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Biofertilization of Maize Crop and its Impact on Yield and Grains Nutrient Content under Low Rates of Mineral Fertilizers

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Abstract: A field experiment was implemented during the two successive seasons of 2002 and 2003 at the Agricultural Experimental Station of National Research Centre located at Qalubeya, Egypt to investigate the associative influence of *Azospirillum brasilense* and/or soil yeast *Rhodotorula glutinis* in the presence of low rates of NPK and sulfur on maize crop. In comparison with the positive control (100 % NPK), comparable results for plant height, ear height and straw yield were obtained due to the biofertilization associated with half doses of NPK in the presence of either half or full dose of sulfur. Inclusion of sulfur to the recommended doses of NPK resulted in significant increases for the straw weight parameter. Application of *Azospirillum* significantly augmented maize growth parameters while the associative effect of *Azospirillum* and *Rhodotorula* was more pronounced. Maize yield and its attributes responded well to biofertilization supported with half doses of NPK and sulfur where the differences were not significant when compared with the positive control. A positive and significant correlation was found between maize yield and each of plant height, ear height, ear weight, ear length, ear diameter, grains weight, shelling percent, grain index, straw yield and biological yield while this correlation was not significant with rows number/ear, grains number/row, crop index and harvest index. Comparable results to the positive control were observed due to the associative action of biofertilizers, low rates of NPK and sulfur for the nutrient elements content of maize grains i.e., nitrogen, phosphorus, potassium sulfur, zinc, iron and manganese.

Key words: Maize, Biofertilizers, Sulfur, Low rates of NPK

INTRODUCTION

More recently, a real challenge faces the workers in the agricultural research field to stop using the high rates of agro-chemicals which negatively affect human health and environment. It is well known that corn crop is considered among the most important cereal crops either in Egypt or all over the world that consumes huge quantities of chemical fertilizers. Many attempts have been tried to replace a part of those harmful chemical fertilizers by biofertilizers to get yield of a good quality without loss in its quantity. Mishra *et al*[8] and El-Kholy and Gomaa[6] have succeeded to reduce the recommended doses of chemical fertilizers needed for corn and millet by 50 % using biofertilizers without loss in the yield. Afifi *et al*[2] indicated that application of *Rhodotorula* sp. as a biofertilizer for corn augmented its grain yield.

The main goal of the current trial is looking for the best biological treatments could be applied to the corn crop to get a high yield with a good quality in addition to keep our environment clean and safe to live in.

MATERIALS AND METHODS

A field trial was achieved at the Agricultural Experimental Station of National Research Centre located at Qalubeya governorate, Egypt during the two successive seasons of 2002 and 2003 on maize crop cv. three-way cross 324 to find out the most effective bio-treatments either alone or combined with two rates of mineral fertilizers (NPK) in addition to two rates of sulfur. Moreover, obtaining a high yield of good quality and lowering the unwise doses of agro-chemicals to stop the soil deterioration and save the environment were born in mind. Chemical, mechanical and microbiological analyses of the experimental soil were shown in Table (1). Two types of biofertilizers liquid cultures were applied i.e., *Azospirillum brasilense* containing 8.4×10^8 cell/ml and soil yeast (*Rhodotorula glutinis*) containing 3.7×10^6 CFU/ml.

Both biofertilizers were applied at the rate of 40 liter/fed. that sprayed immediately on maize seeds after cultivation according to the respective bio-treatments.

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Table 1: Mechanical, chemical and microbiological analyses of the experimental soil.

Measured parameters	Values
Clay (%)	52
Silt (%)	20
Sand (%)	28
Organic matter (%)	1.8
pH	8.0
E.C. (mmohs / cm)	2.18
Nitrogen (%)	0.20
Phosphorus (%)	0.22
Potassium (mg / 100 g)	25
$CaCo_3$ (%)	3.0
Total microbial counts (CFU / g)	1.2×10^8
Total fungi count (CFU / g)	3.7×10^4
Total actinomycetes (CFU / g)	7.1×10^4

