Greener Journal of Agricultural Sciences
Vol. 11(3), pp. 195-203, 2021
ISSN: 2276-7770

https://gjournals.org/GJAS

Influence of Arbuscular Mycorrhizal Fungi on (*Zea mays*) Cultivated on Sewage Contaminated Soil

Anozie, H.I; Wokocha, C.C; Madu, O.V

Department of Crop and Soil Science, Faculty of Agriculture
University of Port Harcourt, PMB 5323, Port Harcourt, Nigeria.

ARTICLE INFO

Article No.: *100621101*
Type: *Research*
Full Text: ***HTML, EPUB***

Accepted: *10/10/2021*
Published: *29/10/2021*

****Corresponding Author***
Anozie, H. I
E-mail: *henry.anozie@uniport.edu.ng*

Keywords: *Sewage; mycorrhiza; soil properties; trace elements; contamination*

ABSTRACT

Soil contamination is one of the major environmental challenges affecting farmers and their crops as a result of improper sewage management, industrial waste mismanagement among others. The influence of three species of AMF (Gigaspora sp, Glomus clarium and Glomus mossea) on Maize (Oba super 98 hybrid variety) cultivated on sewage contaminated soil was assessed in the Screen House. The experiment was laid in a completely randomized design (CRD). Three seeds of Zea mays (L) were planted in each of 32 plastic buckets, 50 g of three species of AMF inocula were inoculated while 1.5 liters of sewage was added at each bucket. Watering was done morning and evening on daily basis. Agronomic data such as plant height, leaf area, stem girth and number of leaves were collected bi-weekly and subjected to Analysis of Variance while means were separated using Least Significant Difference (LSD). Soil physic-chemical properties were also analyzed before and after planting using standard procedures. The result obtained showed that AMF inoculated samples were significantly higher both in soil parameters and growth parameters but significantly lower in Trace elements than in Control as follows: TOC in G. mossae (0.49 %) > Control (0.3 %); TN in Gigaspora sp (0.25 %) > Control (0.20 %); P in G.clarium (4.15 mg/kg) > Control (1.36 mg/kg); CEC (5.97 Cmol/kg) > Control (4.53 Cmol/kg); Zn in Gigaspora sp (9.0 mg/kg) < Control (10.0 mg/kg); Pb in G. mossae (1.8 mg/kg) < Control (5.0 mg/kg); Cu in G.clarium (2.7 mg/kg) < Control (4.0 mg/kg); Ni in G. mossae (0.03 mg/kg) < Control (0.09 mg/kg). Comparatively, G. mossea outperformed other species of AMF used in the experiment both in plant parameters and soil nutrient elements. It is advisable to properly manage the sewage against soil contamination. Farmers are encouraged to adopt the use of AMF to enhance maize production in sewage contaminated soils.

INTRODUCTION

Maize (*Zea mays* L.) is the world's highest supplier of calorie with caloric supply of about 19.5%. Maize is the most important staple food in Nigeria and it has grown to be local 'cash crop' where at least 30% of the crop land has been devoted to small-scale maize production under various cropping systems (Ayeni, 1991). Introduced in Nigeria in the 16th century, maize is the fourth most consumed cereal ranked below sorghum, millet and rice (FAOSTAT, 2012). It has been recognized to be one of the longest ever cultivated food crops. Maize is also grown in several regions of the world and is referred to as the world best adapted crop (IITA, 2008). In Nigeria, the demand for maize is increasing at a faster rate daily (Sadiq *et al.,* 2013).This may be due to the fact that the grain is being used for feeding poultry and also serve as the main food for many households (Ogunniyi, 2011)**.** This has however, necessitated the need for research and more extension services to the rural famers not just to improve farm yield but to as well provide them with alternatives that will help them to continue production especially those living in areas where the land has been frequently polluted with sewage, hence the study. Soil faces serious environmental and health challenge as a result of Heavy Metal (HM) contamination by Sewage pollution. AMF are essential for soil amelioration as they reduce the availability of HMs in the soil as a result of its inoculation due to significant increase in soil pH (Asrar and Elhindi, 2011).

Arbuscular Mycorrhizal Fungi (AMF) are widespread obligate symbiotic forming associations with 85% of the vascular plant species (Brundrett, 2018), dominating most of the tropical forest and temperate grassland ecosystems **(**Soudzilovskaia, 2018***)***. Besides the fundamental role of AMF in plant nutrition and fitness, it is widely recognized that AMF have a substantial impact on ecosystem functioning. The AMF extra-radical mycelium also acts as an active distributor of carbon (C) in the soil, feeding soil heterotrophs **(**Pollierer, 2007**)** and stabilizing carbon in recalcitrant organic compounds **(**Sousa, 2012**).**

