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Effect of silicate fertilizer on the growth and yield of two local varieties of rice (*Oryza sativa* L.)

ABSTRACT

Experiment was conducted to investigate the effect of silicate fertilizer, rice varieties and the interaction between two treatments on the growth and yields of rice. A completely randomized design of factorial pattern with 4 replications was used throughout the experiment. The first factor consisted of No added SiO_2 (Si-0); added 100 kg SiO_2 ha^{-1} (Si-100); added 200 kg SiO_2 ha^{-1} (Si-200), and the second factor were two local varieties of rice, *var. Pandan Wangi* (P1) and *var. Mentik Susu* (P2). The experiment resulted that paramaters observed were not affected by the addition of silica both at 100 and 200 kg SiO_2 ha^{-1}. Genetic factors were thought to have an effect on the performance of both varieties of rice. Silica was absorbed from the rhizosphere of rice and distributed to the shoots, roots and grains.

Key Words: Growth, Rice *var. Pandan Wangi*, Rice *var. Mentik susu,* Silicon, Yield

INTRODUCTION

Rice (*Oryza sativa* L.) plays an important role as it is a staple food for the Indonesian people. Indonesia has very encouraging experienced in connection with rice production as in 1990s Indonesian reached self-sufficiency of rice. However, rice productivity in Indonesia has declined in the last few decades.

Intensive agricultural activity for long period of time may not only decreased soil macro nutrients but also depleted other beneficial element such as Silicon (Si). Depletion of Si in the soil might be one of factors that may contributing the declined of rice yield (Meena *et al.,* 2014). Therefore, it is necessary to improve the quality of soil by implementing silica fertilizer as the application of a certain dose of Si on agricultural land showed beneficial effect on growth and development of crops (Ma 2004; Lian 1995; Ma *et al.,* 1989).

Silicon is the second most abundant element in the eart's crust and it is abundant in most soil (Datnoff *et al.,* 1997; Epstein, 1994). The Si is known as one of beneficial elements that influence the growth and development for many crop spesies. Available Si status in the soil is varied depending on the soil types. It can be provided naturally through weathering process. Therefore, available soil Si in the tropical soil is lesser than that in the temperate soil due to the weathering process (Datnoff and Rodrigues, 2005). The capability in absorbing Si is vary depending on crop species. There are three groups of Si absorbers included Si accummulator crops such as sugarcane, rice and wheat; Si non-accummulator and Si excluder (Marschner 1995; Van der Vorm, 1980). Plants such as rice, wheat, grasses and many other gramineae are considered as great accummulator of Si. It was reported that sugarcane absorbed about 300-700 kg Si ha^{-1}, while rice and wheat absorbed 150-300 and 50-150 kg Si ha^{-1}, respectively (Bazilevich 1993). The most content of Si in plants of the family gramineae such as rice, sugarcane and maize, especially at the surface of leaves, stems and grains (Makarim *et al.,* 2007).

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). Once the physical of plants improved it may influence the absorption of sunlight and cause the increase of photosynthesis rate efficiency and consequently increase crop yield (Prawira *et al.,* 2014; Ma *et al.,* 1989; Yoshida, 1981). Tampoma *et al.* (2017) reported that the application of Si influenced the growth and development of two local varieties of rice namely *the 36-super* and *Tagolu* especially on such paramater as number of panicles, number of grains per panicles and dry weight of crops.

Silicon have a role in absorption soil nutrition as N, P, K and C. Islam and Saha (1969) reported that the addition of Si reduced N uptake by rice with the exception for the very low levels of Si application. Meanwhile, Greger *et al.* (2018) found that generally the avalabiliy and accumulation of nutrients was not affected by application of Si. It was proven that the translocation of some macro nutrients such as N, P and K at the shoot of crops was not influenced by application of Si. In contrast, Neu *et al.* (2017) found that application of Si improved the use N efficiency, C accumulation and P status of crops. On the other hand, it was reported that the C biomass decreased at the Si application compared to that of the control. It was found that the C/N ratio did not show clear pattern but it tend to increase as the Si application increased.

