American Journal of Plant Sciences, 2023, 14, 464-471
https://www.scirp.org/journal/ajps
ISSN Online: 2158-2750
ISSN Print: 2158-2742

Efficacy of Mycorrhizae Based Manure on the Vegetative Growth of Rice Grown within Bauchi State, Nigeria

Muhammad Auwal Ladan*, Fatima Aliyu Deba, Muhammad Muhammad

Department of Biological Sciences, Abubakar Tafawa Balewa University (ATBU), Bauchi, Nigeria
Email: *maladan@atbu.edu.ng

How to cite this paper: Ladan, M.A., Deba, F.A. and Muhammad, M. (2023) Efficacy of Mycorrhizae Based Manure on the Vegetative Growth of Rice Grown within Bauchi State, Nigeria. *American Journal of Plant Sciences*, **14**, 464-471.
https://doi.org/10.4236/ajps.2023.144030

Received: January 21, 2023
Accepted: April 22, 2023
Published: April 25, 2023

Abstract

Background: Rice is one of the staple crops in the African continent for its ability to give maximum yields which can help to achieve food security under the sustainable development goals (SDGs); to those effects, the incessant use of inorganic fertilizer has been employed which proved to have devastating effect in the environment and the ecosystem at large. Therefore, the thirst for an alternative method to ensure bumper production of rice cannot be overemphasized so as to prevent soil alteration and environmental damage. **Objective:** This study aimed at determining the efficacy of mycorrhizae-based manure on the vegetative growth of rice as compared to inorganic fertilizer and its sustainability. **Methods:** Soil samples were collected from seven (7) locations (M1 - M7). Mycorrhiza were isolated from the soils and mass produced, mixed with organic waste to form manure (biofertilizer) and were applied at concentrations of 50 g, 100 g and 150 g to the potted rice in tree (3) replicates. Growth parameters observed were plant height, girth diameter, leaf broadness and leaf number. **Results:** The result revealed mycorrhizal spore count ranging from 1.7×10^7 - to 4.1×10^7 across the locations. The mycorrhizae-based manure gives the highest plant height of 45.33 cm as compared with the least plant height of 18.5 cm from the inorganic fertilizer. Furthermore, the biofertilizer gives a positive influence on the other parameters observed in comparison with the inorganic fertilizer. Statistical analysis shows that, the means of all the parameters except for leaf numbers were significantly different at $p \leq 0.05$ across the sampling locations. **Conclusions:** Mycorrhizae-based manure proves to be an effective replacement of inorganic fertilizer that can boost rice production at a cheaper cost.

Keywords

Biofertilizer, Mycorrhizae, Rice, Agriculture, Rhizosphere

1. Introduction

Agriculture is one of the most important factors contributing to the economic growth of Nigeria in the 70s. Nigeria has 75 percent of its land suitable for agriculture, but only 40% is cultivated [1]. Agriculture alters the natural cycling of nutrients in soils. Intensive cultivation and harvesting of crops for human or animal consumption can effectively deplete the soil of essential plant nutrients. To maintain soil fertility for sufficient crop yields, soil amendments are typically required. In the ancient times, farmers nourished their fields with manure (animal dungs), charcoal, ash and lime ($CaCO_3$) to improve soil fertility [2].

In order to reap a better harvest, farmers inoculate the soil with fertilizers which comes in two types either chemical or bio-fertilizers. Agricultural fertilizers are essential to enhance proper growth and crop yield. Recently farmers have been using chemical fertilizers for quicker and better yield [3]. The increasingly high inputs of chemical fertilizers, have not only left soils degraded, polluted and less productive but have also posed severe health and environmental hazards. Organic farming methods (such as the use of biofertilizers) would solve these issues and make the ecosystem healthier [4].

Naturally grown biofertilizers do not only gives a better yield, but are also harmless to humans. Nearly 22 million hectares of land are now cultivated organically. Organic cultivation represents less than 1% of the world's conventional agricultural production and about 9% of the total agricultural area [5]. There are 17 essential elements required for proper plant growth. The dearth of any of these essential nutrients can result in severe damage to the crop health. Of the mineral elements, primary macronutrients (Nitrogen, Phosphorous and Potassium) are needed in greatest quantities and are in short supplies in agricultural soils [2] [5]. Micronutrients or trace elements are needed in very small amounts and can be toxic to plants in excess. Silicon and Sodium are sometimes considered essential plant nutrients but due to their ubiquitous presence in soils, they are never in short supply [5] [6].