Soil contamination is one of the major environmental challenges affecting farmers and their crops. This however, arises as a result of improper sewage management, industrial waste mismanagement, and such like. Sewage contains some heavy metals that affect crop productivity (Sadiq*et al.,* 2013**)**. Once heavy metals have entered the soil, they have long-term effects on plants. Arbuscular Mycorrhiza are essential bio-agent, as they can significantly enhance the efficiency of the ecosystem by producing fungal structures like arbuscules and aid in the exchange of inorganic compounds and minerals required for the growth of plants, thereby providing considerable strength to plants (Babatunde *et al*., 2007**)**. There is a symbiotic relationship between AMF and the plant roots which help to establish tolerance to HMs (Chandrasekaran et al., 2019). AMF has the ability to enhance the plant ability to uptake essential nutrients and partially exclude non-essential ones (Hashem et al., 2019). Several methods exist to clean up the environment from contaminants; however, many of them are costly or difficult to implement. Therefore, a cheaper and eco-friendly method is indispensable for amelioration of deleterious effects of sewage on soil. Regrettably, there is insufficient information on the influence of AMF on maize cultivated on sewage contaminated soil. Regrettably, there is insufficient information on the influence of AMF on maize cultivated on sewage contaminated soil. Therefore, this study was set up with the following objectives: to assess the influence of AMF on performance of maize cultivated on sewage contaminated soil and identify the best host among the three species of AMF used.

MATERIALS AND METHODS

Study area

The experiment was conducted at the Screen House, Department of Crop and Soil Science, University of Port Harcourt at Latitude $4^0$54N and longitude $06^0$55E with an average temperature of 27 ^{0}C, relative humidity of 78 % but decreases slightly in dry season and an average rainfall ranging from 2500 mm – 4000 mm per annum (Atijegbe et al., 2013).

The area has a biomass rainfall pattern with a long rainfall season between March and July and a short rainy season from September to early July after a short spell in August and a longer period from December to February (Akande et al., 2010)

Source of Seed Variety

The Maize variety used for this study was OBA SUPER 98, sourced from Agro-tropical Institute, Port Harcourt, Rivers State, Nigeria.

Source of AMF inocula

Three pure strains of Arbuscular Mycorrhiza Fungi namely *Gigaspora specie, Glomus clarium* and *Glomus mossea* gotten from the Department of Microbiology, University of Ibadan were used for this experiment.

Soil sampling and Sterilization

Samples of soil (0 – 30 cm depth) were randomly taken from the experimental farm for sterilization. Sterilization was done at a controlled temperature of 121^{0}C for 6 hours and later allowed to cool for 72 hours. The sterilized samples were measured using a weigh balance and 10 kg was poured into each experimental bucket.

Sewage and AMF Application

Sewage measuring 750 ml was introduced to soil sample one week before planting and six weeks after planting respectively. After first sewage application, 50 g of Mycorrhiza inoculum was added to soil samples three days before planting.

Experimental Design and Planting

This experiment comprised of 2 factors (Mycorrhiza and Sewage) laid in completely randomized design (CRD) with 8 replications. Three seeds of maize were planted at 2.5 cm depth above soil surface in each bucket. Watering was done twice daily (morning and night) while weeding was done by handpicking at interval.

Data collection and analysis

Growth parameters such as Plant Height, Leaf Area, Stem Girth and Number of Leaves were collected biweekly. Data collected were analysed with the use of Gen Stat Software (GEN, 2012) and means were separated using Least Significant Difference (LSD) at 5 % significance level.

Soil Laboratory Analysis

Soil samples were analysed before planting and after planting. Soil particles size analysis was done using hydrogen method (Bouyoucos, 1962); Available P by Bray 1 method (Bray and Kurtz, 1945); Soil pH was determined in 1:1 (soil: water) ratio using a glass electrode pH meter. Macro kjedahl digestion distillation method was used in measuring Total Nitrogen. Total organic carbon was determined by the wet combustion method of Walkey and Black (1934) as modified by Juo (1979) in selected methods of soil analysis. Organic carbon was oxidized by potassium dichromate in the presence of concentrated sulphuric acid. Ferrous ammonium sulphate was then added and the excess black titrated with standard potassium permanganate. 1.0 g of representative soil sample was shaken in a conical flask with 50 ml of 1N- ammonium acetate for about 2 hours. The mixture was left over night and then filtered into plastic cups. The filtrate was used for determination of sodium, potassium, calcium and magnesium using Atomic Absorption Spectrophotometer (AAS). A 30 g of soil sample was digested in a mixture of concentrated nitric acid (HNO_3), concentrated hydrochloric acid (HCl) and 27.5 % hydrogen peroxide (H_2O_2) according to the USEPA method 3050B for the analysis of heavy metals (USEPA, 1996). The extracts were analysed by atomic absorption spectrophotometer (Perin Elmer, Model No 2380)

RESULTS

Effect of various Species of AMF on selected Growth Parameters of Maize.

Table 1 show the effects of AMF on growth parameters of maize as follows:

Plant Height

Generally, the height value for the maize plant inoculated with my various species of Mycorrhiza was significantly higher than that of the Control in all weeks except in 10 WAP as shown in Table 1. In 4WAP, *G.clarium* recorded the highest plant height value of 34.2 cm among all the treatments while *Gigaspora specie* had the least 26.7 cm. However, *G.clarium* is statistically higher than Control (27.9 cm) and *Gigaspora specie* (26.7 cm) but the same with *G.mossea* (32.0 cm). In 8WAP, *G.mossea* recorded the highest plant height value of 92.5 cm while the Control had the least value 81.5 cm. Although *G.mossea* is statistically higher than the Control and Plants inoculated with other AMF specie, it is the same with *Gigaspora specie* (88.5 cm) and *G.clarium* (89.5 cm) but different from Control (81.5 cm). In 10WAP, Control recorded the highest plant height value, 90.1 cm while *G.clarium* recorded the least value, 85.8 cm. However, the Control is statistically the same as others.

