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Liquid Biofertilizer Made from Fermented Egg Shells, Fish Scales, and Chicken Feathers as A Plant Growth Stimulator Alternative to Chemical Fertilizer

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Abstract

As agricultural sectors rise due to increased human population, the demand for chemical fertilizer is also uplifted. However, the excessive use of chemical fertilizers reduces soil quality and natural properties. To address these issues, an alternative eco-friendly biofertilizer is needed. Here, we developed a liquid biofertilizer called ESSIK to substitute hazardous chemical fertilizers. It is made from environmentally friendly waste materials—including chicken feathers, egg shells, and fish scales—which are repurposed to provide vital nutrients for plant growth. Egg shells contain calcium useful in the synthesis of plant enzymes, fish scales contain calcium and phosphorus which play a role in accelerating fruit ripening, and chicken feathers contain high protein which can be a source of amino acids. These components were first fermented using effective microorganisms (EM4) to break down complex polymers into forms more readily absorbed by plants. The fermented biofertilizer was tested using mung bean (*Vigna radiata*) with concentrations of 0%, 5%, 10%, 20%, and 100%, and a positive control of 5% EM4. Based on the study, 20% was the best formulation to support the growth of mung bean (*V. radiata*) with a length of more than 41 cm, 16 leaves, and 9 stalks. Also, the leaf's length was approximately 6,6 cm, width 3,8 cm, with a healthy-green appearance. These findings suggest that it has significant potential as an eco-friendly and sustainable biofertilizer alternative to chemical fertilizers, promoting robust plant growth while contributing to waste recycling and environmental conservation for a better future.

Keywords: Biofertilizer; land degradation; hazardous chemicals; sustainable agriculture.

INTRODUCTION

There are various future challenges and threats to human life, such as food scarcity and pollutant accumulation. To meet these human needs, the agricultural sector must be raised despite the decreasing quality of agricultural land due to many factors such as excessive use of fertilizers. Nowadays, fertilizer is a primary material needed in plantation fields (Dewi et. al., 2022). Generally, fertilizers are divided into two types, namely organic fertilizers and inorganic fertilizers. Chemical fertilizers or inorganic fertilizers contain synthetic chemicals that produce side effects on plants, such as poisoning in excessive concentrations, and causing the accumulation in the environment. Also, the price of inorganic fertilizers is relatively high (Huda et. al., 2013). Using chemical fertilizers or inorganic fertilizers over a long period damages soil structure, causes soil hardening, and causes bioaccumulation and biomagnification that threaten human health which is distributed through the food chain (Aisyah et. al., 2019).

Meanwhile, organic fertilizers are made from natural materials such as a mixture of plant and animal biomass processed through some methods such as fermentation technology. Organic fertilizers are divided into compost, green fertilizer, and manure (Dahlianah, 2015). Compost is a fertilizer produced from fermentation involving bioactivators (Simanungkalit et. al., 2006), green fertilizer is a fertilizer derived from plant and animal waste that has been decomposed (Dahlianah, 2014), while manure is a combination of liquid or solid animal waste and a mixture of animal feed residues (Mayadewi, 2007). Based on its form, organic fertilizer is divided into two types, namely solid and liquid (Irsyad et. al., 2019). Solid organic fertilizer is available in solid form, while liquid organic fertilizer is derived from a solution derived from the decomposition or fermentation of natural materials with abundant nutrients (Nur et. al., 2016).

Organic fertilizers are considered safer because they are made from biodegradable materials that do not damage plants or the environment. This type of fertilizer can also improve soil structure, soil permeability, and soil porosity. Thus, the use of organic fertilizers is recommended to support sustainable agriculture in the future (Roidah, 2013).

Thus, the authors initiated producing an environmentally friendly organic biofertilizer composed of egg shells, fish scales, and chicken feathers. These wastes still contain essential compounds vital for plant growth an alternative to chemical fertilizers. Based on Raguraj et. al. (2022), egg shells contain carbon (12.6%), nitrogen (0.40%), hydrogen (0.26%), and magnesium (2.82%) (Khainar et. al., 2022). Additionally, fish scales contain 59.78% protein and 10.54% carbohydrates (Basim et. al., 2022). Chicken feathers contain 47.09% nitrogen, 13.54% carbon, 0.13% phosphorus, and 0.29% potassium. Moreover, chicken feathers also contain calcium, magnesium, and sulfur at concentrations of 0.31%, 0.03%, and 1.61% respectively (Raguraj et. al., 2022).

