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Potential Liquid Fertilizer Made from Goat Feces to Improve Vegetable Product

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Abstract

This study was carried out to examine the production of liquid fertilizer made from goat feces (LFGF) as well as the potency of LFGF for increasing plant growth and yield of vegetables. The study was conducted through 3 studies. The first study was begun with compiling a formulation for LFGF. The selected-raw-material was goat feces added with sugar and ZA, as well as EM (Lactobacillus sp., Actinomycetes sp., Streptomyces sp. and Yeast). The experimental results indicated that an increase in the concentration of ZA resulted in an increase in the total N and S content, as well as an increase EC of LFGF. Increased sugar concentration results in a decrease in pH and an increase in lactic acid content, whereas an increase in ZA decreases the formation of acetic acid. The use of sugar 25 g L⁻¹ water and ZA 50 g L⁻¹ water could produce the best quality of LFGF. The second study was to examine the selected LFGF combined with AB-Mix nutrient solution on the growth and yield of three types of leaf vegetables which were cultivated hydroponically. The results indicated that LFGF can potentially replace AB-Mix fertilizer by up to 50% in hydroponic vegetable cultivation. The third study was to examine the selected LFGF as nutrients availability of mustard that was cultivated in pots, given through planting media with a concentration of 1:40 L⁻¹ water (EC 2300 μ S cm⁻¹). It shows that LFGF has the potential to increase the growth and yield of mustard plants in pots.

Keywords: Liquid fertilizer, Goat feces, Lactic acid, Acetic acid, Foliage vegetables

1. Introduction

Goats are raised in addition to producing meat, they can also produce fur to be made into wool, and feces which are used as manure. Goat manure contains macro nutrients as well as micro elements that can be used as soil fertility amendments [1]. In sustainable agriculture, manure can be used as a potential soil ameliorant to increase soil organic matter and provide plant nutrients [2]. The traditional form of using goat manure is to spread it in its natural form over the land for growing crops and put it in the soil so that its nutritional content is available to plants. Furthermore, goat feces as manure can be made into quality liquid fertilizer [3] that can fertilize the growing media as well as a nutrient solution in hydroponics as modern plant cultivation.

Plant protected cultivation, the so-called, hydroponics and semi-protected cultivation, in particular in pots, is currently in great practices by Indonesian growers, however, the development of hydroponic and potting plant cultivation in Indonesia is still very limited. One of the difficulties of growers in hydroponic development and cultivation in pots is mainly due to the limited availability of quality liquid fertilizers.

One of the most important components in supporting the development of plant cultivation is fertilizer. Fertilizer is a source of nutrients which is one of the factors needed in plant growth. In geoponic plant cultivation, fertilizers are generally applied to the soil in the form of synthetic chemical fertilizers so that the nutrients contained in them can be quickly absorbed by plants. However, the application of synthetic chemical fertilizers can reduce soil fertility and productivity if given continuously. Soil productivity, among others, is determined by the condition of soil fertility, previous fertilization (fertilizer residue), the application of organic matter, and the type of plant cultivated [4].

The narrowing of fertile agricultural land in line with the increasing need for land for housing and offices and other public facilities, becomes a serious obstacle to crop production in the future. The decline in fertile agricultural land mainly occurred in developed and developing countries including Indonesia, encouraging the development of soilless cultivation technology (soilless culture) known as hydroponics. The discovery of liquid organic fertilizers can support the development of hydroponics because it can replace the availability of inorganic fertilizers which are increasingly difficult to obtain on the market in certain country like Indonesia.

To obtain high-quality organic fertilizers, the use of effectiveness microorganism (EM) as organic matter decomposer microbes during fermentation of the raw ingredients is the best way [5, 6]. In the manufacture of liquid fertilizers, urea, NPK, and molasses can be added to provide nutrients and energy sources to EM [7]. EM is a microbial inoculant used in the fermentation of organic matter to increase soil fertility, plant growth, and crop yield [8]. The quality of liquid organic fertilizers is determined not only by the nutrient content and pH of the fertilizer solution, but also the content of other phytochemical compounds such as growth regulators and other organic acids [9, 10].

Currently many quality solid organic fertilizers are offered in the market, such as vermicompost, which can increase crop yields [11, 12]. In addition, currently liquid organic fertilizers (LOF) are even created by the growers [13–15]. However, the availability of quality LOF on the market is still very limited. The current availability of LOF in the market in Indonesia has several weaknesses, such as expensive price, acidic pH, and low EC.

The formulation of the ingredients that are combined will determine the quality of the fertilizer made. Formulation is an important step in the manufacture of liquid organic fertilizers which determines the quality of the fertilizers made. However, in the manufacture of liquid organic fertilizers, there are not many reports that provide detailed formulations. ECHO West Africa Impact Center has conducted training in making liquid organic fertilizer for farmers with a formula consisting of: livestock manure, forage materials, namely green grass or green leaves, and water, each with a ratio of 1: 1: 1 (v/v), plus living earth and 2–3 shovel ash [16]. The ingredients are mixed and put in a drum, then fermented aerobically for 14 days. Every day, do the stirring for 5–10 minutes using a wooden stick. Likewise, the manufacture of liquid organic fertilizer “Herbafarm” by PT. Sidomuncul, with the raw material of liquid waste for making ethanol, the process of making fertilizer is reported in detail [17], while the comparison formula for raw materials and additives is not clearly detailed.

The use of organic fertilizers on the one hand gives a low quantity of crop yields but on the other hand is capable of producing high quality agricultural products. This low yield quantity is partly due to the low nutrient content of organic fertilizers [11, 12], so that in order to provide high yields it is necessary to look for quality organic fertilizers by increasing the nutrient content and the content of other chemical compounds.

It is not enough to carry out fertilizer quality tests in the laboratory to determine the content of nutrients and chemical compounds, but it needs to be done in the field to determine the potential or effect of fertilizers on plant growth and yield. In this study, tests were carried out on the dynamics of pH and EC, and the content of organic compounds of liquid fertilizer made from goat feces (LFGF) at the time of manufacture and storage, the effect of LFGF on the growth and yield of leaf vegetables cultivated hydroponically and in pots. The cultivation techniques used in this study include non-substrate hydroponics using nutrient solution planting media, cultivation techniques in pots using a mixed planting medium of sand, compost, and husk charcoal.

Fertilizer application to plants needs to be regulated in dosage. In the application of liquid fertilizer, the dose of fertilizer can be adjusted by adjusting the concentration, frequency or interval of application. In this study, the LFGF treatment interval was adjusted for planting mustard plants in pots.

