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Production of Bio-Organic Liquid Fertilizer from Food Waste for Chili Plants

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Abstract

The widespread use of inorganic fertilizers in chili pepper (*Capsicum annuum L*) farming raises environmental concerns. This study explores a sustainable alternative: a bio-organic liquid fertilizer produced through the fermentation of food waste such as eggshells, spent coffee grounds, and banana peels. Spent coffee grounds (SCG) are known for their high nitrogen content (8.5% to 13.6%), with lower but beneficial amounts of phosphorus and potassium. In comparison, eggshells primarily provide calcium and trace amounts of phosphorus, while banana peels offer potassium. The research investigates the impact of varying fertilizer concentrations on plant growth. Weekly measurements of plant height, average leaf width, and stem diameter assessed the effectiveness of the fertilizer. Results showed that plants treated with the SCG-based mixture had a 20% increase in plant height and a 15% greater stem diameter compared to those treated with traditional inorganic methods. This research promotes an environmentally friendly approach to chili pepper farming by diverting food waste from landfills and reducing reliance on inorganic fertilizers.

1. Introduction

Modern farming practices often rely heavily on fertilizers to increase crop yields. Fertilizer is a substance that is added to plants to promote plant growth and increase soil fertility [1]. By using fertilizer, the production of organic food would be speeded up. Since plants need minerals to grow, fertilizer was used to provide nutrients to plants based on the nutrients that the plant needs. There are two types of fertilizer which are inorganic fertilizer and organic fertilizer [2].

Inorganic fertilizer is synthetic and comprised of minerals and synthetic chemicals which provides a fast dose of nutrients to plants. Inorganic fertilizers are contaminated with toxic heavy metals such as magnesium and zinc [3]. These fertilizers provide plants with essential nutrients, but their long-term use can have negative consequences such as affecting soil pH value and hardening the soil [4].

Meanwhile, organic fertilizer is natural and unprocessed fertilizer. Organic fertilizer releases nutrients much slower and has a low risk to plants and the environment since its nutrients aren't too concentrated [5]. According to [6], organic fertilizers have the advantage of being cheap, improving soil structure, texture and aeration increasing the soil's water retention abilities and stimulating healthy root development. Organic fertilizer has many sources such as minerals, animal sources, sewage sludge and plants.

Food waste such as fruit and vegetables peel, contains a variety of organic elements. Food waste contains a high key nutrient which includes nitrogen (N), phosphorus (P), potassium (K), and other micronutrients that were important for excellent plant growth. P is necessary for transferring energy in plants and is essential for the growth of roots, blooming, and harvesting. K is required for general plant health and plays a vital role in a variety of metabolic processes that include water intake, enzyme activation, and photosynthesis [7] while N is required for the growth of leaves and stems and contributes to overall plant strength [8].

Eggshells (ES) are known for their high calcium which is important to support plants' cell walls and plant membrane structures. Plant cell walls act as the 'skeletal' part of the plant to keep its structure stable. Around 95% of calcium carbonate can be found in ES [9]. The deficiency of calcium in plants will occur during the development of non-mature fruits and leaves due to the low remobilization of old plant tissue to new plant tissues [10].

Coffee beans hold a rich amount of N required for plant growth and seed germination [11]. However, the nutrient content may differ based on factors such as coffee bean type, brewing method, and whether the grounds are freshly extracted or reused. There were also bacterial and fungal species that can be found in spent coffee ground (SCG) such as a non-pathogenic *Pseudomonas*, *Fusarium*, and *Trichoderma spp*. and pin molds (*Mucorales*) helps prevent pathogenic fungi from established assumption [12].

The mineral composition of banana peel (BP) was phosphorus, iron, calcium, magnesium, and sodium [13]. The peel has been historically claimed to remedy several ailments, including burns, anemia, inflammation, diarrhea, ulcers, diabetes, cough, snakebite, and depression [14] [15]. In addition, banana peel is a good source of bioactive compounds, such as phenolics and carotenoids, and exhibits superior antioxidant, antiviral, antibacterial, and antibiotic activities [16] [17]. Due to their high content of total dietary fibers (43–50%), starch (3%), crude protein (6–9%), and crude lipids (4–11%), the banana peel has a variety of uses [18].

