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Effect of *Glomus intraradices* and Organic Fertilizer on the Yield and Quality of Maize Grown in Calcareous Soil

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Abstract: ***Two field experiments were carried out at the Agricultural Research Station of Nubaria during two summer seasons of 2014 and 2015. This work was to study the effect of arbuscular mycorrhizal fungus (AMF) under four rates of compost and two rates of nitrogen fertilizer as percent of the recommended dose on the yield and quality of maize grown in calcareous soil. These field experiments were arranged statistically in a split- split plot design in randomized complete blocks with three replicates. The development of root length colonization % was significantly increased in the inoculated plants more than the un-inoculated plants. The highest significant increases in shoot dry weight was (120g/ plant) and their NPK uptake were 117.7, 51.6 and 530.9 kg/ha, respectively as an average of the two seasons in the inoculated plants with Glomus intraradices at C_{75}% and N_{100}%. Grain yield was significantly increased in the inoculated plants with G.intraradices in the presence of C_{75}% and N_{100}% (9.7 t/ha) compared to the non-inoculated plants (9.0 t/ha). Inoculated Zea mays with G. intraradices gave the highest significant increases of corn oil (5.0%) and protein (6.0%) as compared to the non-inoculated plants (4.5 % and 5.3 % , respectively) in the presence of C_{75} % and N_{100}%. The results showed that inoculation with AM fungus in the presence of C_{75}% and N_{100}% of the recommended doses enhanced the soil fertility including the increase in the availability of N, P and organic matter content in soil***.

Keywords: AM fungi, Compost, Calcareous soil ,Maize plants , Grain yield and quality

1. Introduction

Maize (*Zea mays*,L.) is the most important cereal crop next to wheat in Egypt. It is mainly used by Egyptian farmer, for animal feed, compost as well as human food consumption and in some industrial purpose for oil, protein, starch, alcohols, organic and amino acids extraction [11].Corn oil rich in oleic acid and triglycerides to regulate blood pressure and circularity by enhancable a good kind of cholesterol level and antioxidant for human cell [6].

Calcareous soil occupies wide areas in Egypt. This soil suffers from the high of $CaCO_3$% and soil pH, low content of organic matter and low activity of microorganisms [9], [11], [25].

The availability of macro and micronutrients is not enough for crop production. In order to increase the productivity in these soils by addition of huge amounts of mineral fertilizers must be added which lead to be the main source of environmental pollutions [17] , [25].

Mycorrhizal fungi play the critical roles in nutrient cycling; increase the root surface area, alleviate the soil pH and ecosystem function [15]. Also mycorrhizal associations enhance nutrient uptake to improve the plant growth and modify the soil fertility [18] , [4].

Compost addition to this soil can increase the organic matter content and the availability of macro and micronutrients [1], [16].

The objectives of this investigation are to study the positive effect of AM fungi, four rates of compost and two rates of N–fertilizer to increase the grain yield, quality and to decrease the chemical pollution.

2. Materials and Methods

Two field experiments were carried out during two summer seasons 2014 and 2015 at the Agricultural Research Stationof Nubaria. The field experiments were laid out in a split-split plot design in randomized complete blocks with three replicates. Each experimental unit (plot) consisted of four rows, 3m long and 3.5m wide with 20 cm distance between each hill. The total area of each unit was 10.5 m^2 and it contained 60 plants .

Maize “*Zea mays* L.” grains of species third hybrid; 321, was provided from the Agricultural Research Center, Ministry of Agriculture, Giza, Egypt. Mycorrhizal strain “*Glomus intraradices*” which was isolated from the Experimental Station of Alexandria University at Abies, Egypt [2] was used. The inoculums consists of expanded clay aggregates (2-4 mm in diameter, leca). It contains of chlamydospores and fungus mycelium [3].The inoculums was applied prior to sowing at the rate of 5.0g / hill .The control plants received the same amount of heat sterilized expanded clay. Compost (plant residues) was used as an organic fertilizer. It was obtained from the Egyptian composting for solid waste recycling. Four different rates of Compost (C) were used (0, 50, 75 and 100% of the recommended dose). The recommended dose was 7.2 t/ha and the compost rates were added ten days before sowing. Chemical analysis of compost (plant residues) was (pH= 7.8, O.M% = 42.3%, total N%=1.93%, P%= 1.3% and K% = 1.1%, total O.C. % =24.5%, C/N ratio = 12.7 and moisture% = 0.37%) according to [5], [10], [19], [28], [20]. Nitrogen fertilizer (Ammonium nitrate = 33.5%N) was used at two levels of 50 and 100% of the recommended dose (288 kg N/ha). Nitrogen fertilizer was added twice in equal doses; at 21 and 45 days after sowing. Soil physicochemical characteristics of the surface layers (0-30 cm) of the experimental field were (pH= 8.2, $CaCO_3$% = 23.49, O.M% = 0.25, available N= 38.86 mg/kg, available P = 3.1 mg/kg and available K= 116.15 mg/kg). Soil contents was sand (54.9%), clay (19.9%) and loam (24.9%) were determined [28], [20].

