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The Effect of ZA and KCl Fertilizers on the Growth and Yield of Red Ginger (*Zingiber officinale* var. Rubrum)

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Abstract
Red ginger is one of the commodities greatly needed by the people of Indonesia. However, the increase in public demand has not been matched by a corresponding rise in red ginger production. Efforts to boost red ginger production can be achieved through adequate fertilization. This study aims to determine the appropriate dosage of ZA+KCl fertilization for promoting red ginger's optimal growth and yield. The research was conducted between March and August 2021 in the experimental area of Pelem, Wonorejo, Jatiyoso, Karanganyar, Central Java, with coordinates 7°43'24.7"S 111°05'31.2"E and an altitude of 762 meters ASL. The study utilized a Randomized Complete Block Design (RCBD) with a single factor and four treatments: D0 (control), D1 (ZA 225 kg.ha^{-1}+KCl 50kg.ha^{-1}), D2 (ZA 450 kg.ha^{-1}+ KCl 100 kg.ha^{-1}), and D3 (ZA 675 kg.ha^{-1}+KCl 150 kg.ha^{-1}), each repeated six times. The results revealed that applying various fertilizer doses did not significantly increase plant height, the number of leaves, or the dry weight of the straw. However, it did lead to a notable 37.11% increase in the number of tillers per clump and a 27.10% increase in the number of tillers per plot. Regression analysis demonstrated that D2 trended toward enhancing rhizomes' fresh and storage weights, with averages of 1.9 t.ha^{-1} and 1.5 t.ha^{-1}, respectively. Further development of this research is warranted, focusing on improving environmental factors to enhance the growth and yield of red ginger.

Keywords: fertilizer; nitrogen; potassium

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Introduction

In Indonesia in 2019, ginger production decreased by 33,030 tons compared to 2018, declining from 207,000 tons to 147,000 tons. The harvested area for ginger in 2019 also saw a decrease of 2,128.47 hectares compared to the preceding year, dropping from 10,205 hectares to 8,077 hectares (1). Ginger imports in Indonesia amounted to 3,886,091 kilograms, with Thailand being the primary importing country at 1,584,145 kilograms (2). The import of ginger in 2019 witnessed a substantial increase of 492.69% from the previous year, totaling 21,783 tons. Thailand maintained its position as the largest importer, totaling 11,377 tons (1).

Among the fertilization methods using chicken manure, Azolla compost, and Universitas Brawijaya compost, the highest yield was achieved through chicken coop fertilization applied 30 days before planting, resulting in a 1.67 ton.ha^{-1} yield. However, these results still fall notably short of the potential for red ginger production through conventional cultivation methods (3). The average yield potential of red ginger is 11 t.ha^{-1} in low-medium land (<600 meters ASL) and 15,2 t.ha^{-1} in upland areas (>600 meters ASL) (4). The yield of Jahira 2 red ginger was measured at 460.20±117.41 g/clump, with rhizome productivity of 12.89±3.29 t.ha^{-1} (5).

The application of nitrogen (N) fertilizer has been shown to enhance both the number of leaves and the height of red ginger. Notably, an application of 100 kg.ha^{-1} N has

demonstrated the ability to increase leaf count compared to alternative treatments (6). Additionally, the utilization of 120 kg.ha^{-1} N fertilizer has exhibited a remarkable 44.1% increase in rhizome weight (7). Regarding vegetative activity, introducing potassium chloride (KCl) fertilizer has proven influential. Specifically, treatments involving 200 kg.ha^{-1} and 350 kg.ha^{-1} of KCl have significantly increased 87.44% in the dry weight of leaves and tillers, respectively (8). Strikingly, the implementation of 450 kg.ha^{-1} potassium (K) fertilizer has yielded the highest ginger production for three consecutive years, averaging 51.6 t.ha^{-1}. Notably, these outcomes significantly differ from the effects observed with other fertilizer dosages (225 kg.ha^{-1}, 675 kg.ha$^{-1,}$ and 900 kg.ha^{-1}) (9).

ZA's nitrogen (N) content is 21%, whereas urea boasts a nitrogen content of 45% (10). Applying N fertilizer at a rate of 1,625 g.plant^{-1} has been shown to elevate plant height compared to situations without N fertilizer (11). A 450 kg.ha^{-1} K fertilizer application has yielded the most substantial ginger yield, averaging 51.6 t.ha^{-1} (9). Applying KCl fertilizer can enhance potassium uptake through plant roots, significantly impacting plant height variables (12). Given that N and K fertilizers often involve substantial quantities, this study was undertaken to ascertain the appropriate ZA and KCl fertilizers conducive to red ginger's growth and yield optimization.

