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Effects of Soil Amendment with Compost and Mycorrhiza on Growth and Yield of White Yam (Dioscorea rotundata Poir.) Under Adamawa Field Conditions

Jeremie Boursi[1,2,*], Delphine Nguemo Dongock[2], Venasius Wirnkar Lendzemo[1], Jordan Nantchouang Ngongang[2], Albert Ngakou[2]

[1]Institute of Agricultural Research for Development, Po Box 65 Ngaoundere, Cameroon
[2]Department of Biological Sciences, Faculty of Sciences, University of Ngaoundere, Po Box 454 Ngaoundere, Cameroon
*Corresponding author: boursi.jeremie@yahoo.fr

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Abstract Yam cultivation helps to improve the stability of the food system and increases the predictability of farmers' incomes. To obtain good yields, yams require soils rich in organic matter and nitrogen. Two trials were carried out at Wakwa in 2023 and 2024, a locality within the high Guinean savannahs of Cameroon, to study the influence of organic and biological fertilisers on the growth and yield of *D. rotundata*, in a bid to develop a sustainable production strategy for this species. Experiments involved five treatments 2:3 compost/soil ratio; 30 g of mycorrhizal inoculum; 30 g of mycorrhizal inoculum + 2:3 compost/soil ratio; zero NPK; the equivalence of 300 kg/ha of NPK 10 10 30, which were organised in a completely randomised block design and repeated three times. Soil sampling was carried out in the top soil horizon between 0 and 20 cm before planting and after harvest. Growth parameters were measured from the 4th week after planting. The parameters used to assess yield at harvest were the number of tubers per plant, and the length and weight of tubers per plant. The soil analysis results showed moderate acidity (pH water = 5.7) and very low concentrations of available phosphorus (2.07 mg/kg) and nitrogen (0.22 mg/kg). The addition of the compost/soil mixture increased the soil pH (pHwater = 6). Phosphorus and nitrogen were levels increased by 92, 87 mg/kg and 0.14% respectively. The compost/soil + mycorrhiza mixture significantly and positively influenced vine height, number of leaves, collar diameter and branching compared with the negative control during the two cropping seasons. The response of *D. rotundata* to the amendment indicated that yield varying between 14 t/ha and 31.6 t/ha under treatment negative control and 2:3 compost/soil + mycorrhiza respectively. Based on the present findings Therefore, treatment 2:3 compost/soil + mycorrhiza ratio is strongly recommended for the sustainable and eco-friendly production of this yam variety.

Keywords: *compost, mycorrhiza, yield, Wakwa, Dioscorea rotundata Poir*

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1. Introduction

Yam is a plant species belonging to the *Dioscoreaceae* family and comprises more than 600 species. The *Dioscorea* genus is cultivated throughout the world mainly for food purposes [1]. Cultivated mainly for its tubers, yam is the staple food of more than 100 million people in the humid and sub-humid tropics [2]. It comprises around ten species, which are found in intertropical zones, and contributes to the food security of many populations in Oceania and the Caribbean [1]. Yam production is mainly concentrated in the savannas, which account for more than 93% of global production around the Gulf of Guinea, forming a ‘yam belt’ and playing a very important role in the food security of at least 60 million people [3]. *D. rotundata*, a species that is very demanding in terms of soil fertility, is grown mainly on fallow-grassland. The shorter the fallow periods, the lower the yield. In order to satisfy growing consumers demand, farmers are looking for more areas to exploit, accelerating deforestation, depleting natural resources and jeopardising the balance of biodiversity in cultivated areas [4]. Taking into account the harmful effects of climate change on farming systems and the growing demand from consumers [4], fertilisation would be a way of combating food insecurity and improving living conditions for people in rural areas [5]. New yam production technologies that reconcile sustainable land management, biodiversity preservation and climate change resilient agriculture are a major challenges [6]. To achieve this, the natural processes of biofertilisation and/or organic fertilisation must be exploited. Soil amendment with compost containing humus rich in mineral compounds and living micro-organisms helps to raise soil fertility levels [7]. Mycorrhizal fungi play an important role in plants, giving the host plant better growth through improved mineral nutrition, particularly phosphate, and consequently higher yields [8]. The objective of this work was to determine the effect of mycorrhiza and compost on the growth parameters and yield of *D. rotundata*. Specifically, the study aimed at: (1) determining the physicochemical properties of the soil at the study sites and of the various compost-based treatments; (2) assessing the effectiveness of the various treatments on the agronomic parameters of *D. rotundata*; (3) evaluating the influence of fertilisation on the mycorrhisation parameters of yam; (4) assessing the effectiveness of the treatments on the yield of *D. rotundata*.

