



Agronomic and Physiological Response of Rice Plant to Application of Silica from Different Sources

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The research aimed to study the response of agronomy and physiology of rice plant to different silica sources.

Study Design: Completely randomized design.

Place and Duration of Study: The research was conducted in screen house of Faculty of Agriculture, Andalas University, Padang, Indonesia from April to December 2018.

Methodology: Completely randomized design was used in the assay. The treatment was 10 Si sources (No silica, Si 1 ppm, Si 2 ppm, Si 3 ppm, husk charcoal 50 g/plant, husk charcoal 100 g/plant, husk charcoal 150 g/plant, husk ash 50 g/plant, husk ash 100 g/plant, husk ash 150 g/plant). The variety was Anak Daro. Each treatment was replicated 3 times so that 30 experimental units were obtained. The data was analysed by using F test in 5% and followed by Duncan's Multiple Range Test (DNMRT) in 5%. The data analysis using software Statistic Tool for Agricultural Research (STAR).

Results: Silica sources affected the agronomic and physiological characters of rice plant. 2,3 ppm of silica, 100 and 150 g of husk charcoal and 100 g of husk ash were the best silica source for plant

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height. 3 ppm silica affected the number of tiller of rice plant. In number of chlorophyll, 150 g of husk ash affected the number of chlorophyll A and the silica sources did not affect the number of chlorophyll B.

Conclusion: The sources of silica affected the agronomic and physiological response of rice plant which can be useful for rice cultivation in the region.

Keywords: Husk ash; husk charcoal; physiology; rice; silica.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of important crop food for half of global population. For Asian people, particularly in East, South and Southeast Asia, rice is main staple food [1]. The demand of Indonesian national rice always increases year by year as the population increases. Average consumption of rice per capita in Indonesia is 87 kg/year [2]. By increasing of population every year, in 2020, Indonesian population is predicted 275 millions [3] and the requirement of rice increases significantly. Area of rice plant in Indonesia in 2013 was 13.8 millions hectare (ha) with the production up to 71.3 ton and productivity was 5.3 ton/ha. This condition describes the rice production should be increased to support national food security.

Recently, many development efforts of rice have been conducted. Unfortunately, many problems that were faced in implementing these efforts such as rice field conversion to be non-agricultural that always increases every year. The availability land for agricultural development is dry land particularly out of Java. However, there is problem in using of the land such as poor nutrients and Al and Fe toxicities[4]. Generally, this land undergoes water deficiency or drought. This condition is inappropriate for rice plant. There were many problems in cultivating rice plant in Indonesia causes appropriate ways to solve these problems are required. One of ways is improvement of cultivation technique such as balanced fertilization. This way is important due to nutrients absorption determines rice plant productivity.

One of fertilizers that is not almost used or applied to soil for supporting rice plant Silicon (Si). This condition causes the productivity and growth of plant nonoptimal. Silicon is second most abundant element of earth. It is not as an essential element, but it is beneficial element for plant growth particularly for Poaceae plants [5]. Si plays vital role in plant cycle. The function of this element is improving plant growth and yield particularly in drought condition. Si promotes

plant photosynthesis by exposing leaves to light [6]. In several Asian countries that apply fertilizer intensively, there is limiting factor to increase rice production, Si. All this time, nutrients requirement of rice relies their ability in nature.

Eventhough Si is not essential element for plant, but almost all plants contain Si in different content and something Si content is high. Si can increase plant production due to Si can improve plant physic characteristic and affect P solubility in soil. There is no other non-essential elements that is presence consistently in plant like Si. In rice plant, Si content is higher than macro elements (N, P, K, Ca, Mg and S)[7]. Deficiency of Si in plant causes plant leaves weak, ineffective to absorb sunlight. These conditions causes low productivity or not optimal. The other effect of Si deficiency is the plant is susceptible to biotic and abiotic stress.