Leaf Area

At 4WAP, *G.clarium* recorded the highest area value (49.8 cm^2) while *G.mossea* recorded the least value 45.0 cm^2. However, there is no statistical difference among treatments. At 8WAP *G.mossea* recorded the highest value (320 cm^2) while Control recorded the least value (187 cm^2). However, *G.mossea* (320 cm^2) is only significantly higher than Control (187 cm^2) but the same with *G.clarium* (258 cm^2) and *Gigaspora specie* (261 cm^2). Also, the Control (187 cm^2), *G.clarium* (258 cm^2) and *Gigaspora specie* (261 cm^2) are statistically the same. At 10WAP, *G.clarium* recorded the highest value (316 cm^2) while *Gigaspora specie* (227 cm^2) recorded the least. However, *G.clarium* (316 cm^2) is statistically higher than *Gigaspora specie* (227 cm^2) but shows no statistical difference with the Control (291 cm^2) and *G.mossea* (312 cm^2).

Number of Leaves

Generally, the mean value of number of leaves in all AMF inoculated buckets were higher than the Control except at 4WAP where the Control recorded the highest mean value of 4.75. At 4WAP, the Control recorded the highest value (4.75) while *Gigaspora specie* recorded the least value (4.17), although no statistical difference was recorded among treatments. At 8WAP, *Gigaspora specie* recorded the highest mean value (6.25) while the Control (5.62) recorded the least value. The *G.clarium* and *G.mossea* recorded (6.1) and (6.0) respectively, but no statistical difference was recorded among treatments. At 10WAP, *G.mossea* recorded the highest value (8.62) while the Control recorded the least value (7.50). The *G.mossea* is statistically higher than the Control (7.50) but the same as *Gigaspora specie* (7.75) and *G.clarium* (7.88), respectively.

Stem Girth

Although, the mean values of stem girth of maize plants inoculated with AMF were higher than the Control except at 10WAP but there was no significant difference was recorded among treatment through the experimental period. At 4WAP, *G.clarium* recorded the highest value (1.500 cm) while *Gigaspora specie* recorded the least value (1.413 cm). No statistical difference between treatments. At 8 WAP, *G.mossea* recorded the highest value (4.330 cm) while *Gigaspora specie* recorded the least value (3.710 cm). However, no statistical difference was recorded among treatments. At 10WAP, the Control recorded the highest value (4.500 cm) while *G.clarium* recorded the least value (4.260 cm). Although *G.mossea* recorded (4.313 cm) and *Gigaspora specie* recorded (4.34 cm), there is no statistical difference among treatments.

Table 1: Effect of Mycorrhizal fungi on selected growth parameters of maize planted on sewage contaminated soil.

	4WAP				8WAP				10WAP			
TRT	PH (cm)	SG (cm)	LA (cm^2)	NL	PH (cm)	SG (cm)	LA (cm^2)	NL	PH (cm)	SG (cm)	LA (cm^2)	NL
Control	27.9	1.425	45.2	4.75	81.5	3.730	187	5.62	90.1	4.500	291	7.50
G.sp	26.7	1.413	45.4	4.17	88.5	3.710	261	6.25	87.1	4.340	227	7.75
G.c	34.2	1.500	49.8	4.38	89.5	3.910	258	6.17	85.8	4.260	316	7.88
G.m	32.0	1.438	45.0	4.25	92.5	4.330	320	6.0	88.4	4.310	312	8.62
LSD ($P \leq 0.05$)	5.86	0.26	13.94	0.903	10.30	0.59	73.4	1.09	14.13	0.43	80	0.913

TRT= Treatment, PH = Plant Height, SG = Stem Girth, LA = Leaf Area, NL = Number of leaves, *G.sp = Gigaspora sp*, *G.c = Glomus clarium*, *G.m = Glomus mossae*, WAP = week after planting.

PHYSIOCHEMICAL PROPERTIES OF THE SOIL

Table 2 shows the physical and chemical properties of the analysed soil.

Sand

The SBSA (85.20 %) and the Control (85.20 %) respectively recorded the highest sand content while *Gigaspora specie* recorded the least value (85.0 %). It is observed that SBSA and the Control are statistically higher than all AMF inoculated soil. It is worthy to note that, there is no significant difference between SBSA and the Control. However buckets inoculated with *G.clarium* (85.10 %) is statistically higher in sand content than buckets inoculated with *Gigaspora specie* (85.00 %) followed by buckets inoculated with *G.mossea* (84.50 %).

Silt

The bucket inoculated with *G.mossea* (4.50 %) is statistically highest among the treatments. It is observed that bucket inoculated with *G.mossea* is statistically higher than that of *G.clarium* (4.06 %) *and Gigaspora specie* (3.90 %) followed by SBSA (2.90 %) and Control (2.85 %). It is worthy to note that there is no significant difference between *G.clarium and Gigaspora specie* likewise SBSA and the Control.

