Effect of Silicate Fertilizer on the Growth and Yield of Two Local Indonesian Varieties of Rice (Oryza sativa L.)

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Effect of Silicate Fertilizer on the Growth and Yield of Two Local Indonesian Varieties of Rice (*Oryza sativa* L.)

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ABSTRACT

Background: The beneficial elements availability such as silicon was determined rice growth and yield. Rice requires a different dose of silicon during the growing period. Experiment was aimed to investigate the effect of silicate levels, rice varieties and the interaction of the two on the growth and yields of two local Indonesian varieties of rice.

Methods: A completely randomized design of factorial pattern with 4 replications was used in the experiment. Treatments consisted of No added SiO_2 (Si-0); added 100 and 200 kg SiO_2 ha^{-1}, respectively for Si-100 and Si-200 and two local rice varieties, *Pandan wangi* (P1) and *Mentik susu* (P2).

Result: The treatment had no significant effect on growth and yield of rice. Addition of 100 and 200 kg SiO_2 ha^{-1} to P1 and P2 did not show a significant difference on the growth and yield of rice compared to control (P0). Plant height and root dry weight at P1 was lower than P2, but the 1,000-grain weight was showed, vice versa. Silicon addition up to 200 kg SiO_2 ha^{-1} may not be recommended to be applied in rice cultivation, especially *Pandan wangi* and *Mentik susu* varieties. Improving the two varieties, further research is needed by increasing the silicon doses.

Key words: Growth, Rice *var. Mentik susu*, Rice *var. Pandan wangi*, Silicon, Yield.

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INTRODUCTION

Rice (*Oryza sativa* L.) plays an important role because it is Indonesia's staple food. Indonesia achieved rice self-sufficiency in the 1990s. However, rice productivity has stagnated in the past decade even though the area of rice cultivation has increased. Rice productivity increased by 3.8% from 2014 to 2015, but decreased by 1.9% in 2016 and subsequently rice productivity remains unchanged from 2016-2018 (Indonesian Ministry of Agriculture, 2019).

Intensive agricultural activity may not only decreased soil macro elements but also depleted other beneficial elements such as Silicon (Si). Silicon is the second most abundant element in the Earth's crust and it is abundant in most soil (Datnoff *et al.,* 1997). Silicon is widely known as a beneficial element that plays an important role in determining the growth and production of plants, especially the family of gramineae. Depletion of Si in the soil might be one of factors that may contributing the declined of rice yield (Meena *et al.* 2014; Ma 2004; Lian, 1995; Ma *et al.,* 1989). There are lots of evidence of the role of Si on agricultural land was reported from around the world (Carrasco-Gil *et al.* 2018; Cuong *et al.,* 2017; Anggria *et al.,* 2016; Abe *et al.,* 2016; Gautam *et al.,* 2016; Klotzbucher *et al.,* 2013; Hattori *et al.,* 2005; Savant *et al.,* 1997a; 1997b). The use of silicates provides an advantage on rice yields had been reported by Sharma in Dikshit *et al.* (2001).

The role of Si in plant growth and yield is very significant (Alvarez and Datnoff, 2001). Silicon increases the strength of the cell wall by forming a double layer of Si-cuticle in the leaf epidermal tissue and plays an important role in leaf firmness, maintaining the balance of plant water, transpiration, photosynthetic activity and xylem vessel structure (Hattori *et al.,* 2005). Plant physical improvement may affect the absorption of sunlight and lead to an increase in the efficiency of the photosynthetic rate and consequently increase crop yields (Prawira *et al.,* 2014; Ma *et al.,* 1989; Yoshida, 1981).

Silicon may play a role in the absorption of soil nutrients such as N, P, K and C. Islam and Saha (1969) reported that the addition of Si reduces N uptake by rice except at very low levels of Si application. It was reported that the application of Si increased the efficiency of N use, the accumulation of C and the P status of plants (Neu *et al.,* 2017). They also found that Si application increased Si accumulation at a higher rate in the vegetative stage than at the reproductive stage. In contrast, Greger *et al.* (2018) found that the accumulation and translocation of macro nutrients such as N, P and K in plant shoots was not affected by Si applications.

The Indonesian government continues to strive to increase rice productivity, which has stagnated in the past decade (Indonesian Ministry of Agriculture, 2019). However, most efforts are mainly focused on the role of macro elements such as N and P, while the role of Si availability has not been given much attention (Husnain *et al.,* 2008).

