inoculated with Rhizobactrin (a composite attains *Rhizobium leguminosarum* by Viceae) at the rate of 300 g per 40 kg maize seeds. The experimental design was a randomized complete block (factorial) with three replicates. The current experiment was laid out with twelve treatments of the previous material, i.e., control (C), foliar spray with both micronutrients (MN) & humic acid (HA), chicken manure (CM), seed inoculation (RI), (MN+HA), (MN+CM), (MN+RI), (HA+RI), (CM+RI), (MN+HA+RI) and (MN+CM+RI).

Maize seeds (single cross 10 hybrid) were sown at the first week of April 2008 in the experimental soil plots. Basal doses of urea, calcium superphosphate and potassium sulphate fertilizers were added to the experimental soil plots. however, calsium superphosphate (15 % P_2O_5) was added to each plot before sowing, while urea (46 % N) and potassium sulphate (48 % K_2O) were added in two equal doses, *i.e.,* 15 and 40 days after planting. Two plant samples (every one represents ten plants were chosen randomly from each treatment in the three replicates) were taken from each experimental plot, the first was taken at 65 days after planting to determine some growth characters, i.e., plant height (m), dry weight of leaves/plant (g), leaf content of chlorophyll a and b (mg/g F.W.). The second sample was taken at harvest (about 4 months after planting) to estimate ear characters (*i.e.,* ear length as m, ear diameter in cm, ear weight in g, raw number/ear and grain number/raw); grain yield (*i.e.,* kg/plot) and grain quality (*i.e.,* weight of 100 grain in g, contents of crude protein content % as well as macronutrients of N, P & K % and micronutrients of N, P, K, Fe, Mn, Zn & Cu as mg/kg).

The collected plant samples of either fresh maize leaves or grains were dried at 70 C^o, ground in a Willy mill and digested with H_2SO_4 and H_2O_2 according to [26]. to determine N, P, K[6]. Fe, Mn, Zn and Cu in grain[11]. Also, leaf chlorophyll a & b as well as reducing sugars in grains were determined according to the methods described by[31,12,3]. Crude protein was calculated by multiplying total N content by 6.25[8]. The obtained results were statistically analyzed according to[14] to define the statistical significance of L.S.D. at 0.05.

Table 1: Some physical and chemical properties as well as nutrients status of the experimental sandy soil.

Soil characteristics	Value			Soil characteristics				Value	
Particle size distribution %:				Soil pH (1.25 soil water suspension)				7.86	
Coarse sand	29.30			$CaCO_3$ %				1.39	
Fine sand	62.60			Gypsum %				0.63	
Silt	3.60			Organic matter %				0.21	
Clay	4.50			CEC (me/100 g soil)				4.95	
Textural class	Sand			ECe (dS/m, soil paste extract)				1.45	
Physical &chemical properties:				*Soluble cations (soil paste, mmol$_c$ /L^{-1})*					
Bulk density g cm^{-2}	1.63	Ca^{2+}	Mg^{2+}	Na^+	K^+	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}
Hydraulic conductivity (cmh^{-1})	16.41	6.36	2.44	5.70	0.15	0.00	2.7	7.65	4.3

Table 2: Some macro and micronutrients status of the experimental sandy soil.

	Available macro and micronutrients (mg/kg)						
N	P	K	Fe	Mn	Zn	Cu	
21.47	3.98	57.32	3.75	0.82	0.43	0.35	
	Critical levels of available nutrients in soil (mg/kg), undertaken by Lindsay and Norvell (1978) and Page et al. (1982).						
Nutrient level	N	P	K	Fe	Mn	Zn	Cu
Low	< 40.0	< 5.0	< 85.0	< 4.0	< 2.0	< 1.0	< 0.5
Medium	40.0-80.0	5.0-10.0	85.0-170.0	4.0-6.0	2.0-5.0	1.0-2.0	0.5-1.0
High	> 80.0	> 10.0	> 170	> 6.0	> 5.0	> 2.0	> 1.0

Table 3: Chemical analysis of the applied chicken manure.

