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Improving Maize Grain Yield and its Quality Grown on a Newly Reclaimed Sandy Soil by Applying Micronutrient, Organic Manure and Biological Inoculation

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Abstract: A field experiment was conducted on maize plants (*Zea mays L.*, cv. single cross 10 hybrid) grown on a newly reclaimed loamy sand soil at the eastern desert rim of Demo village, district and governorate of El Fayoum during the summer season of 2007 to identify the beneficial impacts of foliar spray with micronutrients (MN), organic manure (OM) and seed inoculation with the biological inoculation of Rhizobactrin (SI), used either in solely or combined treatments, on vegetative growth characters, grain yield and its quality, with special reference to the grain contents of some macro- and micro-nutrients. The obtained results indicate that the main mechanical fraction of the studied soil is the sand (quartz), which is not partially capable to retain neither soil moisture nor nutrients for growing plants and organisms as well as it is poor in the nutrient bearing minerals. Under such severe conditions, the productivity of grown maize plants tends to decrease markedly. Also, the obtained data reveal that the studied soil could be classified as "Typic Torripsamments, siliceous, hyperthermic" and evaluated as marginally suitable soil ($S3s_1s_4$), with soil texture (s_1) and gypsum (s_4) as effective limitations for soil productivity. As for the applied treatments, maize grain yield and its quality showed a markedly responded to each of them, either solely added or together. However, the tested treatments recorded significant increases in maize vegetative growth characters (*i.e.,* plant height, dry weight of leaves/plant, leaf contents of chlorophyll a & b, total carbohydrates and sugars); ear characters and grain yield (*i.e.,* ear length, ear diameter, ear weight, raw number/ear, grain number/raw, grain number/ear, weight of 100 grain and grain yield/plot) and grain quality parameters (*i.e.,* its contents of reducing sugars and crude protein % as well as macro- & micro-nutrient contents of N, P, K, Fe, Mn, Zn and Cu), with superiority to the combined treatment of (MN+OM+SI). That was true, since such triple combined treatment resulted in a beneficial effect, which is more attributed to enrich in mineral, organic and bio substances that are essential to plant growth, stimulating and activating the bio-chemical processes in plants (*i.e.,* respiration, photosynthesis and chlorophyll content). The later processes are urgent to increase the grain yield and improving its quality under the severe conditions of the experimental soil.

Key words: Maize, newly reclaimed loamy sand soil, micronutrients, organic manure and biological inoculation.

INTRODUCTION

The soil survey data of Egypt pointed out to a considerable decrease in soil productivity for the desert sandy soils, mainly due to low levels of organic matter content, which represents the main factors for widespread occurrence of some micronutrients deficiency in the different desert regions of the world. Also, low organic matter below the critical level causes exhaustion for micronutrients through removal by plants as well as negatively influence on the availability of these micronutrients for grown crops[32]. This is mainly due to the main mechanical or mineral constituent of sandy soils is the sand fraction or quartz, which is not partially capable to retain neither water nor nutrients for growing plants. Accordingly, these soils are poor not only in the nutrient bearing minerals, but also in organic matter, which are a storehouse for the essential plant nutrients, in turn the productivity of different crops tends to decrease markedly[21].

Hence, increasing sandy soil potential for high productivity of any crop required a proper and justified fertilization policy particularly with regard to micronutrients, where their deficiencies in the majority of Egyptian soils occur. 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 and chemical properties of these soils, and in turn enhancing their productivity.

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Many studies were carried out to investigate the beneficial effects of some materials, such as organic manures or bio-fertilizers as well as micronutrients as foliar spray. However, adding organic manure resulted in increasing soil productivity as a result of increasing the values of micronutrients (*i.e,* Fe, Mn, Zn and Cu) and cation exchange capacity in the newly reclaimed soils[1,25]. Moreover, increasing soil organic matter content due to organic manure application markedly increased the dry weight and the plant contents of Fe, Mn, Zn and Cu at the vegetative and elongation stages of maize. Also, the statistical analysis confirmed that potential bio-availability of micronutrients in soils was strongly controlled by their chemical forms related to solubility[2].

