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Enhancing organic agricultural production through beneficial microorganism and waste-water utilization technology: A concept project and futures thinking approach

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Abstract

A multi-million organic agriculture innovation company in the Philippines was able to discover a bioactivator that enhances degradation and conversion of organic waste into fertilizers which can be used to improve plant growth and development. The problem is that many local communities are not aware of the functionality of this organic bioactivator. Because of this, majority of organic wastes are treated as something not useful and profitable. As a result, more than 50% of municipal wastes generated are organic wastes. The novel ideation in this concept project will contribute is the potential use of domestic liquid waste (laundry and dishwashing wastewater) to water backyard vegetables amended with the organic waste-now-turned-fertilizers, exploiting the ability of the BMB (beneficial microorganism bioactivator) to bioremediate wastewater to make it useful for vegetable production. Experimentation may be set up to compare vegetables grown in organic amended substrate versus those vegetables grown in organic amended substrates treated with liquid domestic wastes. If the bioactivators can provide a bioremediating effect, then plants grown in organic-amended-wastewater-treated will give more produce. This potential breakthrough will give multifold benefits; it will help local stakeholders generate more income through (1) organic fertilizer production; (2) re-use of wastewater and (3) organic vegetable production. Organic fertilizers are sold for 250 pesos per bag, wastewater re-use is estimated to save 250.00 pesos per household per day; and organic vegetable production is estimated to profit more than conventional vegetable production, based on published studies.

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Introduction

The ever-present nature of waste

In all of life's processes: personal, societal, agricultural, and industrial, to name a few, waste is always present. When a service is rendered, when a product is generated, when a development is achieved, and even in the natural flow of our ecosystems, waste is always part of the equation. It is because not all energy is utilized by these natural and artificial systems. Whether it be biological or physical, if energy is generated and used, there will always a by-product we call waste. The natural environment has its own mechanism of recycling waste back to their useful forms. However, our earth has become so populated with billions of human beings. According to Borlaug (2004), the earth's population is projected to balloon up to 8.3 billion by 2025. Every living being is expected to consume energy and generate waste. Due to multifaceted technological advancements in this modern world, more energy is necessary and more wastes must be disposed. Hoornweg and Bhada-Tata (2012) predicted that by the year 2025, urban residents will generate about 1.42 kg/capita/day of municipal waste. That is a total of 2.2 billion tons per year.

Based on the per capita rate of 0.40 and annual projected population, the amount of waste generated annually in the country is calculated and it shows that the amount of waste generated ballooned up from 13 million tons in year 2010 to 16 million tons in 2020. With this significant increase, it is urgent to propose projects that can reduce waste production and translate these wastes into something beneficial for both human beings and the environment.

Organic wastes

Organic wastes are a type of waste derived from biodegradable sources such as those materials coming from either a plant or an animal. These biodegradable wastes can be broken down into carbon dioxide, methane or simple organic molecules. Examples of organic wastes are human feces and urine, wastewater, solid wastes, animal manure, vegetable peelings, dried leaves, and other agro-industrial wastes. If these are left uncontrolled, the community may suffer from pollution originating from organic wastes (Polprasert, 2007). On the other hand, if these wastes are managed properly, they can be used beneficially in agriculture. These organic wastes are used chiefly to improve the soil's physical and chemical properties. They also aid as nutrient sources for growing vegetables and crops (Westerman and Bicudo, 2005).

Biodegradation by super decomposers

Organic biodegradation is defined as a natural process of degradation of organic wastes that is activated by the presence of beneficial microorganisms in the soil. These beneficial microorganisms act as super decomposers that speedup the process of organic wastes and turn them into organic fertilizers. In the present COVID19 pandemic, the world economy is turned upside down. Fuel costs are on an uprise, and the cost of living has become high. With such a huge setback, the use of naturally occurring, environmentally friendly means of food production that secures a sustainable and safe food source and livelihood which be easily adapted by the community becomes a priority. Thus, the use and conversion of organic wastes into organic fertilizer through the aid of beneficial microorganisms have been increasingly investigated (Malusá et al., 2012).