Materials and Method

This research was conducted between March and August 2021 in Pelem Hamlet, Wonorejo Village, Jatiyoso District, Karanganyar Regency, Central Java, Indonesia, at coordinates 7°43'24.7" S 11°05'31.2" E, and an elevation of 762 meters above sea level (MASL). According to soil analysis, the site exhibited slightly acidic pH (5.67), low organic carbon content (1.16%), deficient organic matter (2.01%), inadequate total nitrogen (0.18%), moderate total phosphorus (35.38 ppm), low C/N ratio (6.44), and reduced water content (7.29%). The utilized materials encompassed seeds of the Jahira 2 red ginger variety, ZA fertilizer, and KCl fertilizer. The employed tools included calipers, digital scales, and a ruler.

The study employed a one-factor Randomized Complete Block Design (RCBD), comprising D0 (control), D1 (ZA 225 kg.ha^{-1} + KCl 50 kg.ha^{-1}), D2 (ZA 450 kg.ha^{-1} + KCl 100 kg.ha^{-1}), and D3 (ZA 675 kg.ha^{-1} + KCl 150 kg.ha^{-1}). Each treatment was replicated six times, resulting in 24 experimental units. An experimental unit consisted of a plot measuring 200 cm x 60 cm, with a 30 cm gap between adjacent plots. Within each experimental unit (plot), three plants were randomly selected and designated as experimental samples.

The observed variables included plant height, number of leaves, number of tillers per clump, number of tillers per plot, dry weight of straw, weight of fresh rhizome per clump, weight of fresh rhizome per plot, weight of storage rhizome per clump, weight of storage rhizome per plot, and rhizome size (length, width, and thickness). Observational data were subjected to Analysis of Variance (ANOVA) at a significance level of 5%, followed by Duncan's Multiple Range Test (DMRT) at 5% significance, correlation analysis among variables, and regression analysis for rhizome size and yield parameters.

Results

Applying ZA and KCl fertilizers showed no significant effects on plant height, the number of leaves, the dry weight of straw, the weight of fresh rhizomes, the weight of storage rhizome, and rhizome size. However, applying ZA and KCl fertilizers impacted the number of red ginger tillers significantly (both per clump and plot). Specifically, the dosage of ZA fertilizer at 450 kg.ha^{-1} + KCl 100 kg.ha^{-1} resulted in the highest number of tillers compared to the other treatment combinations.

Table 1. Effect of ZA and KCl fertilizer application on red ginger growth

Dosage of ZA + KCl fertilizer (kg.ha^{-1})	Average				
	Height (cm)	Number of leaves (blade)	Number of tillers (tiller)		Dry weight of straw (g)
			Per Clump	Per Plot	
0	41,80	26,11	6,44a	73,17a	5,21
225+50	47,08	41,55	8,44ab	84,00ab	6,61
450+100	47,44	44,88	8,83b	93,00b	8,95
675+150	44,25	39,38	8,61ab	85,50ab	6,99

Note: The numbers followed by the same letter within a single column indicate no significant difference in the DMRT test at the 5% level.

Table 2. Effect of ZA and KCl Fertilizer Application on Red Ginger Yield

Dosage of ZA + KCl fertilizer (kg.ha^{-1})	Average						
	Weight of fresh rhizome (g)		Weight of storage rhizome (g)		Size rhizome (mm)		
	Per clump	Per plot	Per clump	Per plot	length	width	thickness
0	41,56	248,8a	33,83	198,17	105,59	49,33	18,77
225+50	53,56	253,17	43,33	197,33	120,66	50,49	18,8
450+100	53,83	345,33	42,44	285,67	114,71	53,38	18,07
675+150	52,56	290,00	41,00	229,17	117,87	53,45	19,22

Note: The numbers followed by the same letter within a single column indicate no significant difference in the DMRT test at the 5% level.

