Substitution of ZA with organic fertilizer on monoculture red ginger

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Abstract. This research was aimed to get the role of nitrogen and the role of substitution synthetic nitrogen with organic nitrogen on red ginger cultivation. The research was conducted from March to September 2020 at Wonorejo, Jatiyoso, Karanganyar. The research was carried out using randomized complete block design (RCBD) with 1 factor, 4 treatments, and 6 repetitions namely P0 (Control), P1 (0.3 ton ha⁻¹ ZA), P2 (0.15 ton ha⁻¹ ZA + 1.99 ton ha⁻¹ organic fertilizer), and P3 (3.98 ton ha⁻¹ organic fertilizer). The data will be analyzed using analysis of variance and continued with a DMRT level of 5% if there is a significant difference.

The result showed that the substitution of ZA (Zwavelzure Ammonium) fertilizer with organic fertilizer increased the yield of red ginger cultivation. The use of organic fertilizer with 3.98 ton ha⁻¹ increased the number of leaves, the number of saplings, fresh and dry strawweight, fresh and stored rhizomes weight, and the length of rhizomes.

1. Introduction
Red ginger (Zingiber officinale var. rubrum) is one of the highest export commodities of spices in Indonesia which plays an important role in state revenue. The demand for ginger has increased every year both domestically and abroad [1]. The increasing demand for red ginger commodities is not balanced by the optimal cultivation resulting in the production and quality of red ginger decreased every year. The area of ginger planted in Indonesia in 2017 was 10,675.97 ha with a total production of 216,586.662 tons. In 2018 the planted area and total production decreased with the planted area becoming 10,205.03 ha with a total production of 207,411.867 tons.

One of the main factors is the use of inorganic fertilizers such as Zwavelzure Ammonium. ZA (Zwavelzure Ammonium) is a nitrogen fertilizer that is often used by farmers in plant cultivation because it contains essential nutrients, such as nitrogen and sulfur. The negative impact of using ZA fertilizer is that it can reduce soil pH drastically so it can affect nutrient absorption by plants [2]. One of the solutions to reduce the use of inorganic fertilizers is to substitute the use of ZA by using organic fertilizers such as manure.

The use of manure is recommended for ginger cultivation as a substitute for ZA to improve the quality and yield of red ginger [3]. Organic fertilizers play an important role in increasing the physical, chemical, and biological fertility of the soil. Organic fertilizer in the form of cow dung is used as a
substitute for chemical fertilizers because the ingredients are easy to obtain, have a high nitrogen content, and nutrients can be utilized by plants more quickly [4].

2. Methods
The research was conducted from March to September 2020 at Pelem Hamlet, Wonorejo Village, Jatiyoso District, Karanganyar Regency, the laboratory analysis is located at the Chemistry and Soil Fertility Laboratory, which is located at the Faculty of Agriculture, Sebelas Maret University, Surakarta. The materials used in this study were red ginger, ZA (Zwavelzure Ammonium) fertilizer, and manure or organic fertilizer with the brand Rojo Koyo. The tools used in this research are a digital scale, ruler, newspaper, oven, pencil, and ballpoint pen. The research was carried out using a randomized completely block design (RCBD) with 1 factor, consisting of 4 levels of treatment namely P0 (0 ton ha⁻¹), P1 with a dose of 100% ZA fertilizer (0.3 ton ha⁻¹ ZA), P2 with a dose of 50% ZA fertilizer and 50% manure (0.15 ton ha⁻¹ ZA + 1.99 ton ha⁻¹ organic fertilizer), and P3 with a dose of 100% manure (3.98 ton ha⁻¹ organic fertilizer). Six repetitions were carried out to obtain 24 experimental units. The variables observed were initial soil analysis, plant height, number of leaves, number of saplings, fresh strawweight, dry strawweight, fresh weight of rhizomes, stored rhizomes weight, and the size of rhizomes such as length, width, and thickness of rhizomes. The data will be analyzed using analysis of variance and if there is a significant difference, it will be continued with the DMRT (Duncan Multiple Range Test) levels of 5%.

