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Microbial Enriched Compost and Its Effect on Soil Properties, Growth and Yield of Foxtail Millet (*Setaria italica* (L.) P. Beauv.)

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Abstract

The physical and chemical properties of microbial-enriched compost and the field performance of foxtail millet as affected by MEC were evaluated. The MEC consists of corn stover, wild sunflower residues, and Trichoderma harzianum was used to enrich compost. Phase I was carried out in CRD with three test plants treated with MEC in three replicates. The MEC showed maturity and stability suitable for crop growth. Results of the phytotoxicity evaluation on radish, mungbean, and foxtail millet in vitro revealed that MEC did not significantly affect the germination index of test plants, but significantly affected percent germination and root length. The field trial of foxtail millet applied with MEC was conducted following the Randomized Complete Block Design (RCBD) with nine treatments, in three replicates. The treatments were: Control, Recommended rate of inorganic fertilizer (RRIF), Recommended rate of Commercial Compost (RRCC), MEC at 500 kg ha^{-1}, MEC at 1 ton ha^{-1}, ½ RRIF + 500 kg ha^{-1} MEC, ½ RRIF + 1 ton ha^{-1} MEC, RRIF + MEC at 500 kg ha^{-1} and RRIF + MEC at 1 ton ha^{-1}. The application of microbial-enriched compost resulted in the increased of organic matter from 1.2% to 4.0%, total nitrogen up to 0.200%, extractable phosporus to 147.11 mg kg^{-1} , and exchangeable potassium to 0.0607 cmol kg^{-1},with a slight increase in soil pH from 5.13 to 5.26. The application of MEC and inorganic fertilizers did not significantly affect the plant height, vegetative tillers at 45 DAS, days to flower and maturity of foxtail millet.

Keywords: compost evaluation, phytotoxicity, maturity, stability

1. Introduction

Millet is crucial in terms of food security and economics. The foxtail millet, one of the oldest and most extensively grown millets, is a promising crop with a nutritional profile similar to rice and corn (Verma, 2014). It is cultivated in parts of East and Southeast Asia and Africa due to its adaptability to poor soils and semi-arid climates (Sheahan, 2014). It thrives in tropical climates because it requires minimal water and is adaptable to various soils. In the Philippines, Salingay (2018) noted that it was once a staple crop in the Northern Philippines but eventually lost its dominance to the cultivation of rice in ponds and the increased production of swidden plots of sweet potatoes. Another constraint, such as the availability of quality seeds, the absence of established markets, and a lack of awareness, resulted in relatively limited cultivation. Its production faces several challenges, particularly in marginal lands with low organic matter, poor nutrient content, and degraded soil structure. The growth of the foxtail millet depends on the soil's fertility; when the soil's condition is improved, more crop growth is possible. The development and yield potential of foxtail millet can be enhanced by applying organic fertilizers, such as green manure, compost, and agricultural residues. Organic fertilizers, particularly microbial-enriched compost, improve soil fertility and serve as an alternative for farmers practicing low-input, chemical-free agriculture. Microbial species that enhance the overall nutrient availability of biofertilizers are plant growth-promoting rhizobacteria such as *Azotobacter* spp., *Pseudomonas* spp, and *Bacillus* spp. (Ahmed *et al.,* 2023).

Composting, an ancient agricultural practice, fits perfectly with modern farming methods and may enhance the nutrients available to crops. In addition to improving the soil, agricultural residues can increase the nitrogen accessible to plants. Crop residue is one of the most vital sources of nutrients for crops, and composting plays a significant role in enhancing soil health among the organic sources of readily available plant nutrients.

The common wild sunflower is another potential compost material and is widely cultivated in field and natural ecosystems. These are often regarded as weeds due to their rapid growth and appear in less organized growth patterns, however, it produces abundant biomass that is also suitable for composting. Subhash *et al*. (2014) demonstrate that integrated nutrient management based on inexpensive, readily available organic sources is more sustainable and cost-effective. In line with this, Jama *et al*. (2004) and Taguiling (2014), reported that a type of sunflower known as *Tithonia diversifolia,* a fast-growing perennial shrub is used as green manure is good for enhancing soil fertility has

NPK value of 24.2, 95, and 160 mg/100 g, respectively. Its green leaf biomass is rich in nutrients. Wild sunflower as a compost substrate increases nitrogen, phosphorus, and potassium, as Rawat *et al*. (2017) reported. A branching-stem native sunflower, which is the ancestral form of the domesticated sunflower, *Helianthus annuus*, is a common wild sunflower and considered a weed in many agricultural areas are self-toxic and allelopathic in nature; some species may harm future generations by producing allelochemicals during the breakdown of the plant's subterranean components (Azania *et al*. 2003). For the first time, Azania *et al.* (2003) reported that soil taken from the sunflower populated region and extracts of sunflower plants, decomposing leaves, root exudates, leaf leachate, and soil inhibited seed germination and seedling growth. However, composting wild sunflower alone produces strong odor and may release allelochemicals that can affect plant growth. The process can be improved by the addition of beneficial microbes like T. harzianum, a fungus that can accelerate decomposition and enhance nutrient mineralization. Microorganisms like *T. spp*. play an important role in biological decomposition and activates degradation of organic wastes thereby helps in the leaching of salts and formation of organic acids (Naher *et al*., 2014). The enrichment of the organic manures with beneficial microbial cultures will further contribute to the enhancement of N and P contents through nitrogen fixation and phosphate solubilization. Hence, the enriched organic manures and their combination provide an ideal nutrition strategy for the crop (Khare *et al*., 2014).

