Article

Improving eggplant growth and development by using beneficial microbes in organic fertilizers: Exploring the bioremediating effects of microbes in laundry waste

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Abstract
The growing global population put a lot of pressure to the agricultural industry. Farmers are obligated to use more chemical fertilizers to increase crop production. Consequently, the use of these synthetic fertilizers pose danger in the natural ecosystem flows. The use of organic fertilizer is promising because it reduces the risks of disrupting the natural balance and diversity of soil microbes. However, the production may consequently be reduced because organic fertilizers hold fewer essential macronutrients needed by plants. This present study presents the use of organic fertilizers with beneficial microorganisms as an alternative way to be utilized by farmers and crop growers. The beneficial microbes (BMs) present in these organic fertilizers are expected to help eggplants grow better even when laundry waste is utilized to water them. Through an experimental setup, eggplant seedlings were grown in pots using a randomized complete block design. The eggplants were watered with different levels of laundry waste as they grow in soils amended with organic fertilizer inoculated with beneficial microorganisms. At maturity, the number of branches, SPAD-based leaf nitrogen estimation, and height at flowering were determined. Eggplants grown in soils amended with BM-inoculated organic fertilizers have greater number of branches, significantly higher nitrogen content, and were the tallest plants in their flowering stage. The bigger breakthrough is the comparable growth of laundry-waste watered experimental pots compared to the growth of eggplants watered with tap water, when both treatment groups were amended with BM-bioactivated organic fertilizers. This is indicative of the bioremediating effect of the BMs in organic fertilizer where they potentially transform futile laundry waste to forms releases macronutrients making these nutrients readily available to eggplants.

Keywords beneficial microbes; bioremediation; laundry waste utilization; indiscriminate fertilizer use, organic eggplant production.

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1 Introduction

1.1 The world's population and the pressure in agriculture

The exponential population growth across the globe is a crucial challenge in agriculture. Agricultural scientists have devised sustainable responses to feed a growing population in the world. The lands where crop should grow are becoming limited to accommodate increase population growth (Fes et al., 2011). Aside from the reduced agricultural lands, the remaining areas have become barren due to the indiscriminate use of synthetic fertilizers to catch up to the growing population. This strategy is temporarily helpful but eventually, its losses outweigh its gains. For instance, the undiscerning use of nitrogen not only increases fertilizer consumption ratio but also promotes nutrient imbalance (Shukla et al., 2022). Uncontrolled use of fertilizer also creates pollution to groundwater (Singh et al., 1987). Mishra et al. (2013) pointed out that the indiscriminate use of chemical fertilizers has led to the contamination of soils and water bodies, disrupted biodiversity of natural microbes, reduced soil fertility, and made crops prone to pests and diseases.

1.2 The negative effect of chemical fertilizers

The problem becomes worst in developing countries where agriculture is the most important factor that influences their economic growth. As farmers in developing nations persistently used chemical fertilizers, food grains were sustained but in the expense of degradation of their environment and agricultural soils. It also created a major negative impact on human health (Sharma and Singhvi, 2017). Chemical fertilizers are undoubtedly needed in agriculture and crop production because they provide nutrients to crops to sustain or even to increase crop yield. However, the inefficient but increasing use of chemical fertilizers leads to environmental hazard simultaneously affecting and polluting the land, the air, and the water ecosystems. It is deleterious chiefly because the excessive fertilizer applied leaks into groundwater. Other negative effects of disproportionate use of chemical fertilizers include: emission of nitrous oxides and other greenhouse gases, pollution of soils by heavy metals, surface runoff of macronutrients such as nitrogen and phosphorus causing eutrophication in tributaries, rivers, lakes and larger water bodies and aquatic ecosystems (Umesha et al., 2017).

1.3 The use organic fertilizer, a possible solution to slow down environmental degradation

Environmentalists and agricultural scientists are working hard to slow down environmental degradation while strategizing schemes to sustain agricultural productivity for the growing population. The use of organic fertilizers is a key component towards agricultural sustainability. Organic fertilizers contribute significantly to improving soil quality and fertility (Assefa and Tadesse, 2019). Organic fertilizers are branded as potential replacement to conventional fertilizers. These fertilizers came from decomposed household wastes, green manure and organic compost materials. However, despite their contribution to sustaining soil quality and fertility, stand-alone organic fertilizers are not as effective in bringing the necessary macronutrients, nitrogen, phosphorus and potassium, to plants. Therefore, they are not as effective as chemical fertilizers. Farmers at present still prefer conventional chemical fertilizer than purely organic amendments, to satisfy the required agricultural production (Mishra et al., 2013). To make both ends meet, scientists have proposed the combined use of conventional chemical fertilizer and organic amendments to simultaneously sustain crop production, while preserving the quality of soil, keeping microbes present and abundant in soils, holding necessary macronutrients, and minimizing potential surface run-off and deposition of excessive nutrients to aquatic bodies.