3. Result and discussion
3.1. General condition of the land
The research is located at 7°43'22"SL 111°05'3" EL with an altitude of 772 masl. The field used in this research is a monoculture red ginger plantation. Ginger plants are very suitable to be planted in tropical climates with temperatures ranging from 20-35°C [5]. The type of soil found in this research area is latosol soil. Latosol is a type of soil that undergoes intensive weathering and leaching which causes the cation exchange capacity and the nutrients contained tend to be low. According to the laboratory tests carried out (Table 1) that latosol soil has a slightly acidic pH, which is in the range of 4.5-6.5. Latosol is marginal soil with low organic matter and nutrient content so that latosol needs to be added with organic materials in order to increase fertility and land productivity [6].

| Variable        | Value | Explanation     |
|-----------------|-------|-----------------|
| N total         | 0.21% | Medium          |
| P total         | 0.02% | Low             |
| K total         | 0.06% | Low             |
| C-Organic       | 1.80 ppm | Low          |
| Soil pH         | 6.14 | Slightly Acid   |
| C/N Ratio       | 8.57  | Low             |
| Porosity        | 44.55 % | Low        |
| Soil Organic Matter | 3.10 % | Low        |
| Water Capacity  | 7.12  | Low             |

Source: Soil analysis from Soil Science Laboratory of Sebelas Maret University Surakarta 2020.
Description: Award according to the Indonesian Soil Research Institute in 2009.
3.2. Observation result

Table 2. Result of DMRT at 5% level on growth variables

| Observation Variable | P0 (control) | P1 (ZA 100%) | P2 (ZA 50% + Organic 50%) | P3 (Organic 100%) |
|----------------------|--------------|--------------|---------------------------|-------------------|
| Plant height (cm)    | 57.48 a      | 75.83 b      | 64.30 ab                  | 69.93 ab          |
| Number of leaves (sheet) | 59.80 a     | 130.39 b     | 107.22 b                  | 164.33 c         |
| Number of sapling    | 4.11 a       | 7.83 bc      | 6.78 b                    | 9.33 c           |
| Fresh straw weight (g) | 12.04 a     | 23.09 bc     | 18.83 ab                  | 29.66 c          |
| Dry weight of the straw (g) | 5.20 a   | 9.43 bc      | 5.58 ab                   | 10.31 c          |

Note: Numbers followed by the same letter in the same line show no significant difference at 5% level DMRT.

Table 3. Result of DMRT at 5% level on yield variables.

| Observation Variable | P0 (control) | P1 (ZA 100%) | P2 (ZA 50% + Organic 50%) | P3 (Organic 100%) |
|----------------------|--------------|--------------|---------------------------|-------------------|
| Fresh rhizomes weight (g)   |              |              |                           |                   |
| (a) Per clump         | 93.77 a      | 163.94 ab    | 146.15 ab                 |                  |
| (b) Per plot          | 580.00 a     | 1012.17 ab   | 959.00 ab                 | 1256.67 b        |
| Stored rhizomes weight (g) |            |              |                           |                   |
| (a) Per clump         | 74.60 a      | 149.55 ab    | 118.71 ab                 | 182.43 b         |
| (b) Per plot          | 490.83 a     | 926.50 ab    | 829.17 ab                 | 1134.67 b        |
| Rhizome size (cm)     |              |              |                           |                   |
| (a) Length            | 11.41 a      | 13.16 ab     | 13.18 ab                  | 14.77 b          |
| (b) Width             | 7.00 a       | 7.05 a       | 7.08 a                    | 8.00 a           |
| (c) Thickness         | 2.91 a       | 3.32 a       | 3.91 a                    | 4.81 a           |

Note: Numbers followed by the same letter in the same line show no significant difference at 5% level DMRT.