The importance of Si role for plant, the appropriate application dose should be known for rice plant cultivation, both for Si fertilization and nano-silica. Si dose for rice plant in Japan was 1.5 ton/ha of calcium silicate[8]. The other report showed that best dose of Si for plant growth was 600 kg/ha[9]. There are many report reported the Si beneficial. Several reports revealed that Si is able to increase stress tolerance and decrease membrane damage of tomato (*Solanum lycopersicum*) and spinach (*Spinacia oleracea*)[10]. In other hand, Si helps wheat (*Triticum* spp.) to overcome oxidative damage in pots under drought stress and powdery mildew[11,12]. Silicon also enhances sorghum (*Sorghum bicolor*) resistance to drought stress, enhances of rice (*Oryza sativa*) resistance to sheath blight (*Rhizoctonia solani*) and blast disease[13,14,15]. Moreover, main function of Si in plant is during exposing to biotic and abiotic stress. The macroelement is able to suppress these stresses in plants, leads higher plant productivity.

As non-essential element, Si is not noticed. It is revealed by there is no Si addition in rice cultivation whereas in each harvesting, the rice

plant carries 100-300 kg/ha. Movement of Si to out of rice field through harvesting process and leaching without Si addition is main factor in causing the decreasing of availability Si content in soil [16]. Concentration of monosilicate acid (Si form that absorbed by plant) tends to decrease in intensive agricultural land. Land fertilization degradation occurs along the decreasing of monosilicate acid. One report reported that in 33 years, availability of Si content in soil decreased up to 20%. Si decreasing in soil due to stagnation of rice production in Java and several regions in Indonesia. Decreasing of Si availability was closely related to rice production[17].

In Indonesia, use of Si as fertilizer is difficult to find. This condition due to the information is still limited and the material to build up silica fertilizer is still expensive. 1.5-3.0 ton/ha of Si dose that was applied in Japan, the cost was expensive[18]. It affected the production cost of farmer. This problem encourages the alternative way in using Si fertilizer with low cost. An effort in running this purpose is using agricultural waste products particularly produced by rice plant. The product as Si source is rice husk that is produced by grain milling.

Rice husk is often used in agricultural sector such as in plant cultivation (maize, soybean, chili and other plants). Generally, rice husk is applied in whole form or husk charcoal. Several reports revealed that husk charcoal could increase growth and yield. Si also can be used by isolating Si in husk charcoal. If husk charcoal is burnt, the ash is produced. Husk charcoal ash contains silica content (SiO₂) that is a main content of husk ash. High Si content of husk ash is potential to use in various application. The research aimed to study the response of agronomy and physiology of rice plant to various silica sources.

2. MATERIALS AND METHODS

2.1 Experimental Site

The research was conducted in screen house of Faculty of Agriculture, Andalas University, Padang, Indonesia from April to December 2018. The used materials were rice varieties seedling (Anak daro and Batang Piaman), inorganic fertilizer, N (urea), P (SP-36), K (KCl), Silica (SB) with trademark SiP-Padi HS (44-46% of SiPO₂, 2% of P₂O₅), rice husk, husk charcoal, manure and chemical analysis tools. The equipment used in the assay were hoe, hand tractor, sprayer,

oven, microscope, camera, cuvet, hygrometer, thermometer, grain moisture meter, ordinary and digital scale, porcelain mortar, micro tube, test tube, pipette, centrifuge, spectrophotometer of UV/VIS, marbles and laboratory equipment.

2.2 Method

The experiment was completed through completely randomized design. The treatment was 10 Si sources (No silica, Si 1 ppm, Si 2 ppm, Si 3 ppm, husk charcoal 50 g/plant, husk charcoal 100 g/plant, husk charcoal 150 g/plant, husk ash 50 g/plant, husk ash 100 g/plant, husk ash 150 g/plant). The variety was Anak Daro. Each treatment was replied 3 times so that 30 experimental units were obtained. Each experimental unit consisted of 4 plant population and 2 plants were used as sampling.

2.3 Procedure

The experiment was initiated by preparing the planting medium that is rice field soil with bucket sized 5 kg. The planting medium was mixed with 10 ton/ha of manure. Furthermore, the seedling was sowed in seedbed that was prepared previously. After 21 days, the seedling was moved or transplanted to bucket. For optimizing the plant growth, the fertilization was conducted gradually by using urea, SP-36 and KCl. The doses that were applied according the recommendation of soil analysis result. The husk charcoal application and husk ash were conducted at planting medium preparation by mixing them in planting medium. SiP application was conducted in 15 days after planting. The pest and disease management was conducted manually by observed them in bucket.

