Effect of Arbuscular Mycorrhizal Fungi on the Growth and Yield of Soybean (*Glycine max* L. Merrill) in Bauchi, Nigeria

Abstract

Soybeans (*Glycine max* L.) globally has been regarded as an economically important commodity that is highly traded and also a vital legume used as food source for both humans and animals. The objective of the study therefore is to determine the effect of arbuscular mycorrhizal fungi (AMF) on the growth and yield of soybean (*Glycine max* L.). The experiment was conducted in a screen house wheretwo varieties of soybeans (TGX 1448 and TGX 1951) were grown in a 1 litre pods, filled with sterilized soil and three seedswere sowninto each podat a depth of 2 cm until germination, then reduced to one seedling. Different AMF dose (10 g, 20 g, 30 g, and 40 g) was inoculated at the time of seed sowing and non-inoculated pods as control (0 g). Various parameters were taken into consideration like plant height and number of leaves while shoot dry biomass, root dry biomass and yield attributes were taken at harvest. It was observed that the inoculated plants performed higher than the non-inoculated plants. Growth parameters such as plant height, number of leaves, shoot dry biomass, root dry biomass, and yield attributes increased with increase AMF dose. Therefore, it is concluded that AMF inoculation increase growth and yield of soybeans and can serve as biofertilizer.

Comment [h1]: two

Keywords: *Glycine max* L., arbuscular mycorrhizal fungi, inoculated, biofertilizer

Introduction

Soybeans (Glycine max L.) over the years have been regarded as one of the most economically important legumes in the food chain, with more than one fourth of the global population depending on it for food and other essentials such as animal feeds (Igiehon et al., 2021). The importance of soybean (Glycine max L.) as both oil crop and legumes to the food chain is paramount, belonging to the family Fabaceae (Adeyemi et al., 2020; Cera et al., 2017). Soybeans has 20% oil, when dry with other vital amount of minerals and vitamins present, and also, provides high quality protein for many households and processing industries in Nigeria (Omoigui et al., 2020).

Legumes have been an important way of earning for many farmers in most underdeveloped and developing nation, soybeans being known to improving soil fertility due to the ability to fix atmospheric nitrogen into the soil in the form that can be utilized by plants, thereby, lessening the need for organic and mineral fertilizers. In contrast, more than half of total nitrogen been added to the soil emanate from legumes – rhizobia symbiosis relationship(Bashir et al., 2022). Low yield in soybean farming are usually associated with nutrients imbalance, nutrients leaching and also, due to limited nutrients in the non-fertile soil (Bashir et al., 2022; Thuita et al., 2012)

Comment [h2]: improve

Arbuscular Mycorrhiza fungi (AMF) form symbiosis relationship with most plant species by colonization of the host plant roots in order to source carbohydrates for their growth, development and continuous survival while in return, it provides minerals, nutrients and water to the host plant (Baslam & Goicoechea, 2012; Igiehon et al., 2021; Quiroga et al., 2019). A study by Sugiura et al., (2020) reveals that myristate can be a source of carbon and energy for AMF. Immediately the spore germinate, colonization of the plant root start by forming a hyphopodium on the surface of the root, which penetrate the rhizodermis through a pre-penetration apparatus, these colonizes root tissue intercellularly to form highly form arbuscules in cortical cells which the fungi uses to release minerals to the host plant (Etemadi et al., 2014; Harrison, 2012).Glomalin secreted by AMF help improves soil organic matter (SOM), soil structure, microbial activity, mitigate drought effects (Habibzabeh, 2015; Hong et al., 2018), bioremediation, and reduce loss of fertility (Mrabet et al., 2014; Priscila et al., 2021; Yang et al., 2017).