2. Essential elements and organic acids content of LFGF

2.1 Research methods

Fermentation and incubation of liquid fertilizer were carried out in the laboratory of University of Sarjanawiyata Tamansiswa (UST). The materials are: air dried goat feces, sugar, ZA fertilizer, EM microbial solution, and sterile water. The tools used include: plastic buckets with lids of 30 liters volume, stirring bamboo sticks, 5 liter plastic jerry cans, plastic funnels, and a pH/EC/TDS meter.

Liquid fertilizers were formulated using a 3 x 3 factorial experiment arranged in a completely randomized design (CRD) with three replications. The first factor was the concentration of sugar, consisting of 3 levels: 12.5, 25, and 50 g L⁻¹ of water coded S1, S2, and S3 respectively. The second factor was the concentration of ZA, consisting of 3 levels: 25, 37.5, and 50 g L⁻¹ of water coded Z1, Z2, and Z3 respectively. There were 9 treatment combinations, namely: S1Z1, S2Z1, S3Z1, S1Z2, S2Z2, S3Z2, S1Z3, S2Z3, and S3Z3. Each treatment combination was fermented in 20 liters of water (see Appendix A). All combinations added 100 g of goat feces and 1 ml of EM liquid for every liter of water. Fermentation of the materials consisted of several steps [3, 18].

The fermentation was carried out for 3 weeks, for each combination formula of liquid fertilizer treatment was taken 5 liters of fertilizer solution, then collected in a plastic jerry can container and closed tightly. All plastic jerry cans containing fertilizer solution were placed in a storage room at room temperature for 5 months. Every month the pH and EC of the fertilizer solution were observed.

2.2 Results and discussion

There was no interaction between the sugar and ZA concentrations at the acidity (pH) of LFGF (**Table 1**). The variation of sugar concentration from the lowest to the highest indicates that the sugar concentration of 12.5 g L⁻¹ of water produces the highest pH (6.4) close to neutral, if the concentration of sugar increases 2 to 4 times, the pH drops to 4.9–4, 3 and consistent from the first to the third week. In

Treatments	pH		
	Week I	Week II	Week III
Sugar concentration (g L ⁻¹ water)			
12,5 (S ₁)	6,4 a	6,2 a	6,4 a
25 (S ₂)	4,9 b	5,0 b	5,1 b
50 (S ₃)	4,3 c	4,1 c	3,9 c
S ($\rho > F$)	< 0,0001	< 0,0001	< 0,0001
ZA concentration (g L ⁻¹ water)			
25 (Z ₁)	5,3 a	5,2 a	5,3 a
37,5 (Z ₂)	5,2 a	5,2 a	5,2 a
50 (Z ₃)	5,2 a	5,0 a	5,2 a
Z ($\rho > F$)	0,6222	0,5218	0,2061

Note: The mean number in the column followed by the same letter shows no significant difference based on DMRT 5%.

Table 1.
Effect of sugar and ZA concentrations on pH of LFGF during fermentation.

contrast to the sugar concentration, the use of ZA concentrations of 25, 37.5, and 50 g L⁻¹ water did not result in a change in pH (about 5.0–5.3) from the first to the third week (**Table 1**). This shows that sugar has an effect on the organic acid content of LFGF, the higher the sugar concentration the higher the organic acid content and the lower pH. Although the concentration of ZA did not affect changes in pH, ZA produced relatively acidic LFGF with a pH of about 5.0–5.3. Thus ZA also affects the organic acid content of LFGF but is not as strong as the effect of sugar (**Table 4**).

There was no interaction between the sugar and ZA concentrations on the electrical conductivity (EC) of LFGF (**Table 2**). The sugar concentrations of 12.5, 25, and 50 g L⁻¹ water did not cause changes in EC, which was about 2600 $\mu\text{S cm}^{-1}$ (after 20 times LFGF dilution) consistent from the first week to the third week. In

Treatments	EC ($\mu\text{S cm}^{-1}$)		
	Minggu I	Minggu II	Minggu III
Sugar concentration (g L ⁻¹ water)			
12,5 (S ₁)	2666 a	2713 a	2740 a
25 (S ₂)	2648 a	2680 a	2698 a
50 (S ₃)	2458 a	2528 a	2685 a
S ($\rho > F$)	0,1790	0,1500	0,2061
ZA concentration (g L ⁻¹ water)			
25 (Z ₁)	1929 c	1909 c	1988 c
37,5 (Z ₂)	2548 b	2621 b	2718 b
50 (Z ₃)	3294 a	3391 a	3419 a
Z ($\rho > F$)	<0,0001	<0,0001	<0,0001

Note: The mean number in the column followed by the same letter shows no significant difference based on DMRT 5%.

Table 2.
Effect of sugar and ZA concentrations on EC of LFGF during fermentation.

contrast to the variation in the concentration of ZA, it shows that the ZA concentration of 25 g L⁻¹ of water produces the lowest EC which is around 1900 μS cm⁻¹, if the ZA concentration increases to 37.5 g L⁻¹ of water it results in an increase in EC to around 2500–2700 μS cm⁻¹, and when the ZA concentration was increased to 50 g L⁻¹ water the result was an increase in EC to about 3300 μS cm⁻¹ (Table 5). It can be understood that ZA which has the chemical formula (NH₄)₂SO₄ as a nutrient provider (N and S) can stimulate the growth of microbial increase (EM) so that the breakdown of organic matter (goat feces) increases and results in an increase in the content of total dissolved solids (TDS) as well as EC of LFGF.

There was no interaction between the sugar and ZA concentrations on nutrient content (N, K, S, and Mn) of LFGF (Table 3).

The interaction between the use of sugar and ZA on organic acid content (lactic, acetic and citric acids) occurred (Table 4). High sugar concentration (50 g L⁻¹ water) resulted in the highest lactic acid content both with low ZA concentrations (25 g L⁻¹ water) and high (50 g L⁻¹ water), namely: 7582 mg L⁻¹ and 7270 mg L⁻¹ respectively. This research is in line with research conducted by Yunus and Zubaedah [19] and Zubaedah et al. [20]. Sucrose provides energy and carbon for lactic acid bacteria for lactic acid metabolism, and the accumulation of lactic acid can lower the pH of the media. The results of Yunus and Zubaedah [19] research on the effect of sucrose concentration and fermentation time on the viability of *L. casei* during frozen storage of Ambon Banana Velva, showed that the use of 20% sucrose concentration resulted in 0.19% lactic acid and a pH of 4.89, while 40% sucrose results lactic acid 0.29% and a pH of 4.44. Fermentation by lactic acid bacteria is characterized by an increase in the amount of organic acid followed by a decrease in pH [20].

