The effects of livestock’s manure utilization as fertilizer on coffee plant’s growth

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KEYWORDS

Coffee plants  Fertilizer  Livestock waste  Soil quality

ABSTRACT

Cattle manure contains high organic matter and commonly used as plant nutrients in a form of organic fertilizer. The objectives of this research were to determine the influence of liquid and solid manure from livestock as fertilizer on soil quality and to study the effect of both liquid and solid fertilizer on coffee plant growth. In this research, Completely Randomized Design (CRD) was employed and the collected data was analysed using ANOVA. The F statistical test was applied to measure whether all independent variables could influence the dependent variable by using 5% and 1% (Alpha) degrees. The results showed that one time application of fertiliser from livestock’s liquid manure improved soil’s chemical properties such as C-organic, N, P, CEC, Ca and Mg, while soil chemical properties of pH, K, Na decreased. Two times application of livestock’s liquid manure fertilizer treatment improved soil chemical properties of pH, N total, Ca, Mg and saturation bases. As for livestock’s solid manure, one time treatment increased chemical properties of pH, C organic, N total, Ca and saturation of the base. The two times treatment was also found to improve soil’s chemical properties of pH, N total, P, Ca, Mg, base number and base saturation. Livestock’s liquid manure fertilizer was also found to provide significant effect on the coffee plant height and quality. Additionally, livestock’s solid manure (i.e. compost) was found to have a significant effect on plant height, plant height rate and number of buds.

Introduction

Cattles produce high amount of manure wastes such as feces and urine, which can arise environmental issues and human disease if there is no appropriate waste treatment. Previous studies reported that manure wastes from Holstein dairy cows, which producing an average of 20.3 and 29 kg of milk/day, can be used as nutrients for plant fertilizer (Tomlinson et al., 1996; Wilkerson et al., 1997). Cattle manure has potential to be applied as organic fertilizer and nutrient source for the growth of coffee plants (Chemura et al. 2010).

Waste produced by cattle breeding from the company, particularly solid manure, was used as solid organic fertilizer for the coffee plants, as it provides more advantages than that of the liquid organic fertilizer. Utilization of manure wastes in the form of integrated agriculture may increase the productivity of livestock or farm crops, as well as it is environmentally friendly and sustainable for the long term application (Suyasa and Parwati, 2015). Furthermore, the granular fertilizer contains a variety of macro nutrients and, when combined with boiler ash and neem leaves powder, it can be applied to increase plant resistance to pests due to its insecticidal properties (Brotodjojo et al., 2017). Atilgan et al. (2006) stated that the solid content of fertilizer from the livestock farm is above 25% solid manure; 10-20% semi-solid manure, and 0-10% liquid manure.

The accumulation of organic matter in soil is resulted from the activity of the soil biota. Plants ensure the supply of organic matter, which further transformed by the soil’s microorganisms. In soil, most organic compounds are processed by heterotrophic microorganisms, which use organic carbon as nutrient and energy sources (Fontaine et al., 2003).

Based on Hartatik, et al (2012), the use of liquefied solid organic fertilizers provides more N,
P, and K substances, thus it can be applied easily for plants than that of the solid form. This research focused on comparing the effect of both solid and liquefied organic fertilizers for improving soil nutrients and the growth of coffee plants with Sengon plants as shade. The improved ability to predict nutrient excretion is essential information for technical service providers and producers to consider in developing nutrient management plans (Nennich et al., 2005).

Research Methods
Materials
Liquid fertilizer for coffee plants was taken from the lagoon containing liquid manure in a dairy farm in Blitar, East Java, Indonesia. Soil samples were taken by digging the soil surface with a depth of 10 cm, one week after fertilization.

Experimental Set-Up
In this study, various applications of liquid fertilizer were carried out. The research was designed with two type of fertilizer include solid manure (P) and liquid manure (C). Three different treatments were performed, i.e. control (K), one-time fertilizer application (P1 and C1), and two-time fertilizer application (P2 and C2). All samples were prepared in triplicate, with total of 18 samples treatments. The detailed codes for sample with solid manure fertilizer were KU1, KU2, KU3, P1U1, P1U2, P1U3, P2U1, P2U2, and P2U3, and the codes for liquid manure fertilizer were KU1, KU2, KU3, C1U1, C1U2, C1U3, C2U1, C2U2, and C2U3.

Completely Randomized Design (CRD) was used and ANOVA was employed to describe the total data variation. To analyze the hypothesis, F statistical test was performed to measure whether all independent variables in this study influenced dependent variable by using 5% and 1% (Alpha) degrees. Moreover, Tukey or Honestly Significant Difference (HSD) comparison with 5% level was used to find comparative value in determining a pair of mean values for all treatments averages after variance analysis (ANOVA). Frequency of manure applied to the plant was treated as an independent variable; while physical aspect of the plant was treated as dependent variables (i.e. plant height, canopy diameter, ground cover width, and number of buds).