Composting materials with potential in organic nutrient management should be evaluated through a thorough compatibility test using a biological assay to assess phytotoxicity and compost maturity. Compost maturity is a key indicator of product quality, reflecting the degree of organic matter stabilization and pathogen reduction (Yu *et al*., 2023). Therefore, germination indices below 100% can indicate possible phytotoxicity. The quality, stability, and maturity of compost should be checked before applying it to soil. Unstable or immature compost can negatively affect seed germination, plant growth, and soil health due to lack of oxygen, accessible nitrogen, or the presence of phytotoxic substances (Bernal *et al*., 2009). Physical, chemical, or biological methods can be used to evaluate compost maturity.

Compost maturity evaluation through biological techniques ensures the safety and effectiveness of organic inputs for crop growth. The overall aim of the study was to determine the composition of microbial-enriched compost and its effects on seedling growth of selected crops grown in vitro, as well as to evaluate the field performance of foxtail millet treated with microbial-enriched compost. Specifically, the study will assess the effect of enriched compost on germination, root length, and germination index of radish, mung bean, and foxtail millet grown in vitro to determine the compost's maturity (1), and examine the growth and yield of foxtail millet influenced by different fertilizer treatments (2).

2. Methodology

2.1 Phase 1: Composting and in Vitro Testing of Compost Maturity

Locally available crop residues or agricultural biowastes were collected and used in the study. Corn stovers and wild sunflower accelerator (*Tithonia diversifolia*) were collected as substrate within the locality and some farms in Manolo Fortich, Bukidnon. The microbial-based culture *Trichoderma harzianum* as an activator was obtained from the Regional Crop Protection Center, Bangcud, Malaybalay, Bukidnon.

The corn stover and wild sunflower were manually chopped and shredded to achieve a relatively uniform size, then combined and mixed manually. The cultured *T. harzianum*, was obtained from the Regional Crop Protection Center, Bangcud, Malaybalay City, Bukidnon. The substrates were piled loosely in a plastic bin provided with good aeration. A total of 20 kilograms of combined corn stover and wild sunflower was prepared and supplemented with 20 grams of *T. harzianum*, which served as a compost activator to accelerate the decomposition process. The compost substrates were thoroughly mixed using shovels and turned regularly to maintain uniformity. The compost was placed in a cool, dry, shaded area for 14 and 30 days. This set-up was covered to minimize water evaporation and volatilization of gaseous forms of nitrogen. The temperature and moisture content of the composted substrates were regularly checked using a thermometer and a moisture meter, respectively. Using a sprinkler, water was added to the compost pile (if it appeared dry) to maintain proper moisture levels. The nutrient composition of enriched compost was evaluated before and after enrichment using *T. harzianum*. Composting was done for a four-week period. A 1 kg sample of MEC after enrichment was submitted to the Soil and Plant Laboratory, Department of Soil Science, College of Agriculture, Central Mindanao University, for analysis. Stability and phytotoxicity of compost parameters were evaluated through a common technique, a biological trial, to assess its suitability. Table 1 shows the parameters measured and the corresponding analytical method used.

Table 1. Compost Quality Parameters and Analytical Methods Used

Parameter	Analytical Method	Reference
Compost		
pH	Potentiometric (1:5 compost: water)	Biddle, 1997
Electrical conductivity (EC)	Potentiometric (1:5 compost: water)	Biddle, 1997
Organic carbon	Heanes Method	Biddle, 1997
Total N (%)	Microkjeldhal Analysis	PCAARRD, 1980
Total P_2O_5 (%)	Dry ashing (UV Vis Spectrophotometer)	PCAARRD, 1980
Total K_2O (%)	Dry ashing (Atomic Absorption Spectrophotometer)	PCAARRD, 1980
Phytotoxicity		
Seed Germination Test	Biological trial	Zucconi *et al*, 1981
Germination Index	Biological trial	
Root and Length	Biological trial	

2.1.1 Characterization of Enriched Compost

The nutrient composition of microbial-enriched compost was evaluated before and after enrichment of *T. harzianum*. The compost samples were collected from the top, middle, and bottom of the container and then combined into composite samples. A 1 kg sample of the prepared compost after enrichment was submitted to the Soil and Plant Laboratory, Department of Soil Science, College of Agriculture, Central Mindanao University, for initial analysis.

The chemical properties of compost used in the trial were analyzed for pH, total N, total P_2O_5 (%), total K_2O (%), and organic matter content (%). Agricultural waste samples were collected for initial analysis (Table 2).

On the 14^{th} and 30^{th} days of composting, samples of the compost were taken for initial analysis. After turning, temperature and water content were recorded on a weekly basis. The color, odor, and texture were evaluated based on the criteria for physical appearance as follows:

1. Moisture Content. This is the fraction or percentage of a moist substance that is water.
2. Odor. It is a factor in determining if the compost process is complete. Compost nearing completion had an earthy smell, as opposed to compost that is not near completion, which may have a variety of odors (Table 2).

3. Color. Color is also a factor in determining the readiness of compost for use. As most compost matures, it begins to take on an earthy appearance and turns dark brown or even black. Moisture content will also influence the color. Very moist compost had a darker appearance than similar compost that was very dry (Table 2).

Table 2. Compost Rating based on Color and Odor

Rating	Color	Odor
1	Black	earthy, soil-like, no odor
2	Dark brown	moldy, musty, mildew, swampy
3	Medium brown	fruit, licorice, slight pine or ammonia, burnt
4	Light brown	sour, rotting grass, manure, vinegar, ammonia
5	Yellow-green	fresh yard debris, fresh manure, wet leaves, hay

Source: Cornell Cooperative Extension Compost Education Program, 2015

2.1.2 Preparation of Extract

The extract was prepared by placing 10 g of enriched compost sample (dry weight) at 30 days after composting in a 200 mL flask filled with 100 mL of distilled water and shaken at 125 rpm for 16 hours at room temperature using an electric shaker. The percentage of germination and root elongation in distilled water were used as the control treatment.