Organic matter %	Organic carbon %	Total N %	C/N ratio	Total P %	Total K %	Available content (mg/kg)			EC* (dS/m)	pH**
						N	P	K		
41.82	24.31	2.05	11.86	1.46	2.15	1059	1478	1903	6.97	8.26

* 1:10 water extract ** 1:5 water suspension

RESULTS AND DISCUSSION

Experimental soil: The studied sandy soil is mainly developed on the aeolian deposits as a parent material, and occupying the desert zone adjacent to Ismailia Governorate, Egypt. It is developed under climatic conditions of long hot rainless summer and short mild winter with scare amounts of rainfall. The obtained data in Tables (1and 2) reveal that studied sandy soil is characterized by coarse texture, low CEC, poorer in organic matter, nutrient bearing minerals, retain nutrients and moisture. Such severe conditions get more attention for soil supplying essential nutrients to plants as well as soil amendments.

According to Soil Survey Staff[29] the taxonomic unit is identified as Typic Torripsamments, siliceous, hyperthermic at the family level. Data presented in Table (4) indicate that, by applying the parametric system undertaken by[27] the suitability class of studied sandy soil could be evaluated as marginally suitable class of (S3) either in current or potential conditions, besides soil texture (s1) and gypsum (s4) represent the most effective limitations for soil productivity, with intensity degrees of very severe (rating <40) and slight (rating >90), respectively.

Effect of the applied treatments on vegetative growth characters of maize: Data in Table (5) showed a positively response of the studied treatments either added as solely [(*i.e.,* micronutrients (MN), humic acid (HA), chicken manure (CM) and seed inoculation (RI)] on vegetative growth characters under investigation, *i.e.,* plant height (m), dry weight of leaves/plant (g), leaf content of chlorophyll a and b, with superiority for the treatments of CM and (MN+CM+RI) as solely and combined ones, respectively. The considerably greater increase percentages reached 31.47, 18.08, 27.93 and 25.69 %

for the solely treatment of CM; 47.72, 36.56, 63.84 and 52.38 % for the combined treatment of (MN+CM+RI) over the control treatment, respectively.

It is note worthy to mention that either chicken manure as a solely treatment or its combination with another ones were more effective, however, the applied CM alone or the triple treatment of (MN+CM+RI) gave the considerably greater increase percentages. That is true, since chicken manure, as an organic substance, has been found to a profound effect not only on the biological activity and soil structure, but also on the plant its self. This is due to its positive effect on the increment in bio-released plant nutrients and their availability to be uptake by the growing plant. These results are in harmony with those reported by[30]. who found that the favourable conditions achieved in soil as a result of the applied organic manure are commonly associated with lowering soil pH and forming organo-metalic compounds (*i.e.,* the chelated micronutrients), which represented the next superior form due to a higher portion of these compounds still in maintained active forms for uptake by plant roots. In addition, adding organic manure resulted in increasing crop productivity as a result of increasing soil bio-availability of micronutrients (*i.e,* Fe, Mn, Zn and Cu) and cation exchange capacity in the newly reclaimed soils, and in turn markedly increased the dry weight and the plant contents of these nutrients at the vegetative growth of maize.

Effect of the applied treatments on ear characters of maize: Data in Table (6) indicate that the positive effects of the applied treatments were extended to the ear characters of maize, *i.e.* ear length, ear diameter, ear weight, raw number/ear and grain number/raw.

An almost similar trend of the considerably increases in ear characters (*i.e.,* length, ear diameter, ear weight, raw number/ear and grain number/raw) were occurred to those obtained in the case of vegetative growth parameters. However, the triple treatment of (MN+CM+RI) was achieved a considerably greater increase that reached 53.80, 29.10, 29.93, 31.14 and 42.27 % for length, ear diameter, ear weight, raw number/ear and grain number/raw over the control treatment, respectively. The increases in the studied ear characters as a result of the applied treatments may be achieved due to their ability to release plant promoting substances which might be stimulated plant growth as well as increasing the water and nutrients uptake by plant from the soil[9].

