

Response of soil physics properties to liquid organic fertilizer from liquid waste from tofu factories and banana tubers in ultisol

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ABSTRACT

Productivity in ultisols was not only determined by mineral content, but was also influenced by the physical properties of the soil. Soil physical properties were soil properties that were determined by its constituent materials such as water content, bulk density, total pore space and permeability. The study aimed to determine the effect of the application of liquid organic fertilizer from tofu factory liquid waste on the physical properties of soil in ultisols. This research was designed using a Completely Randomized Design (CRD) with six treatment levels (control treatment, single fertilizers N, P, and K as recommended doses, 125 ml, 250 ml, 375 ml and 500 ml Liquid Organic Fertilizer (LOF) from tofu factory wastewater and banana tubers. Each treatment was repeated 4 times, so there were 24 experimental units. The results showed that LOF treatment had a significant effect on bulk density, total pore space, and permeability and had no significant effect on moisture content in field capacity of green mustard plants in ultisols. The highest value obtained in the LOF treatment is at a dose of 250 ml which had a field capacity water content value of 29.63%, bulk density 0.95 g/cm³, total pore space of 64.00% and soil permeability of 11.56 cm/hour.

Keywords: banana tubers, green mustard, tofu factory, ultisol, wastewater

INTRODUCTION

Ultisol was characterized by its acidic nature (Rusli, 2016). This acidity was caused by its acidic parent material, one of the factors influencing soil formation, alongside time, organisms, topography, and climate. According to Pane et al. (2014), Ultisols have low organic matter due to rapid decomposition processes caused by high temperatures and heavy rainfall, leading to rapid weathering and leaching in the soil. According to Karnilawati (2018), ultisols belong to the red-yellow podzolic soil group. The main issues with Ultisols were low fertility, including low water content due to poor water absorption, high bulk density because of excess minerals, which leads to low total pore space, and reduced permeability. One method to improve these physical properties was by applying organic fertilizers.

Organic fertilizers play a crucial role in enhancing soil physical properties and serve as a

medium for plant growth. Currently, many farmers still rely on chemical fertilizers to supply nutrients to their land. Gradual use of chemical fertilizers could have negative impacts, such as increasing soil compaction. The most appropriate solution for future agriculture was using liquid organic fertilizers (Atikah et al., 2014). The advantage of liquid organic fertilizers was that they were easy to apply to the soil. According to Barus et al. (2014), liquid organic fertilizers could stabilize soil aggregates, acting as a medium that binds soil particles together. There were various types of liquid organic fertilizers, including cow urine, vegetable waste, and tofu factory wastewater. Tofu factory wastewater and banana tubers contains organic compounds crucial for plant growth. Tofu factories were rapidly growing in Indonesia, generating both liquid and solid waste.

According to Angraini et al. (2014), tofu factory wastewater, characterized by high organic content and a pH of 4-5, comes from different

stages of production, including boiling, washing, pressing, and molding. This could cause water pollution if discharged directly into water bodies. Therefore, the best solution for managing this waste was anaerobic treatment to produce liquid organic fertilizer. The main organic components of tofu wastewater were protein, fat, and carbohydrates, along with elements like nitrogen (N), carbon (C), oxygen (O), and hydrogen (H), which were beneficial for soil (Kusumawati et al., 2015). Tofu factory wastewater could be used on vegetable crops like green mustard, which had a growth cycle of only 40 days.

Banana tubers contain various macro and micro nutrients that were essential for plant growth, such as Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca) and Magnesium (Mg) and several other nutrients. Banana hump MOL solution could be used as a decomposer because MOL solution contains bacteria that could decompose organic matter. According to Sapto & Arum (2013), green mustard (*Brassica juncea* L.) cultivation was easy because it could be harvested anytime and was not season-dependent. The crop was usually harvested 40 days after planting. Green mustard was rich in vitamins and minerals, including vitamins A, C, E, K, and folic acid (Rizal, 2017), with broader stems and leaves than other mustard varieties. Given the above, Ultisols have problematic physical properties that could impact plant productivity. The solution needed was the application of liquid organic fertilizer from tofu factory wastewater so that green mustard (*B. juncea* L.) could thrive. The objective of this research was to determine the effect of applying liquid organic fertilizer from tofu factory wastewater and banana tubers on the physical properties of soil in green mustard (*B. juncea* L.) in Ultisols and to find the best dosage for improving soil physical properties.