Sampling and Testing on Livestock’s Liquid And Solid Manure Quality
The testing of sites and parameters along with cattle liquid fertilizer analysis methods can be seen in Table 1. Cattle manure obtained was used as fertilizer in coffee plants. Cow-liquid fertilizer was taken from the lagoon of the company. To avoid plant withered and crop damage, liquid manure was not used in raw condition. The next step was the sampling and analysis of liquid fertilizer, including the pH measurement. Then, location and parameters of tests along with analytical methods performed for both fertilizers were conducted.

Soil Preparation and Plant
This stage covers plotting, labeling and weeding on coffee plants used for research, and labelling each coffee plant. In each treatment there were 3 plots consist of 5 plants per plot; hence, each treatment or plot consists of 15 coffee plants. Plants plotting can be seen in Figure 1.

Most of the selected plants in one plot had similar age of 3-5 years. The plants that had been selected were cleaned by removing weeds from the surrounding coffee plants. The attempt was made to allow coffee plant absorb nutrients from the soil without any competition with the weed.

| Test Parameters | Analysis Method |
|-----------------|-----------------|
| KMnO₄           | QI/LKA/09 (Oxidation) |
| Nitrogen (N)    | APHA. 4500-N-Org B-2005* |
| Phosphor (P)    | SNI 19-2483-1991 |
| Calcium (K)     | APHA. 3111 B-2005* |
| Magnesium (Mg)  | APHA. 3500-Mg B-2005* |
| Sodium (Na)     | APHA. 3111 B-2005* |
| E. coli         | QI/LKA/53 |
| C – Organic     | Spectrophotometry |

Note: * APHA (2005)
Treatment on applying liquid and solid manure to the coffee plant
In this study, one-time and two-time applications were used for both liquid and solid manure fertilizers and applied to the scheme. As for two-time fertilizing, the interval between the first and the second fertilization was 2 weeks. Before fertilizing using liquid and solid fertilizers, soil applied for coffee plants was initially trenched (Figure 2) by digging the soil to a depth of 10-15 cm (until the roots were visible) circling around each coffee plant with a diameter of ~60 cm.
According to Indonesian Coffee and Cocoa Crops Research Center (2006), applying fertilizer to coffee plants depends on the distance and cropping. For more than one meter planting distance, fertilizer should be placed in a circular groove of 30-40 cm from the main stem. This condition was applied to avoid direct contact between the coffee plants with cow liquid fertilizer applied.

Liquid fertilizer for fertilization was poured approximately 6.3 liters for each coffee plant. After applying the manure fertiliser, trenching was carried out with excavated soil to prevent fertilizer loss by rainwater drops, and allow optimal absorption of fertilizer by coffee plants.

Observation and Plant Cultivation
Observation of coffee plants conducted non-destructively, by measuring plant height and diameter using a meter and water buds (black). Actual height is defined as the vertical distance from the topmost living or dead part of the tree (including leaves) to the upslope side of the trunk base (where the trunk and soil meet); hereafter referred to as the ‘base of the tree’ (Larjavaara et al., 2013). The traditional definition of canopy cover includes an “outer edge” or “envelope” of a crown, inside of which the cover is thought to be continuous (Rautiainen et al., 2005). Buds or *Virga singularis* is green orthotropic branches or coffee plants branches that grow upwards from the main stem. The measurement of the height of plant, the diameter of plant and the position of *Virga singularis* can be figured out in Figure 3.

Preliminary analysis of the soil was conducted by direct measurements and by laboratory test. Direct measurements performed in observation on ground cover, soil pH, soil temperature, soil moisture, and sun intensity. Meanwhile, the initial soil test was performed on soil with control treatment through laboratory test at Soil Chemistry Laboratory, Faculty of Agriculture, Universitas Brawijaya with 14 test parameters (soil texture, percentage of soil fraction, base and saturation, pH, C. organic substance, Nitrogen (N), Phosphor (P), Potassium (K), Sodium (Na), Calcium (Ca), Magnesium (Mg), Cation Exchange Capacity (CEC) and C/N ratio). Method of soil testing analysis was performed in accordance to Technical Guidelines for Analysis of Soil, Plant, Water and Fertilizer Chemistry (Agency for Agricultural Research and Development, 2013). Soil sampling was taken from soil under 10 cm deep, as it provides better soil sample for the first test.

The next step was ground cover observation which was initiated by installing the grid to facilitate the observation. The grid was installed using a slap rope and nails forming 25 grids around 1 m² area for coffee plantations. Each grid was measured at 20 cm x 20 cm. Figure 4 present ground cover picture for each coffee plant being studied.

Ground cover observation was performed by calculating the number of grids that were not exposed to sunlight on each coffee plant. This ground cover observation is ideally performed at midday or during the day when the sunlight reached surface at the highest intensity. A grid calculation on the ground cover was a method used to see the percentage of tree or plant cover to the soil as affected by sunlight. The number of grids that were not exposed to sunlight on each plant was calculated using Equation 1.

\[
GC \% = \frac{\sum \text{grid that is not exposed to sunlight}}{\sum \text{total of grids}} \times 100 \%
\] (1)

These calculations present the percentage of plant cover to sunlight on the soil. Other initial observations on soil were performed using soil meters device which include parameters of soil temperature, soil pH, soil moisture and light intensity.

