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Effects of ameliorant application on the growth and yield of rice plants (*Oryza sativa* L.)

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Abstract

An ameliorant is a chemical that can be used to improve soil fertility. The improving agents include dolomite and steel slag. Steel slag is a by-product of the steel industry containing $CaCO_3$, SiO_2, $CaSiO_3$, and MgO, which can be used to improve the growth and yield of rice plants. Dolomite, on the other hand, is a limestone rock containing MgO and CaO, which is useful in agricultural soils. This study aimed to determine the types and doses of ameliorants affecting the growth and yield of rice plants (Oryza sativa L.). The research was carried out at Sukadana Village, Ciomas Serang-Banten District. A non-factorial Group Randomized Design with seven treatments was employed in this investigation. The treatments include P0 = No treatment (control), P1 = 2 t/ha of dolomite, P2 = 2 t/ha of dolomite + 2.5 t/ha of steel slag, P3 = 1.5 t/ha of steel slag, P4 = 2.5 t/ha of steel slag, P5 = 5 t/ha of steel slag, and P6 = 7.5 t/ha of steel slag. Observation was made on steel slag characterization, plant height, the total number of tillers, the weight of 1000 grains, the amount of grain per clump, and the weight of dry-milled grain. The results showed that applying dolomite at 2 t/ha and steel slag at 2.5 t/ha could increase the weight of 1000 grains of rice, and applying steel slag at 1.5 t/ha could enhance the amount of grain per clump.

INTRODUCTION

Rice is one of the staple food crops and a source of carbohydrates that are widely consumed by the people of Indonesia. Along with the increase in population, the demand for rice will also increase. Ideally, the increase in demand for rice is accompanied by an increase in rice production. In 1789, Thomas Robert Malthus, a demographer, stated that the increase in the human population was inversely proportional to the availability of food (Jati, 2015). Therefore, various efforts are needed to increase rice production so that food availability can offset the increase in population. Soil organic matter content is low, which is the main reason for the low paddy field productivity. According to the findings of Agricultural Research and Development Agency research, the degree of soil fertility falls year after year. According to the results of the study site's soil investigation, it has a slightly acidic pH (5.76), low organic C (1.83%), low P (8.21mg/kg), and low N (0.20%); therefore, soil fertility is one of the most important elements that can influence crop development and yield, including rice. Amelioration is one method of increasing soil fertility. Ameliorants have a vital role in enhancing soil fertility since enhanced soil fertility directly impacts pH, minimizes harmful organic acids, and increases the availability of nutrients for plants (Septiyana et al., 2017).

Dolomite is a natural sedimentary rock-derived ameliorant. Pure dolomite minerals, in theory, constitute 45.6% $MgCO_3$ or 21.9% MgO and 54.3% $CaCO_3$ or 30.4% CaO. The chemical formula for the mineral dolomite can be expressed as $CaCO_3$, $MgCO_3$, $CaMg(CO_3)_2$, or Ca xMg1-x CO_3, where x is less than

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one. Dolomite increases soil pH (Royani et al., 2015). Steel slag is an alternate dolomite ameliorant, which is a by-product of the steel manufacturing process. Various countries, including Japan, Korea, America, Germany, China, and others have utilized steel slag as lime to improve pH and as fertilizer for Ca and Mg content (Devinta et al., 2021). In Japan, initially, steel slag was also used as a liming agent, as was the case in Germany and the United States. Steel Slags are rich in Silicon (Si) and other fertilizer components, such as Ca, Fe, Mn, and P (Pitaka et al., 2015). However, as its benefits for rice crops have been proven, steel slag was designated as Si fertilizer by the Ministry of Agriculture, Forestry, and Fisheries in 1955 (Ma and Takahashi, 2002). The type of steel slag commonly used as Si fertilizer is BF slag, which is often known as calcium silicate slag. In China and Korea, steel slag has also been used as silica fertilizer for rice crops (De Datta, 1981). In Indonesia itself, the type of steel slag used is Electric Furnace Slag (EF slag). According to Suwarno (2010), the total production of this type of steel slag in Indonesia reaches 540,000 tons per year, of which 240,000 tons are produced by PT. Krakatau Steel, and the rest (300,000 tons) are produced by other factories. Given its high output potential and underutilized status in agriculture, a study titled "Effects of the ameliorant application on the growth and yield of rice plants (*Oryza sativa* L.)" is required. This study expected to maximize the use of steel slag as an alternative ameliorant for rice plants while preserving the ecology of steel industrial waste.