2. Material and Methods

Study sites: The study was carried out at the Wakwa agricultural research centre (Alt: 1280 mas; LN: 3°47‘; LE: 10°07’). The climate is of sudano-Guinean type, characterised by two seasons: a rainy season from April to October and a dry season from November to March. Annual rainfall is between 1,600 and 1,800 mm, spread over 7 to 8 months [9]. Most of the soil consists of red ferralitic structures developed on old basalt [10]. The vegetation consists mainly of savannas ranging from grasslands to wooded savannas dominated by *Daniellia olivieri* and *Lophira lanceolata*, as well as forest galleries [11]. The density of these species is clearly decreasing due to human activity [12].

Plant material and fertilisers

The plant material consisted of *D. rotundata* Poir. seedlings obtained from farmers of Mbé, a yam growing corridor in the Adamawa region. The mycorrhizal inoculum consisted of spores of two genera, *Glomus* and *Gigaspora* at 150 spores/g of substrate produced in the biofertilizer and biopesticide production unit of the Institute of Agricultural Research for Development (IRAD) WAKWA. The organic fertiliser was a compost made from cow dung, following the composting method described by Ngakou *et al*. [13]. NPK fertiliser (10:10:30) was used as a positive control.

Experimental design

The study was conducted during the 2023 and 2024 cropping seasons on 120 m^2 surface area. The experimental set up was a randomised complete block design comprising five treatments, each of which was replicated three times: compost-soil mixture in the 2:3 ratio (the 95×10^3g of compost and 300×10^3g of soil) inoculated with 30g mycorrhiza, a compost-soil mixture in the 2:3 ratio indicated with 30g mycorrhiza, a positive control with 30g NPK (10:10:30) and a negative control with no amendement or NPK applied. The mycorrizal inoculum and/or compost amendment were applied into the planting holes at the time of planting. NPK (10:10:30) was applied at 2 months after planting. The experimental unit consisted of 10 plants per replication. A total of 150 seedlings were used. Holes were dug 50 cm deep and 40 cm in diameter with a spacing of 1mx1m. Mounds were then made to a height of 30cm. The seedlings were planted to a depth of 10 cm, with one seedling per mound. The seedlings were labelled by treatment and by replication. Data were recorded every fortnight from the date of first budding.

Soil sampling and physico-chemical characterisation

Soil sampling was carried out in layers 0 to 20 cm deep. Samples were analysed at the Soil Analysis Laboratory of the Faculty of Agronomy and Agricultural Sciences (FASA) at the University of Dschang, Cameroon, to determine the initial physical and chemical characteristics of the soil. pHw was determined using an electronic pH meter, in a soil-water solution of 1/2.5, while Carbon and nitrogen content were determined using the AFNOR[14]. The organic matter content was obtained by multiplying the carbon content by 1.724. Available phosphorus content was determined using the method of [15]. Cation exchange capacity and exchangeable base cations were extracted using ammonium acetate and cations were determined by atomic absorption spectroscopy using the absorption spectrophotometer [16].

Assessment of growth and yield parameters

Growth parameters included plant height, number of leaves, stem diameter and branching. These parameters were evaluated as from the fourth week after planting on 21 plants per treatment (7 plants per replicate), respectively by measuring the plant height, counting the number of leaves per plants, the stem diameter using a caliper (mm) and counting the branching per plants during the first three months of the yam's development cycle. At harvest, tuber number per mound, fresh tuber weight and tuber length were determined. The number of tubers per mound were counted. The height length of the tubers were measured using a tape measure. The fresh weight of tubers was determined using a precision electronic balance. Yield was assessed using the following formula described by Pagnè [17]:

Yield (t/ha) = average tuber weight (t) x emergence rate (%) x planting density per hectare (ha)

The average tuber weight and emergence rate were themselves evaluated by the formulae below:

- Average tuber weight per plant (kg) = total tuber weight harvested (kg)/total number of mounds harvested.
- Emergence rate (%) = total number of tubers emerged/total number of tubers planted x 100.