A biofertilizer is an organic product containing a specific microorganism in concentrate form, which is derived either from plant roots or from the rhizosphere zones of the soils [7] [8]. These bio-inputs or bioinoculants improve plant growth and yield [4]. Biofertilizers contain living cells of different microorganisms that have the ability to mobilize nutritionally important elements from non-usable forms through biological processes. It can also be referred to as any substance containing living microorganism that colonizes in the rhizosphere or the interior of the plant [9]. Biofertilizers have shown great potential as supplementary, renewable and environmentally friendly sources of plant nutrients and are important component of Integrated Nutrient Management (INM) and Integrated Plant Nutrition System (IPNS) [10].

Biofertilizers play a very significant role in improving soil fertility by fixing atmospheric nitrogen both in association with plant roots and without it, solubilize insoluble soil phosphates and produce plant growth substances in the soil

[2]. The incorporation of biofertilizers plays major role of improving soil fertility, yields attributed characters and thereby increased final yield, also increases soil biota. The role and importance of biofertilizers in sustainable crop production has been reviewed by many authors [11] [12]. Application of biofertilizers is the only option to improve soil organic carbon for the sustenance of soil quality and future agricultural productivity [13]. Organic farming is the system of production that tends to skip the use of synthetic fertilizers, pesticides and other additives, but relies heavily on biofertilizers and biopesticides.

Most biofertilizers belong to either nitrogen fixing or phosphate solubilizing microorganisms. Nitrogen fixing microorganisms fixes atmospheric nitrogen to the soils in forms which is readily absorbable by the plants [2]. While phosphate solubilizing microorganisms secretes organic acids which enhance the uptake of phosphorus by the roots of the plants by dissolving rock phosphate in the soils. Others are phosphate mobilizers and zinc solubilizers. These microorganisms include both bacteria (*Azotobacter*, *Azosprillum*, *Rhizobium* etc.) and fungi (mainly mycorrhizal fungi) [2].

Arbuscular Mycorrhizae (AM) plays a crucial role in plant nutrient uptake, water relations, ecosystem establishment, plant diversity, and the productivity of plants. Mycorrhizae send out extensive networks of fine thread which facilitate uptake of limiting nutrients to include phosphorous, nitrogen, several micronutrients to the plant [14] and are capable of absorbing inorganic P either from the soluble P pools in the soil or from insoluble forms such as rock phosphates via localized pH alterations or by producing organic acid anions which act as chelating agents [15]. Furthermore, AM fungi can also have a direct effect on the ecosystem, as they improve the soil structure and aggregation and drive the structure of plant communities and productivity [3] [4] [16].

2. Materials and Methods

2.1. Collection of Soil Samples

Soils were collected in Bauchi State within seven local governments in an open field described by Bauchi State Agricultural Development Program (BSADP) all within Bauchi metropolis namely; Dass (M1), Giade (M2), Tafawa Balewa (M3), Darazo (M4), Ganjuwa (M5), Jama'are (M6) and Bauchi (M7). Fifty grams of soil samples containing mycorrhiza fungi were obtained using a hand shovel and placed in a polythene bag from each local government and transported to the laboratory for further analysis.

2.2. Identification of AM Fungi

Identification to genus level is sufficient to determine whether or not a specimen is mycorrhizal. Identification of AM fungi was carried out in two ways:

2.2.1. Macroscopic Identification

Soil specimens collected were physically observed and accurately described using colour charts of "the Mathew handbook of colour" [17].

2.2.2. Microscopic Identification

Heterotrophic counts were made after incubation at room temperature, some fungi were observed to have distinctive features while others lack keys for identification in the field guide. Further microscopy through wet preparations of the pure cultures of the specimens is needed, to carefully examine the hyphal structures and nature of spores within the sporangia as compared to mycorrhizal fungi identification atlas, in order to identify the mycorrhiza to specie level. These can be confirmed by molecular characterization if the specimens [18].

