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Application of ZA Fertilizer on Growth and Production of Red Ginger (*Zingiber officinale* var. Rubrum)

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Abstract
Red ginger is one of the export commodities of spices in Indonesia, and it plays a significant role in the country's foreign exchange earnings. To meet market demand, ginger cultivation must be fertilized to increase production. ZA fertilizer for plants serves to stimulate vegetative growth. This study aims to determine whether the response of red ginger to the application of ZA fertilizer has a significant effect on the development and yield of red ginger and to obtain the optimum dose of ZA fertilizer for the development and yield of red ginger. This research was carried out in March-August 2021 until it was completed in Pelem Hamlet, Wonorejo Village, Jatiyoso District, Karanganyar Regency, Central Java Province with coordinates 7°43'24.7" S 111°05'31.2" E. The experimental design was a Completely Randomized Complete Block Design (RCBD). This study consisted of 4 treatments with 6 replications so that 24 experimental units were obtained, while the treatments in this study were as follows: P0: Control without ZA fertilizer, P1: Treatment 225 Kg ZA/ha or 22.5 g/m2, P2: Treatment 450 Kg ZA/ha or 45 g/m2, and P3: Treatment 675 Kg ZA/ha or 67.5 g/m2. The results showed that ZA fertilizer had no significant effect on all other parameters. Still, on growth observations, P2 treatment with a dose of 450 Kg ZA/ha can significantly affect the increase in the number of plants per plot. The dry weight of the stover was strongly correlated with the weight of fresh rhizomes with correlation values (r) 0.508.

Keywords: correlation; fertilizer dose; red ginger; regression ZA

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Introduction

Red ginger is a rhizome plant that grows in lowland areas to mountainous areas with an altitude of up to 1500 meters above sea level [1]. Red ginger is one of the export commodities of spices in Indonesia, and it plays a significant role in the country's foreign exchange earnings. Red ginger is exported as fresh red ginger, dried red ginger, processed fresh red ginger, and essential oils. The prospect of red ginger development in Indonesia is still bright, especially for exports, the traditional medicine industry, the food and beverage industry, and cooking spices. The multipurpose use of red ginger causes the number of market demands to increase along with the increase in world demand and industrial developments [2]. The market demand for red ginger is high, and the productivity of red ginger must also be balanced with market demand. According to data from the Central Statistics Agency, Indonesia produced 307.24 thousand tons of ginger in 2021. This number increased by 67.42% from 2020, which amounted to 183.52 thousand tons. 2021 is a year when ginger production experienced a significant increase. Since 2017, ginger production in the country has tended to decline. Ginger production in Indonesia was only 216.59 thousand tons in 2017. The amount decreased until 2019 to 174.38 thousand tons [3].

Increased production of red ginger can be achieved by increasing yields, increasing the number of plants, and expanding the land area. Various factors influence the growth and productivity of crop yields. Soil properties are also a factor controlling ginger production and its quality. The development of ginger rhizome

is optimum in fertile, loose soil and contains much organic matter with a pH ranging from 6.8 to 7.4. Regarding soil fertility, ginger requires macro and micronutrients for growth and production. Ginger absorbed higher N and K elements than P, as shown by the higher content of N K and P in various parts of ginger [4].

ZA (Ammonium Sulfate) fertilizer is an inorganic fertilizer containing 20 – 21% N and 24% S [5]. ZA fertilizer provides N elements that are readily available reasonably quickly for plants. Another element contained in ZA fertilizer is sulfur (S), which is used to form tubers. Sulfur is a constituent of essential amino acids that form chlorophyll and is needed in protein synthesis and plant structure. Sulfur is also a constituent of coenzyme A and biotin and thiamin hormones, which are necessary for carbohydrate metabolism. Nitrogen is one of the macro elements plants require in large enough quantities [6]. Applying ZA fertilizer is expected to increase the growth and yield of red ginger.