The percentage of mycorrhizal root length colonization was estimated when plants were 45, 66 days and at harvest (105 days old) according to [21]. The percentage of AM root colonization was estimated according to the equation of [13]. At the harvest, shoot samples were dried and the average weight was calculated for each treatment. Samples of the dry plant leaves were digested according to [24]. The percentage of phosphorous and potassium were determined according to [19] using the vanadomolybdophosphoric method and flam photometer, respectively. Total nitrogen was determined by Nessler's method [5]. Total nitrogen in grain was determined and protein % (N% × 6.25) was calculated. Total oil % in grains was determined by the fixed ether extract [30]. Grain yield for each plot was weighted and expressed as (t/ha). According to [28] at the end of two growing seasons 2014 and 2015 three random soil samples were collected for measuring the available contents of N, P, K and the organic matter content.

3. Results and Discussion

1) The development of mycorrhizal root length colonization %

The percentage of AM colonization was examined at 45, 66 and 105 days old. Figures 1a and b show that the percentage of mycorrhizal root length colonization in inoculated maize plants with *G. intraradices* was significantly increased either with organic or mineral nitrogen fertilizer compared to un-inoculated plants. The highest percentage of AM colonization% was 67.3% and 47.0% when plants were 45 and 105 days old, respectively, as an average of the two seasons when the plants were inoculated with *G. intraradices* under C_{50}% and N_{100}%(Figures 1a and b). No significant differences were found between C_{50}% and C_{75}% treatments under the recommended dose of N- fertilizer in the percentage of AM root length colonization. The same trend of result was observed at 66 days old in both seasons. [33] reported that the inoculation with AM fungi is able to enhance the percentage of mycorrhizal root colonization of host roots. All the factors influencing the AMF community dynamics and association with plants, including the residual composted [7]. Management systems have been reported as a critical factor affecting the development, activity and diversity of AMF [27].

2) Effect of inoculated maize plants with *G. intraradices* in the presence of four rates of compost and two levels of N-fertilizer on growth parameters

a) Shoot dry weight

The percentage increases were found in shoot dry weight in inoculated maize plants with *G. intraradices* compared to un-inoculated plants (Table1) under different rates of compost and N- fertilizer. The highest shoot dry weight was 120 g/ plant (Table 1) as an average of the two seasons for the inoculated plants with *G .intraradices* in the presence of $C_{50\%}$ and N_{100}%. No significant differences in shoot dry weight were found between C_{50}% and C_{75}% treatments under the recommended dose of N-fertilizer. [23] reported that mycorrhizal colonization of maize significantly affected and promoted the dry weight. [29] found that the greatest dry matter yield of inoculated maize with VAM fungi and grown in residue – amended more than maize grown in un-amended soils.

b) NPK uptake in shoots

At the harvest, the highest value of N, P and K uptake in shoots were obtained from the inoculated plants with *G. intraradices* (117.7, 51.6 and 530.9 kg/ha, respectively) compared to un-inoculated plants (38.3, 28.9 and 324.7 kg/ha) as an average of the two seasons in the presence of $C_{50\%}$ and N_{100} % rates (Table 1). The inoculation with *Glomus intraradices* lead to a significant increase in the uptake of N, P and K in shoots more than non-inoculated plants. **[31]** reported that arbuscular mycorrhizal fungi benefit their host by increasing uptake of relatively immobile phosphate and other elements due to the ability of the fungal mycelium to grow beyond the phosphate depletion zone that quickly develops around the root. **[26]** found that combination of mineral (25%) and organic (75%) fertilizers lead to the highest values of N,P and K uptake in maize plants compared with mineral or organic fertilizer.