The need for a future's thinking project

The general idea of the concept project is that majority of wastes generated by local communities are organic wastes. This covers more than 50% of the pie. With regards to this problem, a company in the Philippines was able to discover a wonder catalyst. This technology enhances the decomposition of organic wastes produced by the community. The concept project therefore aims to reduce the amount of solid organic wastes by the community and convert this to organic fertilizers via the bioactivator technology. The researchers in this concept project also recognize that organic wastes comes both in solid and liquid form. To address both, domestic liquid-wastes in the form of dishwashing and laundry wastes will also be used. The organic fertilizers produced

from the bioactivated organic wastes will be introduced in commonly grown backyard vegetables. These vegetables will be watered with domestic liquid wastes. Ultimately, the aim is to convert wastes into its useful form via a bioactivator technology and this technology will be disseminated to the local community for technology adoption. By this perspective, this concept project can help eliminate the wastes generated by the community, while helping them acquire a sustainable and healthy food source as well as giving them the opportunity to increase their income by selling the organic fertilizer and the organic vegetables produced.

The advantages of organically-produced vegetables to human health

There has been an increasing trend and interest in producing organically-cultured vegetables. One of the main reasons to this is the potential benefit derived from it to human's public health. A published study has been conducted regarding the contribution of such organically grown crops to human health. Results of this study showed that organic cultivation did not affect majority of nutritionally beneficial compounds to human health, with one exemption which is the phenolic compounds that were found to increase with the number of organic pathogens. Another interesting result is that there were higher pesticide residues in conventionally grown crops compared to those that were organically grown (Johansson *et al.*, 2014). This indicates that those who eat organically grown crops receive fewer amounts of pesticide residues which further imply lesser toxins are being taken in when these organic crops are eaten.

Review of related literature

The ZWIA and SWANA Zero waste theory

The study is anchored on the Zero Waste Theory defined by Zero Waste International Alliance (ZWIA). The Zero Waste Theory is a goal that is ethical, economical, efficient and visionary, to guide people in changing their lifestyles and practices to emulate sustainable natural cycles, where all discarded materials are designed to become resources for others to use (Seldman, 2014). On the other hand, according to the Solid Waste Association of North America (SWANA), Zero Waste are efforts to reduce solid waste generation to nothing, or close to nothing as possible, by minimizing excess consumption and maximizing the recovery of solid wastes through recycling and composting (SWANA, 2019).

The zero waste 2020 framework

Connett (2010) is the executive director of the American Environmental Health Studies Project (AEHSP) entitled Zero Waste: Theory and Practice around the World. This project established a zero waste 2020 framework putting emphasis on sustainability. The concept of sustainability is multifaceted, and is applicable in all areas for key development. Sustainability must be taught in the academe. Sustainability must be the foundation in architectural designs. We should always consider sustainable energy consumption. Economic development must be sustainable. Community development should also be sustainable. Jobs in industries should be sustainable. Last but not the least, agriculture should be sustainable. These are the key targets of the Zero Waste 2020 Framework.

In relation to this, the present study covers many of the key developments. It focuses more on sustainable agriculture, with its potential ripple effect on sustainable energy, sustainable, economic and community development, sustainable jobs and education for sustainability. In the discovery of a bioactivator that enhances degradation and conversion of organic waste into fertilizers which can be used to improve plant growth and development, a novel ideation is added specifically the potential use of domestic liquid waste (laundry and dishwashing wastewater) to water backyard vegetables amended with the organic waste-now-turned-fertilizers, exploiting the ability of the bioactivators to bioremediate wastewater to make it useful for vegetable production.

The need for organic waste recycling

Naturally produced organic wastes can either exist in a solid- or liquid- state. The solid wastes are commonly knowledge as biodegradable wastes. The

most common sources of organic waste include agriculture, household activities and industrial products. Other organic wastes include the green wastes such as food wastes, non-hazardous wood wastes, landscape wastes and other pruning wastes. Most organic wastes add up to the soil nutrients and minerals. However, if these wastes are uncontrolled, and/or improperly disposed, they will cause severe damage to the environment (Sapkota, 2020). Thus, these organic wastes must be managed in a sustainable way to evade depletion of natural energy resources, to reduce environmental risks, and reduce human health problems (Khalid, 2011). To prove this, the figure below shows the solid waste exposure pathway associated with the poor handling of waste. This is manifested usually through direct exposure of humans and the pollution of surface water and groundwater due to leachate from open dumps (EMB, 2018). These pathways of solid waste are projected in Fig. 1.

