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Effect of Liquid Organic Fertilizer Made from Leaf Vegetable Waste and Tofu Liquid Waste on Chickpea Yield

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ABSTRACT

The use of organic fertilizers represents an effective and sustainable approach to enhancing soil quality. Purpose of this study is to determine the influence of concentrations of liquid organic fertilizer (LOF) made from leafy vegetable waste and tofu liquid waste on chickpea yield as well as to find the best concentration of LOF. Field experiment with 11 levels of LOF concentration arranged in randomized block design was performed in triplicates. The LOF concentration consisted of 0, 25, 50, 75, 100, 125, 150, 175, 200, 225, and 250 mL/L. The data were analyzed with ANOVA, if significant, a further test is carried out with an Honestly Significant Difference (HSD) at 5% level. Observation variables included plant growth (plant height, number of leaves, stem diameter, and number of branches), and plant yield (number of pods, pod length, weight of pod, and pod yield). Results of the study revealed that LOF concentration is significant and concentration of 250 mL/L had a better effect on the number of pods (56.75), pod length (19.29 cm), pod weight (10.62 g/pod), and pod yield (602.17 g/ plant).

1. INTRODUCTION

Chickpeas (*Phaseolus vulgaris* L) with local name "Buncis" have a fairly high economic value and are quite in demand in the international food market. Food and Agriculture Organization (FAO) shows that Indonesia is among the three main chickpea producing countries in the world. The total production of chickpeas nationally in 2021 is 320,774 tons, in 2022 it will increase to 325,602 tons, and in 2023 it decreased to 305,049 tons (BPS, 2024). Given its economic value and Indonesia is among the three main chickpea producing countries, chickpea production needs to be increased. Agricultural activities such as farming aim to get profitable results. For this reason, farmers carry out intensive cultivation, which prioritizes the use of inorganic fertilizers without balancing the use of organic fertilizers. Inorganic fertilizers that are continuously applied in increasing doses no longer have any effect on crop yields. This is because soil productivity decreases due to soil fertility degradation, where the soil is compacted, easily eroded and polluted (Lisdayani & Sari, 2024). The negative impacts of inorganic fertilizers use encourage the application of environmentally friendly agriculture aimed at minimizing environmental damage (Notohadiprawiro, 2021) and maintaining soil fertility through organic fertilizer inputs (Risman, 2017).

The use of organic fertilizers is an effective method for enhancing soil quality in a sustainable manner. This is achieved by the addition of soil humus, thereby improving soil quality including increasing available nutrients (Sutanto, 2002). Organic fertilizers can be made from organic waste such as leaf vegetable waste. These include mustard greens, petsai, and cabbage, which are always available. Leaf vegetables are easily damaged due to their high moisture content, so this waste is produced in large quantities and has the potential to become an environmental pollutant. One of the easy and environmentally friendly efforts is that organic waste which is processed into liquid organic fertilizer (LOF). Leaf vegetable waste has the potential to be good as LOF because of the presence of complex compounds that will contribute to the availability of nutrients. LOF given to plants, including chickpeas, is one of the important factors that affect yields. This is caused by ability of LOF in improving the physical, chemical, and biological properties of the planting medium. LOF has some of the benefits such as stimulating growth of production branches, increasing the formation of flowers and fruits, and reduce the loss of leaves, flowers, and fruit Nurmayulis *et al*. (2014). LOF made from leaf vegetable waste (mustard greens, petsai, and cabbage) and tofu liquid waste contained C-organic of 0.53%, pH 5.73, total N of 0.10%, P_2O_5 of 0.03%, K_2O of 0.19%, total Fe of 19.5 ppm, total Mn of 39.8 ppm, total Cu of 0.23 ppm, and total Zn of 0.19 ppm (Walunguru & Mone, 2024). The nutrient content of LOF relates to the raw materials. Mustard greens contain calcium (Ca) of 123 mg, phosphorus (P) of 40 mg, and potassium (K) of 358.2 mg (Sunarjono, 2013). Petsai contains Ca of 88 mg, P of 23 mg, and iron of 1.9 mg (Pracaya, 2011); and cabbage contains Ca of 64 mg and P of 26 mg (Emawati *et al*., 2017). Yanti *et al*. (2022) reported LOF made from vegetable wastes (white mustard, green mustard, cabbage, and carrot) fermented for 14 days and 24 ml of EM4 activator has N level of 0.68%, P of 0.42%, and K of 0.19%. Syuhriatin & Juniawan (2020) noted that LOF of leaf vegetable waste added with 40 g of EM4 and 80 g of zeolite was characterized by pH of 6.14, C-organic of 0.27%, N-total of 0.07%, P-total of 0.04%, and K-total of 0.46%.

