INTRODUCTION

Soybean (Glycine max L.) is a leguminous crop. It belongs to the family Fabaceae, subfamily Papilionoideae, genus Glycine and subgenus soya. It is an herbaceous annual plant which is one of the world’s most valuable crop used as a source of dietary protein (Park et al., 2020). Tropical Soybean varieties can be categorized into three groups based on the maturity period. Early maturing which matures in less than 105 days after planting, medium maturing which matures between 105-120 days after planting and late maturing which mature after 120 days after planting. The present production of this crop and many other crops are not adequate to meet the growing world population. Climate change and urbanization are the two major factors affecting food production (Borreli et al., 2020). Conventional farming cannot achieve the production of enough food if the population continues to increase at this pace hence, the need to find better and sustainable method of food production so that enough food can be made available. Consequently, the use of organic agriculture and plant growth promoting microorganisms (PGPM) has been adopted. Organic agriculture is important in achieving food security (Muller et al., 2017) and it is regarded as being environmentally friendly than conventional agriculture (Meemken and Qaim, 2018). Application of organic residues to soils increase soil organic matter, buffer soil, improve aggregate stability and enhance water retention capacity of soils. Organic agriculture is environmentally friendly and excludes use of inorganic fertilizer. Manure has been used effectively as organic fertilizer for centuries and their nutrient content varies depending on source and nutrient content (Reganold and Wachter 2016; Zhang et al., 2020) organic manures are efficient in increasing soil nutrient contents, ensuring positive residual effects and enhancing soil’s physical and chemical characteristics (Mamood et al., 2017). The utilization of the inorganic manure is an integral part of agriculture that has been exploited overtime and across ages because of its ability to sufficiently supply major plant nutrients, such as N, P, K, Ca, Mg and stabilizes soil pH.

The PGPM are majorly of bacteria and fungi microbes. They have been successfully implemented in the promotion of growth in various plants (Igiehon et al., 2020; Olanrewaju and Babalola, 2019). Different mechanisms such as growth hormone production, siderophore production, nitrogen fixation, phosphorus solubilization, ACC deaminase production, etc. are employed by PGPMs in improving plant growth and controlling pathogens (Olanrewaju et al., 2017). One major fungus that has been implemented in plant growth promotion is Arbuscular mycorrhizal fungi (AMF). Many agricultural and horticultural crop species form a mutualistic symbiotic relationship with AMF in their roots (Igiehon and Babalola, 2017). AMF are efficient in acquisition of nutrients resulting in improved plant growth (Kim et al., 2017; Liang et al., 2019). Furthermore, root colonization with AMF enhances plant tolerance to abiotic stress (Al-Arjani et al., 2020; Begum, Ahanger, et al., 2019; Begum, Qin, et al., 2019; Mathur et al., 2018; Yasmeen et al., 2019), thus improving crop growth and productivity. AMF are of immense importance in maintaining soil fertility which are influenced by the effect of climatic and seasonal changes on the physical and chemical properties of soil. The objective of the study therefore is to know the effect of selected AMF and poultry manure on growth, yield, and nutrients uptake of soybean under screenhouse conditions.

MATERIALS AND METHODS

Soil collection and analysis

The experimental soil was collected on the agricultural land site of the University of Ibadan, Nigeria (7°24’N; 3°48’E) and pot experiment conducted in the greenhouse of the Department of Agriculture, University of Ibadan, Ibadan, Nigeria. Soil sample was collected at a depth of 0-15 cm, air-dried and sieved with 5 mm mesh size to remove debris before weighing into 5 kg pots. The bulk soil was sub-sampled, air dried at room temperature and grounded to pass through 2 mm and 0.5mm diameter sieve for analysis. The particle size analysis was done by hydrometer method (Gee and Or, 2002). The pH was determined in a 1:2 soil/water suspension using digital pH meter. Organic carbon was determined by Walkley-Black dichromate wet oxidation method (Nelson and Sommers, 1996). Total nitrogen was by micro-Kjeldahl distillation technique as described by Bremer and Mulvaney (1982). Available phosphorus was determined by Bray No 1 method as described by IITA (1982). Exchangeable K, Ca and Mg were extracted using ammonium acetate, K was determined using flame photometer, Ca and Mg determined using atomic absorption spectrophotometer.

Poultry manure preparation

Poultry manure was air – dried and characterized by nitric and sulfuric acids before further analysis to determine the micronutrients following standard protocols (Cater; Kalra and Maynard, 1991).