1.4 Pivotal role of soil microorganisms in nutrient cycling

The presence of microorganisms is what makes organic fertilizer efficient in sustaining soil fertility. Microbes found in organic fertilizers are naturally occurring soil microbes that play crucial role to ecological balance. They play a critical role in plant growth-promotion, provision of essential nutrients for plant growth, as well as improving yield production. These microbes include but are not limited to rhizobacteria, arbuscular mycorrhizal fungi, endophytic fungi and endophytic bacteria (Miransari, 2011). In the study of Ndubuisi-Nnaji et al. (2010), they studied the effect of long-term organic fertilizer application and its effect to microbial dynamics in soils. Particularly, they determined how organic fertilizers affected the presence of culturable resident bacterial and fungal communities. The researchers found out that the application of organic fertilizer in soil restored soil nutrient and structure while leading to the control of the same soil borne bacteria and fungi. In the natural cycle of nutrients such as carbon, nitrogen, phosphorus and potassium, microbes play a vital role. They break covalent bonds in organic matter making them readily available in the soil. Hence, organic fertilizers are produced by naturally occurring microbial decomposers. In the study of Aban (2014), organic-amended soils were found to have higher amount of clay and organic matter. These soils were also found to have higher amount of nutrients available based on electrical conductivity test. Phosphorus and potassium were also found to be readily available in organic-amended farm soils compared to conventional farming soils. Aarons et al. (2009) pointed out that increased microbial biomass found in organic materials such as dung are essential source of nutrients that increases soil fertility. Soils therefore need microbes, and microbes need conducive soil environment for them to thrive and work harmoniously to sustain soil health and fertility.

1.5 Pivotal role of microorganisms in plant hosts

Aside from the importance of microorganisms in the soil, they are also needed by their host plants for their survival. Several studies indicate crucial symbiotic relationship between microorganisms and their hosts, without which will lead to the hosts' peril. The study of Aban (2019) observed that the ability of *Drynaria quercifolia* L. fern epiphyte to light and water deprived environment was due to the presence of root symbiotic fungi in the roots of the host plant. A similar study found out that the greater the environmental stress experienced by the host plant, the greater is the number of the root symbiotic fungi, proving the crucial role of these fungal symbionts to ensure their host's survival (Aban et al., 2017a). According to Grunseich et al. (2020), there is increasing evidence on the critical role of microorganisms in protecting their host plants from their associated herbivore. When investigated in vitro, the symbiotic microbes were discovered to release growth promoting properties (Aban et al. 2017b, Aban, 2020) and anti-oxidative stress-adaptive factors (Aban et al., 2017c). In vitro host plants also survived hormone-inhibited (Aban et al., 2017d) and drought-stress conditions (Aban et al., 2017e) because of the speculated release of important extracellular molecules by the microbes to help plants grow despite stressful conditions. Holistically, microorganisms play an essential role in their hosts' fitness and health (Singh et al., 2019). The compulsory interactions between microorganisms to plants show the interconnectedness of the biotic components in the biosphere (Aban et al., 2024a).

1.6 Effective microorganisms also known as beneficial microbes

On the other hand, effective microorganisms, otherwise known as beneficial microbes are similar to the naturally occurring decomposers in soils. They are, however, inoculated in soils to amplify their number in the soil or to stimulate plant growth and soil fertility for agricultural purposes (Mayer et al., 2010). Effective microorganisms (EMs) are considered as a biotechnological breakthrough. According to Higa (1991), EMs are not only limited to agriculture. They can also be utilized to treat and process sewage as well as purify rivers and aquatic bodies. In the Philippines, an organic agriculture innovation company discovered a bio-activator. This bio-activator are inoculations of diverse naturally occurring soil microbes that enhances biodegradation of organic and biodegradable solid wastes. This innovation enhances the conversion of wastes to organic matter therefore significantly reducing the number the volume of solid wastes produced by communities (Aban et al. 2024b). In this present study, the known role of effective microorganisms in speeding up decomposition and enriching the soil with organic matter will further be exploited to determine whether these beneficial microbes also have the ability to remediate the soil when agricultural crops are watered with laundry waste.

1.7 Objectives of the study

Ultimately, the ambition is to conserve the natural environment while supplying the necessity of the present generation. In doing so, major stakeholders are involved in this concept of sustainability: the citizens, the government, and the academic researchers and scientists (Aban and Manuel, 2019). It is therefore the general aim of the present study to improve the growth and development of eggplants by using effective microorganisms. Specifically, the researchers' objectives are to: (a) determine and compare the effect laundry waste treatments in the number of branches, SPAD-based leaf nitrogen estimation, and flowering height of eggplants at maturity; and to (b) measure the significant differences among treatment groups of eggplants without fertilizer application, with chemical fertilizer application, with organic fertilizer inoculated with effective microbes as these treatment groups are watered with different levels of laundry waste.

2 Study area and Methodology

2.1 Research design

The present study utilized a true experimental research design. The true experimental research design as operationally defined in this study is the cause and effect between variables that were examined. The experimental treatment groups were exposed to treatment conditions and the results were compared to control groups without any treatment conditions. The experimental treatment groups were the different percentage (%) level of laundry waste that were utilized to water eggplant pots. In the agricultural sector, the main objective of experimental design is to estimate the average response of a certain agronomic treatment group or the average differences between the treatment groups as accurately as possible even when the given response differs from one environment to another in any given month of the year (Crossa, 2012). In this present study, the dependent variables measured with response to the treatment groups' agronomic treatment group response were (1) the number of branches, (2) SPAD-based leaf nitrogen estimation, and (3) flowering height of eggplants at maturity.