MATERIALS AND METHODS

The research was carried out in Sukadana Village, Ciomas Serang-Banten District. This research was arranged in a non-factorial Group Randomized Design with 7 treatments, including P0 = No treatment (control). P1 = 2 t/ha of dolomite, P2 = 2 t/ha of dolomite + 2.5 t/ha of steel slag, P3 = 1.5 t/ha of steel slag, P4 = 2.5 t/ha of steel slag, P5 = 5 t/ha of steel slag, and P6 = 7.5 t/ha of steel slag. Each treatment consisted of three replications, resulting in 21 experimental units in this study. There were 144 plant populations in each treatment plot, which has a surface area of 9 m^2 and a planting space of 25 x 25 cm. From each treatment plot, only 16 plants were sampled, thereby resulting in the total sample of 336. Ameliorant was given a week before transplanting. Fertilizing was carried out a total of three times. The first fertilization using NPK fertilizer with a dose of 150 kg/ha was given on 7 DAT (days after transplanting). The second fertilization was given on 20 DAT using NPK at a dose of 150 kg/ha and urea at a dose of 50

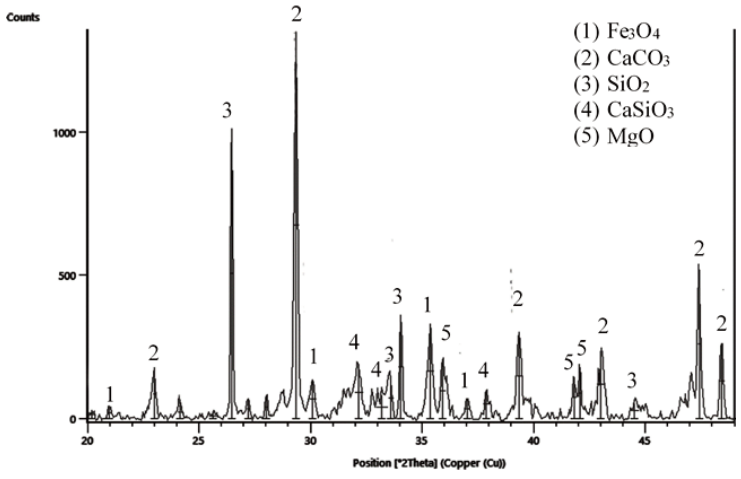

Figure 1. XRD analysis results

Table 1. Composition of elements in steel slag based on XRF analysis results

Element	Mg	Al	Si	P	S	Cd	Ca	Mn	Fe	Ni	Pb
Wt %	7.61	3.31	12	2,29	2.12	0.11	42.12	1.9	28.49	0.01	0.02

kg/ha. And the third fertilization was given on 30 DAT. The fertilizer used was urea fertilizer with a dose of 60 kg/ha. Observation variables include steel slag characterization, plant height, the total number of tillers, the weight of 1000 grains, the amount of grain per clump, and the weight of dry-milled grain. The data were analyzed using ANOVA, followed by the Duncan Multiple Range Test (DMRT) at a significance level of 5%.

RESULTS AND DISCUSSION

Steel slag characterization

The main chemicals and chemical element content of the slag were determined using XRD and XRF analyses. The results of the XRD steel slag analysis can be seen in Figure 1. Figure 1 shows the compounds contained in the steel slag, including Fe_3O_4, $CaCO_3$, SiO_2, $CaSiO_3$, and MgO. The elements contained in the compounds in this steel slag can be macronutrients and micronutrients for soil and plants.

Table 1 displays the findings of the XRF steel slag study. Table 1 shows that the major element in this steel slag sample is Ca (42.12%). Ca has entered the standard level of dolomite fertilizer, which is a minimum of 29%. Fe and Si have relatively high percentages of 28.49% and 12%, respectively.

Plant height

Plant height is one of the variables observed to determine the effect of ameliorant treatment. During the vegetative phase, plant height was measured on 14, 28, and 42 DAT. Figure 2 depicts the findings of the observations. Figure 2 illustrates that the use of several types of ameliorants has no discernible effect on plant height. This is due to the fact that steel slag and dolomite have no effect on plant height. Steel slag has a Fe (iron) percentage of 29.6%, which is high enough to limit rice plant growth during the vegetative period, according to ameliorant content statistics. According to Zulputra and Nelvia (2018), the high concentration of Fe, Al, and Mn cations in the soil can reduce the availability of P elements since P elements are fixed by the three cations, making them a limiting factor for plant growth and production. Based on this description, it is clear that plants require more nutrients for good growth; nevertheless, the number 18 must be modified to the demands of each plant in order to promote optimal growth.

