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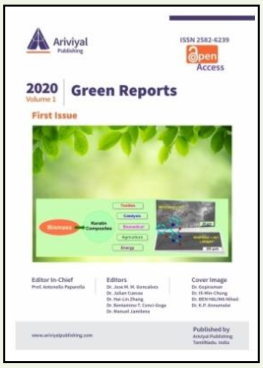

Effects of Mycorrhizal Inoculation and Fertilizer Types on Growth Parameters of Sesame

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Abstract: This research was conducted at the Teaching and Research Farms, Ladoke Akintola University of Technology (LAUTECH) Ogbomosho, Oyo State, Nigeria to investigate the effects of mycorrhizal inoculation and fertilizer types on growth parameters of sesame under greenhouse condition, with three levels of mycorrhizal inoculation (M_0 = No mycorrhizal, M_1 = *Glomus clarum*, M_2 = *Glomus mossae*) and four levels of fertilizer types (F_0 = Control, F_1 = NPK, F_2 = *Jatropha curcas* seed cake and F_3 = Organomineral) in a completely randomized design (CRD) and treatments replicated three times. The analysis of variance and DMRT revealed that F_2 and F_3 fertilizers had significant ($P \leq 0.05$) increased effect on sesame number of branches. Mycorrhizal inoculation (M_2) had increased pronounced significant ($P \leq 0.05$) effects on three (3) growth parameters of sesame (height, stem girth and number of leaves). Fertilizer types and mycorrhizal inoculation interaction (M_2F_2) contributed to the pronounced increased significant ($P \leq 0.05$) effects on sesame height and stem girth. It can be concluded, that M_2 (*Glomus mossae*) inoculation had most pronounced significant ($P \leq 0.05$) effects on three growth agronomic parameters (sesame height, stem girth and number of leaves) and therefore could be recommended for the growth improvement of sesame crop planted on a sandy loam soil.

Keywords: fertilizer; symbiotic association; soil nutrients; non-leguminous; organic materials

1. Introduction

Abusive use of chemical fertilizers by local farmers and lack of appropriate soil conservation strategies are the major causes of rapid depletion of soil nutrients and subsequent low crop productivity persisting in the tropics.[1] Farmers in the tropics apply fertilizers anyhow without minding the scientific recommendations for different crops as well as the importance of improving and maintaining organic matter under tropical soil conditions.[2] Since these undesirable soil conditions considerably affect crop productivity and human welfare amongst others, there is a crying need to practice crop production which will encourage exploitation of natural or biological and organic materials, for improved performance of versatile arable crop like sesame.

Sesame (*Sesamum indicum* L) is an erect, non-leguminous, self-pollinating, annual plant in the genus sesamum. It belongs to the family Pedaliaceae and is one of the most ancient crops and oilseeds known by mankind.[3] It is widely cultivated in the derived, Sudan and Sahel savannas, northern and southern guinea of Nigeria.[4] Seeds are usually used in propagating sesame and they mature between 70-150 days after sowing. Its stem grows up to 50 to 250 cm tall. Growth and development depends on the varieties and soil and environmental conditions.[5] Flowering starts 38-45 days after sowing. It capsules contains small edible seeds which are relatively rich in protein (25%) and about (50%) oil. India is the largest producer of sesame in the world. It also ranks first in the world in terms of sesame growing area.[6]

Mycorrhizal is a mutuality association between plant and fungus localized in a root-like structure in which energy moves primarily from plant to fungus and inorganic resources move from fungus to plant. It intimately associates with plant roots to form a symbiotic association with the host plant.[7] Mycorrhizal association is responsible for up to 80% of the total Phosphorus uptake by plants.[8] One of the strongest effects of Arbuscular Mycorrhizal Fungi inoculation is an increase in the growth and development of the host plant, which is attributed to an increase in water and nutrient uptakes, particularly for those having low soil mobility and low concentration in the soil solution, inoculation of salt stressed tomatoes with mycorrhizal meaningfully increased their dry weight of root and shoots compared to non– mycorrhizal–inoculated plants.[9] Research by[10] indicated strong growth responses of celery plants due to the combination of mycorrhizal fungi, Pseudomonas sp., and biochar with low P fertilization. Increased P and N uptake occurred in treatments combining these microorganisms rather than alone, and this increase especially occurred in the presence of biochar. The root colonization rate of mycorrhizal fungi was