Crops especially rice absorbed Si from the rhizosphere through exodermis, endodermis and xylem stream and deposited the Si on tissues of shoots, roots, and grains. Neu *et al.* (2017) found that application of Si increased the Si accumulation mainly at the vegetative stages (shoots and roots) and higher compared to that of Si content of the grains. The accumulation of Si at the crops of wheat decreased in order shoots, roots and grains. On the other hand, Nayar *et al.* (1982) reported that the absorption of Si was different at the dry season and wet season, respectively ranged from 4,8 to 13,5% and 4,3 to 10.3%.

MATERIALS AND METHODS

Experiment was carried out from May to September, 2017 at the green house of Semarang Agricultural Office Station, Semarang City, Central Java Province, Indonesia (07°03'57"-07°30'00" S and 110°14'55"-110°39'03" E). The experimental site was located at about 348 m above the sea level with monthly temperature range from 19 to 30°C, relative humidity 70 to 95%, and rainfall 2,201 mm year^{-1}, respectively (The Meteorology and Geophysics Center, 2019).

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

Prior to germination, seeds were soaked in distilled water for about 24 hours. Then seeds were placed in a tray that has been equipped with germination media. Germination then was conducted in darkness and room temperature. Time of germination was seen between 4 – 6 days. Seedlings then were allow to grow till 14 days. The 14-day of seedlings then were transplanted into the experimental pots (10 L). Seedlings then were allowed to grow till harvest. During the growing period, the needs of water and fertilizer were maintained by providing irrigation and fertilizer of N and P in according to dose of recommendations.

Rice growth paramaters such as plant height, number of tillers and number of 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 determine the dry weight (DW) of shoots, roots, grains and the 1,000-grain weight. The content of N and C were determined at the Laboratory of Ecology and Crop Productions, Department of Agriculture, Faculty of Animal and Agricultural Sciences, Diponegoro University, Semarang, Indonesia. Meanwhile, the content of Si deposited at shoots, roots, and grains were analyzed using Spektrofotometri UV-vis at the integrated laboratory for research and assesment, Gajah Mada University, Yogyakarta, Indonesia.

A completely randomized design of factorial pattern with four replications was used throughout the experiment. The treatment 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 : Rice *var. Pandan Wangi* and P-2 : Rice *var. Mentik Susu*. Obtained data were analyzed using analysis of variance (ANOVA) (Steel and Torrie, 1960) and it was followed by Duncan's multiple range tests at *p* 5%.

RESULTS AND DISCUSSION

Morphological performance and yield : There was no significant different of interaction Si and rice varieties treatments on the morphological performance of crops such as plant height, number of tillers and panicles, DW of shoots and roots and the yield of crops include the yield of grain and the 1,000-grain weight. The Si treatment did not significantly affect the performance of all paramaters. However, the treatment of rice varieties significantly influenced the plant height, DW of roots and the 1,000-grain weight. The plant height and the DW of roots of *Mentik Susu* was higher than that of the plant height and the DW of roots of *Pandan Wangi*, but the 1,000-grain weight showed the opposite results (Table 1).

On the basis of the data presented at Table 1. shows that all morphological paramaters were not significantly affected by Si application. This is indicated that the addition of Si may not improve the quality of soil and therefore soil may not be able to support rice growth optimally. This finding did not in line with the previous studies (Ma *et al.,* 1989; Yoshida, 1981). This is may be due to the fact that the dose of Si addition was lower compared to that of the previous results so that the presence of Si may not be able to trigger the growth of rice crops. In addition, the doses of added Si might be lower than that it should be. This suggested that the application of Si is likely to be insufficient in increasing the availability of soil Si and may resulting the lower absorption of Si by crops. The Si that absorbed by crops may not be able to increase the strength of plant cell wall optimally and this condition may not influenced the physical growth of crops (Hattori *et al.,* 2005). This indicated that the physical growth of crops may not be able to be improved by the addition of Si, and it may not influence the increasing of sunlight absorption. Consequently the rate of photosynthesis may not be improved and therefore the yield of crops did not increase (Prawira *et al.,* 2014; Ma *et al.*, 1989; Yoshida, 1981). On the other hand, varieties of rice influenced the morphological performance of rice crops (Table 1). This is may be due to the fact that both varieties of rice crops var. *Pandan Wangi* and *Mentik Susu*, genetically had different characteristics. Therefore both varieties show opposite response to the Si application. This finding was in line with Tampoma *et al.* (2017).