The experimental soil which was cultivated with wheat in the previous two seasons was ploughed twice and divided into plots each of (9 m^2). Maize grains were soaked overnight in tap water and then sown in hills of 25 cm apart on June 8 and 12 for the two growing seasons. The chemical fertilizers (NPK) were applied in two rates i.e., half the recommended doses (100, 50 and 60 kg/fed. respectively from calcium superphosphate, 15.5 % P_2O_5; potassium sulfate, 48 % K_2O and ammonium sulfate, 33.5 % N) while the recommended doses were 200, 100 and 120 kg/fed. from the same previously mentioned fertilizers. Also, sulfur was applied in two rates viz, 250 as half the recommended dose and 500 kg/fed. as a recommended dose. Both calcium superphosphate and sulfate were applied during soil preparation, potassium sulfate was divided into two equal doses that were added after thinning while ammonium sulfate was divided into three equal doses that applied before the first, second and third irrigation. The experimental design was split split plot with four replicates where whole scheme of the work is as follow:

- full doses of NPK as a positive control
- full doses of NPK + half dose of sulfur
- full doses of NPK + full dose of sulfur
- Half doses of NPK + half dose of sulfur
- Half doses of NPK + half dose of sulfur + *Azospirillum*(Azos.)
- Half doses of NPK + half dose of sulfur + *Rhodotorula*(Rhod.)
- Half doses of NPK + half dose of sulfur + Azos. + Rhod.
- Half doses of NPK + full dose of sulfur
- Half doses of NPK + full dose of sulfur + Azos.
- Half doses of NPK + full dose of sulfur + Rhod.
- Half doses of NPK + full dose of sulfur + Azos. + Rhod.

The various normal cultural treatments recommended for maize crop were followed. At harvest stage, representative samples of 10 plants from each treatment were picked up randomly to estimate the yield and its attributes.

The combined statistical analysis was carried on the obtained data according to the procedures of Snedecor and Cochran[11] where the means of diverse characters were compared using L.S.D. test at 0.05 level of significance. Further, the combined data of yield and its attributes were subjected to simple correlation according to Neter and Wasserman[9] (1974).

RESULTS AND DISCUSSIONS

The influence of various studied treatments on the diverse growth and yield parameters of maize was presented in Table (2). In comparison with the positive control (100 % NPK), comparable results for plant height, ear height, straw weight (g/plant) and straw yield (ton/fed.) were obtained due to the treatments of half dose of NPK + both types of biofertilizers (*Azospirillum* and *Rhodotorula*) in the presence of either half or full dose of sulfur. Inclusion of sulfur to the recommended doses of NPK resulted in significant increases for the straw parameter. Table (2) also shows that application of *Azospirillum* significantly augmented the previously mentioned growth parameters when compared with the corresponding treatments while the increases owing to the application of yeast were less pronounced. An associative effect between both applied biofertilizers was observed where the combined treatments of *Azospirillum* and *Rhodotorula* induced the highest values for plant height, ear height, straw weight and straw yield in comparison with either the positive control (100 % NPK) or the other tested treatments. Moreover and except few cases, there are no significant differences were noticed between both applied doses of sulfur especially when combined with biofertilizers. Regarding ear characteristics i.e., ear weight (gm), ear length (cm), ear diameter (cm), rows number/ ear, grains number/ear, grains number/row and grain weight/ear, the data presented in Table (2) also show that application *Azospirillum* and yeast in the presence of half dose of NPK and full dose of sulfur

Table 2: The associative influence of biofertilizers and reduced doses of mineral fertilizers and sulfur on maize yield parameters (2002 and 2003 seasons).