Clay

The Control has the highest clay content with mean value (11.95 %) while *G.clarium* has the least clay content with mean value (10.90 %). Control and SBSA (11.90 %) are statistically the same but higher than *Gigaspora specie* (11.10 %) and *G.mossea* (11.00 %) Soil samples inoculated with *Gigaspora specie* and *G.mossea* are statistically the same but higher than *G.clarium* (10.90 %).

Table 2: Physico-chemical Properties of the analysed Soil

Trt	pH	Sand	Silt	Clay	TOC	TN	Av.p	Ca	Mg	K	Na	CEC
		%			mg/kg			Cmol/kg				
SBSA	4.96^{a}	85.2^{d}	2.9^{a}	11.9^{c}	0.2^{a}	0.17^{a}	1.36^{a}	2.23^{a}	2.17^{b}	0.12^{a}	0.14^{a}	4.66^{a}
M0	5.00^{a}	85.2^{d}	2.85^{a}	11.95^{c}	0.30^{b}	0.20^{ab}	1.36^{a}	2.20^{a}	2.06^{a}	0.12^{a}	0.15^{a}	4.53^{a}
M1	5.21^{b}	85.0^{b}	3.90^{b}	11.10^{b}	0.32^{b}	0.25^{b}	3.42^{b}	2.55^{b}	2.40^{c}	0.13^{a}	0.15^{a}	5.23^{b}
M2	5.22^{b}	85.1^{c}	4.0^{b}	10.9^{a}	0.38^{c}	0.32^{c}	4.15^{c}	2.60^{b}	2.45^{c}	0.15^{b}	0.15a	5.35^{b}
M3	5.2b	84.5^{a}	4.5^{c}	11.0^{b}	0.49^{d}	0.45^{d}	5.42^{d}	2.80^{c}	2.80^{d}	0.18^{c}	0.19^{b}	5.97^{c}

SBSA = Soil Before Sewage Application, means with the same alphabets show no statistical difference while different alphabets show statistical difference, M0 = Control, M1 = *Gigaspora sp*, M2 = *Glomus clarium* , M3 = *Glomus mossea*. Trt = Treatment

pH

The results show that *G.clarium* recorded the highest pH mean value (5.22 %) while Soil before Sewage Application (SBSA) recorded the least pH mean value (4.96 %). *G.clarium* (5.22 %), *G.mossea* (5.21 %) and, *Gigaspora specie* (5.21 %) show no significant difference among the treatments but are significantly higher than the Control (5.00 %) and SBSA (4.96 %) respectively. However, the Control and SBSA are statistically the same.

Total Organic Carbon (TOC)

The TOC of *G.mossea* inoculated soil has the highest mean value (0.490 %) while SBSA had the least value (0.20 %). Soil inoculated with *G.mossea* (0.49 %) is statistically higher than *G.clarium* (0.38 %). The Control (0.30 %) is statistically the same with *Gigaspora specie* (0.32 %) but significantly higher than SBSA (0.2 %).

Total Nitrogen (TN)

The soil inoculated with *G.mossea* (0.45 %) has the highest TN content while SBSA has the least value (0.17 %). The soil inoculated with *G.mossea* is statistically higher than that of *G.clarium* (0.32 %) followed by *Gigaspora specie*, The Control and SBSA respectively. There is no statistical difference between the Control and SBSA. The Control and plant inoculated with *Gigaspora specie* are significantly the same.

Available phosphorus (Av.P)

Both SBSA and Control recorded the least Av.P value (1.36 mg/kg) respectively while *G.mossea* recorded the highest Av. P value (5.42 mg/kg). *G.mossea* is statistically higher than *G.clarium* (4.15 mg/kg) and *Gigaspora specie* (3.42 mg/kg), while *Gigaspora specie* is statistically lower than *G.Clarium.*

Calcuim

The highest calcium content was recorded in soil inoculated with *G.mossea* (2.80 Cmol/kg) while the least was the Control (2.20 Cmol/kg). The *G.mossea* is statistical higher than other treatments, although *G.clarium* (2.60 Cmol/kg) and *Gigaspora specie* (2.55 Cmol/kg) are significantly the same, they are statistically higher than Control and SBSA. The SBSA and Control are statistically the same.

Magnesium

Soil inoculated with *G.mossea* has the highest value (2.80 Cmol/kg) of Mg from the results shown in Table 5 while the Control has the least value (2.06 Cmol/kg).The soil inoculated with *G.mossea* is statistically higher than soil inoculated with *G.clarium* (2.45 Cmol/kg), followed by *Gigaspora specie* (2.40 Cmol/kg), then SBSA (2.17 Cmol/kg) and lastly the Control (2.06 Cmol/kg). There is no statistical difference between *G.clarium* and *Gigaspora specie.*

Potassium

Soil inoculated with *G.mossea* has the highest value (0.18 Cmol/kg) while SBSA and Control have the least value (0.12 Cmol/kg) respectively. The soil inoculated with *G.mossea* is statistically higher than *G.clarium* (0.15 Cmol/kg), followed by *Gigaspora specie* (0.13 Cmol/kg), then SBSA and the Control (2.06 Cmol/kg). There is no statistical difference between *Gigaspora specie,* Control and SBSA.