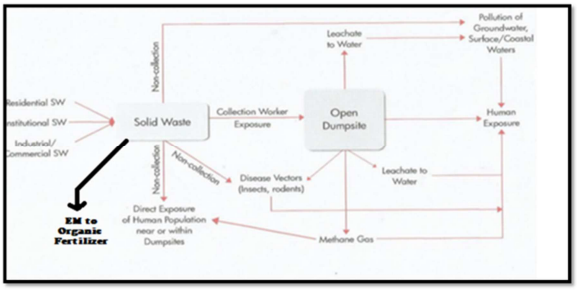

Fig. 1. The solid waste exposure pathway (EMB, 2018) and the unique SW to EM (effective microorganism) to organic fertilizer pathway

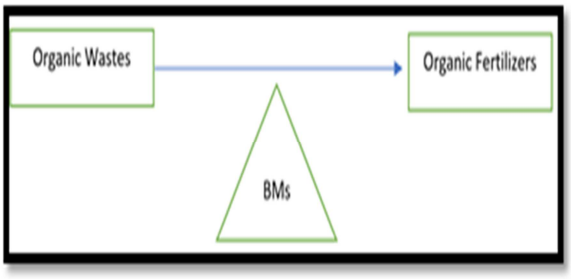

Fig. 2. A simplified diagram of beneficial microorganisms' action on organic wastes

In agriculture, the decrease of organic matter content in agricultural soils is a significant problem by farmers. This lowers soil fertility thus impairing agricultural crop production. In the study of Eden *et al.* (2017), they found out that organic amendments generally trigger beneficial effects on plant available water and other soil properties. Joining these two setbacks creates a win-win situation. The excessive organic wastes can be used as a source to increase the organic matter content in agricultural soils. In doing so, we avoid the depletion of natural sources of energy, we reduce environmental concerns, we sustain people's healthy being and the organic materials applied to these agricultural areas provide benefits to the plant, water and other soil properties.

Beneficial microorganisms (BMs) are microorganisms in the soil that speeds up the process of decomposition of organic wastes (Fig. 2). BMs below to a wide range of genera, classes and phyla of microbes ranging from bacteria, to yeast and fungi which can support organic matter decomposition and plant nutrition via different mechanisms (Malusá *et al.*, 2012). According to Ruiz (2018), the beneficial microorganisms (BM) contained in the wonder catalysts known as the Bio Plus Activator (BPA), are cultured to be super active so they can perform their individual functions as efficiently as they are made to be. This is a one-of-a-kind organic agriculture technology in the Philippines.

The figure above shows the basic action of super decomposers. They are useful to enhance the conversion of waste into fertilizers. They are essential because agricultural soils need to maintain their organic matter content to provide the essential nutrients that plants need. Present soil management strategies are chiefly dependent on chemical-based and inorganic fertilizers which cause serious problems to both the environment and human health. The study of Itelima *et al.* (2018) investigated the microorganisms which are commonly used as bio-fertilizers. These include nitrogen fixers, potassium and phosphorus solubilizers, growth promoting rhizobacteria (PGPRs), endo and ecto mycorrhizal fungi, cyanobacteria and other useful microscopic organisms. Their study proved that the use of biofertilizers has improved soil fertility and crop

productivity. Specifically, these BMs improved nutrients and water uptake, plant growth, and plant tolerance to abiotic and biotic factors. Chew *et al.* (2019) also studied the transformation of biomass waste into sustainable organic fertilizers. Various types of biomass wastes were considered which include: food waste, municipal solid waste, sewage sludge, and animal manure. The recycling of these wastes is applied to produce valuable organic matters that were used as fertilizers to improve soil structure and quality, needful tremendously in the agricultural sector.

Completed organic technology related researches

The Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development of the Department of Science and Technology (DOST-PCAARRD) has funded several organic farming technology projects. One related project is the "Gender-responsive organic vegetable production livelihood enterprise for low-income communities of Los Banos, Laguna. The project imparted know-how and skills on organic vegetable production to farmer-cooperators through a series of trainings that included seed production, organic fertilizer production, vermicomposting, postharvest handling, marketing, among others (Aya, 2017).