The conversion of wastes into value-added components in bio-fertilizer which contains living microorganisms to boost its quality for better plant production such as yeast [19] may be improved by anaerobic digestion (AD) and aerobic composting processes [20]. In the production of bio-fertilizers, diverse types of fermenters, such as bacterial and fungal species, have been identified and characterized [21]. Microorganisms especially yeast, bacteria, or fungi, will transform carbohydrates, such as starches and sugars, into organic acids or alcohol while, peptides and amino acid were broken down from proteins [22]. The main purpose of fermentation is to turn NADH into the coenzyme NAD+ so it can be reused again in glycolysis process. Throughout fermentation, an organic electron acceptor for example, pyruvate or acetaldehyde combines with NADH to generate NAD+, release product such as carbon dioxide and ethanol (ethanol fermentation) or lactate (lactic acid fermentation) [23]. When adding yeast as a fertilizer to plants, plant's defensive mechanisms will increase. Yeast has a positive effect on plants as bio-stimulants and bio-pesticides. A rapid growth of yeast will create biofilm layers on the plant's surface which will inhabit pathogen's mycelial production and the production of spores. Plus, yeast does not produce any toxic metabolites which is why they are biologically safe [24].

Capsicum frutescens L. (Chili Plant) takes around 3 to 6 months to produce fruits and to be sown. Chili plants love warm and sunny places with at least six hours of sunlight to grow properly. The best temperature and pH to grow this plant should be around 18°C to 30°C [25] and in slightly acidic soil around 5.5 to 6.8 pH value [26]. Chili plant is also a water-thirsty plant that needs to be watered once to twice times a day. However, overwatering could lead to root rotting [27]. Hence, this study examines a sustainable option using a bio-organic liquid fertilizer derived from the fermentation of food waste like eggshells, used coffee grounds, and banana peels for chilli plants as well as the impact of varying fertilizer concentrations on chilli plant growth.

2. Materials and Method

As shown in Fig. 1, the methodology in this research is grinding the ES, SCG, and BP, fermentation, dilution and filtering, pH measurement and application of bio-organic liquid fertilizer on chili plants. In the first step, ES, SCG, and BP undergo a process of washing, drying, and grinding to reduce them into smaller pieces, increasing their surface area and contributes calcium, potassium, and other minerals value. Then, four concentration ratio of ES (3:1:1), SCG (1:3:1), BP (1:1:3) and CONST (3:3:3) were measured where the arrangement of the ratio is equal to (ES:SCG:BP). Next, the ground organic matter is combined with store-bought instant yeast (*Saccharomyces cerevisiae*) (9.5g), brown sugar (83g), and distilled water (1L) for fermentation [28]. The addition of brown sugar and yeast ensures proper fermentation by providing nutrients for yeast growth, aiding in the breakdown of organic matter into plant-absorbable nutrients. During the 24-hour fermentation period, the yeast produces beneficial microbes and potentially organic acids.

Four concentrations of bio-organic liquid fertilizers were prepared using different maximum ratios of eggshells (ES), spent coffee grounds (SCG), and banana peels (BP), specifically 3:1:1 for ES, 1:3:1 for SCG, 1:1:3 for BP, and 3:3:3 for the constant (CONST). The ratios refer to the amounts of each ingredient added before fermentation. For example, 30g ES, 10g SCG, and 10g BP for the 3:1:1 ratio. These proportions were measured prior to the fermentation process.