Other good materials for LOF are liquids from tofu waste. The content of organic matter in tofu liquid waste such as carbohydrates, proteins, and fats which, when decomposed, produce nutrients such as N, P, and K that plants need, so they have the potential as liquid fertilizer ingredients (Makiyah *et al*., 2015). Content of tofu waste liquid is N-total of 1.24%, P_2O_5 of 5.54%, K_2O of 1.34%, and organic C of 5.803% (Al-Amin *et al*., 2017). Fresh tofu liquid waste contains P_2O_5 of 222.16 ppm, N-total of 0.66%, and K_2O of 0.042% (Liandari, 2017). The fertilizer provided aims to meet the nutrient needs of plants, therefore one of them must pay attention to the concentration of application. Research by Rizqiyah *et al*. (2014) that the right concentration can improve growth and increase crop yields (Rizqiyah et al., 2014). Research by Saptorini *et al*. (2021), showed that the concentration of LOF of tofu waste affects the growth and production of mustard plants, and a concentration of 20% is the best concentration. LOF made from leaf vegetable waste and liquid tofu added with nutrient-enhancing organic matter that increases nutrients that the concentration of 9% provides the best influence for growth and yield of pakcoy (Walunguru *et al.,* 2024). Purpose of the research is to find out the influence of several concentrations of LOF made from leaf vegetable waste and liquid waste and obtain the best concentration. This research is expected to enrich information about the use of LOF, especially about the concentration of LOF in chickpea plants.

2. MATERIALS AND METHODS

2.1. Materials and equipment

The organic materials utilised in production of LOF are derived from leaf vegetable waste, including mustard greens, chicory and cabbage, procured from conventional markets. The material, amount of material, and how LOF is made are shown in Table 1. Equipment employed in this study comprises plastic barrels, scales, machetes, knives, stirring rods, buckets, jerry cans, sample bottles, padlocks, measuring cups, shovels, hoes, rakes, treatment boards, rulers, harvest baskets, digital callipers, and digital scales.

Table 1. Materials and quantities for making LOF of leaf vegetable waste and liquid waste tofu

Materials	Amount
Leaf vegetable waste: mustard greens, petsai, and cabbage	Each material is 30 kg
Tofu liquid waste	45 L
Gamal leaves, banana stems, and coconut coir	Each material is 0.9 kg
EM4	500 mL
Sugar	250 g

LOF was prepared as the following: (1) Waste leaf vegetables (mustard greens, petsai, and cabbage), gamal leaves, banana stems, and coconut coir were washed thoroughly, chopped into ±1 cm in size, then put in a composter. (2) As much as 35 L of liquid tofu waste is put into a composter, stirred evenly with other fertilizer materials. (3) Bioactivator solution consisted of EM4, sugar, tofu liquid waste (10 L) were mixed evenly, let stand for 20 min, then put in the composter. The materials in the composter are stirred until evenly mixed. The composter was tightly closed. (4) Every two days the materials in the composter are stirred to release the fermented gas. After stirring the composter is closed. (5) Ferment for 3 weeks and LOF mature. Liquid organic fertilizer was filtered to separate the liquid and solid parts.