The DOST-PCAARRD has also funded an organic-technology related project for organic farmers of Angono, Rizal. The group mobilized its instrumentalities by providing technical capabilities in growing backyard vegetables of what agriculture experts would call the "Pinakbet series", with reference to the common ingredients of the popular Northern Luzon delicacy which consists of ampalaya, tomatoes, okra and squash (Starbooks, 2021).

There were other projects spearheaded by DOST-PCAARRD. These activities paved the way for the evaluation of technologies, identification of gaps and showcasing innovative technologies that can help boost the Philippine Vegetable Industry. Among the other technologies were: (1) phytochemical coating; (2) dipping pechay in 1% vinegar solution for two minutes before rinsing; (3) rapid bioassay for pesticide residues (RBPR); and (4) biological control agents (BCAs) against bean rust, powdery mildew in tomato, anthracnose, and alternaria leaf spot in Chinese cabbage (Pelegrina *et al.*, 2017).

Though various projects have been completed to improve organic technology for vegetable production, the use of effective microorganisms as a form of a bioactivator technology is yet to be exploited. In this concept project, the bioactivator plus technology is to be tested on its feasibility and effectivity in converting organic wastes to organic fertilizers to be used in gardening while utilizing domestic liquid waste to water common backyard vegetables.

Methodological and conceptual framework

The bioactivator technology can potentially collect many forms of organic wastes such as vegetable residues, scattered leaves, fruit peelings, food wastes and other organic wastes into organic fertilizers (Fig. 3). This is done using effective microorganisms (EMs) or super decomposers. The organic fertilizers produced could later be used to fertilize agricultural crops which are commonly grown in the backyard. Re-used water (those that were used for laundry and dishwashing) will be used to water the organic-fertilizer grown agricultural crops.

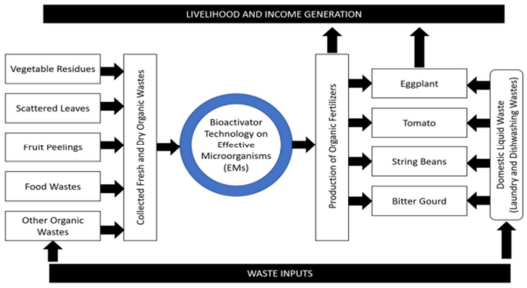

Fig. 3. Organic waste to fertilizer and vegetable production to livelihood and income generation

The methodological and conceptual framework above shows the benefits derived from the research program. More than 50% of municipal wastes generated are organic wastes. Therefore, if 50% of these wastes can be used as input as shown in the framework above, then the total production of wastes to be disposed are reduced significantly. The benefit

does not end here, through the bioactivator technology, the conversion of these organic wastes to organic fertilizers are hastened and in approximately 30 days, these wastes will now be converted to beneficial organic fertilizers ready to be amended on backyard-grown vegetables to enhance their growth and produce more environmentally- safe products that are also safe for our body to consume. Moreover, the novel technology introduced is the use of domestic liquid wastes to water the organic-amended vegetables. As literature reveals that bioactivators can also serve as bioremediators, it is expected that more benefits are derived if wastewater will be used in watering these plants grown in organic-bioactivated soils. Benefit not just in the number and quality of products, but also in reducing water consumption, therefore saving more.

Discussion

Table 1 shows the comparison between conventional, organic-bioactivated, and organic-bioactivated-wastewaterized approach. Conventional agricultural treatment has no impact on organic waste management. On the other hand, both organic-bioactivated and organic-bioactivated-wastewaterized agricultural treatment both convert waste into organic fertilizers. Since conventional agricultural treatment doesn't convert agricultural wastes into fertilizers, this type of agricultural scheme does not generate any profit from wastes. Organic-bioactivated even wastewaterized agricultural schemes may generate 250 pesos per 50 kg bag of organic waste.

In terms of water treatment, tap water is used for both conventional and organic agricultural schemes. On the other hand, waste-water is made useful in watering crops exposed to organic-bioactivated-wastewaterized agricultural treatment. Since tap water is used for both conventional and organic agricultural treatment, there is no profit generated from water management. Organic-bioactivated-wastewaterized treatment on the other hand saves approximately pesos 250 per day because domestic households produce an average of 200 to 300 liters of wastewater per person every day. Since the average price of water in the Philippines is 35.00 pesos per drum price (with approximately 208.20L of water), it therefore implies that 250 pesos is saved daily in a household with five members.