Low sugar concentration (12.5 g L⁻¹ water) with low ZA (25 g L⁻¹ water) resulted in the highest acetic acid content (2512 mg L⁻¹) (Table 4). The results of this study are different from the results of research conducted by Firdausni [21] and Priasty et al. [22]. Research by Firdausni [21] on the effect of sugar and yeast concentrations in vinegar from Rosella (*Hibiscus sabdariffa* L.) on the quality of Rosella vinegar, shows that 10% sugar concentration with 6 g of L⁻¹ yeast produces 5.45% acetic acid, while sugar concentration 20% with yeast 6 g L⁻¹ yield 14.80% acetic acid. Research by Priasty et al. [22] who studied the acid quality of Coconut

Treatment combination	N total (%)	K ₂ O total (%)	S total (%)	Mn total (ppm)
S ₁ Z ₁	0,44 d	0,17 b	0,06 e	21,34 e
S ₁ Z ₂	0,66 c	0,13 cd	0,19 b	24,50 d
S ₁ Z ₃	0,85 a	0,11 d	0,26 a	23,71 d
S ₂ Z ₁	0,39 d	0,14 c	0,09 d	30,49 b
S ₂ Z ₂	0,79 b	0,12 cd	0,24 a	37,54 a
S ₂ Z ₃	0,81 ab	0,12 cd	0,20 b	27,95 c
S ₃ Z ₁	0,44 d	0,19 a	0,06 e	29,55 cb
S ₃ Z ₂	0,66 c	0,19 ab	0,15 c	38,03 a
S ₃ Z ₃	0,85 a	0,21 a	0,20 b	29,44 cb
S * Z (ρ > F)	<.0001	0.0103	<.0001	<.0001

Note: The mean number in the column followed by the same letter shows no significant difference based on DMRT 5%.

S₁, S₂ and S₃: Sugar concentration of 12,5, 25, and 50 g L⁻¹ water respectively.

Z₁, Z₂, and Z₃: ZA concentration of 25, 37,5, and 50 g L⁻¹ water respectively.

Table 3.
 Interaction between the sugar and ZA concentrations on nutrient content (N, K, S, and Mn) of LFGF.

Treatment	Organic acid content (mg L ⁻¹)		
combination	Lactic acid	Acetic acid	Sitric acid
S ₁ Z ₁	49,37 d	2512,17 a	41,09 a
S ₃ Z ₁	7582,52 a	373,89 d	35,80 b
S ₁ Z ₃	17,20 d	915,38 b	29,39 c
S ₃ Z ₃	7270,21 b	439,55 c	30,02 c
S * Z ($\rho > F$)	<0.0001	<0.0001	0.0012

Note: The mean number in the column followed by the same letter shows no significant difference based on DMRT 5%.
S₁ and S₃: sugar concentration of 12,5 and 50 g L⁻¹ water respectively.
Z₁ and Z₃: ZA concentration of 25 and 50 g L⁻¹ water respectively.

Table 4.
Interaction between sugar and ZA concentration on organic acid content of LFGF.

vinegar (*Cocos nucifera* L.) using the slow method, showed that the use of 3% yeast (*S. cerevisiae*) and 10% sugar (C₆H₁₂O₆) produced 11% alcohol (C₂H₅OH), while the use of yeast with a concentration of 3% and 16% sugar produces 16.67% alcohol. Alcohol (ethanol) through the alcohol dehydrogenase process turns into acetaldehyde (CH₃OH), then through the aldehyde hydrolase process acetaldehyde changes to hydrase acetaldehyde, finally through the aldehyde dehydrogenase process the hydrated acetaldehyde turns into acetic acid.

High citric acid content was produced in a combination of low ZA concentration (25 g L⁻¹ water) with low sugar (12.5 g L⁻¹ water) and high sugar (50 g L⁻¹ water), namely 41.09 mg L⁻¹ and 35.80 mg L⁻¹ respectively (**Table 4**). In contrast to the research on the manufacture of citric acid conducted by Hamat and Sasmita [23] who studied the use of tapioca flour waste as a submerge culture in citric acid fermentation, the results showed that making citric acid from tapioca flour waste needed to be added with sugar with a concentration of 140 g L⁻¹ of water., used *Aspergillus niger* bacteria, it takes 9 days of fermentation, 100 ml of tapioca waste can produce 1.54 g of citric acid with a pH of 5.

The higher the lactic acid content is due to the higher the sugar concentration used, resulting in lower LFGF pH, which can reduce the quality of the fertilizer. However, several studies have shown that lactic acid can stimulate plant growth. Giving lactic acid at a very low concentration can stimulate plant growth. Lactic acid can stimulate the growth of duckweed (*Lemna minor* L.) and corn (*Zea mays* L.) which is indicated by increasing plant biomass [24]. However, until now there has been no explanation of the mechanism of lactic acid stimulating effect on plant growth.

In the experiment on the germination of tomato seeds (*Lycopersicon esculentum* Mill) by Murthy et al. [25] showed that the treatment of lactic acid bacteria was treated with *L. paracasei* subsp. tolerant (LAB I) and *L. paracasei* subsp. *paracasei* (LAB II) resulted in the percentage of seeds germinated not significantly different from the control treatment, namely 78.13% (LAB I), 79.76% (LAB II), and 76.10% (control). The three treatments resulted in a higher percentage of seeds germinating than seeds treated with wilt bacteria (*Ralstonia solanacearum*) strains 1–5 which resulted in an average seed germination of 35%. On the other hand, LAB I and LAB II treatments produced higher plant vigor index (sprouts), namely 1112.76 (LAB I) and 1130.20 (LAB II) higher than controls with plant vigor index 700.08, and *Ralstonia solanacearum* treatment with plant vigor index 196–216.83. This shows that the treatment of lactic acid bacteria can stimulate plant growth and produce a higher plant vigor index.

Lactic acid and acetic acid can make plants healthy. Both of these organic acids can reduce fungal infections in seeds, however at high concentrations they can

have a negative effect on germination and reduce the vigor of Zinnia seedlings [26]. Compared to lactic and acetic acids, the content of citric acid of LFGF is very low. Citric acid can also stimulate plant growth. Talebi et al. [27] reported that citric acid is an environmentally friendly chemical, at a concentration of 300 mg L^{-1} , which can have a positive effect on the growth and development of Gazania plants.

Experiments examining the effect of organic acids on germination, vigor, and health of Zinnia plant seedlings [26], showed that 5% acetic acid treatment inhibited seeds from germinating, resulting in 14–26.3% germinating seeds, lower than the treatment of 1% acetic acid which produced 78.3–84% germinated seeds which was not significantly different from the control treatment (84–91% germinated seeds). However, the 5% acetic acid treatment resulted in the seeds being attacked by disease with the smallest percentage, namely 8.3–12.7% which was not significantly different from the 5 g kg^{-1} fungicide treatment (11.7–16.7%) which was lower than the control treatment (19.3–30.3%). While 1% or 5% lactic acid treatment did not inhibit seed germination, resulting in 85.7–86% germinated seeds for 1% lactic acid treatment and 73% for 5% lactic acid treatment. However, lactic acid treatment did not reduce the disease-stricken seeds compared to control.

