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Optimization Of Zinc Sulfate Application To Improve The Quantity And Quality Of Rice Crops (*Oryza Sativa* L.)

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Abstract
Background. Zinc (Zn) is known as an important micronutrient for plants, playing a significant role in optimizing growth, yield, and the quantity and quality of rice plants.
Aims. This study focuses on determining the optimal dose of Zinc Sulfate Heptahydrate (ZnSO4) fertilizer in response to the growth and yield of rice plants, as well as the Zn content in rice.
Methods. This study was conducted in Kaliaren, Kuningan, from May to August 2025. This study used a single-factor randomized block design (RAK) with 5 dose treatments and 5 replicates. The data will be processed using Analysis of Variance (ANOVA) and Duncan's multiple range test (DMRT).
Conclusion. The results of this study indicate that 8 kg/ha of zinc sulfate heptahydrate fertilizer is the optimal dose for increasing the quantity and quality of rice (Oryza sativa L.) yields.

Keywords: Rice, Zinc Sulfate, Quantity, Quality.

INTRODUCTION

Zinc is an essential micronutrient that plays an important role in plants. In addition, zinc is also an important micronutrient for human metabolism. Rice contains various nutrients that are important for the body, both as a source of energy and to support other physiological functions. One of the world's main sources of carbohydrates is rice.

Zinc (Zn) is one of the essential micronutrients needed by plants and humans. For plants, zinc plays a role in optimizing growth, yield, and nutritional quality (Hamam et al., 2018a). According to Hafeez (2012), zinc is directly involved in plant physiological and metabolic processes, including gene expression, reproductive organ development, enzyme activation, protein synthesis, and the metabolism of carbohydrates, lipids, nucleic acids, and auxins (Sunar et al., 2021).

Meeting the zinc requirements of plants results in high chlorophyll levels, thereby optimizing the plant's ability to perform photosynthesis (Maulana et al., 2023). Insufficient Zn availability can cause stunted plant growth and development, reduced crop yields, and decreased nutrient levels in each part of rice plants (Shakeel et al., 2024).

Zinc deficiency is very common in flooded rice fields. Under anaerobic conditions, Zn forms insoluble Zn phosphate (Hafeez et al. 2013 in Amin et al., 2022). According to Neue et al. (1998), symptoms of zinc deficiency in rice plants include seedling death, chlorosis in leaves 1-4 weeks after planting or transplanting, wilting due to loss of turgidity in leaves, stunted plant growth, and reduced tillering (Amin et al., 2022). Zinc deficiency also causes a decrease in starch and zinc.

For humans, zinc is a mineral that plays many important roles in the body. In Hafeez et al. (2012), zinc functions to boost the immune system by activating white blood cells or T lymphocytes, thereby enabling the body to avoid infection. In addition, zinc in the human body also functions to optimize growth, tissue formation, and overcome infertility in men (Hamam et al., 2018a). Zinc deficiency in humans also affects appetite, which can lead to malnutrition (Chao et al., 2018).

As Indonesia's population grows, so does the demand for food. Rice, as the main food commodity for the Indonesian people, plays an important role as a source of daily energy and nutrition, so that the sustainability of rice production greatly affects national food security. However, in addition to quantity, the nutritional quality of rice is also a concern, especially in relation to meeting the need for zinc (Zn), which is an essential mineral for human growth and development.

METHOD

This research took place in Kaliaren, Kuningan, until May to August 2025. The equipment use in this rersearch were hoes, sickles, marking ropes, sacks, tarpaulins, scales, rulers, writing instruments, name tags, bamboo, scissors, and ovens. Materials included Mapan 05 rice seeds, Zinc Sulfate Heptahydrate ($ZnSO4.7H2O$) fertilizer, and various fertilizers including manure, urea fertilizer, SP-36, and KCL.