3.2.1. Plant Height. Table 2 shows that based on the results of DMRT analysis 5% treatment P1 (0.3 ton ha\(^{-1}\) ZA) gave significantly different results to red ginger plant height at treatment P0 (control). The nitrogen content of ZA can meet the needs of plants in the phase of plant height growth. Nitrogen availability in plants with the right dose will increase plant growth and yield. Nutrients contained in ZA can be available more quickly to plants so that nutrient needs can be fulfilled faster. ZA was easily soluble in water so that the available nutrients can be absorbed by plants more quickly [7].

Treatment P1 was not significantly different from treatment P2 (0.15 ton ha\(^{-1}\) ZA + 1.99 ton ha\(^{-1}\) organic fertilizer) and P3 (3.98 ton ha\(^{-1}\) organic fertilizer). The main essential nutrient supplied by the P1, P2, and P3 treatments was nitrogen. Nitrogen nutrient is an essential nutrient that influences plant growth, especially plant height. Sufficient nitrogen needs can encourage plants to grow higher than other treatments. The research on rice plants proves that there is an increase in plant height which is a response to the addition of N fertilizer [8]. Nitrogen is needed to stimulate growth, especially in the stems, branches, and leaves. Nitrogen content can stimulate vegetative growth of plants [9].

3.2.2. Number of leaves. Based on the results of the analysis of variance with the DMRT 5% test (Table 2), it showed that P1 (0.3 ton ha\(^{-1}\) ZA), P2 (0.15 ton ha\(^{-1}\) ZA + 1.99 ton ha\(^{-1}\) organic fertilizer), and P3 (3.98 ton ha\(^{-1}\) organic fertilizer) were significantly different from the P0 treatment (0 ton ha\(^{-1}\)). The content of essential nutrients in ZA and organic fertilizer is able to meet the needs of plants in increasing the number of leaves of ginger plants, especially nitrogen nutrients. Nitrogen is an essential element for metabolic processes in plants. Nitrogen plays an important role in the vegetative growth of plants. The optimum amount of nitrogen can increase the photosynthesis process [10].

The P3 treatment was significantly different from the P0, P1, and P2 treatments and produced the highest number of leaves among all treatments. The application of cow manure was able to increase biological activity and the availability of nutrients in the soil so that it could increase the number of leaves of ginger plants [11]. Cow manure contains a number of nutrients, both macro and micronutrients,
as well as organic matter that is very beneficial for the availability of nutrients in the soil [12]. Organic fertilizers contain high organic matter so they can improve the structure and properties of the soil. A good soil structure will reduce the mechanical resistance of the soil, causing roots to develop more easily and could also easily absorb available nutrients. Well absorbed nutrients resulting in optimal growth in ginger plants so more leaves can grow.

3.2.3. Number of saplings. Table 2 shows the results of the analysis DMRT at 5% level that the P3 (3.98 ton ha$^{-1}$ organic fertilizer) significantly different from P0 (0 ton ha$^{-1}$) and P2 (0.15 ton ha$^{-1}$ ZA + 1.99 ton ha$^{-1}$ organic fertilizer) treatments and also produced the highest number of saplings. Giving organic fertilizers larger doses can meet the needs of plants in increasing the number of tillers, in the P2 treatment, the absorption of nutrients in plants is not optimal because two types of fertilizers have different functions in supplying nutrients. The combination of ZA and manure was not significantly different in the growth of rice plants. ZA and manure are different in supplying nutrients to plants where ZA can be available faster than manure so that the nutrient could not be optimally absorbed by plants [13]. The content of available macronutrients can meet the optimum needs of plants. Not only macronutrients but micronutrients also play an important role in increasing plant productivity.