2.1.3 Phytotoxicity Evaluation (Seed Germination Test)

This was used to assess the maturity of the prepared compost, which indicates its stability. Three test plants were used to cover a broad range of possibilities. A germination test was conducted for radish, mung bean, and foxtail millet seeds sown in compost extracts (Zucconi *et al*., 1981). Whatman filter papers were placed in petri dishes and moistened with 5 mL of filtered compost-water extract. Three replicates of each germination test were performed using different seed samples. Seeds of radish, mung bean, and foxtail millet, with 50 pieces each, were placed on the moist paper. Distilled water served as a control. The petri dishes were covered and kept in incubation or germination chambers for periods ranging from 1 to 6 days, at temperatures between 20°C and 28°C. On day 3 and day 6, germinated radish, mung bean, and foxtail millet seeds were counted, and root lengths were measured, respectively.

2.1.4 Data Gathered

A. Crop Data. The percentage germination and root elongation based on Zucconi *et al*. (1981) were calculated as follows:

1. Percent Germination - Samples for germination were taken from 1-6 days after sowing. The percent germination was computed using the formula below (Equation 1):

$$\%\ Germination = \frac{No.of\ germinated\ seeds}{No.of\ seed\ sown}\ x\ 100 \qquad (1)$$

2. Root Length (cm) - This was done by measuring the length of root from the shoot-root junction to the tip of the longest roots of ten sample seedlings per experimental unit using a ruler at 6 days after sowing.

3. Germination Index (GI) - The seedlings were tested for phytotoxicity of the compost and were calculated using Equation 2:

$$Germination\ Index = \frac{\%\ Germination\ x\ \%\ Root\ Growth}{100} \qquad (2)$$

where % root growth was calculated using Equation 3:

$$\%\ Root\ Growth = \frac{Mean\ root\ length\ in\ each\ extract}{Mean\ root\ length\ in\ control}\ x\ 100 \qquad (3)$$

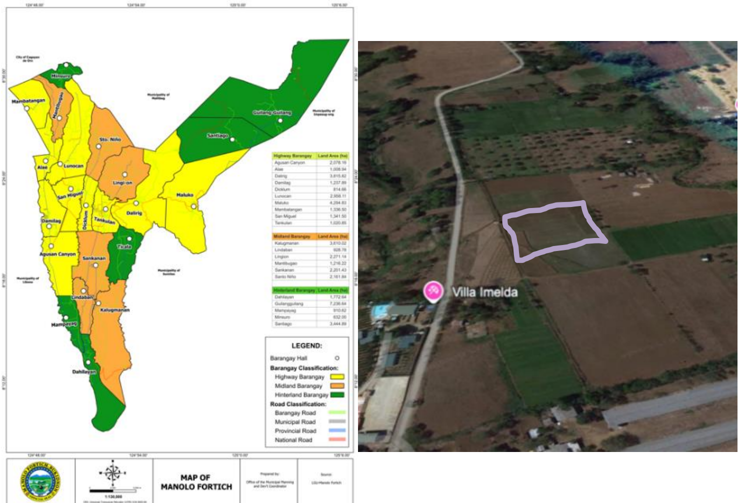
2.1.5 Statistical Analysis

The data were analyzed using Analysis of Variance (ANOVA) for a Factorial in a completely randomized design (CRD). The significant differences among treatments were compared using the Honestly Significant Difference (HSD) Test.

2.2 Phase II: Growth and Yield of Foxtail Millet Applied with Microbial Enriched Compost and Inorganic Fertilizers

2.2.1 Description of the Study Site and Duration of the Study

An agricultural field that had not been cultivated recently in Barangay Dicklum, Manolo Fortich, Bukidnon (Figure 1) was selected as the study site for the response of Foxtail Millet (*Setaria italica* L.) to the addition of microbial-enriched compost. The study was conducted from December 2019 to May 2020. The mean annual rainfall in Manolo Fortich is 2000 mm, which is favorable for high-value crops and highland crops. Rainfall during the study period was measured at 4 mm, 15 mm, 1.8 mm, 19 mm, and 37.8 mm from January to May 2020, respectively. May 2020 had more rainfall (37.8 mm) while March 2020 received less (1.8 mm), as shown in Figure 2. The mean temperature from January to May ranged from 21.1°C to 31.1°C.



Source: https://web.manolofortich.gov.ph/pages/map

Figure 1. Experimental site at Diclum, Manolo Fortich, Bukidnon, Philippines

2.2.2 Soil Sampling and Analysis

Soil samples were randomly taken from the field following standard procedures prior to land preparation. A composite soil sample consisting of 15 subsamples were taken from 0-15 cm depth, traversed in a zigzag pattern around the area as the representative soil sample. The representative soil samples were mixed, air-dried, and sieved to pass 2 mm sieve to obtain data on initial soil physical and chemical properties. Soil samples collected were brought to the Soil and Plant Analysis Laboratory (SPAL) at the Department of Soil Science, Central Mindanao University, Musuan, Bukidnon for initial nutrient analysis. The characterization of the soil was done to determine its soil textural class and chemical properties such as the pH, organic matter content, total nitrogen, extractable phosphorus and exchangeable potassium contents. Soil samples were also collected from each experimental plot after the harvest of foxtail millet. The methods used in the analyses are given in Table 3.