MATERIALS AND METHODS

Tools and Materials

The materials were water (until the final volume reached 20,000 mL), 250 gr egg shells, 50 gr fish scales, 800 gr chicken feather flour, 7000 mL rice washing water, 500 gr additional carbon source (sugar), and 20 mL Em4 (Effective microorganisms). The tools included filters, stirrers, simple bioreactors (buckets), acid hydrolysis containers, ladles, blenders, 1000 mL beakers, and 100 mL beakers. The packaging tools were bottles measuring 100, 250, and 500 mL along with the logos of each package.

Acid hydrolysis

All ingredients were ground and soaked in an acid solution for 2 days, then crushed using a blender. The crushed ingredients along with the protein hydrolysate were mixed in a container and supplemented with Effective Microorganism (20 mL), rice washing water (7L), and additional carbon sources (500g). The mixture was fermented for 2 weeks. Soaking using the acid solution aims to soften the ingredients and dissolve the protein. Effective Microorganism 4 aims to facilitate the occurrence of microbial enzymatic hydrolysis with the help of various enzymes such as proteases which will break down polymers, making them more easily absorbed by plant roots. Adding rice washing water and additional sugar sources aims to support the growth of effective microorganisms (Cruz-Casas et al., 2021).

Seedling

Mung bean seeds were sown using soil for about 7-14 days. The grown seedlings were transferred to new pots with soil before treatment was given.

Biofertilizer testing and measurements

The treatments were done by mixing 10 mL of biofertilizer into 1000 mL of water and then watering it into the rhizosphere. Watering was done every 2-3 days in the morning and evening. In this treatment, the mung bean plants were not given additional nutrients or chemical fertilizers. The observation was done for about 5 weeks after planting. The stem length, leaf length, and leaf width were measured using a measuring tool about 5 weeks after planting.

Morphology observation

Morphological observations were conducted on leaf color, spots on the leaf surface, flowers, fruits, and leaf shape. Observations were conducted for 5 weeks after planting.

Data analysis

Data on stem height, number of leaves, number of stalks, length, and width of leaves were analyzed using one-way ANOVA at a 95% confidence level.

Figure 1. The workflows of making essik, a liquid biofertilizer made from fermented waste.

RESULTS AND DISCUSSION

This Biofertilizer is an organic green fertilizer product made of egg shells, fish scales, and chicken feathers fermented using microorganisms as the main hydrolysis agent. The microorganisms such as *Lactobacillus* sp. protect plant roots from pathogen attacks (Natsir et. al., 2019). It is classified as a liquid organic fertilizer rich in nutrients and offers some advantages compared to solid fertilizers. Liquid fertilizer can overcome nutrient deficiencies more effectively, reduce the risk of nutrient leaching/bleaching, can be the main source of nutrients for plants, and is more easily absorbed by roots than solid fertilizer (Nur et. al., 2016). The essential nutrients are nitrogen, calcium, potassium, carbon, magnesium, and phosphorus, produced through the decomposition or hydrolysis of eggshell polymers, fish scales, and chicken feathers by effective microorganisms dominated by *Lactobacillus* sp.

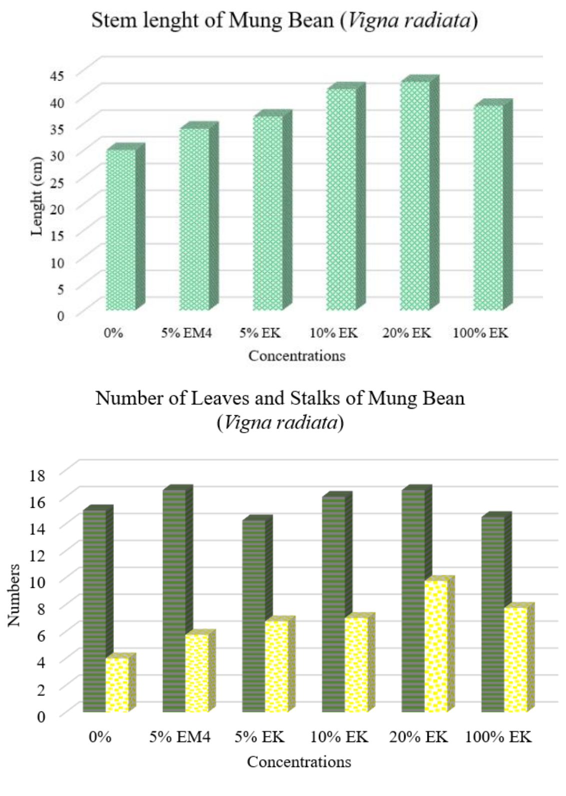

Figure 2. Stem length and numbers of leaves and stalks of mung bean (*Vigna radiata*)