This research employed an experimental approach using a Randomized Block Design (RBD) with a single treatment factor. Five doses of zinc fertilizer were tested, namely 0, 8, 16, 24, and 32 kg/ha. Each treatment was applied with five replicattions, producing a total of 25 experimental units. The experiment was conducted on a 2 m × 1.5 m plot of land that was adjusted for the needs of the research. According to Shivay et al. (2008), as cited in Hamam et al. (2018), increased zinc uptake in plants can be achieved through foliar spraying or by applying zinc to the soil together with urea fertilizer (ZEU/Zinc-Enriched Urea).

Growth observations covering plant height were conducted three times, namely on the 21, 28, and 35 days after planting (DAP). Harvest observations were conducted 105 days after planting (DAP), this covered the number of tillers per clump, yield, harvest age, number of productive tillers, Harvested Dry Grain (HDG) and Milled Dry Grain (MDG) weight per plot per plant, the weight of 1000 grain, and zinc content in rice. The observation data were analyzed using Analysis Of Variance (ANOVA) and followed by a DMRT test. These test were conducted at a 5% significance level.

DISCUSSION

Plant height

Based on the analysis results, it was outcomes that the application of zinc sulfate fertilizer had a significant impact on the average height growth of rice plants at 21, 28, and 35 days after planting. The application Z1 (8 kg/ha) produced the highest plant height and was significantly different from all other treatments (Table 1).

Table 1. Effect of Zinc Sulfate Fertilizer Application on Rice Plant Height

Treatment	Plant Height		
	21 DAP	28 DAP	35 DAP
Z0 (kontrol)	50.36 b	58.54 c	67.60 b
Z1 (8 kg/ha)	56.01 d	62.05 d	72.26 c
Z2 (16 kg/ha)	52.64 c	58.02 c	67.26 b
Z3 (24 kg/ha)	48.48 a	54.92 a	63.90 a
Z4 (32 kg/ha)	52.32 c	56.69 b	67.08 b

Notes : According to Duncan's test ($p < 0.05$), common letters following numbers in the column indicate no significant difference between the corresponding numbers.

The application of Z1 (8 kg/ha) was the optimal dose for a plant height growth. Table 1 shows that increasing the dose of zinc sulfate above 8 kg/ha resulted in a decrease in average plant height. This is thought to be because zinc sulfate application exceeding the optimal dose causes Zn toxicity in rice plants. These finding correspond to the study of Abhay, et al. (2024), who said that combining zinc sulfate fertilization at a dose of 8 kg/ha with sulfur at 45 kg/ha can significantly increase plant height, with an average rice plant height of 117.14 cm. In addition, according to Sahana et al. (2023), zinc plays an important role in various physiological processes in plants, one of which is through the synthesis of indole-3-acetic acid (IAA). This phytohormone stimulates stem elongation, which can increase plant height.

Number of Rice Tillers

The number of tillers is one of the important growth components in rice plants that greatly affects yield potential. The results of this study in Table 2 show that there is a significant effect between the application of zinc sulfate fertilizer and the number of rice tillers at 21, 28, and 35 days after planting.

Table 2: Effect of Zinc Sulfate Fertilizer Application on Number of Rice Tiller

Treatment	Number of Rice Tillers		
	21 DAP	28 DAP	35 DAP
Z0 (kontrol)	9b	16c	20b
Z1 (8 kg/ha)	11d	18d	24c
Z2 (16 kg/ha)	9b	15b	21b
Z3 (24 kg/ha)	8a	14a	19a
Z4 (32 kg/ha)	10c	14a	21b

Notes : According to Duncan’s test ($p < 0.05$), common letters following numbers in the column indicate no significant difference between the corresponding numbers.

Treatment Z1, application of zinc sulfate fertilizer at a dose of 8 kg/ha, produced the highest number of rice tillers, namely 24 stems, and was significantly different from the other treatments. This difference may have occurred due to differences in nutrient intake, which is very important in supporting optimal rice plant growth and development.