2.2 Location of the study area

The aerial view of Don Mariano Marcos Memorial State University – North La Union Campus, Bacnotan, La Union, Philippines with the following coordinates: 16° 43′ 30.8″ N 120° 23′ 37.6″ E is shown in Fig. 1. This is a higher education institution in the Northern Philippines that perennially conduct life science and agriculture-related research works. The experimental field was conducted in this abovementioned locale in the Philippines.

2.3 Sampling technique and experimental lay-out

The sampling area has a distance of 1.5 meters between treatment groups (per row and column). Random sampling technique was used in the selection of eggplant grown in pots. Pots with at least 15 inches diameter was used for each eggplant seedling. These seedlings were distributed into three blocks using a randomized complete block design (RCBD). Each block contained seven treatments that were randomly assigned per block. Each treatment had 10 replicates arranged in two rows per block.

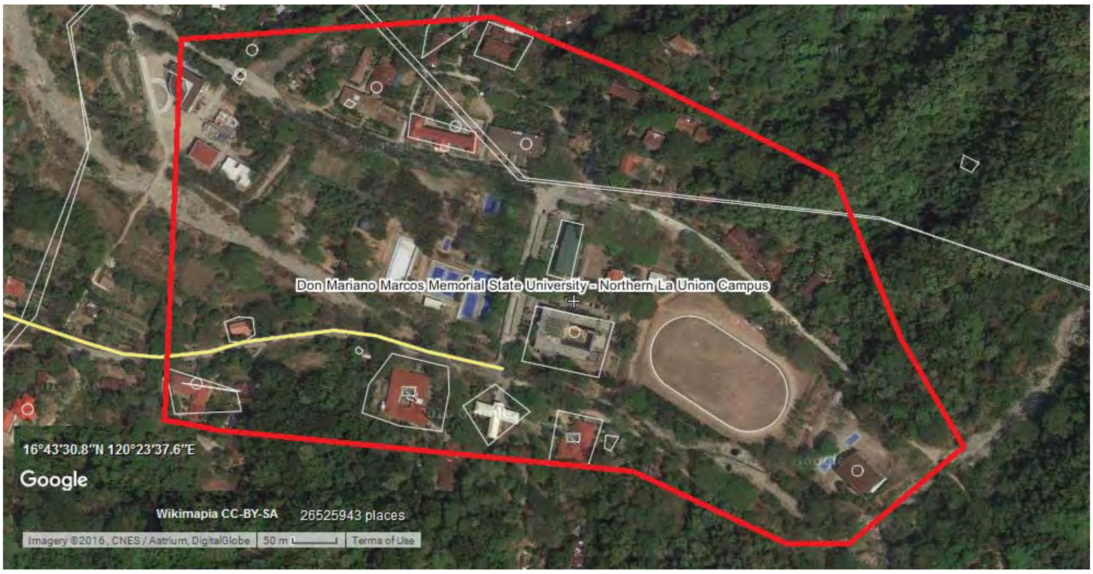

Fig. 1 Aerial view of Don Mariano Marcos Memorial State University – North La Union Campus, Bacnotan, La Union, 2515 Philippines with the following coordinates: 16° 43′ 30.8″ N 120° 23′ 37.6″ E (From Wikimapia Imagery © 2016, Powered by Google).

2.4 Treatment and control groups

In the true experimental research approach used in this present study, there were a total of 210 eggplant seedling pots distributed using RCBD. The treatment groups representing laundry waste utilization and fertilizer application techniques were as follows:

T0 –100% tap water without fertilizer application (negative control)

T1 – 100% tap water with chemical fertilizer application (positive control 1)

T2 – 100% tap water with beneficial microbes-inoculated organic fertilizer (positive control 2)

T3 – 25% laundry waste + 75% tap water with beneficial microbes-inoculated organic fertilizer

T4 – 50% laundry waste + 50% tap water with beneficial microbes-inoculated organic fertilizer

T5 – 75% laundry waste + 25% tap water with beneficial microbes-inoculated organic fertilizer

T6 – 100% laundry waste with beneficial microbes-inoculated organic fertilizer

2.5 Source of beneficial microbes-inoculated organic fertilizer

The source of beneficial microbes-inoculated organic fertilizer was the existing organic fertilizer manufacturing site of the ELR Family Trading Company Incorporated located in Barangay Bagong Sikat, Science City of Munoz, Nueva, Ecija, Philippines with the following coordinates (15.7362^{o}N, 120.9197^{o}E). All organic fertilizers with beneficial microbes utilized in the present study were purchased in this trading company.