MATERIALS AND METHODS

Time and Location

This research was conducted in the greenhouse of the Soil Department, Faculty of Agriculture, Sriwijaya University, Indralaya. The analysis of physical properties was carried out at the Physics Conservation Survey and Evaluation Laboratory of the Soil Department, Faculty of

Agriculture, Sriwijaya University. The research was conducted from July to September 2024.

Research Tools and Materials

The tools used in this research included: 1) Permeability determination tools, 2) Watering tools, 3) Stationery, 4) Sieves, 5) Soaking tubs, 6) Hoes, 7) Buckets, 8) Measuring cups, 9) Gauze, 10) Analytical balance, 11) Oven, 12) Clamps, 13) Polybags, 14) Sample rings, 15) Filters, 16) Copper tubes, and 17) Scales. The materials used in the research included: 1) Water, 2) Green mustard seeds, 3) Liquid organic fertilizer from tofu factory wastewater, 4) banana tubers 5) NPK fertilizer, 6) Soil samples, and 7) Soil.

Research Method

This research was designed using a Completely Randomized Design (CRD) with 6 treatment levels. Each treatment was repeated 4 times, resulting in 24 experimental units. The treatments consisted of the following:

A: Control treatment

B: Single fertilizers N, P, and K as recommended doses

C: 125 ml Liquid Organic Fertilizer (LOF) from tofu factory wastewater and banana tubers (applied 5 times)

D: 250 ml LOF from tofu factory wastewater and banana tubers (applied 5 times)

E: 375 ml LOF from tofu factory wastewater and banana tubers (applied 5 times)

F: 500 ml LOF from tofu factory wastewater and banana tubers (applied 5 times)

Procedures

The way this research works was as followed:

Preparation of Planting Media

Soil samples were collected from a depth of 0-30 cm in the experimental field of the Faculty of Agriculture, Sriwijaya University. The soil was then sieved with a 2 mm sieve and placed into polybags measuring 40 cm x 50 cm, with each polybag containing 5 kg of soil (oven-dried).

Seed Sowing of Green Mustard (*Brassica juncea* L.)

Sowing green mustard seeds (*B. juncea* L.) was done in a tray with soaked seeds. Green

mustard seeds (*B. juncea* L.) were planted in one hole with a distance of 1 cm. After that, sowing was carried out for approximately 2 weeks before being transferred into polybags.

Planting of Green Mustard (*Brassica juncea* L.)

Planting green mustard greens (*B. juncea* L.) using polybags with seeds that were 2 weeks old. Green mustard seedlings (*B. juncea* L.) were planted into the planting holes that have been made. Three seeds were planted in one polybag. Then cover the hole again with soil. After growing, choose one of the best green mustard plants to maintain until harvest.

Addition of Single Fertilizer N, P dan K

The addition of single N, P, and K fertilizers was carried out according to the dose calculation, namely 0.375 g of urea fertilizer, 0.375 g of SP-36 fertilizer, and 0.25 g of KCl fertilizer. The dose was added to treatment B at the beginning of the planting period.

Application of POC Liquid Waste from Tofu and Banana Tubers

The application of LOF from tofu factory liquid waste and banana tubers was carried out on the day the seeds were planted and periodically every week. The use of LOF was diluted first using water to a volume of 200 ml. Application was carried out by pouring LOF into the soil after the seeds were planted according to the treatment dose.

Harvesting

Harvesting of green mustard plants could be done when the green mustard plants were 40 days old from the planting period. After that, soil samples were taken using a sample ring measuring 5 cm in diameter and 5 cm high for

physical properties observations which will be carried out at the physics, Conservation, Survey and Evaluation Laboratory of Sriwijaya University Soil Department. Soil samples were taken in the morning after 15 hours of watering with the aim that the soil did not experience water saturation or dryness.

Observed Variables

The observed variables in this study were the physical properties of the soil, including field capacity water content, bulk density, total pore space, and permeability. All parameters were observed after harvesting.