Sodium

Soil inoculated with *G.mossea* has the highest value (0.19 Cmol/kg) while SBSA has the least value (0.14 Cmol/kg). *G.mossea* is statistically higher than *G.clarium* (0.15 Cmol/kg), *Gigaspora specie* (0.15 Cmol/kg), Control (0.15 Cmol/kg), SBSA (0.14 Cmol/kg). There is no statistical difference between *G.clarium, Gigaspora specie,* the Control and SBSA.

Cation Exchange Capacity (CEC)

Soil inoculated with *G.mossea* has the highest CEC value (5.97 Cmol/kg) while the Control has the least value (4.53 Cmol/kg). Soil inoculated with *G.mossea* is statistically higher than *G.clarium* (5.35 Cmol/kg), followed by *Gigaspora specie* (5.23 Cmol/kg), then SBSA (4.66 Cmol/kg) and lastly Control (4.53 Cmol/kg). There is no statistical difference between *G.clarium* and *Gigaspora specie* and also between the Control and SBSA.

Chemical properties of Selected Trace elements

The chemical properties of selected trace elements are shown in Table 3 below.

.

Table 3: Chemical properties of Selected Trace Elements on the analyzed soil Samples

Trt	Cu	Zn	Pb	Ni
	⟶	mg/kg	⟵	
SBSA	1.4^a	7.0^b	2.0^a	0.02^a
M0	4.0^d	10.0^c	5.0^b	0.09^d
M1	3.6^c	9.0^c	4.0^b	0.06^c
M2	2.7^b	7.0^b	2.0^a	0.06^c
M3	1.7^a	5.5^a	1.8^a	0.03^b

SBSA = Soil Before Sewage Application, means with the same alphabets show no statistical difference while different alphabets show statistical difference, M0 = Control, M1 = *Gigaspora sp*, M2 = *Glomus clarium* , M3 = *Glomus mossea*, Trt = treatment

Copper

The soil sample before sewage application (SBSA) recorded Copper mean value of 1.4 mg/kg before planting but statistically increased with the application of sewage in Control to value 4.0 mg/kg. When AMF was added, soil inoculated with *G.mossea* recorded the least value 1.7 mg/kg but not statistically difference with SBSA. Soil inoculated with *G.clarium* recorded a mean Cu value of 2.7 mg/kg which is statistical lower than soil inoculated with *Gigaspora specie* (3.6 mg/kg) but higher than SBSA and soil inoculated with *G.mossea*.

Zinc

The SBSA recorded Zn mean value of 7.0 mg/kg but increased to 10.0 mg/kg in the Control. Soil inoculated with *G.mossea* (5.5 mg/kg) recorded the least mean value of Zinc followed by *G.clarium* (7.0 mg/kg) and lastly *Gigaspora specie* (9.0 mg/kg). The *G.mossea* is statistical lower than other treatments. The *G.clarium* and SBSA are statistically the same but lower than *Gigaspora specie* and the Control. However, *Gigaspora specie* shows no significant difference with the Control

Lead

The SBSA recorded lead mean value of 2.0 mg/kg which is statistically the same with soil inoculated with *G.clarium* (2.0 mg/kg) and *G.mossea* (1.8 mg/kg) respectively, but they are significantly lower than soil inoculated with *Gigaspora specie* and Control. However, Soil inoculated with *Gigaspora specie* (4.0 mg/kg) is statistically the same with Control.

Nickel

The Control has the highest Nickel value 0.9 mg/kg while SBSA has the least value 0.02 mg/kg. The SBSA is statistically lower than Soil inoculated with *G.mossea* (0.03 mg/kg) which is statistically lower than soil inoculated with *G.clarium* (0.06 mg/kg) and *Gigaspora specie* (0.06 mg/kg) respectively and they are all statistically lower than Control. The soil inoculated with *G.clarium* and *Gigaspora specie* are not significantly different from each other.

DISCUSSION

Soil Particles

Generally the value for Sand content statistically decreased in AMF inoculated samples (84.5 %) than in SBSA (85.2 %) and Control (85.2 %). Similarly, Clay content statistically decreased in AMF inoculated (10.9 %) than its value in BP (11.9 %) and in Control (11.95 %). On the other hand, the Silt content increased in AMF inoculated samples (4.5 %) compared to those of the Control (2.85 %) and SBP (2.9 %). It is obvious that AMF inoculation positively influenced soil aggregation in the study. This observation is in agreement with the studies of Tisdall and Oades (1982) who reported that AMF and other fungi are hypothesized to be important for soil aggregation at the macro-aggregate level, where direct hyphal involvement is thought to be most pronounced. Additionally, as micro-aggregates are thought to form most frequently within macro-aggregates, AMF-facilitated stabilization of macro-aggregates would be expected to result indirectly in micro-aggregate formation. Also, AMF and their diversity have been shown to be important controllers of the productivity of plant communities (van der Heijden et al., 1998), in part via their effects on plant community composition.

pH

The pH in AMF inoculated soils ranges between (5.00 – 5. 22) which slightly deviated from the findings of Wang et al. (1993) who reported that AMF develop optimum number of spores at pH value ranging from (5.5 – 7.5). The increase in soil pH and reduction in amount of trace elements as shown in Table 2 and 3 respectively, supports earlier report by Shen et al., (2006) who observed reduction in available heavy metals as a result of AMF inoculation due to significant increase in soil pH and strongly supports the use of AMF to curb the effect of sewage contamination in soil.

