Effect of liquid fertiliser for soil quality and coffee plants’s vegetative growth

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Abstract. The aim of this research was to determine the influence of liquid fertiliser that comes from the waste of dairy farms for soil quality and vegetative growth of coffee plants. There are three kinds of fertilization intensity (treatment) that is without fertilization (K0), one-times fertilization (C1) and two-times fertilisation (C2). The results were analysed using Group Randomized Design as experimental design; ANOVA and Tukey Test 5% as analysis method. The results showed that the treatment affects soil quality. The treatment also gives a significant influence (p < 0.05) at the height rate of coffee plants in the 2nd week and the canopy diameter rate of coffee plant in the 2nd and 4th week. The results of this research are expected to provide input especially for cattle farmers and coffee planters who want to integrate their livestock and their crops.

1. Introduction

Currently, increasing the population is parallel to an increase in the food demands, including the needs of milk. Global milk output in 2018 was estimated as much as 843 million tonnes or increased by 2.2% from 2017 [1]. This situation encourages the emergence of a new dairy farm, one of which is a dairy farm in Blitar, Indonesia. Every kg of milk produced by dairy cow generates two kilograms of cow’s solid waste [2]. The amount of manure and urine produced reaches 10% of the weight of cattle, with the ratio per dairy cow is 2.2:1 or 69% of manure and 31% urine [3]. If not properly managed, waste of cow farm can cause environmental pollution, as well as cause a detrimental effect on human health.

Not far from the dairy farm, there is a Robusta coffee plantation. The potential utilisation of fertiliser in that coffee plantation is huge. Therefore, valorizing the wastes from the dairy farm as organic fertiliser for coffee plants can be one of the options. This approach is not only beneficial for farmers, but also can provide a clean technology to protect the farm environment. This condition encourages research about the utilization of cow urine to be used as a liquid fertiliser for coffee plant. Previous study reported that cow urine is potential to be used as organic fertiliser [4]. The use of organic manure as fertiliser can improve the growth performance of young coffee [5]. Thus, the aim of this research was to determine the influence of liquid fertiliser made of cow urine on the soil quality and on the vegetative growth of coffee plants.
2. Materials and Method
Liquid fertiliser for coffee plants was taken from the lagoon 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.

2.1. The preparation of coffee plant and land
The research site was located in one of the coffee plantations in Blitar, East Java, Indonesia. In the plantation, Coffea canephora var. Robusta grew heterogeneous with sengon (Paraserianthes falcataria) as a shade. At the beginning of the study, the plant was plotted, labeled and weeded. Each treatment consisted of three plots (replications), in which each plot consisted of five plants. Thus, each treatment used 15 plants with the total plant in the study was 45 plants.

2.2. Liquid fertiliser treatment for coffee plant (fertilisation)
In the first step of fertilisation, the soil was dug as deep as 10-15 cm surrounding each coffee plant with a diameter of 60 cm [6]. A total of 6.3 L liquid fertiliser was poured evenly into the soil, then the hole was closed back with soil. There were three types of fertilisation treatment, include without fertilisation (K0), one-time fertilisation (C2) and two-times fertilisation (C2). The first fertilisation was done in the initial week (or the 0 week) and the second fertilisation was done on the 2nd week.

2.3. The observation of coffee plant
There were three non-destructive observation parameters in the study, include the height of the plant, the diameter of canopy, and the number of buds (or it called “wiwilan” in Indonesian). The height of the plant was measured starting at the bottom of the stem from the ground up to the growing point of the coffee plant. The canopy diameter was measured from the outer leaf of the coffee plant, through the trunk to the other side of the outer leaf. The selected canopy diameter was the canopy with the longest diameter. The number of buds, calculated for this study, was branches of green coffee plants that grew upwards from the main stem of the coffee plant. The observations were carried out on a two-week basis for three months.