Coffee plants treatment was performed collaboratively with local farmers. As in the initial analysis, observations and maintenance in this study were conducted through observation on plant height, plant diameters, number of shoots (ground) and ground cover and environmental conditions, including soil pH, soil temperature, soil moisture and light intensity using the soil meter device. Observations were conducted every 2 weeks for 3 months, mainly on environmental conditions, using Soil Meters in 2 weeks, and 2 observations were made with different observation hours. Observations were conducted in the morning (8 am) or in the afternoon (4 pm) and during the day (12 am), to see the differences in environmental conditions at these hours. The timeline of fertilization time, soil sampling and observations is presented in Figure 5.
Results and Discussion

Livestock’s Solid Manure Quality

The characteristics of solid manure from the livestock are shown in Table 2. The solid substance was analyzed using solid standard (crumb/bulk) of solid organic fertilizer without adding any microbes that was stated in The Indonesian Ministry of Agriculture Regulation No. 70 of 2011.

The test result showed that pH from livestock’s solid manure was quite acidic at value of 6.2. The pH value presented hydrogen ion concentration in solid. The pH value was well within the standard pH value of 4-9. Thus, the solid manure used in this study was potential to be used as solid organic fertilizer. The solid P substance from the farm was 0.10%. Potassium (K) supported the formation of proteins and carbohydrates accelerated the growth of plants, hardened straw and parts of the wood that wither, increased plant resistance to drought and disease and improved the quality of seeds/fruit. A potassium substance in solid cattle breeding was 0.01%, it increased to 0.2% when adding N, P and K substance in solid organic fertilizer. The value of C/N ratio in solid manure from cattle farms was 40. This value did not meet the quality standards of solid organic fertilizers that require a C/N ratio of 15-25.

Livestock Liquid Manure Quality

Liquid manure was analyzed to investigate its content as liquid fertilizer (Table 3). The liquid fertilizer substance was also analyzed using Organic Liquid Fertilizer Quality Standards as stipulated in The Indonesian Ministry of Agriculture Regulation No. 70 of 2011 and Animal Wastewater Quality Standards stipulated in The Indonesian Ministry of Environment and Forestry No. 5, 2014.

Based on test results, pH of liquid manure (or fertilizer) was 7.4, which is classified as neutral. KMnO₄ value in cow liquid fertilizer was 6,487 mg/L. This value describes the amount of organic substances in cow liquid fertilizer. Permanganate oxidizing agents were not able to oxidize all organic substances; however, the value obtained from the permanganate test might represent Biological Oxygen Demand (BOD) value.
Table 2. Analysis on solid manure from the cattle farming

| Parameters      | Solid Manure Quality of Cattle Farm | Quality Standard of Organic Fertilizer |
|-----------------|------------------------------------|----------------------------------------|
|                 | Unit  | Result | Unit  | Result |
| pH H₂O          |       | 6.20   |       | 4-9    |
| C-organic       | %     | 3.62   | %     | Min 15 |
| Organic matter  | %     | 6.27   | -     | -      |
| Nitrogen Total  | %     | 0.09   | N %   |        |
| Phosphor (P)    | %     | 0.10   | P₂O₅ %| Min 4  |
| Potassium (K)   | %     | 0.01   | K₂O % |        |
| Natrium (Na)    | %     | 0.11   | -     | -      |
| Calcium (Ca)    | %     | 3.25   | -     | -      |
| Magnesium (Mg)  | %     | 0.12   | -     | -      |
| C/N ratio       | -     | 40     | 15-25 |        |

Table 3. Analysis on livestock’s liquid manure

| Parameters      | Liquid manure of Cattle Farm | Quality Standard of Liquid Fertilizer | Quality Standard of Liquid manure |
|-----------------|------------------------------|--------------------------------------|-----------------------------------|
|                 | Units | Result | Units | Result | Units | Result |
| pH              |       | 7.4    |       | 4-9    |       | 6-9    |
| KMnO₄           | mg/L  | 6,487  |       | -      |       | -      |
| Natrium (Na)    | mg/L  | 1,137  |       | -      |       | -      |
| Phosphor (P)    | mg/L  | 1,439  |       | (3-6)10⁴* |    |        |
| Nitrogen        | mg/L  | 43.1   |       | (3-6)10⁴* | mg NH₃-N/L | Max 25 |
| Magnesium (Mg)  | mg/L  | 50.09  |       | -      |       | -      |
| Stool coli      | MPN/100mL | 170 | MPN/100mL | Max 10⁴* |    |        |
| C Organic       | mg/L  | 1,620  |       | Min 6x10⁴* |    |        |
| C/N ratio       | -     | 37.59  | -     | -      |       | -      |

