THE EFFECT OF SILICA AND MANGANESE APPLICATION ON RICE GROWTH AND YIELD
Paul Benyamin Timotiwu* and Maya Maeistia Dewi
Faculty of Agriculture University of Lampung
Jl. Sumantri Brojonegoro No.1 Bandar Lampung 35145 Bandar Lampung Indonesia
*) Corresponding author Phone: +62-8154039127 E-mail: paul.timotiwu@gmail.com
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ABSTRACT
The application of silica and manganese through the leaves can be directly absorbed by the rice plants for growth and yield. This study aimed to determine the effect of the increasing silica and manganese concentration and their interaction on plant growth and rice yield. The greenhouse research was conducted in the Seed and Plant Breeding Laboratory, Agriculture Faculty, Lampung University from June–September 2013. The treatments were arranged in a 5x2 factorial consisting of five concentrations of Si [(0, 50, 100, 150, and 200 ppm), and two concentrations of Mn (0 and 5ppm)] in a randomized complete block design with three replications. The results showed that increasing concentration of Si increased the green of leaves, the number of productive tillers, dry weight, filled grains number, and decreased angle of the tiller and the number of empty grains. The application of Mn increased the growth and rice yield, except angle of tillers and the number of empty grains. In addition, the effect of Mn depended on the level of Si concentration. Application of Mn with increasing Si concentration increased plant growth and rice yield.

Keywords: manganese, rice, silica

INTRODUCTION
The application of silica and manganese through the leaves can be directly absorbed by the rice plants for growth and yield. This study aimed to determine the effect of the increasing silica and manganese concentration and their interaction on plant growth and rice yield. Indonesia has sought to increase yield of rice through many ways, one of which is intensification cultivation through fertilization. Fertilization is the provision of materials, both to the soil and the plants intended to supplement for the nutrients that can improve soil fertility and increase the quantity and quality of crops (Thompson and Troeh, 2005).

During the growth period, rice plants require a balanced nutrition to support their survival. In addition to macro nutrients, there are several other micro nutrients, such as silica (Si), which is also beneficial to the rice crop. Some studies suggested that Si has some important roles to the rice crop. The application of Si improves yields through increased efficiency of photosynthesis and induces resistance to pests and diseases (Makarim et al., 2007).

Another essential micro nutrient, manganese (Mn) is also beneficial for the growth of rice. Manganese plays a role in the physiological processes in plants as an activator of several enzymes and a catalyst in splitting water molecules during photolysis process of photosynthesis (Gardner et al., 1985; Humphrise, 2006; and Aref, 2012). According to Sutedjo (2008) and Agustina (2011), Mn could maintain the condition of the green leaves, especially on older leaves. With an addition of Mn, the old leaves were expected to be able to photosynthesize which resulted in the increase of yield potential.

Both Si and Mn are expected to directly increase the production of rice in order that the rice demand could be met. This study aimed to determine the effect of increasing concentration of silica and manganese, as well as their interaction on the rice growth and yield.
MATERIALS AND METHODS

The research was conducted in the Green-house of the Seed and Plant Breeding Laboratory, Faculty of Agriculture, University of Lampung from June–September 2013.

The materials used were Mekonggar rice variety, urea, SP-18, KCl, distilled water, silica (SiO$_2$), manganese (MnSO$_4$.4H$_2$O), chloro-bromo acid 50%, Fipronyl 50 g l$^{-1}$, and Fenobukarb 500 g l$^{-1}$. The laboratory instruments used were electronic scales with 0.01 g sensitivity, measuring cups, measuring flask, plastic bucket, hand sprayer, Konica Minolta SPAD 502 series chlorophyll meter, gauge, protractor, oven, and seed blower.

The treatments were arranged in factorial with five concentrations of Si and two concentrations of Mn. The study was conducted in a randomized complete block design with three replications. The first factor is the five concentration of Si, 0 ppm Si (Si$_0$), 50 ppm Si (Si$_1$), 100 ppm Si (Si$_2$), 150 ppm Si (Si$_3$), and 200 ppm Si (Si$_4$). The second factor was the two concentrations of Mn, 0 ppm Mn (Mn$_0$) and 5 ppm Mn (Mn$_1$). There were 30 experimental plots altogether.

The micronutrient Si and Mn were applied three times started on day 21 after planting with a 4 week interval. The applications were done in the morning from 9:00–11:00 pm. The treatment was applied to the entire surface of the leaves of rice plants. The Si and Mn were applied on the same day, and Mn was first applied to the rice leaves, followed by Si.

Observed variables on the plant growth and yield of rice were the green level of leaf, angle of tillers, number of productive tillers, dry weight, number of filled grains, number of empty grains, and yield. Data were then analyzed using Orthogonal Contrast and Polynomial for Mn and Si. The entire test was done at the level $\alpha$ of 5% and 1%.

