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Bioremediating role of effective microbes (Ems): Improving the vegetative growth response of eggplants using organic fertilizer with ems and laundry waste utilization technology

Jomar L. Aban*, Analyn V. Sagun, Jenilyn A. Asirot

[1]*Department of Biochemistry and Food Technology, Nangui Abrogoua University, Abidjan, Côte d'Ivoire*

[2]*Department of Biochemistry-Genetics, Peleforo Gon Coulibaly University, Korhogo, Côte d'Ivoire*

[3]*Formerly Laboratory of Food Technology, National Center for Agronomic Research, Abidjan, Côte d'Ivoire*

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Abstract

The indiscriminate use of synthetic fertilizer disrupts the natural ecosystem. This conventional way of agricultural production is still prevalent because the negative environmental impact is shrouded by the temporary return of investment by farmers and agriculturists. However, the negative consequences in the soil due to unsystematic use of chemical fertilizers will become evident in a few years. This present research attempts to circumvent this deleterious agricultural scheme by using beneficial microorganisms bioactivated organic fertilizers, instead of using the synthetic ones. The effective microorganisms present in the organic fertilizer are expected to create a bioremediating effect when laundry wastes are used to water eggplant. A true experimental design was utilized using randomized complete block design. Two hundred ten eggplant seedlings were grown in pots and organic fertilizers with effective microbes were applied. These eggplants were watered with different levels of laundry waste and were allowed to grow. Results of the present study show the bioremediating effect of beneficial microbes in the organic fertilizers used. Eggplants grown in soils with organic fertilizer containing effective microbes were significantly taller to those eggplants that received chemical fertilizer treatments, even if these eggplants were watered with laundry waste. The effective microbes potentially converted the toxic materials found in laundry waste into useful products or nutrients that are readily assimilated by the eggplants causing the plants to grow better than the control groups. In conclusion, effective microbes found in organic fertilizers have bioremediating role to improve the vegetative growth response of eggplants. Therefore, laundry waste can be used to water eggplants in soils amended with organic fertilizers with effective microbes.

* **Corresponding Author:** Jomar L. Aban ✉ jaban@dmmmsu.edu.ph

Introduction

Agriculture is vital for food security. It is a direct measure of a country's livability and sustainability. Though industrialization and technological advancement are essential markers of development, sustainable agriculture is necessary. The judicious way of land management and agriculture ensures that the ecosystem of the future is not compromised by potential exploitation of the present resources just to succor the rapidly growing population. Another global problem is the alarming impact of climate change on the build-up of soil salinity (Mukhopadhyay *et al.*, 2021). Due to soil health concerns caused by climate change, farmers are forced to indiscriminately use synthetic fertilizer to keep up with their agronomic crops' productivity. The problem escalates rapidly because the indiscriminate use of fertilizer creates water pollution (Singh *et al.*, 1987) and significantly degrade the environment (Rahman and Zhang, 2018).

To slow down the imminent destruction of the natural environment caused by unsustainable agriculture, scientists have promoted the use of effective microorganisms, and the utilization of organic fertilizers.

Effective microorganisms are a mixture of naturally occurring beneficial microbes that are utilized to enhance crop production (Olle and Williams, 2013). Scientists have been consistently promoting beneficial and effective microorganisms for a sustainable agriculture and environment (Higa and Parr, 1994). Effective microorganisms can do ecologically significant processes such manure bio-stabilization to improve its agronomic value (Hidalgo *et al.*, 2022), use of residual sulfur-enhanced biochar to improve soil property and plant growth (Abd El-Mageed *et al.*, 2020), improving soil quality in the saline-alkali soils (Cui *et al.*, 2021), as well as increasing the growth and yield of vegetables (Zhang *et al.*, 2021).

The environment, the cultural method, and their interaction will lead to better discernment in the vegetative growth of eggplants (Abney and Russo, 1997). The soil macronutrients such as nitrogen, phosphorus, and potassium have significant effect on the growth and yield of eggplant. Nitrogen strongly influences vegetative and reproductive growth of eggplants under field conditions (Aminifard *et al.*, 2010). Aside from nitrogen levels, vegetative growth and yield components of eggplant are also influenced by irrigation intervals (Mirdad, 2011), and water use efficiency (Amiri *et al.*, 2012). The vegetative responses of agronomic plants are evident manifestation of their health. These parameters also reflect that the plant can sip in quality and necessary nutrients below the ground. Thus, an indirect reflection of soil's health.