Experiment were carried out to determine the effect of silicate fertilizers, rice varieties and the interaction between the two treatments on the growth and yield of two Indonesian local rice varieties.

MATERIALS AND METHODS

Experiment was conducted from October 2017 to February 2018 at the Agricultural Office Station, Semarang city (07°03′57"-07°30′00" S and 110°14′55"-110°39′03" E), Central Java Province, Indonesia. The experimental site was located at about 348 m above the sea level with monthly temperature ranged from 19 to 30°C, relative humidity 70 to 95% and rainfall 2,201 mm year^{-1}, respectively (Anonymous, 2016).

Soil used was taken from area closed to the industrial region in Semarang municipal. Soil samples were dried at the greenhouse for about 4 days. Air-dried soil were crushed into pieces and sieved passed to 2 mm mesh. Soil was classified as Grumusol type, loam texture, pH 7.7 with the N, P, K and Si content respectively were 0.10%, 0.25%, 0.06% and 0.18%. Soils then were put into experimental plactic pots and placed inside the greenhouse. A certain amount of Si as a treatment was incorporated into soil. Soil then was irrigated with destilled water and left for about 24 hours to reach the field capacity.

Seeds were obtained from a local rice plant breeder "Al-barokah organic rice association" located in Ketapang village, Susukan sub-district, Semarang district (7°26′56" S and 110°33′58" E), Central Java Province, Indonesia. The *Pandan wangi* and *Mentik susu* varieties are both native to Indonesia, belong to Javanica group, aromatic rice. *Pandan wangi* varieties aged 115-120 days after planting (DAP), plant height 150-170 cm, round grain, high quality, resistant to fall, the 1000-grain weight about 300 g, potential yield 6-7 tons/ha. While *Mentik susu* varieties aged 125-130 DAP, oval grain, high quality, resistant to fall, the 1000-grain weight about 360 g, potential yield of 5.5-6 tons/ha. The first panicles appeared on 70 and 90 DAP, for *Pandan wangi* and *Mentik susu* respectively.

Two varieties are well known throughout Indonesia but are cultivated in limited areas, especially on the island of Java. *Pandan wangi* is generally cultivated in West Java province, while *Mentik susu* is in Central and East Java provinces. Both varieties are resistant to pests and diseases.

Seeds were germinated in a tray equipped with germination media and conducted at room temperature. Rice seeds germinate in 4-6 days, then the seeds were allowed to grow for up to 14 days and then these were transplanted into experimental pots (10 L) (Anggria *et al.,* 2017). During the growth period, the need for water and fertilizer was maintained by providing irrigation and N and P fertilizers according to the recommended dosages of 150 kg N/ha and 30 kg P_2O_5/ha, respectively (Indonesian Ministry of Agriculture, 2007).

Rice growth parameters such as plant height, number of tillers and panicles were collected weekly during the growth periods. At harvest shoots, roots and grains were separated. Fresh samples were taken, weight and ovened at 70°C for about 72 hours in order to determined the DW of shoots, roots, grains and the 1,000-grain weight (Candra *et al.,* 2009). The N and C content were determined by using Kjeldahl method and Gravimetric method respectively at the Faculty of Animal and Agricultural Sciences, Diponegoro University, Semarang, Indonesia. Meanwhile, the content of Si deposited at shoots, roots and grains were analyzed using Spectrophotometri UV-vis method (Purwanto and Ernawati, 2012), at Gajah Mada University, Yogyakarta, Indonesia.

A completely randomized design of factorial pattern with four replications was used throughout the experiment. Treatments consisted of silicate fertilizer doses, Si-0 : no added SiO_2, Si-100 : 100 kg SiO_2 ha^{-1} and Si-200 : 200 kg SiO_2 ha^{-1} and two rice varieties, P-1 : *Pandan wangi* and P-2 : *Mentik susu*. Obtained data were analyzed using ANOVA and followed by Duncan's multiple range tests at *p* 5% (Steel and Torrie, 1960).

