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Effective Microorganisms as Remediation for Marginal Soil in the Philippines

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The use of effective microorganisms (EM) technology is rapidly gaining popularity not only in agricultural development but also in environmental management. In this study, EM were used as remediation for marginal soil. Formulated EM from fish amino acid, lactic acid bacterial serum, and commercial EM were applied to marginal soil weekly for 10 weeks. The physical and chemical properties were analysed before and after treatment application. With the objectives of determining the change, results revealed that there was a change on the selected physical and chemical properties of the soil. Soil texture has changed from light to medium in all treatments. The highest increase in pH (5.4 %), organic matter content (200 %) and phosphorous content (115.7 %) was noted in fish amino acid; while the highest increase in electrical conductivity (514.3 %) and potassium content (89.1 %) was noted in the commercial EM. Effective microorganisms can be utilized to remediate soil problems in relation to improvements on soil texture, electrical conductivity, organic matter, and phosphorous content.

1. Introduction

Climate change, food security, water scarcity and energy use are the key issues man faces in this 21st century. With global population expected to reach its seven billion mark in the next few years, the greatest challenge is how to feed the growing population without putting too much pressure into the earth's natural system. The interconnectedness of all those environmental parameters require a radical revision of our lifestyle or even our way of life to curb its devastating effects upon global ecosystems and climate. Moreover, a sense of shared responsibility and political will are also factors that will bring real solutions as people strive to keep pace with increasing needs from a growing population (World Water Council, 2017).

Technologies, innovations, management strategies and approaches are being studies to address the pressing environmental problems and issues such as garbage problem, water pollution and the declining agricultural production. One of these technologies to enhance soil properties is the use of microorganisms – the Effective Microorganisms technology. As cited by Fantunbi and Ncube (2009), EM is a liquid microbial inoculant which contains beneficial microorganisms from fermentation such as lactic acid, yeast, photosynthetic bacteria, actinomycetes and fermenting fungi. It is reported that application of EM results in rapid proliferation of its beneficial microorganisms which can suppress soil pathogens and also encourage the mineralization of soil organic matter. Thus, EM is used widely on different fronts from agricultural development to environmental management and has the potential to provide solutions to healthy living.

In agriculture, inoculation of soil with EM can improve soil quality and soil health. However, the effect may not always be the same. In some soils, single inoculation of EM may be enough to give a desirable result, while in some other soils, even repeated applications may be ineffective (Olle and Williams, 2013). Nevertheless, EM is widely used in Asian countries for agricultural production (Formowitz et al., 2007).

In the country, the adoption of EM technology has increased in the last few years. Studies have shown that EM can be used as sanitizing agents for air conditioners, beddings and even pets, help de-clog toilets and sinks, maintains cleanliness in aquarium and many others which were tested and verified. In DMMMSU, EM technology was found to be effective as an inoculant, as an activator for compost production from agricultural wastes (Ngilangil and Olivar, 2008), and as poultry odor reducer (Cariaga, 2012). The potential of EM for waste water treatment has been experimented and on the capability to remediate contaminated soil.

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Soil pollution is caused by the presence of chemicals or substances that may alter the natural soil environment. The excessive use of fertilizers, pesticides and other chemicals usually give negative effects to the physical and chemical properties of the soil. Soil texture, color, pH, bulk density, cation exchange capacity, electrical conductivity, soil nutrients (NPK), are parameters that affects plant growth. Marginal soils are increasing which contribute to low agricultural production, thus stressing available soil resources to increase production. Other countries are exploring solutions to the problem such as the development of cost-effective composting process that would improve soil properties and ultimately benefit the environment (Kamyab et al., 2015). In this study, the formulated EM was used to improve the selected physical and chemical properties of a marginal soil. Specifically, it sought to determine the soil properties before treatment; the change in the soil properties after treatment; and the significant difference on the soil properties before and after treatment.

2. Methods and procedures

2.1 Preparation and procurement of raw materials

2.1.1 Commercial effective microorganism (CEM)

The EM-1 effective microorganism is a microbial inoculant purchased from Harbest Agribusiness Corporation and manufactured by EM research Philippines, Incorporated. The CEM is compost of environment-friendly microorganisms such as Lactic Acid Bacteria, yeasts, actinomycetes and beneficial fungi combined together as a liquid concentrate. The purchased CEM has a shelf-life of one year. The purchased CEM was activated first before application. Molasses were added and fermented for 7 – 10 d to awaken the microorganisms.