2.2. Experimental Design

The research was conducted in Baumata Village [10º12'00.6"S and 123º40'47.3"E] between April and November 2024. The experiment employs a randomized block design with 3 blocks according to replication. Each block consisted of 11 planting beds, so that there were a total of 33 planting beds. The beds designated for the cultivation of chickpeas as test plants were 2m × 2m in size. The layout of the research block in the form of planting beds is shown in Figure 1.

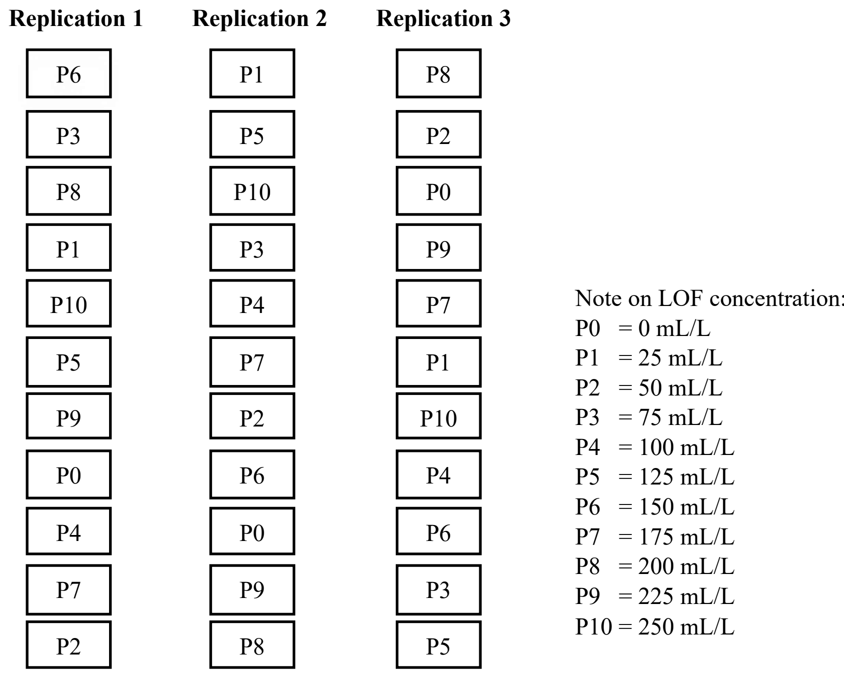

Figure 1. Planting bed layout on each block

The LOF concentration of 0, 25, 50, 75, 100, 125, 150, 175, 200, 225, and 250 mL/L were applied in triplicates, resulting in a total of 33 experimental units. The LOF was made from leaf vegetable waste and tofu liquid waste. Experimental unit was a bed comprising 16 chickpea plants, four plants selected randomly were designated as samples. The application of LOF made every another day from the 14^{th} to 60^{th} day after planting (DAP). LOF solution (25 mL/L) was prepared by combining 25 mL of LOF with water until the volume of the solution is one liter. Other concentrations were prepared in the same way, where the amount of LOF and water is adjusted according to the treatment being tested. The LOF solution was applied in the morning in root area of the plant with a dose of 250 ml per plant.

2.3. Supporting and Main Variables

The following variables were identified as supporting (Figure 2a-d) and main variables (Figure 2e). The measurements of supporting variables were taken at the 5^{th} WAP, including plant height, stem diameter, and number of leaves.

a. Plant height: The height of the sample plant was measured from stem base to tip of longest leaf of the chickpea plant. The tool used is a ruler, with a unit of measurement in centimeters (cm). Measurements were taken at the 3rd, 4th, and 5th weeks after planting (WAP).
b. Number of leaves: Leaves amount each plant is resulting based on total amount of leaves observed in the sample plant. The calculated leaves are those that have been fully formed, including young and old leaves. Measurements were carried out on the 3^{rd}, 4^{th}, and 5^{th} WAP.

(a) (b) (c) (d) (e)

Figure 2. Measurement: (a) plant height, (b) stem diameter, (c) number of leaves, (d) number of branches, (e) chickpea weight

c. Stem diameter: Diameter of the stem in the sample plant was measured at the base, middle, and tip. A digital caliper with millimeters (mm) graduations was used to obtain the measurements. The measurements were taken at the 3rd, 4th, and 5th WAP.
d. Number of branches: All branches on the sample plant were counted.