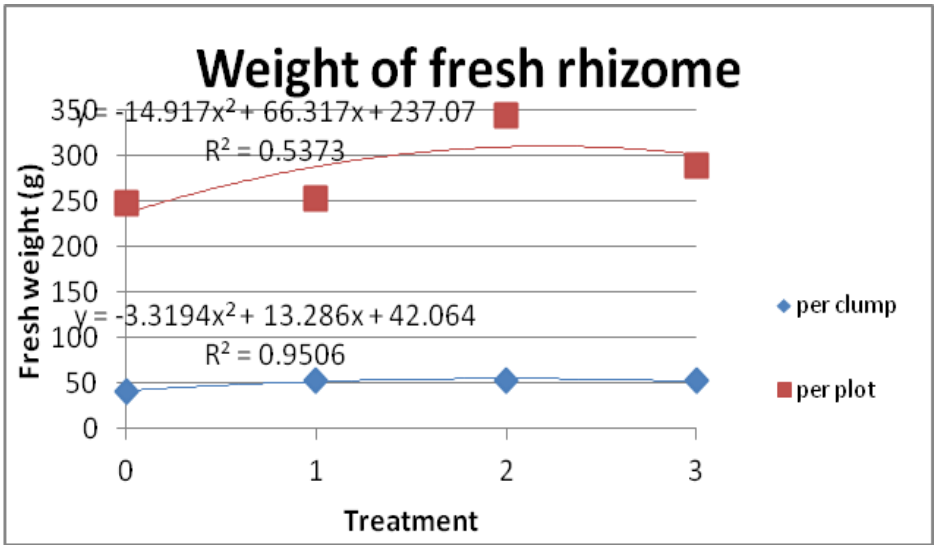

Figure 1. Regression analysis of the effect of ZA and KCl fertilizers on the weight of fresh rhizome

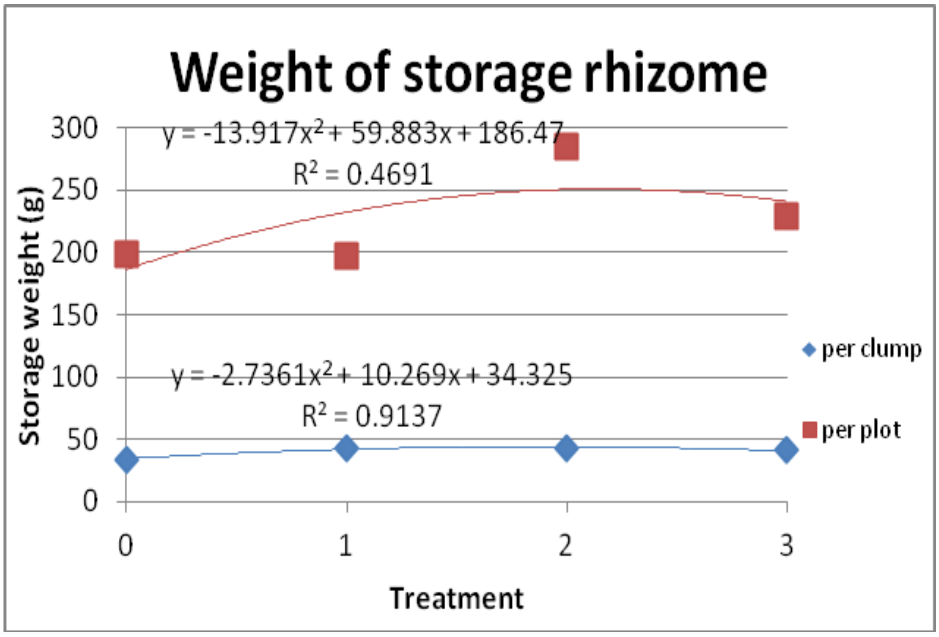

Figure 2. Regression analysis of the effect of ZA and KCl fertilizers on the weight of storage rhizome