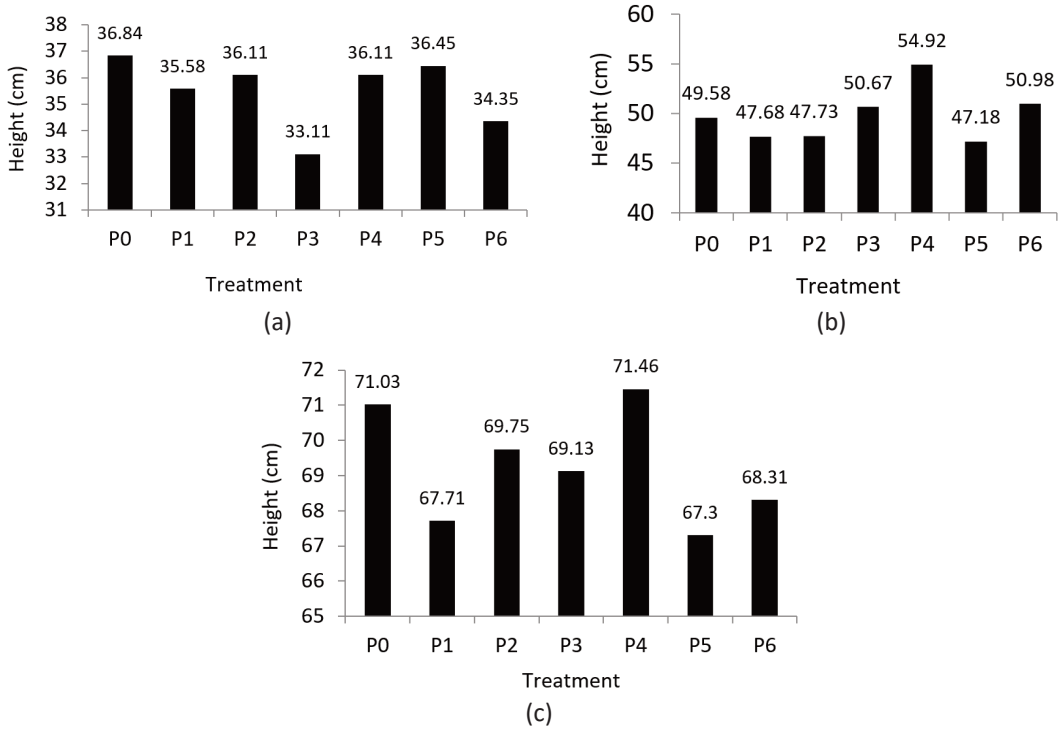

Figure 2. Height of rice plants (*Oryza sativa* L.) as affected by ameliorant application

Remarks: P0: control; P1: Dolomite 2 t/ha; P2: Dolomite2 t/ha + Steel slag 2.5 t/ha; P3: Steel slag 1.5 t/ha; P4: Steel slag 2.5 t/ha; P5: Steel slag 5 t/ha; P6: Steel slag 7.5 t/ha 14 DAT (a); 28 DAT (b); 42 DAT (c).

Total number of tillers

The total number of tillers was examined to determine the effect of ameliorant therapy. During the vegetative phase, the total number of tillers was observed on 14, 28, and 42 DAT. Figure 3 depicts the findings of the total number of tillers observed. Figure 3 shows that the application of various types of ameliorants has a substantial influence on the total number of tillers, where the control treatment differs significantly from the other treatments. This is assumed to be due to the fact that the control treatment already has adequate nutrients from urea and NPK fertilizer.

Weight of 1000 grains

One of the variables observed to determine the effect of ameliorant treatment is the weight of 1000 grains. A weight of 1000 grains iwass observed at the time of harvest. The results of the observations can be seen in Figure 4. Based on Figure 4, the dolomite treatment of 2 t/ha + steel slag of 2.5 t/ha significantly