The main variables included the following:

e. Amount of pods: All pods that met the harvest criteria on the sample crop were counted. The amount of pods is calculated at harvest time (harvest period 2 weeks).
f. Pod length: Harvested pods are measured in length (cm). Pod length is measured from base to tip of the pod using a rope, then measured with a ruler.
g. Pod weight (g/plant): Pods were harvested at 44 DAP. All pods each plant were weighed using a digital scale (g).
h. Pod weight (g/pod): Weight of each pod is the result of dividing pods weight by the amount of pods of each plant.

2.4. Data Analysis

Analysis of variance (ANOVA) was performed to determine the effect of treatment. If the treatment is significant, an Honestly Significant Difference (HSD) test was continued at a level of $\alpha = 5\%$.

3. RESULTS AND DISCUSSION

3.1. Supporting Variables

The average height of plant, leaves amount, diameter of stem, and branches amount at planting age of 5 WAP chickpeas are shown in Table 2. The highest plants at a concentration of 250 ml/l LOF made from leaf vegetable waste and tofu liquid waste (80.46 cm), the largest amount of leaves (89.42 leaves), the largest stem diameter (5.33 mm) and the largest amount of branches (9.42 branches). Based on the data in Table 2, LOF made from leaf vegetable waste and liquid tofu waste given at the highest concentration of 250 ml/l resulted in better chickpeas growth compared to other concentrations.

Table 3. Effects of LOF concentration on the growth parameters of chickpea at 5 week after planting

LOF Concentration	Plant Height (cm)	Number of Leaves	Stem Diameter (mm)	Number of Branches
0 ml/l	51.41	60.42	3.27	5.25
25 ml/l	54.83	61.58	3.58	6.42
50 ml/l	57.50	65.50	3.66	6.50
75 ml/l	59.64	69.25	3.64	6.92
100 ml/l	61.55	69.08	3.91	7.25
125 ml/l	63.88	70.92	4.03	7.58
150 ml/l	63.30	73.25	4.33	7.42
175 ml/l	66.06	76.50	4.43	8.08
200 ml/l	67.94	79.50	4.58	8.50
225 ml/l	71.15	85.25	5.00	8.92
250 ml/l	80.46	89.42	5.33	9.42
p-value	3E-17	2E-17	2E-17	1E-15

Iyus *et al*. (2022) informs that combination of 6 cm^3/L LOF bio nutrient and 6 ton/ha of sugarcane compost had a better effect on chickpea height (10.96 cm) and number of leaves (20.43) at 21 days after planting (DAP). Study by Nurani *et al*. (2022) revealed that the highest concentration, which is 22.5 mL/L of PGPR (Plant Growth Promoting Rhizobacteria) biofertilizer water, has a better effect on plant length (210.50 cm), and leaves amount (18.50 pieces). Studies that have been conducted by Saptorini *et al*. (2021) inform LOF from tofu liquid waste and coconut water given at the highest concentration, which is 20% had a better effect on the growth and yield of mustard plants. Another study informed that the application of moringa leaf LOF to chickpea plants with the highest concentration, which is 500 ml/l of water resulted in the highest plant (42.84 cm) and the largest stem diameter (0.69 cm) (Harahap & Nasution, 2023). The results of the study conducted by Bukit & Maghfoer (2023), showed that the administration of LOF PGPR at the highest concentration, which is15 ml/l and highest dose is 10 tons/ha resulting in a better influence on chickpeas growth at 35 DAP, namely leaves amount (29.42 pieces), branches amount (9.08 branches), and the area of leaves (2822.39 m^2).