Table 3. Edaphic Data and Analytical Methods Used

Parameter	Analytical Method	Reference
Soil		
pH	Potentiometric (1:5 soil to water)	Biddle, 1997
Organic Matter	Walkley and Black	PCAARRD, 1991
Nitrogen	Microkjeldahl	PCAARRD, 1980
Available P	Bray P_2	PCAARRD, 1991
Exchangeable K	1N NH_4OAc pH 7.0 (Extraction Method)	PCAARRD, 1991

2.2.3 Experimental Design

The study was laid out in Randomized Complete Block Design (RCBD) with nine treatments replicated three times. Each plot had a dimension of 5 m x 5 m with alleys of 1.5 m between blocks and 1.0 m between plots. The different fertilizer treatments were the following:

T_1 – Control
T_2 - RRIF (Recommended Rate of Inorganic Fertilizer based on the results of soil analysis) at 80 kg N, 20 kg P_2O_5, 30 kg K_2O ha^{-1}
T_3 - RRCC (Recommended Rate of Commercial Compost) at 2 tons ha^{-1}
T_4 – Microbial E- Compost at 500 kg ha^{-1}
T_5 – Microbial E- Compost at 1 ton ha^{-1}
T_6 - ½ RRIF + 500 kg ha^{-1} Microbial E-Compost
T_7 - ½ RRIF + 1 ton ha^{-1} Microbial E-Compost
T_8 - RRIF + Microbial E-Compost a 500 kg ha^{-1}
T_9 - RRIF + Microbial E- Compost at 1 ton ha^{-1}

2.2.4 Cultural Management

The site was cleared of crop residues. Land preparation was done before the application of compost. The field was thoroughly prepared by plowing and harrowing until the soil was favorable for foxtail millet seeds. The area was plowed twice at one-week intervals, then three days after each plowing, while the soil was pulverized by harrowing to produce a fine tilth. After the final harrowing, furrows were set at 30 cm apart.

During the final harrowing, the different levels of enriched compost were applied on the set furrows based on the assigned treatments. These were incorporated in experimental plots designated for the treatments.

Enriched compost was applied after the final harrowing, based on rates specific to each treatment. The amounts of inorganic fertilizers were applied basally at planting time, as assigned by treatment.

2.2.5 Planting, Thinning, and Water Management

Foxtail millet seeds were sown and covered lightly with soil to increase germination. Foxtail millet seeds were planted by the drill method at a row distance of 30 cm with 10 plants per linear meter. Replanting of missing hills was done one week after emergence, and thinning was done three weeks after emergence.

Watering of plants was done only when needed. Depending on the weather conditions, foxtail millets were irrigated using the sprinkler method from the vegetative to the flowering stage. On the other hand, it is necessary to control weeds for a successful crop growth and development. Weed management was carried out through manual hand-pulling to minimize competition for nutrients, water, and light with the test crop.

2.2.6 Pest Identification

The field was monitored for the presence of birds and other pests that might attack the test crops. All types of insects present in a 1 m^2 area within the data rows were identified, observed, and recorded.

2.2.7 Harvesting and Post-Harvest Handling

Foxtail millets were harvested when 90% of their grains and third leaves turned brown. Harvesting was done by cutting the panicle using a pair of scissors and a cutter. Manual threshing was done by hand, and the grains were sundried to a moisture content of 14%. Sundried grains were stored in hermetic containers.

2.2.8 Data Gathered

A. Edaphic Data

1. Initial Soil Properties – Composite soil samples were taken from the experimental site prior to land preparation. Representative soil samples were mixed, air-dried, and sieved to pass a 2 mm sieve for initial analysis on soil pH, %OM, extractable P, and

exchangeable K at the Soil and Plant Analysis laboratory (SPAL) using the methods mentioned in Table 2.

2. Final Soil Analysis. At harvest, soil samples were also collected randomly from each treatment plot. Soil samples from each plot were air dried, sieved, and analyzed to monitor nutrient changes in the soil.

B. Agronomic Characteristics

1. Plant Height (cm) - 10 randomly selected hills (tagged hills) per treatment were measured in each plot at 30, 60, 90, and 120 DAS. The height of foxtail millet plants was measured from the base of the plant to the tip of the longest leaf per treatment at weekly interval starting two weeks after germination.

2. Vegetative Tillers - This was counted from 10 randomly selected hills per plot taken at 45 DAS and the average per treatment was recorded.

3. Days to Flowering - This was recorded from the day of sowing up to the time when 50% of the tillers in each plot had totally exerted panicles.

4. Days to Maturity - This was counted from the day of sowing until the panicles of 80-85% of the total plant population turned 80% to 90% brown.

C. Yield and Yield Components

1. Numbers of Productive Tillers per Hill - The productive tillers of 10 tagged hills per plot were counted at 90 DAS using the same samples where the number of vegetative tillers was taken. The average was recorded after.
2. Panicle Length - This was recorded as the average length of 10 randomly selected panicles per plot. This was measured from the neck node to the tip of the panicle using a meter stick; the average was then recorded.

3. Panicle Diameter - This was recorded as the average diameter of 10 randomly selected panicles per plot measured using a vernier caliper and the average was recorded thereafter.

4. Weight of Grains - This was recorded as the average weight of one thimble (approximately 15 mL liquid capacity, where 1 mL=1 g) grains per plot.

5. Threshing Percentage - This was recorded as the amount of grains in a panicle, computed as the quotient of the weight of grains from ten randomly selected panicles per plot divided by the weight of unshelled panicles multiplied by 100. The average was recorded after.

6. Adjusted Grain Yield per Hectare - It was based on the grain yield of the effective harvest area (EHA). Adjusted grain yield per hectare at 14% moisture content was computed using Equation 4:

$$Grain\ yield\ \left(\frac{kg}{ha}\right) = \frac{Yield\ of\ EHA\ x\ 10{,}000m^2}{EHA}\, x\, \frac{(100 - \%Field\ MC)}{86} \quad (4)$$

Where: $EHA = 13.5\ m^2$

2.2.9 Statistical Analysis

The data were analyzed statistically using SPSS 17.0 (2008) (SPSS Statistics for Windows, USA). The significant differences among treatment means were compared using the Honestly Significant Difference (HSD) Test.