Data Analyzed

The obtained data were analyzed using ANOVA (Analysis of Variance) with a Completely Randomized Design (CRD) at a 5% test level. If the F value was greater than the F table at 5%, it indicated a significant effect of the treatment on the observed variables, followed by Duncan's test to identify which treatments caused significant differences.

RESULTS AND DISCUSSION

Initial Soil Analysis

The initial soil used was ultisol which was taken from the experimental garden of the Faculty of Agriculture, Sriwijaya University. The soil used was soil at a depth of 0 to 30 cm and had the analysis results listed in Table 1.

The analysis in Table 1 indicates that the field capacity water content of Ultisol was 28.08%, with a bulk density of 1.02 g/cm³, classified as medium. The total pore space of Ultisol was porous, with an analysis value of 61.3%. Lastly, the permeability of Ultisol was moderately fast, with a value of 10.08 cm/hour.

Table 1. Initial soil analysis

Parameter	Unit	Analysis Results	Criteria
Field Capacity Water Content	%	28.08	-
Bulk Density	g/cm ³	1.02	Currently
Total Pore Space	%	61.3	Shaft*
Permeability	cm/hour	10.08	Rather fast**

Note: *: source Arsyad, 1989, **: source Uhland and O'neal, 1951.

According to Sulistyono and Abdillah (2017), field capacity water content reflects the soil's ability to retain water under any condition. Low field capacity water content leads to reduced water availability in the soil, causing it to dry quickly. Therefore, watering should be done in the morning and evening to prevent Ultisol from drying out. The field capacity water content of Ultisol was 28.08%.

Bulk density measures soil weight. According to Harahap et al. (2021), bulk density was closely related to total pore space; the higher the bulk density, the lower the soil pore space, and vice versa. The bulk density of Ultisol was 1.02 g/cm³, classified as medium. The total pore space of Ultisol is categorized as porous, with a value of 61.3%. High total pore space results from microbial activity in the soil. According to Khair et al. (2017), microbial activity helps form aggregates, increasing pore volume and making total pore space more porous. Porous total pore space facilitates better root growth as air and water circulation was more efficient. The permeability of Ultisol was classified as moderately fast, with a value of 10.08 cm/hour. Factors affecting water transmission include large pore sizes, preventing excessive soil compaction. According to Rauf et al. (2020), pore distribution influences soil permeability; larger pores ease water flow. Based on the description above, it could be concluded that the physical properties of ultisol still have problems being used as a planting medium for pak choy so that efforts were needed to increase soil fertility by one of the methods being the addition of liquid organic fertilizer from liquid waste from tofu factories and banana tubers.

Analysis of Liquid Organic Fertilizer

The liquid organic fertilizer used was the result of liquid waste from tofu factories and banana tubers. According to Mulyaningsih et al. (2013), tofu factory liquid waste and banana tubers were waste that had high organic compounds because it contains macro and micro nutrients. These nutrients were useful as a food source for microbes. Tofu factory liquid waste and banana tubers could be used as liquid organic fertilizer. The results of the liquid organic fertilizer analysis were presented in Table 2.

In the LOF analysis of tofu factory liquid waste, this was research from Ismail, (2022). The

table showed that the pH in liquid organic fertilizer from tofu factory and banana tubers liquid waste had a value of pH H₂O with a value of 6.18, meaning that the pH of H₂O was categorized as acidic and meets the SNI criteria, for The N-Total result in liquid organic fertilizer from tofu factory and banana tubers liquid waste had a value of 0.0002%, which means the N-Total value was very low.

Table 2. Liquid organic fertilizer analysis results

Parameter	Unit	Analysis Results*	Criteria**
pH H ₂ O	-	6.18	Fulfil
N- Total	%	0.0002	Does not meet the
P-Available	%	0.02	Does not meet the
K-Available	%	0.01	Does not meet the

Note: *) Value Based (Ismail, 2022), **) Organik Fertilizer Standars (SNI: 261/KPTS/SR.310/M/4/2019)

In the results of the P analysis, available liquid organic fertilizer from tofu factory liquid waste had a value of 0.02%, which means that the P content available in liquid organic fertilizer from tofu factory liquid waste was relatively low. Likewise, the K value available in liquid organic fertilizer from tofu factory liquid waste was relatively low with a value of 0.01%. In accordance with organic fertilizer standards, the N, P and K values do not meet the minimum criteria, namely 2%.