RESULTS AND DISCUSSION

Morphological performance and yield of rice

There was no significant effect of the interaction between levels of Si and rice varieties on plant morphological parameters such as plant height, number of tillers and panicles, shoots and roots dry weight (DW), plant yield and the 1,000-grain weight. The treatment of Si levels did not significantly affect all the parameters observed. However the treatment of rice varieties showed a significant effect on plant height, roots DW and the 1,000-grain weight. The plant height and roots DW of the *Mentik susu* was higher than the plant height and roots DW of *Pandan wangi*, but the 1,000-grain weight of the *Mentik susu* was lower than the 1,000-grain weight of *Pandan wangi* (Table 1).

Data presented at Table 1 showed that addition of Si at 100 and 200 kg SiO_2/ha was not significantly different from the control. This indicated that the application of Si into the soil has not been able to exceed the ability of the rice in the treatment without addition of Si in affecting the growth and yield of *Pandan wangi* and *Mentik susu* varieties. This finding was not in line with previous studies (Ma *et al.,* 1989; Yoshida, 1981). This may be due to the fact that the doses of Si addition was lower than that the previous study. This suggested that Si application may not be sufficient to increase soil Si availability and consequently cannot support Si uptake by crops so that the presence of Si may not effectively trigger the growth of rice crops. Therefore, the absorption of Si may not be able to increase the strength of plant cell walls optimally and this condition did not affect the physical growth of the plant (Hattori *et al.* 2005). This indicated that the addition of Si had no effect on the physical growth of crops and therefore it did not influence the increase potential of sunlight absorption. As a result, the rate of

Table 1: Morphological performance and yield of rice affected by the treatments.

Rice varieties	Added-Silicon	Plants height (cm)	Tillers (No.)	Panicles (No.)	DW of shoots (g pot^{-1})	DW of roots (g pot^{-1})	DW of grains (g pot^{-1})	The 1,000-grain weight (g pot^{-1})
P1	Si-0	120.3±4.7^{a}	21.5±2.5	17.5±1.3	62.4±3.6	22.3±2.5^{a}	77.9±6.6	26.2±0.4^{a}
	Si-100	119.9±5.1^{a}	23.0±4.1	21.0±3.7	62.2±9.3	29.9±9.6^{a}	76.9±11.7	25.7±0.6^{a}
	Si-200	125.5±3.7^{a}	19.5±1.3	18.8±1.7	63.6±13.1	32.1±7.3^{a}	77.1±8.5	25.6±0.3^{a}
P2	Si-0	134.0±3.7^{b}	19.8±1.7	18.5±0.6	54.9±12.1	57.7±5.5^{b}	72.6±3.7	19.8±0.3^{b}
	Si-100	138.4±8.1^{b}	20.8±1.0	20.8±1.0	68.7±14.5	51.4±9.6^{b}	71.9±3.8	21.4±2.8^{b}
	Si-200	135.6±1.7^{b}	22.8±2.8	19.3±2.1	48.9±4.9	57.8±7.3^{b}	70.1±5.1	21.9±1.9^{b}

Different supercripts at the same column showed significantly differences at $P<0.05$.

Tabel 2: The N percentage and N yield of shoots and roots affected by the treatments.

Rice varieties	Added-Silicon	N-shoot (%)	N-root (%)	N yield of shoots (g pot^{-1})	N yield of roots (g pot^{-1})
P1	Si-0	0.46±0.0	0.72±0.23	29.6±3.7	15.5±4.2^{a}
	Si-100	0.39±0.1	0.66±0.26	24.4±9.1	21.4±4.8^{a}
	Si-200	0.40±0.2	0.81±0.10	31.4±13.9	32.2±20.3^{b}
P2	Si-0	0.56±0.2	0.89±0.12	30.7±12.7	65.2±21.2^{b}
	Si-100	0.49±0.0	0.96±0.12	26.7±3.7	45.5±5.7^{b}
	Si-200	0.49±0.0	0.91±0.08	33.1±4.8	51.4±6.6^{b}

Different supercripts at the same column showed significantly differences at $P<0.05$.

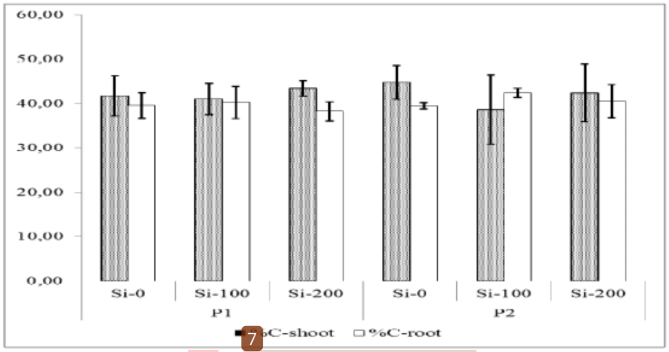

Fig 1: The C content of shoots and roots of rice (%).