3. Results and Discussion

3.1 Phase I: Composting and in Vitro Testing of Compost Maturity

Compost is generated from the natural decomposition of organic materials. The quality of compost is often described as the maturity and stability which promotes plant growth. Bernal *et al*. (2009) stated that the unstable and/or immature compost can have adverse effects on seed germination, plant growth and soil environment due to the decreased supply of oxygen and/or available nitrogen or the presence of phytotoxic compounds. The physical and chemical changes in the compost were observed over four weeks. Compost samples were analyzed for chemical properties as shown in Table 3.

3.2 Chemical Composition of Compost with and without enrichment

3.2.1 Compost pH

The properties of compost with and without *T. harzianum* were observed and gathered 14 and 30 days after composting, as shown in Table 4. There was an appreciable change in the pH of the compost during the process. The pH of compost without enrichment was 8.92 and 8.83 at 14 and 30 days after composting, respectively. The pH observed for enriched compost was moderately alkaline at 14^{th} days after enrichment with *T. harzianum* and slightly alkaline at 30 days after enrichment.

Table 4. Physical and chemical composition of compost with and without enrichment

Properties	No Enrichment		Enriched Compost	
	14	30	14	30
Chemical Composition				
pH	8.92	8.83	8.94	7.96
EC ($\mu s\ cm^{-1}$)	240	2.66	2.57	2.47
Organic carbon (%)	2.78	17.6	16.01	7.73
C:N ratio	9:1	15:1	6:1	10:1
Total N (%)	0.297	1.208	1.208	1.579
Total P_2O_5 (%)	0.132	0.150	0.171	0.100
Total K_2O (%)	0.126	0.160	0.151	0.055
Physical Composition				
Moisture Content (%)	20.62	20.66	20.56	20.67
Temperature	35 °C	33 °C	35 °C	30 °C
Color	Medium brown	Dark Brown	Dark brown	Black
Odor	fruit, licorice, slight pine or ammonia, burnt	Moldy, musty, mildew, swampy	Moldy, musty, mildew, swampy	Earthy, soil-like, no odor
Compost Rating	3	2	2	1

The decrease in the pH of enriched compost was noticeable at 30 days which suggests that it has something to do with the effect of microbial culture with the quality of organic amendment. The changes could be due to the formation of organic acids and mineralization of organic wastes. At pH levels above 9, ammonium is converted to ammonia gas which volatilizes and contributes to unpleasant odors. Below pH 9 substantially helps stabilize and yield a mature compost. The pH observed, although close, however, was not within the recommended limit (5 to 7) for fully mature compost.

3.2.2 Electrical conductivity

Electrical conductivity measures the salinity in organic materials and is an indicator of a good amendment (Lasaridi *et al.*, 2006). The electrical conductivity of compost was highest on the 14th day after enrichment (1257 µs cm^{-1}). The electrical conductivity of compost without enrichment reduced from 240 µs cm^{-1} in 14 days to 2.66 in 30 days. Electrical conductivity of the enriched compost after 14 and 30 days of enrichment is 1257µs cm^{-1} and 2.47µs cm^{-1}. At 30 days after enrichment, the electrical conductivity is more acceptable for an amendment to be mature (Table 3). The decrease of electrical conductivity of microbial-enriched compost was caused by precipitation or leaching of soluble salts. A high electrical conductivity may be phytotoxic to plants, adversely affecting plant growth, and symptoms may appear. Some plants are sensitive or less sensitive to salinity. Lasaridi *et al.* (2006) reported that plants have a maximum EC tolerance limit of 4.0 µs cm$^{-1,}$ which can be applied for plant growth below this value. Microorganisms like *T. spp*. play an important role in biological decomposition and activate the degradation of organic wastes; thereby, it helps in the leaching of salts and formation of organic acids (Naher *et al*., 2014).

3.2.3 Organic Carbon

The organic carbon of compost with and without enrichment ranges from 2.78 to 16.01%. The maximum organic carbon was found in compost enriched with *T. harzianum* 14 days after composting. The increase in carbon content might be due to the fungus applied, which had an impact on fortification and improvement of the quality of organic amendments. High carbon content indicates that the substrates are still in the transitional stage of decomposition. Microorganisms like *Trichoderma spp*. play an important role in biological decomposition and activate degradation of organic wastes; thereby, it helps in the leaching of salts and formation of organic acids (Naher *et al*., 2014).

3.2.4 Carbon:nitrogen ratio

The carbon-to-nitrogen ratio (C:N) of compost with and without enrichments ranges from 6:1 to 15:1 (Table 3). Compost without *T. harzianum* at 14 days after composting has 9:1 carbon to nitrogen ratio while carbon to nitrogen ratio at 30days after composting was 15:1. Microbial-enriched compost at 14 days has a C:N ratio of 6:1 while at 30 days it has a C:N ratio of 10:1. Compost with and without enrichment are optimal and has the potential to be a good compost. The decrease in C:N ratio could be attributed to the addition of N from the substrate's wild sunflower and enrichment.

3.2.5 Total nitrogen, phosphorus, and potassium

The amounts of nitrogen, phosphorus, and potassium are very important factors in determining good quality compost. There was a slight increase in total nitrogen with composting time. It was observed that compost without *T. harzianum* has 0.297% total nitrogen 14 days after composting, while at 30 days after composting, it has 1.208%. The highest value of total nitrogen was recorded in the 4th week after enrichment (1.579%). The results align with findings of Math and Sreenivasa (2014), where enriching organic manures with beneficial microbial cultures further enhanced nitrogen and phosphorus content through nitrogen fixation and phosphate solubilization. Total phosphorus was highest during the initial stage of decomposition and decreased at later stages. It is known to be a good supplementary source of organic nitrogen. Additionally, wild sunflowers used as a compost substrate increase nitrogen, phosphorus, and potassium, as reported by Pariana (1992).