Mycorrhiza source

Sample of mycorrhiza propagules was collected from Soil Microbiology Laboratory of the Department of Agronomy, University of Ibadan, Nigeria. They are Glomus clarum (G.c), Glomus gigaspora (G.g), Glomus deserticola (G.d), and Glomus mosseae (G.m). Arbuscular mycorrhizal inocula (20 g each) were applied at third-quarter central top of the soil 24 hours before soybean seed were sown into the soil (Carling et al., 1978).
Experimental design and treatments
The experimental was a factorial with mycorrhiza having five levels, poultry manure with three levels of poultry manure viz 6.25 g (1 pm), 12.5 g (2 pm) and a control. The experiment was arranged in a completely random design and replicated three times to give a total of 45 pots. The variety of soybean planted was (TGX 1448 -2E). Two soybean seed were sown in 5 kg pot filled with topsoil. The mycorrhiza inoculum was applied alone, and the two levels of poultry manure were also applied alone after which each inoculum was applied in consortia with each level of poultry manure. There was a control in which nothing was applied. Standard agronomic practices were followed.

Statistical analyses
All data were analyzed using analysis of variance (ANOVA) with the statistical analysis software (SAS) version 9.4 (SAS Institute, Inc., Cary, NC, USA), and Duncan’s Multiple Range Test (DMRT) at P<0.05 was used to separate the means. Multivariate analysis was done using the R statistical package (R Core Team, 2019). Principal component analysis (PCA) was done using the FactoMineR package (Le et al., 2008) and Pearson correlation was performed using the core function of the stats package in R. A hierarchical cluster analysis was performed using the ward. D2 method in a cluster R package (Maechler, 2019).

RESULTS
Soil and poultry manure nutrient analysis

Table 1 Nutrient content of poultry manure, soil chemical characteristics and particles size distribution

| Poultry manure | Soil |
|----------------|------|
| Nutritional components | Chemical properties |
| Total nitrogen (%) | Nitrogen (g/kg) | 3.00 |
| Total phosphorus (%) | Bray P (mg/kg) | 16 |
| Ca (%) | Exc Ca (cmol/kg) | 7.56 |
| Mg (%) | Exc Mg (cmol/kg) | 0.22 |
| K (%) | Exc Na (cmol/kg) | 0.56 |
| Mn (%) | CEC (cmol/kg) | 10.03 |
| Fe (%) | Exc k (cmol/kg) | 0.56 |
| Cu (%) | Mn (mg/kg) | 76 |
| Na (%) | Fe (mg/kg) | 15 |
| Zn (%) | Zn (mg/kg) | 17 |
| pH in H2O | Cu (mg/kg) | 2 |
| pH in KCl | pH in H2O | 6.85 |
| Organic carbon (%) | pH in KCl | 6.13 |
| Organic matter (%) | Organic carbon (g/kg) | 12.4 |
| | Organic matter | 2.1 |
| | Sand (g/kg) | 789 |
| | Silt (g/kg) | 91 |
| | Clay (g/kg) | 120 |
| | Soil textural class | Sandy |

Plant growth characteristics
For At 2 weeks, the mean values of the plant height of the control and the inoculated plants are relatively close (Table 2). Starting from 3 weeks, we start seeing clear disparities in the mean values up to the 5th week. At 2 weeks, combination of Glomus mosseae and 6.25 g poultry manure followed by sole application of poultry manure. At the 5th week, combination of Glomus mosseae and 6.25 g manure still have the highest value, the same as the combination of Glomus deserticola and 12.5 g manure which is 66.33 cm followed by single application of 6.25 g manure which is 61.67 cm. In relation to the control, at 2, 3, 4, and 5 weeks, the control mean value is higher than 4, 6, 1, and 0 numbers of treatments respectively.

Table 2 Effect of mycorrhizal and poultry manure application on plant height (cm) at 2.3.4, and 5 WAP

| Treatments | 2 | 3 | 4 | 5 |
|------------|---|---|---|---|
| Control | 21.67 cd | 28.50 bc | 34.33 e | 35.67e |
| G.d | 21.00 cd | 23.83 cd | 38.67 de | 55.00 ed |
| G.m | 21.83 cd | 26.50 bc | 42.00 cd | 56.67 cd |

Legend: Means in the same column with the same letter are not significantly different at 5% level of probability using DMRT. G.d = Glomus deserticola, G.m = Glomus mosseae, G.c = Glomus Clarum, G.g = Glomus gigaspora, 1 pm = 6.25 g poultry manure, 2 pm = 12.5 g poultry manure, WAP = Week After Planting