Material and Methods

The research was carried out from March 2021 to completion. The research location is in the Sebelas Maret University Experimental Field (UNS) Pelem Hamlet, Wonorejo Village, Jatiyoso District, Karanganyar Regency, Central Java. It is located at the coordinates of 7°42'43.5"S & 111°06'18.5"E and an altitude of ± 700 meters above sea level. The materials used in this study include two months of red ginger seeds and ZA fertilizer.

The experimental design was a Completely Randomized Complete Block Design (RCBD). This study consisted of 4 treatments with 6 replications so that 24 experimental units were obtained, while the treatments in this study were as follows: P0: Control without ZA fertilizer, P1: Treatment 225 Kg ZA/ha or 22.5 g/m2, P2: Treatment 450 Kg ZA/ha or 45 g/m2, and P3: Treatment 675 Kg ZA/ha or 67.5 g/m2. The variables observed were plant height, number of leaves, number of stems per clump, number of stems per plot, dry weight of stover, fresh weight of rhizome per clump, fresh weight of rhizome per plot, storage weight per clump, storage weight per rhizome, rhizome length, width. rhizome, and rhizome volume. Data analysis using variance analysis continued with the DMRT (Duncan Multiple Range Test), regression test, and correlation test.

Results and Discussions

The Experimental Land in Jatiyoso has a lithosol soil type. [7] Ginger plants require soil that is relatively fertile and loose, contains lots of humus and high organic matter, and is well drained. Red-brown Litosols and Andosols are generally more appropriate. [8] Litosol soil undergoes intensive weathering, resulting in the leaching of nutrient cations and organic matter by leaving iron oxide (Fe2O3) and aluminum oxide (Al2O3).

Table 1. Soil chemical analysis

Soil Properties	Unit	Score	Appreciation
C Organic	%	1,18	Low
Organic material	%	2,04	Medium
N total	%	0,20	Low
Soil pH	-	5,71	Acid
P total	ppm	38,44	Medium
K total	Mg/100g	30,74	Medium
C/N	-	5,90	Low
Porosity	%	47,64	-
Water content	%	7,88	Low

Source: Appreciation according to the Soil Research Institute (2005)

Soil chemical analysis showed that the organic C content (1.18%) and C/N (5.90) were low, the total N (0.20) was moderate, and the soil pH (5.71) was slightly acidic. Other soil analysis was organic matter (2.04%), total P (38.44 ppm), total K (30.74 Mg/100g), porosity (47.64 %), and water content (7.88 %). The use of ZA fertilizer can decrease the pH content because the sulfate ion dissolves powerfully, while the ammonium ion is weaker; this fertilizer has the potential to lower the pH of the soil affected by its application, [9] ZA besides being able to increase the total N content in the soil, it also tends to decrease the pH value of the soil or in other words acidifying the soil.

Plant Height

Table 2. Effect of ZA fertilizer on red ginger plant height

Treatment	Average (cm)
P2	47,86
P1	46,83
P3	45,36
P0	44,08

Table 2 shows that the plant height of red ginger in all treatments gave similar results. Factors that affect yields that are not significantly different in plant height, one of which is the administration of fertilizer doses that are not optimal, [10] good growth, it is not only essential to know how to use fertilizer, the type of fertilizer and the right time of fertilization, but it is also essential to know the dose of fertilization optimal. The fertilizer incorporated into the planting row is vital to getting the crop off to a strong start. The preplant application includes a complete fertilizer and additional nitrogen. Nitrogen is supplied as a complete fertilizer at 300-500 lb (136227 kg) per acre. Applying ZA fertilizer is expected to add nitrogen (N) nutrients needed for plant growth.

Red ginger plant height is also influenced by factors such as air temperature. The ideal air temperature for red ginger is around 20-35°C. [11] high air temperature causes low humidity; the transpiration rate increases so that the amount of water needed for plants is reduced and plant growth is inhibited; in addition to air temperature, sufficient water availability is also an essential factor for the growth of red ginger. The availability of water is obtained from the rainfall at the observation location. [12] Red ginger can grow well in areas with rainfall between 2500-4000 mm/year and 7-9 wet months yearly. Plants use sufficient water for the photosynthesis process to produce photosynthesis.