3.2.6 Temperature

The temperature of the compost varies depending on the stage of decomposition. The change in compost temperature depends on the stages or phases of decomposition, where microorganisms initiate the process. It was observed that the compost temperature was 35°C in the 2nd week and 30°C in the 4th week. The gradual decrease in temperature indicated that the compost was maturing.

3.2.7 Moisture content

As observed, the moisture content of compost without enrichment ranges from 20. 62% to 20.66% while compost with enrichment ranges from 20.56% to 20.67%. The results in the moisture content of compost are within the minimum requirements of Philippine National Standards (2016) for the actual moisture content.

3.3 Biological Trial Parameters for Compost suitability

3.3.1 Germination (%)

Radish, mung bean, and foxtail millet seeds were chosen as the test crop seed for biological tests. Data on percent germination of the three kinds of seeds were observed from 1-6 days (Table 5). Radish, mung bean, and foxtail millet seeds were treated with microbial-enriched compost extracts and distilled water as the control.

Table 5. Mean percent germination, root growth, and germination index of crops as affected by different extracts

Treatments				
Extracts	Test Plant	Germination (%)	Root Length (cm)	Germination Index
Control (Distilled water)	Radish	92.0	5.0a	92.0
	Mungbean	93.0	3.2bc	92.0
	Foxtail Millet	90.0	2.6bc	90.0
Compost Extract	Radish	79.0	5.1a	88.88
	Mungbean	96.0	4.1ab	142.86
	Foxtail Millet	77.0	2.4c	79.62
Extract Means(A)				
Extract		91.67	3.6	92.0
Distilled water		84.00	3.9	103.8
Test Plants				
Radish		85.5	5.05	90.44
Mungbean		94.5	3.65	117.43
Foxtail Millet		83.5	2.50	84.81
F-test				
Extract (A)		ns	ns	ns
Test Plants (B)		ns	**	ns
AxB		ns	ns	ns
CV (A)		8.57	15.30	20.14
CV (B)		8.57	15.38	20.21

Means followed by the same letter(s) are not significantly different at 5% level of significance based on HSD Test

The results showed that the effect of compost extracts, tested crops, and the interaction between crops and compost extracts on percent germination was not significant. There was a decline in the percent germination of radish, mung bean, and foxtail millet treated with compost extracts. Mung bean seeds treated with compost extracts had a higher percent germination (96%) compared to radish (79%) and foxtail millet (77%). Conversely, it was observed that radish, mung bean, and foxtail millet seeds without compost extracts had higher percent germination. In this study, compost extracts produced smaller germination values than the control. The effects of compost extracts on percent germination were attributed to nutrient availability and the salinity effect of enriched compost.

As shown in Table 5, the effects of compost extracts on the tested crops' root length varied significantly across all treatments. The longest root length was observed in radish (5.1 cm), while the shortest was in foxtail millet (2.4 cm). The data on pH and electrical conductivity indicated values that were detrimental to seed growth and caused delays in germination, as well as inhibition of plant growth or other adverse effects caused by specific substances (phytotoxins) or unsuitable growth conditions.

3.3.2 Root Length (cm)

The effects of compost extracts on root length have the potential to damage roots. An increase in soil acidity can harm roots and decrease nutrient uptake. The decline in values was likely caused by changes in pH, electrical conductivity, and available nutrients. Crops like radish were used in experiments to evaluate phytotoxicity due to their sensitivity and rapid germination. Although the results were not significantly different, T. harzianum helped speed up decomposition.

3.2 Phase II: Growth and Yield of Foxtail Millet Applied with Microbial-Enriched Compost and Inorganic Fertilizers

The highest soil pH (5.24) was observed in plots treated with the recommended rate of inorganic fertilizers combined with microbial-enriched compost at 500 kg ha-1, followed by plots treated with only the recommended rate of inorganic fertilizers. Based on the results, there were no significant differences among the plots. The pH values observed in each plot ranged from strongly acid to moderately acid. The application of microbial-enriched compost alone or with inorganic fertilizers did not significantly ($P \leq 0.05$) affect soil pH. However, a slight increase in pH was seen following the addition of MEC @ 500 kg ha-1, ½ RRIF + 500 kg ha-1 MEC, and RRIF + MEC @ 500 kg, likely due to the liming effect of the compost because of its richness in alkaline cations.

It can be observed in Table 6 that application of Microbial E- Compost at 500 kg ha^{-1} and Microbial E- Compost at 1 ton ha^{-1} were beneficial to the increase in organic matter content of the soil. The organic matter content ranges from 3.36% to 4.0%. Application of MEC at 500 kg ha^{-1} and MEC @ 1 ton ha^{-1} have increased organic matter content of soils.
The total nitrogen obtained from the different plots with different treatments ranged from 0.168 % to 0.200%. Based on the analysis, the different rates of microbial-enriched compost and inorganic fertilizers did not significantly affect the total nitrogen of the soil from each plot. However, as the amount of microbial-enriched compost and inorganic fertilizers increases, the total nitrogen after harvest increased.

Maximum total nitrogen was observed in treatments with microbial-enriched compost at 500 kg ha^{-1} (0.200%) and 1 ton ha^{-1} (0.200%) compared to the control. This might be because of the abundance of nutrients from the applied compost.

The highest (147.11 mg kg^{-1}) and lowest (66.65 mg kg^{-1}) value of extractable phosphorus was obtained from application of MEC at 1 ton ha^{-1} and MEC at 500 kg ha^{-1} respectively. Increasing the application of MEC increase the phosphorus content of soil due to the reason that compost enhances phosphorus availability. The increase in the available potassium was due to the application of recommended rate of commercial compost, RRIF and MEC at 500 kg ha^{-1}.