2.6 Eggplant vegetative growth and development assay

The eggplant production guide followed the Agricultural Training Institute – Department of Agriculture, Philippines eggplant package of technology (ATI-DA, n.d.). Eggplants were grown in low elevations and in sandy loam soil. A single variety of eggplant seedlings were procured. The seedlings grew for four weeks before transplanting. A soil science expert determined the necessary chemical fertilizer needed, particularly for T1. For the organic treatment groups (T2 to T6), 200 g of beneficial microbes-inoculated organic fertilizer was applied per pot. The area was irrigated before transplanting. One seedling was planted per pot. The eggplant per pot was watered through drench technique in the soil for at least one (1) inch per week. Tap water was used to water all the control groups while laundry waste at different levels was used for all experimental groups.

2.7 Data collected and agronomic traits measured

There were three vegetative parameters measured during eggplant maturity: (1) number of branches, (2) estimated nitrogen content, and (3) flowering height. The **number of branches** is the total number of live branches emerging from the main stem of eggplants at maturity stage. The **SPAD-based leaf nitrogen estimation** is the soil plant analysis development (SPAD) chlorophyll meter that is commonly used agricultural diagnostic tool to measure crop nitrogen. It is a pivotal tool for assessing and optimizing crop health by measuring chlorophyll content in leaves. The **height at flowering** was the total height from the base of the main step to the tip of the apical / terminal bud of a matured flowering eggplant. The height was measured in centimeters (cm).

2.8 Data presentation, interpretation and statistical analysis

The visualized data for the number of branches, SPAD-based leaf nitrogen estimation, and height of eggplants at flowering were presented using Box and Whisker in Microsoft Excel. The data was further analyzed using AAT Bioquest ANOVA Calculator (AAT Bioquest, Inc., 2024). The one-way ANOVA was used to determine significant differences between two or more groups. Tukey's test was used as post-hoc analysis.

3 Results and Discussion

3.1 Remediating effect of effective microbes on eggplants' number of branches

The present study investigated how the effective microbes present in organic fertilizers affect the vegetative growth and development of eggplants in terms of the number of branches. Table 1 shows the mean value and he standard deviation in the number of branches of eggplants (in cm) during maturity. The computed F-statistics was 6.06 and the p-value was 7.42×10^{-6}. This means there is significant different between the treatment groups. The least number of branches were manifested by the positive (T1: x̄ = 3.97+1.35 cm) and the negative control (T0: x̄ = 3.93+1.39 cm) groups. All treatment groups (T2: x̄ = 4.93+1.23 cm; T3: x̄ = 5.13+1.04 cm; T4: x̄ = 5.10+0.92 cm; T5: x̄ = 4.73+1.01 cm; and T6: x̄ = 4.80+0.76 cm) with beneficial microbes-inoculated organic fertilizer are significantly better than the control groups. This means that the effective microbes contributed in the increased number of branches in eggplants. It is also interesting to note that all treatment groups applied with various level of laundry waste have significantly greater number of branches of eggplants than the control groups. This implies that the effective microorganisms facilitated in the potential degradation of toxic waste in laundry waste and convert them into useful nutrients that were readily assimilated by plants. Fig. 2 processed the same data on the number of branches of eggplants during maturity but is visualized using the box and whisker plot.

Table 1 Number of branches of eggplants (cm) during maturity.

Code	Treatment Name (Formulation)	Mean	±S.D	Stat.
T0	100% tap water without fertilizer application (negative control)	3.93	±1.39[a]	
T1	100% tap water with chemical fertilizer application (positive control 1)	3.97	±1.35[a]	
T2	100% tap water with beneficial microbes-inoculated organic fertilizer (positive control 2)	4.93	±1.23[b]	F-Stat 6.06
T3	25% laundry waste + 75% tap water with beneficial microbes-inoculated organic fertilizer	5.13	±1.04[b]	
T4	50% laundry waste + 50% tap water with beneficial microbes-inoculated organic fertilizer	5.10	±0.92[b]	P-Val 7.42e^{-6}
T5	75% laundry waste + 25% tap water with beneficial microbes-inoculated organic fertilizer	4.73	±1.01[ab]	*significant
T6	100% laundry waste with beneficial microbes-inoculated organic fertilizer	4.80	±0.76[b]	

Legend: SD = standard deviation; F-stat = F-statistics; P-Val = P-value, *significant = there is significant difference. Means with different letters are significantly different (α level of significance = 0.05).