Note: * in similar unit

In Adesanya's research (2011), the BOD₃ value of dairy farm wastewater was 1.81 mg/L, and the lactating milk had a highest of BOD₃ values of 2.4 mg/L. The BOD5 level in wastewater affected the nitrification process in soil. It is because there is a competition between nitrifying bacteria and removal microorganisms of BOD5 (Gaveau et al., 2004). High BOD or COD is an indicator of the organic content. The organic matter content can be decomposed by mineralization process. Mineralization rates are affected by soil temperature and moisture conditions as well as by the accessibility and nature of the organic matter (Flavel and Murphy, 2006; Hadas et al., 2004; Hartz and Johnstone, 2006; Leirós, 1999). The potential sources of N in organic production are primarily composed of organic materials and occasionally small amounts of soluble nitrate or ammonium. All of these organic N sources, including soil organic matter (SOM), undergoes a mineralization process in which soil microbes metabolize organic carbon (C) and convert organic N compounds into ammonium and a subsequent process that quickly oxidizes the ammonium to nitrate (nitrification) (Gaskell and Smith, 2007).

Sodium (Na) substance in cow liquid fertilizer was below 0.0064 mg/L, hence it was not detected during the tests. A potassium substance in livestock liquid fertilizer was 13.75 mg/L which did not meet the quality standards of organic liquid fertilizers containing potassium (3-6) 10⁴ mg/L. Total phosphorus substance (total phosphate) in liquid fertilizer was 1,439 mg/L. This value did not meet the quality standards of organic liquid fertilizer which was set at (3-6) 10⁴ mg/L. Application of chemical fertilizers and animal manure to agricultural land have improved soil P fertility and crop production. Maintaining a proper P-supplying level at the root zone can maximize the efficiency of plant roots to mobilize and acquire P from the rhizosphere by an integration of root morphological and physiological adaptive strategies (Shen et al., 2011).
Total nitrogen substance in liquid fertilizer was 43.1 mg/L. This value did not meet the quality standards of organic liquid fertilizer (3-6) 10^4 mg/L and did not meet the quality standards of cow farm wastewater. However, nitrogen substance of 43.1 mg/L was Kjedahl Total nitrogen substance.

Magnesium in livestock liquid fertilizer was 50.09 mg/L. Magnesium quality standards have not been listed on the quality standards of organic liquid fertilizers or cow farm wastewater. According to Agricultural Research and Development Agency (2013), Mg nutrient substance in cow farm wastewater is 1.0% or equivalent to 10,000 mg/L. This value may decrease while in waste treatment to produce the organic liquid fertilizer. C-organic contained in cow farms liquid fertilizer was 1,620 mg/L which did not meet the quality standards of liquid organic fertilizer which should be at least 60,000 mg/L. Therefore, in application to the soil, a large amount of liquid fertilizer is necessary. The value of C/N ratio in livestock’s liquid manure was 37.59. Ratio of carbon to nitrogen (C: N) is well known and indicate how quickly the effluent would decompose in soil (Longhurst et al., 2017).

**Effect of Liquid and Solid Manure Fertilizer to Soil Quality Improvement**

The physical properties of soil tested in this study were the percentage of soil fraction and soil texture. The texture was the relative ratio of sand grains (0.05-2.00 mm), dust (0.002-0.05 mm) and clay (<0.002 mm) (Ritung et al., 2011). Therefore, the percentage of soil fraction determines the type of soil texture through a triangular texture diagram. In Table 6, treatment of giving one-time (1x) and two-time (2x) liquid or solid manure fertiliser was found to improve sand fraction, while at the same time decreased the dust fraction. By applying 1x solid manure fertiliser, sand and clay fraction rose by 3.67% and 4.33%, while the dust fraction dropped to 8% compared to the control. Applying 2x solid manure fertiliser increased clay fraction to 4.67%, while dust fraction dropped to 4.67% and the clay fraction remained compared to the control. Despite the reduction, improvement was shown in soil fraction, the overall soil texture of each treatment, i.e. control, 1x and 2x solid fertiliser application treatment, and clay texture. Ritung et al. (2011) had classified land based on land suitability for Robusta coffee plant growth. They classified clay-coated textured soil in coffee plantation as fine texture which was greatly suitable for Robusta coffee plants.