Evaluation of the mycorrhizal colonization

Plant roots taken 3 months after sowing were analysed in the microbiology laboratory at IRAD in Wakwa. They were preserved in 70% alcohol, then thinned. The roots were washed and cut into fragments 1 to 2 cm length. they were then put in test tubes containing 10 % sodium hydroxide (NaOH) solution, and heated in water bath at 90 °C for 30 min to destroy the plant cells content and decolorize tannins in woody roots; then the NaOH solution was poured out, then root solution was filtered and rinsed three times with tap water and then placed in 10% solution of hydrochloric acid. The acidified yam root fragments were removed, put in beakers containing 0.01% acid Fuchsin solution as staining agent, heated in a water bath for 15 minutes. The root fragments were subsequently removed and placed in a destaining solution of lactic acid-glycerol-water (v/v/v : 5-3- 2) for 24 hours. Root fragments (30 per treatment) were then mounted on a slide and covered with coverslips in groups of 10 and observed under a microscope at magnification 40 [18]. The root fragments were screened under the microscope for the presence or absence of structures characteristic of mycorrhization (Hyphae, Spores, Arbuscules and Vesicles):

- Percentage of colonization: **TC (%) = (n/N) x100**, where (n) is the number of root fragments observed with one or more mycorrhizal structures and (N) is the total number of root fragments (10 fragments) found on the slide-lamellar mount. It provides information on the number of mycorrhizal root fragments out of a total of 30 fragments analysed.

- Mycorrhization intensity corresponds to the degree of root colonisation by arbuscular fungi. It is calculated as follows

I% = (95n5 + 70n4 + 30n3 + 5n2 + n1) / N, where n5, n4, n3, n2, n1 are the number of root fragments noted 5, 4, 3, 2 and 1 respectively.

Statistical analysis

Data collected were subjected to analysis of variance (ANOVA) with STATGRAPHICS 16.0 programme and significant differences among treatment means were evaluated using least significant difference (LSD).

3. Results and Discussion

Physico-chemical characteristics of the soil before and after harvesting, of the compost and of the 2/3 compost/soil ratio

Table 1 indicates the physico-chemical properties of the soil taken from the study site, the compost and the 2:3 compost/soil ratio. Initial soil analysis showed that the soil was moderately acidic (pHwater = 5.7) and had a low phosphorus content (2.07 mg/kg). It was very low in nitrogen (0.22 mg/kg), while the organic matter content was very high, with an organic carbon content of 4.3 (mg/kg). The cation exchange capacity was average (13.45 meq/100g), the exchangeable bases were poor in exchangeable cations (Na^+, Mg^{2+}, K^+, Ca^{2+}) respectively 0.01, 0.56, 0.94, 4 meq/100g. The soil showed an average saturation level (40.97%). This result has revealed that the level of soil fertility and acidity linked to cation exchange capacity were low, while the exchangeable base saturation rate was average. These observations are similar to those noted by Kouassi *et al.* [19] in the savannah zone of Ivory Coast.

The pH-water, phosphorus, nitrogen and organic matter levels increased respectively following soil amendment. The compost/soil mixture improved phosphorus, nitrogen, pH-water and soil organic matter. This result indicates that the addition of compost increased soil pH, organic matter content and also nutrient levels, in line with those of [13], who showed that compost has neutralised soil acidity and improved soil structure. Alium *et al.* [20] also reported that the high concentrations of nutrients in compost are linked to the degradation of woody components by bacteria and the release of nutrients sequestered in the organic matter as they break down during the composting process.

Table 1. Physico-chemical properties of soil, compost and 2/3 compost/soil ratio

Parameters	Soil 2023	Soil 2024	Compost	Compost/soil (ratio 2/3) 2023	Compost/soil (ratio 2/3) 2024
pHwater	5.7	5.8	6.3	6	6.1
pHKCl	4.8	5	5.1	5.6	5.8
CO%	4.3	4.7	7.16	6.21	6.29
MO%	7.41	7.52	12.34	10.70	10.75
Ca(méq/100g)	4	3.8	1.76	0.27	0.23
Na(méq/100g)	0.01	0.02	0.18	9.76	9.89
Mg(méq/100g)	0.56	0.62	1.92	4	4.3
K(méq/100g)	0.94	0.98	1.44	0.45	0.48
Fe(mg/kg)	54.29	55	86.71	41.3	42.7
CEC(méq/100g)	12.45	12.53		13.78	13.84
N(mg/kg)	0.22	0.20	0.13	0.27	0.26
P(mg/kg)	2.07	2.17	58.19	151.06	155.23

Legend: S: sand; L: silt; Ar: clay; CO: organic carbon; OM: organic matter; Mg: magnesium; Ca: calcium; Na: sodium; K: potassium; Fe: iron; CEC: cation exchange capacity; pH: hydrogen potential; N: nitrogen; P: phosphorus.