The P3 treatment was not significantly different from the P1 treatment (0.3 ton ha$^{-1}$ ZA) on the number of saplings, this was due to the presence of essential nutrients, especially nitrogen which is important for plant vegetative growth. Nitrogen nutrients have a very important role in increasing the number of saplings. The nitrogen element will increase the rate of photosynthesis so that photosynthetic content will increase plant growth [14].

3.2.4. Fresh straw weights. The results of the analysis DMRT with a level of 5% (Table 2) showed that the P1 treatment (0.3 ton ha$^{-1}$ ZA) was not significantly different from the P3 treatment (3.98 ton ha$^{-1}$ organic fertilizer) but the two treatments were significantly different from the P0(control). This is because the needs of plants in the P1 and P3 treatments can be fulfilled due to the sufficient nutrient content and also increase the rate of photosynthesis. Photosynthesis that goes well will be followed by an increase in the weight of the straw. The strawweight has a close relationship with the availability of nutrients because plants grow well if the required nutrients are available in sufficient quantities which will be optimally absorbed by the plant [15].

The P3 treatment was significantly different from P0 (0 ton ha$^{-1}$) and P2 (0.15 ton ha$^{-1}$ ZA + 1.99 ton ha$^{-1}$ organic fertilizer) and produced the highest fresh strawweight. The results showed that the application of manure could increase the fresh weight of plants. The macro and micronutrients contained in manure have been proven to increase the number of leaves produced so that the photosynthesis process increases [16]. The higher the rate of photosynthesis of a plant will increase the weight of the plant straw produced by the ginger plant.

3.2.5. Dry weight of the straw. The results of the DMRT test (Table 2) showed that P3 (3.98 ton ha$^{-1}$ organic fertilizer) was significantly different from the P0 (control) and P2 (0.15 ton ha$^{-1}$ ZA + 1.99 ton ha$^{-1}$ organic fertilizer). The dry weight of straw is related to the accumulation of biomass and the results of photosynthesis in plant organs. The availability of sufficient nutrients to meet plant needs causes plant growth to take place optimally [17]. P3 was not significantly different from P1 (0.3 ton ha$^{-1}$ ZA). This is caused by the content of essential nutrients in manure and ZA fertilizer can stimulate plant growth so the dry weight of the straw produced is high. Nitrogen can stimulate vegetative growth of plants such as plant height, number of leaves, and number of tillers. The increase in plant weight is also influenced by the height of a plant and the number of leaves that undergo photosynthesis. Increasing plant height, number of leaves, number of tillers, and other organs in plants will result in high dry weight of the straw. Treatment P1 and P3 resulted in high plant height, number of tillers, and number of leaves so that it also affected the dry weight of the straw.

The highest dry weight of the straw was found in the P3 treatment because manure contained essential nutrients N, P, and K which can help the development and growth of plants such as increasing plant
height, number of tillers, and number of leaves and can optimize the process of photosynthesis so as to produce photosynthate. Therefore, the total dry weight of the straw will increase [18]. The provision of N, P, and K elements can increase the rate of photosynthesis so that it can stimulate vegetative growth. An increase in the amount of these nutrients will produce protein in large quantities so that the growth of plant tissue and its weight increases [19].

3.2.6. *Fresh rhizomes weight.* The results of the analysis of variance with the DMRT at 5% level (Table 3) showed that the P3 treatment (3.98 ton ha\(^{-1}\) organic fertilizer) was significantly different from the P0 treatment (0 ton ha\(^{-1}\)). In order for ginger plants to grow optimally so they can produce high rhizome weights, they require enough nutrients to supply the needs of the ginger plant. P3 treatment was not significantly different from P1 (0.3 ton ha\(^{-1}\) ZA) and P2 (0.15 ton ha\(^{-1}\) ZA + 1.99 ton ha\(^{-1}\) organic fertilizer); the three treatments provided additional nutrient intake through fertilizer on ginger plants. The formation of ginger rhizomes requires sufficient nutrients to produce rhizomes with optimal weight. A good and proper composition of planting media can help the rhizome to grow well [20].