Based on the correlation test results, plant height significantly correlated with the number of leaves (r = 0.630). [13] the increase in plant leaves is related to plant height because an increase will follow plant height in stem nodes.

Number of Leaves

Table 3. Effect of ZA fertilizer on the number of red ginger leaves

Treatment	Average
P1	39,38 b
P0	36,27 ab
P2	35,94 ab
P3	31,05 a

Table 3 shows that ZA fertilizer treatment gave significantly different results regarding the number of red ginger leaves. Treatment P1 had the highest average of 39.38 cm, and treatment P3 had the lowest average of 31.05 cm. Treatments P0 and P2 gave results that were not significantly different, with a mean treatment of P0 of 36.27 cm and treatment of P2 of 35.94 cm. Leaves are responsible for capturing light and are the site of photosynthesis. [14] The number of leaves will also affect the development of plants. [15] The number of leaves on a plant will affect the growth and development of plants, where plants with more leaves will provide more energy for photosynthesis than those with fewer leaves.

ZA fertilizer significantly affects the number of leaves of red ginger plants because it has the central element nitrogen. Nitrogen is a primary nutrient for plant growth to form or grow plant vegetative parts such as leaves, stems, and roots. [16] Nitrogen element increases plant vegetative growth, especially in stimulating leaf growth.

The number of leaves was positively correlated with the dry weight (r = 0.810) of the stover, where the more the number of leaves, the more the dry weight of the stover will increase, [17] the more the number of leaves the fresh weight of the stover will be more significant.

Number of Plants per Clump

Table 4. Effect of ZA fertilizer on the number of plants per red ginger clump

Treatment	Average
P2	5,61
P0	5,16
P1	5,11
P3	4,77

Table 4 shows that ZA fertilizer treatment gave insignificant results on the number of plants per clump. P2 treatment with an average of 5.61, followed by P0 and P1 treatment with an average of 5.16 and 5.11, respectively; the lowest treatment was directed by P3 treatment with an average of 4.77. Treatment with ZA fertilizer did not significantly affect the number of plants per clump; this was probably because the dose given was insufficient, so the red ginger plants could not absorb the elements optimally. [18] that various efforts to increase plant productivity and quality are by using fertilizers consisting of a combination of several macro and microelements, [19] the availability of nutrients that plants can absorb is one of the factors that can affect the rate of plant growth and development.

Number of Plants per Plot (1,8 m^2)

Table 5. Effect of ZA fertilizer on the number of plants per red ginger plot

Treatment	Average
P2	79,33 b
P3	72,00 a
P1	70,83 a
P0	70,00 a

Based on the results of the variance analysis, ZA fertilizer treatment significantly affected the number of red ginger plants per plot because ZA fertilizer contained essential elements, namely nitrogen and sulfur. [20] nitrogen is necessary for plant growth and development, and sulfur is vital for increasing protein and activating enzymes. Internal factors also greatly influence the increase in red ginger plants per plot. [19] Internal factors such as soil nutrients, climate, and biological factors stimulate growth and control plant genetics.

The number of plants is generally influenced by the element nitrogen obtained from ZA fertilizer treatment. Nitrogen fertilization is one of the macronutrients needed for plant growth to meet plant nutrient needs.[21] nitrogen can benefit plants; for example, nitrogen can stimulate growth above the soil.

Dry Weight of Stove

Table 6. Effect of ZA fertilizer on the dry weight of red ginger stover

Treatment	Average (g)
P2	5,61
P1	5,60
P0	4,25
P3	3,97

Table 6 shows that the ZA fertilizer treatment did not significantly affect the dry weight of the stover. The application of ZA fertilizer, which could have been more optimal, had an insignificant impact on the dry weight of the red ginger stove because the red ginger plant also could not absorb nutrients optimally. [22] the amount of nutrients absorbed by plants can increase plant vegetative growth, causing the amount of plant biomass to grow and produce a high dry weight of stover. Plants absorb nutrients for various metabolic processes to maintain plant physiological functions.