Fig. 1. Sesame plant

increased by the combination of the inoculation of Pseudomonas sp. and biochar rather than AM fungi and/or Pseudomonas sp. Inoculation with mycorrhizal showed more efficiency, and were positively reflected in sesame growth traits (plant height, leaf number, dry weight, tissue phosphorus and nitrogen) than addition of mineral phosphorus.[11]

Tropical soils are inherently infertile and characteristically low in soil organic matter content and could not support reasonably support intensive cultivation due to the rapid rate of fertility decline particularly under intensive cultivation.[12] The use of various fertilizers had been reported to address these problems.[13]

Integrated Nutrient Management Approach (INMA) is an environmental friendly technology which involves proportionate combination of multiple fertilizer materials of different origins or sources (e.g organic, inorganic and biological), may be economical and even more suitable for enhanced crop productivity and soil quality than using any other fertilizer from a single source. It was researched[14] and discovered that most seed yield (4261 k ha^{-1}) and higher N and P use efficiency of sesame was due to the combined biofertilizer and multi-cap seed. In addition, INMA safeguards the environment for future generations.[15]

Therefore, it is reasonable to develop a sustainable technology in form of Integrated Nutrient Management Approach, which combines applications of organic materials (e.g Jatropha seed cake and inorganic fertilizer e.g NPK urea) or microbes for improving the performance of protein and oil rich arable crop like sesame, hence the objective of this research was to determine the effects mycorrhizal inoculation and fertilizer types on growth parameters of sesame.

2. Materials and methods

Greenhouse experiment was carried out at the Teaching and Research Farms, Ladoke Akintola University of Technology (LAUTECH) Ogbomosho, (latitude 80 10'N and longitude 40 10E, Oyo State, which falls under the southern guinea savannah zone of Nigeria. The zone is characterized by bimodal rainfall distribution (whereby the early rainy season starts in late march and ends in late July/early August, followed by a short dry spell in August and finally the late rainy season. The annual mean rainfall was between 1150mm and 1250 mm (LAUTEC weather station, 2016). The experiment was carried out in February to July 2016.

2.1. Propagating materials

Sesame seeds of Variety E8 (an early maturing type) were obtained from National Cereal Research Institute (NCRI) at Badeji Niger State, Nigeria. The seeds were surface sterilized by using 95% ethanol for 10 seconds and were later rinsed six (6) times with sterile water after shaking for three to five minutes in 3% hydrogen peroxide. Four seeds were sown per pot and later thinned to one seedling per pot. Mycorrhizal strains were obtained at Soil Microbiology Unit, Department of Agronomy, University of Ibadan. Jatropha seed cake was obtained from Professor Balewu at the University of Ilorin. NPK fertilizer was also obtained from Oyo State Agricultural Development Programme (OYSADEP) while Organomineral fertilizer from Alesinloye market, Ibadan.

2.2. Treatments and experimental design

The experiment was a factorial experiment (3 x 4). The experiment was arranged in a completely randomized design (CRD), replicated three times. Three inoculations; M_0 = Control (No = mycorrhizal inoculation), M_1 = inoculation with *Glomus clarum* strain, M_2 = inoculation with *Glomus mossae* strain, four types of fertilizer; F_0 = Control, F_1= NPK fertilizer application, F_2 = *Jatropha curcas* seed cake application, F_3= Organomineral fertilizer application.