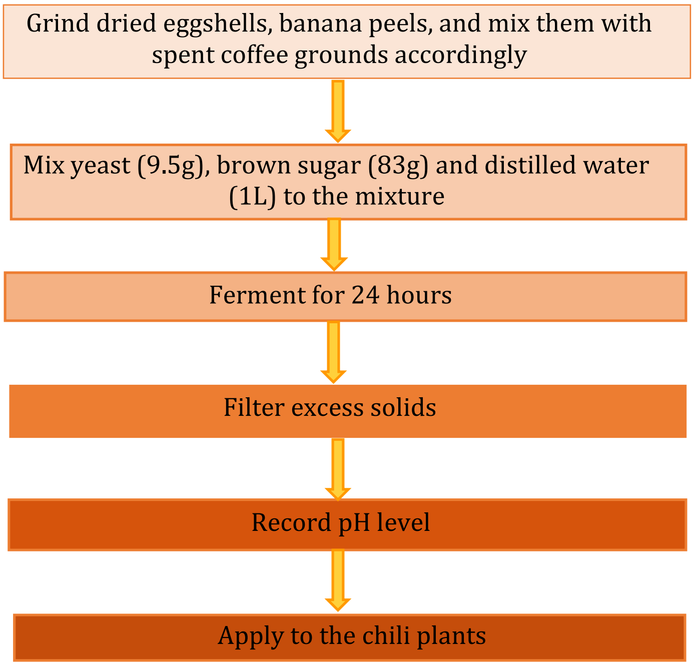

Fig.1 *Flowchart on the process of developing the bio-organic liquid fertilizer*

After fermentation process completed (see Fig. 2(a)), the solid ingredients were filtered out and pH measurement was taken for four concentration of fertilizer using pH meter. The early measurement of the chili plants was recorded. Throughout the observation for six weeks, the bio-organic fertilizer was applied to the chili plants accordingly as can be seen in Fig. 2(b). Each plant was receiving six pumps of spray of the liquid fertilizer that were applied on the chili plant's leaves and stem. Then for each week, the chili plants were measured for various growth parameters at certain times using measuring tape. The parameters encompass; the width of leaves (WOL), average width of leaves (AWOL), diameter of stem (DOS) and height of plant (HOP). By comparing plant growth in treated groups versus a control group that did not receive the solution, the fermented mixture can be determined whether it has a positive impact on chili development.

(a) **(b)**

Fig. 2 *(a) Fermentation process; (b) Application on chilli plants*

3. Result and Discussion

Based on the reading obtained from pH meter, all fertilizer has an acidic pH that falls between the range of 5.3 to 5.5. The SCG liquid fertilizer (1:3:1) has pH 5.3, the ES liquid fertilizer (3:1:1) has pH 5.5, the BP liquid fertilizer (1:1:3) has pH 5.3 while the constant liquid fertilizer (3:3:3) has pH 5.3. All the liquid fertilizer produced is suitable for the plant since chili plants are best grown in a slightly acidic state of soil [26]. The slightly acidic pH of the fertilizers (5.3 to 5.5) may have optimized nutrient availability, as chili plants generally thrive in slightly acidic soil. pH levels affect nutrient uptake, particularly for nitrogen, phosphorus, and potassium, contributing to improved growth in plants treated with these fertilizers.

The weekly observations were arranged with 20 chili plants for experimentation. Four ratio fertilizers were prepared to be tested on chili plants including maximum number of SCG (1:3:1), maximum number of ES (3:1:1), maximum number of BP (1:1:3), and a constant fertilizer (3:3:3). Five set plants were used to be tested with each type of fertilizer and control plant. The control plant was only given water throughout the observation weeks. The plants were subsequently examined by assessing the variations in the parameters over six weeks. The parameters noted include the WOL, AWOL, DOS, and HOP. The data collected each week was then analysed in graph formats. This makes it simple to determine the best fertilizer.

