Effectiveness of giving organic fertilizer with different doses on the growth and yield of red ginger (*Zingiber officinale* var Rubrum)

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**Abstract.** Red ginger has not been cultivated intensively, so that there was a production decrease in 2018 of 4.24% from 2017. The increase in red ginger cultivation can be done by fertilizing organic fertilizers. This study aimed to obtain an effective dose of organic fertilizer in increasing the growth and yield of red ginger. From March to October 2020, the research was conducted at the UNS experimental area in Wonorejo Village, Jatiyoso, with an altitude of 778 masl. The study was conducted using a randomized complete block design (RCBD) with 1 factor and 5 treatments it is P0 (control), P1 (dose 1 kg. m⁻²), P2 (dose 1.5 kg. m⁻²), P3 (dose 2 kg. m⁻²), and P4 (dose 2.5 kg. m⁻²). The results showed that the application of organic fertilizer had an effect. The effective dose of organic fertilizer in increasing the growth and yield of red ginger was a dose of 2 kg. m⁻².

1. Introduction

Red ginger is one type of rhizome medicinal plant widely used by people as traditional and herbal medicine. The use of rhizome medicinal plants has been known for a long time with the development of the herbal medicine industry. With the fast development of the food and health drinks industry, traditional and herbal medicines made from red ginger are not compensated by the rapid production of raw materials. Generally, the productivity of red ginger in Indonesia is still relatively low. In 2017-2018, ginger experienced a decrease in yield as big as 4.24%. Ginger yields in 2018 decreased to 207,411,867 kg. ha⁻¹ compared to the previous year that reached 216,586,662 kg. ha⁻¹. During the 2014-2018 period, ginger productivity reached 0.98% per year [1]. The decline in ginger yields in Indonesia because it has not been cultivated intensively.

The main problem of ginger cultivation in Indonesia is the use of inorganic and organic fertilizers that have not been balanced and efficient [2]. Indonesia's farmers mostly use inorganic fertilizers in cultivation. The use of inorganic fertilizers that are carried out continuously will decrease environmental quality, such as soil hardening. One of the efforts to improve the environment and increase the yield of red ginger is by giving organic fertilizer. Organic fertilizers can improve soil conditions because good soil conditions will help grow and yield red ginger plants. This study aimed to determine the effectiveness of organic fertilizer application and obtain the optimal dose of fertilizer for increasing the growth and yield of red ginger.
2. Materials and methods
The research was conducted in the UNS experimental field in Wonorejo Village, Jatiyoso District, Karanganyar Regency, Central Java, in March-August 2020. The analysis activities were carried out at the Laboratory of Ecology and Plant Production Management and the Laboratory of Chemistry and Soil Fertility, Faculty of Agriculture, UNS. This research was a field experiment by fertilizing and observing red ginger plants. The research design used a Randomized Completely Block Design (RCBD). In this study, there were 5 treatments and repeated 5 times so that there were 25 experimental units. The treatments used in this study were:

T0 = Control (Without organic fertilizer)
T1 = Organic fertilizer dose of 1 kg. m⁻²
T2 = Organic fertilizer dose of 1.5 kg. m⁻²
T3 = Organic fertilizer dose of 2 kg. m⁻²
T4 = Organic fertilizer dose 2.5 kg. m⁻²

There were 25 treatment plots, and each was 1 m². The plots were made using a rope and given a treatment mark as a marker. The ginger plants in the plots were randomly selected as many as three plants and used as samples. Fertilization is done by sprinkling fertilizer around the red ginger plant with an appropriate dose of fertilizer in each plot. Growth observations were carried out once a month, with observation variables included plant height, number of leaves, and number of tillers.

Meanwhile, the harvesting observation is carried out simultaneously. The observation variables were rhizome size (length, width, thickness), fresh weight of rhizome per clump and plot, rhizome storage weight per clump and plot, and fresh straw and dry straw plant weight. Data analysis was performed using analysis of variance (ANOVA) to determine the effect of treatment on variables. Then, data were continued with DMRT (Duncan Multiple Range Test) at the level of 5% to compare the mean of each treatment.