2.3. Soil Sampling and analysis

The soil sample was done with bucket auger and bulked into a composite sample. The sample was air dried, crushed and sieved through 2 mm meshes for the determination of particle size, soil pH (H_20), total nitrogen (N), organic carbon, available Phosphorus (P), Iron (Fe), copper (Cu), Znic (Zn), the exchangeable cations, (Ca, Na, Mg and K) and exchangeable acidity were also analysed. The particle size was carried out according to,[16] hydrometer method, using sodium hexameta phosphate as the dispersant. Total N was determined by the macro-kjedahl method[17] and colorimetric determination by Technicon Autoanalyser, while the cations was determined using Atomic Absorption Spectrometer (Model Buck 200A). Olsen P was determined by extraction with Sodium bicarbonate.[18] Soil was sterilized by autoclaving at 1200^{O}C, for one hour for 48 hours. Organic carbon was determined by chromic acid digestion.[19]

2.4. Determination of mycorrhizal root colonization

After harvesting, root samples were cut into 1 cm length and stored in 50% ethanol, Roots samples were then carefully rinsed with slow running tap water (before the commencement of root staining procedure) mycorrhizal staining commenced by heating the root in 10% KOH for 40 minutes at 800^{O}C. Roots were bleached in alkaline H_2O_2 for 10 minutes, after which they were rinsed in water and

Table 1. Pre-cropping soil physical and chemical properties of the soil used.

Soil characteristics	Values
pH (H_2O)	6.2
Organic Carbon (g kg^{-1})	4.0
Total N (g kg^{-1})	0.3
Available P (mg kg^{-1})	4.8
Fe (mg kg^{-1})	12.7
Cu (mg kg^{-1})	2.8
Zn (mg kg^{-1})	2.8
Exchangeable K (cmol kg^{-1})	0.3
Exchangeable Na (cmol kg^{-1})	0.2
Exchangeable Ca (cmol kg^{-1})	4.2
Exchangeable Mg (cmol kg^{-1})	2.5
Sand (g kg^{-1})	880.8
Silt (g kg^{-1})	92.4
Clay (g kg^{-1})	26.8
Textural class	Sandy loam

soaked in one percent HCL for 10 minutes. The staining solution chlorazol black E[20] was used on the root staining containing 0.03% of chlorazol black E, lactic acid (400 ml) and water (200 ml). Stained root were later distilled with 50% glycerol. The degree of mycorrhizal colonization was assessed by spreading the root samples evenly on a grid plate and observing them under the dissecting microscope at low magnification. The total numbers of roots and the infected roots intercepting the grid were counted using the grid line intersect method. The percentage mycorrhizal root colonization was calculated by ratio between the number of intersect with infection and the total number of intersects multiplied by 100.[7]

2.5. Propagation and cultural practices

Four seeds of sesame (variety E8), were sown in 2 kg soil-filled pots with fertilizer treatments (15 gm) and later thinned to one seedling per pot at two weeks after sowing. All plants were regularly watered. Pots were manually weeded by careful hand-pulling of all the emerging weed seedlings from the pots on weekly basis. About 3 cm to the brim of each pot was left unfilled, to prevent undesirable washing away of the soil particles and fertilizer materials which may occur during watering. Also, four perforations were carefully made at the bottom of each pot, using hot-red 2 inches (5 cm) nail, prior to pot filling. The perforations made were plugged with cotton wool to regulate drainage and encourage proper aeration.

2.6. Data collection

Data were collected on growth parameters at the end of the experiment (14 weeks). The growth parameters determined were; plant height, stem girth, number of leaves and number of branches. The plant height was determined using tape rule by placing it on the stem base and run it to the tip of the plant. Stem circumference (girth) was determined using venier caliper which gave the value of the diameter, and was later converted to stem girth using formula πd (Where π = 3.142 and D = the value of diameter obtained from venier caliper's readings. The number of leaves and branches were simply counted.

2.7. Statistical analysis

All data collected were subjected to Analysis of Variance (ANOVA) and significant means were separated using Duncan Multiple Range Test (DMRT) at 5% probability level.

3. Results and Discussions

The pre-cropping chemical and physical analysis of the soil sample showed that the soil had a pH of 6.2, slightly acidic and low in essential nutrients particularly nitrogen and phosphorus (Table 1). This showed that the soil samples used were inadequate in nutrient and therefore artificial supply of nutrients or application of fertilizer to meet the nutrient required for optimum growth and yield of sesame is needed. These results are in agreement with the other earlier researchers,[1] who reported that soil, at the study area are slightly acidic and inadequate in nutrient to support successful completion of the vegetative and reproductive stages of most tropical crops.