TOC

The TOC is the remains of plant and animals of microorganisms at various stages of decomposition. The result obtained from the analysis, shows significant increase in the TOC of soil inoculated with *G.mossea* (0.49 mg/kg) when compared with the Control (0.30 mg/kg) and SBSA (0.20 mg/kg). This observation is in support of earlier findings by Cardoso and Kuyper (2006) who reported that AMF plays role in the carbon cycling thus; increasing AMF will increase carbon flow into soil.

Available P

There was an increase in P content of AMF inoculated soils, *G.mossea* (5.42 mg/kg) compared with SBSA (1.36 mg/kg) and Control values (1.36 mg/kg) as shown in Table 2. This is in tandem with the findings of (Smith et al., 2003); (Buckling and Shacker-Hill, 2005) who reported that Phosphorus is made available in the soil due to the presence of mycorrhiza. The increase in the agronomic parameters of plants as recorded for Plant height of *G.mossea* with mean value of 32.0 cm at 4WAP and 92.5 cm at 8WAP for AMF inoculated soils could be as a result of sufficient P availability unlike the plants in the Control thus support earlier findings by Bucher (2007) who reported that under stressed condition, AMF improves phosphorus supply in the soil.

Total N

The result obtained shows an increase in Nitrogen when soil inoculated with AMF (0.45 mg/kg) is compared with the Control value (0.20 mg/kg) and

SBP (0.17 mg/kg) as shown in Table 2. The same trend is observed in growth parameters at 8WAP where *G.mossea* recorded the significantly highest plant height mean value (92.50 cm) and stem girth mean value (4.33 cm) compared with the Control with least plant mean value (81.5 cm) and (3.73 cm) for plant height and stem girth respectively. These results confirm earlier report of Hawkins et al., (2000) which states that AMF enhances Nitrogen uptake and utilization in soil.

Exchangeable Cations

The soil inoculated with AMF had the significantly highest K value (0.18 Cmol/kg), Ca value (2.80 Cmol/kg), Mg value (2.80 Cmol/kg) and CEC value (5.97 Cmol/kg) when compared to their SBSA value, K value (0.12 Cmol/kg), Ca value (2.23 Cmol/kg), Mg value (2.17 Cmol/kg) and CEC value (4.66 Cmol/kg). This is agreement with the report of Sharifi et al., (2007); Terrer et al.,(2016) and Turrini et al., (2017) which states that the main function of AMF is to enhance the nutrient uptake of elements like K, Ca, Mg and CEC by host plants, improves the nutrient metabolism capacity and nutrient level and promote plant growth. In addition, the observation also in agreement with the findings of Nazeri et al., (2013) and Leigh et al., (2009) who reported that when soil is inoculated with AMF, there is an increase the uptake of nutrients in the soil, such as Calcuim and Magnesium.

Trace elements

The amount of trace elements as shown in the result is higher in SBSA when compared with soil inoculated with AMF; this could be traceable to the presence of these metallic elements in the sewage applied. This observation supports the finding of Tyla, et al., (2016) who reported that Sewage contains heavy metals such as Cadium (Cd), Zinc (Zn), Lead (Pb), Copper (Cu) etc. The metallic elements in inoculated soil samples significantly reduced, this is due to the presence of AMF in the soil as it has ability to survive in contaminated soils. The mean value of Cu in soil inoculated with *G.mossea* statistically reduced when compared with SBSA and this observation agrees with the findings of Lee and George (2005) who reported that *G.mossea* contributes to 75 % of Cu uptake in contaminated soil.

In this study, AMF significantly increased the growth rate of maize in sewage contaminated soil, as seen in the Leaf Area recorded at 8WAP where plants inoculated with AMF *G.Mossea* (320 cm^2) is significantly higher than the Control with mean value (187 cm^2) and this is in agreement with Shen et al,. (2006) who observed that AMF inoculation on maize enhances plant growth, P content and plant tolerance to metals like Zn either by lowering its level in the uptake process or through up-taking it into the extra-radical mycelium of the AMF and also the works of (Kaldorf et al., 1999; Aroca et al., 2013; Wu et al., 2014; Hashem et al., 2016) who reported that AMF has the ability to enhance plants capacity to uptake essential nutrient while partially excluding non-essential ones. Thus AMF inoculation can be considered a feasible practical method in reclaiming soils contaminated by sewage (Turnau et al., 2006).

CONCLUSION

This report reveals that sewage contaminated soil is deleterious in maize cultivation. AMF inoculation ameliorates the deleterious effect of sewage in agricultural soils as it aids the absorption and utilization of nutrient elements like phosphorus.

Comparatively, assessing the three (3) species of Mycorrhiza used during the experiment; *Glomus mossea* outperformed *G.clarium* and *Gigaspora specie* both in plant and soil parameters. Therefore, *Glomus mossea* is recommended as Soil amendment and biofertilizer for maize cultivation in soil contaminated with sewage. Furthermore, extensive research is needed in understanding the biochemical dynamics of Mycorrhiza and trace metals found in sewage contaminated soils.