2.4. Data analysis
The Group Randomized Design was used to design the experimental works in this study. A dependent variable (i.e. the intensity of liquid fertiliser) was used, with the quality of soil and the vegetative growth rate of plants measured as the responses. The ANOVA analysis was used to describe the total diversity of the collected data, F statistical test was used to measure the influence of the independent variables on the dependent variable (p<0.05). The Tukey or Honestly Significant Difference (HSD) test was used to identify the comparative value in determining a pair of mean values for all treatments after ANOVA analysis. All the data analysis was carried out using IBM SPSS statistics 20 software.

3. Results and Discussion
3.1. The diary farm liquid fertiliser quality
The characteristics of the liquid fertiliser from cow urine is presented in Table 1. Based on Table 1, pH of liquid fertiliser was still classified as neutral, therefore, no significant pH changes were observed when the fertiliser was applied to the soil. The content of macro-nutrients (i.e. N, P, K) for plants were still lower than the value of the standards quality for the organic liquid fertiliser. The content of magnesium (Mg), considered as a secondary macro-nutrient for the plant, was 50.09 mg/L, while the Sodium (Na) was < 0.0064 mg/L (i.e. it was is not detected at the time in the laboratory test). The value of KMnO4 representing the total amount of organic matter in liquid fertiliser was 6,487 mg/L. The C-organic value, measured as the amount of organic carbon content in liquid fertiliser, was much lower than the acceptable value of the standard quality of organic liquid fertiliser. The C/N ratio of the liquid fertiliser was high, with the value of 37.59, exceed the standard value of 15.
Table 1 also shows that the number of pathogen (i.e. *E. coli*) was 170 MPN (Most Probably Number) per 100 mL of liquid fertiliser, which as below the standard quality value of the liquid organic fertiliser. This indicates that the liquid fertiliser contained low pathogen, therefore it is safe to be used to the soils. Based on the characteristics data, the quality of the liquid fertiliser from cow manure is meeting the standard quality, thus its application would not contaminate soil and groundwater.

### Table 1. The characteristics of the liquid fertiliser from cow urine

| Parameters | Methods | Units | Liquid Fertiliser | Quality Standart* |
|------------|---------|-------|-------------------|-------------------|
| pH         | Direct Measurement | -     | 7.4               | 4-9               |
| TKN**      | APHA. 4500-N-Org B-2005 | mg/L  | 43.1              | (3-6)10⁴          |
| Phosphor (P) | SNI 19-2483-1991 | mg/L  | 1.439             | (3-6)10⁴          |
| Pottasium (K) | APHA. 3111 B-2005 | mg/L  | 13.75             | (3-6)10⁴          |
| Magnesium (Mg) | APHA. 3500-Mg B-2005 | mg/L  | 50.09             | -                 |
| Sodium (Na) | APHA. 3111 B-2005 | mg/L  | LD***             | -                 |
| KMnO₄       | Q/L/KA/09 Oxidation | mg/L  | 6,487             | -                 |
| C-Organic   | Spectrofotometry   | mg/L  | 1,620             | Min. 6.10⁴        |
| C/N ratio   | Calculation        | -     | 37.59             | -                 |
| *E. coli*   | Q/L/KA/53 Double Tube | MPN/100mL | 170               | Max. 10⁴          |

Note : *Quality Standart of Liquid Organic Fertiliser (Regulation of Ministry of Agriculture, Republic of Indonesia No.70/Permentan/Sr. 140/10/2011); **Total Kjedahl Nitrogen; ***Limit Detection

3.2. The soil quality

The methods of soil testing analysis had been appropriate with technical guidelines for chemical analysis of soil, plant, water, and fertiliser [7]. Based on Table 2, there is no significant change in the soil texture after fertilisation. This occurs because the soil’s texture is one of soil properties that is permanent (the innate nature) or very difficult to change even with soil’s management [8].

The soil pH after fertilisation was remained the same and still in acidic condition. Soil pH is soil properties that changed easily on a daily period or routine [8]. A decreased in soil pH can be caused by a decomposition of organic material in the soil. This organic material has a reactive group (i.e. carboxyl and phenol) that dominates a complex exchange and can be acidic, thus it can dissociate and produce a lot of H ions [9]. An increase in soil pH was possibly due to the addition of organic fertiliser. Several mechanisms on causing an increase in pH were reported include (1) the release of OH⁻ in the oxidation process of organic acid anions, (2) the consumption of protons during the decarboxylation of inorganic acids, (3) the release of OH⁻ ion during the mineralisation organic, (4) the release of OH⁻ due to the specific adsorption of humic material and/or organic molecules into the hydroxide of Al and Fe, and (5) an increase in the content of bases cation [10, 11].