It could be stated that the micronutrient contents may become a limiting factor in crop production in sandy soils, however, Negm and Zahran[24] reported that supplying micronutrients to plants as foliar spray, at specific physiological growth is undoubtedly of great importance, especially in case of deficient sandy soils. That is true, since the essential roles of micronutrients in plant metabolism, as activators or co-factor in all vital processes of a plant, can not be ignored. Undoubtedly, this leads to increase crop production, which is considered as the main goal in this respect. In this connection, Ghaly *et al.*[14] found that application of Fe- and Zn-EDTA to soil 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 soils through the agronomic practices such as application of bio, organic and/or mineral fertilization. This is emphasized by the obtained findings by Moussa *et al.*[23] for the application of micronutrients (Fe, Mn and Zn) and their beneficial effects on some bio-processes, vegetative growth and crop yields of plants grown in sandy soil as well as the effective microorganisms technology, which is used extensively by Li and Sun[18] who mentioned that the application of specific bacteria strains enhanced soil micro fauna. The later case leads to improve soil physical and chemical properties as well as enhanced nutrients availability, and in turn encouraging the vegetative growth as well as increased yields of crops, even over that of chemically fertilized systems. Also, Yadav[37] stated that efficiency of effective microorganisms attributed to its role on accelerating the mineralization processes of organic and help nutrient release under temperate conditions and this enhance utility values of organic matter.

The current work aimed to evaluate the integrated effect of applied micronutrients as foliar spray in combination with organic manure and specific effective microorganisms on maize yield and its components. Also, the effect of such treatments on grain quality and its chemical composition would be a matter of concern in this study.

MATERIALS AND METHODS

The previous target was achieved through a field experiment was conducted on maize plants (*Zea. mays L.*, cv. single cross 10 hybrid) grown on a sandy soil at the eastern desert rim of Demo village, district and governorate of El Fayoum during a summer season of 2007. Some physical and chemical properties as well as some nutrients status of the studied soil in which the experiment was carried out were determined according to the standard methods outlined by Chapman and Pratt[7], Black *et al.*[6] and Jackson[17], and the obtained data are presented in Table (1).

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 300 L/fed in each time. Organic manure was added in form of poultry manure at a rate of 4 ton/fed, and its chemical analysis is presented in Table (2).

Biological inoculation was carried out before planting, however, maize seeds were inoculated with appropriate amount of bio-fertilizer "Rhizobactrin" (*i.e.,* a composite attains *Rhizobium leguminosarum* by Viceae) at a rate of 300 g per 40 kg maize seeds. The current experiment was conducted in fixed plots with an area of 10.5 m^2 (3.0 x 3.5 m), and it was laid out with eight treatments of the previous materials, i.e., C (control), MN (foliar spray), OM (organic manure), SI (seed inoculation, (MN+OM), (MN+SI), (OM+SI) and (MN+OM+SI) with three replicates arranged in a complete randomized block design.

Maize seeds (single cross 10 hybrid) were sown at the second week of May 2007 in soil, under sprinkler irrigation system. Nitrogen and potassium fertilizers were added to the experimental soil plots in two equal doses during the growing period (after 15 and 40 days) in the forms of ammonium sulphate (20.5 % N) and potassium sulphate (48 % K_2O) at rates of 120 kg N/fed and 100 kg K_2O /fed, respectively. Also, 30 kg P_2O_5/fed as calcium superphosphate fertilizer (15 % P_2O_5) was added during preparing the soil for cultivation.

Table 1: The main characteristics of the studied experimental soil.

Soil characteristics	Value	Soil characteristics	Value
Particle size distribution %:		*Soluble cations (soil paste, mmolc/L):*	
Sand	81.50	Ca^{2+}	10.05
Silt	6.80	Mg^{2+}	3.46
Clay	11.70	Na^{+}	9.80
Textural class	LS*	K^{+}	0.25
Soil physical properties:		*Soluble anions (soil paste, mmolc/L)*:	
Bulk density, g cm^{-2}	1.59	CO_3^{2-}	0.00
Total porosity %	45.05	HCO_3^{-}	2.30
Available water %	7.68	Cl^{-}	13.45
Hydraulic conductivity, cm h^{-1}	14.75	SO_4^{2-}	7.81

Soil chemical properties:		*Available macro and micronutrients (mg/kg)*:						
Soil pH**	7.92	N	P	K	Fe	Mn	Zn	Cu
$CaCO_3$ %	8.65	17.25	4.03	63.75	3.49	0.86	0.47	0.35
Gypsum %	0.57	These values are lying at the low levels according to the critical available plant nutrients in mg/kg as outlined by Lindsay and Norvell (1978) and Page *et al.*,(1982) *as follows:*						
Organic matter %	0.11							
CEC (me/100 g soil)	4.67							
ECe (dS/m, paste extract)	2.34	< 40.0	< 5.0	< 85.0	< 4.0	< 1.0	< 0.5	< 0.5