Apart from lactic acid and acetic acid, citric acid also has a positive effect on plant growth. Experiments conducted by Marjenah et al. [28] who studied the effect of a mixture of beef bone with organic acids to increase available P and growth of maize in inceptisol soil, showed that citric acid was able to more strongly dissolve P-organic cow bone ash than acetic acid and lactic acid, so that P availability increased for plants.

The results of this experiment showed that the formula with a combination of 100 g goat feces +12.5 g sugar +50 g ZA produced a normal pH (range 6.0–6.5), the highest EC (range $3200\text{--}3400 \mu\text{S cm}^{-1}$, after dissolving in water at a ratio of 1:20), and has the highest total N and S content, however, the formula produced the lowest lactic acid content and had an unpleasant odor. Observation of color and odor showed that the treatment of sugar concentration of 50 g L^{-1} produced yellow LFGF with a sour smell, sugar 25 g L^{-1} of water produced LFGF brownish yellow with slightly acid, while the treatment of sugar concentration 12.5 g L^{-1} water produced a blackish brown and unpleasant odor. The sour odor indicates the high organic acid content of the LFGF produced.

LFGF with the formula S2Z3 (goat feces 100 g L^{-1} water, sugar 25 g L^{-1} water, ZA 50 g L^{-1} water, EM 1 ml L^{-1} water), has a slightly acidic pH (5.0–5.2), high EC, slightly sour smell, selected to be the LFGF tested applied to plants.

3. Mixture of LFGF and AB-mix on hydroponic leaf vegetables

3.1 Research methods

Fermentation of LFGF [3] is carried out at the Laboratory of the Sarjanawiyata Tamansiswa University. The manufacture of liquid fertilizer was carried out in the first week to the fourth week of February 2017. Experiments on using LFGF were carried out from March to August 2017 at Agricultural Technology Park, Nglanggeran Wonosari Yogyakarta.

The research materials included: the seeds of pakcoy mustard (*Brassica rapa subsp. chinensis*), lettuce (*Lactuca sativa* L), and red spinach (*Amaranthus tricolor* L), liquid fertilizer made from goat feces (LFGF), and AB-mix fertilizer. The tools used included: hydroponic installation shallow flow technique (SFT), digital pH/EC/TDS meter, calipers, scales, digital chlorophyll meters, and ovens.

Experiments on the use of LFGF on leaf vegetable plants used a 3 x 4 factorial arranged by completely randomized design (CRD). The first factor was the kinds of

leaf vegetables, consisting of 3 levels: T1: pakcoy mustard, T2: lettuce, and T3: red spinach. The second factor was the combination of nutrient solutions, consisting of 4 levels: A1: LFGF + AB-Mix (v/v: 1:1), A2: LFGF + AB-Mix (v/v: 1:3), A3: LFGF + AB-Mix (v/v: 3:1), and A4: AB-Mix as controls. Each treatment combination was repeated 3 times so that there were 36 experimental units.

The seeds of pakcoy mustard, lettuce, and red spinach were sown in compost for two weeks until they grow into seedlings, then they were selected to obtain uniform seeds. The vegetable seedlings were then planted in a hydroponic installation with a series of 4-inch diameter PVC pipe using the shallow flow technique (SFT) method with a distance between the planting holes of 30 cm, and a vertical distance of 40 cm between the pipes (see Appendix B). Plants were fertilized with nutrient solution according to treatment. The concentration of the nutrient solution was adjusted in the range 1600–1650 $\mu\text{S cm}^{-1}$, and the pH was in the range of 5.5–6.5 (EC, pH, N and P content were observed in each combination of nutrient solutions). Nutritional solution replacement was carried out every 4 days when the plants were 1–12 days old, then once every 3 days until the plants were 21 days old, and once every 2 days until the plants were harvested (35 days old).

Five weeks after planting, observations were conducted on the variables of the number of leaves, shoot fresh weight, shoot dry weight, root dry weight, leaf chlorophyll content, and root/shoot ratio, on five sample plants from each treatment unit. Chlorophyll content was observed directly on the leaves without destructive, on the leaves that were located at the bottom, middle and top of the plant. Observation of chlorophyll content using a digital chlorophyll meter “CCM 200 plus Chlorophyll Content Meter”.

3.2 Results and discussion

The results of EC and pH observations of the nutrient solution from each mixture of LFGF and AB-Mix are listed in **Table 5**.

EC and pH of those various nutrient solution mixtures are ideal for the growth of leaf vegetable plants. Lettuce, carrots, strawberries, and onions require EC 1400 $\mu\text{S cm}^{-1}$, while broccoli, cabbage, tomato, cucumber, radish, and chili plants require EC 3000 $\mu\text{S cm}^{-1}$ [29]. Spice plants require EC 2500 $\mu\text{S cm}^{-1}$ and pH 5.5–6.5 [30]. Nutritional solutions with a pH of 5.8–6.5 are the most ideal for plant growth in hydroponic systems [31]. Ornamental plants *Gypsophila paniculata* require EC 1000 $\mu\text{S cm}^{-1}$ for plant growth in the first month and 2000 $\mu\text{S cm}^{-1}$ for the following month [32]. Lettuce requires EC 1200 $\mu\text{S cm}^{-1}$ at 5 days of age, 2100 $\mu\text{S cm}^{-1}$ at 10 days of age, and 1800 $\mu\text{S cm}^{-1}$ at 15 to 35 days of age [33].

EC regulation of nutrient solution to make it stable was done by replacing the nutrient solution with short time intervals, namely when the plants were 1–12 days old, did once every 4 days, then once every 3 days until the plants were 21 days old, and once every 2 days until the plants were 35 days old. The results of experiments conducted

Nutrient solution	pH	EC ($\mu\text{S cm}^{-1}$)
P ₁	5,85	1625
P ₂	6,25	1636
P ₃	5,54	1618
P ₄	6,52	1650

Note: P₁: LFGF + AB-Mix (v/v: 1:1), P₂: LFGF + AB-Mix (v/v: 1:3), P₃: LFGF + AB-Mix (v/v: 3:1), P₄: AB-Mix.