The outcome as shown in Fig.3 indicates that in the initial week of application, tested CONT plants had the smallest WOL which is 1.7cm whereas tested (3:1:1) plants had the largest WOL recorded as 2.9cm. In the sixth week, tested (3:3:3) plant measurement was only 1.6cm. While those with (1:1:3) had the largest WOL measurement recorded which is 2.7cm. However, based on the Fig. 3, only tested (1:3:1) plants had a consistent increasing WOL result compared to other tested plants measurement during the observation weeks. Total N molecules in coffee are very consistent among species, as well as during roasting, with values ranging from 8.5% to 13.6%. Nitrogen is required for the growth of leaves and stems, and it also contributes to overall plant strength [8].

The varying levels of NPK in the fertilizers likely influenced plant growth. Nitrogen promotes leaf and stem growth, while phosphorus aids root development and flowering, and potassium enhances overall plant strength and disease resistance. The SCG (1:3:1) fertilizer, rich in N, showed consistent improvements in leaf width and stem diameter due to nitrogen's role in vegetative growth.

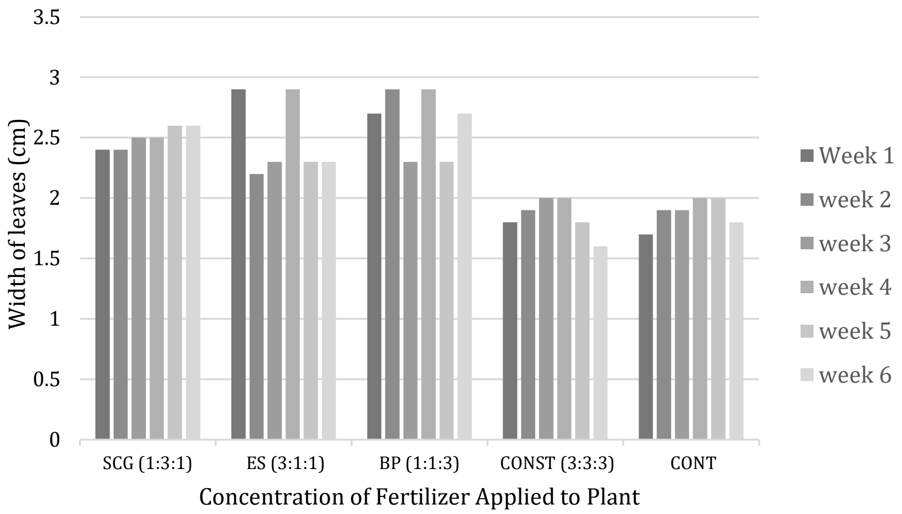

Fig.3 *Width of leaves*

The first week's reading from Fig. 4 indicates that the AWOL of CONT tested plants is the smallest when compared to the others. CONT AWOL measurement for the initial week is only 1.4cm. Tested (1:3:1), (3:1:1) and (1:1:3) plants on the other hand had the widest WOL which is 1.9cm. In the sixth week of observation, (3:3:3) tested plants had the smallest AWOL measurement which only reaches up to 1.8cm. Tested plants of (1:3:1), (3:1:1) and (1:1:3) still have the largest AWOL measurement which is 2.3cm. This implies that the treatments given to these tasted plants had a positive impact on leaf width, potentially because of improved nutrient distribution and ideal growth distribution [29].

The outcome as shown in Figure 5 indicates that in the initial week of application, tested on ES (1:3:1) plants had the smallest diameter of stem (DOS) which is 2.3cm whereas tested SCG (1:3:1), BP (1:3:1), CONST (3:3:3) plants had the largest DOS recorded as 3.0cm. In the sixth week, tested BP (1:1:3), CONST (3:3:3), and CONT plants measurement was only 2.5cm. While those with SCG (1:3:1) had the largest DOS measurement recorded which is 3.5cm. However, based on Fig.5, only tested SCG (1:3:1) plants had a consistent increasing DOS result compared to other tested plants measurement during the observation weeks. Generally, SCG contains a significant amount of nitrogen, which is crucial for the growth of plants, especially for the development of leaves and stems [30]. Meanwhile, CONT tested plants showed there's no improvement in growth, remaining at a value of 2.5 cm for DOS. This indicates that the basic conditions without fertilizer are not enough to encourage substantial stem growth [31].