2.3. Mass Production of Mycorrhizal Fungi

Twenty grams of soil samples from each local government are poured into a 25 L container, containing 2 L of microbial growth enhancer (molasses), aerator placed within the closed 25 L for proper mixing and left for about 4 - 5 days as described by [17].

2.4. Local Manure Production

Manure production was carried out as described by [17]. 25 kg of chicken dunk was mixed with the 25 L content and mixed with 10 kg of soil. The mixture is left for the period of 2 - 3 weeks in a moist condition to enable mycorrhizae extension.

2.5. Growing of Rice Seeds

Two-third (2/3) of the pots were filled with normal sand and the produced manure containing mycorrhizal fungi were introduced into the various pots to fill the remaining 1/3 of the pots. The seeds were sown and nurtured for 2 weeks before transplanted in an open filed using a (2 × 2) meter complete block design [19] [20].

2.6. Application of Fertilizers

Mycorrhizae-based biofertilizer and synthetic fertilizer were applied in the early hours of the day between 6.00 am - 7.00 am. 50 g, 100 g and 150 g of the biofertilizer were used. While the synthetic fertilizer was applied twice at the same rate of 50 g, 100 g and 150 g [2].

2.7. Recording of Growth Parameters

Growth parameters such as: Plant height (cm) using a meter-rule (starting from the surface of the soil to the tip of the flag leaf), Number of leaves, Girth diameter (cm) using a thread placed round the mid portion of the culm and then placed on a meter-rule and Leaf broadness (cm) using a meter-rule were recorded to determine the growth and development of the rice crop treated with mycorrhiza biofertilizer as compared with synthetic fertilizer [2].

3. Results and Discussions

The spore count across the sampling areas ranges from 1.7×10^7 - to 4.1×10^7

with Dass (M1) having the highest count while Darazo (M4) had the least count. Similar range was reported by [2], who observed spore count ranging from 1.6×10^7 - 3.8×10^7 in the same sampling locations. Spore population within the soil rhizosphere could be attributed to the soil richness, topography and level of disturbance within the sampling locations (**Table 1**).

Results of this study revealed the effects of mycorrhizae base manure (organic) and inorganic fertilizer on the vegetative growth of rice across the sampling locations. The results show that mycorrhizae-based manure treated rice (M1T1) collected from Dass had the highest plant height (45.33 cm), followed by M3T1, M1T2 and M2T1 with 44.8 cm, 41.47 cm and 41.20 cm respectively. While the least plant height (18.5 cm) was recorded on the inorganic fertilizer treated rice (F4) collected from Darazo. The statistical analysis (MANOVA) revealed significant difference between the mean plant heights across the sampling locations at $P \leq 0.05 = 0.000$ (**Table 2**). This result agrees with the reports of [3] and that of [2], who observed that organic manure enhances plant height in maize.

Furthermore, the result revealed that mycorrhizae-based manure treated rice M3T1 gotten from Tafawa Balewa had the highest girth diameter of 2.03 cm followed by M7T1, M4T1 and M4T2 with 1.97 cm, 1.87 cm and 1.83 cm respectively. While the least girth diameter of 0.57cm, was observed on the inorganic fertilizer treated rice F4 collected from Darazo. Also, MANOVA revealed significant difference between the mean girth diameter across the sampling locations at $P \leq 0.05 = 0.000$ (**Table 2**). This is concurrent with work of [2] who reported increase girth with organic manure treatment in maize plant.

On leaf broadness the result revealed that, the highest leaf broadness of 1.23 cm was observed on the mycorrhizae-based manure treated rice M1T3, followed by M2T1 and M3T1 with leaf wideness of 1.17 cm and 1.13 cm respectively. Whereas, the least leaf wideness of 0.33 cm was seen on the inorganic fertilizer treated rice F6. The result is in agreement with the findings of [4] who reported increased growth as a result of organic manure applications. The analysis conducted shows that, there is significant difference between the mean leaf broadness across the sampling stations at $P \leq 0.05 = 0.001$ (**Table 2**).

More so, the result of this study recorded highest number of leaves (4) on both mycorrhizae-based manure treated rice M3T1 and inorganic fertilizer treated rice F1 and F4 respectively. While the least number of leaf (1) was recorded on the control C4. This is in contrast with work of both [3] and that of [2] who only recorded highest number of leaves on the organic fertilizer treated maize.