The N content and N yield of crops : There was no significant different of interaction Si and rice varieties treatments on the N content and N yield of shoots and roots. The Si treatment did not influence the N content and N yield of shoots, and roots. Meanwhile, the rice varieties treatment has no effect on the N content and N yield of shoots and roots with the exception of N yield of roots where it of *Mentik Susu* was higher than that of *Pandan Wangi* (Table 2).

Data presented at Table 2 shows that the N content and N yield of shoots and roots did not influence by the Si treatment, but the rice varieties treatment influenced the N yield of roots where it of *Mentik Susu* was higher than that of *Pandan Wangi* (Table 2). This finding was in accordance with Greger *et al.* (2018) who found that N translocation to shoots and roots was slightly decreased due to the addition of Si. The decreased of N concentration was clearly understood due to the increase of crops' age that consequently providing dillution effect. This finding was also in accordance with Islam and Saha (1969) who reported that the addition of Si reduced N uptake by rice with the exception for the very low levels of Si. The content of C shoots and roots was not affected by the addition of Si. As the N content of shoots and roots was stable and therefore, the C/N ratio of both shoots and roots was also stable (Figures 1 and 2). These findings were similar to the previous results (Greger *et al.,* 2018; Neu *et al.*, 2017).

The distributin of silicon on the crops : There was no significant different of interaction Si and rice varieties treatments on the Si content of shoots, roots and grains. The Si treatment did not influence the Si content of shoots, roots, and grains. Likewise, rice varieties treatment did not affect the deposite of Si on shoots, roots and grains (Figure 3).

On the basis of the data presented at Figure 3 suggested that Si absorbed from the rhizosphere of rice at the control and Si applications were distributed equally to the crop parts such as shoots, roots and grains. This finding was in line with Neu *et al.* (2017) who suggested that the accumulation of Si at the crops of wheat were decreased in order shoots, roots and grains. The finding was also in line with Makarim *et al.* (2007) who stated that the most content of silica of gramineae such as rice, sugarcane and maize, mainly at the surface of leaves, stems and grains.

CONCLUSION

On the basis of the results found throughout the experiment, it may be concluded that the addition of Si up to 200 kg SiO_2 ha^{-1} to rice cultivation under pots management generally did not affect the growth and yield of rice both of varieties *Pandan Wangi* and *Mentik Susu*. However, genetic factors of both varieties were thought to have an effect on the morphological performance of rice. Silica was absorbed from the rhizosphere of rice and distributed to the shoots, roots and grains.

ACKNOWLEDGMENT

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

Rice	Added-	Plants	Tillers	Panicles	DW of	DW of	DW of	The

varieties	Silicon	height (cm)	(No.)	(No.)	shoots (g pot^{-1})	roots (g pot^{-1})	grains (g pot^{-1})	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