Parameters Treatments	Plant height (cm)	Ear height (cm)	Straw height (g/plant)	Ear weight (g/plant)	Ear length (cn)	Ear diameter (cm)	Rows (no./ear)	Grains (no./raw)	Grains weight (g/ear)	Shelling (%)	Grain index (G)	Grain yield (Ton/Fed.)	Straw yield (Ton/Fed.)	Biological yield (Ton/Fed.)	Crop index (%)	Harvest index (%)
100 % NPK	174.0	121.5	413.7	228.8	21.8	4.5	14.0	45.0	189.7	84.7	366.2	3.793	8.287	12.080	31.4	45.8
100 % NPK + 50% sulfur	175.7	122.3	423.3	227.3	22.0	4.5	14.0	45.3	191.5	84.2	369.0	3.830	8.467	12.297	31.1	45.3
100 % NPK + 100% sulfur	177.2	125.8	433.3	239.0	223	4.6	14.0	46.2	194.0	81.2	374.2	3.880	8.667	12.547	30.9	44.8
50 % NPK + 50% sulfur	164.8	113.8	387.8	214.2	20.1	4.2	13.3	44.7	172.5	80.5	360.2	3.450	7.697	11.147	31.0	44.8
50 % NPK + 100% sulfur	165.2	114.0	389.5	217.1	20.9	4.4	13.3	44.7	176.5	81.3	361.1	3.530	7.790	11.305	31.2	45.3
50 % NPK + 50% sulfur + *Azospirillum.*	168.0	118.8	395.7	220.4	20.8	4.4	13.3	45.0	183.3	83.2	362.6	3.667	7.913	11.580	31.7	46.3
50 % NPK + 100% sulfur + *Azospirillum*	169.0	118.6	400.8	221.5	21.0	4.4	14.0	45.0	183.7	82.9	363.4	3.673	7.987	11.660	31.5	46.0
50 % NPK + 50% sulfur + *Rhodotorula.*	166.0	115.9	391.0	218.0	20.7	4.4	14.0	44.3	177.5	81.5	361.4	3.550	7.820	11.370	31.2	45.4
50 % NPK + 100% sulfur + *Rhodotorula.*	167.5	118.2	393.8	219.3	21.0	4.4	14.0	44.7	181.3	82.7	361.1	3.627	7.877	11.503	31.5	46.0
50 % NPK + 50% sulfur + *Azospirillum+ Rhodotorula.*	171.5	121.6	409.5	222.0	21.0	4.4	14.0	45.0	185.6	83.7	364.3	3.713	8.190	11.880	31.3	45.4
50 % NPK + 100% sulfur + *Azospirillum* + *Rhodotorula.*	172.7	121.2	412.0	223.4	21.5	4.5	14.0	45.0	188.0	84.1	365.3	3.760	8.240	12.000	31.3	45.7
L.S.D. at 5 %	3.5	2.4	4.7	6.0	0.4	0.1	N.S	0.9	4.4	1.0	4.4	0.090	0.116	0.132	N.S	N.S

induced comparable measures to the positive control (100 % NPK) without significant differences. Replacing the full dose of sulfur with half dose in the same previous treatment also produced no significant differences with the positive control for rows number/ear, grains number/row and grains weight/ear. Further, the same aforementioned trend was recorded for each of shelling percentage, grain index, grain yield (ton/fed.), straw yield (ton/fed.) and biological yield (ton/fed.). In respect to both crop index and harvest index, Table (2) shows that there are no significant variations were recorded between the various treatments in comparison with the positive control.

Concerning the correlation between grain yield and the diverse studied maize characters, Table (3) reveals that a positive and highly significant correlation was recorded between grain yield and each of plant height , ear height, ear weight, ear length, ear diameter, straw weight (g/plant), straw yield (ton/fed.), grain weight (g/ear) and biological yield (ton/fed.). Moreover, a positive and significant correlation was found between maize grain yield and each of shelling percent and grain index. Meanwhile, the correlation between grain yield and each of rows number/ear, grains number/row, crop index and harvest index was not significant.

Table (4) demonstrates the effect of various tested treatments on certain mineral contents of maize grains. Of nitrogen content, inclusion of biofertilizers simultaneously with the reduced doses of mineral fertilizers and sulfur induced comparable results with those of the positive control. Moreover, the nitrogen percent of maize grains ranged from 1.03 to 1.23. With regard to phosphorus, potassium and sulfur contents in grains of maize, they ranged between 0.42 and 0.54 %, 0.56 and 0.65 % and 0.24 and 0.43 % respectively. Generally, inexplicit variations between the different treatments were

Table 4: The impact of reduced doses of NPK, sulfur, biofertilizers and their combinations on nutrient status of maize grains.