The parameters observed in the assay were morphology or growth and physiology components. The morphology components were plant height and number of tiller. Physiology parameters were number of stomata, chlorophyll content a, b and total of plant leaves. Chlorophyll content was measured in 8 weeks after planting and before harvesting. The number of stomata was measured in 8 weeks after planting. The yield components were number of productive tiller, number of panicle per clump, length of panicle, flowering age, harvesting age, number of grain per panicle, number of filled grain per panicle and weight of 1000 grain, weight of grain per panicle. The data was analysed by using F test in 5% and followed by Duncan's Multiple Range Test (DNMRT) in 5%. The data analysis using software Statistic Tool for Agricultural Research (STAR).

3. RESULTS AND DISCUSSION

3.1 Plant Height

Silica application affected the plant growth of rice plant in 4-8 weeks after planting. The application 2 ppm/plant, 3 ppm and 100 g of husk ash were the best treatment for plant growth (93.67 cm, 93.08 cm and 89.33 cm)(Table 1). According the result, Si application was important in increasing the rice plant growth due to Si was functional nutrient that could increase the plant growth by encouraging physiology process. Si was considered as beneficial nutrient or nutrient builder for plant growth. According the requirement, Si was classified to accumulator and non-accumulator[19]. Accumulator plant was a plant that contained Si was much more than absorbed Si. Accumulator plant absorbed Si actively [20].

According the result, the plant growth developed significantly from 4 WAP to 8 WAP (Fig. 1). This condition indicated that the silica role in growth and development of plant was significant. Even though silica was not a essential element, the silica presence was important. Si could increase the production of plant due to Si maintained the plant durability, improved soil physic characteristic and affected P solubility in soil[21].

The role of Si was significant for growth and productivity of rice. Guntzer et al. [16] stated that Si was the biggest number of element that absorbed by plant. Number of Si that absorbed by plant was 10 times of N absorption, 20 times of P, 6 time of K and 30 times of Ca absorption. But, the study and Si use as plant nutrient was still rare if compared to other macro and micro

elements. This condition due to Si was assumed as inessential nutrient. Yoshida (1985) observed several Si deficiency symptoms such as limp leaves, wilt in lower leaves surface and drying particularly in panicle formation. Yaherwandi et al. [22] also stated that Si was element that contribute in plant resistance to brown planthopper. This element induced the toughness of plant cell wall structure (lignin and cellulose).

3.2 Number of Tiller

Application of silica affected the number of tiller of rice in 8 WAP. 3 ppm silica was the best application in producing of rice tiller number (30.27)(Table 2). Generally, increasing of number of tiller per unit area was the most important component of yield that associated to number of fertile tillers, filled grains per tiller [23].

Silica affected the number of rice tiller. Accumulated silica in leaves caused the leaves stand vertical and stretch. This condition caused the leaves surface obtained more sunlight so that light absorption for photosynthesis process was more optimal. The photosynthate was used for growth process such as stem elongation. Moreover, the Si application caused the root well developed so that the nutrient absorption was more optimal. The nutrients were used for metabolism process in plant and it supported the plant growth[24]. Hall et al.[25] also stated that silica could increase the nutrients particularly P, an element played a role as cell division so that it encouraged the tiller formation. P also played a role in photosynthesis process, respiration, energy storage, and cell enlargement.

Table 1. Plant height of rice in application of various silica sources in 4-8 weeks after planting (cm)

Treatment	Plant age (Weeks after planting)		
	4	6	8
Control	39.33 c	46.28 b	76.42 c
1 ppm silica	43.09 b	55.93 a	86.26 ab
2 ppm silica	46.62 a	54.53 a	93.67 a
3 ppm silica	46.44 a	52.99 a	93.08 a
50 g husk of charcoal	44.50 ab	54.07 a	83.01 b
100 g of husk charcoal	48.07 a	58.02 a	89.15 a
150 g of husk charcoal	47.17 a	56.90 a	88.77 a
50 g of husk ash	43.81 b	53.15 a	81.36 b
100 g of husk ash	41.79 b	51.87 ab	89.33 a
150 g of husk ash	44.15 a	55.47 a	83.85 ab