3. Results and discussion
3.1. General condition of the land
The research was conducted in the research area of the Faculty of Agriculture, Sebelas Maret Surakarta University located in Wonorejo Village, Jatiyoso, Karanganyar. The research location is located at coordinates 7°43'23" SL 111°5'31" EL. The research is situated at an altitude of 778 masl and tropical climate. Ginger plants can grow at an altitude of 0-1500 masl. The optimal temperature for ginger plants ranges from 25-30°C [3].

The type of soil found in the research land is latosol soil. Latosol soils generally have relatively low levels of nutrients and organic matter [4]. Laboratory tests carried out that latosol soil has a low N, P, K, low C/N ratio, and a slightly acidic pH (Table 1). Latosol soil is a marginal soil with a low fertility rate, so it is necessary to add organic matter to improve fertility and productivity [5]. Table 1 shows the results of the initial soil analysis of the research land.

3.2. Plant height
Plant height is one of the most important plant growth variables used to determine the effect of the environment or treatment on plants. Nitrogen (N) can influence plant height. Nitrogen has a major role in stimulating overall growth, primarily stems and leaves [6]. At high plants, red ginger has a different average in each treatment (Table 2). The T3 treatment had a high average plant height, while the P0 treatment had a low average plant height compared to other treatments.

Increasing the dose of cow manure will further increase the length of the cucumber [7]. The giving organic fertilizers can provide macro and micronutrients that plants need to increase plant growth. The availability of macronutrients enough for plants can increase the plant height, and optimal nitrogen uptake can support plant growth [8]. Red ginger plants grow quickly in the vegetative phase and decrease when entering rhizome development [9].
Table 1. Initial soil analysis.

| No | Variable         | Value  | Explanation       |
|----|------------------|--------|-------------------|
| 1  | pH Land          | 6.14   | Slightly Acid     |
| 2  | P Total          | 0.02 % | Low               |
| 3  | K Total          | 0.06 % | Low               |
| 4  | N Total          | 0.21 % | Medium            |
| 5  | C Organic        | 1.80 ppm | Low            |
| 6  | C/N Ratio        | 8.57   | Low               |
| 7  | Water Capacity   | 7.12 % | Low               |
| 8  | Porosity         | 55.45  | Good              |
| 9  | Particle density | 2.11 g/cm³ | Low       |
| 10 | Bulk density     | 1.17 g/cm³ | -           |
| 11 | Soil organic matter | 3.10  | Low               |

Source: Result of Analysis of the Soil Science Laboratory of Agriculture Faculty Sebelas Maret University Surakarta 2020.
Description: Award according to BALITTANAH in 2009.

3.3. Number of leaves
Leaves are where the photosynthesis process takes place and also play a role in capturing sunlight. Good plant growth can be shown by the number of leaves produced. The more leaves on the plant indicate that photosynthesis is going well. Table 2 showed that T0 had a low number of leaves while the T3 treatment had a high number of leaves per clump. The number of leaves is influenced by the environment and the availability of nutrients in the growing place. Plants that get enough nutrients, especially nitrogen, will form leaves that are high in chlorophyll for photosynthesis [10]. Photosynthate will be formed and allocated to the plant's vegetative parts, such as leaves and stems. Plants that produce high photosynthesis will have many leaves [11]. Photosynthate allocation will be transferred to the rhizome when the red ginger plant enters the rhizome development phase.

3.4. Number of tillers
Tillers are shoots that grow at the top of the rhizome and become new red ginger plants' tillers. Table 2 showed that the number of tillers produced in each treatment was different. T3 had the highest number of tillers, and T0 had the lowest tillers compared to other treatments. The formation of tillers is influenced by nitrogen and phosphorus elements. Element P is needed at the beginning of growth in spurring the additional tillers, and element N plays a role in stimulating the number of tillers [12]. The high and low availability of nutrients will affect the plant's metabolism. Red ginger plants will show an optimal growth response when given sufficient nutrients [13]. The number of tillers formed is the result of the photosynthesis process that produces photosynthesis. The amount of photosynthate will affect the red ginger plant in generating many new tillers [11].