The highest concentration of fertilizer causes more fertile planting medium to be inserted, increasing the availability of nutrients. This will further support the plant's metabolic processes, including the photosynthesis process, so that it will produce more assimilates. According to Mindari *et al*. (2017), the nutrients available and that can be absorbed by plants will affect the rate of plant growth and development. When more assimilates are produced then the plant organs grow better because more energy is available for the plant to grow. Plant growth is influenced by nutrients that affect photosynthesis in producing assimilates (Lakitan, 2018). In addition to being stored as a food reserve, assimilates are also used as energy for growth and production. If the energy produced is more, then the growth of plants will be better.

Liquid organic fertilizer made from leaf vegetable waste and liquid tofu waste given to the planting medium will be more fertile and contribute more nutrients. This will have an impact on plants to absorb nutrients better so that they are more supportive of plant growth. Plant growth is not only influenced by genetic factors, but also by environmental factors such as the availability of nutrients in the growing medium (Pujiwati, 2021). Plant growth is a physiological process and cell division occurs that requires a sufficient amount of nutrients (Lakitan, 2018). Sufficient available nutrients during the vegetative phase have an impact on the active and optimal photosynthesis process. The nutrients absorbed affect metabolic processes, including photosynthesis in the production of assimilates. The Assimilates are distributed to plant organs as a reserve of food and energy for plants to grow and develop (Pujiwati, 2021). According to Lakitan (2018), if there are enough nutrients available, the assimilates produced will more support the activity of cells in the meristem tissue (growth point) to divide, then the plant organs grow better, causing the plant to increase in height, form new leaves, increase the diameter of the stem and form new branches.

3.2. Main Variables

The results of ANOVA showed that LOF made from leaf vegetable waste and tofu liquid waste given at various concentrations had a significant influence on plant yield, namely the pods amount, length of pod, weight of pod each plant, and weight of each pod chickpea. Average amount of pods, pod length, pod weight of each plant, and weight of each chickpea pod and the results of the 5% HSD test are shown at Table 3. The highest of pods amount, which is 56.75 pods, is resulted at a concentration of 250 ml/l (equivalent to 10 L/ha) which is significantly more than other concentrations. The longest pod measuring 19.29 cm and the heaviest pod of 10.62 g were produced at a concentration of 250 ml/l. This result was not significantly different with a concentration of 225 ml/l, but it was significantly different from other concentrations. The heaviest pod weight of each plant, which is 602.17 g, was produced at a concentration of 250 ml/l which was significantly different from other concentrations. Rizqiani (2005) reported the use of that LOF for chickpea and found that LOF dose of 10 L/ha produce the best yield 8.07 t/ha and further increasing the dose to 20 and 30 L/ha did not significantly increase the yield.

Application of LOF from leaf vegetable waste and tofu liquid waste affects the carbohydrate metabolism process and stimulates the translocation of photosynthetic results from leaves to other parts of the plant. This will affect the size and quantity of storage organs. Highest concentration, which is 250 ml/l, causes the planting medium to be more fertile, including the availability and absorption of nutrients, so that the crop yield is better. This results in enhanced metabolic processes and the production of a greater quantity of assimilates, which in turn leads to an increase pods amount, pods length, weight of pod, and overall weight of a pod each plant. Study by Taslim *et al*. (2020) on the addition of LOF from golden snails at a dose of 200 ml/plant, resulted in a higher number of pods, weight of pod per plant, weight of pod per

Table 3. Effect of LOF concentration yield of chickpea

LOF concentration	Amount of pods	Pod length (cm)	Weight of pods (g/plant)	Weight of pod (g/pod)
0 ml/l	28.17 a	15.73 a	201.66 a	7.13 a
25 ml/l	36.83 b	16.36 ab	272.93 b	7.41 a
50 ml/l	37.33 b	16.90 bc	270.83 b	7.26 a
75 ml/l	40.58 d	17.09 bcd	348.46 c	8.58 b
100 ml/l	41.25 d	17.37 cde	373.95 d	9.07 bc
125 ml/l	41.58 d	17.46 cde	388.14 e	9.33 cd
150 ml/l	42.17 d	17.73 de	384.25 e	9.12 bc
175 ml/l	46.92 e	18.09 ef	458.40 f	9.76 de
200 ml/l	46.75 e	18.09 ef	468.97 g	10.01 e
225 ml/l	47.92 e	18.69 fg	487.32 h	10.18 ef
250 ml/l	56.75 f	19.29 g	602.17 i	10.62 f
p-value	1.969E-16	2.594E-11	1.226E-15	1.015E-31
LSD 5%	3.11	0.79	0.58	8.25
CV (%)	16.20	6.42	6.60	14.21