*Loamy sand Soil pH was measured in 1:2.5 soil water suspension

Table 2: Chemical analysis of the applied poultry 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		
45.72	26.58	2.35	11.31	1.62	2.27	1146	1675	1832	7.52	8.17

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

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 panting to determine some growth characters, i.e., plant height (m), dry weight of leaves/plant (g), leaf content of chlorophyll a & b (mg/g F.W.), leaf content of carbohydrates and sugars (mg/g D.W.). The second sample was taken at harvest (about 4 months after planting) to estimate ear characters (*i.e.,* ear length in m, ear diameter in cm, ear weight in g, raw number/ear, grain number/raw, grain number/ear); grain yield (*i.e.,* kg/plot) and grain quality (*i.e.,* weight of 100 grain in g, contents of reducing sugars (mg/g D.W.), crude protein %, macronutrients of N, P and K %, micronutrients of Fe, Mn, Zn and Cu in mg/kg).

The plant samples of either fresh maize leaves or grains were dried at 70 C°, ground in a Willy mill and digested with H_2SO_4 and H_2O_2 according to Parkinson and Allen[8] to determine N, P, K[7], Fe, Mn, Zn and Cu in grain[12]. Also, leaf chlorophyll a, b and total carbohydrates as well as reducing sugars in both leaves and grains were determined according to the methods described by Welburn and Lichtenthaler[35], Herbert *et al.*[13] and A.O.A.C.[4], respectively. Moreover, crude protein was calculated by multiplying total N content by 6.25[12]. The obtained results were statistically analyzed according to Gomez and Gomez[15], and the statistical significance was defined at 0.05.

RESULTS AND DISCUSSION

General View on the Experimental Soil: The experimental sandy soil is mainly encompassing the siliceous veins within the Eocene limestone as a parent material, and occupying the eastern desert zone adjacent to El Fayoum depression, 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 Table (1) indicate that sand (quartz grains) is the dominant mechanical fraction, hence the experimental soil is characterized by siliceous in nature, and in turn it is not only poorer in the nutrient bearing minerals but also poorer in soil retain moisture (available water). Moreover, it is surveyed as non-saline and poorer in both soil organic and inorganic (clay) colloids, which is parallel close to the relatively low CEC value. Consequently, such severe conditions of inadequate available nutrient contents and soil moisture get more attention for soil supplying essential nutrients to plants as well as undoubtedly of great importance for micronutrients in such deficient sand soil.

According to the updated Key of Soil Survey Staff[33], the taxonomic unit at the family level, which is considered as a scientific term of the modern language in soil field, the experimental soil is classified as Typic Torripsamments, siliceous, hyperthermic. As shown in Table (3) and according to parametric system undertaken by Sys and Verheye[31], the suitability condition in either in current or potential classes of the studied soil could be categorized as marginally suitable class of (S3) and subclass of ($S3s_1s_4$), besides soil texture (S_1) and gypsum (S_4) represent the most effective limitations for soil productivity, with intensity degrees of severe (rating <50) and slight (rating >90), respectively. The relative coarse texture (S_1) has a direct adverse effect due to the dominant of sand fraction, which is not partially capable to retain neither soil moisture nor nutrients for growing plants and organisms as well as it is poorer in nutrient bearing minerals.

Effect of the Applied Treatments on the Maize Grain Yield and its Quality: Vegetative Growth Characters: The obtained data illustrated in Table (4) showed a significant positively effect of the applied treatments as solely ones, *i.e.,* micronutrients (MN), organic manure (OM) and seed inoculation (SI) on the studied vegetative growth characters, *i.e.,* plant height (m), dry weight of leaves/plant (g), leaf content of chlorophyll a & b (mg/g F.W.), leaf contents of total carbohydrates and sugars, with a superiority for organic manure (OM). The corresponding relatives increase percentages were 15.57, 5.71, 13.65, 28.26, 11.04 and 7.76 % for MN; 23.11, 8.67, 17.99, 29.86, 16.32 and 11.98 % for OM; 10.85, 3.74, 12.15, 24.71, 5.84 and 5.09 % for SI over the control treatment, respectively. The beneficial influences of the combined treatments were more effective, however, the triple treatment of (MN+OM+SI) gave the considerably greater increase percentages reached 33.96, 22.48, 43.09, 36.84, 37.96 and 26.81 % over the control treatment, respectively.