The addition of organic fertiliser can actually increase the C-organic content of the soil, as it was observed in the C1 treatment. However, no significant influence was found on the C-organic content of the soil from the C2 treatment. Such condition was possibly happened because the process that occurs in the soil itself, where decomposition and mineralization of the organic materials simultaneously. The content of organic materials is reduced and replaced by the formation of nutrients such as N, P, K, Ca, Mg and other micro-elements [13]. The mineralisation can also be observed from the C/N ratio of the soil sample, as indicated by the value of less than 15. The input of organic material derived from organic liquid fertiliser promotes the occurrence of priming, thus influencing or increasing the decomposition of organic material in soil. This condition was caused by an increase in the soil microbial activity due to a higher energy availability as a result of new organic material decomposition. With the influence of priming, more organic materials are decomposed, indicating more nutrients are available to support the growth and production of crops [14].
an increase in P level therefore Fe of after C2 treatment.

Soil fertili... major limiting factor for the growth of coffee plants because it cannot be used by plants [13], as well as can stimulate the soil microbial growth, alter the soil microbia structure, and increase the enzyme activity [20]. Thus, the decomposition and mineralisation occurs faster due to the presence of those microbial agents.

Available phosphorus (P) levels was tested using P. Bray1 extractor because of the acidic soil conditions [7]. The P content on the soils after C1 treatment was much higher compared to that of after C2 treatment. This was possibly influence by the initial soil pH level in each treatment. In soil pH of 4.52, the amount of P absorbed by the coffee plant is low [21]. On low pH soils (acids), P reacts with Fe ions and aluminum phosphate, forming chemical compounds that are difficult to dissolve in water, therefore it cannot be used by plants [22]. In C1 treatment, a decrease of soil pH may potentially cause an increase in P level the soil, as P is becoming hard to be consumed by plants. However, in the C2

| Table 2. The soil quality |
|--------------------------|
| Parameters               | Units    | Before Fertilisation | After Fertilisation |
|                          |         | K0                   | C1 | C2 |
|                          |         | Result | Grade* | Result | Grade* | Result | Grade* |
| Fraction of Sand         | %       | 24.00  | -      | 21.00  | -      | 29     | -      |
| Fraction of Dust         | %       | 44.00  | -      | 46.67  | -      | 35.33  | -      |
| Fraction of Clay         | %       | 32.00  | -      | 30.00  | -      | 35.67  | -      |
| Soil texture             | -       | -      | Clay Loam | -      | Clay Loam | -      | Clay Loam |
| pH H2O                   | -       | 4.60   | Acid   | 4.50   | Acid   | 5.07   | Acid   |
| pH KCl                   | -       | 4.13   | -      | 4.07   | -      | 4.73   | -      |
| C-organic                | %       | 0.97   | Very Low | 0.98   | Very Low | 0.61   | Very Low |
| Nitrogen total           | %       | 0.12   | Low    | 0.127  | Low    | 0.133  | Low    |
| C/N ratio                | -       | 8.00   | Low    | 8.00   | Low    | 4.67   | Very Low |
| P. Bray1                 | mg/kg   | 21.2   | Middle | 64.34  | Very High | 4.60   | Very Low |
| Cation Exchange Capacity (CEC) | me/100g | 33.1   | High   | 33.53  | High   | 20.59  | Middle |
| Pottasium (K)            | me/100g | 0.95   | High   | 0.80   | Very Low | 0.52   | Very Low |
| Sodium (Na)              | me/100g | 1.84   | Very High | 1.11  | Very High | 0.70   | Middle |
| Calssium (Ca)            | me/100g | 4.19   | Low    | 4.19   | Low    | 4.71   | Low    |
| Magnesium (Mg)           | me/100g | 0.43   | Low    | 0.49   | Low    | 0.53   | Low    |
| Bases amount             | -       | 7.41   | -      | 6.59   | -      | 6.46   | -      |
| Alkaline saturation      | %       | 22.3   | Low    | 20.00  | Low    | 31.67  | Low    |