Microorganisms play a pivotal role in maintaining soil health (Shah *et al.*, 2021), decomposition, recycling of materials and plant growth and development (Prasad *et al.*, 2021). Despite the known significance of microorganisms in the agricultural sector, there is still much to learn about them. For instance, symbiotic fungi are known to influence their host plants. However, at present, little is known about their diversity, taxonomy (Aban *et al.*, 2017a; Aban, 2019) and their specific influence to their host. According to Aban (Aban, 2019) only 75 thousand species of fungi are well studied in comparison to their total estimated diversity of around 1.5 million species. Aside from fungi, bacteria are as equally important; however, their diversity, taxonomy and soil functions are still underestimated. The actual diversity of bacteria is 170 times higher than the bacterial isolates collected from the same soil (Torsvik *et al.*, 1996). These data show that there is still much to learn about these microorganisms in terms of their diversity and taxonomy.

Microorganisms particularly bacteria and fungi have been studied exhaustively, and yet there is still much to learn in terms of their physiology, influence, decomposition roles and contribution to agriculture. To cite a few examples, both fungi and bacteria are crucial in nitrate assimilation in soil (Myrold and Posavatz, 2007). Fungi were found to produce growth promoting factors (Singh *et al.*, 2000; Hossain and Sultana, 2020; Aban *et al.*, 2017b), and they have antioxidant radical scavenging activities (Masalu *et al.*, 2012; Aban *et al.*, 2017c). Fungi were also found to induce growth (Mehmood *et al.*, 2019; Aban *et al.*, 2017d), and drought tolerance (Pang *et al.*, 2020; Aban and Hipol, 2017) to agricultural crops, in vitro. Various species of bacteria were also found to have plant growth promoting mechanisms (Bouizgarne, 2012; Husen, 2003).

With the given importance of soil microorganisms, exploiting their potential contribution to agricultural crops is obligatory. The present study sought to improve the vegetative growth response of eggplants using organic fertilizer with effective microbes. The novelty technology in this study is the subjection of the eggplants to laundry waste. It is anticipated that the organic fertilizer with effective microbes will biologically disintegrate the toxic materials in laundry waste. It is assumed further that the beneficial microorganisms will convert these laundry waste materials to forms that are useful to plants. Therefore, the present study sought to determine the role of effective microorganisms found in organic fertilizer in terms of eggplants' first week height, and final height when the plants are watered with laundry waste instead of tap water.

Materials and methods

Research design

This study utilized a true experimental research approach in the determination of the role of organic fertilizers with beneficial microorganisms in its effect to eggplants watered with laundry waste. True experimental designs are considered as the most rigorous of all research designs. It is regarded as the most accurate form of experimental studies. In a true experimental design, a control and several experimental groups are used. The dependent variable in all groups is initially observed. Later, the experimental treatment groups are induced with the independent variable. After the exposure of the treatment groups to the independent variable, observations of the dependent variable for all groups are performed (LavanyaKumari, 2013). In this present study, the laundry waste is considered as the independent variable applied to the treatment groups. The dependent variable observed for all groups are the initial plant height, plant height after 1-week transplantation, and the final height of eggplants.

The control and treatment groups

There were a total of 210 eggplant seedling pots in the study. These seedlings were distributed into three blocks using a randomized complete block design (RCBD). Each block contained seven (7) treatments that were randomly assigned per block. Each treatment had ten (10) replications. The treatment groups represented the organic fertilizer with effective microbes and laundry waste utilization technology (OFEM-LUTech).

Experimental layout

The randomized complete block design (RCBD) was used in the study. Pots with at least 15 inches diameter was used for each seedling. These seedlings were distributed into three blocks. Each block contained seven treatments that were randomly assigned per block. Each treatment had ten replicates arranged in two rows per block.

Study site

The study was implemented in Don Mariano Marcos Memorial State University, Bacnotan, La Union, Philippines with coordinates 16°43'31"N 120°23'37"E.

Eggplant vegetative growth assay

The eggplant growth requirements were based on the eggplant package of technology from Agricultural Training Institute (Department of Agriculture) (Agricultural Training Institute, Department of Agriculture (ATI-DA), n.d.). The following were the ideal eggplant production requirement:

Climatic soil requirements: Eggplants were grown from low to mid elevations. To ensure best production, and if it is possible, the eggplants were grown during dry, cool months in sandy loam soil.

Seedling production: A single variety of eggplant seedlings will be procured from DA growers. The seedlings should be four weeks old and ready for transplanting.

Potting media preparation: All the eggplants were grown in pots with the abovementioned soil and climatic conditions. The potting media for the negative (T0) and positive control group (T1) included the soil from the study site and carbonated rice hull. For the conventional treatment group (T1-positive control), complete fertilizer (14-14-14) at 10-15g per pot was applied and was covered lightly will soil. Actual amount may, however, be adjusted based on the results of the soil analysis. A soil science expert was consulted for this purpose. For the organic treatment groups (T2-T6) 200g of the organic fertilizer with effective microbes was applied per pot.