Liquid organic fertilizer from tofu factory liquid waste and banana tubers does not yet meet the fertilizer criteria requirements, however POC liquid waste from tofu factories and banana humps already had several nutrients as followed P, K, N, B, Mg, Ca, Zn, Cu. The elements contained in LOF rom tofu factory liquid waste and banana tubers could be said to be complete when compared to chemical fertilizers, which on average have a single element. According to Hamzah (2015), LOF elements have benefits for plants, including being able to stimulate growth and being able to provide maximum growth and being able to act as a nutrient mobilizer in the soil, making it easier for plant roots to absorb it.

Effect of Liquid Organic Fertilizer on Field Capacity Water Content

Based on the results of the analysis of field capacity water content, it was stated that liquid organic fertilizer with various doses had no significant effect on field capacity water content. The average treatment of applying liquid organic

fertilizer with various doses on the water content and field capacity of Green mustard plants was presented in Table 3 as followed:

Table 3. Effect of LOF application on field capacity water content

Treatment	Average Field Capacity Water Content (%)
A (Control)	28.73
B (Single Fertilizer N, P, K)	33.45
C (Tofu Factory Liquid Waste LOF 125 ml)	25.13
D (Tofu Factory Liquid Waste LOF 250 ml)	29.63
E (Tofu Factory Liquid Waste LOF 375 ml)	27.30
F (Tofu Factory Liquid Waste LOF 500 ml)	29.03

Table 3 showed that the highest field capacity water content was achieved with the LOF dose of 250 ml, with a value of 29.63%. The highest overall value was observed in the single fertilizer treatment (N, P, K) with 33.45%. High field capacity water content could enhance soil water availability due to increased pore space, which retains more water. According to Septiaji et al. (2024), The amount of water that could be held in the soil will determine the level of stability of the soil structure, in addition to determining the level of water availability needed by plants to be able to grow and develop optimally. In treatment C with a LOF dose of 125 ml of tofu factory liquid waste, the field capacity water content value was the lowest compared to the LOF dose of other tofu factory liquid waste with a value of 25.13%. Apart from that, treatment C also experienced a decrease of 2.95% from the initial soil which originally had a field capacity water content value of 28.08%. The cause of the low field capacity water content was because the pore space value of treatment C was the lowest of all treatments. Low field capacity water content will result in low water availability in the soil, thereby inhibiting plant growth, especially the leaves. In line with research by Mudhor et al. (2022), low field capacity water content will reduce the availability of water in the soil and water scarcity conditions will trigger biological stress that could interfere with physiological processes and functional activities in the organism.

The cause of the low water content in all treatments was due to the planting site being located in a greenhouse which had more heat than when planted in a normal place. The effect

of this greenhouse will have an impact on plants that require more water nutrients. Water shortages could trigger biological stress that could disrupt physiological processes and functional activities in organisms. According to Zamharir et al. (2016), high environmental temperatures in greenhouses will cause excessive evaporation of water so that the soil dries out more quickly. Based on the analysis of field capacity water content, it shows that the application of LOF from tofu factory liquid waste and banana tubers had no significant effect on field capacity water content, but shows a tendency to increase from the initial soil analysis value, except for Treatment C with a LOF dose of 125 ml and treatment E with a dose of 375 ml which experienced a decrease. from the soil analysis the value was 29.63%, for the overall initial analysis the value was 28.08%.

Effect of Liquid Organic Fertilizer on Bulk Density

The analysis of variance for bulk density showed that liquid organic fertilizer (LOF) significantly influenced bulk density. The average bulk density values under different treatments were presented in Table 4.

Table 4. The effect of LOF application on bulk density

Treatment	Average Bulk Density (g/cm^3)	Criteria*
A (Control)	0.95 ab	Currently
B (Single Fertilizer N, P, K)	0.87 a	Low
C (Tofu Factory Liquid Waste LOF 125 ml)	1.04 c	Currently
D (Tofu Factory Liquid Waste LOF 250 ml)	0.95 b	Currently
E (Tofu Factory Liquid Waste LOF 375 ml)	0.95 ab	Currently
F (Tofu Factory Liquid Waste LOF 500 ml)	0.87 a	Currently

Note: Numbers followed by the same letter were not significantly different at the 0.05 level of the DUNCAN test, *: Lab source. Physics Jur. Tanah FP-UB, 2006.