**Table 4.** Comparison of livestock’s solid manure substance with soil quality for each treatment

| Parameters           | Solid manure Content | Soil Quality |
|----------------------|----------------------|--------------|
|                      | Units | Result | Unit | Grade | 1x Solid | Grade | 2xSolid | Grade |
| **Physical Parameters** |       |        |      |        |          |       |          |       |
| Fraction of Sand     | -     | -      | %    | 24.00  | -        | 27.67 | -        | 28.67 |
| Fraction of Dust     | -     | -      | %    | 44.00  | -        | 36.00 | -        | 39.33 |
| Fraction of Clay     | -     | -      | %    | 32.00  | -        | 36.33 | -        | 32.00 |
| Soil Texture         | -     | -      | -    | Clay   | -        | Clay  | -        | Clay  |
| **Chemical Parameters** |       |        |      |        |          |       |          |       |
| pH H2O               | -     | 6.2    | -    | 4.60   | Acid     | 4.93  | Acid     | 5.00  |
| pH KCl               | -     | -      | -    | 4.13   | -        | 4.73  | -        | 4.60  |
| Organic Content (%)  | %     | 6.27   | %    | 0.97   | Very Low | 1.14  | Low      | 0.92  |
| N. Total (%)         | %     | 0.09   | %    | 0.117  | Low      | 0.177 | Low      | 0.183 |
| C/N ratio (%)        | -     | 40     | -    | 8.00   | Low      | 6.33  | Low      | 5.00  |
| Brayl                | %     | 0.10   | mg/kg| 21.24  | Middle   | 11.01 | Low      | 30.36 |
| KTK                  | -     | -      | me/100g| 33.15  | High     | 19.84 | Middle   | 22.64 |
| K                    | %     | 0.01   | me/100g| 0.95   | High     | 0.90  | High     | 0.86  |
| Na                   | %     | 0.11   | me/100g| 1.84   | Very High| 1.25  | Very High| 0.57  |
| Ca                   | %     | 3.25   | me/100g| 4.19   | Low      | 4.55  | Low      | 5.60  |
| Mg                   | %     | 0.12   | me/100g| 0.43   | Low      | 0.32  | Very Low | 1.17  |
| Amount of Base       | -     | -      | %    | 22.33  | Low      | 35.33 | Low      | 36.33 |
| Base Saturation      | -     | -      | %    | 7.41   | -        | 7.00  | -        | 8.20  |

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Based on Table 4 and the above explanation, it demonstrated that the application of one-time solid manure fertilizer can improve the soil’s chemical properties of pH, C. organic, N. total, Ca and alkaline saturation, while the soil chemical properties of C/N ratio, P, CEC, K, Na, Mg and the amount of base decreased. The two-time solid manure fertilizer application improved soil chemical properties of pH, N. total, P, Ca, Mg, base number and base saturation, while other organic chemical properties, such as C/N ratio, CEC, K and Na decreased. The difference between treatments was not significant or consistent, as the distance between the first and second fertilizing times had a considerable time span; therefore, some soil nutrients that have been previously drained have been used by coffee plants for growth and development. In addition, high rainfall during fertilization and soil sampling caused nutrients loss, and hence the research was located in tilted and the highlands (Dariah, 2004). Higashino et al. (2014) showed that the number or nitrogen fertilizer applied in paddy fields is washed out during the rainy season.

There were no significant changes in the texture of each treatment, both in control and with liquid fertilizer (one-time and two-time application), as the texture is one of the properties of the soil that is permanent (innate nature), its nature is difficult to change, even unchangeable (Islam and Weil, 2000 in Dariah, 2004). Therefore, in crop cultivation, checking soil texture of one area is necessary to see whether it is suitable or not for the plants, to achieve the expected production results.

Based on Table 5, it can be concluded that application of one-time livestock’s liquid manure fertilizer can improve the chemical properties of C-organic, N. total, P, CEC, Ca and Mg, while the soil
chemical properties of pH, K, Na, the amount of base and saturation of bases decreased. The C/N and Ca ratio parameters were remained the same during the one-time liquid fertilizer treatment. Two-time liquid fertilizer treatment improved soil chemical properties of pH, N, total, Ca, Mg and base saturation, while other chemical properties of C, organic, C/N ratio, P, CEC, K, Na, and the amount of base decreased.

The difference between treatments was not significant or consistent, as the distance between the time of giving the first and second liquid fertilizers had a considerable time span, thus some nutrients in the soil that have been previously drained were used by coffee plants for growth and development. Moreover, soil erosion and high rainfall during fertilization is considered as the major environmental problems, as it causes soil and nutrient losses and is associated with flooding, sedimentation and pollution of water bodies (Portela et al., 2018). Phosphorous losses were mainly associated with soil particles and the land uses that gave rise to higher P losses was agricultural under any intensity, while P losses increased significantly in forest and afforested land use /land cover at rainfall high intensity (Ramos et al., 2019).

Effect of Liquid Manure Fertilizer on Coffee Plant Growth

Figure 6a shows that the height of coffee plant in each week increased, both in treatment without and with one-time or two-time liquid fertilizer application. After ANOVA analysis, it was found that the treatments had a significant effect on coffee plant height at week 0, mainly due to the difference in the initial plant height. The coffee plant in control treatment was the highest, and hence during statistical analysis, it was found different effect due to a high difference between control treatment and other treatments. However, as the week prolonged, the p value was > 0.05, showing that the treatment had no significant effect on the height of the coffee plant, as can be seen in Table 6. The important factor for coffee plant growth is water supply, where the unreliable rainfalls and frequent droughts may inhibit the coffee plant growth, yield, and quality of coffee (DaMatta, 2004; Worku and Astatkie, 2010).

The significant effect of treatment on coffee plants growth occurred in the 2nd week. During the week, the height of control treatment plants was significantly different from the height of two-time liquid fertilizer treatment. However, it was not significantly different from the height of coffee plant from one-time liquid fertilizer treatment. When comparing between one-time and two-time liquid fertilizer application treatment, the rate of plant height was not significantly different. This is because the second week was considered as "post fertilization" period as the fertilizer was firstly applied at week 0. Therefore, between week 0 and 2, C1 and C2 treatment was considered as the period where the soil was rich in nutrients due to the addition of organic liquid fertilizer.