The average sesame height was increased from control (66.8, 55, and 55.3 cm) to (105.4, 105.4 and 108.4 cm) due to *jatropha curca* seed cake fertilizer, inoculation with *Glomus mossae* and *Glomus mossae innoculum* x *jatropha curca* seed cake fertilizer respectively (Table 2), analysis of variance (Table 3) however, indicated that application of fertilizer only had no significant ($P \leq 0.05$) influence on the sesame height, but inoculation only and inoculation x fertilizer types had statistical significant ($P \leq 0.05$) effect on the sesame height, separation of the means height by DMRT (Table 2), observed *Glomus mossae* inoculums and *Glomus mossae* inoculums x *jatropha curca* seed cake fertilizer had increased significant ($P \leq 0.05$) effect on the sesame height than other treatments. These results are in agreement with the report from[18] which emphasized that the plant vegetative growth and development are influenced by nutrient availability particularly nitrogen, phosphorus and potassium.

The average sesame stem girth followed the same trend of sesame height; the average stem girth was increased from control (1.3, 1.1 and 1.2 cm) to (1.9, 2.0 and 2.1 cm) due to *jatropha curca* seed cake fertilizer, inoculation with *Glomus mossae* and *Glomus mossae* inoculum x *jatropha curca* seed cake fertilizer (Table 2), analysis of variance (Table 3) however, indicated that application of fertilizer only had no significant ($P \leq 0.05$) influence on the sesame stem girth, but inoculation only and inoculation x fertilizer types had statistical significant ($P \leq 0.05$) effect on the sesame stem girth, separation of the means stem girth by DMRT (Table 2), observed *Glomus mossae* (2.0a) and *Glomus clarum* (1.9a) inoculums had the same significant ($P \leq 0.05$) increased effect on the sesame stem girth and statistically ($P \leq 0.05$) different from the control, also *Glomus mossae* inoculums x *jatropha curca* seed cake fertilizer and *Glomus clarum* inoculums x organomineral had the same increased significant ($P \leq 0.05$) effect on the sesame stem girth but significantly ($P \leq 0.05$) different from the control interaction. All these results indicated above agreed with the earlier report on biofertilizer, particularly *Glomus clarum* which have been reported to be an alternative source to chemical fertilizer in order to be able to increase soil fertility and crop production in sustainable farming.[21]

Table 2. Effects of mycorrhizal inoculation and fertilizer types on the average growth parameters of sesame (n = 36)

Parameters	Fert types				Inoculation			Fert x inoculation		
	F_0	F_1	F_2	F_3	M_0	M_1	M_2	M_0F	M_1F	M_2F
PH	66.8a	73.2a	105.4a	104.3a	55c	98.9b	105.4a	55.3b	98.6a	108.4a
SG	1.3a	1.7a	1.9av	1.8a	1.1b	1.9b	2.0a	1.2b	1.8a	2.1a
NL	37a	39a	65a	69a	35c	56b	67a	36c	55b	69a
NB	6b	6b	9a	9a	8a	9a	9a	6a	8a	8a

Mean followed by same letters are not significantly different at 5% probability level, using Duncan's Multiple Range Test (DMRT). M_0= No mycorrhizal inoculation, M_1=inoculation with *Glomus clarum* strain, M_2=inoculation with *Glomus mossae* strain, F_0=Control with no fertilizer application, F_1=NPK fertilizer application, F_2=*Jatropha curcas* seed cake application and F_3=Organomineral fertilizer application.

Table 3. Analysis of variance of effects of mycorrhizal inoculation and fertilizer types on growth parameters of sesame (n = 36).