Statistical analysis shows that there is no significant difference in the mean number of leaves across the sampling stations at $P \leq 0.05 = 0.327$ (**Table 2**).

Table 1. Spore counts of prepared sample gotten from different Sampling Locations within Bauchi state.

	Sampling Locations						
	M1 (Dass)	M2 (Giade)	M3 (T|Balewa)	M4 (Darazo)	M5 (Ganjuwa)	M6 (Jama'are)	M7 (Bauchi)
Spore count	1.7×10^7	2.3×10^7	1.5×10^7	2.1×10^7	3.1×10^7	3.8×10^7	1.6×10^7

Table 2. Mean Effects of both Mycorrhizae-based Manure and Inorganic Fertilizer of the vegetative Growth of *Oryza sativum* (Rice) Sampled within Bauchi State.

Cultivars	Plant Height	Girth Diameter	Leaf Broadness	No. of Leaves
M1T1	^{a}45.33 ± 2.08	^{b}1.63 ± 0.21	^{a}1.23 ± 0.25	^{abc}3.00 ± 1.00
M1T2	^{ab}41.20 ± 5.50	^{a}1.70 ± 0.17	^{a}1.23 ± 0.15	^{abc}3.00 ± 1.15
M1T3	^{c}35.80 ± 10.39	^{b}1.50 ± 0.85	^{a}1.27 ± 0.21	^{abc}3.00 ± 1.00
M2T1	^{ab}41.47 ± 1.39	^{b}1.50 ± 0.27	^{b}1.17 ± 0.15	^{abc}3.00 ± 0.00
M2T2	^{b}38.70 ± 6.69	^{b}1.67 ± 0.64	^{d}1.00 ± 0.00	^{c}2.00 ± 0.00
M2T3	^{ab}40.43 ± 2.99	^{b}1.60 ± 0.53	^{a}1.23 ± 0.25	^{abc}3.00 ± 0.00
M3T1	^{ab}44.80 ± 2.81	^{a}2.03 ± 0.45	^{b}1.13 ± 0.12	^{a}4.00 ± 1.00
M3T2	^{ab}40.37 ± 9.10	^{ab}1.73 ± 0.15	^{b}1.10 ± 0.10	^{abc}3.00 ± 1.00
M3T3	^{c}37.37 ± 3.00	^{c}1.20 ± 0.00	^{c}1.03 ± 0.06	^{abc}3.00 ± 0.58
M4T1	^{g}26.77 ± 2.40	^{a}1.87 ± 0.23	^{c}1.03 ± 0.25	^{abc}3.00 ± 1.00
M4T2	^{f}28.83 ± 2.02	^{a}1.83 ± 0.06	^{d}1.00 ± 0.00	^{c}2.00 ± 1.00
M4T3	^{e}29.90 ± 6.37	^{b}1.63 ± 0.32	^{c}1.03 ± 0.06	^{d}2.00 ± 0.00
M5T1	^{d}32.90 ± 4.62	^{ab}1.73 ± 0.25	^{d}1.00 ± 0.00	^{abc}3.00 ± 1.00
M5T2	^{f}28.20 ± 1.20	^{c}1.47 ± 0.46	^{d}1.00 ± 0.00	^{c}2.00 ± 1.00
M5T3	^{e}29.87 ± 4.46	^{b}1.60 ± 0.44	^{e}0.93 ± 0.12	^{c}2.00 ± 0.58
M6T1	^{c}37.00 ± 0.46	^{a}1.87 ± 0.15	^{b}1.07 ± 0.12	^{abc}3.00 ± 1.00
M6T2	^{c}35.40 ± 0.53	^{a}1.80 ± 0.20	^{d}1.00 ± 0.00	^{c}2.00 ± 0.00
M6T3	^{d}32.10 ± 4.43	^{a}1.77 ± 0.21	^{b}1.13 ± 0.23	^{abc}3.00 ± 1.00
M7T1	^{e}29.47 ± 2.24	^{a}1.97 ± 0.06	^{b}1.10 ± 0.17	^{c}2.00 ± 0.00
M7T2	^{b}38.60 ± 1.06	^{a}1.77 ± 0.31	^{d}1.00 ± 0.00	^{abc}3.00 ± 1.00
M7T3	^{c}36.57 ± 0.51	^{a}1.77 ± 0.40	^{d}1.00 ± 0.00	^{b}3.00 ± 0.00
F1	^{d}31.20 ± 1.57	^{c}1.40 ± 0.20	^{e}0.90 ± 0.17	^{a}4.00 ± 1.00
F2	^{f}22.80 ± 2.98	^{d}0.83 ± 0.29	^{b}1.10 ± 0.20	^{abc}3.00 ± 1.00
F3	^{f}26.17 ± 1.16	^{d}1.07 ± 0.06	^{b}1.10 ± 0.26	^{abc}3.00 ± 1.00
F4	^{g}18.50 ± 1.50	^{d}0.57 ± 0.21	^{e}0.47 ± 0.06	^{a}4.00 ± 1.53
F5	^{f}21.00 ± 1.00	^{d}0.60 ± 0.10	^{e}0.40 ± 0.10	^{c}2.00 ± 1.00
F6	^{g}19.60 ± 1.77	^{d}0.80 ± 0.36	^{e}0.33 ± 0.15	^{c}2.00 ± 1.00
F7	^{f}27.30 ± 2.07	^{b}1.50 ± 0.36	^{b}1.17 ± 0.21	^{abc}3.00 ± 1.00
C1	^{f}27.70 ± 1.85	^{c}1.37 ± 0.55	^{e}0.90 ± 0.17	^{c}2.00 ± 0.58
C2	^{f}26.57 ± 1.25	^{c}1.33 ± 0.58	^{b}1.13 ± 0.25	^{c}2.00 ± 0.58
C3	^{f}25.27 ± 1.30	^{c}1.30 ± 0.61	^{e}0.83 ± 0.15	^{abc}3.00 ± 1.00
C4	^{f}24.03 ± 1.00	^{d}0.87 ± 0.15	^{e}0.40 ± 0.10	^{d}1.00 ± 0.58
C5	^{f}25.40 ± 0.96	^{c}1.23 ± 0.32	^{d}1.03 ± 0.15	^{abc}3.00 ± 1.00
C6	^{f}25.00 ± 2.00	^{c}1.30 ± 0.61	^{d}1.03 ± 0.25	^{abc}3.00 ± 1.00
C7	^{f}22.90 ± 1.74	^{c}1.30 ± 0.61	^{c}1.07 ± 0.31	^{c}2.00 ± 1.00
MANOVA based on treatment across the sampling stations ($P \leq 0.05$)	0.000	0.000	0.001	0.327