Note : Different letter indicate a significant difference according DNMRT in 5%

Table 2. Number of tiller of rice plant in application of various silica sources in 8 weeks after planting

Treatment	Number of tiller
Control	20.00 e
1 ppm silica	23.33 d
2 ppm silica	28.33 b
3 ppm silica	30.27 a
50 g husk of charcoal	25.41 c
100 g of husk charcoal	25.43 c
150 g of husk charcoal	28.42 b
50 g of husk ash	23.50 d
100 g of husk ash	28.42 b
150 g of husk ash	25.40 c

Note : Different letter indicate a significant difference according DNMRT in 5%.

Table 3. Number of stomata of rice in application of various silica sources in 8 weeks after planting

Treatment	Number of stomata
Control	54.80 a
1 ppm silica	43.26 b
2 ppm silica	39.46 b
3 ppm silica	42.38 b
50 g husk of charcoal	43.50 b
100 g of husk charcoal	45.93 b
150 g of husk charcoal	42.20 b
50 g of husk ash	43.50 b
100 g of husk ash	45.00 b
150 g of husk ash	42.25 b

Note : Different letter indicates a significant difference according DNMRT in 5%.

3.3 Number of Stomata

According the data, silica application affected the number of stomata of rice plant in 8 WAP. But, the result of silica sources was lower than control. The control treatment resulted 54.80 stomata. Among the silica sources, there is no different effect of silica pplication (Table 3). The other report reported the number of stomata of rice was 41.67[26]. This condition indicated that the silica did not affect the number of stomata even the silica suppressed the number of stomata. Sacala[27] stated that silica played a role as in increasing the efficiency of osmoregulator by affecting the number of stomata so that this condition affected the water content, decreased the water loss from transpiration, nutrient adequacy controlling and restricting the toxic ion absorption. Arista et al.[28] stated that silica also could suppress the transpiration rate and encouraged the photosynthesis rate.

The silica treatments also affected the form shape and size of stomata (Fig. 1). The

increasing of stomata number caused the density of stomata also increased. The silica in leaf caused the leaf well standed and stretched. This condition caused the plant absorbed high light intensity so that the sunlight absorption was optimum. The increasing of stomata number is assumed as the plant adaptation to environment as result of high evaporation[24].

3.4 Number of Chlorophyll A and B

The result showed that the silica sources application affected the number of chlorophyll A, but they did not affect the number of chlorophyll B in rice plant in 8 WAP. The 150 g of husk ash was the best in producing number of chlorophyll A (0.3559 mg) (Table 4).

Number of leaf chlorophyll is an important parameter that is regularly measured as an indicator of chloroplast content, photosynthetic mechanism, and plant metabolism. Chlorophyll A played a role as main pigment for photosynthesis process[29]. Accumulated silica in cell walls formed silica layer. Under cuticle, silica

associated with cellulose so that the silica layer became thicker and leaf became thicker[30]. Thick silica layer caused the leaves stronger, sturdy and stretch so that the light absorption became more optimal and photosynthesis rate

increased. Yoshida [31] stated that the silica increased photosynthesis 10 times than the rice plant was not applied by silica. Silva et al. [32] stated that Si could increased the number of chlorophyll in tomato plant.