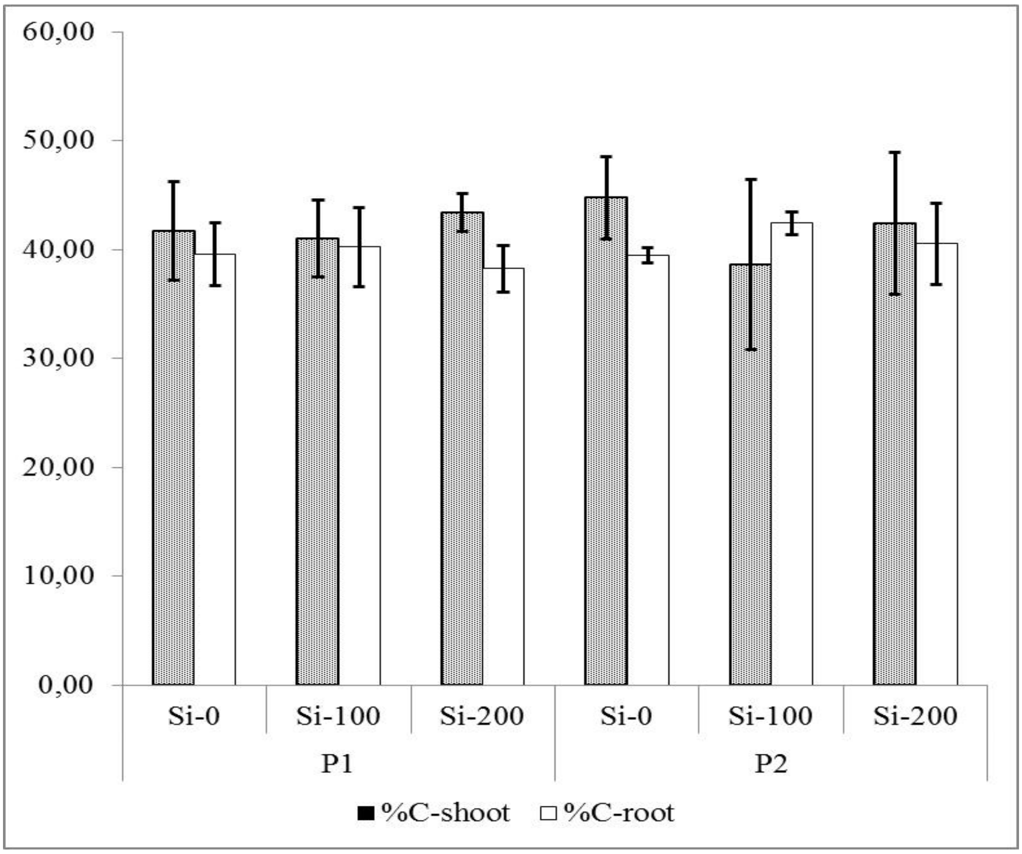

Figure 1. The C content of shoots and roots of rice (%)