4. Conclusion

The results revealed mycorrhizae-based organic fertilizer efficacy on the increased vegetative growth phases of rice plant, its low cost of production and it had been ecofriendly with little or no damage on soil composition. Furthermore, it can be utilized for the colonization and propagation of desired vegetation in a natural environment and significant impact in habitat restoration efforts. Agriculture might also be positively impacted by shorter crop cycles which in turn will contribute to achieve sustainable agriculture in Nigeria [21].

Acknowledgements

The authors are grateful to Abubakar Tafawa Balewa University, Bauchi and IBR TETFUND REF/ATBU/DVC/Acad/12 for their financial support and also grateful to Department of Biological Sciences for providing us with the work bench and their expert support. Lastly, it's a tribute to our late mentor Dr. Muhammad Muhammad who initiated this research.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Ayodele, O.S., Obafemi, F.N. and Ebong, F.S. (2013) Challenges Facing the Achievement of the Nigeria Vision. *Global Advanced Research Journal of Social Sciences*, **27**, 143-157.

[2] Deba, F.A., Isma'il, S., Sahal, M.R. and Okpanachi, I.Y. (2019) Evaluation of Economic Importance of Locally Produced Manure over Inorganic Fertilizer for Maize Production: Vegetative Performance and Cost Implication. *American Journal of Molecular Biology*, **9**, 64-74. https://doi.org/10.4236/ajmb.2019.92006

[3] Okpanachi, I.Y. and Sahal, R.M. (2018) The Mycorrhiza Initiative: A Better Way to Manure Production for Sustainable Agriculture. Abubakar Tafawa Balewa University, Bauchi.