Effect of fertilisers on characteristics growth of *Dioscorea rotundata*

Plant height: Plant height was influenced by the amendment used (Figure 1). Over the first 12 weeks after planting in both cropping seasons (2023 and 2024), plant height increased over time regardless of type fertilisers. During the 2023 cropping season, between week 2 and week 6, the mycorrhiza inoculated plants recorded the greatest heights compared with the other plants under another amendment. In 2024 cropping season, the compost-mycorrhiza mixture improved plant height compared with the other treatments. At week 12, the compost-mycorrhiza mixture significantly ($P \leq 0.001$) stimulated better growth in height (414.21±34.42 cm; 397.44 ±32.81 cm) compared with the negative control (195.66 ± 13.99 cm; 135.66 ± 11.35 cm), which recorded the lowest plant height. This result could be attributed to the synergistic effect of the combination of fertilising elements (mycorrhiza and compost). Indeed, mycorrhiza are known to improve nutrient uptake by plants by increasing the surface area explored by roots [21]. Compost, meanwhile, enriches the soil with essential plant nutrients [22,23]. These results are consistent with field observations by Ngoyi *et al.* [24], who showed that cow dung compost significantly stimulated the height growth of potato plants in the DRC.

Number of leaves: Figure 2 shows that the number of leaves on plants varies according to the fertilisers used. Plants amended with the compost-mycorrhiza mixture showed a high number of leaves between week 8 and week 12 during the 2023 cropping season. Therefore, in 2024 cropping season, the growth of leave was earlier and were same trend was same trend was observed between week 6 and week 12. Analysis of variance shows a significant difference ($P \leq 0.05$) for the different amendment compared with the others throughout the crop cycle. According to Conley *et al.* [25] (2005), plant foliage is closely linked to the availability of nutrients such as nitrogen, phosphorus and potassium in the soil. The effectiveness of the compost-mycorrhiza mixture could therefore be explained by this interaction. According to Rivero *et al*. [26], Erhart *et al.* [27] and Landry *et al.* [28], the addition of compost to the soil plays a crucial role in preventing mineral leaching thanks to its high organic matter content. This characteristic helps retain the nutrients available to plants, promoting their growth while limiting diseases caused by soil pathogens. In addition, mycorrhiza help to improve nutrient uptake by exploring deep soil layers with their hyphae, giving them access to organic and inorganic phosphorus, which is often unavailable to non-mycorrhised plants [29]. These observations are consistent with studies by Sawadogo *et al.* [22] and Sanna *et al.* [30], which have shown that the combination of different fertilisers, whether organic or mineral, in balanced proportions, significantly stimulates plant growth characteristics.

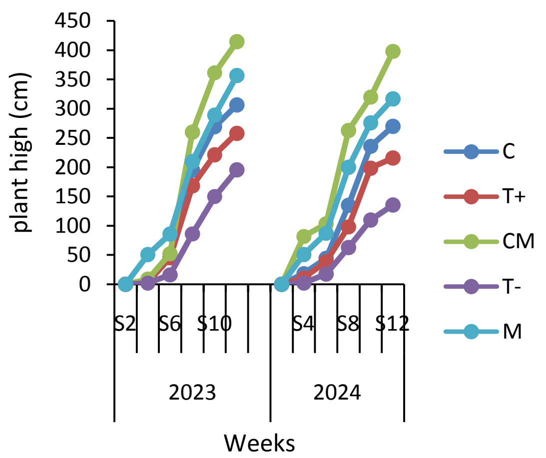

Figure 1. Variation in length growth of Dioscorea rotundata Poir. with the type of amendment and the time between as a function of time. C: compost; T+: positive control (NPK); CM: compost/mycorrhiza; T-: negative control (without fertilizer); M: mycorrhiza; S: week