This research shows that the application of 8 kg/ha of zinc sulfate fertilizer is the optimal dose that has been proven to meet the growth needs of rice plants and increase the number of tillers. This is in line with what was stated by Maulana et al. (2023), that meeting the zinc requirements of plants can produce high chlorophyll levels, thereby optimizing the plants' ability to perform photosynthesis. Maximal photosynthesis can increase the formation of rice tillers. Excess Zn can interfere with the absorption of other essential nutrients (such as Fe, Mn, and P), decrease photosynthetic activity, and increase the production of reactive oxygen species (ROS) that damage plant tissues (Alloway, 2008). Therefore, increasing the dose of zinc sulfate fertilizer can interfere with the growth process of rice tillers.

Number of Productive Tiller of Rice

Rice plants transitioning into the reproductive phase or generative phase starting around 60 days after planting (DAP) until harvest. In this phase, rice plants require nutrient intake to support panicle formation, flowering, and grain filling.

The number of productive tillers plays a role in determining rice production potential. The results of Table 3 show that the application of zinc sulfate fertilizer has a significant effect on the number of productive rice tillers. Treatment Z1 (8 kg/ha) had the best average number of productive tillers, namely 18 tillers, which was significantly different from the other treatments. These finding correspond to the study of Sunar et al. (2021) that the application of heptahydrate zinc sulfate fertilizer can increase the number of productive tillers. This can occur because zinc acts as an enzyme cofactor in plant metabolism, which acts as a catalyst (accelerating reactions).

Table 3. Effect of Zinc Sulfate Fertilizer Application on Yield Components (Number of Productive Tiller and 1000 Grain Weight of Rice Plants

Treatment	Number of Productive Tiller	1000 grain weight (g)
Z0 (Kontrol)	14b	27,43a
Z1 (8 kg/ha)	18d	28,75a
Z2 (16 kg/ha)	16c	25,98a
Z3 (24 kg/ha)	13a	27,14a
Z4 (32 kg/ha)	14b	27,58a

Notes : According to Duncan's test ($p < 0.05$), common letters following numbers in the column indicate no significant difference between the corresponding numbers.

1000 Grain Weight of Rice Grain

Based on Table 3, it is known that zinc sulfate fertilization has no significant effect on the weight of 1000 rice grains. This may occur because each rice variety has a grain size limit determined by genes that control the length, width, and thickness of the grain, such as OsMADS56 and OsPUB3. Therefore, even though Zn availability is increased, the size of rice grains cannot exceed their existing genetic potential and ultimately cannot affect rice grain weight. (Zuo et al., 2022; Wang, et al. 2022).

Weight of Harvested Dry Grain (GKP) and Weight of Milled Dry Grain (GKG) Per Plant and Per Plot

Table 4. Effect of Zinc Sulfate Fertilizer Application on Weight of Harvested Dry Grain (HDG) and Weight of Milled Dry Grain (MDG) per plant and per plot.

Treatment	Harvested Dry Grain (HDG)		Milled Dry Grain (MDG)	
	Per Plant (g)	Per Plot (kg)	Per Plant (g)	Per Plot (kg)
Z0 (Control)	51,06b	2,67c	48,51b	2,50b
Z1 (8 kg/ha)	55,41c	2,83d	51,65c	2,74c
Z2 (16 kg/ha)	43,76a	2,44b	42,94a	2,29a
Z3 (24 kg/ha)	45,85a	2,33b	43,52a	2,16a
Z4 (32 kg/ha)	45,40a	2,46a	44,28a	2,27a

Notes : According to Duncan's test ($p < 0.05$), common letters following numbers in the column indicate no significant difference between the corresponding numbers.

Based on the analysis results, it shows that treatment Z1 has a significant effect on harvested dry grain (HDG) per plant and per plot as well as milled dry grain (MDG) per plant and per plot compared to the results of other treatments.