Transplanting and maintenance: The area was irrigated before transplanting. One seedling was planted per pot. The plant in pots was watered (drench technique in the soil) well at least 1 inch per week. Tap water was used for all the control groups, while laundry waste was used for all the experimental groups, but in different proportions corresponding to the treatment group specifications. The conventional potted plants (T1) was side dressed with urea at 10g/per pot every 2-4 weeks during its vegetative stage. Equal parts urea and 0-0-60 was used at the start of fruiting. Weeds were removed 2-3 times during the growing season, or as necessary. Mulching was practiced to minimize weed growth and maintain uniform soil moisture.

Laundry waste collection and storage

Household laundry wastes was used to water the treatment groups in the study. All laundry wastes were stored using 200-liter blue plastic drums for not more than a week before it was used to water the experimental treatment pots. Approximately one liter (1 L) was used to water per pot. Therefore, 120 L was used to water 120 seedlings for T3-T6 which were watered every week until 6 months.

Data interpretation and statistical analysis

The data were analyzed using AAT Bioquest ANOVA Calculator (AAT Bioquest, Inc., 2024). The one-way ANOVA (Analysis of Variance) is used in determining differences between more than two group means. ANOVA uses F-statistic and its corresponding p-value to find out whether data comes from the same population. A significant p-value indicates that some of the group means are different. Since ANOVA is an omnibus test statistics, it cannot be used to find out which specific groups were significantly different from each other. Due to this limitation, a Tukey's multiple pairwise-comparisons were used as post-hoc analysis. The model assumes that each factor is sampled randomly, the factors are independent, and the factors belong to a normally distributed population with unknown but equal variances. In the online ANOVA calculator used in the study enables visualization through box and bar plots. Assumptions are verified through analysis of model residuals (Q-Q Plot). Simultaneously, multiple comparison tests (Shapiro-Wilk) is performed to ascertain conclusions on normality and check homogeneity of variances.

Results

This true experimental study utilized 210 eggplant seedling pots, distributed into three blocks using a randomized complete block design. Each block contained seven treatments with ten replicates each.

It can be gleaned from Table 1 the initial height measurement of eggplants after pot transplantation. T3 (mean = 10.05cm) appeared to have the lowest highest among the treatments. The height of eggplants grown in T3 is significantly lower than T1 (mean = 12.35 cm), T2 (mean = 12.58 cm) and T5 (mean = 12.35 cm). The alpha level of significance at 0.05 showed significant differences among the different treatment groups, however, this does not signify potential bias to any of the groups because the difference could be attributed to the present environmental conditions during field experimentation. As the eggplants grow, it is anticipated that the independent variables which are (1) the application of synthetic or organic fertilizer, and (2) the laundry waste water treatment that would contribute to the dependent variable (plant height) that would be measured, 1 week after transplantation, and its final measurement during the eggplants' maturity.

Table 1. Initial height measurement of eggplant after transplantation (cm)

Code	Treatment name (Formulation)	Mean	±S.D	Sig.
T0	Negative Control (No Fertilizer + 100% Tap Water)	11.82	±2.80	ab
T1	Positive Control 1 (Synthetic Fertilizer + 100% Tap Water)	12.35	±2.05	bc
T2	Positive Control 2 (OF with EM + 100% Tap Water)	12.58	±3.19	bc
T3	Experimental Group 1 (OF with EM + 25% LW & 75% Tap Water)	10.05	±2.39	a
T4	Experimental Group 2 (OF with EM + 50% LW & 50% Tap Water)	11.72	±3.58	ab
T5	Experimental Group 3 (OF with EM + 75% LW & 25% Tap Water)	12.35	±2.19	bc
T6	Experimental Group 4 (OF with EM + 100% LW)	12.13	±2.40	ab

Means with different letters are significantly different (α level of significance = 0.05).