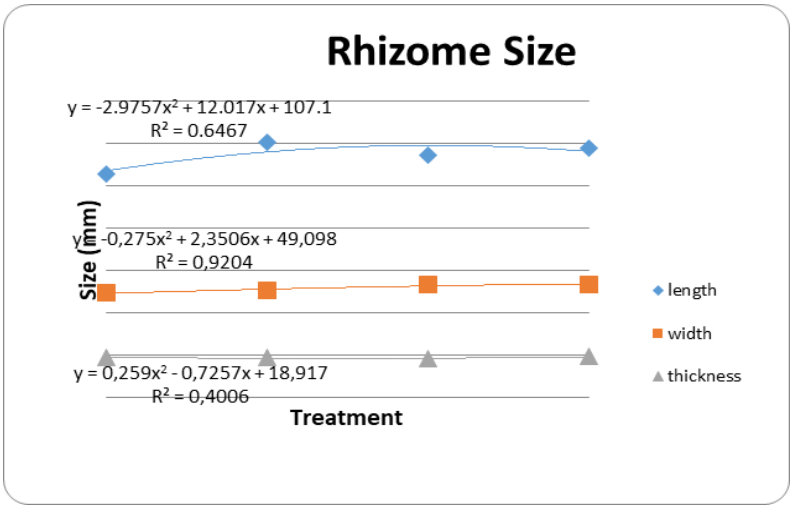

Figure 3. Regression analysis of the effect of ZA and KCl fertilizers on weight of size rhizome

Table 3. Correlation between red ginger variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12
12	0,431*	0,402*	0,488*	0,724**	0,467*	0,221	0,502*	0,419*	0,261	0,261	0,980**	1
11	0,446*	0,433*	0,500*	0,696**	0,492*	0,219	0,487*	0,456*	0,275	0,261	1	
10	0,703**	0,656**	0,744**	0,569**	0,768**	0,633**	0,728**	0,725**	0,996**	1		
9	0,698**	0,687**	0,779**	0,595**	0,788**	0,636**	0,723**	0,704**	1			
8	0,537**	0,325	0,417*	0,392	0,475*	0,489*	0,809**	1				
7	0,498*	0,347	0,537**	0,542**	0,480*	0,432*	1					
6	0,525**	0,436*	0,446*	0,489*	0,415*	1						
5	0,786**	0,910**	0,821**	0,568**	1							
4	0,482*	0,586**	0,782**	1								
3	0,639**	0,893**	1									
2	0,732**	1										
1	1											

Note: * = significant correlation at a 5% level
**= significant correlation at 1% level

Based on the analysis of variance, ZA and KCl fertilizers significantly impacted growth parameters, precisely the number of tillers per clump and the number of tillers per plot. However, they did not yield a significant effect on height, the number of leaves, and the dry weight of the straw (Table 1). Conversely, ZA and KCl fertilizers did not yield a notable effect on yield parameters, including fresh weight, storage weight, and rhizome size (Table 2). The ZA Fertilizer treatment observed the highest number of tillers at 450 kg.ha^{-1} + KCl 100 kg.ha^{-1}. They applied ZA fertilizer at 450 kg.ha^{-1} + KCl 100 kg.ha^{-1} led to a remarkable increase of 37.1% in the number of tillers per clump and 27.1% in the number of tillers per plot compared to the control.

Figures 1, 2, and 3 indicate that the regression testing for various dosages of ZA and KCl fertilizers suggests a tendency to form a quadratic curve with a downward opening. This quadratic curve pattern illustrates that, as the fertilization dose increases, the yield parameters of red ginger show an initial increase, but beyond a certain point, further dose escalation can lead to a decrease in yield parameters. The downward-opening curve demonstrates this trend. As depicted in Table 3, the number of leaves exhibits a positive correlation with all the observed variables, suggesting that an increase in the number of leaves is predictive of increased values across the other variables.

Discussion

Applying ZA and KCl fertilizers significantly impacted the number of red ginger tillers per clump and plot, as shown in Table 1. They applied ZA fertilizer at a rate of 450 kg.ha^{-1} + KCl 100 kg.ha^{-1} resulted in a notable increase of 37.1% in the number of tillers per clump and 27.1% in the number of tillers per plot compared to the control. This effect can be attributed to the essential nutrients nitrogen (N) and potassium (K) in ZA

and KCl fertilizers, which play crucial roles in promoting the growth of red ginger tillers. Notably, the lowest number of tillers occurred in the treatment without N and P fertilizers, indicating the pivotal role of nitrogen and phosphorus in enhancing tiller numbers (13). An N+K fertilizer blend yielded more tillers than the control and individual treatments involving N, P, and K (14).