Comment [h3]: form hyphae from which highly branched structure arbuscules developed in

Comment [h4]: fungi use (fungi is plural form)

Several scholars have reported positive effects of using AMF to boast growth and yield of plants particularly legumes and cereals (Adeyemi et al., 2020; Buysens et al., 2016; Douds et al., 2016; Emam, 2016; Ming-hung et al., 2007; Novais et al., 2020; Zhu et al., 2010, 2014)and similarly, other scholars have reported no or less effects of using AMF(Farmer et al., 2007; Pellegrino & Bedini, 2014). Therefore, it is necessary to investigate the effect of different dose of AMF on the growth and yield of soybeans (Glycine max L.) varieties (TGX 1448 and TGX 1951).

Comment [h5]: boost

Materials and Method

Experimental site

The experiment was conducted in the Screen house of Abubakar Tafawa Balewa University in Bauchi, Bauchi State, Nigeria.

Soil analysis

pH (H_2O), Electrical Conductivity (dsm^{-1}), Exchangeable Acidity (cmol kg^{-1}), Ca^{2+} (cmol kg^{-1}), Mg^{2+} (cmol kg^{-1}), K^+ (cmol kg^{-1}), Na^+ (cmol kg^{-1}), Cation Exchange Capacity (cmol kg^{-1}), Total Exchangeable Base (cmol kg^{-1}), Base Saturation (%), N (%), Organic Carbon (%), Organic Matter (%), Carbon to Nitrogen, Available Phosphorus (mg kg^{-1}), Clay, Sand, Silt, Texture were determined.

Source of Soybean seeds

Two varieties of soybean (TGX 1448 and TGX 1951) were purchased from Bauchi State Agricultural Development Programme (BASADP), Bauchi, Nigeria. Viability test was carried out according to

Source of AMF Inoculum

AMF inoculum was sourced from University of Aberdeen, School of Biological Sciences, Aberdeen, Scotland.

Screen House Experiment

Plantswere grown in1litre pot with 4 replications.Different concentration of AMF*Glomus intraradices*(10g, 20g, 30g, and 40g)were inoculated and non-inoculated pot as control.Growth characteristics such as (plant height, number of leaves, root and shoot biomass, yield) were determined.

Comment [h6]: concentrations

Comment [h7]: pot was used

The pre-planting soil was collected in a transparent Ziplock polythene bag and taken to University of Maiduguri, Department of Soil Science for physical and chemical analysis. The result of the pre-planting soil analysis is presented in Table 1.

Experimental design and treatment

The experiment was set-up in a completely randomized design (CRD) using1 litre pots filled with 5 mm sieved soil. Three soybean seeds were planted into each pot at a depth of 2 cm which after germination others were removed, maintaining one at each pot. The inoculation of AMF (10g, 20g, 30g, and 40g i.e. average of 40 spores per 10 g) were done at the time of sowing.

Data collection

Plant height, and number of leaves were recorded at two weeks intervals while Root biomass, shoot biomass, weight of seeds and number of seeds per plant were recorded at harvest i.e. at thirteen weeks.

Comment [h8]: root

Comment [h9]: after harvesting

Statistical analysis

Data collected from growth indices (plant height, number of leaves, root biomass, shoot biomass and yield) were analysed using DSAAT statistical software on Microsoft excel and GraphPad Prism version 8.0 software.

Result

The results of the physical and chemical properties of the experimental soil are presented in table 1. The result indicated that soil pH was 6.68 with EC of 0.84(dsm^{-1}). Available phosphorus value of 12.25 (mg kg^{-1}) and the texture was identified as sandy loam.

Table 1. Physical and chemical properties of the pre-planting soil

Soil property	Value
pH (H_2O)	6.68
EC (dsm^{-1})	0.84
EA (cmol kg^{-1})	1.90
Ca^{2+} (cmol kg^{-1})	2.40
Mg^{2+} (cmol kg^{-1})	3.60
K^{+} (cmol kg^{-1})	0.17
Na^{+} (cmolkg^{-1})	0.13
CEC (cmol kg^{-1})	6.30
TEB (cmol kg^{-1})	8.20
Base Sat. (%)	76.83
N (%)	0.18