Based on the experiment, the provision of each treatment was known to increase the height of the stems of mung beans as seen in Figure 2. All plants supplemented with this biofertilizer had a height of more than 35 cm in the 5th week. The highest stem height was found in the 20% treatment with a more than 41 cm height. The other two highest heights were found in 10% and 100%, more than 35 cm. The height of the plants which was only given by EM4 5% was less than 35 cm, and the treatment 0% was less than 30 cm. Based on the one-way ANOVA, the provision of this biofertilizer significantly enhanced the growth of mung bean stems with a sig value <0.05.

These results can be attributed to the nutrient contents including nitrogen, calcium, and phosphorus which enhance the growth of mung bean stems. According to Rinsema (1983), the rise in plant length requires various nutrients such as nitrogen which is vital in DNA synthesis and the formation of new cells. In addition to nitrogen, other nutrients play an important role in plant growth, such as magnesium, calcium, phosphorus, and so on. The lack of nutrients such as magnesium and phosphorus leads to chlorosis (Pertawasari, et al, 2012).

Phosphate is a transporting agent of metabolic energy to stimulate flowering, fertilization, root growth, seed formation, plant cell division, and cell tissue enlargement (Susi, et al, 2018). Moreover, calcium is vital in thickening cell walls, increasing root cell elongation, enzymatic and hormonal cofactors, and protection from heat, pests, and diseases (Ernawati, et al, 2019). Potassium also supports optimal root growth (Syauqi, et al, 2022).

In addition, based on Figure 2, the provision of 20% biofertilizer also produced plants with the largest number of leaves and stems compared to other treatments, which were 16 leaves and 9 stalks. Meanwhile, plants given 100% treatment had 14 leaves and 7 stalks. In the 10% treatment, the number of leaves and stalks was 15 and 6. On the other hand, plants that were only given water had 14 leaves and 5 stalks. Based on one-way-ANOVA, the number of stalks in each treatment was significantly different as seen from the sig value <0.05.

The number of leaves and stalks is influenced by nutrient availability in the rhizosphere. Nutrition is a determining factor for the success of plants in continuing their growth. According to Sulistio et al. (2018), when sufficient nutrients are available, cell division and elongation occur more quickly to increase the number of leaves. Nitrogen is a chlorophyll component; using fertilizers rich in nitrogen will stimulate better leaf and stem growth (Sulistio et al., 2018).

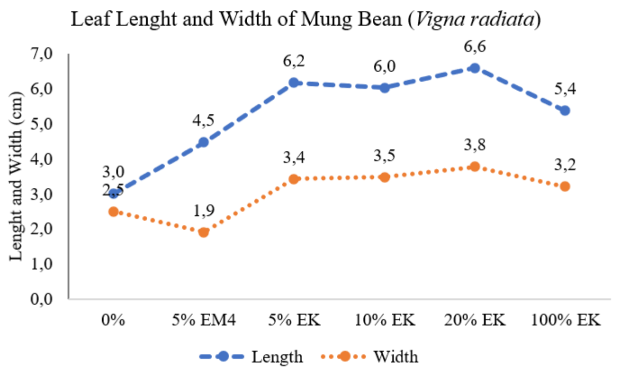

Figure 3. leaf length and width of mung bean (*Vigna radiata*) in the Fifth Week

The treatments also significantly affected the leaf length and width of mung bean plants (*V.*radiata*) as shown in Figure 3 above. There are differences in the response of the length and width of mung bean leaves to various treatments. Plants given fertilizer with a dose of 20% had the most optimal growth with a leaf length of 6.6 cm and a leaf width of 3.8 cm. All treatments produced plants with a leaf length of more than 5.4 cm and a width of more than 3.2 cm. On the other hand, the treatment of Em4 5% only had leaves with a length of 4.5 cm and a leaf width of 1.9 cm. Plants without fertilizer only had leaves with an average length of 3 cm and a width of 2.5 cm. Based on one-way-ANOVA, the provision of the treatment significantly affected the length and width of mung bean with a sig value <0.05.

Perwtasari et. al. (2012), state that the ammonium and nitrogen content is critical in accelerating plant growth, initiating leaf formation, helping stem growth, enlarging cell size, and increasing disease resistance. Plants that lack nitrogen are more susceptible to pathogen attacks. This is also supported by Sandra's study (2001), which suggests that during vegetative growth, fertilizer with high N content should be given, because this element is the main component of protein needed for cell division.