Note: Numbers with the same letters in same column are not significantly different based on the 5% BNJ test. CV = Coefficient of Variance

plot, and weight of pod per hectare of chickpea plants than other doses. Pandaleke *et al*. (2023) reported the application of LOF from dry leaf waste at concentration of 100 mL/L provides the best result in term of plant height, leaf width, and wet weight of pakcoy plants. Another study showed that the application of PGPR to chickpeas with the highest concentration of 15 ml resulted in the largest pods amount each plant (22.92 pods), heaviest pod fresh weight each plant (92.76 g), and the longest pod (17.31 cm) (Ningsih *et al*., 2018).

Table shows that LOF made from leaf vegetable waste and tofu liquid waste given at a concentration of 250 ml/l results in taller plants, more leaves, larger stem diameters, and more branches. Vegetative growth is related to the assimilates to be produced which have an impact on plant yields. If the plant growth is better, more assimilates will be produced so that the crop yield is better. However, if assimilates are not produced enough, there will be competition between vegetative and generative organs in using assimilates, this will reduce plant yields. Research conducted by Tanjung *et al*. (2021), found that there was a positive correlation between height of plant, leaves amount, and branches amount with pod weight each plant, weight of pod each land area 7.5 m^2, and pod weight per ha. Another study found that the number of leaves at age 35 DAP positively correlated by 40.9% to the weight of the chickpea of the Lebat-3 cultivar, showing that the plant growth component affected the yield component (Harijanto *et al*., 2016).

Taller plants have a greater amount of leaves, which affects photosynthesis process. Plant height has a positive relationship with the number of leaves, the taller the more. An increase in the amount of leaves will further support the photosynthesis process, thereby increasing its efficiency and resulting in the production of a larger amount of assimilation. Leaves are an integral part of the process of photosynthesis, which produces organic compounds that are essential for plant growth. The larger stem diameter allows for the translocation of larger amounts of assimilates to plant organs. The assimilates are used by plants for growth and development, more assimilates allow for the production of more and larger pods. An increase in the amount of branches allows for greater flower production, which in turn allows the plant to produce more pods.

Figure 3 shows that the concentration of LOF made from leaf vegetable waste and liquid waste affects the amount of pods, pod length, weight of pod each plant, and weight of each pod chickpea. The correlation (R^2) between the LOF concentration and number of pods is 0.88, with equation $y = 0.0835x – 31.95$, LOF and pod length of $R^2 = 0.96$ with equation $y = 0.012x – 16.03$, LOF and weight of each pod of $R^2 = 0.93$ with equation $0.0143x + 7.1703$, and LOF con centration with pod weight per plant ($y = 0.7048x – 147.76$ with $R^2 = 0.9443$). The data showed a strong correlation between LOF concentration and the number of pods, pod length, pod weight of each plant, and pod weight of each plant.

Figure 4 illustrates the components of chickpea yield, namely the pods amount and length of pod, which influence the pods weight each plant. A correlation coefficient (R^2) of 0.9677 was observed between the pods amount and weight of pod each plant, with equation $y = 15.301x - 261.54$. The correlation coefficient (R^2) of length of pod and weight of pod each plant is 0.9322, with the equation $y = 90.221x - 420.42$. The value of R^2 for weight each pod and pod weight