OC (%)	0.64
OM (%)	1.10
C:N	3.56
AP (mg kg^{-1})	12.25
Clay	16.50
Sand	75.30
Silt	8.20
Texture	Sandy loam

EC-Electrical conductivity, EA-Exchangeable acidity, Ca^{2+} -Calcium, Mg^{2+} -Magnesium, K^{+} -Potassium, Na^{+} -Sodium, CEC- Cation exchange capacity, TEB- Total exchangeable base, Base sat- Base saturation, N- Nitrogen, OC- Organic carbon, OM- Organic matter, C:N- Carbon to Nitrogen, and AP- Available Phosphorus.

(A) **(B)**

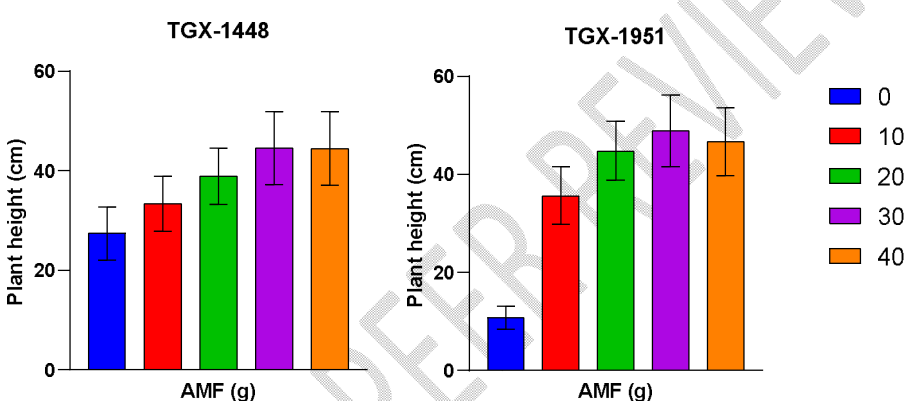

Figure 1: **A** - Effect of AMF (*Glomus intraradices)* on plant height of *Glycine max* (TGX 1448)**B** - Effect of AMF (*Glomus intraradices)* on plant height of *Glycine max* (TGX 1951)

Figure 1A shows the plant height of *Glycinemax* variety TGX 1448 inoculated with different dose of arbuscular mycorrhiza fungi (AMF) of which at harvest, there is no significant difference between 30g and 40g AMF while 0 g i.e. control recorded less plant height and there is significant difference between control (0g), 10g and 20g AMF. Figure 1B shows plant height of *Glycine max* variety TGX 1951 inoculated with different dose of arbuscular mycorrhiza fungi (AMF), at harvest, 30 g AMF has the highest plant height but there is no significant difference between 20 g, 30 g and 40 g while there is significant difference between control (0g), 10g and 20g AMF.

(A) **(B)**

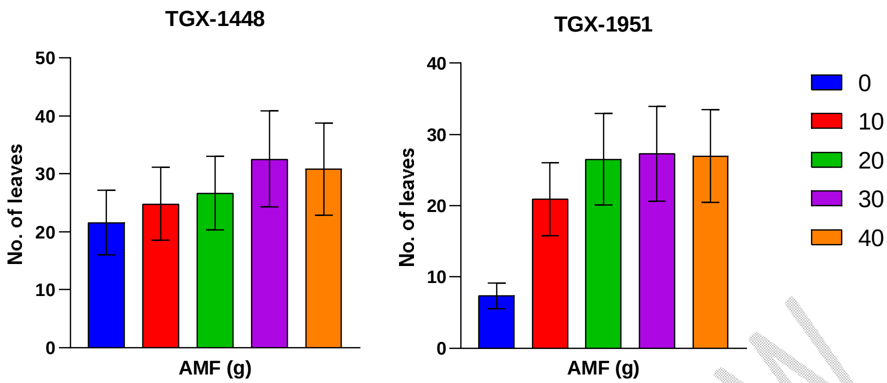

Figure 2: **A** -Effect of AMF (*Glomus intraradices)* on number of leaves of *Glycine max* (TGX 1448)**B** -Effect of AMF (*Glomus intraradices)* on number of leaves of *Glycine max* (TGX 1951)