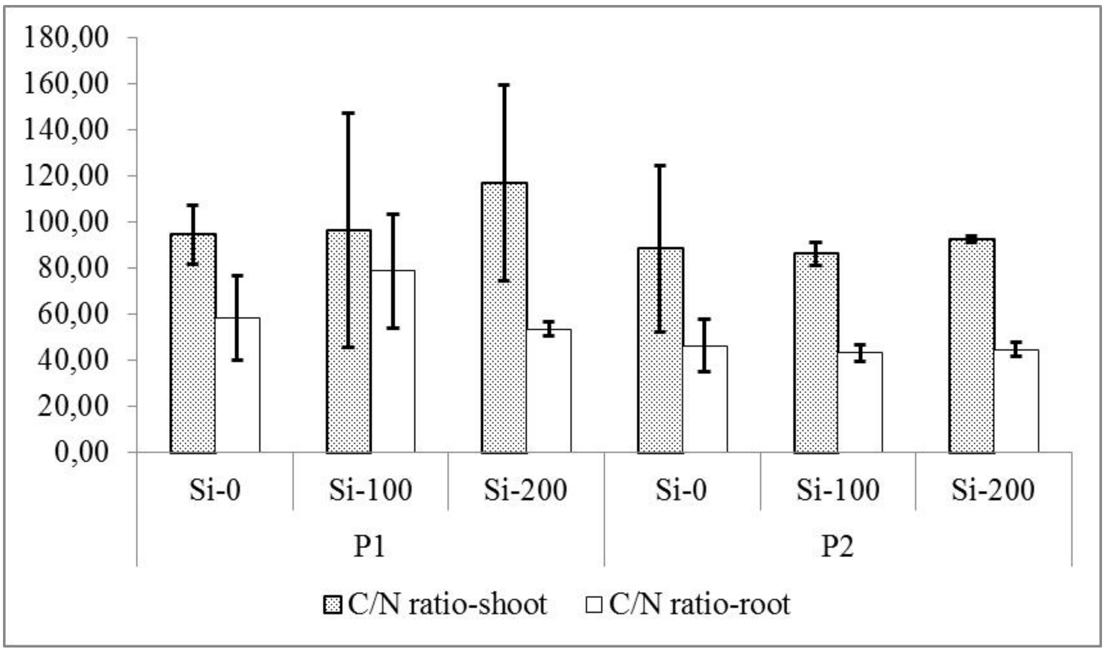

Figure 2. The C/N ratio of shoots and roots of rice

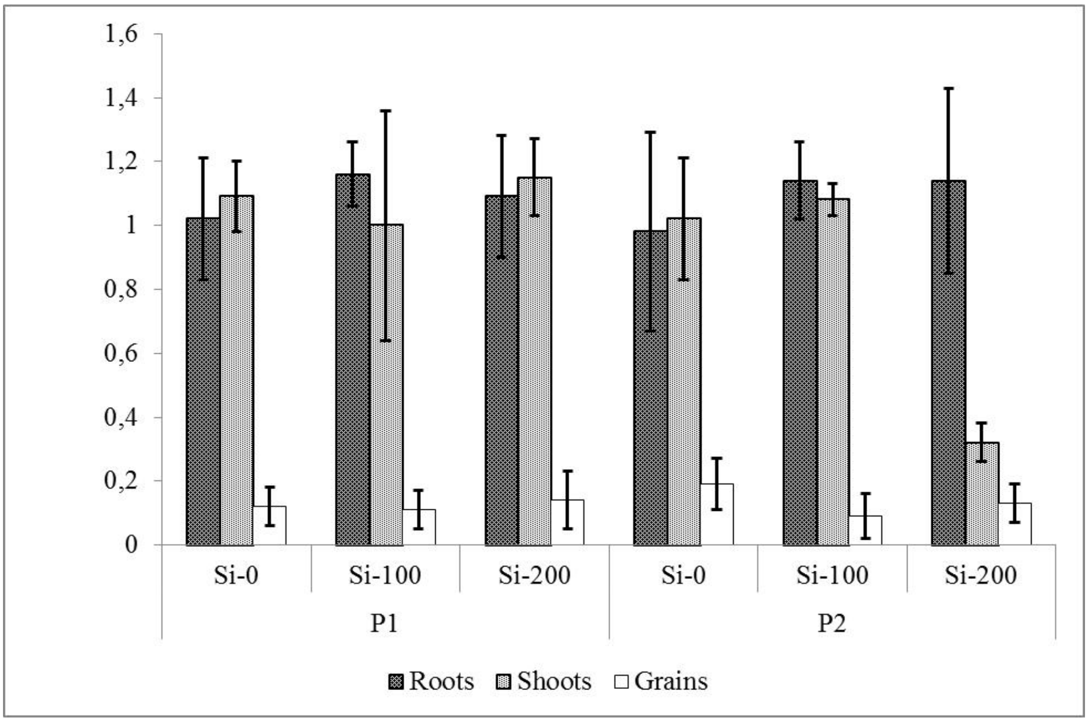

Figure 3. Silicon accumulation at different part of crops (%)

Original Research Article **A-559**

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. Pandan wangi*, Rice *var. Mentik susu,* 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; Chong *et al.* 2017; Anggria *et al.* 2016; Abe *et al.* 2016; Gautam *et al.* 2016; 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 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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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 $P<0.05$

