Effects of silicic acid rate and application method on plant growth, yield components and yield of *Oryza sativa* L. var. MR284

M Y M Najib¹, M H Hasnuri², M N N Izham² and A R M N Fadzli¹

¹MARDI Seberang Perai, Pulau Pinang, Malaysia  
²School of Biological Science, Universiti Sains Malaysia, Pulau Pinang, Malaysia

*Corresponding author’s e-mail: najib@mardi.gov.my

Abstract. Silicon is one of the beneficial elements to the rice plant for plant growth and the effects could be detected particularly under the biotic and abiotic stress conditions. Plants take up silicon in a form of monosilicic acid from various sources of silicon. A pot experiment was conducted under a greenhouse condition to study the uptake of silicon by local Malaysian rice variety MR284 in a form of silicic acid. The experiment was carried out under 2 x 4 factorial design consist of two methods of silicic acid application namely foliar spray and drench method and four silicic acid rate at 0, 0.02, 0.04 and 0.06 mol L⁻¹ set up in Complete Randomized Design (CRD) with four replications. Parameters measured were plant growth, yield component and grain yield. Paddy with foliar spray application of silicic acid had a better performance than of paddy with drench method in term of yield increment. The application of silicic acid did not have significant effects on panicle length, plant height and thousand grain weight. The number of tillers and number of panicles had increased with an increasing silicic acid rate, while percentage of filled grain and grain yield decreased with the increasing of silicic acid rate. The findings suggest that the ideal amount of silicic acid for optimum effects on growth and yield of paddy can be used at 0.02 mol L⁻¹ as foliar spray application.

1. Introduction

Rice has been known as silicon (Si) accumulating plant which the silicon being deposited beneath the cuticle in the form of silicic acid [1]. Silicon is the second most abundant element of the earth’s crust [2]. It is taken up through the absorption by plant root [1] from various sources in a form of monosilicic acid [3]. As a beneficial element in plant growth, Si has been reported to play a role in reducing the biotic and abiotic stress condition [5], improve the phosphorus uptake and decrease iron toxicity [6].

Studies has been done on silicon using different sources such as steel slag [7] with effects of increased rice growth and yield at the same time reduce the brown spot incidence when applied at 935 mg Si/kg. The application of potassium silicate as foliar spray at 4 g Si/L reduced blast incident [8]. While Syu et al. [9] found sodium silicate at 750 kg SiO₂/ha applied into the soil can be used to reduce arsenic uptake by rice seedlings. Meanwhile, Patil et al. [10] discovered 200 kg/ha of calcium silicate applied with general recommended dose of fertilizer could give the highest plant growth, yield components and grain yield under both soil order of Vertisols and Inceptisols. As the information on Si application and its
benefit to crops is limited, this study was aimed to use silicic acid as a Si source with different method of application and to study their effects on plant growth, yield component and also grain yield.

2. Materials and Methods

Experiment was carried out in a greenhouse at Malaysian Agricultural Research and Development Institute (MARDI) Seberang Perai, Pulau Pinang, Malaysia using 1 m (l) x 1 m (w) x 0.5 m (h) pots filled with soils from nearby rice field. The soil texture was classified as clay loam with 0.14 mg/kg available nitrogen, 8.9 mg/kg available phosphorus, 122 mg/kg available potassium, 37.9% silicon, 9.9 cmol/kg cation exchange capacity (CEC), and 5.4 pH value. The experiment was laid up under 2x4 factorial design which consists of two application methods of silicic acid i.e foliar spray and drench method and four levels of silicic acid; 0, 0.02, 0.04 and 0.06 mol/L. Silicic acid was applied four times for the whole growing period at 15 days after transplanting (DAT), 30 DAT, 45 DAT and 70 DAT with spray volume 450L/ha.

MR284 rice variety was transplanted as single seedling at age of 14 days after sowing with 30 cm x 16 cm of plant spacing (18 seedlings per meter square). The water depth was maintained for 5 cm from 5 DAT until 90 DAT. Standard fertilizer practice for MR284 with 122.7 kg N/ha, 60.1 kg P₂O₅/ha and 121.5 kg K₂O/ha were used and split into 4 growth stage of application at 15 DAT (19.97% N; 66.72% P₂O₅; 36.21% K₂O), 30 DAT (29.99% N), 45 DAT (35.62% N; 30.78% P₂O₅; 28.81% K₂O) and 70 DAT (14.43% N; 2.5% P₂O₅; 34.98% K₂O).