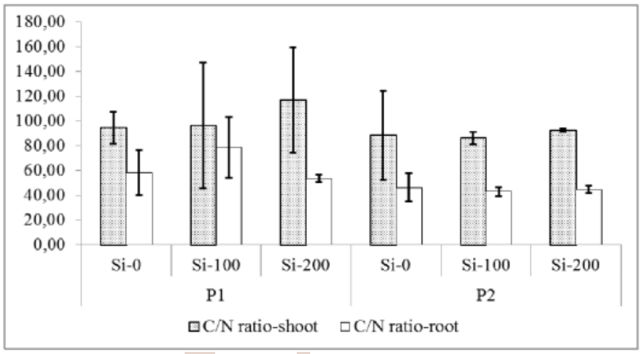

Fig 2: The C/N ratio of shoots and roots of rice.

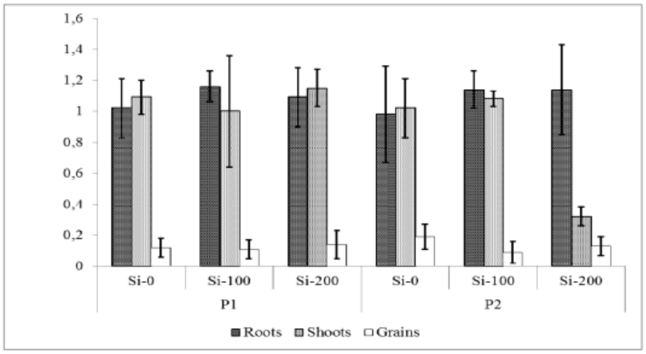

Fig 3: Silicon accumulation at different part of crops (%).

photosynthesis did not increase and consequently did not affect to the yield of crops (Prawira *et al.,* 2014; Ma *et al.* 1989; Yoshida *et al.,* 1981). On the other hand, rice varieties affected the morphological appearance of rice plants (Table 1). This may be due to the fact that both varieties of rice are genetically different. Therefore, the two varieties showed opposite responses to Si application.

N content and N yield of plants

Treatment of Si levels, rice varieties and their interactions did not show a significant effect on N content and N yield of shoots and roots, except for the treatment of rice varieties on N yields, where N yield of *Mentik susu* was higher than *Pandan wangi* (Table 2). This finding was in line with Greger *et al.* (2018) and Islam and Saha (1969), where the application of Si reduces N uptake by plants and translocation of N to shoots and roots. The C content of shoots and roots was also not affected by the addition of Si. Since the N content of shoots and roots was stable, the C/N ratio of both shoots and roots were also stable (Fig 1; Fig 2). These findings are similar to previous results (Greger *et al.,* 2018; Neu *et al.,* 2017).

The distribution of Si on plants

There was no significant difference due to the treatment of Si levels, rice varieties and the interactions of the two treatments on Si content of shoots, roots and grains (Fig 3). This indicated that the Si absorption from the rice rhizosphere due to different Si applications and without Si addition was eventually distributed to shoots, roots and grains. This finding was in line with Neu *et al.* (2017) and Makarim *et al.* (2007) who reported that the accumulation of Si in wheat and rice plants were both deposited to shoots, roots and grains.

CONCLUSION

The results showed that the treatment of Si levels, rice varieties and the interactions of the two treatments did not significantly affect the growth and yield of *Pandan wangi* and *Mentik susu* rice varieties. The addition of 100 kg and 200 kg SiO_2 ha^{-1} at P1 and P2 did not show significant difference on the growth and yields of *Pandan wangi* and *Mentik susu* rice varieties compared to the control (P0). Plant height and root DW at P1 were lower than that at P2, but the 1,000-grain weight at P1 was higher than that at P2. It may be concluded that the addition of silicon up to 200 kg SiO_2 ha^{-1} may not be recommended to be applied in rice plants cultivation, especially the varieties of *Pandan wangi* and *Mentik susu*. However, to improve the performance of the two local rice varieties, further research is needed by increasing the doses of silicon applications.

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