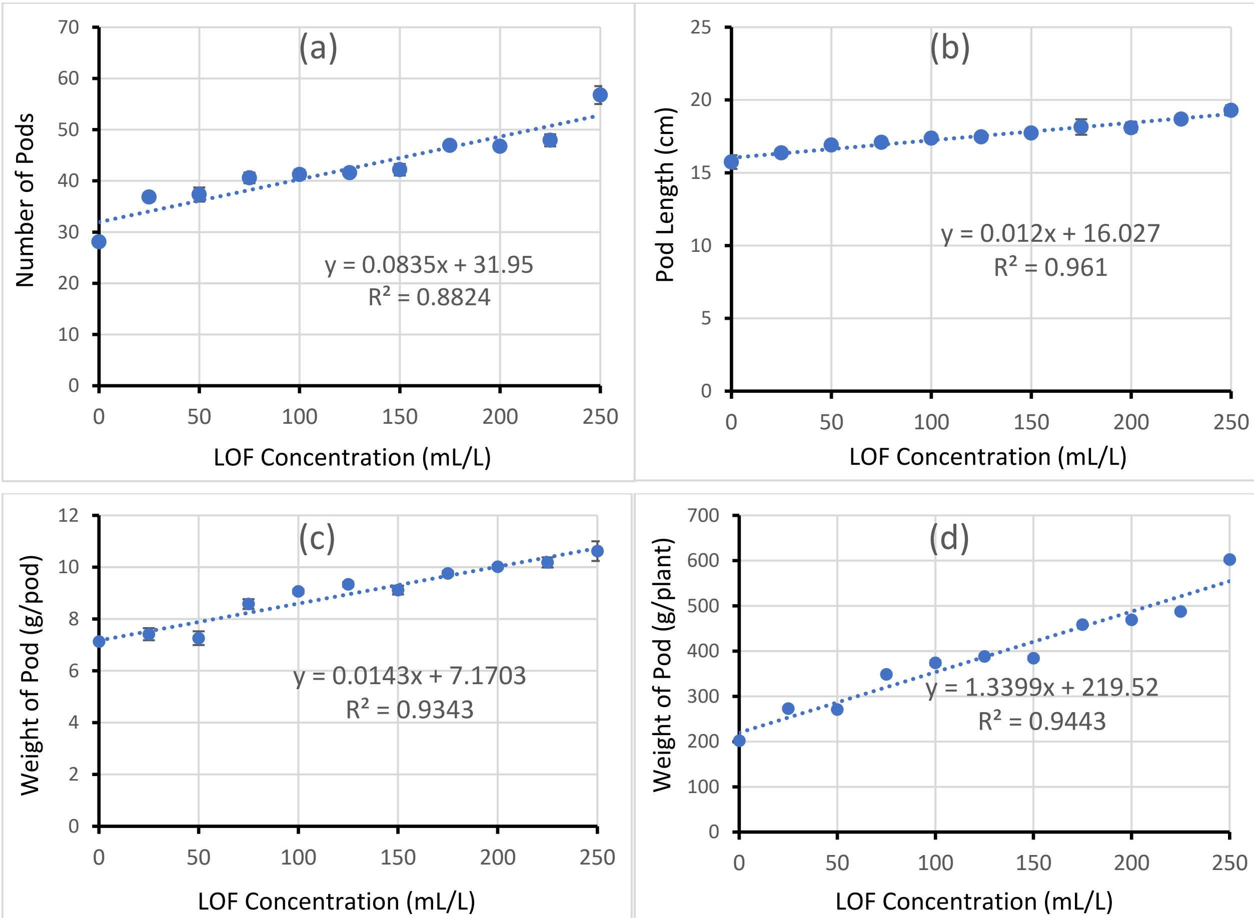

Figure 3. The relationship of LOF concentration and growth parameters: (a) number of pods, (b) pod length, (c) weight of pod (g/pot), and pod weight (g/plant)