Table 6. Soil Properties affected by the application of Microbial-Enriched Compost and Inorganic Fertilizers

Treatment	Soil Properties				
	pH	Organic Matter (%)	Total Nitrogen (%)	Extractable Phosphorus (mg kg^{-1})	Exchangeable Potassium (cmol kg^{-1})
T_1- Control	5.04	3.87	0.194	83.51	0.0533c
T_2- RRIF	5.20	3.36	0.168	117.27	0.0524bc
T_3 – RR Commercial Compost	4.95	3.96	0.198	79.91	0.0584bc
T_4 – MEC at 500 kg ha^{-1}	5.26	4.00	0.200	66.65	0.0607bc
T_5 – MEC @ 1 ton ha^{-1}	4.97	4.00	0.200	147.11	0.0391bc
T_6 – ½ RRIF + 500 kg ha^{-1} MEC	5.17	3.92	0.196	70.31	0.0353bc
T_7 – ½ RRIF + 1 ton ha^{-1} MEC	4.84	3.79	0.190	97.02	0.0405bc
T_8 – RRIF + MEC at 500 kg ha^{-1}	5.24	3.75	0.188	83.58	0.0345b
T_9– RRIF + MEC at 1 ton ha^{-1}	4.91	3.71	0.186	81.46	0.0172b

3.2.1 Plant Height (cm)

Based on the results on plant height at 30, 60, 90, and 120 DAS, foxtail millet has responded to the increasing amount of compost and inorganic fertilizers however, no significant differences were observed among all treatments (Table 7). At 30 days after sowing, plots applied with recommended rate of inorganic fertilizer has the highest plant height (31 cm) followed by recommended rate of commercial compost at 2 ton ha^{-1} (30.1 cm). At 60 DAS, plots applied with RRIF + Microbial-enriched compost at 500 kg ha^{-1} exhibited higher value of plant height (58.6 cm), however, the lowest value was observed in plots with MEC at 1 ton ha^{-1} (49.9 cm). At 90 DAS, it was observed that plots with RRIF + Microbial-enriched compost at 500 kg ha^{-1} has the highest plant height (79.0 cm) while the lowest was observed at MEC at 1 ton ha^{-} (63.5 cm). At 120 DAS, plots applied with RRIF had the highest plant height (92.2cm) while the lowest was observed in plots with MEC at 1 ton ha^{-} (69.3 cm).

Table 7. Mean plant height of foxtail millet as affected by the application of Microbial-Enriched Compost and Inorganic Fertilizers

Treatment	Plant Height (cm)			
	30DAS	60DAS	90DAS	120DAS
T_1- Control	29.2	55.2	70.5	77.6
T_2- RRIF	31.0	58.3	77.6	92.2
T_3 – RR Commercial Compost	30.1	54.8	69.1	73.1
T_4 – MEC at 500 kg ha^{-1}	27.8	54.5	73.2	83.3
T_5 – MEC @ 1 ton ha^{-1}	26.4	49.9	63.5	69.3
T_6 – ½ RRIF + 500 kg ha^{-1} MEC	26.9	56.2	74.5	80.4
T_7 – ½ RRIF + 1 ton ha^{-1} MEC	26.8	53.8	70.7	75.3
T_8 – RRIF + MEC at 500 kg ha^{-1}	26.8	58.6	79.0	89.1
T_9– RRIF + MEC at 1 ton ha^{-1}	28.2	55.8	76.6	87.3
F-test	ns	ns	ns	ns
CV (%)	8.24	10.75	9.86	13.26

MEC – Microbial-Enriched Compost,
RRIF- Recommended Rate of Inorganic Fertilizer
RRCC- Recommended Rate of Commercial Compost

3.2.2 Agronomic Characteristics

It was evident in the results that the number of tillers at 45 days after sowing increased with increasing amount of NPK wherein application of recommended commercial compost, ½ RRIF + 500 kg ha^{-1} MEC, ½ RRIF + 1 ton ha^{-1} MEC and RRIF + MEC at 500 kg ha^{-} have resulted to higher number of tillers (5 tillers) at 45 DAS (Table 8). The lowest mean number of tillers was noticed in plots applied with RRIF (recommended rate of inorganic fertilizer) kg ha^{-1}. The number of days to flower and to mature as affected by the application of microbial enriched compost and inorganic fertilizers showed no significant differences. The days to maturity ranged from 101 to 109 days. Plots with RRIF + Microbial-enriched Compost at 500 kg ha^{-1} has the longer days to mature while the shortest days to mature was observed in plots with RRIF.

Table 8. Agronomic characteristics of foxtail millet as affected by the application of Microbial-Enriched Compost and Inorganic Fertilizers

Treatment	Agronomic Characteristics		
	Vegetative Tillers (45 DAS)	Days to Flower (DAS)	Days to Maturity (DAS)
T_1- Control	4.40	93	103
T_2- RRIF	2.77	90	101
T_3 – RR Commercial Compost	4.77	98	108
T_4 – MEC at 500 kg ha^{-1}	3.47	93	104
T_5 – MEC @ 1 ton ha^{-1}	3.97	97	108
T_6 – ½ RRIF + 500 kg ha^{-1} MEC	4.60	97	107
T_7 – ½ RRIF + 1 ton ha^{-1} MEC	4.70	96	108
T_8 – RRIF + MEC at 500 kg ha^{-1}	4.47	97	109
T_9– RRIF + MEC at 1 ton ha^{-1}	4.10	94	106
F-test	ns	ns	ns
CV (%)	25.44	5.21	4.29

Table 9. Yield and Yield Components of foxtail millet as affected by the application of Microbial-Enriched Compost and Inorganic Fertilizers