[4] Okpanachi, I.Y. and Sahal, R.M. (2018) The Mycorrhiza Initiative: A Better Way to Manure Production for Sustainable Agriculture. https://www.academia.edu/37072691/

[5] Javaid, A. (2009) Arbuscular Mycorrhizal Mediated Nutrition in Plants. *Journal of Plant Nutrition*, **32**, 1595-1618. https://doi.org/10.1080/01904160903150875

[6] Parikh, S.J. and James, B.R. (2012) Soil: The Foundation of Agriculture. *Nature Education Knowledge*, **3**, 2.

[7] Chen, J.H. (2006) The Combined Use of Chemical and Organic Fertilizers and/or Biofertilizer for Crop Growth and Soil Fertility. *International Workshop on Sustained Management of the Soil Rhizosphere System for Efficient Crop Production and Fertilizer Use*, Bangkok, 16-20 October 2006.

[8] Gupta, A. and Sen, S. (2013) Role of Biofertilizers and Biopesticides for Sustainable Agriculture. Scholar.google.com

[9] Muraleedharan, H., Seshadri, S. and Perumal, K. (2010) Biofertilizer (Phosphobate-

ria). Shri Murrugapa Chettiar Research Centre, Chennai.

[10] Raghuwanshi, R. (2012) Opportunities and Challenges to Sustainable Agriculture in India. *NEBIO*, **3**, 78-76.

[11] Katyal, J.C., Das, S.K., Korwar, G.R. and Osman, M. (1994) Technology for Mitigation Stresses: Alternate Land Uses. In: Virmani, S.M., Katyal, J.C., Eswaran, H. and Abrol, I.P., Eds., *Stressed Ecosystems and Sustainable Agriculture*, Oxford and IBH Publishing Co. Pvt. Ltd, New Delhi, 291-305.

[12] Wani, S.P. and Lee, K.K. (1995) Microorganisms as Biological Inputs for Sustainable Agriculture. In: Thampan, P.K., Ed., *Organic Agriculture*, Peekay Tree Crops Development Foundation, Cochin, 39-76.

[13] Ramesh, P. (2008) Organic Farming Research in M.P. Organic Farming in Rainfed Agriculture. Central Institute for Dry Land Agriculture, Hyderabad, 13-17.

[14] Leifheit, E.F., Veresoglou, S.D., Lehmann, A., Morris, E.K. and Rillig, M.C. (2014) Multiple Factors Influence the Role of Arbuscular Mycorrhizal Fungi in Soil Aggregation—A Meta-Analysis. *Plant and Soil*, **374**, 523-537. https://doi.org/10.1007/s11104-013-1899-2

[15] Lombin, G. (1988) Soil Science. In: Youdeowei, A., Ezedinma, F.O.C. and Onazi, O.C., Eds., *Introduction to Tropical Agriculture*, Longman Group, London, 34-87.

[16] Pennisi, E. (2004) The Secret Life of Fungi. *Science*, **304**, 1620-1622. https://doi.org/10.1126/science.304.5677.1620

[17] Rillig, M.C. and Mummey, D.L. (2006) Mycorrhizas and Soil Structure. *New Phytologist*, **171**, 41-53. https://doi.org/10.1111/j.1469-8137.2006.01750.x

[18] Rillig, M.C., Aguilar-Trigueros, C.A., Bergmann, J., Verbruggen, E., Veresoglou, S. D. and Lehmann, A. (2015) Plant Root and Mycorrhizal Fungal Traits for Understanding Soil Aggregation. *New Phytologist*, **205**, 1385-1388. https://doi.org/10.1111/nph.13045

[19] Singh, L. (1987) Soil Fertility and Crop Yield in Savanna. *Proceedings of an International Drought Symposium*, Nairobi, 19-23 May 1986, 417-427.

[20] Singh, A., Carsky, R.J., Lucas, E.O. and Danshiell, K. (2001) Grain Yield Response of Maize to Previous Crop and Residue Management in the Guinea Savanna of Nigeria. *Proceedings of the Regional Maize Workshop*, Cotonou, 14-18 May 2001, 214-224.

[21] Verheye, W. (2010) Growth and Production of Maize: Traditional Low-Input Cultivation. In: Verheye, W.H., Ed., *Land Use*, *Land Cover and Soil Sciences*, UNESCO-EOLSS Publishers, Oxford, 1-24. http://www.eolss.net