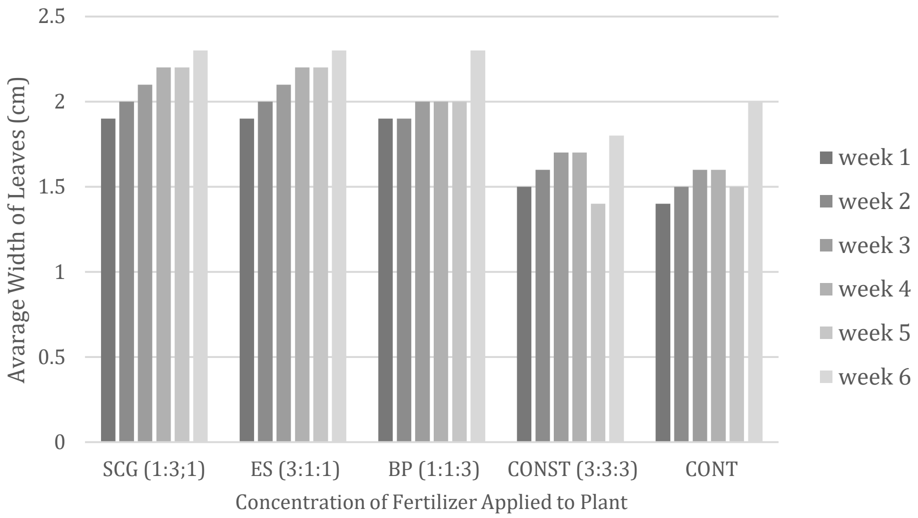

Fig.4 *Average width of leaves*

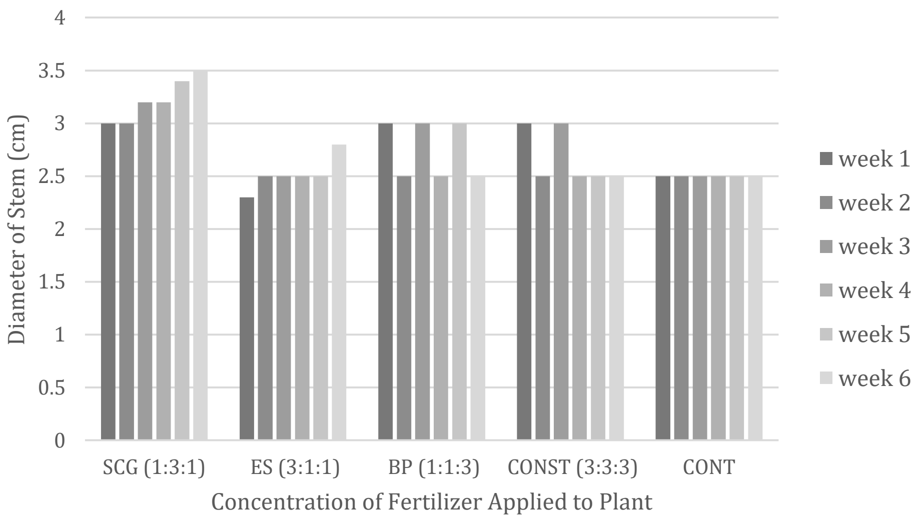

Figure 5 *Diameter of stem*

Fig. 6 indicates that in the initial week of application, tested ES (3;1:1) plants had the smallest height of plant (HOP) which is 9.0cm whereas tested BP (1:1:3) plants had the largest HOP recorded as 17.5cm. In the sixth week, tested ES (3;1:1) plants measurement was only 10.6cm. While those with BP (1:1:3) had the largest HOP measurement recorded which is 20.5cm. However, based on the Fig. 6, only tested SCG (1:3:1) plants had a consistent increasing HOP result compared to other tested plants measurement during the observation weeks. SCG improve soil quality encourages stronger root development and improved nutrient absorption, ultimately leading to increase plant growth [32].