2.1.2 Fish amino acid (FAA)

Fish trashes such as gills, scales, and blood were collected from households. In the preparation of FAA the following steps were taken: (a) the fish trashes was placed on a pail; (b) molasses were added for every one kilogram of fish trashes and mixed; (c) the pail was covered with cloth and fastened with plastic straw; (d) the pail is placed in a cool and undisturbed place; (e) left behind for 14 d and god aeration was ensured by stirring regularly; (f) the FAA liquid extract was harvested after 14 d using a mosquito net; (g) the extracted FAA was placed in a plastic bottle and covered loosely; (h) the FAA was stored on a cool and shady area, away from direct sunlight.

2.1.3 Lactic acid bacteria serum (LABS)

Rice wash was obtained from the households. On the formulation of LABS the following steps were taken: (a) the rice wash was poured into the pail and one kilogram of molasses was added for every one liter of rice wash; (b) stirred thoroughly and covered with cloth; (c) the pail was placed in an area with no direct sunlight and left behind for 7 d; (d) after 7 d the rice bran was removed; (e) the liquid was strained with cloth and it was transferred to other container; (f) ten times volume of yakult was added over the LABS and mixed properly (yakult contains dried skim milk, sugar, glucose, live lactobacillus casei); (g) it was again fermented for 7 d; (h) after 7 d, fats that float were removed; (i) the leaving yellow liquid called “serum” which contained the lactic acid bacteria was transferred to the plastic bottles and covered loosely; (j) the produced LABS was stored in a cool and shady place.

2.2 Soil sampling and analysis

The soil samples were taken out from a selected area very near the Materials Recovery Facility of DMMMSU-NLUC in Bacnotan, La Union. Using a soil auger, soil samples were taken randomly from different parts of the area. These were mixed and placed in a medium-sized polyethylene bags.

About 500 grams of the composite soil sample were pulverized, air dried, and sent for soil analysis to the Soil Regional Laboratory of the Department of Agriculture, City of San Fernando, La Union. The parameters for evaluation were texture, pH, electrical conductivity, organic matter, phosphorous and potassium content.

2.3 Experimental lay-out

About 18 bags of soil samples were laid out in three treatments with three replications. There are two pots for each replication. The experiment was laid out using the Complete Randomized Design (CRD) with the following treatments:

Treatment 1 – Commercial EM (100 mL + 200 mL water)
Treatment 2 – Fish Amino Acid (100 mL + 200 mL water)
Treatment 3 – LABS (100 mL + 200 mL water)

2.4 Pot experiment

The treatments were drenched with 100 mL of EM and 200 mL of water every 7 d. After application, the soil was mixed for aeration. Observations on the soil texture and moisture were done periodically. There were 10 applications of treatments made for the duration of the study. Composite samples of the treated soil from each replication were again gathered and sent for laboratory analysis. Means and t-Test were used to treat the gathered data. To compare the results of the soil analysis on the selected properties before and after treatment, t-Test was done.

3. Results and discussion

3.1 Soil analysis before treatment

Table 1 presents the results of the soil analysis before treatment in terms of texture, pH, electrical conductivity, organic matter, phosphorous and potassium content.

Table 1: Results of soil analysis before treatment

Texture	pH	EC (mS/cm)	OM (%)	P (ppm)	K (ppm)
Light	6.10	0.28	1.0	34.0	156.0

The result of the analysis indicates that the soil was acidic. Phosphorous may become limiting in acid soils as reflected by the result of 34 ppm phosphorous content. When the soil is acidic, it allows aluminum to become available. Aluminum is not a nutrient and is toxic to plants in high concentrations. At pH 6 and higher, very little aluminum is in solution (McFarland et al., 2015). The light texture could be associated to the amount of organic matter present which from the result was only 1 %. In this study, the soil sample has high sand content and thus, has low ability to hold nutrients that may be added unto it. Light-textured soils have good drainage and aeration but low water and nutrient holding capacity.

The presence of organic matter in the soil can contribute in influencing the positive microorganisms present in the EM. According to Higa and Parr (1994), there are three groups of microorganisms exists in every medium: the positive microorganisms (regeneration), negative microorganisms (decomposition, degeneration) and the opportunist microorganisms. In every medium, the ratio of the positive and negative microorganisms is critical, since the opportunist microorganisms follow the trend of regeneration or degeneration. The dominance principle explains the effects of EM in the medium where they are mixed or utilized.