Table 5.
EC and pH of ready-to-use nutrient solutions.

on hydroponic pakcoy [34] showed that the EC was too high ($9600 \mu\text{S cm}^{-1}$) or too low ($0\text{--}600 \mu\text{S cm}^{-1}$) causing low plant fresh and dry weight, leaf area narrow, low net photosynthesis rate, and decreased taste value. Based on growth and quality criteria, the optimal EC is $1800\text{--}2400 \mu\text{S cm}^{-1}$. Too high or too low EC causes nutrient stress, increases antioxidant enzyme activity, and reduces plant growth and quality.

The results showed that there was no interaction between the combination of nutrient solution and kinds of leaf vegetables on the variables of leaf number, shoot fresh weight, shoot dry weight, root dry weight, and leaf chlorophyll content (**Table 6**). In mustard greens (**Table 6**), the nutrient solution treatment consisting of a mixture of LFGF + AB-Mix (v/v: 1: 3) (P2) resulted the highest canopy fresh weight, canopy dry weight, root dry weight as well as the highest chlorophyll content, while LFGF + AB-Mix (v/v: 1: 1) (P1) treatment and AB-Mix nutrient solution treatment without adding LFGF (P4) resulted in canopy fresh weight, canopy dry weight, and root dry weight not significantly different. The two treatments (P1 and P4) produced higher canopy fresh weight, canopy dry weight, and root dry weight than LFGF + AB-Mix treatment (v/v: 3: 1) (P3) (see Appendix C).

The results of field practice show that mustard greens are the most sensitive to changes in pH and EC of nutrient solutions compared to other leaf vegetables such as lettuce and spinach. In this experiment, the best growth and yield of mustard plants were obtained in the LFGF + AB-Mix (v/v: 1: 3) treatment, the LFGF + AB-Mix (v/v: 1: 3) treatment also produced the highest leaf chlorophyll content. This shows that the LFGF + AB-Mix (v/v: 1: 3) mixture produces the best nutrient solution for plant growth, the nutrient solution not only contains complete nutrients but also contains growth stimulants and growth nourishing (organic acids) in optimal concentration.

Plants	Treatments	Leaf number	Canopy fresh weight (g)	Canopy dry weight (g)	Root dry weight (g)	Chlorophyll content (%)
Mustard	P ₁	16.44 ab	132.47 b	11.59 b	1.60 b	17.12 b
	P ₂	18.44 a	155.23 a	14.63 a	2.08 a	20.00 a
	P ₃	15.22 b	99.07 c	9.27 c	1.27 c	16.88 b
	P ₄	17.67 a	125.20 b	11.13 b	1.56 b	16.69 b
$\rho > F$		0.0284	0.0031	0.0005	0.0006	0.0578
Lettuce	P ₁	13.44 a	79.03 a	3.30 ab	0.47 a	4.50 a
	P ₂	12.77 a	81.66 a	3.80 a	0.58 a	6.11 a
	P ₃	13.11 a	66.72 a	2.51 b	0.45 a	4.90 a
	P ₄	13.32 a	75.33 a	3.17 ab	0.58 a	4.80 a
$\rho > F$		0.9809	0.8799	0.0626	0.3101	0.2794
Red spinach	P ₁	18.11 bc	108.61 a	16.44 a	2.01 a	15.39 a
	P ₂	20.66 a	126.28 a	19.19 a	2.10 a	16.84 a
	P ₃	16.78 c	83.31 b	12.69 b	1.56 b	15.27 a
	P ₄	19.33 ab	106.51 a	16.23 a	1.86 ab	15.25 a
$\rho > F$		0.0011	0.0067	0.0064	0.0529	0.2935

Note: The mean number in the column followed by the same letter shows no significant difference based on DMRT 5%.

P₁: LFGF + AB-Mix (v/v: 1:1), P₂: LFGF + AB-Mix (v/v: 1:3), P₃: LFGF + AB-Mix (v/v: 3:1), P₄: AB-Mix.

Table 6.
 Effect of mixture of LFGF and AB-mix on growth and yield of leaf vegetables.

AB-Mix is the most commonly used fertilizer for providing hydroponic nutrient solutions. The addition of LFGF to AB-Mix at a high ratio (v/v: 3: 1) could inhibit growth and reduced the yield of mustard greens, this was probably because the mixture of LFGF + AB-Mix (v/v: 3: 1) contained high organic acids so that it could inhibit plant growth. The experiment conducted by Szopińska [35] showed that 5% acetic acid treatment inhibited seed germination in *Zinnia elegans* plants, resulting in 14–26.3% lower germinated seeds compared to 1% acetic acid treatment which resulted in 78.3–84% germinated seeds no different real with control treatment with seeds germinated 84–91%.

LFGF + AB-Mix (v/v: 1: 1) treatment resulted in the growth and yield of mustard plants which was not significantly different from the control treatment (AB-Mix). Thus, this treatment can save the use of A/B- Mix fertilizer by 50%, so it can save costs because the price of AB-Mix fertilizer is expensive. To manufacture LFGF the cost per liter (unit cost L⁻¹) is not more than IDR 2,000 and to produce 1000 liters of ready-to-use solution (EC 1500 $\mu\text{S cm}^{-1}$) requires LFGF 20 liters (costs IDR 40,000), while for preparing a ready-to-use AB-Mix nutrient solution 1000 liters (EC 1500 $\mu\text{S cm}^{-1}$) requires a package of AB-Mix (1 kg) for IDR 100,000.

In this experiment, LFGF was diluted by adding water with a ratio of 1:50 (v/v) to obtain an EC of about 1500–1600 $\mu\text{S cm}^{-1}$. In hydroponic systems, the optimum EC for leaf vegetable plants such as pakcoy is 1.8 mS cm^{-1} , too low or too high EC will cause nutrient stress, stimulate antioxidant enzyme activity, and inhibit growth and reduce plant quality [34]. Pakcoy can grow well in nutrient solutions with an EC of about 1.5–2.5 dS m^{-1} , while lettuce at EC is 1.6 dS m^{-1} [36].

In lettuce (**Table 6**), nutrient solution treatment only had a significant effect on the variable dry weight of the canopy. Treatment P2 resulted in a higher canopy dry weight than treatment P3 but it was not significantly different from treatment P1 and P4. Treatments P1, P3 and P4 produced the same dry weight of the canopy (see Appendix D).

In red spinach (**Table 6**), treatment P1, P2, and P4 produced canopy fresh weight and dry weight of the canopy were not significantly different (see Appendix E). The three treatments resulted in the fresh weight of the canopy and the dry weight of the canopy which was higher than that of the P3 treatment. As in mustard greens, LFGF + AB-Mix (v/v: 1: 3) treatment can produce better growth of lettuce and red spinach than LFGF + AB-Mix (v/v: 3: 1) treatment.