Plant growth parameter which is number of tillers and plant height were measured, and recorded at 15 DAT, 35 DAT, 55 DAT, 75 DAT and at maturity stage. Number of panicles and its length was measured and recorded prior harvesting. Six clumps from each pot were taken for yield component parameter which were counted for the number of spikelets, number of panicles, filled grains, empty grains and thousand grain weight. At maturity the rice plant was harvested and the whole dried grain yield were weighed at 14% moisture content. All data were expressed as means and analyzed using the ANOVA procedure with SAS Statistical software package (version 9.4 for windows). Differences among the treatments were determined using Tukey’s (HSD) test at 0.05 probability level.

3. Results and Discussion

3.1. Effects of Silicic Acid Methods of Application and Rates on Grain Yield and Yield Components

The grain yield was not significantly affected by the method of applications, the grain yield is almost 5% higher by using foliar application. Foliar application was more convenient to be adopted throughout the plant growth while the canopy of the plant getting denser. The rates of silicic acid were significantly affected the grain yield. The grain yield production reduced as the silicic acid rate were increased statistically the silicic acid rate at 0.02 mol/L had a same level of grain yield as control untreated plant. Further addition of silicic acid reduced the grain yield by 12.23% and 26.71% compared to the plant treated with 0.02 mol/L of silicic acid (Table 1). Similar result was obtained [11];[12] which the additional of Si more than optimum rate reduced the grain yield

Application of silicic acid by drench method had a great effect on number of spikelets per panicle with 24.71% more spikelets as compared to foliar application (Table 1). Buck et al. [8] noticed the formation of silicate polymer on the leaf surface has cause low efficacy of Si absorption by rice leaf. Although there is no significant effect of silicic rates on spikelets per panicle, it was observed that the use of silicic acid could increase the number of spikelets for 17.32%, 8.93% and 10.61% respectively, compared to untreated plants.

Thousand grain weight and number of panicles per meter square was not affected by silicic acid rates and the method of applications. The average thousand grain weight was 23.65 g while the average number of panicles per meter square was 199 panicles as shown in Table 1. Filled grain was affected by method of application and silicic acid rates. The percentage of rice filled grain using drench method was higher (7.31%) than foliar application. Agostinho et al [13] found soil-application remain the most effective method to enhance the uptake of Si. Paddy crops with the rate of silicic acid at 0.02 mol/L and 0.04 mol/L had the same level of percent filled grain as untreated plant. Increasing silicic acid
concentration reduced the percentage of filled grain (14.55%). On a contrary, the percentage of empty grain was increased correspondingly with the concentration of silicic acid. Singh and Singh [14] observed that application of Si did not have significant different in thousand grain weight but it increased the productive tillers and spikelet per panicle. While Crusciol [15] reported increased the number of productive tiller but did not have significant effects on number of spikelet per panicle, spikelet fertility and thousand grain weight.

### Table 1. Effects of grain yield, number of spikelet, thousand grain weight, filled grain, empty grain, and number of panicles per meter square treated with different concentration of silicic acid using foliar and drench application.

| Treatments              | Grain yield (kg/ha) | Spikelet per panicle | 1000 grain weight (g) | Filled grain (%) | Empty grain (%) | Panicle per meter square |
|-------------------------|---------------------|----------------------|----------------------|------------------|----------------|-------------------------|
| Application (F&D)       |                     |                      |                      |                  |                |                         |
| Foliar Application      | 4717 a              | 174 b                | 23.57 a              | 75.57 b          | 24.43 a        | 207 a                  |
| Drench Application      | 4496 a              | 217 a                | 23.74 a              | 81.10 a          | 18.90 a        | 191 a                  |
| Silicic rates (mol/L)   |                     |                      |                      |                  |                |                         |
| 0                       | 5387 a              | 179 a                | 23.71 a              | 82.58 a          | 17.43 b        | 180 a                  |
| 0.02                    | 4995 a              | 210 a                | 23.53 a              | 84.10 a          | 15.90 b        | 191 a                  |
| 0.04                    | 4384 b              | 195 a                | 23.48 a              | ab               | 23.89 ab        | 209 a                  |
| 0.06                    | 3661 c              | 198 a                | 23.90 a              | 70.56 b          | 29.44 a        | 216 a                  |
| F&D                     | ns                  | **                   | ns                   | *                | *              | ns                      |
| Silicic rates **        | ns                  | ns                   | ns                   | *                | *              | ns                      |
| (F&D) x Silicic rates   | ns                  | ns                   | ns                   | ns               | ns             | ns                      |
| Mean                    | 4607                | 195                  | 23.65                | 78.33            | 21.66          | 199                     |
| C.V                     | 8.44                | 12.07                | 3.55                 | 8.89             | 32.17          | 14.35                   |