Treatment	Yield and Yield Components					
	No. of Productive Tillers per Hill (90 DAS)	Panicle Length (cm)	Panicle Diameter (cm)	Weight of Grains (g)	Threshing Percentage (%)	Adjusted Grain Yield per Hectare (kg ha^{-1})
T_1- Control	2.50	23.2c	1.14	10.3	64.05	471.11
T_2- RRIF	2.60	28.1ab	1.34	10.0	82.07	655.80
T_3 – RR Commercial Compost	2.50	26.7abc	1.33	11.5	64.32	442.23
T_4 – MEC at 500 kg ha^{-1}	2.23	26.6abc	1.35	10.3	68.06	610.29
T_5 – MEC @ 1 ton ha^{-1}	2.33	23.7c	1.15	12.2	78.74	498.01
T_6 – ½ RRIF + 500 kg ha^{-1} MEC	2.47	28.0ab	1.40	10.2	63.20	579.15
T_7 – ½ RRIF + 1 ton ha^{-1} MEC	2.43	24.0bc	1.18	11.0	75.60	445.84
T_8 – RRIF + MEC at 500 kg ha^{-1}	2.53	26.5abc	1.23	11.5	70.17	504.21
T_9– RRIF + MEC at 1 ton ha^{-1}	2.73	28.5a	1.51	12.0	72.77	609.31
F-test	ns	*	ns	ns	ns	ns
CV (%)	17.61	8.35	10.94	8.02	11.32	21.12

Means followed by the same letter(s) are not significantly different at 5% level of significance based on HSD Test

*ns - non significant; *-significant ** - highly significant*

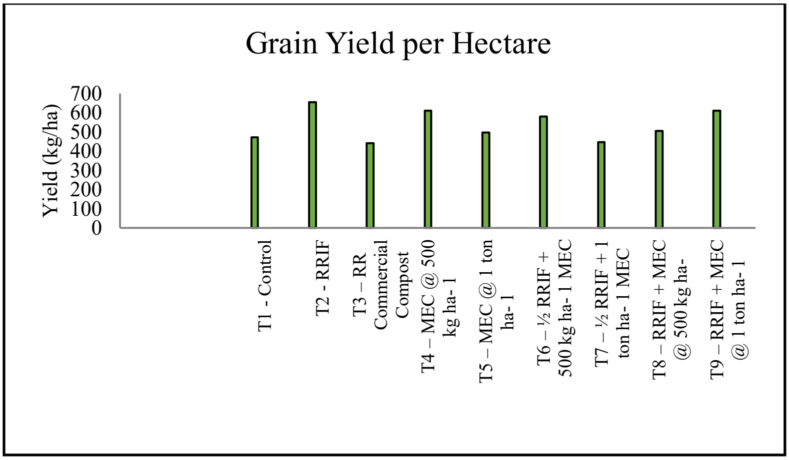


Figure 2. Grain yield of foxtail millet as affected by the application of Microbial Enriched Compost and Inorganic Fertilize

3.2.3 Yield and Yield Components

The number of productive tillers per plant (Table 9) as affected by the application of compost and inorganic fertilizers did not vary significantly. Plots treated with ½ RRIF + 500 kg ha^{-1} MEC, ½ RRIF + 1 ton ha^{-1} MEC and RRIF + MEC at 500 kg ha^{-} obtained the highest number of productive tillers at 90 DAS. The highest number of productive tillers was observed in plots applied with RRIF + MEC at 1 ton ha^{-1} with 4.10 vegetative tillers at 45 DAS. The longest (28.5 cm) and the shortest (23.2 cm) panicle length were observed in plots applied with RRIF + MEC at 1 ton ha^{-1} and no fertilizer respectively. There were no significant differences on the panicle diameter as affected by the application of MEC and inorganic fertilizers at maturity. Application of RRIF + MEC at 1 ton ha^{-1} had the widest panicle diameter followed by ½ RRIF + 500 kg ha^{-1} MEC. The highest weight of grains was produced due to the application of MEC at 1 ton ha^{-1} (12.2 g), followed by RRIF + MEC at 1 ton ha^{-1} (12.0 g), RR Commercial Compost (11.5 g) and RRIF + MEC @ 500 kg ha^{-1} (11.5 g). The analyses have shown that application of microbial enriched compost and inorganic fertilizers did not affect the threshing percentage of foxtail millet. The threshing percentage ranged from 63.20% to 82.07%. It can be observed that higher threshing percentage was obtained from plots with RRIF (82.07%) compared with other treatments and control. Plots applied with recommended rate of inorganic fertilizer, microbial enriched compost at 500 kg ha^{-1} and RRIF + MEC at 1 ton ha^{-1} had the highest adjusted grain yield (655.80 kg/ha, 610.29 kg/ha, 609.31 kg/ha) respectively.

4. Conclusion and Recommendation

The study showed that enriching organic residues with *T. harzianum* affected the physicochemical properties of compost during the early decomposition stages (Phase I). Changes in both pH and electrical conductivity indicate suitability. The pH of compost enriched with *T. harzianum*, which was moderately alkaline on the 14th day, shifted to slightly alkaline by the 30th day. Additionally, microbial enrichment helped lower the electrical conductivity of the compost below phytotoxic levels, making it suitable for crop growth. Foxtail millet responded to the application of microbial-enriched compost at 500 kg ha^{-1} with improved soil pH, organic matter, and nutrient content. However, these changes were not statistically significant. The use of microbial-enriched compost and inorganic fertilizers showed no significant effects. While 500 kg ha^{-1} was effective, combining it with other treatments such as ½ RRIF + 500 kg ha^{-1} MEC and RRIF + MEC at 1 ton ha^{-1} may be beneficial. Microbial-enriched compost possesses good physical and chemical properties suitable for crop production. It is a valuable source of nutrients and organic matter.

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