That is true, since the obtained results outlined by Wahdan *et al.*[34] pointed out that the favourable conditions of the combined treatments with organic manure are commonly achieved by 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 as well as improving most of physical properties 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. These findings are in harmony with those obtained by Badawy[5] who 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.

Ear Characters: As for ear characters, data in Table (5) reveal that the beneficial effects of the applied treatments were extended to the ear characters, *i.e.* ear length, ear diameter, ear weight, raw number/ear, grain number/raw and grain number/ear. A parallel trend of the relative increase percentages in ear length, ear diameter, ear weight, raw number/ear, grain number/raw and grain number/ear were occurred for the triple treatment of (MN+OM+SI) and reached 33.60, 15.48, 25.17, 14.13, 31.82 and 35.48 % over the control treatment, respectively. Such increases in the studied ear characters as a result of the applied treatments were probably due to many factors that suggested by many workers, *i.e.,* a) its ability to release plant promoting substances might be stimulated plant growth[10], b) increasing the water and nutrients uptake from the soil and c) its stimulation effect on cell division and expansion and physiological processes[30].

Grain Yield and Quality: The obtained results in Table (6) indicate that the prevailing favourable conditions of vegetative growth and ear characters positively reflected on the maize grain yield and its quality. That was true, since the effect of triple combined treatment of (MN+OM+SI) showed a considerably greater in each of grain yield/plot, weight of 100 grain, reducing sugars and crude protein reached 48.99, 17.11, 53.73 and 48.97 % over the control treatment, respectively. These increases were statistically confirmed (L.S.D. at 0.05), however, the triple treatment exhibited a significantly superior over the other studied ones.

These results are in harmony with those undertaken by Yu *et al.*[38] who showed that the beneficial effects of the applied treatments on either ear length or

Table 3: Limitations and rating indices for the evaluation of the studied soil.

Suitability condition	Topography (t)	Wetness (w)	S: Soil texture (s1)	S: Soil depth (s2)	S: $CaCO_3$ (s3)	S: Gypsum (s4)	Soil salinity/ Alkalinity (n)	Rating (Ci)	Suitability class	Suitability subclass
Current	100	100	55	100	100	90	100	49.50	S3	$S3s_1s_4$
Potential	100	100	55	100	100	90	100	49.50	S3	$S3s_1s_4$

Table 4: Effect of the applied treatments on vegetative growth characters of maize plants.

Treatments	Plant height (cm)	Leaves dry weight (g)	Chlorophyll a (mg/g F.W.)	Chlorophyll b (mg/g F.W.)	Total carbohydrates (mg/g D.W.)	Total sugars (mg/g D.W.)
Control	2.12	66.90	1.267	0.874	65.38	55.17
MN	2.45	70.72	1.440	1.121	72.60	59.45
OM	2.61	72.70	1.495	1.135	76.05	61.78
SI	2.35	69.40	1.421	1.090	69.20	57.98
MN+OM	2.79	80.65	1.705	1.156	88.00	68.15
MN+SI	2.63	73.46	1.501	1.139	78.70	63.25
OM+SI	2.75	77.44	1.617	1.147	83.51	65.40
MN+OM+SI	2.84	81.94	1.813	1.196	90.20	69.96
L.S.D. at 0.0	0.22	2.45	0.146	0.116	3.52	2.46

MN=Micronutrients, OM=Organic manure, SI=Seed inoculation, F.W.=Fresh weight and D.W.=Dry weight

Table 5: 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	Grain number /ear
Control	16.01	4.20	168.75	13.80	31.90	452.65
MN	18.25	4.46	185.64	14.85	35.56	495.28
OM	18.73	4.53	191.89	15.10	36.75	536.37
SI	17.86	4.40	177.16	14.56	33.90	476.94
MN+OM	20.92	4.76	207.97	15.57	41.12	602.18
MN+SI	19.14	4.60	196.19	15.29	37.79	559.70
OM+SI	20.03	4.68	202.45	15.40	39.40	5.78.47
MN+OM+SI	21.39	4.85	211.23	15.75	42.05	613.25
L.S.D. at 0.0	1.74	0.18	3.52	0.74	1.17	4.23

MN=Micronutrients, OM=Organic manure, SI=Seed inoculation, F.W.=Fresh weight and D.W.=Dry weight

diameter might be due to their stimulation effect on cell division and expansion. In addition, the increase in number or weight of grain/year also may be attributed to the increment in cell division and cell elongation.