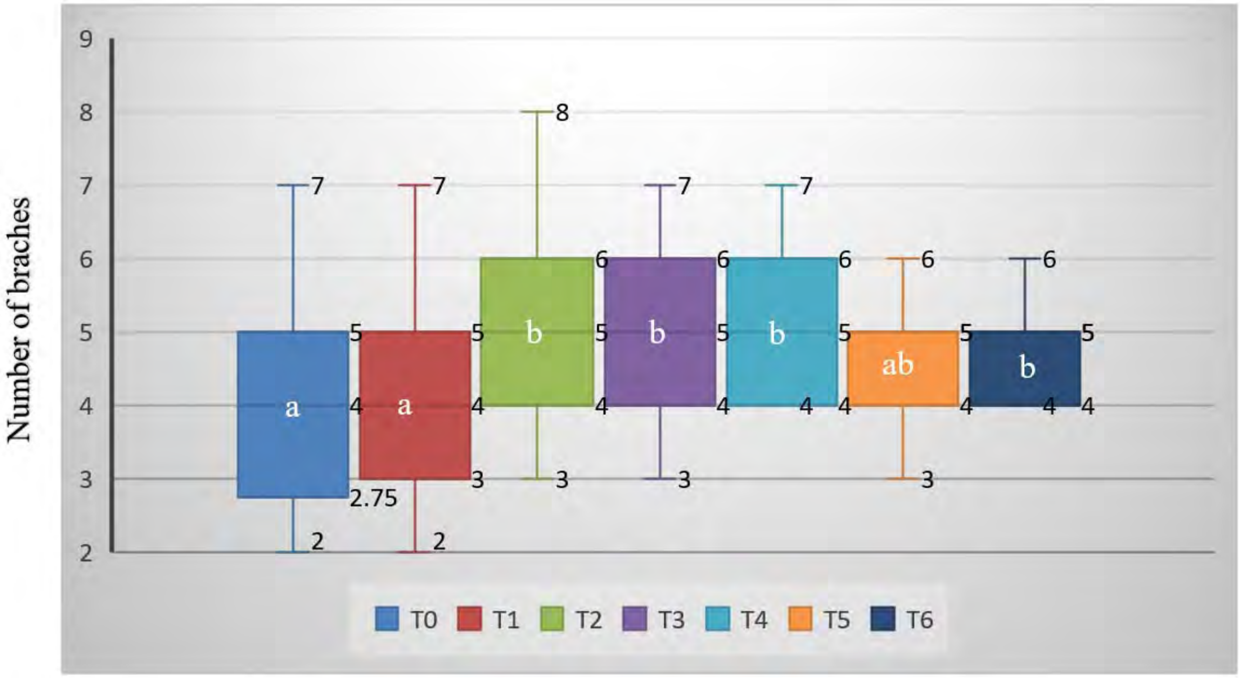

Fig. 2 Box and whisker visualization of the number of branches of eggplants (cm) during maturity.

This present study provides tangible evidence that the number of branches is improved when eggplants are grown in organic fertilizer with effective microorganisms. The exogenous application of nitrogenous fertilizers and effective microorganisms in the study of Youssef et al. (2021) improved the plant growth of stevia (*Stevia rebaudiana*) and enhanced fertility of soil. According to Yakhin et al. (2017), using biofertilizers is one of the most crucial steps to increase plant growth and agronomic crop yield while conserving the environment. Similar to this present study, it was observed that as biofertilizer was introduced to the soil medium during the field experimentation of eggplants, there was a significant increase in the number of eggplant branches at the time of eggplant maturity. Increased number of branches means increased tendency of having fruit-bearing branches. More fruit-bearing branches means greater eggplant crop yield. Another study on onion vegetative growth spearheaded by Mahmoud et al. (2019) proved increased vegetative growth and productivity of the test plants when fulvic acid and effective microorganisms were introduced. The researchers pointed out, based on the results of their investigation, that the use of effective microbes and application of fulvic acid can be a partial substitute for chemical inorganic fertilizers for sustainable production of agricultural crops.

It is also important to point out that even if the eggplants were watered with laundry waste, their number of branches were more than the control groups. The effective microorganisms seemed to degrade futile or even the toxic compounds present in laundry detergent and convert these substances to nutrient compounds and made them readily available to crops. According to Sinaga et al. (2020), the most active components of laundry waste are alkylbenzene sulfonate, sodium sulfate, sodium carbonate, benzene sulfonate, sodium dodecyl benzene sulfonate, linear alky sulfonate (LAS), and ammonium chloride. The researchers also reiterated that these materials are not biodegradable. However, in this present study, it seemed that these nonbiodegradable environmental and soil toxic substances were reduced to forms useable to plants. This was similar to the discovery of Adekanmbi et al. (2018) where they were able to notice bioremediation potential of bacteria *Paenibacillus amylolyticus* BAL1 (PAB) and *Bacillus lentus* BAL2 (BLB), both having sodium dodecyl sulphate (SDS) and metal-removing abilities making them useful bioremediating agents of wastewater.