The number of branches increases at the different weeks (Table 3). At 2 weeks, treatments Glomus mosseae and combination of Glomus clarum with 12.5 g manure are statistically different while the control is not like any of the other treatment at 3 and 5 weeks, the values recorded are not statistically different for the number of leaves (Table 4) at 2 weeks, all treatments are significantly higher than the control, same for the period of the experiment. However, the combination treatments have significant values than the single treatments and the control. Statistically, the responses of the leaf area of the plants to the various inoculations at the different weeks are not different at each week (Table 5). However, the combined treatments gave higher leaf area than the other treatments.

Table 3 Effect of mycorrhizal and poultry manure application on number of branches at 2,3,4, and 5 WAP

| Treatments | 2 | 3 | 4 | 5 |
|------------|---|---|---|---|
| Control | 1.67 b | 3.00 a | 3.33 c | 5.66 a |
| G.d | 2.00 ab | 2.66 a | 4.00 bc | 6.33 a |
| G.m | 2.33 a | 3.33 a | 4.33 abc | 5.66 a |
| G.c | 2.00 ab | 2.66 a | 4.00 bc | 5.66 a |
| G.g | 2.00 ab | 2.66 a | 4.33 abc | 6.67 a |
| 1pm | 2.00 ab | 3.67 a | 5.00 ab | 6.67 a |
| 2pm | 2.00 ab | 3.00 a | 4.67 abc | 5.67 a |
| G.d + 1pm | 2.00 ab | 3.33 a | 4.00 bc | 6.33 a |
| G.m + 1pm | 2.00 ab | 3.33 a | 5.00 ab | 6.33 a |
| G.c + 1pm | 1.67 b | 2.67 a | 4.00 bc | 6.33 a |
| G.g + 1pm | 2.00 ab | 3.67 a | 4.67 abc | 7.00 a |
| G.m + 2pm | 2.00 ab | 3.33 a | 5.00 ab | 6.33 a |
| G.c + 2pm | 2.33 a | 2.67 a | 4.66 abc | 6.00 a |
| G.g + 2pm | 2.00 ab | 3.67 a | 5.67 a | 6.00 a |
| F statistics | 1.07** | 1.15* | 1.67* | 0.64** |
| C.V. | 14.91 | 20.33 | 17.49 | 14.43 |

Legend: Means in the same column with the same letter are not significantly different at 5% level of probability using DMRT. G.d = Glomus deserticola, G.m = Glomus mosseae, G.c = Glomus Clarum, G.g = Glomus gigaspora, 1 pm = 6.25 g poultry manure, 2 pm = 12.5 g poultry manure, WAP = Week After Planting

Table 4 Effect of mycorrhizal and poultry manure application on number of leaves at 2, 3, 4, and 5 WAP

| Treatments | 2 | 3 | 4 | 5 |
|------------|---|---|---|---|
| Control | 6.67 b | 10.00 b | 15.33 bc | 16.67 b |
| G.d | 8.33 ab | 10.33 bc | 14.33 c | 19.67 ab |
| G.m | 9.00 ab | 10.67 bc | 15.33 bc | 18.00 ab |
| G.c | 8.33 ab | 10.67 bc | 14.00 c | 21.33 ab |
| G.g | 8.00 ab | 11.00 ab | 16.00 ab | 26.00 a |
| 1pm | 9.00 ab | 13.00 a | 16.67 ab | 23.33 ab |
| 2pm | 8.00 ab | 11.00 a | 13.33 ab | 18.33 ab |
| G.d + 1pm | 8.67 ab | 11.66 ab | 13.00 e | 18.33 ab |

Legend: Means in the same column with the same letter are not significantly different at 5% level of probability using DMRT. G.d = Glomus deserticola, G.m = Glomus mosseae, G.c = Glomus Clarum, G.g = Glomus gigaspora, 1 pm = 6.25 g poultry manure, 2 pm = 12.5 g poultry manure, WAP = Week After Planting
Table 4 Cont.