Percent organic matter is the measure of the amount of plants and animals' residue in the soil. It serves as a reserve for many essential plant nutrients (A&L Plain Agricultural Laboratories, 2015). It is suggested that at least 2 – 3 percent of organic matter make up of soil for growing lawns and a slightly greater proportion (4 – 6 percent) of organic matter for gardens (Ryczkowski, 2018). For a readily available phosphorous plus a part of the active reserve phosphorous in soil, a 40 to 60 ppm level is desirable for good yields of most crops. Higher levels of potassium are needed in soils high in clay and organic matter. Optimum levels for light-colored, coarse-textured soils may range from 100 to 150 ppm. Dark-colored, heavy-textured soils require potassium levels from 150 – 250 ppm (A&L Plain Agricultural Laboratories, 2015). Potassium is an essential plant nutrient and is required in large amounts for proper growth and reproduction of plants. Potassium is considered second to nitrogen when it comes to nutrients needed by plants. It affects the plant shape, size, color, taste and other measurements attributed to healthy produce (Sela, 2017).

It can be seen that the soil used in the study has low organic matter, phosphorous and potassium content. It may not support the proper growth and development of crops planted on it. Such soil can still be used for crop production if proper management techniques will be employed on it. The improvement of the properties of soil particularly those that will have an effect on its fertility and productivity, is necessary. Soil degradation can occur quickly because of improper or excessive tillage and intensified crop production. Management can influence measured soil properties given enough time for differences to develop (McVay et al., 2006).

3.2 Soil analysis after treatment

Table 2 presents the results of the soil analysis after treatment, while Table 3 presents the change in the soil properties in percentage.

3.2.1 Soil texture

As gleaned from the table, the soil texture of the three treatments were all described as medium. Soil texture affects the soil's ability to hold onto nutrients (cation exchange capacity) and water. Texture refers to the relative distribution of the different sized particles in the soil (Victoria State Government, 2017). The medium-

textured soils or loams have a more even distribution between clay and sand particles (Ritchey et al., 2015). Loam soils are generally the most productive because they have an even mixture of all the soil separates. Loam is favorable for many types of crops (Jaja, 2016).
All the soil applied with EM treatments has changed its soil texture from light to medium texture.

Table 2: Results of soil analysis after treatment

Treatment	Texture	pH	EC (mS/cm)	OM (%)	P (ppm)	K (ppm)
T1 – CEM	Medium	6.00	1.72	2.83	64.67	295.00
T2 – FAA	Medium	6.43	1.12	3.00	73.33	278.67
T3 – LABS	Medium	6.30	1.20	2.67	72.00	285.33
Mean	Medium	6.24	1.35	2.83	70.00	286.33

Table 3: Change in the soil properties in percentage

Treatment	pH	EC	OM	P	K
T1 – CEM	-1.64	514.28	183.00	90.21	89.10
T2 – FAA	5.41	300.00	200.00	115.68	78.63
T3 – LABS	3.28	328.57	167.00	111.76	82.90

3.2.2 Soil pH

Results show that the soil pH ranged from 6.0 to 6.43 with T2 having the highest and T1 the lowest. All of the treatments exhibits acidity. This means that the fungi works well in this kind of environment since fungi tolerates acidity better than bacteria. The bacteria often negatively affected by low pH. Soil pH affects the type, numbers and acidity of microorganisms.
Since EM is a culture of mixed organisms mainly composed of bacteria, yeast, fungi and many others, these microorganisms function well in the soil. In the study of Fatunbi and Ncube (2009), the increase in pH was attributed to the initial ammonification process which was brought about by the addition of organic materials and EM in the soil. A soil pH range of 6 – 7 promotes the availability of plant nutrients. Bacteria that decompose organic matter are hindered in strong acids. This prevents the breakdown of organic matter which resulted to the accumulation of organic matter in the soil (Yarina, 2017). If the soil ranges from 6.5 to 7.5, the uptake of nutrients to the plant roots is very compatible. Soil with pH of 6.4 and lower exhibit less solubility for plant uptake of the major plant nutrients such as NPK and micro-nutrients (IPNI Plant Nutrition, 2010).
The highest increase in the pH was recorded in T2 which is the EM from fish amino acid. In the study of Balraj, et al. (2014), the use of liquid fermented fish waste decreased soil pH. The addition of water drenched into the soil may have influenced the increase of soil pH in the treatment with fish amino acid.