In terms of vegetable production inputs, conventional agricultural schemes need chemical fertilizer application, pesticides, and other synthetic inputs that degrade the environment. Organic gardening uses natural products that are environmentally friendly. Organic-bioactivated-wastewaterized also uses natural products that are environmentally friendly.

Generally, the price of vegetables grown in conventional agricultural scheme is lower compared to organic vegetables. Those vegetables that are both grown using the organic, and organic-wastewaterized agricultural schemes have higher pricing.

Table 1. Comparison between "conventional", "organic-bioactivated" and "organic-bioactivated-wastewaterized" backyard vegetables

Particulars	Conventional Gardening	Organic Gardening with Bioactivator Technology	Organic Gardening with Bioactivator Technology with Wastewater Treatment
Organic Waste Management	No impact on waste management	Waste is converted into organic fertilizers	Waste is converted into organic fertilizers
Profit Generated from Organic Waste	No profit generated from organic waste	250 PhP per 50kg bag of organic waste	250 PhP per 50kg bag of organic waste
Water Management	Tap water is used	Tap water is used	Wastewater is used
Profit generated from water management	No profit because tap water is used	No profit because tap water is used	Saves approximately 250 PhP per day Domestic households produce an average of 200 to 300 L of wastewater per person every day. The average price of water in the Philippines is 35.00 PhP per drum (approximately 208.20L)
Inputs for vegetable production	Need chemical fertilizer, pesticides, and other synthetic inputs that degrades the environment	Uses natural products that is environmentally friendly	Uses natural products that is environmentally friendly
Price of vegetables	Generally lower pricing compared to organic vegetables	Generally higher pricing compared to conventionally-grown vegetables	Generally higher pricing compared to conventionally-grown vegetables
Number and quality of products	potentially good product but may affect both body and environmental health (due to pesticide and other synthetic residues)	good product and safe to the body and safe to the environment	good product and safe to the body and safe to the environment *May produce potentially better products if bioactivators with bioremediate wastewater into useful forms beneficial to plants
Overall impact on the issue of waste	No impact. Can even contribute in greater waste generation	More than 50% of municipal waste generated are organic waste which can be converted to fertilizers	More than 50% of municipal waste generated are organic waste which can be converted to fertilizers. Liquid wastes are also utilized to water vegetables, exploiting the use of bioactivators to remediate the wastewater to forms beneficial to plants.

Regarding the number and the quality of products, conventional schemes may produce potentially good products but may affect both body and environmental health due to pesticide and other synthetic residues. Vegetables grown in organic schemes are also good products that are relatively safe to the body and to the environment. On top of these benefits, those vegetables grown in organic-wastewaterized treatment may produce potentially better products if the bioactivators are able to bioremediate wastewater into useful forms that are beneficial to plants.

Finally, in terms of the overall impact on the issue of waste, conventional agricultural scheme may negatively contribute to greater waste generation. Organic-bioactivated schemes in contrary can help in reducing more than 50% of municipal organic wastes by converting them into organic fertilizers. On top of this, the organic-bioactivated-wastewater treatment also utilizes liquid wastes to water vegetables, exploiting the use of bioactivators to remediate the waste water to forms that are helpful to vegetables and crops.

Conclusion

On the basis of researcher's review on the effect of organic and chemical fertilizers to plants, they pointed out that the increased use of conventional (even called synthetic) fertilizers triggered many human health issues as well as pollution in the environment. To address these issues, there have been agricultural practices that have been tried and tested such as the use of organic fertilizers to replace the synthetic ones. They observed that inorganic fertilizers accumulate salt which produces more energy to extract water from the soil, consequently making the appearance of the surrounding dried out. The problem further aggravates when there is rainfall because the synthetic fertilizers applied may be washed away (run-off) and may be deposited into water bodies causing water pollution. These synthetic residues can also pollute the plant food chain by being leached away from plant root zones, which will later bioaccumulate and cause health hazards. On the other hand, organic fertilizers may induce high chlorophyll production, as well as improving other biochemical performance of the crop plants such as improving protein and carbohydrate concentration.

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