RESULTS AND DISCUSSION

The results of study showed that rice plants were responsive to the increasing concentration levels of Si and Mn. Polynomial analysis on the level $\alpha$ of 5% and 1% presented in Table 1 and 2 shows that there was an interaction between concentration of Si and Mn on rice growth and yield. Increasing concentration of Si to 200 ppm with addition of 5 ppm Mn showed the best response of rice plants in all variables, except the angle of tillers and number of empty grains. This was caused by the differences between mobilization and distribution of Si and Mn in the plant tissues. Distribution and mobilization of Si in the plant tissues was faster and easier than those of Mn (Humphrire, 2006). In the leaf tissues, Mn was relatively immobile and accumulated in the leaf tissues of rice plants. In addition, Si was distributed faster to the rice stem lignin bound to the components of the cell wall. Silica bound into the cell wall caused rice seedling angle to become more upright without the presence of Mn (Figure 1).

Table 1. Recapitulation effect of an increase in the concentration of Si and the addition of Mn on the rice growth

| Comparison | TA | TLG | PT | DW | % difference | labyrinth |
|------------|----|-----|----|----|--------------|-----------|
| P1: Mn$_0$ vs Mn$_1$ | -1.16 nd | 3.61 ** | 13.58 ** | 6.14 ** |
| P2: Si+Linear | ** | ** | ** | ** |
| P3: Si+Quadratic | nd | nd | nd | nd |
| Interaction | P4: P1xP2 | ** | ** | ** | ** |
| P5: P1xP3 | nd | nd | nd | nd |

The response curve of Si

| Comparison | TA | TLG | PT | DW | % difference | labyrinth |
|------------|----|-----|----|----|--------------|-----------|
| P6: S0: Mn$_0$ vs Mn$_1$ | -8.69 nd | 6.18 ** | 1.88 nd | 9.27 nd |
| P7: S1: Mn$_0$ vs Mn$_1$ | -11.49 ** | 3.07 ** | 5.17 nd | 9.13 ** |
| P8: S2: Mn$_0$ vs Mn$_1$ | 3.27 nd | 2.10 ** | 17.64 ** | 7.58 ** |
| P9: S3: Mn$_0$ vs Mn$_1$ | 5.28 nd | 3.47 ** | 18.31 ** | 3.34 ** |
| P10: S4: Mn$_0$ vs Mn$_1$ | 8.01 nd | 3.27 ** | 20.27 ** | 0.49 ** |

The response curve of Si

Remarks: Mn$_0$= 0 ppm Manganese; Mn$_1$= 5 ppm Manganese; Si$_0$= 0 ppm Silica; Si$_1$= 50 ppm Silica; Si$_2$= 100 ppm Silica; Si$_3$= 150 ppm Silica; Si$_4$= 200 ppm Silica; TA= angle of tillers; TLG= the level of greenness of leaves; PT= productive tillers number; DW= dry weight. * and ** significant at $\alpha$ = 5% and 1%, nd= not significant at $\alpha$ = 5%

As reported, the utilization of Si on rice improved yield through increased efficiency of photosynthesis. According to Makarim et al. (2007), increased levels of Si in the plant tissues strengthen the tissues mechanically so as to prevent the occurrence of leave and stem droops on rice plants.
When sunlight was absorbed by the leaves, a photolysis process of splitting water molecules happened. Millaleo et al. (2010) mentioned that the role of Mn as a catalyst in the photolysis process would indirectly increase the activity of photo-synthesis. Increased photosynthetic activity affected the concentration of chlorophyll in the leaf tissues. Chlorophyll concentration determined leaf green index measured as SPAD value. The greater the chlorophyll concentration was, the greater the value of SPAD would be, which measured the greater leaf green level. The result showed that the addition of 5 ppm Mn increased the green level of leaves of rice, as compared to those without Mn addition (Figure 2). Working with beans, Santoz et al. (2013) reported that a decline in the rate of photosynthesis and the SPAD values as much as 18% and 70%, respectively in the leaves resulted from Mn deficiency. It proved that Mn participated in enhancing photosynthetic activity through increasing the concentration of chlorophyll. These conditions made the leaves remain green even though they were at senescence age.

The positive effects of increased concentrations of Si and Mn applications on the rice plants were also evident from the increase in the number of productive tillers (Figure 3) and dry weight (Figure 4). The increasing concentration to 200 ppm accompanied by the addition of 5 ppm Mn increased organic compounds synthesized by plants through the increased photosynthesis. This synthesis produced starches, lipids, and proteins which were used by the plant for the division process and the increase of cell size, which resulted in the increase on the number of tillers (Salisbury and Ross, 1991 and Taiz and Zeiger, 2010). Assimilated products were then used to increase the supply of organic materials in the plant tissues in order to increase their dry weight. Junior et al. (2010) found that the addition of 2 mmol l⁻¹ accompanied by an increase in Mn concentration up to 10 μmol l⁻¹ can increase dry matter production of rice. Similar result was found in cucumber plants grown with Si supply, Maksimović et al. (2012) described that root and shoot dry weight increased significantly as the concentration of Mn in the nutrient solution was 0.5 μM.