Figure 6b shows that the diameter of the coffee canopy on each week was bigger, which indicated that in each treatment, canopy diameter grew up, both in control and one-time and two-time liquid fertilizer treatment. However, after ANOVA analysis was carried out (Table 6), it was found that the treatment had no significant effect on the coffee plant canopy diameter at all weeks. The p-value at each week was > 0.05, indicating that the treatment did not significantly affect the diameter of the coffee plant canopy.

Table 6 shows that the highest diameter growth rate of coffee canopy plants in each observation week occurred in two-time liquid fertilizer treatment, as the soil got significant addition of nutrients that enables vegetative growth, one of which is the optimal diameter of the canopy. The limitation of nitrogen contain in soil can decline the canopy carbon assimilation. A direct reduction of the leaf photosynthesis and gradual reduction of the rate of new leaf area, can lead to a rapid senescence of leaf. Therefore, the nitrogen content in soil is very important to canopy growth (Massignam et al., 2012).

The obvious effect of treatment on coffee plant canopy diameter occurred in week 2 and 4. During the week, diameter growth rate of coffee plants from the control treatment was significantly different compared to that of from two-time liquid fertilizer treatment. But, one-time application treatment of liquid fertilizer has no significant different in the plant canopy diameter rate whether with control or with two-time application treatment. This indicated that fertilization with liquid fertilizer did have effect on the diameter growth rate. The first fertilization for C1 and C2 treatment was started at week 0, and the second fertilization for C2 treatment was given at week 2. Direct fertilization results were observed 2 weeks after fertilization, such as in the 2nd and 4th weeks, where the treatment had a significant effect on canopy diameter rate. The soil would contain a lot of nutrients after applying liquid fertilizer, and hence the canopy diameter rate was optimal. At 6th, 8th,
10th and 12th weeks, treatment had no significant effect on canopy diameter rate despite the growing of canopy diameter, as shown by similar alphabet notation in Table 6.

Figure 6c shows the number of *Virga singularis* in coffee plants increased every week. *Virga singularis* grows very fast, as most of the food substances that are absorbed from the ground are channeled to these shoots (Subandi, 2011). It can be seen in the Table 6 that the number of *Virga singularis* in liquid fertilizer treatment was higher compared to that of in the control treatment. Furthermore, adding more frequent liquid manure fertiliser also had positive effect on increasing the number of *Virga singularis*. This indicates that the amount of liquid fertilizer affects the number of *Virga singularis* in coffee plants as the soil can contain more nutrients with more fertilizer added. Although *Virga singularis* is usually pruned for the maintenance, it can be cut for coffee plants vegetative breeding (Subandi, 2011). Figure 6d shows that the ground cover rate for each week was not significantly affected by the treatment given. Ground cover rates on a weekly basis show a good volatile trend. The ground cover rate in control treatment shows the ground cover rate has increased until 8th weeks then continue to decrease. Furthermore, the groundcover rate has increased in every week either for one-time or two-time application of liquid manure.

![Figure 6](image.png)

**Figure 6.** The effects of liquid manure fertilizer on coffee plants growth: (a) height of coffee plant; (b) canopy diameter; (c) number of *Virga singularis*; and (d) ground cover
Tabel 6. The effects of liquid manure as fertilizer on coffee trees height (cm), coffee height rate, canopy diameter, canopy diameter rate, the number of *Virga singularis*, coffee trees ground cover (%) and ground cover rate of coffee trees

| Treatments | Weeks | Control | C1 | C2 |
|------------|-------|---------|----|----|
|            | 0     | 190.22b | 141.56a | 142.67a |
|            | 2     | 194.00  | 160.00  | 162.89  |
|            | 4     | 195.78  | 164.11  | 171.44  |
|            | 6     | 197.44  | 167.89  | 177.22  |
|            | 8     | 198.33  | 169.11  | 178.67  |
|            | 10    | 198.89  | 170.11  | 179.56  |
|            | 12    | 199.11  | 170.78  | 180.78  |
| p-value (Sig) | 0.01* | 0.061 | 0.056 | 0.053 |

| Treatments | Weeks | Control | C1 | C2 |
|------------|-------|---------|----|----|
|            | 0     | 190.22b | 141.56a | 142.67a |
|            | 2     | 194.00  | 160.00  | 162.89  |
|            | 4     | 195.78  | 164.11  | 171.44  |
|            | 6     | 197.44  | 167.89  | 177.22  |
|            | 8     | 198.33  | 169.11  | 178.67  |
|            | 10    | 198.89  | 170.11  | 179.56  |
|            | 12    | 199.11  | 170.78  | 180.78  |
| p-value (Sig) | 0.01* | 0.061 | 0.056 | 0.053 |