Based on Table 4, it shows that the lowest value in the liquid organic fertilizer treatment for bulk density was obtained in treatment (D), liquid organic fertilizer with a dose of 250 ml had a value of 0.95 g/cm^3 . Overall, in the bulk density analysis, the lowest value was obtained in the single N, P and K fertilizer treatment with a value of 0.87 g/cm^3 . The low bulk density value obtained will be an advantage for Green mustard plants in ultisol. One of them could enlarge the

soil pores so that the soil density was not too dense.

This will provide an air cycle and water could enter the soil easily so that plant roots could spread widely and microorganisms in the soil will develop. In line with the opinion of Matheus & Djaelani (2021), the improvement in the quality of soil physical properties was due to the application of liquid organic fertilizer so that microorganisms in the soil develop and could reduce bulk density. Apart from that, the bulk density value of single fertilizer N, P and K was low due to the presence of N and P elements available in the soil so that microbial activity develops and will influence the soil structure to make it loose. These two elements were formulated by N-fixing and P-solubilizing bacteria.

In treatment C with a LOF dose of 125 ml of tofu factory liquid waste and banana tubers, it had the highest bulk density value of all treatments with a value of 1.04 g/cm³. The higher the bulk density value, the more difficult it was for water and air to enter the soil and make it difficult for plant roots to develop. Apart from that, all treatments except the single N, P and K fertilizer treatment had bulk density values which were categorized as medium. This was due to the presence of excessive minerals so that the pore space between the soil becomes small. Excessive minerals will cause the density of the contents to become denser. According to Harahap et al. (2021), excess minerals will affect the physical properties of the soil, such as reducing the bulk density value. Based on bulk density analysis, it shows that giving LOF from tofu factory liquid waste had a real effect on bulk density. All treatments experienced an increase from the initial soil analysis value, except Treatment C with a LOF dose of 125 ml experienced a decrease from the initial soil analysis value which had a value of 1.02 g/cm³.

Effect of Liquid Organic Fertilizer on Total Pore Space

Based on the results of analysis of variance in total pore space, it shows that liquid organic fertilizer had a significant effect on total pore space. The average treatment of applying liquid organic fertilizer with various doses to the total pore space of Green mustard plants was presented in Table 5 as followed:

Table 5. The effect of LOF application on total pore space

Treatment	Average Total Pore Space (%)	Criteria*
A (Control)	64.13 bc	Shaft
B (Single Fertilizer N, P, K)	67.05 c	Shaft
C (Tofu Factory Liquid Waste LOF 125 ml)	60.50 a	Shaft
D (Tofu Factory Liquid Waste LOF 250 ml)	64.00 bc	Shaft
E (Tofu Factory Liquid Waste LOF 375 ml)	62.98 ab	Shaft
F (Tofu Factory Liquid Waste LOF 500 ml)	62.90 ab	Shaft

Note: Numbers followed by the same letter were not significantly different at the 0.05 level of the DUNCAN test

*: source Arsyad, 1989.

Based on Table 5, it shows that the highest value in the liquid organic fertilizer treatment for total pore space was obtained in treatment (D) of liquid organic fertilizer with a dose of 250 ml with a value of 64.00%. The liquid organic fertilizer treatment had the lowest value compared to the control treatment with a value of 64.13%. Overall, in the total pore space analysis, the highest value was obtained in the single N, P and K fertilizer treatment with a value of 67.05%. The higher the total pore space value, the easier it was for air and water to enter the soil. The high pore space value was influenced by the low bulk density value and the presence of soil microbial activity. In line with Junedi, (2014) research, it was revealed that microbial activity in the soil will help the soil structure become better and will have an impact on increasing pore space and decreasing soil weight.