Effect of the applied treatments on grain yield and quality of maize: Undoubtedly, the modifying soil medium and the prevailing favourable conditions of both vegetative growth and ear characters were positively reflected on the maize grain yield and its quality. That was true, since a considerably greater increase was recorded in each of grain yield/plot, weight of 100 grain and crude protein %, Table (7). These increases were statistically confirmed (L.S.D. at 0.05), however, the triple treatment of (MN+CM+RI) exhibited a significantly superior over the other studied ones. The corresponding relative increase percentages reached 55.43, 33.07 and 39.80 % over the control treatment, respectively.

The obtained results are in harmony with those undertaken by[33] who showed that the beneficial effects of the applied treatments on either ear length or diameter might be due to their stimulation effect on cell division and expansion or elongation, consequently increasing number or weight of grain/ear. Also, such beneficial effects of the studied treatments were 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[7,10,2].

Effect of the applied treatments on maize grain content of some nutrients: Maize grain content of some macronutrients (*i.e.,* N, P and K) and micronutrients (*i.e.,* Fe, Mn, Zn and Cu) showed a greatly response to the studied treatments added as either solely or together, with considerably greater values strictly associated with the triple one (MN+CM+RI), as shown in Table (8). That was true, since such treatment surpassed the control treatment by 82.41, 80.65, 58.05, 61.182 53.81, 48.40, and 80.41 % for the previous studied nutrients, respectively. These increases were statistically confirmed by the obtained data of L.S.D. at 0.05 for either applied individual (MN, HA, CM and RI) or combined (MN+HA, MN+RI, HA+RI, CM+RI, MN+HA+RI and MN+CM+RI), which showed significantly increased in N, P, K, Fe, Mn, Zn and Cu contents of maize grain.

Moreover, the effects of the combined treatments, especially those associated with the applied organic manure, were superior to the solely ones with significant differences among them. Consequently, the positive effects of the studied treatments are more attributed to improve the efficiency of micronutrients to be available in soil as well as to accumulate in the maize grain that showed a closely relationship to their corresponding available contents in the treated soil plots[1,23].

It is noteworthy to mention that the applied treatment of rhizobium inoculation (RI) either added alone or in combination with others showed relatively low values for the studied maize parameters. These findings are in agreement with those obtained by [20,15]. On the other hand, RI showed a more pronounced beneficial effect when added in combination with OM for increasing the studied plant parameters of maize. This may be attributed to the integrated effect of organic substances and effective bacterial strains on enhancing the biosynthesis of the plant organs[24]. In addition, such integrated effect leads to accumulate both organic and mineral substances that are essential to plant growth, stimulating and activating the bio-chemical processes in plants which increasing the grain yield and improving its quality[18].

Finally, the positive effects of the studied treatments added as solely or together on the investigated characters of both vegetative growth and ear of maize plants as well as grain yield and its quality could be categorized in a descending order of (MN+CM+RI) > (MN+HA+RI) > (MN+CM) > (MN+HA) > (CM+RI) > (MN+RI) > CM > (HA+RI) > MN > HA > RI > control treatment, under the prevailing conditions of the current experiment.

Table 4: Soil limitations and rating indices for the evaluation of the studied soil.

Suitability condition	Topography (t)	Wetness (w)	S				Soil salinity/ Alkalinity (n)	Rating (Ci)	Suitability ciass
			Soil texture (S1)	Soil depth (S2)	$CaCO_3$ (S3)	Gypsum (S4)			
Current	100	100	30	100	100	90	100	27	S3
Potential	100	100	30	100	100	90	100	27	S3

Table 5: Effect of the applied treatments on vegetative growth characters of maize plants.