Note: *The criteria of assessment [14, 15]

Total nitrogen (N) describes the content of all nitrogen in the soil either in the form of available nitrogen or in organic compounds [9]. In Table 2, the content of total N increases with more intense fertilisation, although the total N is still relatively low. It can be seen in the C2 treatment, more intense the fertilization as indicated by providing more fertiliser on the soil has impact on increasing the total N of the soil. N availability in the soil is closely related to the content of organic matter in soil [16]. Organic carbon is metabolized and transformed by soil microbes to ammonium. Through the process of nitrification, ammonium is oxidized to nitrate [17]. The study indicates that increasing the dose of liquid fertiliser used causing an increase in the organic material supplied into the soil. Thus, it increases the activity of the decomposition agent which ultimately increases the N content in the soil. N element is a major limiting factor for the growth of coffee plants [18].
treatment, because the soil pH increase, P content in the soil is easily used by the plants, thus decreasing the P level.

Organic materials increase the soil ability to withstand nutrients (i.e. the exchange rate of soil cation becomes high) and become a source of energy for microorganisms. Similarly, this study demonstrates that, when the C-organic increased, the CEC also increased, as shown in the C1 treatment. While in the C2 treatment, as C-organic decreased, the value of CEC also decreased.

The absorption of potassium (K) by the plants is relatively high because K has important function for the plants. Macro-nutrient of K is absorbed by plants in a sufficient amount or sometimes higher than the amount of N [9]. In this study, both treatments indicate a reduction of K level in the soil after fertilization.

In this study, the liquid fertilizer from cow urine contains a small amount of sodium /Na (< 0.0064 mg/L), therefore an additional Na to the soil was less significant. An increase in Ca and Mg on the soil can occur due to the addition of organic materials during the soil fertilisation. In the process of mineralisation, several minerals in the plants is released, including Ca and Mg [12].

The amount on bases is generated from the amount of cations of K, Na, Ca and Mg in soil. Table 2 shows that a small change of pH may affect the soil’s base saturation. Usually, under an acidic pH, the solubility of and the number of the acid cation are increasingly higher, while the number of base cations were lower.

Table 2 shows that the C1 treatment can improve the chemical properties of C-Organic, Total N, Total P, CEC and Mg. However, after C1 treatment some soil chemical properties were found to decrease include pH, K, Na, bases amount and alkaline saturation. The C/N ratio and Ca did not influence by the C1 treatment. This study reveals that the C2 treatment was able to enhance the soil chemical properties (i.e. pH, N. Total, Ca, Mg and alkaline saturation), but it tends to decrease of other chemical properties (i.e. C-Organic, C/N ratio, P, CEC, K, Na, and bases amount). The difference between each treatment was not significant as indicated by statistical analysis. This study also shows that after soil fertilisation treatment, some nutrients in the soil have been used by the coffee plants.

3.3. The vegetative growth of coffee plant

Growth rate data was derived from reduction results of growth (plant height and canopy diameter) at week (n) with growth at week (n-2). The analysis results of ANOVA and Tukey test of plant height rate and the canopy diameter rate of the coffee plants are presented in Table 3, 4 and 5.

| Treatment | 2       | 4       | 6       | 8       | 10      | 12      |
|-----------|---------|---------|---------|---------|---------|---------|
|           | Plant Height Rate of Coffee Plant (cm) |         |         |         |         |         |
| K0        | 3.78a   | 1.78    | 1.67    | 0.89    | 0.56    | 0.22    |
| C1        | 18.44ab | 4.11    | 3.78    | 1.22    | 1.00    | 0.67    |
| C2        | 20.22b  | 8.58    | 5.78    | 1.44    | 0.89    | 1.22    |
| p-value   | 0.037*  | 0.051   | 0.199   | 0.301   | 0.211   | 0.121   |
| Canopy Diameter Rate of Coffee Plant (cm) |         |         |         |         |         |         |
| K0        | 4.00a   | 2.89a   | 3.00    | 3.44    | 2.56    | 1.00    |
| C1        | 12.89ab | 7.67ab  | 4.56    | 4.11    | 3.67    | 4.44    |
| C2        | 16.56b  | 9.33b   | 4.56    | 6.67    | 3.33    | 3.44    |
| p-value   | 0.030*  | 0.050*  | 0.395   | 0.248   | 0.826   | 0.078   |