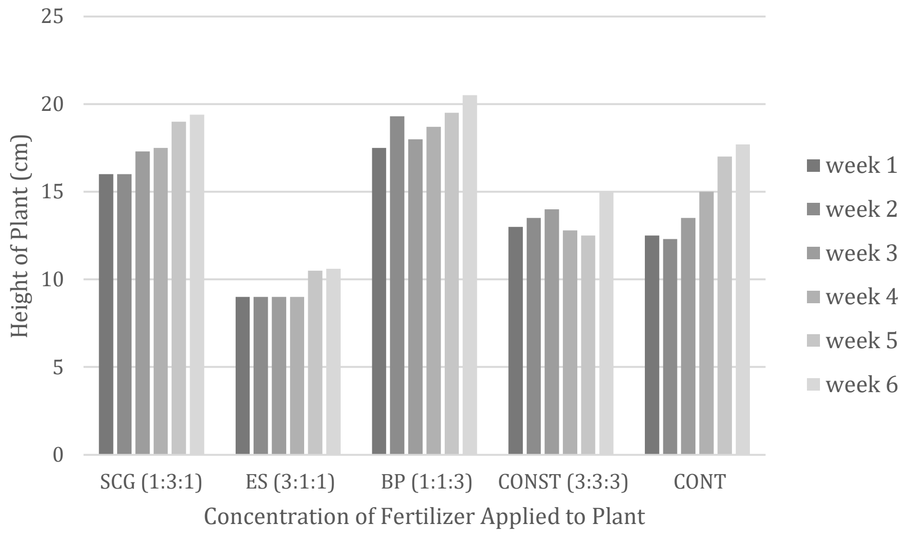

Fig. 6 *Height of plant*

4. Conclusion

This study successfully created a bio-organic liquid fertilizer from food waste from ES, SCG, and BP by fermenting. The efficacy of the fertilizer was assessed on chili plants by examining growth parameters such as WOL, AWOL, DOS, and HOP. The findings showed that the different concentration of the bio-organic liquid fertilizer affected the growth of chili plants, with SCG fertilizer showing the most beneficial impact on chili plants. This indicates that bio-organic liquid fertilizer with high concentration of SCG was the best for ideal growth of chili plants. It was found that SCG contains richer NPK concentration than ES and BP. Thus, plants would gradually grow better with the application of SCG fertilizer compared to ES and BP fertilizer. SCG were also reported to have a higher concentration of K and other macronutrients compared to ES [33]. Furthermore, since SCG contains richer sources of nutrients than ES and BP, these properties make SCG a perfect fit for the production of organic fertilizers [34]. This research also found that ES tested plants show greater plant growth compared to BP tested plants. However, during the germination process, ES tested plant grows slower than BP tested plants because BP contains higher P concentration than ES. P supports root growth and plant's early maturity. Although BP contains higher P concentration, ES tested plants still manage to surpass BP tested plants due to the amount of calcium it has which were then show an amazing growth of the plants [35].

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Adlina Aqilah Binti Ayob, Nurul Hamizah Binti Hamzah , Siti Nordiana Sahira Binti Rosli, Norhaliza Binti Abu Bakar;* ***data collection:*** *Adlina Aqilah Binti Ayob, Nurul Hamizah Binti Hamzah , Siti Nordiana Sahira Binti Rosli;* ***analysis and interpretation of results:*** *Adlina Aqilah Binti Ayob, Nurul Hamizah Binti Hamzah , Siti Nordiana Sahira Binti Rosli,;* ***draft manuscript preparation:*** *Adlina Aqilah Binti Ayob, Nurul Hamizah Binti Hamzah , Siti Nordiana Sahira Binti Rosli, Norhaliza Binti Abu Bakar. All authors reviewed the results and approved the final version of the manuscript.*

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