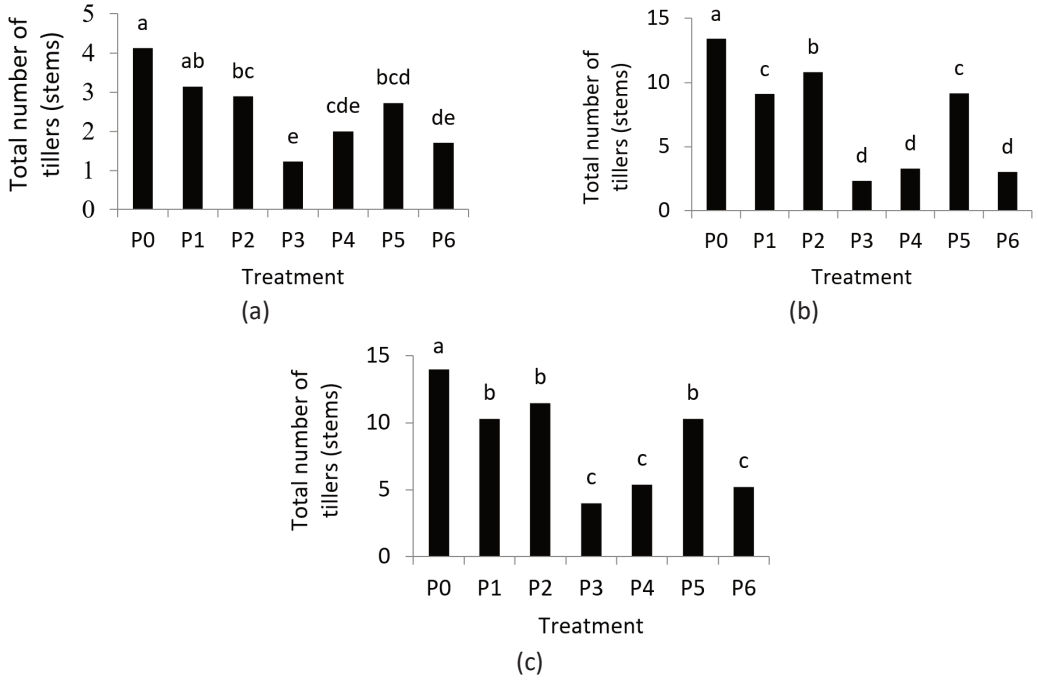

Figure 3. Total number of tillers of rice plants (*Oryza sativa* L.) as affected of ameliorant application

Remarks: P0: control; P1: Dolomite 2 t/ha; P2: Dolomite2 t/ha + Steel slag 2.5 t/ha; P3: Steel slag 1.5 t/ha; P4: Steel slag 2.5 t/ha; P5: Steel slag 5 t/ha; P6: Steel slag 7.5 t/ha 14 DAT (a); 28 DAT (b); 42 DAT (c).

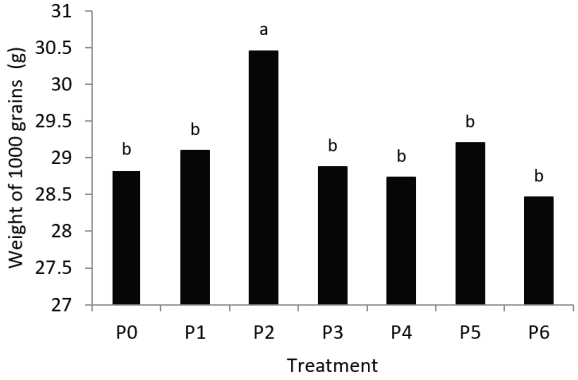

Figure 4. Weight of 1000 grains of rice plant (*Oryza sativa* L.) as affected by ameliorant application

Remarks: P0: control; P1: Dolomite 2 t/ha; P2: Dolomite2 t/ha + Steel slag 2.5 t/ha; P3: Steel slag 1.5 t/ha; P4: Steel slag 2.5 t/ha; P5: Steel slag 5 t/ha; P6: Steel slag 7.5 t/ha.

produced the highest weight of 1000 grains, with an average of 30.45 grams per 1000 grains. This is because of the high concentration of Si elements in steel slag and dolomite, which has no discernible effect on grain weight. According to the findings of Birnadi et al. (2019), the application of fertilizers containing Si nutrients has no actual impact on the grain weight of 1000 grains. However, if nutrients are consistently provided at the highest level required by the plant, they will reach their maximum point, resulting in decreased plant growth and production.

Amount of grain per clump

The amount of grain per clump is one of the variables observed to determine the effect of ameliorant treatment. The amount of grain per clump was measured after harvest. Figure 5 depicts the findings of the observations. Figure 5 demonstrates that the 1.5 t/ha steel slag treatment has significantly more grain per clump than the other treatments, with a total grain of 32929.66 grains. This is assumed to be due to the presence of Si in steel slag, which contributes to the amount of grain per clump. According to the findings of the Si analysis on soil, the Si concentration in the treatment of steel slag increased to 319.04–341.71 mg/kg. According to Rao and Susmitha (2017), silica (Si) is a plant-beneficial ingredient that is agronomically crucial for increasing and maintaining rice output. Furthermore, silica can boost nutrient levels (Zn, N, P, K, Mg, Ca, and S), decrease toxicity, and reduce biotic and abiotic stress in plants.