| Treatments       | 2       | 3       | 4       | 5       |
|------------------|---------|---------|---------|---------|
| G.m +1pm         | 8.00 ab | 13.33 a | 16.33 ab| 18.00 ab|
| G.d +1pm         | 7.33 a  | 11.33ab | 14.67 c | 22.00 ab|
| G.g +1pm         | 10.33 a | 13.33 a | 17.33 a | 23.33 ab|
| G.d +2pm         | 9.00 ab | 14.00 a | 18.67 a | 23.33 ab|
| G.m +2pm         | 8.33 ab | 13.33 a | 18.00 a | 21.00 ab|
| G.c +2pm         | 8.67 ab | 11.67 ab| 16.67 ab| 20.33 ab|
| G.g +2pm         | 8.33 ab | 12.66 ab| 16.67 ab| 20.00 ab|
| F Statistics     | 0.77ab  | 0.87ab  | 1.06ab  | 1.16ab  |
| C.V.             | 19.44   | 20.33   | 18.75   | 20.24   |

Legend: Means in the same column with the same letter are not significantly different at 5% level of probability using DMRT. G.d = Glomus deserticola, G.m = Glomus mosseae, G.c = Glomus Clarum, G.g = Glomus gigaspora, 1 pm= 6.25 g poultry manure, 2 pm = 12.5 g poultry manure, WAP = Week After Planting

Table 5 Effect of mycorrhizal and poultry manure application on leaf area at 2, 3, 4, 5 WAP

| Treatments       | 2       | 3       | 4       | 5       |
|------------------|---------|---------|---------|---------|
| Control          | 11.32 a | 20.57 a | 21.27 c | 25.53 b |
| G.d             | 12.63 a | 13.77 a | 22.30 b | 26.76 ab|
| G.m             | 12.00 a | 19.63 a | 23.80 abc| 29.13 ab|
| G.c             | 11.43 a | 17.60 a | 21.23 c | 26.83 ab|
| G.g             | 14.67 a | 17.47 a | 27.36 abc| 33.56 ab|
| 1pm             | 14.80 a | 25.90 a | 38.33 a | 42.63 a |
| 2pm             | 11.86 a | 27.33 a | 27.77 ab| 33.63 ab|
| G.d +1pm        | 11.86 a | 27.33 a | 23.47 abc| 29.13 ab|
| G.m +1pm        | 17.26 a | 20.87 a | 28.67 abc| 33.63 ab|
| G.c +1pm        | 12.03 a | 15.07 a | 27.77 abc| 31.67 ab|

Legend: Means in the same column with the same letter are not significantly different at 5% level of probability using DMRT. G.d = Glomus deserticola, G.m = Glomus mosseae, G.c = Glomus Clarum, G.g = Glomus gigaspora, 1 pm= 6.25 g poultry manure, 2 pm = 12.5 g poultry manure, WAP = Week After Planting

Figure 1 Effect of mycorrhizal and poultry manure application on biomass yield, grain yield, mycorrhiza spore count, root colonization, and days to 50% flowering. Means in the same column with the same letter are not significantly different at 5% level of probability using DMRT. G.d = Glomus deserticola, G.m = Glomus mosseae, G.c = Glomus Clarum, G.g = Glomus gigaspora, 1 pm= 6.25 g poultry manure, 2 pm = 12.5 g poultry manure.

Principal component analysis

The principal component of the variances taken by component responses of the plants on the traits over the treatments used in the study are represented in a biplot (Figure 2). PC1 and PC2 account for 67.9% of the total variances observed. Among the variables, the plant height, number of branches, leaf area, and dry biomass yield are the major contributing components of PC1 while number of seeds, fresh biomass yield, and grain yield contribute highest to PC2 (Table 6). Treatments that improve fresh biomass yield and number of seeds also increases the grain yield.

Table 5 Cont.

| Treatments       | 2       | 3       | 4       | 5       |
|------------------|---------|---------|---------|---------|
| G.g +1pm         | 12.18 a | 16.63 a | 27.30 abc| 33.10 ab|
| G.d +2pm         | 15.07 a | 22.67 a | 35.00 abc| 39.96 ab|
| G.m +2pm         | 19.97 a | 21.97 a | 37.57 ab | 43.40 a |
| G.c +2pm         | 13.60 a | 22.97 a | 30.63 abc| 35.77 ab|
| G.g +2pm         | 16.67 a | 24.60 a | 30.93 abc| 37.77 ab|
| F Statistics     | 0.83**  | 0.92**  | 1.40**  | 1.30**  |
| C.V.             | 33.95   | 34.35   | 28.62   | 25.48   |

Legend: Means in the same column with the same letter are not significantly different at 5% level of probability using DMRT. G.d = Glomus deserticola, G.m = Glomus mosseae, G.c = Glomus clarum, G.g = Glomus gigaspora, 1 pm= 6.25 g poultry manure, 2 pm = 12.5 g poultry manure, WAP = Week After Planting.