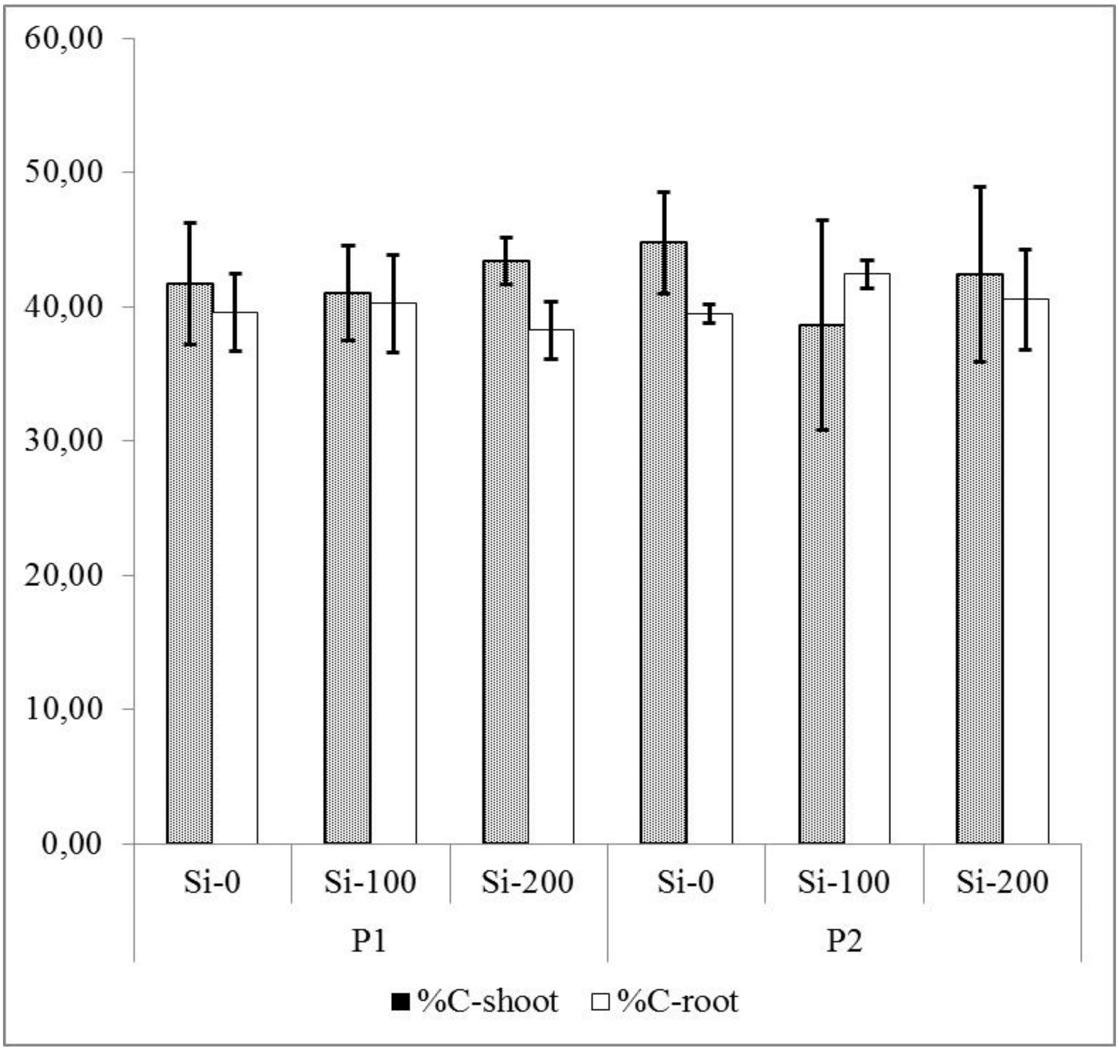

Fig. 1: The C content of shoots and roots of rice (%)