Similar to the quantitative data above, the effectiveness of the treatments can also be seen from the morphology of the mung bean as presented in Table 1. 20% was the optimum treatment that produces plants with healthy stems and leaves. In this treatment, the stems of the mung bean are taller, larger, and stronger than those in other treatments. The leaves were also larger, wider, green, and had no yellow spots. This can be caused by the availability of micro and macronutrients in the form of nitrogen, phosphorus, magnesium, and iron needed by the mung bean (Susi et al., 2018). Generally, all treatments supplemented with biofertilizer had healthier stem and leaf morphology than treatments without biofertilizer. this biofertilizer also accelerates flower and fruit initiation. This can be seen in some plants that have grown flowers and fruits in the 5th week after planting. Meanwhile, plants that were not given essik had an unhealthy morphology. Meanwhile, in the 0% treatment, the stems of the mung bean were small, stunted, weak, and shorter. In the same treatment, the mung bean leaves were smaller and yellow, with curly tips and yellow spots spread across the leaf surface. This can be caused by a lack of phosphorus (Perwtasari et. al., 2012). In addition, a lack of nitrogen also causes chlorosis which inhibits growth and decreases plant resistance to pests (Perwtasari et. al., 2012).

Table 1. Morphology of mung bean (*Vigna radiata*) in the Fifth Week.

Treatments	Morphology	Description
0% (only water)		Stunted, weak, and short stem. Small, yellowish leaves with many white / brown spots.
5% EM4		Tall stem, healthy oval green leaves with some flowers.
5% Biofertilizer		Tall stem, more leaf branches, green leaves, with some fruits.
10% Biofertilizer		Tall and strong stem, with many stalks, green leaves, and some fruits.

Table 1. *Cont.*

Treatments	Morphology	Description
20% Biofertilizer		Tall, strong, branched stems. Dark green leaves, some fruits and flowers
100% Biofertilizer		Tall and large stem, some stalks, dark green leaves, with some fruits.

Product Development and Future Perspective

This biofertilizer is named ESSIK Green Biofertilizer. The word Essik comes from eggshells, fish scales, and chicken feathers, abbreviated to make it easy to remember and recognize. Essik is a liquid organic fertilizer that can be used as an alternative for farmers to replace chemical fertilizers that are harmful to the environment. Fertilizers made from waste are rich in essential nutrients plants need, environmentally friendly, cheaper, and support actions to save the environment. In addition to being made from waste, the method of making essik green biofertilizer is also environmentally friendly because it involves microorganisms as the main agents in breaking down polymer, dominated by photosynthetic bacteria, Lactobacillus sp., Streptomyces sp., to yeast (Sundari et. al., 2012). Thus, the development of essik production on a mass scale needs to be carried out in the future to support sustainable agriculture. The development scheme for Essik Green Biofertilizer is presented in Figure 4.

In the development of Essik Green Biofertilizer, cooperation with various parties is needed, especially sponsors who can provide support, both materially and non-materially. The consistency of the writing and development team and the supervising teacher continues to realize the vision and mission of Essik as an alternative fertilizer for the future to support the government's program, namely food independence. To establish relationships, recognition, and sponsorship, the writing team supported by the SMAIT Harapan Mulia Palembang Foundation continued to actively promote Essik Green Biofertilizer. One was participating in Thailand Inventor Days 2024 which was held in Bangkok, Thailand, on February 2-7. Through this activity, the writing and development team was awarded the bronze prize.

Figure 4. Thailand Inventor Days in Bangkok, 2024 (left) and audience at the South Sumatra Governor's Office (right).

CONCLUSIONS

Based on the discussion above, Essik Green Biofertilizer is a potential alternative fertilizer choice that supports sustainable agriculture in the future. Organic fertilizer from egg shells, chicken feathers, and fish scales contains various essential nutrients for plant growth such as nitrogen, phosphorus, magnesium, and calcium. The optimal concentration was 20%, which enhanced the growth of mung bean with a stem height of more than 41 cm, 16 leaves, 9 stalks, a leaf length of 6.6 cm, a leaf width of 3.8 cm, with a healthy and fresh morphology. In the future, the development and mass production of essik needs to be carried out to support the food independence program by using more environmentally friendly fertilizers at more affordable prices.

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Competing Interests: The authors declare that there are no competing interests.

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