Treatments	N %	P %	K %	S %	Fe ppm	Zn ppm	Mn ppm
Positive Control (100%NPK)	1.05	0.43	0.53	0.35	95.0	31.0	12.0
100%NPK +50% sulfur	1.23	0.54	0.63	0.38	110.4	33.3	13.2
100%NPK+100% sulfur	1.10	0.47	0.60	0.43	103.6	36.3	10.5
50%NPK+50% sulfur	1.15	0.46	0.60	0.28	103.1	39.6	11.7
50%NPK + 100% sulfur	1.03	0.42	0.56	0.39	134.8	55.0	11.6
50%NPK+50% sulfur + *Azospirillum*	1.19	0.55	0.57	0.34	108.8	30.9	13.2
50%NPK +100% sulfur + *Azospirillum*	1.12	0.52	0.58	0.39	101.1	39.6	13.2
50% NPK+ 50% sulfur + yeast	1.05	0.51	0.59	0.24	90.1	36.3	11.6
50%NPK+100% sulfur + *Rhodotorula*	1.06	0.46	0.57	0.32	78.3	33.6	12.1
50%NPK + 50% sulfur + *Azospirillum* + *Rhodotorula*	1.22	0.47	0.66	0.24	96.5	28.9	12.6
50% NPK +100% sulfur +*Azospirillum* + *Rhodotorula*	1.18	0.49	0.65	0.27	89.0	33.0	12.1

Table 3: Simple correlation between grain yield and the various studied parameters of maize.

Source	R
Plant height (cm)	0.813**
Ear height (g)	0.816**
Straw weight (g/plant)	0.778**
Ear height (g/plant)	0.754**
Ear length (cm)	0.768**
Ear diameter (cm)	0.775**
Rows number/ear	0.318
Grains number/ear	0.243
Grains weight (g/ear)	1.000**
Shelling percentage	0.507*
Grain index (g)	0.585*
Straw yield (ton/fed.)	0.779**
Biological yield (ton/fed.)	0.893**
Crop index (%)	0.375
Harvest index (%)	0.394

observed for the previously mentioned nutrient elements except sulfur where the biofertilizers included treatments recorded lower values in comparison with the positive control. Concerning micro-nutrients i.e., iron, zinc and manganese, the data in Table (4) show that the biofertilized treatments induced lower values in comparison with the mineral ones for iron and zinc while little differences between treatments were found regarding manganese element.

Application of biofertilizers became of great necessity to get a yield of high quality and to avoid the environmental pollution as well. The combined application of *Azospirillum* and *Rhodotorula* in presence of half the recommended doses of NPK and either the full or half the recommended dose of sulfur produced comparable results to that obtained due to the application of the recommended doses of NPK regarding plant height, ear height, straw weight (g/plant) and straw yield (ton/fed.). Also, no significant variations were recorded between the biofertilized treatments and those received the full does of NPK and sulfur for each of number of rows/ear crop index and harvest index. This promoting effect of *Azospirillum* and soil yeast could be attributed to the biologically active substance produced by these biofertilizers such as auxins, gibberellins, cytokinins, amino acids and vitamins[3,4,2]. Afifi *et al*[2] obtained similar results where they stated that inoculation of maize with *Rhodotorula* and *Azotobacter* in the presence of half the recommended doses of NPK induced results for growth parameters matched those of the recommended doses of NPK. Furthermore, there are no significant differences regarding the yield and its attributes were recorded between the positive control (100 % NPK) and the treatment included biofertilizers and half doses of NPK and either half dose or full dose of sulfur. Okon[10] mentioned that increasing yield was attributed to the plant growth promoting substances by root colonizing bacteria more than the biological nitrogen fixation. Beside, Lin *et al*[7] stated that bacteria increased yield due to promoting root growth which in turn enhancing nutrients and water uptake from the soil. Abd El-Gawad *et al*[1] attributed the increase of maize yield to the increases in ear weight, grain weight, ear length, ear diameter and grains number/row,

while they ascribed the increase in grains number/row to the improvement of female inflorescence development and pollination in addition to increasing the assimilatory materials and translocation to the grains. Application of sulfur had a reasonable role in maize yield productivity, beside being a nutrient element, it is quickly oxidized to sulfuric acid which in turn reduce the pH value in the alkaline soil and increasing the availability of certain nutrient element[12,5].

In conclusion, the combined application of efficient biofertilizers, reduced doses of NPK and half the recommended dose of sulfur could be an integrated treatment to be applied in maize production to get a yield of good quantity and quality in addition to keep the environment clean.

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