Treatment	Plant height (cm)	Leaves dry weight (g)	Chlorophyll (mg/g fresh weight)	
			a	b
C (control)	1.97	61.95	1.067	0.698
MN (micronutrients)	2.53	69.02	1.350	0.919
HA (humic acid)	2.45	67.48	1.281	0.877
CM (chicken manure)	2.59	73.15	1.493	1.003
RI (rhizobium inoculation)	2.34	65.33	1.214	0.836
MN+HA	2.73	77.41	1.701	1.091
MN+CM	2.79	79.05	1.775	1.133
MN+RI	2.62	74.90	1.560	1.007
HA+RI	2.57	71.64	1.422	0.96
CM+RI	2.69	76.53	1.630	1.05
MN+HA+RI	2.86	82.97	1.840	1.174
MN+CM+RI	2.91	84.60	1.912	1.216
L.S.D. at 0.05	0.28	2.74	0.124	0.109

Table 6: Effect of the applied treatments on ear characters of maize plants.

Treatments	Ear length(cm)	Ear diameter (cm)	Ear weight (g)	Raw number /ear	Grain number /raw
C (control)	14.33	4.02	162.14	12.91	29.74
MN (micronutrients)	17.24	4.45	175.32	14.15	33.47
HA (humic acid)	16.57	4.37	170.61	13.78	32.4
CM (chicken manure)	18.41	4.62	184.05	14.83	35.73
RI (rhizobium inoculation)	15.95	4.30	165.75	13.45	31.3

Table 6: Continue

MN+HA	20.17	4.92	196.98	15.90	39.05
MN+CM	20.85	5.00	201.76	16.22	40.16
MN+RI	19	4.72	187.83	15.20	36.87
HA+RI	17.8	4.53	179.69	14.50	34.59
CM+RI	19.62	4.81	193.45	15.54	37.95
MN+HA+RI	21.53	5.11	207.15	16.60	41.2
MN+CM+RI	22.04	5.19	210.67	16.93	42.31
L.S.D. at 0.0	1.37	0.21	3.50	0.39	1.48

Table 7: Effect of the applied treatments on grain yield and its quality.

Treatments	Grain yield (kg/plot)	Grain quality	
		Weight of 100 grain (g)	Protein content %
C (control)	6.35	29.85	14.07
MN (micronutrients)	7.84	33.16	16.1
HA (humic acid)	7.57	32.23	15.6
CM (chicken manure)	8.5	34.75	16.96
RI (rhizobium inoculation)	7.62	31.46	15.81
MN+HA	9.25	37.14	18.31
MN+CM	9.49	37.95	18.76
MN+RI	8.74	35.54	17.42
HA+RI	8.15	33.91	16.53
CM+RI	9.02	36.32	17.86
MN+HA+RI	9.65	38.89	19.21
MN+CM+RI	9.87	39.72	19.67
L.S.D. at 0.05	1.14	1.53	1.62

Table 8: Effect of the applied treatments on grain contents of some macro- and micronutrients.

Treatments	Macronutrients %			Micronutrients (mg/kg)			
	N	P	K	Fe	Mn	Zn	Cu
C (control)	2.16	0.274	2.05	57.45	46.37	31.65	7.35
MN (micronutrients)	2.79	0.334	2.53	67.02	53.58	35.79	9.7
HA (humic acid)	2.64	0.315	2.45	63.81	51.40	44.40	9.25
CM (chicken manure)	3.08	0.375	2.69	73.42	58.00	38.50	10.57
RI (rhizobium inoculation)	2.52	0.295	2.36	61.65	49.25	33.05	8.8
MN+HA	3.5	0.425	2.94	82.97	64.36	42.64	11.9
MN+CM	3.62	0.447	3.05	86.15	66.78	44.00	12.35
MN+RI	3.21	0.392	2.77	76.59	60.20	39.92	11
HA+RI	2.93	0.355	2.60	70.20	55.80	37.15	10.13

Table 7: Continue

CM+RI	3.35	0.412	2.85	79.75	62.37	41.25	11.45
MN+HA+RI	3.78	0.467	3.15	89.35	69.05	45.49	12.87
MN+CM+RI	3.94	0.495	3.24	92.60	71.32	46.97	13.26
L.S.D. at 0.05	0.28	0.015	0.27	3.54	2.61	1.25	1.34

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