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Table 4 shows that the effect of zinc application on harvested dry grain (HDG) per plant and per plot in treatment Z1 (8 kg/ha) showed the highest results, namely 55.41 g and 2.83 kg, respectively. The results for milled dry grain (MDG) showed the same pattern as the results for harvested dry grain (HDG), where treatment Z1 (8 kg/ha) again showed the highest results with 51.65 g per plant and 2.74 kg per plot.

According to Qaisrani (2011), zinc application can significantly increase rice yields. The high dry harvested grain and dry milled grain yields were influenced by the optimal application of zinc sulfate, which plays a role in grain filling. This is because zinc plays a role in carbohydrate metabolism, both in photosynthesis and in the conversion of sugar to starch (Keram et al., 2012), and Sunar et al. (2021) stated that the application of zinc sulfate heptahydrate (ZnSO4) fertilizer has a significant effect on the number of productive tillers, 1000-grain weight, harvested dry grain (HDG), and milled dry grain (MDG).

The Milling Yield

The milling yield provides an indication of weight loss by calculating the weight of white rice produced divided by the weight of paddy milled. The lower the milling yield, the greater the weight loss.

Table 5. Effect of Zinc Sulfate Fertilizer Application on Rice Milling Yield

Treatment	Milling (%)
Z0 (Kontrol)	58a
Z1 (8 kg/ha)	59a
Z2 (16 kg/ha)	57a
Z3 (24 kg/ha)	59a
Z4 (32 kg/ha)	63b

Notes : According to Duncan's test ($p < 0.05$), common letters following numbers in the column indicate no significant difference between the corresponding numbers.

Based on the data in Table 5, which has been analyzed for variance in the factor of zinc sulfate fertilizer dosage on rice milling yield, the results show a significant effect on treatment Z4. The application of zinc sulfate fertilizer at a dosage of 32 kg/ha produced the highest milling yield of 63% compared to other treatments.

The milling yield can be greatly influenced during the rice milling process. The milling process is highly dependent on the raw rice material (variety and moisture content), how the rice is handled before milling, and the milling process configuration model (Rusmono and Aminudin, 2022). The optimal moisture content for milling is around 14%. If the moisture content is too low, the rice will break easily during milling, resulting in a lot of broken rice and husks.

Zinc Content in Rice

Table 6. Effect of Zinc Sulfate Fertilizer Application on Zinc Content in Rice

Treatment	Zinc Content (ppm)
Z0 (Kontrol)	18.40a
Z1 (8 kg/ha)	22.20b
Z2 (16 kg/ha)	25.00c
Z3 (24 kg/ha)	25.40c
Z4 (32 kg/ha)	25.60c

Notes : According to Duncan's test ($p < 0.05$), common letters following numbers in the column indicate no significant difference between the corresponding numbers.

Based on the analysis results, it shows that the application of zinc sulfate fertilizer has a significant effect on zinc content in rice. As shown in Table 6, zinc content in rice significantly increased along with increasing doses of zinc sulfate fertilizer. Treatment Z4 (32 kg/ha) showed the best results in increasing the zinc content in rice by up to 39.1% compared to the control treatment without zinc sulfate fertilization.

These results are in line with the research by Priyanto et al. (2024) that $ZnSO_4$ fertilizer was applied using the foliar technique can significantly increase the zinc content in rice. This can occur due to the addition of zinc sulfate fertilizer which can increase the effectiveness of zinc absorption in plants and translocation during rice seed formation and grain filling. Another study also mentioned that $ZnSO_4$ fertilization can increase zinc content in rice by 29% compared to the 0 dose group (Yogi et al., 2023).

CONCLUSION

Based on the results of data analysis, the following conclusions were obtained that the application of zinc sulfate fertilizer has a significant effect on increasing the quantity and quality of rice yields. The treatment of zinc sulfate fertilizer application as much as 8 kg/ha is the most optimal dose for the growth and yield of rice cultivar Mapan 05. Meanwhile, the highest increase in zinc content in rice was obtained through zinc sulfate fertilization at a dose of 32 kg/ha.

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