Figure 2A shows number of leaves of *Glycine max* variety TGX 1448 inoculated with different dose of arbuscular mycorrhiza fungi (AMF), at harvest, 30g has the highest leaves number, but there is no significant difference between 30 g and 40 g AMF while there is no significant difference between control (0g), 10g and 20g respectively. Figure 2B shows number of leaves of *Glycine max* variety TGX 1951 inoculated with different dose of arbuscular mycorrhiza fungi (AMF) at harvest, there is no significant difference between 20 g, 30 g and 40 g while there is significant difference between control (0g), and 10g.

Comment [h10]: mycorrhizal

(A) **(B)**

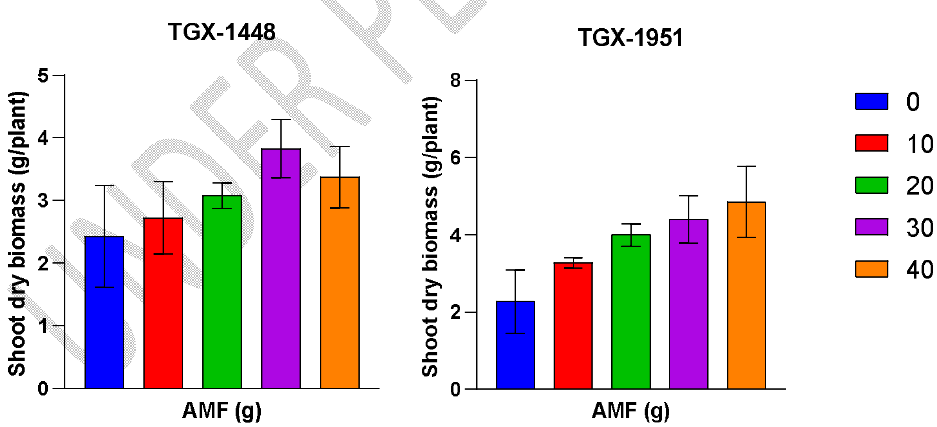

Figure 3: **A**- Effect of AMF (*Glomus intraradices)* on shoot dry biomass of *Glycine max* (TGX 1448)**B** - Effect of AMF (*Glomus intraradices)* on shoot dry biomass of *Glycine max* (TGX 1951)

Figure 3A shows shoot biomass of *Glycine max* (TGX 1448) inoculated with different dose of mycorrhizal (AMF). 30g has the highest weight, followed by 40g. For shoot, there is no significant difference between control (0 g), 10 g, 20 g and 40 g AMF. Figure 3B shows shoot

Comment [h11]: AMF

biomass of Glycine *max* (TGX 1951) inoculated with different dose of mycorrhizal (AMF). The weight increase with increased in AMF dose of which 40g has the highest weight in shoot biomass.

(A) **(B)**

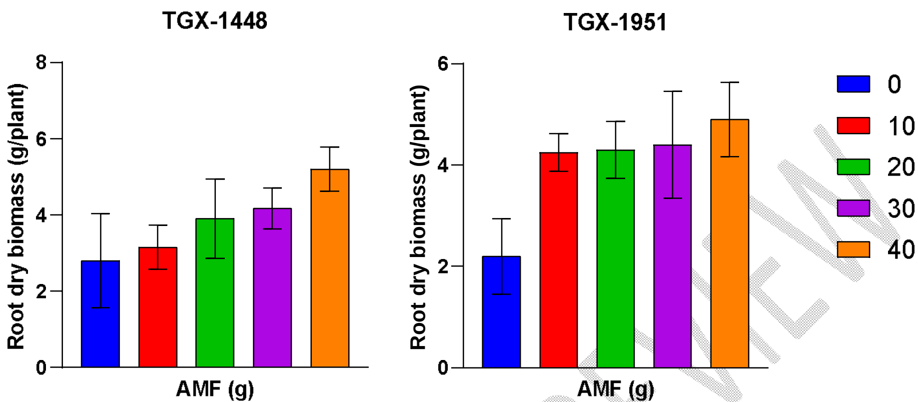

Figure 4 A **-** Effect of AMF (*Glomus intraradices)* on root dry biomass of *Glycine max* (TGX 1448)**B -** Effect of AMF (*Glomus intraradices)* on root dry biomass of *Glycine max* (TGX 1951)