REFERENCES

Akande .M .O; Oluwatoyinbo.F.I. ;Makinde ,A.S; Adepoju and I.S Adepoju (2010). Response of Okra to Organic and Inorganic Fertilization. Journal of Nature and Science; 8(11)

Aroca, R., Ruiz-Lozano, J. M., Zamarreño, A. M., Paz, J.A., García-Mina, J. M., Pozo, J. A., et al. (2013). Arbuscular mycorrhizal symbiosis influences strigolactone production under salinity and alleviates salt stress in lettuce plants. *J. Plant Physiol.* 170, 47–55. doi: 10.1016/j.jplph.2012.08.020

Asrar, A.W.A., and Elhindi, K.M. 2011. Alleviation of drought stress of marigold (Tagetes erecta) plants by using arbuscular mycorrhizal fungi. Saudi Journal of Biological Science, 18:93–98.

Atijegbe, S. R; Nuga, B.O.; Lale, N. E.S.; Nwanna, R.O (2013). The growth of cucumber (*cucumis sativus* L.) in the humid tropics and the incidence of insect pests as affected by organic and inorganic fertilizer. Journal of applied science and Agriculture. vol 8 No 7 pp 1172 – 1178 ref.30

Ayeni, A.O. (1991). Maize Production in Nigeria: Problems and Prospects. *Journal of Food and Agriculture,* 2 (1): 123–129.

Bouyoucos, G.J. (1962). Directions for Making Mechanical Analysis by the Hydrometer Method. Soil Science, 42: 225-229.

Bray, R.H. and Kurtz, L.T. (1945). Determination of Total Organic and Available Forms of Phosphorus in Soil. Soil Science, 59: 39-45

Brundrett MC, Tedersoo L. (2018). Evolutionary history of mycorrhizal symbioses and global host plant diversity. New Phytologist.; 220(4):1108–15.

Bucher, M. (2007). Functional biology of plant phosphate uptake at root and mycorrhizae interfaces. New Phytol. 173, 11–26. doi: 10.1111/j.1469-8137.2006.01935.x

Bucking H, Shacker-Hill Y (2005) Phosphate uptake, transport and transfer by arbuscular mycorrhizal fungus is increased by carbohydrate availability. New Phytol 165: 889–912

Cardoso, I. M and Kuyper, T. W (2006). Mycorrhizas and tropical soil fertility. *Agriculture Ecosystems & Environment* 116(1-2):72-84. DOI: 10.1016/j.agee.2006.03.011

Chandrasekaran, M., Chanratana, M., Kim, K., Seshadri, S., and Sa, T. (2019). Impact of arbuscular mycorrhizal fungi on photosynthesis, water status, and gas exchange of plants under salt stress—a meta-analysis. Front. Plant Sci. 10, 457. doi: 10.3389/fpls.2019.00457

FAOSTAT (2012). Top maize production. Retrieved June 20, 2012 from www.faostat.fao.org

Hashem, A., Abd Allah, E.F., Alqarawi, A.A., Al-Huqail, A.A., Shah, M.A., (2016). Induction of osmoregulation and modulation of salt Stress in Acacia gerrardiiBenth. by arbuscular mycorrhizal fungi and Bacillus subtilis (BERA 71). BioMed.Res. Int., 6294098https://doi.org/10.1155/2016/6294098.

Hashem, A., Abd_Allah, E. F., Alqarawi, A. A., Wirth, S., and Egamberdieva, D. (2019). Comparing symbiotic performance and physiological responses of two soybean cultivars to arbuscular mycorrhizal fungi under salt stress. *Saudi J. Biol. Sci.* 26, 38–48. doi: 10.1016/J.SJBS.2016.11.015

Hawkins H-J, A. Johansen and E. George (2000). Uptake and transport of organic and inorganic nitrogen by arbuscular mycorrhizal fungi. Plant and Soil 226: 275–285.

IITA (2008). Increasing maize production in West Africa.http://www.iita.org/news item/increasing-maize-production-west-africa/ Accessed May 3, 2018.Influencing Farmers' Adoption of Improved Maize Production Practices in Ikara Local Government Area of Kaduna State, Nigeria.*Agrosearch,* 16 (2): 15–24.

Juo, A.S.R. (1979). Selected Methods for Soil and Plant Analysis. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

Kaldorf, M., Kuhn, A.J., Schroder, W.H., Hildebrandt, U and Bothe, H, 1999. Selective element deposits in maize colonized by a heavy metal tolerance conferring arbuscular mycorrhizal fungus. J. Plant Physiol.,154:718–728.

Lee Y.J. and George E. (2005) Hort.Science. 40:378–380.

Lee, Y.J and George, E. (2005). Contribution of Mycorrhizal Hyphae to the Uptake of Metal Cations by Cucumber Plants at Two Levels of Phosphorus Supply. *Plant Soil* 278, 361–370. https://doi.org/10.1007/s11104-005-0373-1

Leigh. J, Hodge. A and Fitter A.H (2009) Arbuscular mycorrhizal fungi can transfer substantial amounts of nitrogen to their host plant from organic material. *New Phytol* 181: 924–937.

Nazeri NK, Lambers H, Tibbett M, Ryan MH (2013). Do arbuscular mycorrhizas or heterotrophic soil microbes contribute towards pH acquisition of a Pulse of mineral phosphate? Plant and Soil doi: 10.1007/s11104-013-1838-2

Ogunniyi, L.T. (2011). Household Consumption of Cassava Products in Oyo State.*Global Journal of Science Frontier Research*. 11 (6): 38–44.