Note : *Significant (p<0.05)
Based on Table 3, it can be seen that adding the liquid fertiliser gives effect to the high growth rate of the plant at 2nd week (p< 0.05). This occurs because the 2nd week is counted as a "post-fertilizing" time. Between the 0 and 2nd weeks, for the treatment of C1 and C2, it is a time when the soil is rich in nutrients. From Table 3, it is also known that the highest rate of the plant height (except the 10th week), occurs in the C2 treatment almost every week. This is because the higher the intensity of organic liquid fertiliser, the more nutrients are located in the soil. Thus, the nutrients were optimally supplied for the vegetative growth of coffee plants (height plant). In addition to providing nutrients for the staple plants, the application of organic materials also encourages the improvement of soil health and the activity of microbial in the soil. Increasing the activity of the soil microbial contributes to increase the level of growth regulator, if present alongside with the nutrients in the soil, can simultaneously increase the growing and production of the coffee plants [23].

Table 3 also indicates that all treatments gave a significant effect on the canopy diameter rate in the 2nd week and the 4th week. These results are related to the time of soil fertilisation used in this study. Fertilisation was carried out at the 0 week for the treatment of C1 and C2, then continues to the 2nd week for the C2 treatment. The fertilisation results can be immediately seen in two weeks. N contained in manure and organic materials can donate a number of N nutrients for crop growth, especially the plant heading [24]. The canopy diameter provides a strong direct influence on the production of coffee. Coffee plant with wide canopy diameter has wide area of roots.

| Treatment | 0  | 2  | 4  | 6  | 8  | 10 | 12 |
|-----------|----|----|----|----|----|----|----|
| K0        | 0  | 1.40 | 3.40 | 6.20 | 8.53 | 10.33 | 13.13 |
| C1        | 0  | 2.00 | 3.87 | 6.87 | 8.80 | 13.33 | 15.87 |
| C2        | 0  | 3.27 | 5.27 | 7.27 | 9.60 | 15.47 | 18.07 |
| p-value (Sig) | -  | 0.079 | 0.109 | 0.525 | 0.712 | 0.112 | 0.256 |

Note: *Significant (p<0.05)

According to Table 5, the number of buds increases consistently in each week, especially in the C2 treatment. The coffee buds grows rapidly as the nutrients was flowing from the ground into the bud [25]. Table 5 showed that the number of buds on the K0 treatment was lower that of after soil fertilisation treatments. However, when comparing between C1 and C2 treatments, the number of buds from the C2 treatment was higher than that of the C1 treatment. This result indicating that the amount of liquid fertiliser used affects the number of buds. A more intense addition of liquid fertiliser causes an increase on the nutrients available in the soil for the plant. Therefore, the number of the coffee buds increased. Although buds is usually trimmed for the maintenance of coffee plants, however, the thrived buds can be a material cutting for the plant breeding of coffee plants [25].

4. Conclusions
This study confirmed that providing the liquid fertiliser on the soil of coffee plants have positive impact on improving the quality of the soil as well as the growth of the plants. After addition of the liquid fertilisers, a significant effect to the plant height rate (in the 2nd week) and the canopy diameter rate (in the 2nd and 4th week) was observed. The number of buds in coffee plants is also affected by the addition of the liquid fertilisers. The significant effect of giving liquid fertiliser occurs only in the early weeks after soil fertilization. This is possibly due to the nature of and the contents of liquid fertiliser itself, which are much easier to use by plant than that of the solid fertiliser. Therefore, adding the liquid fertiliser routinely could be more effective in increasing the growth and the production of the coffee plant continues.
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