Legend: OF = organic fertilizer; EM = effective microorganisms; LW = laundry waste

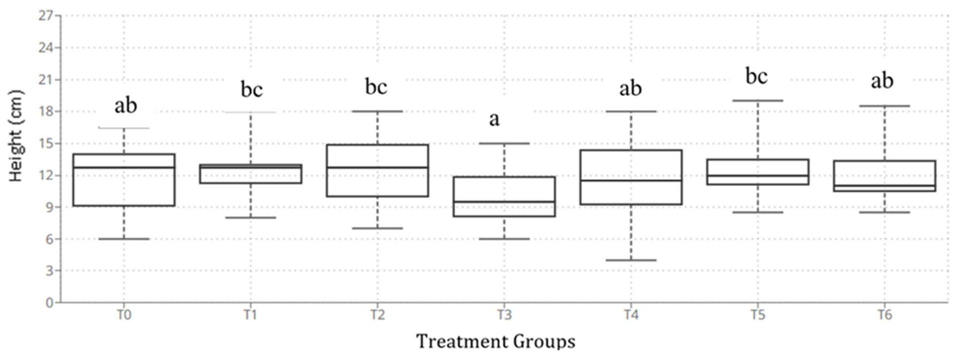

Fig. 1. Box plot visualization of the initial height of eggplants (cm) after transplantation

Fig. 1 is the box pot visualization of the initial height of eggplants after transplantation. This figure allows us to envision the significant differences among the treatment groups. It can be gleaned from the figure that T3 is significantly lower than T1, T2, and T5, respectively.

Table 2 shows the height of eggplants one week after transplantation. It can be gleaned from the table that T1 - Positive Control 1 (Synthetic Fertilizer + 100% Tap Water) and T5 - Experimental Group 3 (OF with EM + 75% LW & 25% Tap Water) are both significantly higher than T0 - Negative Control (No Fertilizer + 100% Tap Water). This implies that the treatment groups with both synthetic and organic fertilizer application watered with 75% laundry waste was significantly better than the negative control.

Table 2. Height of eggplant one (1) week after transplantation (cm)

Code	Treatment name (Formulation)	Mean	±S.D	Sig.
T0	Negative Control (No Fertilizer + 100% Tap Water)	17.18	±3.64	a
T1	Positive Control 1 (Synthetic Fertilizer + 100% Tap Water)	20.83	±4.04	bc
T2	Positive Control 2 (OF with EM + 100% Tap Water)	18.78	±4.69	ab
T3	Experimental Group 1 (OF with EM + 25% LW & 75% Tap Water)	16.67	±2.90	a
T4	Experimental Group 2 (OF with EM + 50% LW & 50% Tap Water)	18.83	±4.87	ab
T5	Experimental Group 3 (OF with EM + 75% LW & 25% Tap Water)	21.63	±5.09	bc
T6	Experimental Group 4 (OF with EM + 100% LW)	17.88	±3.46	ab

Means with different letters are significantly different (α level of significance = 0.05).

Legend: OF = organic fertilizer; EM = effective microorganisms; LW = laundry waste

The box plot visualization of the height of eggplants one week after transplantation can be seen in Fig. 2. T1 (Positive Control 1) that utilized synthetic fertilizer and 100% tap water as well as T5 (Experimental Group 3) that used organic fertilizer with effective microbes and was watered with 75% laundry waste and 25% tap water grew significantly taller than T0 (Negative Control) where no fertilizer was applied and watered with 100% tap water.

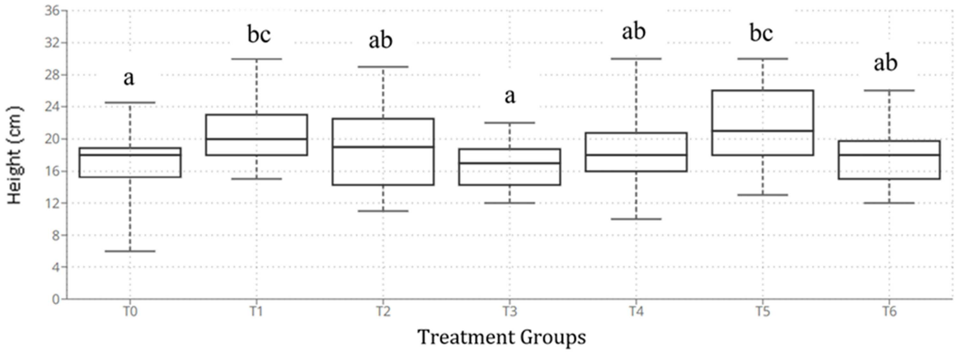

Fig. 2. Box plot visualization of the height of eggplants (cm) one (1) week after transplantation

The final height of eggplants at the age of maturity is presented in Table 3. This data was measured before the time of harvest. It is evident that those treatment groups applied with organic fertilizer with effective microorganisms (T2, T3, T4, T5, T6) grew taller than the eggplants with no fertilizer application (To) and those eggplants that received synthetic fertilizer application watered with 100% tap water. The tallest eggplants grew from T3 and T5. These eggplants were applied with organic fertilizer with effective microorganisms and were watered with laundry waste.