The high yield of fresh rhizomes weighed in P3 treatment happened because during the process of forming ginger, rhizomes require a lot of nutrients in order to produce high-weight rhizomes. Rhizome growth not only requires macro nutrients but also requires micro nutrients [21]. Organic fertilizers provide various benefits for plant growth and development. Organic fertilizers provide macro and micro nutrients needed by plants. The increasing application of organic fertilizers will increase soil fertility, increase organic matter in the soil and improve soil physical conditions.

3.2.7. *Stored rhizomes weight.* The results of the analysis of variance based on the DMRT test with a level of 5% (Table 3) on the variable stored rhizomes weight per clump and per plot showed that P3 (3.98 ton ha\(^{-1}\) organic fertilizer) was significantly different from the P0 (0 ton ha\(^{-1}\)). The content of nutrients that can be supplied by organic fertilizers in the form of macro and micro nutrients such as elements of N, P, K, Ca, Mg and also can stabilize pH of soil, improve chemical properties in the soil so that it can stimulate the growth of ginger plants for the better, improve morphological characters and yields from ginger[22]. P3 treatment gave the best results on stored rhizomes weight per clump and per plot. The nutrient content of N, P, and K when given in sufficient conditions can play a positive role in ginger planting such as helping the formation of protein and carbohydrates and also can help root development. The content of macro nutrients such as N, P, and K contained in manure can play a role in increasing the yield of red ginger plants.

Treatments P1 (0.3 ton ha\(^{-1}\) ZA), P2 (0.15 ton ha\(^{-1}\) ZA + 1.99 ton ha\(^{-1}\) organic fertilizer), and P3 had the same effect on stored rhizomes weight. The fresh weight of rhizomes will affect the weight of rhizomes that have undergone storage [23]. The higher the fresh weight of the rhizomes per clump and per plot, the stored weights also tend to be high. On the other hand, the lower the fresh weight of the rhizomes, the lower the stored weights will be. In treatments P1, P2, and P3 the fresh weight of the rhizome was quite high so that after being stored, the rhizome's weight was still high.

3.2.8. *Rhizome size.* The results of the variance test with DMRT at the 5% level (Table 3) showed that the largest rhizome size was found in P3 treatment (3.98 ton ha\(^{-1}\) organic fertilizer) which produced the highest rhizome length, width and thickness among all treatments. This is caused by both macro and micro nutrients contained in organic fertilizers that can meet plant needs so as to increase the photosynthesis process in plants. The increasing photosynthate can increase the size of the ginger rhizome [24]. The use of organic fertilizers from manure containing N, P, K elements which are needed by plants also can improve the physical, chemical and biological properties of the soil. The content of organic matter in manure is not only in charge of providing nutrients but also useful for improving the physical properties of the soil so that it can facilitate roots and rhizomes to grow and develop properly and optimally [25].

The results of the DMRT test at the 5% level (Table 3) also showed that the width and thickness of the rhizome at various fertilization treatments were not significantly different. Ginger rhizomes grow in
various sizes from one clump to another. Each part of the rhizome of the ginger plant will be formed at different times and shapes so that it produces a variety of shapes from one rhizome to another each time [26].

4. Conclusion
Based on the results of the study of substitution of ZA with organic fertilizer on monoculture red ginger, it can be concluded that replacement of nitrogen fertilizer ZA 0.3 ton ha\(^{-1}\) ZA with organic fertilizer 3.98 ton ha\(^{-1}\) organic fertilizer can increase the yield of red ginger better by 24%. The use of organic fertilizer as much as 3.98 ton ha\(^{-1}\) organic fertilizer can increase the growth and yield of red ginger in the form of number of tillers, number of leaves, weight of fresh and dry straw, fresh weight of rhizome per clump and per plot, rhizome storage weight per clump and per plot, and rhizome length.

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