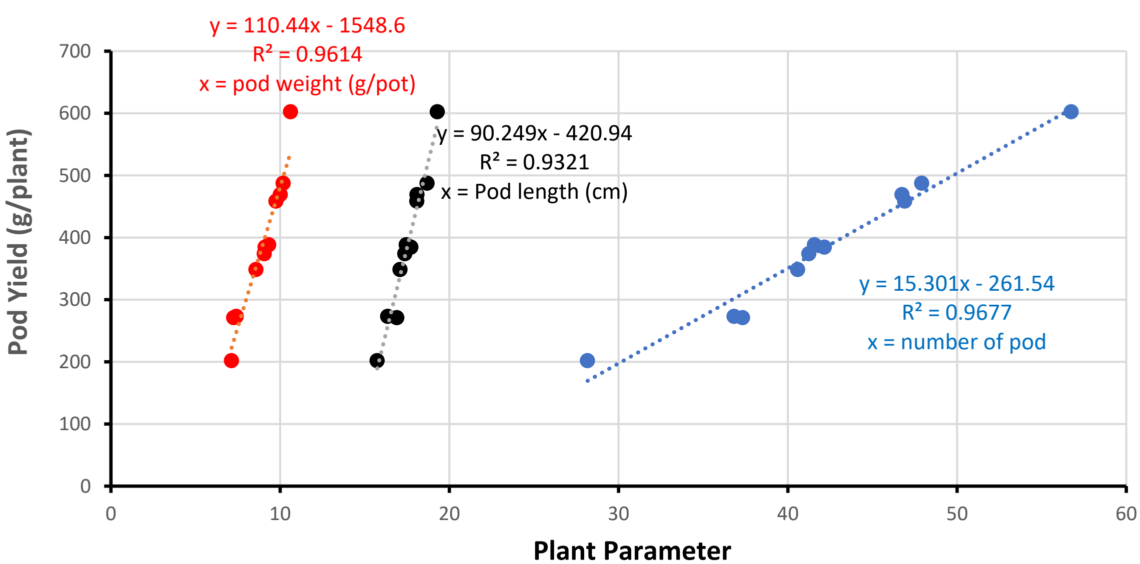

Figure 4. The relationship between plant parameters and chickpea pod yield.

each plant was 0.9612, with the equation y = 110.3x - 1546.2. Data showed a strong correlation between pods amount, length of pod, and weight of each pod with the pod weight of pod each plant. This means that as pods amount increases, the pods become longer, and the weight of each pod increases, so pod weight each plant will increase. Research conducted by Rizqiyah *et al*. (2014), that amount of pods each plant and weight each pod have a direct effect on chickpea yield. The correlation between growth and chickpea yield was shown by the amount of leaves of 4 WAP affecting the pod weight each plant, which was 0.2089 based on the results of cross-analysis (Lestari *et al*., 2022). The length of the chickpea pods of the Maxipro variety according to the description is 16-18 cm, the length of the pods produced at a concentration of 175 to 250 mL/L is longer than the description (18.09-19.29 cm). The weight produced by each pod in the LOF application with a concentration of 75-250 mL/L ranged from 8.58-10.62 g. In the concentration range of 100 to 250 mL/L, the pods produced are heavier than the plant description. This means that the concentration of 175-250 mL/L of LOF from leafy vegetable waste and liquid tofu waste is able to support the genetic potential of plants, especially for pod length and weight of each pod.

4. CONCLUSION

Liquid organic fertilizer from leaf vegetable waste and liquid tofu waste applied at several concentrations affects the growth and yield of chickpea plants. For plant growth, the highest concentration, which is 250 mL/L, produces better chickpeas growth, namely plant height 80.46 cm, 89.42 leaves, stem diameter 5.33 mm, and 9.42 branches. The highest concentration, which was 250 mL/L, affected the yield of chickpeas better, namely the amount of pods (56.75 pods), pod length (19.29 cm), weight of each pod (10.62 g) and pod weight of each chickpea plant (602.17 g). The concentration of LOF made from leaf vegetable waste and liquid waste affects the amount of pods, pod length, weight of pod each plant, and weight of each pod chickpea. The weight of the pods of each plant has a strong correlation with the number of pods, length, and weight of each pod. Further research on LOF needs to be conducted on other horticultural crops based on concentration, dose, or other treatments in order to obtain more and diverse information.

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