Table 3. Final height of eggplants (cm) at the age of maturity

Code	Treatment name (Formulation)	Mean	±S.D	Sig.
To	Negative Control (No Fertilizer + 100% Tap Water)	95.40	± 20.72	a
T1	Positive Control 1 (Synthetic Fertilizer + 100% Tap Water)	96.53	± 23.71	a
T2	Positive Control 2 (OF with EM + 100% Tap Water)	117.07	± 17.50	b
T3	Experimental Group 1 (OF with EM + 25% LW & 75% Tap Water)	120.13	± 16.82	bc
T4	Experimental Group 2 (OF with EM + 50% LW & 50% Tap Water)	110.17	± 23.67	ab
T5	Experimental Group 3 (OF with EM + 75% LW & 25% Tap Water)	124.20	± 16.23	bc
T6	Experimental Group 4 (OF with EM + 100% LW)	115.00	± 16.13	b

Means with different letters are significantly different (α level of significance = 0.05).

Legend: OF = organic fertilizer; EM = effective microorganisms; LW = laundry waste

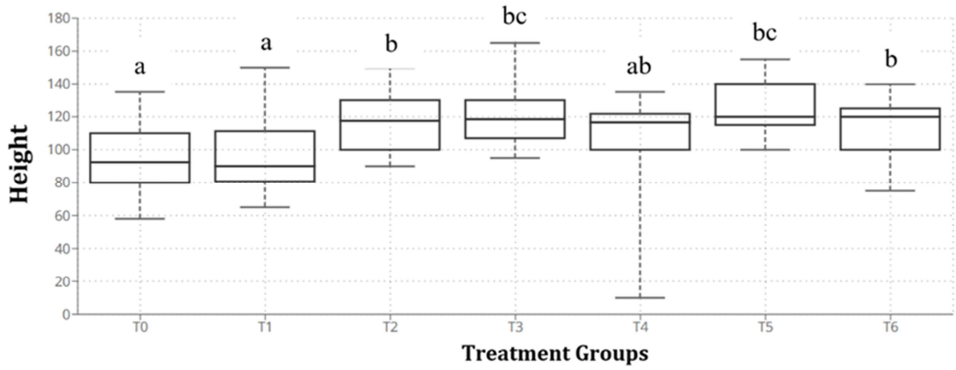

Fig. 3. Box plot visualization of the final height of eggplants (cm) at the age of maturity

Fig. 3 shows the box plot visualization of the final height of eggplants in cm at the age of maturity. This figure provides visual evidences that eggplants applied with organic fertilizers with effective microorganisms and were watered with laundry waste: T2, T3, T4, T5, and T6, respectively, grew significantly better than the eggplants that did not receive any fertilizer application. Moreover, it also showed that the same treatment groups (T2, T3, T4, T5, and T6) that received organic fertilizers with effective microorganisms watered with laundry waste are statistically taller than the eggplants applied with synthetic fertilizer and watered with tap water.

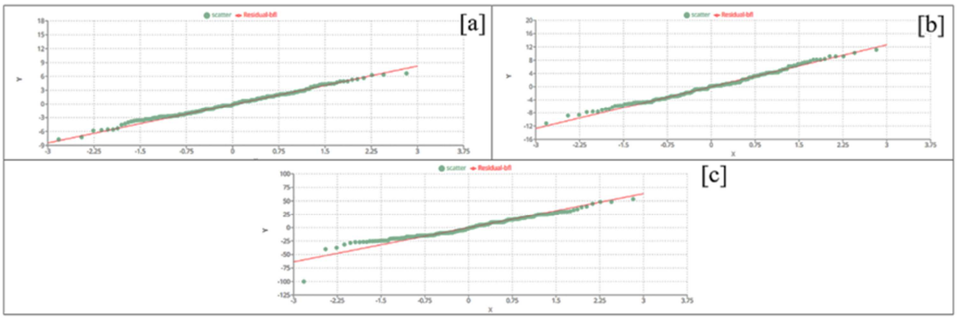

Fig. 4. Normal Q-Q plot to verify assumptions through residual analysis [a] initial height measurement of eggplant after transplantation (cm) [b] height of eggplant one (1) week after transplantation (cm) [c] final height of eggplants (cm) at the age of maturity

The Q-Q plot or the quantile-quantile plot in Fig. 4 is a graphical tool to help us verify that the set of data on the (a) initial height measurement of eggplant after transplantation (cm), (b) height of eggplant one (1) week after transplantation (cm), and (c) final height of eggplants (cm) at the age of maturity plausibly came from a normal distribution. Since the dots in the figure generally follow the straight-line y = x, the sample distribution is said to be like the theoretical one.