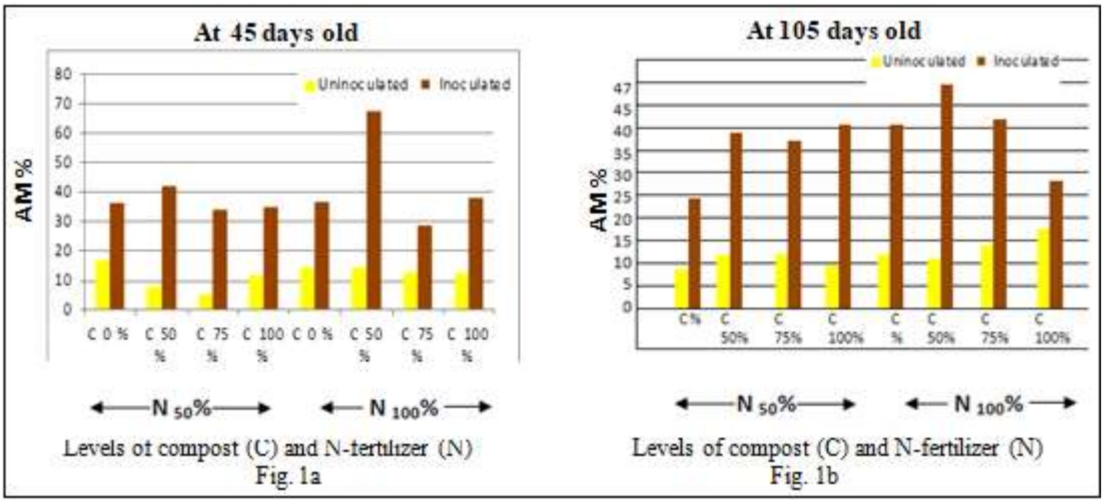

Figure 1: Effect of inoculated *Zea mays* with *G. intraradices* in the presence of four different rates of compost and two levels of N-fertilizer on the development of mycorrhizal root length colonization (%) at 45 and 105 days old as an average of both seasons (2014 and 2015)

Table 1: Effect of inoculated Zea mays plants with G .intraradices in the presence of four rates of compost and two levels of N-fertilizer on shoot dry weight and their NPK uptake as an average of the two seasons 2014 and 2015

Compost rates	N-fertilizer levels, %	Shoot dry weight (g /plant)			N-uptake (kg/ha)			P uptake (kg/ha)			K uptake (kg/ha)		
		Un-Ino.	**Ino.**	**± %**	**Un-ino.**	**Ino.**	**± %**	**Un-Ino.**	**Ino.**	**± %**	**Un-Ino.**	**Ino.**	**± %**
C 0%	**50**	43.8*	71.2	62.6	22.2	29.6	33.3	11.2	19.9	77.7	130.7	315.6	141.5
	100	41.7	122.0	192.6	36.3	77.6	113.8	13.8	46.8	239.1	111.4	371.4	233.4
C 50%	**50**	102.9	104.3	1.4	108.0	48.9	- 54.7	33.2	34.8	4.8	288.6	385.6	33.6
	100	85.9	120.0	39.7	38.3	117.7	207.3	28.9	51.6	78.5	324.7	530.9	63.5
C 75%	**50**	102.9	83.4	-18.2	44.8	83.7	86.8	38.4	21.2	-44.8	396.5	357.0	-9.9
	100	102.3	116.2	13.6	66.9	56.9	-14.9	26.9	43.0	59.9	345.2	391.5	13.4
C 100%	**50**	45.9	83.4	81.7	40.1	48.4	20.7	17.2	23.9	38.9	224.4	428.2	90.8
	100	73.5	84.4	14.8	42.2	72.5	71.8	21.0	27.7	31.9	281.6	343.7	22.1

± % increase or decrease to un-inoculated plants.
**Mean values of 6 plants per each treatment.*
Plants age 105 days.

4. Effect of inoculated maize plants with *G.intraradices* in the presence of four rates of compost and two levels of N-fertilizer on grain yield and quality

a) Grain yield

Grain yield of the inoculated plants with *Glomus intraradices* was significantly increased than non- inoculated plants under the different rates of compost and mineral N-fertilizer. The highest grain yield of inoculated plants was 9.7 t/ha compared to non-inoculated plants 9.1 t/ha as an average of the two seasons in the presence of C_{75}% and N_{100}% (Table2). There were no significant differences between C_{75}% and C_{100}% for the inoculated plants under the recommended dose of N- fertilizer. [8] reported that the combination between compost treatment with 3/4 recommended dose of mineral NPK fertilizers lead to the highest yield. [32] reported that the inoculation with *Glomus* spp. of plants with rhizospheric microorganisms is necessary to take advantage of their beneficial properties for yield enhancement.

b) Oil % in grains

The highest optimum value of corn oil % was 5.0% of the inoculated plants with *G.intraradices* compared to non-inoculated plants (4.5%) as an average of the two seasons in the presence of C_{75}%and N_{100}% (Table 2). [8] detected that no clear effect of both compost and mineral fertilizers on the identification of fatty acids and oil% in maize grains.

c) Protein % in grains

The highest percentage of protein was 6.2% in case of inoculated plants with *G. intraradices* compared to un-inoculated plants (4.2%) in the presence of C_{50}% and N_{100}% as an average of the two seasons (Table 2). The percentage increase was 47.6 % in case of inoculated plants more than non- inoculated once in the presence of C_{50}% and N_{100}% (Table2). No significant differences were found in both seasons of protein% in grains. The different treatments did not affect the percentage of protein in maize grains. [14] and [26] reported that the combination of compost application and mineral NPK fertilizers lead to a significant increase in protein% of maize grain. [22] suggested that improved maize crop productivity and protein% of corn grain linked to the presence of effective AM networks. The functional AM hypha network in a crop cycle is a key factor to crop nutrition and growth [15].