| Treatments | Weeks | Control | C1 | C2 |
|------------|-------|---------|----|----|
|            | 0     | 177.33  | 131.11 | 140.78 |
|            | 2     | 181.33  | 144.00 | 157.33 |
|            | 4     | 184.22  | 151.67 | 166.67 |
|            | 6     | 187.22  | 156.22 | 171.22 |
|            | 8     | 190.67  | 160.33 | 177.89 |
|            | 10    | 193.22  | 164.00 | 181.22 |
|            | 12    | 194.22  | 168.44 | 184.67 |
| p-value (Sig) | 0.255 | 0.413 | 0.513 | 0.558 |

| Treatments | Weeks | Control | C1 | C2 |
|------------|-------|---------|----|----|
|            | 0     | 4.00    | 12.89 | 16.56 |
|            | 2     | 2.89    | 7.67  | 9.33  |
|            | 4     | 3.00    | 4.56  | 4.56  |
|            | 6     | 3.44    | 4.11  | 6.67  |
|            | 8     | 2.56    | 3.67  | 3.33  |
|            | 10    | 1.00    | 4.44  | 3.44  |
|            | 12    |         |       |       |
| p-value (Sig) | 0.030 *) | 0.050 *) | 0.395 | 0.248 |

| Treatments | Weeks | Control | C1 | C2 |
|------------|-------|---------|----|----|
|            | 0     | 2.67    | 0.00  | 0.80  |
|            | 2     | 3.20    | 1.33  | 1.87  |
|            | 4     | 3.20    | 2.40  | 4.00  |
|            | 6     | 6.13    | 4.27  | 4.80  |
|            | 8     | 10.13   | 8.80  | 6.67  |
|            | 10    | 10.67   | 8.80  | 11.20 |
|            | 12    | 11.73   | 10.93 |       |
| p-value (Sig) | 0.300 | 0.561 | 0.718 | 0.484 |

| Treatments | Weeks | Control | C1 | C2 |
|------------|-------|---------|----|----|
|            | 0     | 0.53    | 0.80  | 0.80  |
|            | 2     | 0.61    | 1.07  | 1.07  |
|            | 4     | 2.93    | 1.87  | 1.87  |
|            | 6     | 4.00    | 4.53  | 4.53  |
|            | 8     | 0.53    | 4.3 | 4.3 |
|            | 10    | 1.07    | 2.13  | 2.13  |
|            | 12    | 1.87    | 4.53  | 4.53  |
| p-value (Sig) | 0.918 | 0.510 | 0.612 | 0.218 |

Note: *) = Significantly different; Different alphabet notation indicates significant differences between treatments
Effect of Solid Manure Fertilizer on Coffee Plant Growth

As for growth rate, the treatment effect was significant in the 8th week. Table 7 shows that the control treatment has the highest growth rate compared to the one-time or two-time solid manure application treatment. However, addition of one-time or two-time solid manure fertilizer had no significant different rate on the coffee plant height, as shown in Figure 7a and Table 7.

The effect on coffee plant canopy diameter rate was occurred at 6th and 8th weeks (Figure 7b). During that week, the diameter rate of coffee plants from control treatment was significantly different with that of from two-time solid manure fertilizer application. One-time application of solid manure fertilizer has no significant different on the plant canopy diameter compared with the control and two-time solid fertilizer application treatment, as indicated by similar alphabetic notation in Table 7.

This trend was observed from the 2nd to 12th weeks, despite a small growth on the canopy diameter.

According to Purba et al. (2012), canopy diameter contributes to strong direct influence on coffee production. This is because the wider the diameter of the canopy is, the wider the root coverage area to obtain nutrients. Thus, more elements obtained by the root may maximize the photosynthesis and increase the formation of flowers and fruit. It can avoid damage of coffee plant caused by strong winds, rains or hail (Alvarenga, et al, 2004 in Jose et al, 2017). In addition, the advantage of canopy implementation is to escalate the nutrient and soil organic matter. Therefore, the canopy diameter can significantly affected to crop production consistency (Campanha et al, 2007 in Jose et al, 2017). On plant growth and canopy diameter, both rates at 8th week show that solid manure fertilizer treatment has a significant effect, due to its slowly released nutrients ability.

![Figure 7](image-url)
Table 7. The effects of solid manure as fertilizer on coffee trees height (cm), coffee height rate, canopy diameter, canopy diameter rate, the number of Virga singularis, coffee trees ground cover (%) and ground cover rate of coffee trees

| Treatments | Weeks |
|------------|-------|
| Control    |       |
| P1         |       |
| P2         |       |