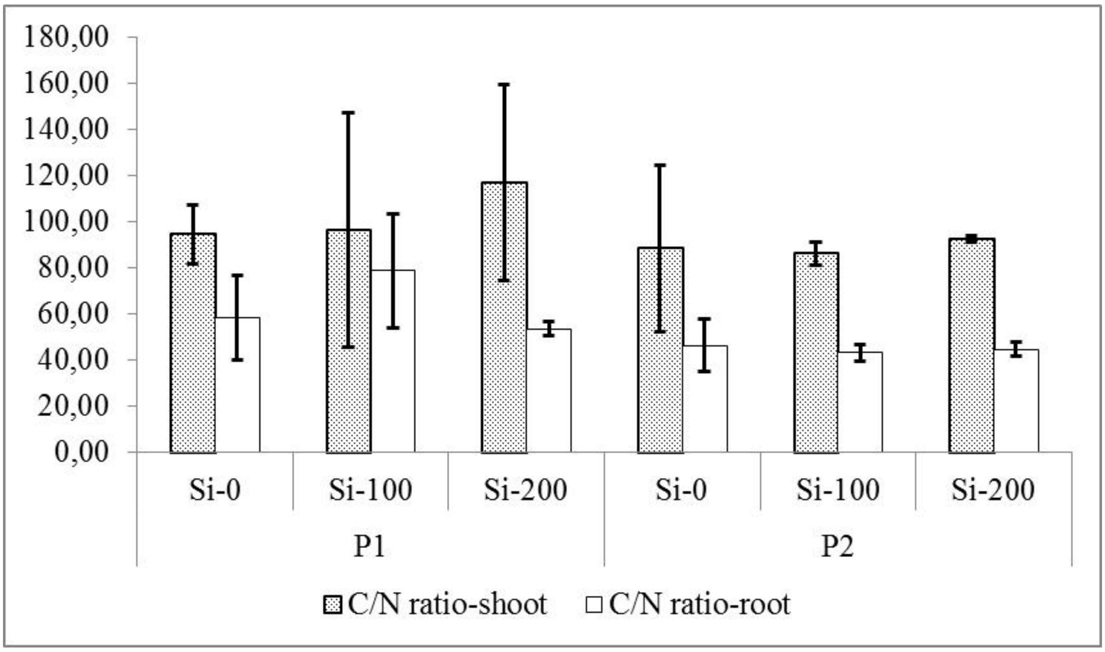

Fig. 2: The C/N ratio of shoots and roots of rice

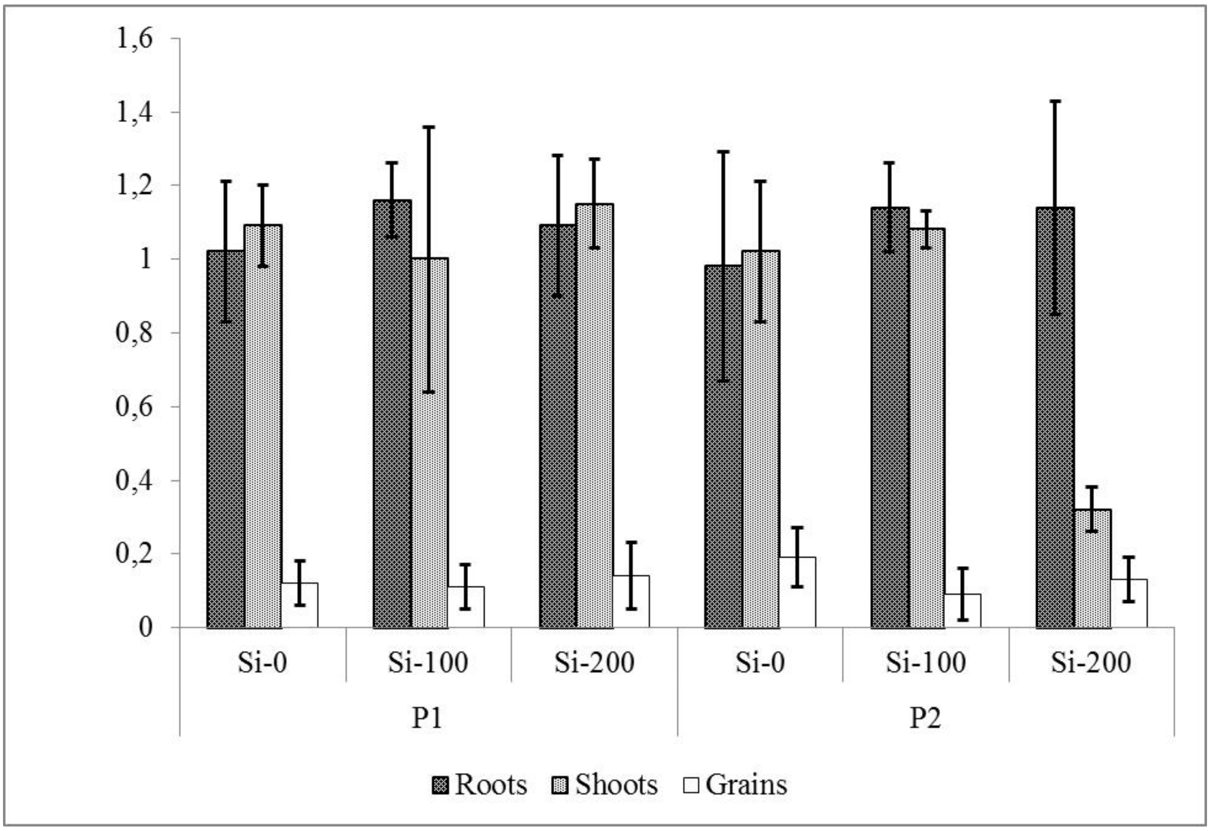

Fig. 3: Silicon accumulation at different part of crops (%)