Discussion

The purpose of this study is to determine whether organic fertilizers with effective microorganisms can be watered with laundry waste. The effective microorganism found in these organic fertilizers were claimed to have multiple eco-biologically active microorganisms that enhances decomposition of organic matter. In this present study, their eco-biological active mechanisms are exploited further by determining whether these microbes also have a bioremediating effect. The researchers attempted to discover if these microbes can convert laundry waste residues and other toxic materials to components assimilable to plants.

The concept of effective microorganisms

The concept of effective microorganisms is based on the introduction of microbes that are known to enhance biodegradation of organic matter. These microbes are inoculated into substrate with the intention to improve microbial diversity and equilibrium thus creating an improved ecological system that will eventually enhance agricultural productivity (Balogun *et al.*, 2016). The present study is timely to the fast-paced industrial and technological era where there are tendencies to compromise environmental health just to achieve the necessary economic progress. The application of this present study is anchored to the concept project and future's thinking approach where laundry waste is encouraged to be used to water agricultural crops and vegetables after these were subjected to organic fertilizers with effective microorganisms due to their suspected ability to bioremediate wastewater and make use of it as an amendment to agricultural production (Aban *et al.*, 2024a). The underlying concepts in ecological systems diversity points out to environmental conservation. When these concepts are put into practice, sustainable development is achieved and the far-reaching effects of human-instigated environmental degradation is curtailed (Aban, 2024).

Bioremediating activities of effective microorganisms

In this present study, eggplants watered with laundry waste grew significantly taller when they are applied with organic fertilizers with effective microorganisms one week after transplantation. Even until the time of harvest, their maximum growth potential was achieved even when laundry waste was used to water them, if organic fertilizers with effective microorganisms were applied to the eggplants. The experimentation showed an agricultural breakthrough because those eggplants applied with organic fertilizer with effective microbes that were watered with laundry waste are significantly taller than those eggplants applied with synthetic chemical fertilizers.

Bioremediation describes the process of using biological agents, particularly microorganisms, to remove toxic wastes and materials from the environment (Singh, 2014). Microbes are best candidates for bioremediation if they are rapidly growing and then can easily be manipulated (Ayilara and Babalola, 2023). It is therefore assumed in the present study that the effective microorganisms found in the organic fertilizer are decomposers that speed up the decomposition process and they also have mechanisms of rapid growth in soil substrate to increase microbiological diversity in their natural soil ecosystems. Bollag *et al.* (1994) described the role of microorganisms in soil bioremediation. The rhizosphere is the area in soils where there is an increased microbial activity that may improve degradation and biotransformation of toxic materials. This supports the result of the present study. The organic fertilizer with effective microbes was introduced in the rhizosphere of soils for eggplant growth and development. Since there is an increased microbial activity in the rhizosphere, the ability of the effective microbes to bio-transform and degrade the toxic materials in laundry waste was enhanced, turning these wastes to nutrients and other useful forms that are readily assimilated by plants. The additional bio-transformed nutrients from laundry waste was used as amendment to eggplants causing them to grow significantly better than the control group subjected to synthetic chemical fertilizers.

Degradation of toxic substances in laundry waste by effective microorganisms

The present study supports the theory that effective microorganisms can degrade toxic substances found in laundry waste. The eggplants grown in soils subjected to organic fertilizers with effective microbes grew significantly taller compared to the control groups. This shows the ability of the effective microbes to degrade toxic substances in laundry waste and convert them to nutrients that are readily assimilated by the eggplants. In the study of Osadebe *et al.* (2018) they also discovered microbes with the ability to degrade anionic surfactants from laundry detergents. Anionic surfactants are harmful by-products of laundry waste that can pose serious hazards to human health (Nelson, 2024). There are dearth literatures published regarding the degradation of toxic substances in laundry waste by effective microorganisms.

Conclusion

Eggplants grown in soils amended with organic fertilizers containing effective microorganisms, and were watered with laundry waste, grew significantly better than those eggplants that received chemical fertilizer application. This is a breakthrough in the field of agriculture because it is now possible to use laundry waste instead of tap water especially when growing eggplants in soils applied with organic fertilizer and EMs. Since effective microorganisms grow best in the rhizosphere, their ability to bio-transform and degrade toxic materials is enhanced. This present study provided evidences that effective microorganisms in organic fertilizers can degrade toxic substances found in laundry waste.

Acknowledgements

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References

AAT Bioquest, Inc. 2024, May 2. Quest Graph™ ANOVA Calculator. AAT Bioquest. https://www.aatbio.com/tools/anova-analysis-of-variance-one-two-way-calculator.