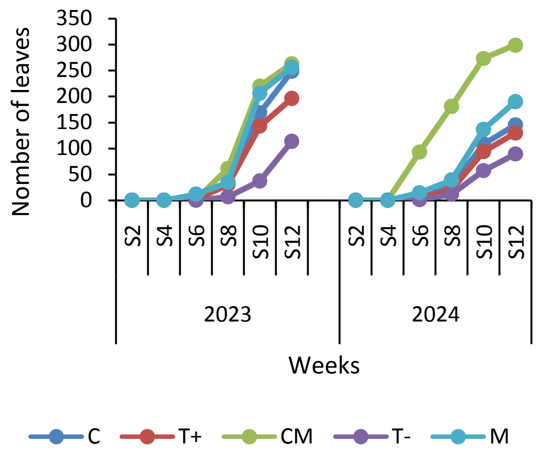

Figure 2. Dynamics of leaf number *Dioscorea rotundata* Poir. as a function of fertilisers and time. C: compost; T+: positive control (NPK); CM: compost-mycorrhiza; T-: negative control (without fertilizer), M: mycorrhiza S: week

Stem diameter: Changes in stem diameter vary as a function of amendment and time (Figure 3). A rapid increase stem diameter was noted from week 4 after planting to week 8, after which it slowed down in both cropping seasons. At week12, there was a significant difference between stem diameters for all amendments in both cropping season. The compost-mycorrhiza mixture had the best stem diameter in both cropping season (11.58 ± 0.13 mm; 11.71 ± 0.02 mm) and the smallest stem diameter was obtained on treatment without any of the fertilizer (7.28 ± 0.18 mm; 8 ± 0.41 mm). These observations corroborate the work of Soro *et al.* [31] and Agbede *et al.* [32], who all highlighted the beneficial effect of organic amendments on yam growth characteristics. This is because organic matter promotes the uptake of mineral elements, particularly nitrogen, by plants, which improves the efficiency with which these fertilisers are used [33].

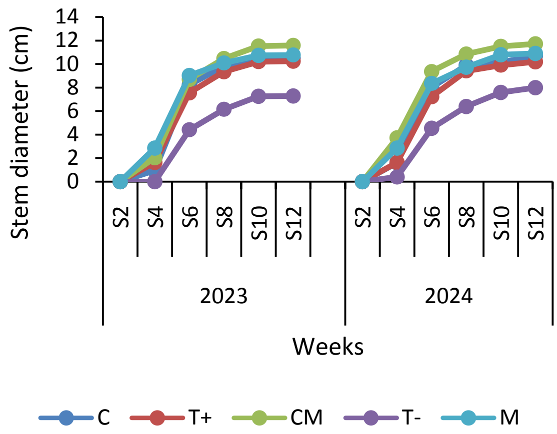

Figure 3. Changes over time in neck diameter of *Dioscorea rotundata* Poir. under different treatments. C: compost; T+: positive control (NPK); CM: compost-mycorrhiza; T-: negative control (without fertilizer), M: mycorrhiza S: week

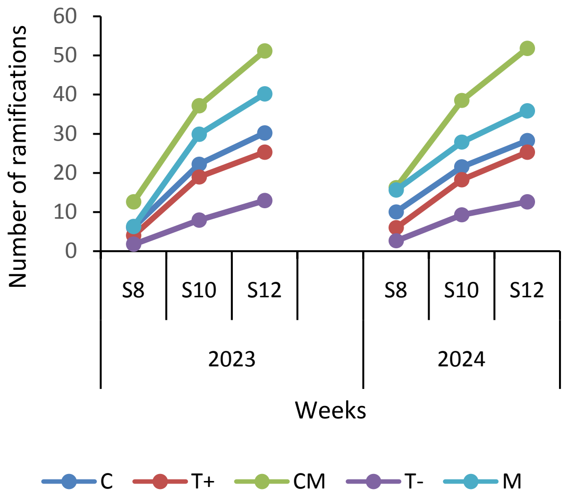

Figure 4. variation over time in the number of branches of *Dioscorea rotundata* Poir. under different fertilisers. C: compost; T+: positive control (NPK); CM: compost-mycorrhiza; T-: negative control (without fertilizer); M: mycorrhiza; S: week

Vine branching: The results show that branching varies according to the type of amendment in all weeks.

The compost-mycorrhiza mixture showed a higher number of ramifications at week 12 in 2023 cropping season (51 branchings). The same trend was observed in 2024 cropping season. The effectiveness of the compost-mycorrhiza fertiliser can be attributed to two main factors: organic fertilisers that promote rapid release of mineral elements into the soil, which directly benefits the crops [34]; arbuscular mycorrhizal fungi that improve nutrient uptake, optimise nutrition, stimulate growth and increase plant production [35]. Furthermore, the lowest branching observed on plant without any of the fertilizer over the two cropping season is an evidence of poor soil health. According to Suja [36], additional fertiliser resulted in increasing the agronomic characteristics of *D. rotundata*.