The dry weight of the stover is also influenced by the availability of water in the plant. Water is an essential factor needed for plant growth and development. Metabolic processes and plant life cycles will be disrupted without water. [23] Lack of water can disturb nutrient transport in plants, affecting biochemical processes.

The dry weight of the stover is positively correlated with the fresh weight of red ginger (r = 0.508); this is because the more significant the weight of the stover, the greater the fresh weight of the red ginger, where the dry weight of the stover reflects the results of photosynthesis in plants.

Rhizome Size

Table 7. Effect of ZA fertilizer on red ginger rhizome size

Treatment	Rhizome Size		
	Length (cm)	Width (cm)	Volume (ml)
P0	9,67	4,70	25,83
P1	9,89	5,52	38,33
P2	11,45	5,87	38,66
P3	9,56	5,14	30,83

Table 7 shows that all ZA fertilizer treatments did not significantly affect rhizome size. Fertilization factors influence the size of the rhizome. [24] so that red ginger can be maximized and produce good rhizomes, it is necessary to add nutrients for plants. [25] Fertilized ginger plants produce better rhizome sizes than those that are not fertilized; this is because ginger plants are plants that require fertilizer for production.

Based on the regression graph of the rhizome's length, width, and volume, the results showed that increasing the dose gave good results. Still, if the addition of an excessive dose of fertilizer gave poor results, [26] applying fertilizer according to the dosage and needs could increase the yield to the contrary. Excessive feeding will reduce crop yields. According to the mathematical model, the optimum dosage was 360-386 Kg ZA/ha.

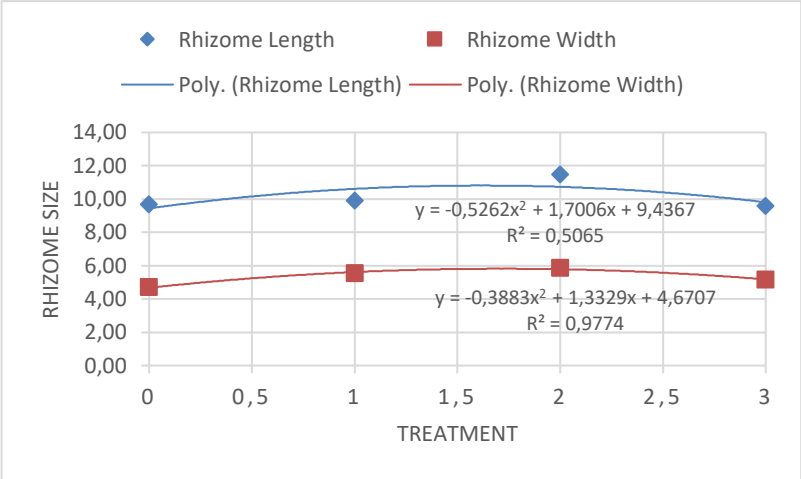

Figure 1 Regression test on red ginger rhizome size

Rhizome Fresh Weight

Table 8. Effect of ZA fertilizer on rhizome fresh weight

Treatment	Average (g)	
	Clump	Plot (1,8 m²)
P0	24,16	242,67
P1	39,38	344,00
P2	39,66	341,33
P3	26,77	254,17

Table 8 shows that the ZA fertilizer treatment had no significant effect on the fresh weight of the rhizomes. Nutrients and water are essential factors affecting red ginger rhizome's fresh weight. [27] Nutrients and water absorbed by plants depend on the opportunity to get water and nutrients in the soil; because the plant's needs for nutrients and water are limited, the role of roots and the number of nutrients available in the root media complement each other for the formation of rhizomes. The results of red ginger in this study were obtained for P0, namely control without ZA of 1,382 Kg rhizome/ha, P1 with a dose of ZA 225 Kg rhizome/ha of 1,406 Kg rhizome/ha, P2 with a dose of 450 Kg rhizome/ha of 1,918 Kg rhizome/ha, and P3 with a dose of 675 Kg rhizome/ha by 1,611 Kg rhizome/ha.