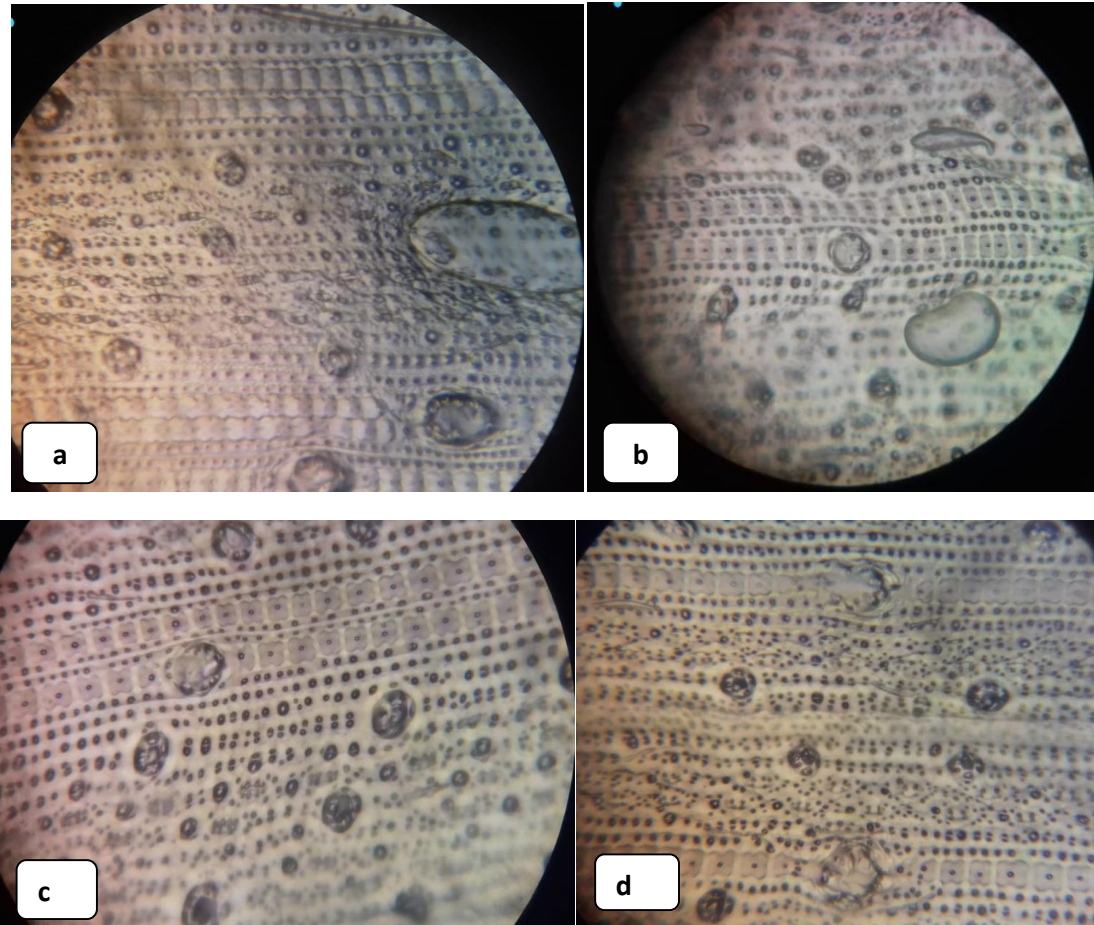


Fig. 1. Stomata morphology per treatments (a. Control; b. Silica; c. husk ash; d. husk charcoal)

Table 4. Number of chlorophyll A and B of rice plant in application of several silica sources in 8 WAP

Treatment	Chlorophyll A	Chlorophyll B
Control	0.2421 d	0.103
1 ppm silica	0.2644 bcd	0.089
2 ppm silica	0.2609 bcd	0.089
3 ppm silica	0.3238 abc	0.111
50 g husk of charcoal	0.2912 abcd	0.116
100 g of husk charcoal	0.2534 bcd	0.092
150 g of husk charcoal	0.2496 cd	0.088
50 g of husk ash	0.3140 abcd	0.121
100 g of husk ash	0.3266 ab	0.082
150 g of husk ash	0.3559 a	0.101

Note : Different letter indicates a significant difference according DNMRT in 5%

Number of chlorophyll B was not affected by silica. This condition due to chlorophyll B played a role as supporting pigment in leaves tissue so that it absorbed the light for supporting chlorophyll A in photosynthesis process [33].

4. CONCLUSION

Silica sources affected the agronomic and physiological attributes of rice plant. 2,3 ppm of silica, 100 and 150 g of husk charcoal and 100 g of husk ash were the best silica source for plant height. 3 ppm silica affected the number of tiller of rice plant. In number of chlorophyll, 150 g of husk ash affected the number of chlorophyll A and the silica sources did not affect the number of chlorophyll B.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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