In treatment C with a LOF dose of 125 ml of tofu factory liquid waste and banana tubers, it had the lowest value of all treatments with a value of 60.50%. Apart from that, this treatment experienced a decrease of 0.8% from the initial soil which was originally 61.3%. The low value of pore space was caused by C treatment, which increases the bulk density. In addition, it will inhibit plant root growth and water drainage. So the soil becomes denser. Inhibition of plant root growth caused crop production to take a long time to harvest. According to Minangkabau et al. (2022), The weight of the contents was an indication of soil density. The denser the soil, the higher the weight of the contents, which means that it was more difficult to pass water or be penetrated by plant roots. The porosity of the soil will be high if the content of organic matter in the soil was also high. soil with a high bulk density causes low pore space and increases soil density

so that water flow was hampered. Based on the total pore space analysis, it shows that giving LOF from tofu factory liquid waste had a significant effect on the total pore space. All treatments experienced an increase from the initial soil analysis value, except Treatment C with a LOF dose of 125 ml experienced a decrease from the initial soil analysis value which was 61.3%.

Effect of Liquid Organic Fertilizer on Soil Permeability

Based on the results of soil permeability variance analysis, it showed that liquid organic fertilizer had a significant effect on soil permeability. The average treatment of applying liquid organic fertilizer with various doses on the soil permeability of green mustard plants was presented in Table 6.

Table 6. The effect of POC application on soil permeability

Treatment	Average Soil Permeability (cm/jam)	Criteria*
A (Control)	12.20 ab	Rather Fast
B (Single Fertilizer N, P, K)	14.41 b	Fast
C (Tofu Factory Liquid Waste LOF 125 ml)	10.07 a	Rather Fast
D (Tofu Factory Liquid Waste LOF 250 ml)	11.56 a	Rather Fast
E (Tofu Factory Liquid Waste LOF 375 ml)	11.04 a	Rather Fast
F (Tofu Factory Liquid Waste LOF 500 ml)	11.39 a	Rather Fast

Note: Numbers followed by the same letter were not significantly different at the 0.05 level of the DUNCAN test, *: source Uhlund & O'neal, 1951

Based on Table 6, it shows that the highest value in the liquid organic fertilizer treatment for soil permeability was obtained in treatment (D) of liquid organic fertilizer with a dose of 250 ml with a value of 11.56 cm/hour, overall in the permeability analysis the highest value was obtained in the fertilizer treatment. single N, P and K with a value of 14.41 cm/hour. High permeability was caused by high total pore space and low bulk density of the soil. High permeability will also make it easier for water to flow into the soil, so that water drainage was smooth and plant roots can absorb water easily. According to Handayani and Karnilawati (2018), bulk weight was related to porosity and permeability. A high bulk weight will result in low permeability and low porosity. In treatment C with a LOF dose of 125 ml of tofu factory liquid

waste, it had the lowest value of all treatments with a value of 10.07 cm/hour. Apart from that, this treatment experienced a decrease of 0.1 cm/hour from the initial soil which was originally 10.08 cm/hour.

This was because treatment C had a high bulk density value and a lower total pore space than other treatments. For all treatments except the single fertilizer treatment N, P, and K had a rather fast permeability class. This was because ultisol had a clay texture because it was classified as a red-yellow podzolic soil. This texture caused the pore space between the soil to become dense, resulting in decreased soil permeability. According to Mulyono et al. (2019), soil that had a clay texture will result in permeability. All treatments experienced an increase from the initial soil analysis value, except Treatment C with a POC dose of 125 ml experienced a decrease from the initial soil analysis value which was 10.08 cm/hour.

CONCLUSIONS

Based on the results obtained from the study on the effect of liquid organic fertilizer from tofu factory wastewater and banana tubers on the physical properties of soil in green mustard (*Brassica juncea* L.) in Ultisols, the following conclusions can be drawn. The application of liquid organic fertilizer from tofu factory wastewater and banana tubers significantly affected bulk density, total pore space, and permeability in the cultivation of green mustard (*B. juncea* L.) in Ultisols. The best values for field capacity water content, bulk density, total pore space, and soil permeability were achieved with the application of 250 ml of liquid organic fertilizer from tofu factory wastewater and banana tubers, which yielded a field capacity water content of 29.63%, bulk density of 0.95 g/cm³, total pore space of 64.00%, and soil permeability of 11.56 cm/hour.

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