Mycorrhization

Percentage colonisation

Results in Figure 5 indicate the mycorrhization frequency of *D. rotundata* during the 2023 and 2024 cropping season, under different amendments: compost-soil mixture in the 2:3 ratio, inoculation with 30g mycorrhiza, a compost-soil mixture in the 2:3 ratio with 30g mycorrhiza, a positive control with 30g NPK (10:10:30) and a negative control without any of the fertilizer.

In 2023 cropping season, the mycorrhiza significantly stimulated (P≤0.001) a higher frequency of mycorrhization compared with the other amendments, making it possible to classify the fertilisers into four categories: the highest mycorrhization was obtained from mycorrhiza with 60.66%, medium mycorrhization with compost-soil mixture in the 2:3 ratio with 30g mycorrhiza (53.66%) and negative control (49%), intermediate mycorrhization with compost-soil mixture in the 2:3 ratio (35.66%), and the lowest mycorrhization was recorded in the NPK (27.33%). In 2024 cropping season, this trend persisted, with a significant difference (p<0.0001) in favour of the mycorrhiza.

These results are consistent with those of Djital [37] and Tchabi *et al.* [38], confirming that yam is a plant that can be mycorrhized. The frequency of mycorrhization in this study ranged from 21.66% to 63.66%, in agreement with the work of Tchabi *et al.* [39], who reported yam mycorrhization of between 10% and 86.66% in the central region of Togo. This study also revealed that the lowest mycorrhization values were recorded with the compost-soil mixture in the 2:3 ratio and NPK treatments, suggesting that excessive fertiliser application could inhibit mycorrhization, as observed by Haro *et al.* [40] and Maryamou *et al.* [41].

Mycorrhization intensity

The results in Figure 6 present a comparison of mycorrhization intensity values under different amendments (compost-soil mixture in the 2:3 ratio, inoculation with 30g mycorrhiza, a compost-soil mixture in the 2:3 ratio with 30g mycorrhiza, a positive control with 30g NPK (10:10:30) and a negative control without any of the fertilizer) of *Dioscorea rotundata* Poir. in 2023 and 2024 cropping season. The analysis of variance shows a highly significant difference (P≤0.001) between the mean mycorrhization intensities for all types of amendment in 2023 cropping season: mycorrhiza (31.5%), compost-soil mixture in the 2:3 ratio + mycorrhiza (30.33%), negative control (27.5%), compost-soil mixture in the 2:3 ratio (11.83%) and NPK (9.5%). In 2024 cropping season, the same trend was maintained, with high mycorrhization intensity values for the mycorrhiza compost-soil mixture in the 2:3 ratio + mycorrhiza and negative control without any of the fertilizer treatments, compared with the NPK and compost-soil mixture in the 2:3 ratio treatments. Fertilisation significantly reduced natural mycorrhisation of yam in both cropping season. According to Bossou *et al.* [42], phosphorus could limit the establishment of mycorrhizal symbiosis at both very high and low concentrations. In the event of low phosphorus availability, the plant increases its association with arbuscular mycorrhizal fungi to improve its access to this resource, leading to high mycorrhization and better health and production [43]. Maryamou *et al.* [41] have shown that the host plant can benefit from a controlled supply of compost and mycorrhiza, as shown by the average mycorrhization intensity under the following.

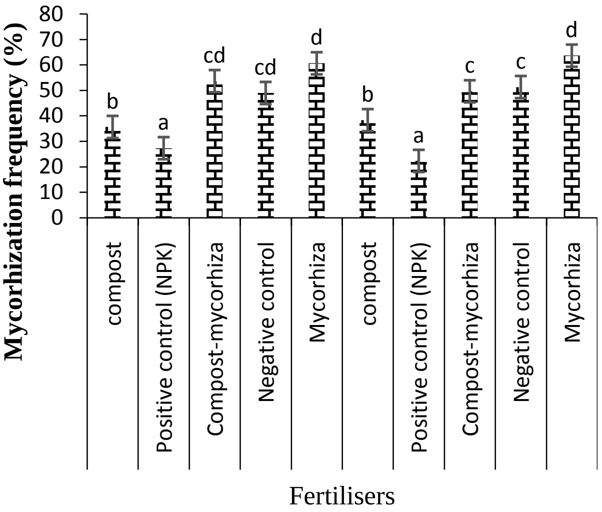

Figure 5. Mycorrhization frequency of *Dioscorea rotundata* Poir. under different fertilisers. For a given cropping season, bars with the same letter are not significantly different at the 0.05% probability threshold