Table 2. Effect of organic fertilizer application on plant height, number of leaves, and number of tillers.

| Treatment  | Plant Height (cm) | Number of Leaves (leaves) | Number of Tillers |
|------------|-------------------|---------------------------|-------------------|
| T0 (Control) | 53.04 a           | 82.33 a                    | 5.27 a            |
| T1 (Dose 1 kg. m⁻²) | 57.29 ab         | 99.53 ab                   | 6.20 ab           |
| T2 (Dose 1.5 kg. m⁻²) | 60.95 ab         | 117.79 ab                  | 6.33 ab           |
| T3 (Dose 2 kg. m⁻²) | 65.38 b          | 136.13 b                   | 7.07 b            |
| T4 (Dose 2.5 kg. m⁻²) | 62.04 b          | 125.66 b                   | 6.87 b            |

*The numbers in the column followed by the same letter show no real difference in the DMRT level of 5%
3.5. Fresh straw weight
The fresh weight of straw indicates the effectiveness of plants in absorbing water and nutrients. Treatment P0 had the lowest straw fresh weight compared to other treatments (Table 3). Plants that were not fertilized generally had a lower fresh weight compared to plant fertilized [11]. The fresh weight of straw is related to the accumulation of photosynthate and the water content in the plant. The weight will increase if plant growth continues. In Table 3, the fresh straw weight did not significantly differ in all treatments because red ginger plants were harvested at nine MAP. At that age, the red ginger plant has passed an active vegetative growth phase so that most of the photosynthetic results will be allocated to the rhizome [14]. Red ginger plants are harvested in wilted and dry conditions, so the water content is reduced, resulting in a low fresh straw weight.

3.6. Dry straw weight
The plant dry weight balances CO₂ uptake (photosynthesis) and CO₂ (respiration) released by plants. If respiration is greater than photosynthesis, it will decrease the straw’s dry weight [15]. Table 3 shows that the dry weight of the red ginger straw was not significantly different in each treatment. In each treatment, there was no difference in water absorption and photosynthate accumulation in plants. In addition, red ginger plants cannot carry out photosynthesis anymore when they enter the age of 7 MAP until harvest so that the accumulation of biomass in the stems and leaves is low.

Table 3. Effect of organic fertilizer application on the fresh and dry straw weight.

| Treatment          | Fresh straw weight (g) * | Dry straw weight (g) * |
|--------------------|---------------------------|------------------------|
| T0 (Control)       | 27.77                     | 4.66                   |
| T1 (Dose 1 kg. m⁻²) | 28.92                     | 5.20                   |
| T2 (Dose 1.5 kg. m⁻²)| 38.88                     | 6.45                   |
| T3 (Dose 2 kg. m⁻²)| 48.11                     | 7.95                   |
| T4 (Dose 2.5 kg. m⁻²)| 41.91                     | 6.58                   |

3.7. Rhizome size (length, width and thickness)
The size of the red ginger rhizome is influenced by external factors, namely the number of nutrients and water for plants. The result showed that it did not significantly differ in length, width, or thickness (Table 4). The not optimal nutrient will not help the rhizome development process. A dry environment and lack of water can also disrupt the growth and rhizomes development [16]. Rhizome-producing plants such as red ginger require quite a lot of nutrients. Table 4 showed that T4 treatment T4 has length, width, and thickness were higher than the other treatments. Red ginger plants that can absorb the elements N, P, and K will have a larger rhizome size. K is an essential factor for ginger productivity and plant physiological processes, such as enzyme activity, photosynthesis, transport of photosynthetic products, nutrients and water, and metabolism of starch and protein [17].

Ginger plants that grow and can adapt well to the environment will produce large rhizomes. The internal factors, like variety, also influence red ginger rhizome size. Red ginger has a red rhizome, and the size is much smaller than the emprit ginger and elephant ginger [18]. It also causes the size of the red ginger rhizomes produced in this study to be small-sized.