The coffee trees height (cm)

| Treatments | 2   | 4   | 6   | 8   | 10  | 12  |
|------------|-----|-----|-----|-----|-----|-----|
| Control    | 3.78| 1.78| 1.67| 0.89| a   | 0.56| 0.22|
| P1         | 6.22| 2.44| 3.11| 2.67| b   | 1.67| 0.44|
| P2         | 7.89| 2.89| 2.78| 3.11| b   | 1.89| 2.33|

p-value (Sig) 0.281 0.528 0.176 0.007*) 0.097 0.137

The Canopy Diameter

| Treatments | 2   | 4   | 6   | 8   | 10  | 12  |
|------------|-----|-----|-----|-----|-----|-----|
| Control    | 4.00| 2.89| 3.00| 3.44| a   | 2.56| 1.00|
| P1         | 7.67| 4.44| 5.00| 5.11| Ab  | 2.78| 1.22|
| P2         | 7.22| 5.44| 7.11| 7.11| b   | 3.44| 1.89|

p-value (Sig) 0.274 0.243 0.050*) 0.041*) 0.887 0.688

The Canopy Diameter Rate of Coffee Trees (Cm)

| Treatments | 0   | 2   | 4   | 6   | 8   | 10  | 12  |
|------------|-----|-----|-----|-----|-----|-----|-----|
| Control    | 0.53| 0.00| 2.93| 4.00| 0.53| 1.07|     |
| P1         | 0.27| 0.72| 1.13| 1.20| 0.70| 1.33|     |
| P2         | 0.72| 4.53| 6.93| 13.07| 18.13| 19.73| 21.33|

p-value (Sig) 0.395 0.814 0.156 0.066 0.144 0.092 0.110

The Number Of Virga Singularis (Pieces)

| Treatments | 0   | 2   | 4   | 6   | 8   | 10  | 12  |
|------------|-----|-----|-----|-----|-----|-----|-----|
| Control    | 0.00| 3.00| 3.20| 6.20| 8.53| 10.13| 10.67|
| P1         | 0.27| 7.60| 11.60| 16.20| 22.47| 23.93| 24.87|
| P2         | 0.00| 6.13| 13.07| 18.13| 19.73| 21.33|     |

p-value (Sig) - 0.250 0.310 0.061 0.081 0.028*) 0.030*)

The Coffee Trees Ground Cover (%)

| Treatments | 0   | 2   | 4   | 6   | 8   | 10  | 12  |
|------------|-----|-----|-----|-----|-----|-----|-----|
| Control    | 2.67| 3.20| 3.20| 6.13| 10.13| 10.67| 11.73|
| P1         | 0.53| 3.20| 7.20| 9.87| 11.20| 11.47| 13.33|
| P2         | 1.87| 4.53| 6.93| 13.07| 18.13| 19.73| 21.33|

p-value (Sig) 0.395 0.814 0.156 0.066 0.144 0.092 0.110

The Ground Cover Rate of Coffee Trees

| Treatments | 0   | 2   | 4   | 6   | 8   | 10  | 12  |
|------------|-----|-----|-----|-----|-----|-----|-----|
| Control    | 0.53| 0.00| 2.93| 4.00| 0.53| 1.07|     |
| P1         | 2.67| 4.00| 2.67| 1.33| 0.27| 1.87|     |
| P2         | 2.67| 2.40| 6.13| 5.07| 1.60| 1.60|     |

p-value (Sig) 0.309 0.129 0.318 0.156 0.484 0.744

Note: *) = Significantly different; different alphabet notation (a, b) indicates significant differences between treatments

Figure 7c shows that, during the observation period, the fertilizer application treatment only had a significant effect on the number of Virga singularis in coffee plants in the 10th and 12th weeks. Table 7 indicates that the number of Virga singularis in the control treatment was significantly
different than that of from one-time or two-time solid manure fertilizer application. However, between one-time and two-time fertilizer application treatments, there was no significant difference was observed. As seen from Figure 7c, the number of Virga singularis in coffee plant after treated with fertilizer application was higher than the control treatment. Furthermore, addition of higher solid manure fertilizer had triggered more Virga singularis in the coffee plants. This finding confirmed that the amount of solid manure fertilizer influence the amounts of nutrients available in the soil, thus affecting the growth of Virga singularis in the coffee plants.

Figure 7d shows that each treatment, both control and solid manure fertilizer application did not significantly affect the ground cover of coffee plant soil. Greater ground cover value illustrates tighter plants cover (leaves or branches) to the soil due to sunlight. This soil cover is crucial to minimize the soil’s damage caused by rainwater and to prevent a highly temperature increase in the soil. Table 7 demonstrates that the ground cover rates on a weekly basis were not significantly affected by the treatment given and showed a good volatile trend. All treatments indicate an increase in the ground cover rate per week.

Conclusion

Utilization of livestock liquid and solid manure as a fertilizer either in one- or two-time application was found to enhance the chemical properties of the soils. Liquid manure fertilizer application had a significant effect on the height of coffee plant at the beginning of observation and on the rate of plant height at the 2nd week. Similarly, solid manure fertilizer application had also a significant effect to the height of coffee plant and the number of Virga singularis. These findings confirmed that fertilization with liquid and solid manure from cattle farm can be applied in coffee plant by farmers. Application of liquid and solid manure fertilizer has no direct effects to Virga singularis growth, the canopy diameter of coffee plant, and the ground cover. The amount of sunlight received by the coffee plants was found to be the critical factor influencing the canopy diameter, the ground cover, and the growth of Virga singularis.

Conflict of interest

The author declares that there is no conflict of interest in this publication.

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