3.2 The remediating effect of beneficial microbes on the estimated nitrogen in eggplants

The remediating effect of beneficial microbes on the estimated nitrogen contents in eggplants was presented in Table 2. The nitrogen was calculated using the soil plant analysis development (SPAD) chlorophyll meter. The F-statistics computed was 12.0025 while the p-value was $1.5877e^{-11}$. This indicates significant difference between the treatment groups. As gleaned in the table, T2 that utilized beneficial microbes-inoculated organic fertilizer produced the greatest estimated nitrogen (T2: $\bar{x}$ = 47.65+9.05 μmol m^{-2}) by measuring the chlorophyll content in eggplant leaves. The eggplants in treatment groups that received beneficial microbes-inoculated organic fertilizer and watered with any level of laundry waste (T3: $\bar{x}$ = 45.57+4.07 μmol m^{-2}; T4: $\bar{x}$ = 47.54+2.84 μmol m^{-2}; T5: $\bar{x}$ = 45.26+5.22 μmol m^{-2}; and T6: $\bar{x}$ = 45.02+6.65 μmol m^{-2}) have comparable estimated nitrogen to that T2 control group. This means that the effective beneficial microorganisms present in the organic fertilizer was able to degrade the toxic and nontoxic compounds present in laundry waste and convert it into forms that are readily assimilated by plants. The treatment group that received chemical fertilizer application (T1: $\bar{x}$ = 37.36+6.04 μmol m^{-2}) received the lowest estimated nitrogen which is comparable to the negative control (T0: $\bar{x}$ = 41.07+5.32 μmol m^{-2}) that did not receive any fertilizer application. Fig. 3 also is the visual representation of the remediating impact of effective microorganisms on the estimated nitrogen content measured through SPAD chlorophyll test through box and whisker plot diagram.

Table 2 Estimated nitrogen in eggplants (μmol m^{-2}) during maturity.

Code	Treatment Name (Formulation)	Mean	±S.D	Stat.
T0	100% tap water without fertilizer application (negative control)	41.07	±5.32[ab]	
T1	100% tap water with chemical fertilizer application (positive control 1)	37.36	±6.04[a]	
T2	100% tap water with beneficial microbes-inoculated organic fertilizer (positive control 2)	47.65	±9.05[c]	F-Stat 12.0025
T3	25% laundry waste + 75% tap water with beneficial microbes-inoculated organic fertilizer	45.57	±4.07[c]	
T4	50% laundry waste + 50% tap water with beneficial microbes-inoculated organic fertilizer	47.54	±2.84[c]	P-Val $1.5877e^{-11}$
T5	75% laundry waste + 25% tap water with beneficial microbes-inoculated organic fertilizer	45.26	±5.22[bc]	*significant
T6	100% laundry waste with beneficial microbes-inoculated organic fertilizer	45.02	±6.65[bc]	

Legend: SD = standard deviation; F-stat = F-statistics; P-Val = P-value, *significant = there is significant difference. Means with different letters are significantly different (α level of significance = 0.05).

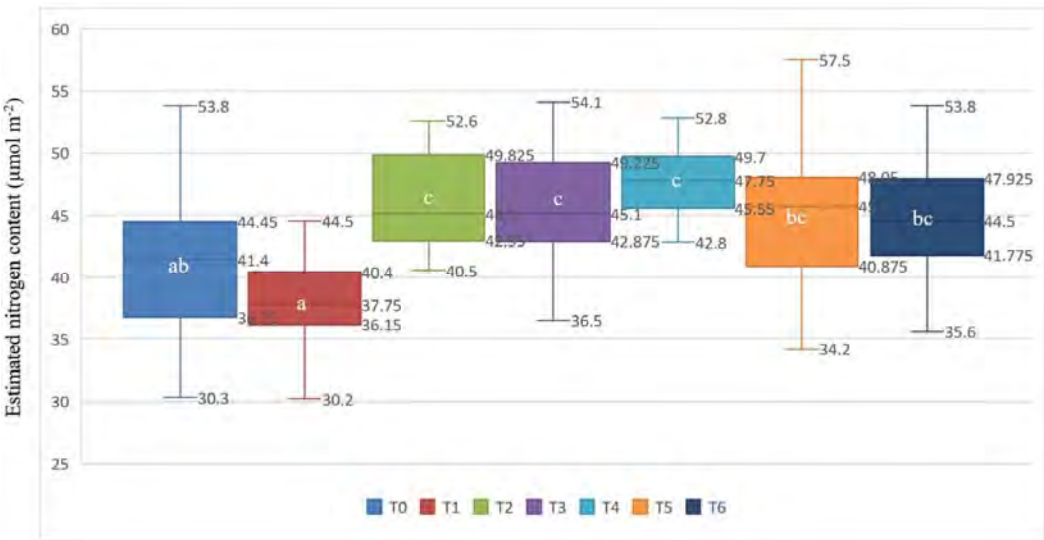

Fig. 3 Diagrammatic representation of the estimated nitrogen content (SPAD – chlorophyll analysis).

The estimated nitrogen contents in eggplants at maturity were enhanced by the application of organic fertilizer with effective microorganisms. This breakthrough implies that eggplant's nitrogen content can be improved through the use of beneficial microbes inoculated in organic fertilizers. All critical processes in plants require protein, and nitrogen forms part of the amino group in proteins. It is the most essential element for proper growth and development in plants. When nitrogen is properly assimilated and plants are nourished by the right nitrogen source, it will significantly increase plant quality and plant yield (Leghari et al., 2016). Physiologically speaking, nitrogen plays pivotal role in the formation of organs for photosynthesis and nutrient absorption, in flower formation, and in production, accumulation and translocation of yield components (Murata, 1969). It is the nutrient element that is central to plant growth and development (Haynes, 1986). A recent investigation by Muhammad et al. (2023) raised a paradigm shift in using beneficial effective microorganisms to enhance nitrogen source efficiency to achieve a sustainable environment. The researchers noticed a significant increase in soil organic matter when beneficial microbes were applied. There was also an increased trend in soil organic matter status. Overall, the use of effective microbes showed increased nutrient sources efficiency. In the present study, the nitrogen content in plants were also significantly increased when beneficial microbes present in the organic fertilizer were applied to the soil medium.