Table 4. Effect of organic fertilizer application on red ginger rhizome size.

| Treatment          | Rhizome Size                          |
|--------------------|---------------------------------------|
|                    | Length (cm) * | Width (cm) * | Thickness (cm) * |
| T0 (Control)       | 14.42        | 6.21 a       | 2.43           |
| T1 (Dose 1 kg. m⁻²)| 15.67        | 6.95 ab      | 2.52           |
| T2 (Dose 1.5 kg. m⁻²)| 16.51        | 7.01 ab      | 2.61           |
| T3 (Dose 2 kg. m⁻²)| 17.00        | 7.27 ab      | 2.83           |
| T4 (Dose 2.5 kg. m⁻²)| 17.91        | 7.72 b       | 2.84           |

*The numbers in the column followed by the same letter show no real difference in the DMRT level of 5%.
3.8. The weight of fresh rhizome

Fresh weight is the primary indicator of red ginger yield. The fresh weight of the rhizomes was obtained by weighing the rhizomes that had been cleaned of roots and adhering to soil. The fresh weight of the rhizome has different results. The T3 treatment had higher yields of fresh rhizome weight 303.07 g (Table 5). The application of organic fertilizer provides better availability of nutrients, and it can also improve soil properties. Good soil conditions cause plant roots to develop and absorb nutrients and water optimally for plant growth and production [19].

Red ginger plants require high nutrients to increase their productivity of red ginger. The availability of sufficient nutrients, especially elements of N and K, can stimulate the increase in fresh weight of ginger rhizome [20]. In Table 5, the rhizome's fresh weight in the P4 treatment had a lower yield than the P3 treatment. K fertilization combined with N increased the yield and quality of turmeric rhizome [21]. The yield of rhizomes will increase with increasing doses of K fertilizer, but the addition of excess K elements will reduce yields [21]. Absorption of excess nutrients can be toxic to plants and cause the rhizomes not to gain weight [11].

| Treatment         | The weight of fresh rhizome (g) * |
|-------------------|-----------------------------------|
| T0 (Control)      | 185.66 a                          |
| T1 (Dose 1 kg. m⁻²)| 192.00 a                          |
| T2 (Dose 1.5 kg. m⁻²)| 192.53 a                        |
| T3 (Dose 2 kg. m⁻²)| 303.07 b                          |
| T4 (Dose 2.5 kg. m⁻²)| 193.13 a                        |

*The numbers in the column followed by the same letter show no real difference in the DMRT level of 5%.

3.9. The weight of rhizome storage

The weight of rhizome storage is the weight of ginger yield production that is ready to be marketed. The rhizome storage weight was obtained by drying the fresh rhizomes for seven days at room temperature (22-26°C). Drying of red ginger rhizomes is done by storing red ginger in an open space without direct sunlight. The value of storage weight is influenced by storage time and temperature [22].

| Treatment         | The weight of rhizome storage (g) * |
|-------------------|------------------------------------|
| T0 (Control)      | 158.06 a                           |
| T1 (Dose 1 kg. m⁻²)| 166.06 a                           |
| T2 (Dose 1.5 kg. m⁻²)| 169.13 a                          |
| T3 (Dose 2 kg. m⁻²)| 269.27 b                           |
| T4 (Dose 2.5 kg. m⁻²)| 176.67 a                         |

*The numbers in the column followed by the same letter show no real difference in the DMRT level of 5%.

The rhizome storage weight of red ginger showed significant results in the P3 treatment both per clump and per plot (Table 6). The application of organic fertilizers can change soil conditions to increase rhizomes development [23]. Red gingers have been cleaned of roots, soil, and other impurities attached to the rhizome before being stored. Soil that is still attached to the rhizome will cause the shrinkage of the rhizome [24]. The shrinkage of the red ginger rhizome indicates a decrease in water content in the rhizome due to the evaporation process of ginger during storage. The storage
weight of the rhizomes (Table 6) is always lower than the fresh weight of the rhizomes (Table 5). The stored rhizomes absorb or release water until the moisture content reaches equilibrium with the surrounding air humidity [25]. The higher the shrinkage of the rhizome indicates that the food reserves in the rhizome are getting lower [26].

4. Conclusion
The application of organic fertilizer at a dose of 2 kg.m⁻² based on analysis of variance and further tests showed that all variables had high yields, except for rhizome size. In conclusion, the effective dose of organic fertilizer for the red ginger growth and yield was organic fertilizer with a dose of 2 kg.m⁻².

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