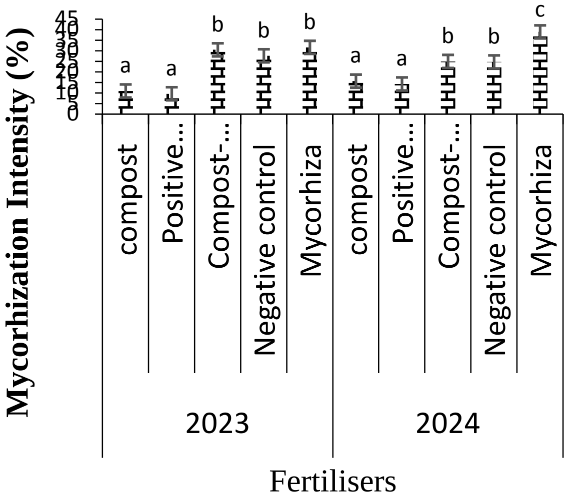

Figure 6. Mycorrhization intensity of *Diocorea rotundata* Poir. yam varietie under different fertilisers. For a given cropping season, bars with the same letter are not significantly different at the 0.05% probability threshold

Influence of fertilisation on yield at harvest

The response of amendments application on fresh tuber yield over the two cropping seasons is presented in Figure 7. In 2023 cropping season, the highest yields were recorded in the compost + mycorrhiza (34.33 ± 0.66 t/ha), compost (27.16 ± 0.25 t/ha) and mycorrhiza (21.33 ± 0.11 t/ha) compared with the negative control (11 ± 0.2 t/ha). Analysis of variance showed a significant difference between plants from different fertilisers ($P \leq 0.001$). The same treatments (compost + mycorrhiza (33.43 ± 0.68 t/ha), compost (28 ± 26 t/ha), mycorrhiza (20.86 ± 0.07 t/ha)) proved better in 2024 cropping season compared with the negative control (11.5 ± 0.15 t/ha). In fact, when used in the right proportions, compost not only provides essential nutrients, but also favourable conditions for mycorrhiza, resulting in a significant improvement in yields. These results are in line with the work of Droh *et al.* [34], who demonstrated that combining compost with CMAs improves crop performance. Maryamou *et al.* [41] also confirmed this observation by showing that ratio of 2:3 compost/soil, combined with 30g of mycorrhiza, resulted in a higher yield per hectare compared with the use of NPK.

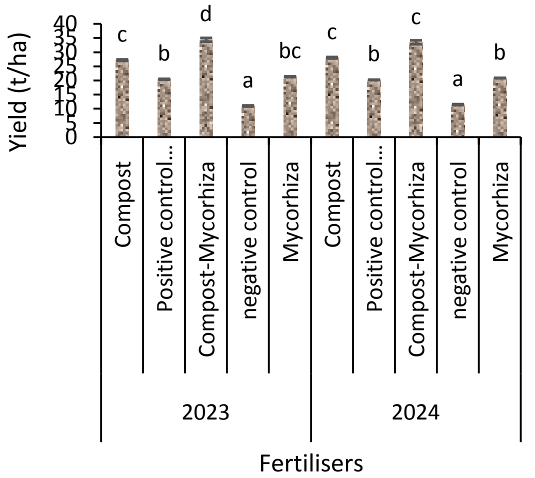

Figure 7. Effectiveness of fertilisers on the yield per hectare of *Diocorea rotundata* Poir. yam varietie. For a given cropping season, bars with the same letter are not significantly different at the 0.05% probability threshold.

4. Conclusion

As the outcome of this study that was conducted to assess the effect of mycorrhiza and compost on the growth parameters and yield of *Dioscorea rotundata* Poir. in the locality of Wakwa, 2:3 compost+mycorrhiza mixture has revealed to improve better growth and yield of fresh tubers. Consequently, this treatment could be recommended for sustainable cultivation of *Dioscorea rotundata* Poir.in the study area.

Conflict of Interest

The authors are hereby declaring that no conflict of interest exists.

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