Figure 4A shows root biomass of *Glycine max* (TGX 1448) inoculated with different dose of mycorrhizal (AMF). the weight increase with increased in AMF dose of which 40g has the highest root weight, while there is no significant difference between control, and 10g AMF. Subsequently, there is no significant difference between 20g, and 30g AMF.Figure 4B shows root biomass of Glycine *max* (TGX 1951) inoculated with different dose of mycorrhizal (AMF). In root biomass, the weight increase with increased in AMF dose of which 40g has the highest weight in root biomass while there is no significant difference between control, and 10g, 20 g and 30 g AMF. Subsequently, there is significant difference between non- mycorrhizal inoculated control (0g) with the inoculated mycorrhizal ones.

Comment [h12]: differences

(A) **(B)**

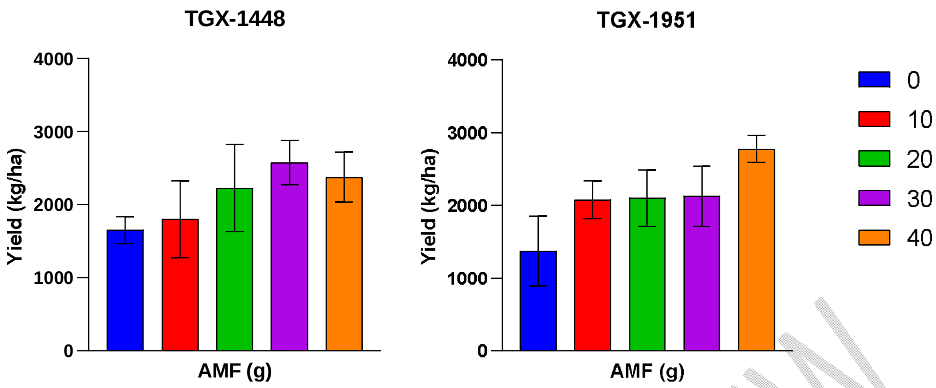

Figure 5: **A-** Effect of AMF (*Glomus intraradices)* on root dry biomass of *Glycine max* (TGX 1448)**B -** Effect of AMF (*Glomus intraradices)* on root dry biomass of *Glycine max* (TGX 1951)

Figure 5A shows yield of different varieties of *Glycine max* (TGX 1448) inoculated with different dose of AMF. Among the different treatments of variety TGX 1448, 30g has best yield as compared to the other treatments and there is no significant difference between control, and 20g, 30 g and 40 g AMF.Figure 5B shows yield of variety of *Glycine max* (TGX 1951) inoculated with different dose of AMF. Variety 2-TGX 1951 40g has the best yield as compared to the different treatments and there is no significant difference between 10 g, 20g, and 30 g AMF. Subsequently, there is significant difference between non- mycorrhizal inoculated control (0g) with the inoculated mycorrhizal ones.