Single treatments of Glomus deserticola, Glomus gigaspora, Glomus mosseae, and combination treatments of Glomus mosseae+6.25 g manure, Glomus gigaspora+6.25 g manure, Glomus deserticola+12.5 g manure, Glomus clarum+12.5 g manure, and Glomus gigaspora+12.5 g manure are not statistically different from one another (Figure 1). However, single treatments of 6.25 g manure gave the highest fresh and dry biomass yields. Furthermore, treatments with Glomus clarum inoculum, gave the highest mycorrhizal count. The control and the Glomus deserticola treated plants are not statistically different in their mycorrhizal count. It was observed that combination treatment of Glomus clarum+6.25 g manure gave the highest root colonization percentage and all treatments with 12.5 g of manure were seen to show higher root colonization than those with 6.25 g or those without manure.

This suggests that high manure content influences the root colonization ability of the mycorrhiza species. Furthermore, treatment Glomus gigaspora+6.25 g manure produced the highest number of seeds followed by Glomus clarum+12.5 g manure and Glomus mosseae+6.25 g manure. The grain yield is similar in all treatments except for the control which is much lower than the other treatments. Like the grain yield, days to 50% flowering is similar for all treatments in their effects.
**DISCUSSION**

Crop yield is affected by nutrient availability, pests and diseases, water availability, and poor soil condition among others (Donatelli et al., 2017; Röös et al., 2018; J. Zhang et al., 2020). AMF enhances plant ability to absorb minerals and improve growth through mineral solubilization, production of growth hormones, etc. Manure from various sources have been identified in plant growth promotion (Abbas et al., 2020; Ekinci et al., 2019) with the sources playing a crucial role (Bibiano et al., 2019).

**Principal component analysis**

Biplot represents the association among different traits, and the length of the lines shows the contribution of each trait in the variations observed (Figure 2). The eigenvalues and the corresponding factors are sorted by descending order of how much of the initial variability they represent. The Eigenvalue significance is shown by the asterisks.

**Correlation analysis**

There are lots of significant correlations among the traits scored (Figure 4). Either positive or negative correlations, the asterisks indicate if it is statistically significant or not. The red colors show negative correlations while the blue colors show positive correlations. The deeper the colors, the stronger the correlations. Plant height has a positive correlation with all other traits except days to 50% flowering but only correlations with fresh and dry biomass yield, mycorrhiza spore count, number of seeds, and yield that are significant statistically. Number of branches on the other hand has a positive correlation with number of leaves, leaf area, fresh and dry biomass yield, root colonization, number of seeds, and yield with the last two being only the positive significant correlations. Number of leaves is positively and significantly correlated with fresh and dry biomass yield, mycorrhiza spore count, and yield while leaf area is significantly positively correlated with yield. Fresh biomass yield is significantly positively correlated with percentage root colonization but significantly negatively correlated with mycorrhiza spore count, number of seeds, days to 50% flowering, and yield. Dry biomass yield correlates positively and significantly with percentage root colonization and yield but negatively and significantly with mycorrhiza spore count. Days to 50% flowering has negative correlations with all the traits.

The level of significance of the correlations at p<0.05 is shown by the asterisks. Either positive or negative correlations, the asterisks indicate if it is statistically significant or not. The red colors show negative correlations while the blue colors show positive correlations. The deeper the colors, the stronger the correlations.
criterion, as described by Kaiser (1960) was used to select statistically significant principal components. The biplot analysis can be used to select the best treatment in breeding for a trait.

**Clustering and Correlation analysis**
The clustering grouped majority of the combined treatments together in the same clusters (Figure 3), hence we can say that they produce similar responses different from the sole treatments. The correlation matrix shows traits that have impact on each other (Figure 3). It aids the selection of traits without over-picking traits for improved breeding. From the traits, tall plants produce high yield hence, farmers will prefer treatments that favor tall plants (Figure 2) so they can have high yield.

**CONCLUSION**
The study concludes that the treatments have effects on the growth and yield parameters of soybean. It was also observed that combination treatments of AMF with higher quantity of manure produce the best result on growth and yield. This study was conducted in a greenhouse however due to diverse environmental factors, diversity in soil microbiome of the field, it is suggested that further the study should be replicated on the field to know if these treatments will still yield the same result.

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