Parameters	Fert types		Mycorrhizal inoculation		Inoculation x Fert	
	ms	p	ms	p	ms	p
PH	1236ns	0.32	2395.3**	0.00	3187*	0.02
SG	0.19ns	0.63	0.63**	0.00	0.88*	0.02
NL	842ns	0.15	749.8**	0.00	1009ns	0.12
NB	11.11*	0.03	1.00ns	0.42	8.33ns	0.17

**Significant at p ≤ 0.01, *Significant at p ≤ 0.05, ns = not significant at p ≤ 0.05

The average sesame number of leaves was increased from control (37, 35, and 36) to (69, 67 and 69) due to organomineral fertilizer, this finding was similar to[22,23] on tomato and pepper respectively, inoculation with *Glomus mossae* and *Glomus mossae* inoculum x organomineral fertilizer (Table 2), analysis of variance (Table 3) however, the application of fertilizer only had no significant ($P \leq 0.05$) influence on the sesame number of leaves, but inoculation only and inoculation x fertilizer types had statistical significant ($P \leq 0.05$) effect on the sesame number of leaves, separation of the means number of leaves by DMRT (Table 2), observed *Glomus mossae* inoculums and *Glomus mossae* inoculum x organomineral fertilizer had increased significant ($P \leq 0.05$) effect on the sesame number of leaves than other treatments.

The average sesame number of branches was increased from control (6, 8, and 6) to (9, 9 and 8) due to *jatropha curca* seed cake or organo- mineral fertilizer, inoculation with *Glomus clarum* or *Glomus mossae*, and *Glomus clarum* or *Glomus mossae* innoculum x *jatropha curca* seed cake or organomineral fertilizer (Table 2), analysis of variance (Table 3) however, showed the application of fertilizer only had significant ($P \leq 0.05$) effect on the sesame number of branches, this was in agreement with the report of,[8,24] that vegetative growth can be increased with fertilizer application, but inoculation only and inoculation x fertilizer types had no statistical significant ($P \leq 0.05$) effect on the sesame number of branches, separation of the means number of branches due to fertilizer application by DMRT (Table 2), indicated that *jatropha curca* seed cake and organomineral fertilizers had the same increased significant ($P \leq 0.05$) effect on the sesame number of branches and statistical ($P \leq 0.05$) different from the reduced effect of control and NPK fertilizer on the average number of branches of sesame, this was also consistent with the findings of.[25]

4. Conclusions

The effects of mycorrhizal inoculation and fertilizer types on growth parameters (plant height, stem girth, number of leaves and number of branches) of sesame was investigated under the green house condition with three levels of mycorrhizal inoculation (M_0 = No mycorrhizal, M_1 = *Glomus clarum*, M_2 = *Glomus mossae*) and four levels of fertilizer types (F_0 = Control, F_1 = NPK, F_2 = *Jatropha curcas* seed cake and F_3 = Organomineral) in a 3 x 4 factorial experiment and treatments replicated three times. The least values for all the growth parameters were obtained from the control experiment. The highest sesame height (108.4 cm), stem girth (2.1 cm), number of leaves (69) and number of branches (9) were obtained from the interaction of fertilizer types and mycorrhizal inoculation. The analysis of variance and DMRT revealed that fertilizer types had no statistical significant ($P \leq 0.05$) on sesame height, stem girth and number of leaves but F_2 = *Jatropha curcas* seed cake and F_3 = Organomineral had significant ($P \leq 0.05$) increased effect on sesame number of branches. Mycorrhizal inoculation had no significant ($P \leq 0.05$) effect on sesame number of branches but significant ($P \leq 0.05$) increased effects were observed on sesame height, stem girth and number of leaves, however, M_2 = *Glomus mossae* had increased pronounced significant ($P \leq 0.05$) effects on sesame height, stem girth and number of leaves. Fertilizer types and mycorrhizal inoculation interaction had no significant ($P \leq 0.05$) effects on number of leaves and branches, but significant ($P \leq 0.05$) effects were observed on the sesame height and stem girth, also it was discovered that M_2F_2 (*Glomus mossae* x *Jatropha curcas* seed cake) had pronounced increased significant ($P \leq 0.05$) effects on the sesame height and stem girth.

It can be concluded, that M_2 (*Glomus mossae*) inoculation had most pronounced significant ($P \leq 0.05$) effects on three growth parameters (sesame height, stem girth and number of leaves) and therefore could be recommended for the improvement of sesame crop planted in a sandy loam soil.

Conflicts of Interest

The authors declare no conflict of interest.

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