5. Effect of inoculated maize plants with *G. intraradices* in the presence of four rates of compost and two levels of N-fertilizer on the soil fertility

The inoculation with *Glomus intraradices* lead to a significant increase in the availability of N and P compared to un-inoculated ones (Table 3) .The highest significant increases in the availability of N , P and K were in the presence of C_{75} % and N_{100}% of the recommended doses (Table 3). [29] suggested that N mineralization of residue – amended soil was enhanced by the presence of AM fungi. The combination between AM fungus, residue-amended soil and mineral N fertilizer improved the availability of N, P and K approximately doubled compared with control [34] , [26].

Table 2: Effect of inoculated Zea mays with G.intraradices in the presence of four rates of compost and two levels of N-fertilizer on grain yield and quality as an average of the two seasons 2014 and 2015

Parameters		Grain yield (t\ha)			Oil %			Protein %		
Compost	N- fertilizer	Un- Inco.	Inco.	±%	Un- Inco.	Inco.	±%	Un- Inco.	Inco.	±%
$C_{0\%}$	$N_{50\%}$	3.9*	4.6	17.9	4.6	4.7	2.2	4.5	4.4	-2.2
	$N_{100\%}$	6.4	7.5	17.2	4.3	4.5	4.7	4.4	5.1	15.9
$C_{50\%}$	$N_{50\%}$	6.1	6.5	6.6	4.4	4.7	6.8	4.1	3.8	-7.3
	$N_{100\%}$	7.2	7.9	11.3	5.1	4.5	-11.8	4.2	6.2	47.6
$C_{75\%}$	$N_{50\%}$	8.1	8.3	2.5	4.3	4.8	11.6	4.7	5.3	12.8
	$N_{100\%}$	9.1	9.7	6.6	4.5	5. 0	11.1	5.3	5.7	7.5
$C_{100\%}$	$N_{50\%}$	8.1	8.6	6.2	4.4	4.4	0	3.4	3.1	-8.8
	$N_{100\%}$	9.3	10.1	8.6	4.5	4.5	0	4.4	2.8	-36.4

* mean values of 6 plants per each treatment
±increase or decrease to un-inoculated plants

Table 3: Effect of inoculated Zea mays plants with G.intraradices in the presence of four rates of compost and two levels of N-fertilizer on the soil fertility

Parameters		Available N mg/kg	Available P mg/kg	Available K mg/kg	Organic matter content
N-fertilizer	$N_{50\%}$	19.06 ^{b}	10.96 ^{a}	65.935 ^{a}	1.59 ^{a}
	$N_{100\%}$	23.59 ^{a}	11.29 ^{a}	54.5 ^{b}	1.66 ^{a}
L.S.D 0.05		2.6377	1.42	7.163	0.165
Compost	$C_{0\%}$	17.77 ^{b}	10.78 ^{c}	59.45 ^{b}	1.6 ^{b}
	$C_{50\%}$	20.51 ^{a}	8.61 ^{d}	50.79 ^{b}	1.47 ^{b}
	$C_{75\%}$	21.3 ^{a}	13.46 ^{a}	72.25 ^{a}	1.66 ^{b}
	$C_{100\%}$	18.12 ^{b}	11.65 ^{b}	57.34 ^{b}	1.913 ^{a}
L.S.D 0.05		2.134	1.745	9.708	0.1952
AM Inoculum	+AM	21.92 ^{a}	14.165 ^{a}	64.77 ^{a}	1.59 ^{a}
	- AM	18.19 ^{b}	12.765 ^{b}	55.66 ^{a}	1.76 ^{a}
L.S.D 0.05		1.8084	1.571	9.46	0.278

6. Conclusion

Inoculated *Zea mays* plants with *Glomus intraradices* in the presence of C_{75} % of the recommended dose of compost and N_{100} % of the recommended dose of mineral nitrogen fertilizer lead to a significant increase in grain yield (9.7 t/ha), optimum corn oil % (5.8 %) , promote the percentage of proteins (6.2 %) in corn flour. As well as a significant increases in shoot dry weight (120 g/plant) and their NPK uptake (kg/ha). Also, to achieve high quality of compost from maize plant residues, this is rich in macro elements and organic matter contents.

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