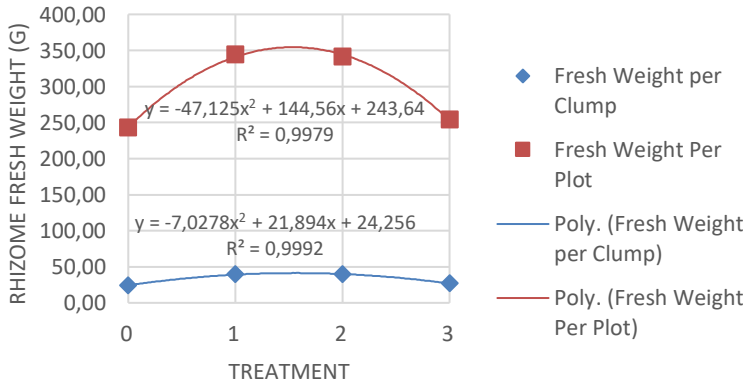

Figure 2 Regression test on fresh weight of red ginger rhizome

Based on the regression graph of the fresh weight of the rhizomes, it was found that adding the ZA fertilizer dose gave good results, but if the fertilizer dose was added too much, it gave poor results. [28] Efficient fertilization will increase the rhizome weight. The regression analysis results showed that the optimal dose of ZA fertilizer on the fresh weight of red ginger was between treatments P1 and P2, with a dose of 350 Kg ZA/ha.

Rhizome Dry Weight

Table 9. Effect of ZA fertilizer on red ginger rhizome storage weight

Treatment	Average (g)	
	Clump	Plot (1,8 m²)
P0	16,16	154,33
P1	26,38	234,33
P2	26,33	233,67
P3	19,44	180,17

The results showed that ZA fertilizer treatment had no significant effect on the storage weight of the rhizomes. Rhizome storage weight is affected by the storage of red ginger rhizome after harvesting. The storage method used is the air-dried storage method. [29] This drying is used to dry the soft rhizome material, which contains volatile active compounds but takes the longest (7 x 24 hours). The decrease in rhizome weight is closely related to the reduced water content in the rhizome [30], which is a decrease in rhizome weight. It is closely associated with reduced water, starch, fiber, and wax on the rhizome surface.

Based on the regression test results, it can also be said that adding the ZA fertilizer dose gave a good dry weight to the rhizome, but if the ZA fertilizer dose were added in excess, the yield would decrease. The regression analysis showed that the optimal dose of ZA fertilizer on the storage weight of the rhizomes was between treatments P1 and P2, with a dose of 363 Kg ZA/ha.

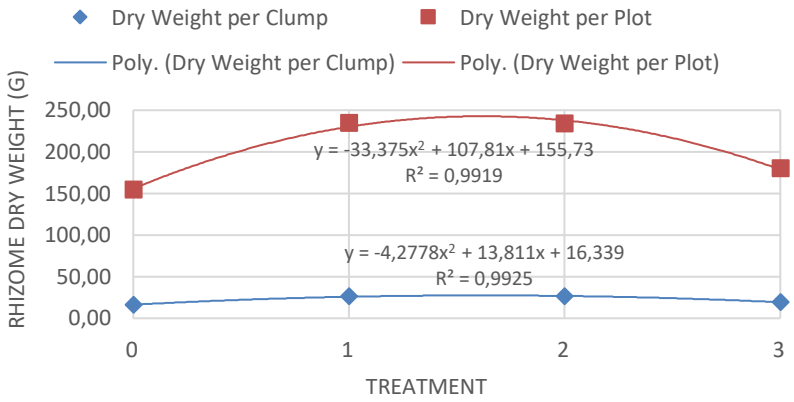

Figure 3 Regression test on red ginger storage weight

Conclusions

The dose of ZA fertilizer did not increase the yield of red ginger**. Still, on** growth observations, treatment P1 with a dose of 225 Kg ZA/ha gave an increase in the number of red ginger leaves per clump with an average of 39.38**,** and in treatment P2 with a dose of 450 Kg ZA/ha can increase the number of plants per plot and based on **a** mathematic model from regression the optimum dose of ZA fertilizer for red ginger is ± 360 Kg ZA/ha.

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