4. LFGF treatment on mustard plants in pots

4.1 Research methods

The experiment was carried out from March to July 2017 in the greenhouse of the Agricultural Faculty of UST. The experiment began with the manufacture of LFGF [3] and continued with the treatment of LFGF on mustard plants cultivated in plastic pots. Materials for the LFGF application test included: the seeds of Caisin mustard (*Brassica chinensis* var. *parachinensis*), polybags, husk charcoal, sand and compost. Tools that included EC/DHL/pH meters, scales, ovens, plastic pots with a diameter of 15 cm and watering cans.

The LFGF application experiment in the cultivation of mustard greens in pots was carried out with a single factor experiment which was designed in a completely randomized design. Types of treatment included the time interval for LFGF fertigation (watering): once a day (P1), two days (P2), three days (P3), four days (P4), and without the application of LFGF (P0). The experiment used 5 replications. Each experimental unit used 5 mustard plants grown in plastic pots.

The mustard plant seeding was carried out in a seedbed filled with a mixture of sand, compost and husk charcoal (v/v: 1: 1: 1). The mustard greens were sown by sowing the mustard seeds in a seedbed that had been filled with media. Spray the media twice a day in the morning and evening using a hand sprayer so that the nursery media was always moist. The mustard seedlings were allowed to grow in a seeding tub for 2 weeks, after which the mustard seeds were transferred to a black plastic pot filled with sand, husk charcoal and compost with a ratio of 1: 1: 1 (v/v) for treatment P₀, and filled sand and husk charcoal with a ratio of 1: 1 (v/v) for treatment P₁, P₂ and P₃. Filling the planting medium into the plastic pot was carried out to a height of 12.5 cm from the bottom of the plastic pot.

Plant maintenance included watering the plants with LFGF according to the treatment. LFGF was given by diluting with water with a ratio of 1: 40 (v/v) to obtain a concentration (EC) of 2,300 μScm^{-1} . Watering with LFGF was done in the morning on the plants and the potting media to field capacity (about 250 ml per plant) using a watering can. The control plant (P₀) was watered only. In the afternoon all the plants were watered with water to field capacity.

Harvesting was done when the plants were 35 days old by removing the plants from the growing medium. The roots of the plants were cleaned from the planting medium, then observed growth variables including: root/stem fresh weight, leaf fresh weight, root/stem dry weight, leaf dry weight, and plant dry weight.

4.2 Results and discussion

LFGF fertigation treatment at intervals of 3 days (P₃) and 4 days (P₄) resulted in better mustard plant growth than LFGF fertigation at intervals of 1 day (P₁), 2 days (P₂), and without LFGF fertigation (P₀) (**Table 7**) (see Appendix F). The P₀ planting medium used in this experiment consisted of a mixture of sand + compost + husk charcoal (v/v: 1: 1: 1), a relatively fertile planting medium with a pH of 7.3, 25% organic matter content, N 1.97%, and P 1.35%, while the planting media P₁, P₂, P₃, and P₄ consisted of a mixture of sand + husk charcoal (v/v: 1: 1) having a pH of 7.5, 17% organic matter content, N 0.25%, and P 0.09%.

Treatment	Leaf fresh weight (g)	Root/stem fresh weight (g)	Leaf dry weight (g)	Root/stem dry weight (g)	Plant dry weight (g)
P ₀	57,60 c	41,4 b	5,07 c	5,11 b	10,18 b
P ₁	128,4 b	38,8 b	11,11 b	4,87 b	15,98 b
P ₂	127,0 b	44,0 b	11,52 b	5,52 b	17,04 b
P ₃	202,4 a	65,6 a	18,22 a	8,25 a	26,47 a
P ₄	175,6 a	70,8 a	15,19 a	8,55 a	23,74 a
P ($\rho > F$)	<0,0001	<0,0001	<0,0001	0,0018	<0,0001

Note: The mean number in the column followed by the same letter shows no significant difference based on DMRT 5%.

P₀: Without LFGF fertigation.

P₁: LFGF fertigation with interval 1 day.

P₂: LFGF fertigation with interval 2 days.

P₃: LFGF fertigation with interval 3 days.

P₄: LFGF fertigation with interval 4 days.

Table 7.

Average leaf fresh weight, root/stem fresh weight, leaf dry weight, root/stem dry weight, and mustard plant dry weight at 35 days after planting.

The planting medium in this experiment was half of sand, so it required more frequent fertilizer application. According to Relf et al. [37], sand soil requires more frequent fertilization than clay soil. Vegetables grown on porous growing media require more frequent fertilization, vegetables grown on clay require less fertilizer than vegetables grown on sandy soil [38]. Other factors that affect the frequency of fertilizer application include the type of plant, the plant growth stage, the frequency and amount of water given, and the type of fertilizer. Leaf vegetable plants require more nitrogen fertilizer [37]. Plants grown on organic soil require a little extra fertilizer. Liquid fertilizers are usually given with a frequency of once a week [38].

In this experiment LFGF was given with EC $2,300 \mu\text{Scm}^{-1}$. The application of liquid organic fertilizer to paprika plant seeds with liquid organic fertilizer made from shrimp and seaweed extract fermented using *Trichoderma harzianum* can improve the quality of plants fertilized 3 times a week with EC 1.5 mScm^{-1} and watering every day as needed [39]. Experiments on elephant grass plants grown in pots showed that the treatment of liquid organic fertilizer from the *Centrosema pubescens* plant extract at a dose of 40 ml pot^{-1} resulted in a higher number of tillers and plant fresh weight than the lower dose treatment, namely 30, 20, 10 ml pot^{-1} . The lower the dose of liquid organic fertilizer, the less the number of tillers and the fresh weight of the plant [40]. Liquid organic fertilizer treatment can increase the ability of citrus plants to absorb macro and micro elements [41]. Furthermore, organic fertilizers have a positive effect on the carbohydrate content (fructose, glucose, and sucrose) of citrus fruits.

In this experiment, the planting medium used was limited in volume, accommodated in a plastic pot with a diameter of 15 cm. The planting medium used was a mixture of sand, husk charcoal and compost with a ratio of 1: 1: 1 (v/v) for control treatment, and a mixture of sand and husk charcoal with a ratio of 1: 1 (v/v) for other treatments. The limited volume of planting media resulted in limited availability of nutrients in the P0 treatment (control) despite the addition of compost, so that the growth and yield of control plants (without LFGF treatment) was not optimal. The size of the plastic pot (planting container) has an effect on the volume of plant roots, thereby affecting plant growth [42]. Pooter et al. [43] suggest that researchers be careful in determining the size of the pot in their research, as small pots can adversely affect the results of the study. However, the LFGF treatment (P1, P2, P3, and P4) gave better plant growth and yield than without LFGF treatment (P0). This indicates that the provision of LFGF can lead to more adequate availability of plant nutrients so that it does not require a heavier root volume.