Applying ZA and KCl fertilizers did not significantly affect plant height, the number of leaves, and the dry weight of the straw, as indicated in Table 1. This outcome can be attributed to several factors, including the relatively low fertilizer dosages, the absence of additional organic fertilizers, and the timing of fertilizer application. In contrast, a combination of urea fertilizer at 500 $kg.ha^{-1}$ + SP-36 at 300 $kg.ha^{-1}$ + KCl 600 $kg.ha^{-1}$ demonstrated a positive impact on the growth of red ginger (15). Incorporating organic fertilizers at rates of 15 $t.ha^{-1}$ and 30 $t.ha^{-1}$ led to an increase in the number of leaves per clump. Moreover, the application of 120 $kg.ha^{-1}$ N fertilizer, gradually applied at 45, 90, and 135 days after planting, contributed to a remarkable 52.7% increase in the number of leaves. It is important to note that ineffective fertilization can lead to nutritional deficiencies and hinder overall growth (16).

The environmental factors influencing the administered treatments, including pH, water availability, and sunlight intensity, did not exhibit significant differences. A soil pH within the neutral range is conducive to optimal nutrient availability (17). pH levels nearing neutrality exert a more positive influence on nitrogen (N) and phosphorus (P) uptake compared to acidic pH levels (18). The soil's low water content adversely affects soil moisture, consequently impacting plant growth. Implementation of irrigation enhances soil moisture levels, thereby fostering plant growth; the treatment without irrigation exhibited fewer leaves than the treatment with irrigation (19). Notably, a rise in the number of leaves was observed with moderate to ample watering, as opposed to the water stress treatment (20). For C3 plants, full sunlight can trigger a reduction in the rate of photosynthesis due to photorespiration (21). Regarding ginger, withholding shade resulted in the lowest plant dry weight (22).

The application of ZA and KCl fertilizers yielded no significant impact on rhizome fresh weight, storage weight, and rhizome size, as detailed in Table 2. It can be attributed to several factors, including the low fertilizer dosage, the methodology of fertilizer application, soil composition, and storage conditions. Notably, ginger demands substantial nutrient uptake during the rhizome development phase; an insufficient nutrient composition can hinder the transition to the rhizome enlargement phase, leading to steady tiller growth but smaller rhizomes (23). Contrastingly, applying KCl fertilizer at doses of 300 $kg.ha^{-1}$ and 350 $kg.ha^{-1}$ produced the highest rhizome yield (8). It is similarly employing 115 $kg.ha^{-1}$ N fertilizer (equivalent to 250 kg of urea) through three applications resulted in the most significant yield of turmeric rhizome (24). Looser crumb soil structure offers ample room for rhizome expansion. In contrast, Latosol soil features a clay structure, moderate porosity, and high cation exchange capacity (25).

Small rhizome size can influence the storage weight of red ginger. Smaller rhizomes have a comparatively more extensive surface area than their larger counterparts. The substantial decrease in rhizome weight can be attributed to the diminutive size of the red ginger rhizomes, resulting in a greater surface area for evaporation compared to more extensive rhizomes (26). The reduced water content in red ginger can be attributed to its smaller rhizome size compared to sizeable white ginger and small white ginger varieties (27). Rhizomes inherently possess hygroscopic properties, absorbing moisture from their surroundings when the rhizome's water content is lower than the surrounding environment (28).

Figures 1, 2, and 3 demonstrate that as the fertilizer dosage increases, it leads to an enhancement in red ginger's yield parameters; however, there comes a point where further dosage increments result in diminished yield parameters. Applying fertilizer in alignment with the appropriate dosage can amplify crop yields; conversely, surpassing the optimal dosage can reduce yield (29). Excessive application of inorganic fertilizers can potentially undermine land productivity (30). As presented in Table 3, the observed variables exhibit a positive correlation among themselves. An ample number of leaves can facilitate increased photosynthetic output distributed to other components, such as roots and sinks (31). The number of tillers strongly correlates with the wet weight of the primary rhizome and the total rhizome weight (32). Additionally, the number of tillers exhibits a robust correlation with the weight of the parent

rhizome, the secondary rhizome, and the overall rhizome yield per plant (33).

Conclusion

Applying 450 kg.ha^{-1} of ZA + 100 kg.ha^{-1} of KCl has the potential to enhance the growth of red ginger, particularly evident in the variable of the number of stems per clump, which increased by 37.11%, and the number of stems per plot, which increased by 27.10%. However, applying various dosages of ZA and KCl fertilizers did not increase the yield of red ginger rhizomes. Notably, applying 450 kg.ha^{-1} of ZA + 100 kg.ha^{-1} of KCl exhibited a propensity for yielding higher quantities of red ginger than other dosages.

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