In this respect, Wilson and Allison[36] suggested that grain yield may sometimes be limited by photosynthesis (source) and grain (sink) simultaneously and it is possible to increase grain yield by keeping safe the balance between them. 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 Cheng *et al.*[8], El Nagar[11] and Abd El Hady *et al.*[3].

Grain Content of Some Nutrients: The maize grain contents of the studied macronutrients (N, P and K) and micronutrients (Fe, Mn, Zn and Cu), which are presented in Table (7), showed a greatly response to

Table 6: Effect of the applied treatments on grain yield and its quality.

Treatments	Grain yield (kg/plot)	Grain quality		
		Weight of 100 grain (g)	Reducing sugars (mg/g D.W.)	Protein content %
Control	6.41	31.04	25.35	15.07
MN	8.04	33.55	28.65	17.35
OM	8.35	34.08	30.50	18.90
SI	7.90	32.91	27.95	16.96
MN+OM	9.05	35.72	37.03	21.50
MN+SI	8.48	34.63	32.40	19.65
OM+SI	8.76	35.01	34.85	20.56
MN+OM+SI	9.55	36.35	38.97	22.45
L.S.D. at 0.0	1.31	1.72	2.45	1.65

MN=Micronutrients, OM=Organic manure, SI=Seed inoculation, F.W.=Fresh weight and D.W.=Dry weight

Table 7: 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
Control	2.42	0.305	2.17	59.54	47.20	32.10	7.85
MN	3.29	0.437	2.51	67.48	53.93	35.47	9.75
OM	3.37	0.446	2.59	70.45	56.40	37.00	10.32
SI	3.10	0.329	2.45	63.54	51.95	33.96	9.30
MN+OM	3.55	0.473	2.86	81.55	66.52	44.80	11.97
MN+SI	3.42	0.457	2.68	73.75	58.79	39.42	10.86
OM+SI	3.48	0.466	2.75	77.24	62.25	41.20	11.42
MN+OM+SI	3.85	0.480	3.05	85.75	69.13	47.65	12.52
L.S.D. at 0.0	0.58	0.021	0.23	3.45	2.66	1.24	1.41

MN=Micronutrients, OM=Organic manure, SI=Seed inoculation, F.W.=Fresh weight and D.W.=Dry weight.

either applied solely or combined treatments, with considerably greater values strictly associated with the applied triple treatment (MN+OM+SI), since it surpassed the control treatment by 59.09, 57.38, 40.55, 44.02, 46.47, 48.44 and 59.49 %, respectively. Consequently, the positive effects of the studied treatments are more attributed to improve the efficiency of micronutrients to accumulate in the maize grain that showed a closely relationship to their corresponding available contents in the treated soil plots[1,2,25].

These increases were statistically confirmed by the obtained data of L.S.D. at 0.05 for either applied individual (MN, OM and SI) or combined treatment (MN+OM, MN+SI, OM+SI and MN+OM+SI), which showed significantly increased in N, P, K, Fe, Mn, Zn and Cu contents of maize grain. Moreover, the effects of the combined treatments were superior to the solely ones with significant differences among them. Accordingly, the positive effect of the applied treatments (solely or together) on the studied vegetative growth and ear characters of maize plants as well as grain yield and its quality could be arranged in an ascending order of (MN+OM+SI) ≥ (MN+OM) > (OM+SI) > (MN+SI) ≥ OM ≥ MN > SI > control treatment.

It is noteworthy to mention that the applied treatment of SI added exhibited relatively lower values for the studied maize parameters. These findings are in harmony with those obtained by Mishra *et al.*[22] and Ibrahim *et al.*[16]. In addition, the statistical analysis of L.S.D. at 0.05 are emphasized these results, however, its data showed a more pronounced beneficial effect of SI when added in combination with OM for increasing the studied parameters of the vegetative growth, grain yield and quality of maize. These results are in agreement with those reported by Nissanka and

Sangakkara[26] who pointed out that the increases in the tested plant parameters were attributed to the integrated effect of organic substances and bacterial inoculation on enhancing the biosynthesis of the plant organs.

Moreover, such positive findings are mainly achieved as a result of beneficial effects of both organic manure and biological inoculation, since they are rich in both organic and mineral substances essential to plant growth, stimulating and activating the bio-chemical processes in plants, which increasing the grain yield and improving its quality, i. e., the grain weight and number of grains/ear[20]. In addition, the bio-fertilization enhancing and sustaining the crop yield as well as greatly increased vegetative growth, grain yield and improved their quality and the chemical constituents[29].

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