Pollierer MM, Langel R, Ko¨rner C, Maraun M, Scheu S. (2007). The underestimated importance of belowground carbon input for forest soil animal food webs. Ecology Letters.; 10(8):729–36.

Sabia, E., Claps, S., Morone, G., Bruno, A., Sepe, L., Aleandri, R. (2015). Field inoculation of arbuscularmycorrhiza on maize (*Zeamays* L.) under low inputs: preliminary study on quantitative and qualitative aspects. *Italian J. Agron.* 10, 30–33. doi: 10.4081/ija.2015.607

Sadiq, M.S., Yakassai, M.T., Ahmad, M.M., Lakpene, T.Y., and Abubakar, M. (2013). Profitability and Production Efficiency of Small-Scale Maize Production in Niger State, Nigeria.*IOSR Journal of Applied Physics* (IOSR-JAP), 3 (4): pp 19–23.

Sharifi M, Ghorbanli M, Ebrahimzadeh H. Improved growth of salinity-stressed soybean after inoculation with pre-treated mycorrhizal fungi, *Journal of Plant Physiology*, 2007, vol.164 (pg. 1144-1151)

Sharma, S., Prasad, R., Varma, A., Sharma, A. K. (2017). Glycoprotein associated with *Funneliformiscoronatum*, *Gigaspora margarita* and *Acaulosporascrobiculata* suppress the plant pathogens *in vitro*. *Asian J. Plant Pathol.* 11 (4), 192–202. doi: 10.3923/ajppaj.2017.199.202

Shen, H., Christie, P., and Li, X. (2006). Uptake of zinc, cadmium and phosphorus by arbuscular mycorrhizal maize (Zea mays, L.) from a low available phosphorus calcareous soil spiked with zinc and cadmium. Environ. Geochem. Health 28, 111. doi: 10.1007/s10653-005-9020-2

Smith, S. E., Smith, F. A., and Jakobsen, I. (2003). Mycorrhizal fungi can dominate phosphate supply to plants irrespective of growth responses. Plant Physiol. 133, 16–20. doi: 10.1104/pp.103.024380

Soudzilovskaia NA, van Bodegom PM, Terrer Moreno C, van't Zelfde M, McCallum I, Fisher JB, (2018). Human-induced decrease of ectomycorrhizal vegetation led to loss in global soil carbon content. bioRxiv..

Sousa CS, Menezes RSC, Sampaio EVdSB, Lima FS. Glomalin: (2012). Characteristics, production, limitations and contribution to soils. Semina: Ciências Agra´ rias.; 33(6Supl1):3033–44.

Terrer C, Vicca S, Hungate BA, Phillips RP, Prentice IC. 2016. Mycorrhizal association as a primary control of the CO2 fertilization effect. Science 353: 72–74. doi: 10.1126/science.aaf4610

Tisdall JM, Oades JM. (1982). "Organic matter and water-stable aggregates in soils". *Journal of Soil Science* 33: 141–163.

Turnau, K., Jurkiewicz, A., Lingua, G., Barea, J. M., and Gianinazzi-Pearson, V., 2005, Role of arbuscular mycorrhiza and associated microorganisms in phytoremediation of heavy metal-polluted sites, in: Trace Elements in the Environment, M. N. V. Prasad, K. S. Sajwan and R. Naidu, Taylor & Francis, CRC Press, Boca Raton, FL, pp. 229–246.

Turrini, Alessandra; Giovanni Caruso, Luciano Avio, Clizia Gennai, Michela Palla, Monica Agnolucci, Paolo Emilio Tomei, Manuela Giovannetti, Riccardo Gucci (2017). Protective green cover enhances soil respiration and native mycorrhizal potential compared with soil tillage in a high-density olive orchard in a long term study. Applied Soil Ecology, Volume 116, Pages 70-78, https://doi.org/10.1016/j.apsoil.2017.04.001.

Van der Heijden, MGA, Klironomos, JN, Ursic M, Moutoglis P, Streitwolf-Engel R, Boller T, Wiemken A, Sanders IR. (1998). “Mycorrhizal fungal diversity determines plant biodiversity, ecosystem variability and productivity”. *Nature* 396: 69–72

Walkey, A. and Black, I.A. (1934). An Examination of the Degtjarett Method of Determining Soil Organic Matter and Proposed Modification of the Chromatic Acid Titration Method Soil. Soil Soc., 37: 29-38

Wang G.M; Stribley D. P., Tinker P. B. and C.Walker (1993). Effect of pH on arbuscular mycorrhiza I. Field observation on the long-term liming experiment at Rothamsted and Woburn. New PhytoL, 124, 465-472

Wu, Q., Zou, Y.N., Abd_Allah, E.F., 2014. Mycorrhizal association and ROS in plants. In: Ahmad, P. (Ed.), Oxidative Damage to Plants. Elsevier Inc. http://dx.doi.org/10.1016/B978-0-12-799963-0.00015-0.

Cite this Article: Anozie, HI; Wokocha CC; Madu, OV (2021). Influence of Arbuscular Mycorrhizae Fungi on (*Zea mays*) Cultivated on Sewage Contaminated Soil. *Greener Journal of Agricultural Sciences* 11(3): 195-203.