* = significant at 5% **= significant at 1% ns = non-significant. Means followed by the same letter within columns are not significantly different according to Tukey’s test

3.2. Effects of Silicic Acid Methods of Application and Rates on Plant Growth

Foliar application had significantly affected the plant height at maturity stage with 3.08% taller compared to drench method. While the rice plant height at 15, 35, 55 and 75 days after transplanting (DAT), were not affected by the treatments. The average plant height at 15 DAT, 35 DAT, 55 DAT and 75 DAT were 21.7 cm, 55.5 cm, 86.1 cm and 97.4 cm, respectively. While effect of silicic acid rate on plant height observed only at 75 DAT with the highest plant height recorded is 99.7cm (untreated treatment) which is 4.62% higher compared to plant treated with 0.06 mol/L of silicic acid as shown in table 2. Panicle length of paddy did not affect neither by the method of application nor silicic acid rates (Table 2). However, panicle length of paddy supplied with Si through foliar application was 4.15% longer than that of drench application.

Application method of Si onto paddy did not have any effect on number of tillers per meter square in any growth stage. The average number of tillers per meter square for both applications at 35DAT, 55DAT, 75DAT and at maturity stage (107DAT) were 149, 273, 252 and 234 tillers, respectively. Meanwhile, silicic acid rates affected the number of tillers at 35 DAT, 55 DAT and 75 DAT (Table 3). Generally, number of tillers were increased as the concentration of silicic acid was increased. At 35 DAT, number of tillers of paddy treated with 0.06 mol/L was significantly greater than that of in 0.02 mol/L and control treatment. Similarly, at 55 DAT, number of tillers of paddy treated with 0.06 mol/L
was significantly greater than paddy treated with 0.02 mol/L and control treatment whereas similar effect was observed with treatment of 0.04 mol/L. Meanwhile, in 75 DAT, more than 15.88% number of tillers recorded in paddy plant treated with 0.04 mol/L of silicic acid compared to the plant without silicic acid addition (Table 3). Prakash et al [12] reported the application of foliar silicic acid did not affect the growth parameters at hilly zone. Sing and Sing [14] reported Si application did not increase the plant height. Meanwhile in Vietnam, Cuong [11] also observed there is no significant in plant height with the increase of Si.

**Table 2.** Effects of multiple rates of silicic acid with foliar and drench application methods on plant height of rice at 5 different sampling time and panicle length at harvest.

| Treatments                  | Plant Height (cm) | Panicle Length (cm) |
|-----------------------------|-------------------|---------------------|
|                             | 15DAT  | 35DAT  | 55DAT  | 75DAT  | Harvest | Harvest |
| Application (F&D)           |        |        |        |        |         |         |
| Foliar Application          | 21.7 a | 55.9 a | 86.7 a | 98.0 a | 103.7 a | 25.1 a  |
| Drench Application          | 21.7 a | 55.1 a | 85.7 a | 96.9 a | 100.6 b | 24.1 a  |
| Silicic rates (mol/L)       |        |        |        |        |         |         |
| 0                           | 21.8 a | 55.4 a | 88.8 a | 99.7 a | 102.5 a | 24.6 a  |
| 0.02                        | 20.8 a | 56.4 a | 84.3 a | 98.3 ab| 103.4 a | 24.8 a  |
| 0.04                        | 21.7 a | 55.4 a | 83.8 a | 96.4 ab| 100.1 a | 25.3 a  |
| 0.06                        | 22.5 a | 55.0 a | 87.8 a | 95.3 b | 102.7 a | 23.8 a  |
| F&D                         | ns     | ns     | ns     | *      | ns      |         |
| Silicic rates               | ns     | ns     | ns     | *      | ns      |         |
| (F&D) x Silicic rates       | ns     | ns     | ns     | *      | ns      |         |
| Mean                        | 21.7   | 55.5   | 86.1   | 97.4   | 102.1   | 24.6    |
| C.V                         | 6.88   | 3.97   | 5.67   | 3.04   | 3.35    | 7.53    |

* = significant at 5% ** = significant at 1% ns = non-significant. Means followed by the same letter within columns are not significantly different according to Tukey’s test.