Watering LFGF once every 3 days (P3) or once every 4 days (P4) resulted in higher plant growth and yield than watering LFGF once a day (P1) or once every 2 days (P2). This shows that the P3 and P4 treatments cause the availability of nutrients and organic acids in the optimum conditions for plant growth, while in the P1 and P2 treatments the availability of organic acids is too high so that it inhibits plant growth. At high concentrations it can have a negative effect on plant growth [35].

5. Conclusions

Increasing the concentration of ZA results in an increase in the total content of N and S, as well as an increase in EC of LFGF. Increasing the sugar concentration

stimulates the formation of lactic acid at both low and high ZA concentrations, while an increase in ZA decreases the formation of acetic acid at both low and high sugar concentrations. Increasing the organic acid content decreases the pH of LFGF.

The combination of LFGF + AB-Mix (v/v: 1: 3) (P2) shows that the most ideal nutrient solutions, nutrient solutions not only having complete and optimum nutritional content, but also containing organic acids in optimum concentrations. It can produce the best growth and yield of pakcoy mustard plants are better than the control (AB-Mix), while the P2 treatment on lettuce and red spinach results in the same plant growth and yield as the control.

LFGF treatment with EC $2,300 \mu\text{Scm}^{-1}$ and a time interval of 3 days on a mixed planting medium of sand + husk charcoal (v/v: 1: 1) can result the availability of nutrients and other compounds (organic acids) in optimal conditions for the growth of caisin mustard plants. It can produce the highest growth and yield of caisin mustard plants.

The non-traditional use of goat manure in the form of LFGF can increase the yield of leaf vegetables, both in potted and hydroponic cultivation, so that it can be economically profitable.

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Conflict of interest

None.