Aban JL, Barcelo RC, Oda EE, Reyes GA, Balangcod TD, Gutierrez RM, Hipol RM. 2017. Auxin production, phosphate solubilisation and ACC deaminase activity of root symbiotic fungi (RSF) from *Drynaria quercifolia* L. Bulletin of Environment, Pharmacology and Life Sciences **6**(5), 26-31.

Aban JL, Barcelo RC, Oda EE, Reyes GA, Balangcod TD, Gutierrez RM, Hipol RM. 2017. Quantification of the total antioxidative-, enzymatic- and phenolic-activities of dominant root symbiotic fungi (RSF) from *Drynaria quercifolia* L. Journal of Applied Environmental and Biological Sciences **7**(7).

Aban JL, Barcelo RC, Oda EE, Reyes GA, Balangcod TD, Gutierrez RM, Hipol RM. 2017. Dominant root associated fungi (RAF) from *Drynaria quercifolia* L. either induce or retard growth of PSB Rc10 rice (*Oryza sativa* L.) in gibberellic acid-inhibited medium. Applied Environmental Research **39**(2), 89-98.

Aban JL, Hipol RM, Balangcod TD, Gutierrez RM, Barcelo RC, Oda EE, Reyes GA. 2017. Diversity and phylogenetic relationships among isolated root symbiotic fungi from *Drynaria quercifolia* L. in La Union, Philippines. Manila Journal of Science **10**, 87-100.

Aban JL, Hipol RM. 2017. Isolated root symbiotic fungi (RSF) from *Drynaria quercifolia* L. show various stress tolerance effects on PSB RC10 (Pagsanjan) rice (*Oryza sativa* L.) exposed to Snap-peg 8000 mild drought. International Journal of Agriculture and Environmental Research **3**, 352-362.

Aban JL, Sagun AV, Asirot JA. 2024. Enhancing organic agricultural production through beneficial microorganism and waste-water utilization technology: A concept project and future's thinking approach. Journal of Biodiversity and Environmental Sciences. Preprint available at: 10.13140/RG.2.2.31872.65284.

Aban JL. 2019. Isolation, molecular identification, phylogenetic analysis and biodiversity of root symbiotic fungi (RSF) from *Drynaria quercifolia* L. IAMURE International Journal of Ecology and Conservation **27**(1), 1-1.

Aban JL. 2024. Symbiotic fungal biodiversity, structure, role, and benefits to their host plants - discovering microbes with potential agricultural significance: A literature probe. International Journal of Biosciences. Preprint available at: 10.13140/RG.2.2.28517.20966.

Abd El-Mageed TA, Rady MM, Taha RS, Abd El Azeam S, Simpson CR, Semida WM. 2020. Effects of integrated use of residual sulfur-enhanced biochar with effective microorganisms on soil properties, plant growth and short-term productivity of *Capsicum annuum* under salt stress. Scientia Horticulturae **261**, 108930.

Abney TD, Russo VM. 1997. Factors affecting plant height and yield of eggplant. Journal of Sustainable Agriculture **10**(4), 37-48.

Agricultural Training Institute, Department of Agriculture (ATI-DA). n.d. Package of Technology (POT) for Eggplant Production (Eggplant Production Guide). Retrieved from: https://ati.da.gov.ph/rtc10/sites/default/files/EGGPLANT%20PRODUCTION%20GUIDE.pdf.

Aminifard MH, Aroiee H, Fatemi H, Ameri A, Karimpour S. 2010. Responses of eggplant (*Solanum melongena* L.) to different rates of. Journal of Central European Agriculture.

Amiri E, Gohari AA, Esmailian Y. 2012. Effect of irrigation and nitrogen on yield, yield components and water use efficiency of eggplant. African Journal of Biotechnology **11**(13), 3070-3079.

Ayilara MS, Babalola OO. 2023. Bioremediation of environmental wastes: The role of microorganisms. Frontiers in Agronomy **5**, 1183691.

Balogun RB, Ogbu JU, Umeokechukwu EC, Kalejaiye-Matti RB. 2016. Effective micro-organisms (EM) as sustainable components in organic farming: principles, applications and validity. Organic Farming for Sustainable Agriculture, 259-291.

Bollag JM, Mertz T, Otjen L. 1994. Role of microorganisms in soil bioremediation.

Bouizgarne B. 2012. Bacteria for plant growth promotion and disease management. In Bacteria in Agrobiology: Disease Management (pp. 15-47). Berlin, Heidelberg: Springer Berlin Heidelberg.

Cui Q, Xia J, Yang H, Liu J, Shao P. 2021. Biochar and effective microorganisms promote *Sesbania cannabina* growth and soil quality in the coastal saline-alkali soil of the Yellow River Delta, China. Science of the Total Environment **756**, 143801.