**Table 3.** Effects of silicic acid rates and methods of application on rice number of tillers.

| Treatments                  | Number of tillers per meter square |
|-----------------------------|-----------------------------------|
|                             | 35DAT  | 55DAT  | 75DAT  | Harvest |
| Application (F&D)           |        |        |        |         |
| Foliar Application          | 147 a  | 270 a  | 254 a  | 234 a   |
| Drench Application          | 151 a  | 275 a  | 250 a  | 233 a   |
| Silicic rates (mol/L)       |        |        |        |         |
| 0                           | 134 c  | 242 b  | 233 b  | 225 a   |
| 0.02                        | 145 bc | 257 b  | 247 ab | 224 a   |
| 0.04                        | 156 ab | 292 a  | 270 a  | 243 a   |
| 0.06                        | 162 a  | 300 a  | 258 ab | 242 a   |
| F&D                         | ns     | ns     | ns     | ns      |
| Silicic rates               | *      | **     | ns     |         |
| (F&D) x Silicic rates       | ns     | ns     | ns     | ns      |
| Mean                        | 149    | 273    | 252    | 234     |
| C.V                         | 7.43   | 7.50   | 7.13   | 7.11    |

* = significant at 5% ** = significant at 1% ns = non-significant. Means followed by the same letter within columns are not significantly different according to Tukey’s test.
4. Conclusions
Paddy grown with addition of silicic acid at 0.02 mol/L had better result in term of grain yield and percentage of filled grain. The foliar application of Si to paddy crop was better than drench application in term of yield increment with greater number of panicles per meter square. These findings will benefit future study particularly on the adoption of silicic acid amendment towards any crops under abiotic and biotic stress condition.

References
[1] Guntamukkala B R 2017 *Int. J. Chem. Studies* 5 (6) 1359-61.
[2] Luyckx M, Hausman J-F, Lutts S and Guerriero G 2017 *Front. Plant Sci.* 8 411.
[3] Linca A, Husnain, Kuniaki S and Tsugiyuki M 2017 *Indonesian J. Agricultural Sci.* 18 69-76.
[4] Ma J F 2004 *Soil Sci. Plant Nutrition* 50 11-18.
[5] Guntamukkala B R, Poornima Y P, and Elizaberth K S 2017 *J. Pharmacognosy and Phytochemistry* 6 (6) 390-392.
[6] Flore G, Catherine K and Jean-Dominique M 2012 *Agronomy for sustainable development* 32 (1) 201-213.
[7] Ning D, Song A, Fan F, Li Z and Liang Y 2014 *Plos ONE* 9 (7) e102681.
[8] Buck G B, Korndorfer G H, Nolla A and Coelho L 2008 *J. Plant Nutrition* 31 231-237.
[9] Syu C H, Huang C C, Jiang P Y, Chien P H, Wang H Y, Su J Y and Lee D Y 2015 *Soil Science and Plant Nutrition* 62 (4) 357-366.
[10] Patil A A, Durguda A G, Pharande A L, Kadlag A D and Nimbalkar C A 2017 *Int. J Chemical Studies* 5 (6) 545-549.
[11] Cuong T X, Ullah H, Datta A and Hanh T C 2017 *Rice Science* 24 (5) 283-290.
[12] Prakash N B, Chandrashekarar N, Mahendra C, Patil S U, Thippeshappa G N and Laane H M 2011 *J. Plant Nutrition* 34 (12) 1883-93.
[13] Agostinho F, Tubana B, Martins M, and Datnoff L 2017 *Plants* 6 (4) 6030035.
[14] Singh K K and Singh K 2005 *Int. Rice Research Notes* 30 (1) 40-41.
[15] Crucio C A C, Soratto R P, Castro G S A Neto J F and Costa C H M 2013 *Semina: Ciencias Agrarias* 34 (6) 2803-08.