The beneficial microorganisms in the present study also provided another significant breakthrough. Eggplants grown in soils applied with organic fertilizer inoculated with beneficial microorganisms have an increased nitrogen content even when laundry waste was utilized to water them. This points to the essence of these effective microbes to reconfigure the nitrogen present in laundry waste to make it assimilable to plants. This process of reconfiguration of nitrogen is crucial because crop productivity depends profoundly on nitrogen fertilization (Xu and Miller, 2012).The study of Ray et al. (2019) highlighted the heterotrophic bioconversion process of nitrogen from wastewater through microbial assimilation. The researchers discovered the role of heterotrophic microbes towards removal of nitrogen by microbial nitrifiers. As nitrogen becomes readily available to plants, plants soon utilize these assimilable nitrogen compounds for their growth and development. The present study supports Ray et al. (2019) significant findings. The increased nitrogen content measured through SPAD chlorophyll meter indicates eggplant's accumulation of assimilable forms of nitrogen present in soils amended with bio-inoculated organic fertilizers.

3.3 Effective microbes affect the flowering height of eggplants

The flowering height of eggplants were also affected by beneficial microbes present in the organic fertilizer, as observed in Table 3. The F-statistics computed was 26.77 and the p-value was $2.1417e^{-23}$. This means a significant difference exist between the treatment groups. The least height at flowering was manifested by the negative control or those eggplants that did not receive fertilizer application (T0: $\bar{x}$ = 54.90+8.40 cm). This value was comparable to the eggplants applied with chemical fertilizer and drenched with 100% tap water (T1: $\bar{x}$ = 57.65+11.97 cm). T0 and T1 was significantly lower than the rest of the eggplant soil formulations that received organic fertilizer with beneficial microbes' inoculation (T2: $\bar{x}$ = 74.85+6.92 cm; T3: $\bar{x}$ = 71.35+6.95 cm; T4: $\bar{x}$ = 69.05+6.12 cm; T5: $\bar{x}$ = 72.50+8.20 cm; T6: $\bar{x}$ = 70.82+6.53 cm). This implies that the eggplants' flowering height was enhanced when they received organic fertilizer with effective microbes. It is also critical to point out that the eggplants watered with laundry waste were statistically as good as those that received 100% tap water as long as these treatments received organic buffer with effective microbes. This is an excellent indication that the effective microorganisms present in the applied organic fertilizer have the ability to break down the futile and potentially toxic materials in laundry detergents and modify them to form nutrient compounds that are useful to eggplants. In Figure 4, the effect of beneficial microbes to the flowering height was visualized using a box and whisker plot diagram.

Table 3 Flowering height of eggplants (cm).

Code	Treatment Name (Formulation)	Mean	+S.D	Stat.
T0	100% tap water without fertilizer application (negative control)	54.90	+8.40[a]	
T1	100% tap water with chemical fertilizer application (positive control 1)	57.65	+11.97[a]	
T2	100% tap water with beneficial microbes-inoculated organic fertilizer (positive control 2)	74.85	+6.92[b]	F-Stat 26.77
T3	25% laundry waste + 75% tap water with beneficial microbes-inoculated organic fertilizer	71.35	+6.95[b]	
T4	50% laundry waste + 50% tap water with beneficial microbes-inoculated organic fertilizer	69.05	+6.12[b]	P-Val $2.1417e^{-23}$
T5	75% laundry waste + 25% tap water with beneficial microbes-inoculated organic fertilizer	72.50	+8.20[b]	*significant
T6	100% laundry waste with beneficial microbes-inoculated organic fertilizer	70.82	+6.53[b]	

Legend: SD = standard deviation; F-stat = F-statistics; P-Val = P-value, *significant = there is significant difference. Means with different letters are significantly different (α level of significance = 0.05).