### Table 2. Recapitulation of the effect of an increase in the concentration of Si and the addition of Mn on rice yield

| Comparison       | Variable | PG   | EG   | RY   |
|------------------|----------|------|------|------|
| **Variable**     |----------|------|------|------|
| Manganese        |          |      |      |      |
| P1: Mn₀ vs Mn₁   |          | 13.04** | -57.58** | 1.78** |
| Silica           |          |      |      |      |
| P2: Si-Linier    |          | **   | **   |      |
| P3: Si-Quadratic |          | **   | nd   |      |
| Interaction      |          |      |      |      |
| P4: P1 x P2      |          | **   | **   |      |
| P5: P1 x P3      |          | nd   | *    | nd   |
| The response of Mn |          |      |      |      |
| P6: Si₀Mn₀ vs Mn₁ |          | 3.69nd | -107.34** | 1.20nd |
| P7: Si₁Mn₀ vs Mn₁ |          | 11.33** | -55.14** | 3.23nd |
| P8: Si₀Mn₀ vs Mn₁ |          | 14.53** | -49.52** | 10.85** |
| P9: Si₀Mn₀ vs Mn₁ |          | 16.82** | -35.57** | 3.23nd |
| P10: Si₀Mn₀ vs Mn₁ |         | 17.43** | -32.58** | 14.42** |
| The response curve of Si |          |      |      |      |
| P11: Mn₀:Si-Linier |        | **   | **   |      |
| P12: Mn₀:Si-Quadratic |          | -    | **   |      |
| P13: Mn₀:Si-Linier |          | **   | tn   |      |
| P14: Mn₀:Si-Quadratic |         | -    | tn   |      |

Remarks: Mn₀= 0 ppm Manganese; Mn₁= 5 ppm Manganese; Si₀= 0 ppm Silica; Si₁= 50 ppm Silica; Si₂= 100 ppm Silica; Si₃= 150 ppm Silica; Si₄= 200 ppm Silica; PG= filled grains number; EG= the empty grains number; RY= rice yield. * and ** significant at α = 5% and 1%, nd= not significant at α = 5%
Figure 1. Relationship between elevated concentrations of Si with and without Mn on angle of tillers

Figure 2. Relationship between elevated concentrations of Si with and without Mn on the level of greenness of leaves

Figure 3. Relationship between elevated concentrations of Si with and without Mn the number of productive tillers
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Figure 4. Relationship between elevated concentrations of Si with and without Mn on dry weight

\[ y = 0.07x + 96.20 \]
\[ R^2 = 0.97^{**} \]
\[ y = 0.02x + 95.20 \]
\[ R^2 = 0.97^{**} \]

Figure 5. Relationship between elevated concentrations of Si with and without Mn on the number of filled grains

\[ y = 4.0593x + 2537.1 \]
\[ R^2 = 0.944 \]
\[ y = 1.6331x + 2395.9 \]
\[ R^2 = 0.954 \]

Figure 6. Relationship between elevated concentrations of Si with and without Mn on the number of empty grains

\[ y = 0.00x^2 - 0.09x + 24.43 \]
\[ R^2 = 0.95^{**} \]
\[ y = 11.42 \]
Increasing assimilated products as an indicator of photosynthetic efficiency improvement due to the increased concentration of Si and Mn addition increased the number of filled grains (Figure 5). Assimilated products of photosynthesis translocated from the leaves into the grain to increase the number of filled grains. The increasing number of filled grains and the reducing number of empty grains were shown at Figure 6. Increasing the number of filled grains led to an increase in rice production (Figure 7).

Overall, the results demonstrated that the interaction between the Si and Mn increased the growth and production of rice. Concentration of Si with Mn application increased the efficiency of photosynthesis beneficial to rice yield and growth.

CONCLUSIONS AND SUGGESTION

CONCLUSIONS

The increase of Si concentration to 200 ppm increased the green level of leaves, the number of productive tillers, dry weight, the number of filled grains, and rice yield, and reduced the angle of tillers and the number of empty grains.

The addition of 5 ppm Mn increased the growth and rice yield when compared to without Mn as indicated by all variables, except the angle of tillers and the number of empty grains.

Rice growth and yield increased with the increasing concentration of Si with the addition of 5 ppm Mn.

SUGGESTION

To support the efforts to increase rice production, the research toward limiting factors such as the environment is necessary. Since this study was done in a greenhouse, environmental factors could be controlled in a good fashion, so that the results obtained were not able to describe the yield significantly compared to the study conducted in the field. Therefore, similar field study on rice needs to be done to obtain more realistic results.

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