Weight of dry milled grain (DMG)

One of the variables observed to determine the effect of the treatment of giving various types of ameliorants is the percentage of dry milled grain.

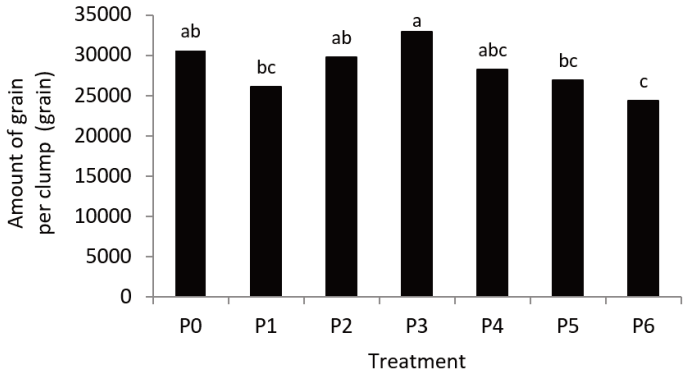

Figure 5. Amount of grain per clump of rice plants (*Oryza sativa* L.) as affected by ameliorant application

Remarks: P0: control; P1: Dolomite 2 t/ha; P2: Dolomite2 t/ha + Steel slag 2.5 t/ha; P3: Steel slag 1.5 t/ha; P4: Steel slag 2.5 t/ha; P5: Steel slag 5 t/ha; P6: Steel slag 7.5 t/ha.

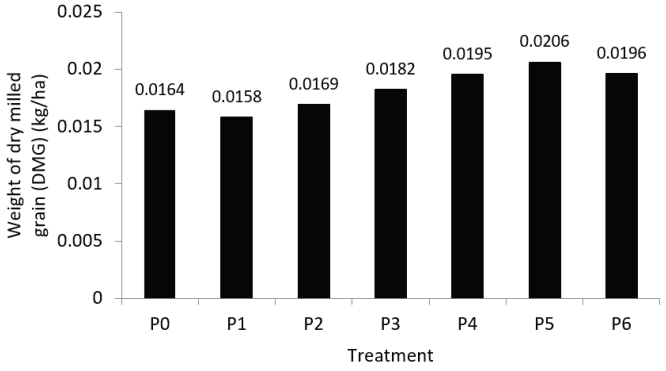

Figure 6. Weight of dry milled grain (DMG) of rice plants (*Oryza sativa* L.) as affected by ameliorant application

Remarks: P0: control; P1: Dolomite 2 t/ha; P2: Dolomite2 t/ha + Steel slag 2.5 t/ha; P3: Steel slag 1.5 t/ha; P4: Steel slag 2.5 t/ha; P5: Steel slag 5 t/ha; P6: Steel slag 7.5 t/ha.

The percentage of dry-milled grain was observed at the time after harvest. The results of the observations can be seen in Figure 6. Based on Figure 6, the application of ameliorants does not give significant effect on the weight of dry-milled grain (DMG). According to the results of research by Ning et al. (2014), the provision of steel slag as an ameliorant can increase the weight of grain in rice plants. This is due to the fact that steel slag application can increase the availability of Si, Ca, Mg, and soil pH components (Suwarno, 2002). Steel slag's Ca and Mg composition allows it to act as both a lime to raise soil pH and a fertilizer by providing these two essential elements. The Si content of steel slag is also used to boost the Si content of the soil. Si plays a key function in the production of grains and husks in rice plants. Sufficient Si will spur the absorption of essential nutrients optimally so that it can improve the growth and production of rice plants (Siregar et al., 2020). However, the weight of DMG fell again in the steel slag treatment at a dose of 7.5 t/ha. According to Birnadi et al. (2019), the addition of nutrients will reach a maximum point if it is added continually to the maximum limit required by plants, resulting in decreased plant growth and production.

CONCLUSIONS

According to the research, providing ameliorants did not increase the total number of tillers, the number of productive tillers, the weight of dry milled grain, the percentage of filled grain, and the percentage of empty grain. However, a dolomite treatment of 2 t/ha plus a steel slag treatment of 2.5 t/ha could increase the weight of 1000 grains, and a steel slag treatment of 1.5 t/ha could increase the amount of grain per clump.

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