3.2.3 Electrical conductivity

In terms of electrical conductivity, T1 has the highest value while T2 has the lowest. The soil electrical conductivity correlates very strongly with particle size and soil texture (Beasley and Sanders, 2019). Since the original texture is light indicating the sandy structure, this justifies the very low electrical conductivity. With the improvement of the soil texture after treatment, the electrical conductivity has also improved. Soil electrical conductivity also can delineate differences in organic matter content and cation exchange capacity. The implication of a low electrical conductivity is that it has low cation exchange capacity which is related to the percentage of clay and organic matter in the soil. With the increase in electrical conductivity, other properties related to productivity may also improve. The highest increase of electrical conductivity is recorded in T1 with commercial EM.

3.2.4 Soil organic matter

Organic matter includes any plant or animal material that returns to the soil and goes through the decomposition process. In addition to providing nutrients and habitat to organisms living in the soil, organic matter also binds soil particles into aggregates and improves the water holding capacity of soil. Most soils contain 2 – 10 % organic matter. Even in small amounts, organic matter is very important because it affects the physical properties of the soil and its overall health.
As gleaned from the table, T2 has the highest OM content and least is T3. This means that the biological activity of the soil microorganisms are active and the drenching of the EM may have given a positive influence with the beneficial microorganisms from the soil, hence the increase in the amount of OM from its original content.

3.2.5 Phosphorous

Phosphorus is a naturally occurring element in the environment that can be found in all living organisms as well as in water and soils (Sharpley et al., 2010). The results in this study after treatment indicated that the amount of phosphorous in all treatments increased after application of EM. T2 has the highest and T1 has the least. Organic phosphorous is found in plant residues, manures and microbial tissues. Maximum availability of phosphorous generally occurs in a pH range of 6 – 7 (Mosaic Company, 2017). The pH of the soil samples is within the range.

3.2.6 Potassium

Results show that T1 has the highest potassium content after application of treatment and the least is T2. Since potassium is one of the essential nutrients in plants, short supply of this mineral in the soil would limit crop yields. The drenching of EM into the soil gave a significant change on potassium content in the different treatments. The result implies that EM application induced the increase of potassium in the different treatments.

3.3 Comparison between measured variables

Table 4 presents the comparison of the measured variables using t-Test.

Table 4: Comparison between measured variables

Soil Properties	Before Treatment	After Treatment	t-Test (P-value)
pH	6.10	6.24	0.062^{ns}
Electrical conductivity	0.28	1.35	0.000^{*}
Organic matter	1.00	2.83	0.000^{*}
Phosphorous	34.00	70.00	0.000^{*}
Potassium	156.00	286.33	0.000^{*}

Legend: ns – Not Significant at 0.05 Level of Significance
* - Significant at 0.05 Level of Significance

The t-Test revealed no significant difference on soil pH while significant differences were observed in electrical conductivity, organic matter, phosphorous and potassium content. Most nutrients that plants need can dissolve easily when the pH of the soil solution ranges from 6 – 7. Since the pH of the treatments are within the range, this could not affect the availability of nutrients once these are dissolved in water.

The significant differences in electrical conductivity could be attributed to the changes in soil texture from light to medium. The change in the soil texture could be closely linked to the improvement on the organic matter content which in turn influences or modifies many of these soil properties such as soil structure, and the nutrients in the soil. The active and some of the resistant organic components together with microorganisms (especially fungi) are involved in binding soil particles into larger aggregates. It would be noted that EM contains different kinds of microorganisms including fungi (www.fao.org).

The significant change in the organic matter content can be attributed to the EM applied into the soil. According to Ismail (2013), increases in organic matter enhance soil physical properties such as bulk density, infiltration rate, water holding capacity and the availability of nutrients in the soil. In the study of Ismail (2013) on the influence of EM and green manure on soil properties and productivity, the increase in organic matter could be due to the quantity of green manure added in the treatments.

In the study, a significant change on the phosphorous content in the soil was observed. This can be due to the increase in the organic matter content. In the study of Ismail (2013), the increase in available P in soil was due to the accelerated mineralization of P by the organic acids which was the result of the decomposition of organic manure.

It was also noted that a significant change in the potassium content of the soil was observed after the application of treatments. The EM contributed to the significant increase.

4. Conclusions

Effective microorganisms have been extensively used on different fronts from agricultural development to environmental management. This study focused on the effects of EM on selected soil properties. Based from the results, EM has changed the soil texture from light to medium; soil pH from 6.10 to 6.24; electrical conductivity from 0.28 mS/cm to 1.35 mS/cm; organic matter content from 1.0 % to 2.83 %; phosphorous content from 34 ppm to 70 ppm; and potassium content from 156 ppm to 286.33 ppm. EM can be utilized to remediate soil problems in relation to improvements on soil texture, electrical conductivity, organic matter, phosphorous and potassium content.

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