Hidalgo D, Corona F, Martín-Marroquín JM. 2022. Manure biostabilization by effective microorganisms as a way to improve its agronomic value. Biomass Conversion and Biorefinery **12**(10), 4649-4664.

Higa T, Parr JF. 1994. Beneficial and effective microorganisms for a sustainable agriculture and environment (Vol. 1, pp. 16-16). Atami: International Nature Farming Research Center.

Hossain MM, Sultana F. 2020. Application and mechanisms of plant growth promoting fungi (PGPF) for phytostimulation. Organic Agriculture **1**, 31.

Husen E. 2003. Screening of soil bacteria for plant growth promotion activities in vitro. Indonesian Journal of Agricultural Science **4**(1), 27-31.

LavanyaKumari P. 2013. Significance of Solomon four group pretest-posttest method in true experimental research-A study. IOSR Journal of Agriculture and Veterinary Science **5**(2), 51-58.

Masalu RJ, Hosea KM, Malendeja S. 2012. Free radical scavenging activity of some fungi indigenous to Tanzania. Tanzania Journal of Health Research **14**(1).

Mehmood A, Hussain A, Irshad M, Hamayun M, Iqbal A, Khan N. 2019. In vitro production of IAA by endophytic fungus *Aspergillus awamori* and its growth promoting activities in *Zea mays.* Symbiosis **77**, 225-235.

Mirdad ZM. 2011. Vegetative growth yield and yield components of eggplant (*Solanum melongena* L.) as influenced by irrigation intervals and nitrogen levels. Journal of King Abdulaziz University: Meteorology, Environment and Arid Land Agriculture Sciences **22**, 31-49.

Mukhopadhyay R, Sarkar B, Jat HS, Sharma PC, Bolan NS. 2021. Soil salinity under climate change: Challenges for sustainable agriculture and food security. Journal of Environmental Management **280**, 111736.

Myrold DD, Posavatz NR. 2007. Potential importance of bacteria and fungi in nitrate assimilation in soil. Soil Biology and Biochemistry **39**(7), 1737-1743.

Nelson M. 2024. Are surfactants toxic? The dangers and alternatives. Branch Basics. Published online https://branchbasics.com/blogs/cleaning/are-surfactants-toxic.

Olle M, Williams IH. 2013. Effective microorganisms and their influence on vegetable production–a review. The Journal of Horticultural Science and Biotechnology **88**(4), 380-386.

Osadebe A, Onyiliogwu C, Suleiman B, Okpokwasili G. 2018. Microbial degradation of anionic surfactants from laundry detergents commonly discharged into a riverine ecosystem. Journal of Applied Life Sciences International **16**(4), 1-11.

Pang Z, Zhao Y, Xu P, Yu D. 2020. Microbial diversity of upland rice roots and their influence on rice growth and drought tolerance. Microorganisms **8**(9), 1329.

Prasad S, Malav LC, Choudhary J, Kannojiya S, Kundu M, Kumar S, Yadav AN. 2021. Soil microbiomes for healthy nutrient recycling. Current trends in microbial biotechnology for sustainable agriculture, 1-21.

Rahman KA, Zhang D. 2018. Effects of fertilizer broadcasting on the excessive use of inorganic fertilizers and environmental sustainability. Sustainability **10**(3), 759.

Shah KK, Tripathi S, Tiwari I, Shrestha J, Modi B, Paudel N, Das BD. 2021. Role of soil microbes in sustainable crop production and soil health: A review. Agricultural Science and Technology **13**(2), 109-118.

Singh A, Sharma J, Rexer KH, Varma A. 2000. Plant productivity determinants beyond minerals, water and light: *Piriformospora indica*- A revolutionary plant growth promoting fungus. Current Science, 1548-1554.

Singh IP, Singh B, Bal HS. 1987. Indiscriminate fertilizer use vis-à-vis groundwater pollution in central Punjab. Indian Journal of Agricultural Economics **42**(3), 404-409.

Singh R. 2014. Microorganism as a tool of bioremediation technology for cleaning environment: A review. Proceedings of the International Academy of Ecology and Environmental Sciences **4**(1), 1.

Torsvik V, Sørheim R, Goksøyr J. 1996. Total bacterial diversity in soil and sediment communities-a review. Journal of Industrial Microbiology and Biotechnology **17**(3-4), 170-178.

Zhang J, Liang Z, Wang C, Li S. 2021. Compound effective microorganisms treatment increases growth and yield of vegetables. Journal of Agricultural Science and Technology **23**(4), 943-954.