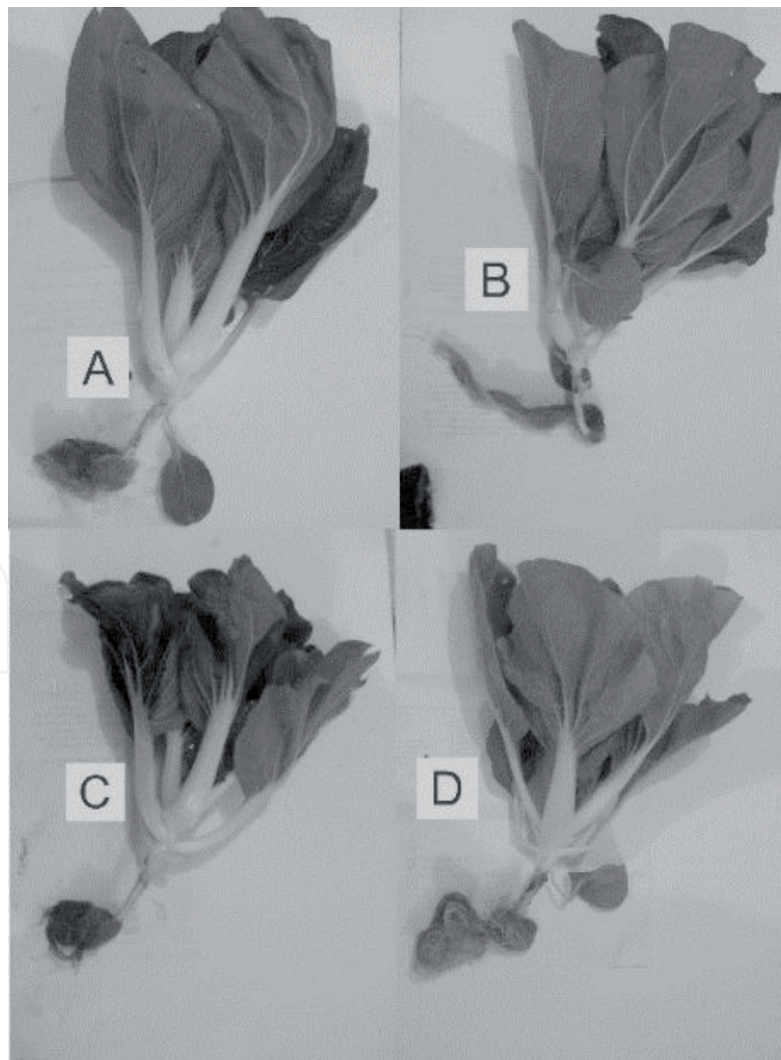
Appendix A. Fermentation of LFGF



B. Hydroponic installation of Shallow Flow Technique (SFT)

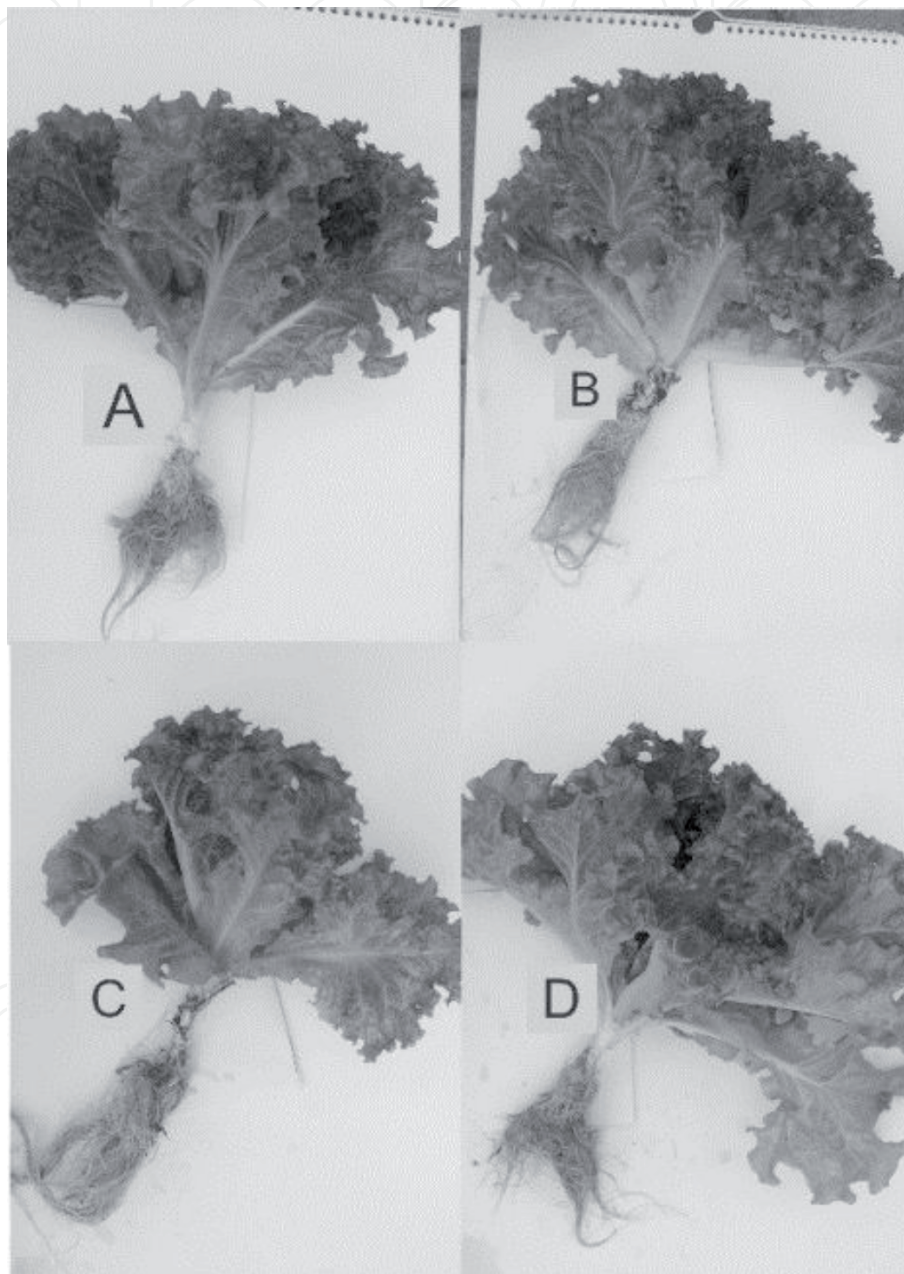


C. Pakcoy mustard plants at 35 days of age



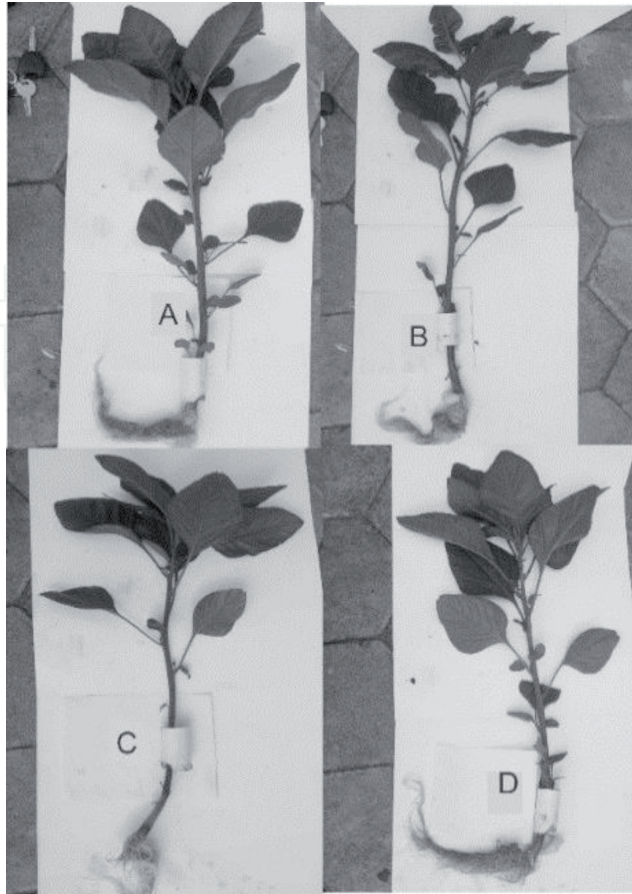
- A: Plant treated with LFGF + AB-Mix (v/v: 1:1) (P1).
- B: Plant treated with LFGF + AB-Mix (v/v: 1:3) (P2).
- C: Plant treated with LFGF + AB-Mix (v/v: 3:1) (P3).
- D: Plant treated with AB-Mix (v/v: 1:1) (P4).

D. Lettuce plants at 35 days of age



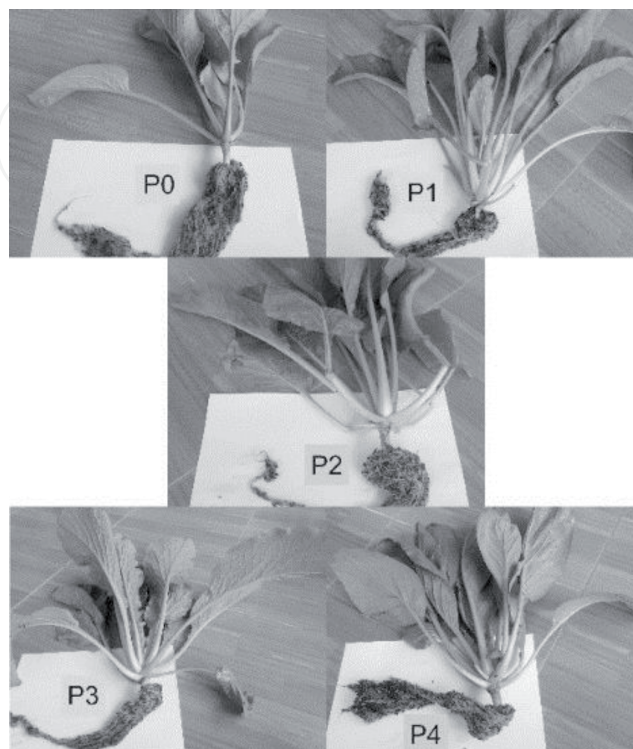
- A: Plant treated with LFGF + AB-Mix (v/v: 1:1) (P1).
- B: Plant treated with LFGF + AB-Mix (v/v: 1:3) (P2).
- C: Plant treated with LFGF + AB-Mix (v/v: 3:1) (P3).
- D: Plant treated with AB-Mix (v/v: 1:1) (P4)

E. Spinach plants at 35 days of age



- A: Plant treated with LFGF + AB-Mix (v/v: 1:1) (P1).
- B: Plant treated with LFGF + AB-Mix (v/v: 1:3) (P2).
- C: Plant treated with LFGF + AB-Mix (v/v: 3:1) (P3).
- D: Plant treated with AB-Mix (v/v: 1:1) (P4)

F. Caisin mustard plants at 35 days of age



- P₀: Plant treated without LFGF fertigation.
- P₁: Plant treated with LFGF fertigation with interval 1 day.
- P₂: Plant treated with LFGF fertigation with interval 2 days.
- P₃: Plant treated with LFGF fertigation with interval 3 days.
- P₄: Plant treated with LFGF fertigation with interval 4 days.

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