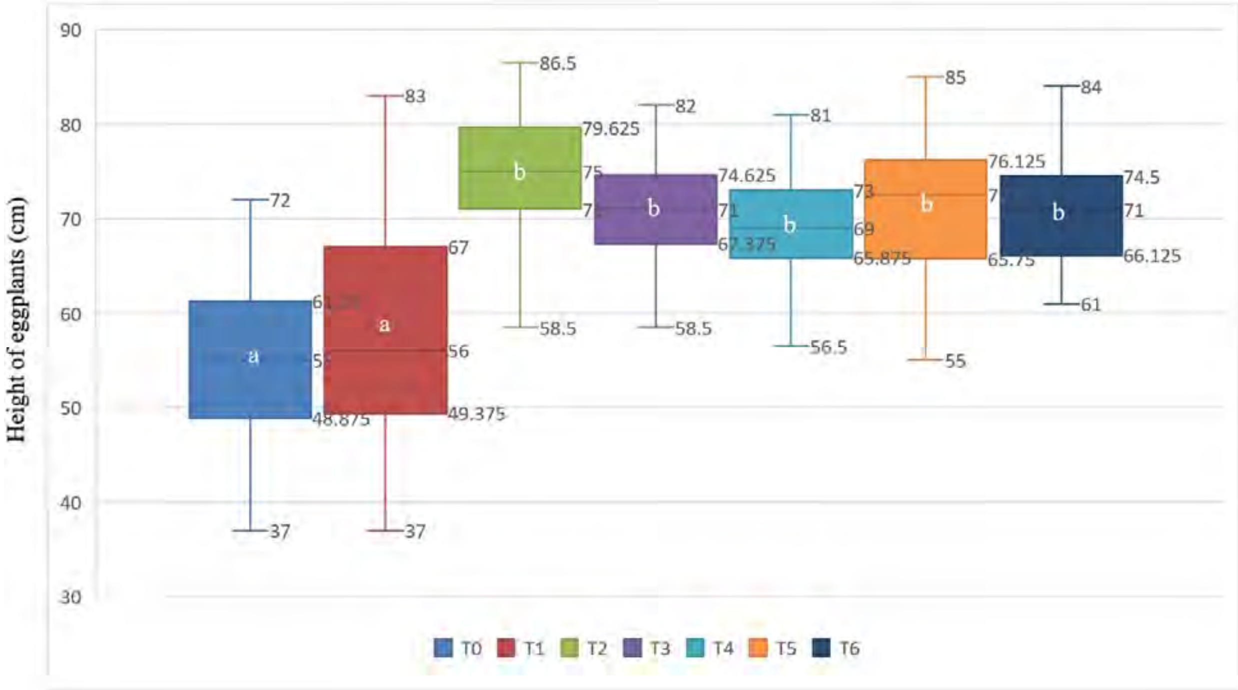

Fig. 4 Visual representation of the flowering height of eggplants.

The flowering height of eggplants were enhanced by the application of bio-inoculated organic fertilizers. These organic fertilizers contain effective microbes that increased the flowering height of eggplants. The measurement of this vegetative growth parameter indicates increased plant health. According to Trivedi et al. (2020), healthy plants host diverse communities of microbes. These plant microbiota attempts to colonize every accessible tissue in plants. As a result of plant-microbe symbiosis, plants receive substantial advantages to its survival and health efficiency. These plants that interact with effective soil microbes abundantly experience growth promotion, and increased nutrient uptake. There was also an observed stress tolerance and pathogen resistance in them. In this present study, it is theorized that the increased flowering height of eggplant is indicative to increased health efficiency due to the abundance of these effective microbes in the soil amended with organic fertilizer. Agricultural lands that apply bio-enriched organic fertilizers make their soils rich in organic matter, humus, humate, humic acid, humin and fulvic acid. These organic compounds are critical to soil fertility and plant's health (Pettit, 2004). The present study proved the potential formation of organic matter and other nutrient-rich organic compounds and can easily be attributed to the presence of effective microbes in the organic fertilizer applied in the eggplant pots.

It is fascinating to emphasize that even the eggplants that were grown in soils watered with laundry waste grew as good as those watered with tap water. It is postulated that the beneficial microbes inoculated in the organic fertilizer-amended soils made the eggplants grow significantly better than the control groups and were comparable to eggplants grown to organic fertilizer amended soils that received 100% tap water. Laundry waste was bioremediated through the use of the beneficial microbes in organic fertilizer. According to (Nayan and Bhuiyan, 2019), biological remediation is the safest and most practical way to treat waste water by effective microbes. As these water wastes are treated, the soil becomes enriched with additional nutrients available to plants. The use of microbes to remove contaminants from waste water is significantly effective. In this present study, the effectiveness in the removal of contaminants in laundry waste may also be assumed, and the conversion of compounds in laundry waste to forms useful to plants was also observed.

4 Conclusions

Eggplant growth and development were improved by using beneficial microbes (BMs) in organic fertilizers. This present study successfully explored the bioremediating effects of beneficial microorganisms. Effective microbes (EMs) have a remediating effect on eggplants' number of branch at maturity. These microbes increased the total number of branches of mature eggplants. When the eggplants were watered with laundry waste, the BMs were able to degrade toxic waste in laundry and convert them to useful nutrients evidenced by the significantly greater number of branches on the laundry waste treated eggplants than the positive and negative control. The remediating effect of beneficial microbes on estimated nitrogen content in eggplant was also apparent. Nitrogen content was highest in eggplants grown in organic fertilizer with bio-inoculated EMs. Even when these eggplants were watered with laundry waste, they still attributed the greatest nitrogen content. This breakthrough indicates that the EMs have the ability to release the nitrogen present in laundry waste and make it readily available to plant assimilation. Finally, the height of eggplants was also enhanced through the use of EMs in organic fertilizer. Eggplants grown in soils with organic fertilizer are significantly taller than the positive and negative control. The EMs ability to bioremediate was again exploited and it was observed that eggplants growth at flowering age were statistically highest in laundry waste watered treatments.

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