Discussion

The used of AMF (*Glomus intraradices*) have increase plant growth and yield attributes of the two varieties (TGX 1448 and TGX 1951) of soybeans. These increase in overall growth and yield have earlier been reported by (Adeyemi et al., 2020; Klironomos et al., 2000). The presence of AMF has influence growth and yield attributes such as plant height and number of leaves due to the fact AMF may have influence nutrient uptake. AMF increase colonization in the rhizobia which subsequently provides the support by enhancing photosynthetic rate through the supply of phosphorus and nitrogen. The photosynthetic enzymes responsible for light harvesting complex solely depends on essentials nutrients supply by AMF of whichphosphorus are known to stimulate many functions in plants such as canopy photosynthesis, nutrient movement and energy transfer in plants(Groot et al., 2003; Mo et al., 2016; Tereucán et al., 2022; Zhao et al., 2017). Similarly, AMF have positive effect on antioxidant enzyme activities in plants (Zhang et al., 2019)

The symbiotic relationship between plant and mycorrhiza positively enhance the root length , root biomass, root density, increase nutrient uptake especially nitrogen, phosphorus, iron and zinc (Barea, 2015; Delavaux et al., 2021; Ingraffia et al., 2019; Rouphael et al., 2015) and also, uptake of potassium (Ouledali et al., 2018; Wang et al., 2017). Root colonisation of the both varieties of soybeans (TGX 1448 and TGX 1951) inoculated with AMF were higher which may have resulted due to optimal value of available phosphorus in the soils(Carrasco et al., 2006;

Comment [h13]: increased
Comment [h14]: increases
Comment [h15]: increases
Comment [h16]: essential
Comment [h17]: has
Comment [h18]: has
Comment [h19]: enhances
Comment [h20]: increases
Comment [h21]: colonization

Vasar et al., 2021). AMF symbiosis is more established predominantly in marginal soil allowing the secretion of root exudates by the plant which increased colonisation in the rhizobia(Adeyemi et al., 2020; Smith, 2008; Torrecillas et al., 2012).

Comment [h22]: colonization

Bacterial growth and vitality are influence by mycelial exudates which enhance the community of bacterial in the rhizosphere (Lindahl et al., 2007; Tanaka et al., 2022; Toljander et al., 2006). The ability of AMF hyphae to form symbiotic association with the plant root depends on the different bacterial groups present in the soil (Kohler et al., 2017; Scheublin et al., 2010). According to Tsoata et al., (2015) and Abdalla & Ahmed, (2021) AMF can be used as effective tool for ameliorating the negative impact of drought stress on plant by enhancing plant resistance and tolerance to abiotic stress which result in increased yield.

Comment [h23]: influenced

Comment [h24]: influenced

Comment [h25]: bacteria

Comment [h26]: resulted

The plant height and number of leavesbetween the inoculated AMF plants and the non-inoculated AMF plants (0 g) in both soybeans varieties is visible, the inoculated plants performed higher than the non-inoculated AMF plants which agrees to the study of (Oliveira et al., 2022). Furthermore, shoot dry biomass and root dry biomass in the inoculated AMF plants exhibit similar pattern of performance with plant height and number of leaves of which the inoculated AMF plants have higher weight than the non-inoculated AMF plants which agrees with the study of (Oliveira et al., 2022).

Comment [h27]: soyabean

In contrast, high yield performancerecorded in TGX 1951 at high AMF dose plants relates to increase growth parameters specifically plant height and number of leaves, of which high photosynthesis directly relates to increased assimilatory surface, resulting to increased shoot and root biomass and finally, increased yield attributes(Abdel et al., 2016; Adeyemi et al., 2020).

Comment [h28]: in

Conclusion

In conclusion, AMF (*Glomus intraradices*) exhibit greater potential to increased yield under favourable condition. The result validates the influence of AMF on the growth and yield of soybeans varieties (TGX 1448 and TGX 1951). It reveals that high yield attributes were observed with increase AMF dose in both varieties of soybeans which relates to high AMF colonisation around the roots, thereby increasing both water and nutrient uptake through the roots by the plant. TGX 1951 has the best performance with AMF inoculation then TGX 1448.

Comment [h29]: exhibits

Comment [h30]: increased

Comment [h31]: colonization

Abbreviations

AMF	Arbuscular mycorrhizal fungi
BASADP	Bauchi state agricultural development programme
CRD	Completely randomized design
DSAAT	Digital situational awareness assessment and training
SOM	Soil organic matter

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