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Utilization of Silicon Fertilizer Application on Pepper Seedling Production

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Abstract

The purpose of this research was study the rate and application method of calcium silicate (Ca_2SiO_4) fertilizer appropriated for pepper seedling production. This study was divided into two experiments. Experiment 1, the effect of Ca_2SiO_4 fertilizer application in pepper seedling by mixed in growing media was arranged in 2x6 factorials in Completely Randomized Design (CRD) with 4 replications. Factor A was seed preparation methods (seed primed with Ca_2SiO_4 fertilizer at a rate 2 g L^{-1} and non-seed primed) and factor B was application rates of Ca_2SiO_4 fertilizer at 0, 30, 60, 120, 240 and 480 kg ha^{-1}. Experiment 2, the effect of Ca_2SiO_4 fertilizer application in pepper seedling by foliar method was arranged in 2x6 factorials in CRD with 4 replications. Factor A was seed preparation methods and factor B was application rates of Ca_2SiO_4 fertilizer at 0, 2, 4, 6, 8 and 10 g L^{-1}. All experiments data were collected such as plant growth and total silicon content in plant at 28 days after sowing (DAS). From experiment 1, the results showed that seed primed with Ca_2SiO_4 fertilizer application at a rate 120 kg ha^{-1} gave the good plant growth and total silicon in plant. Experiment 2, the results showed that seed primed with Ca_2SiO_4 fertilizer application at a rate 2 g L^{-1} gave the highest of plant growth and total silicon in plant. To conclude, Ca_2SiO_4 fertilizer application can be employed for enhancing plant growth of pepper seedling and increasing silicon content in plant.

Keywords: foliar, fertilizer, pepper seedling, silicon, mixed in growing media

1. Introduction

Pepper (*Capsicum* sp.) is the fruit of plants from the genus *Capsicum*, and family, Solanaceae. Pepper is a high nutrition value and consists of a protein, vitamin and mineral. Peppers are a rich source of spicy-hot capsaicin. They are also very high in antioxidant carotenoids, which are linked with numerous health benefits. Capsaicin is a one of the most studied plant compounds in peppers. It is responsible for their pungent (hot) flavor and many of their health effects. Pepper is a vegetable popular consumption in Thailand. It can be seen that pepper was composed in many Thai foods. It very famous in Thai people because high antioxidant and it can be improves the good health. In Thailand, the area plantation pepper it found that in the northern part and northeastern part. In 2015, pepper area plantation was 31,000 ha^{-1} and trend to decreasing from 2010 (56,570 ha^{-1}) (Department of Agriculture, 2015). The reason for the decline of area because farmer change plant for cultivate and pepper yield less quality destruction caused by disease and insects, also low seed quality and expensive seed. Total pepper yield production in Thailand was 0.25 tons ha^{-1} and crop removal in pepper amount of 1.04 kg Si ha^{-1} (2.23 kg SiO_2 ha^{-1}) (Department of Agriculture, 2015). Then, silicon (Si) is necessary for pepper, because Si loss of crop removal and therefore Si not enough for pepper and soil. So that we must add Si for pepper, since preparation seed, seedling and add direct in soil. Also, Si is the second most abundant element on the surface of the earth. It is not considered to be an essential element for higher plant (Neumann et *al*., 2001). Si can be classified as beneficial element (Epstein, 2005). Si in soil solution is mainly present in the form of an uncharged monomeric molecule, silicic acid. Many plants show the better growth as the Si form available (H_4SiO_4 or SiO_4^{2-}). Si is reported to the component of cell (Ma et *al*., 2001), improve plant resistance to a range of biotic and abiotic stresses (Ma & Yamaji, 2006), stimulate on growth and yield (Ma & Takahashi, 2002), leaf erectness, haulm stability and lodging and increase photosynthesis (Epstein & Bloom, 2005). In addition, calcium (Ca) is relatively abundant in soil and rarely limits corps production. It makes up about 3.6% of earth's crust. It present in soil minerals such as amphibole, apatite, calcite, dolomite and feldspar. Ca is a component of cell wall and is

also important for cell division and elongation permeability of cell membranes. Moreover, seed priming is a pre-sowing treatment in which seeds are soaked in osmotic that allows the seeds to imbibe water and go through the first stages of germination. In addition, seed priming enhanced germination speed and uniformity of seeds (McDonald, 2000). The primed seed increase germination speed and uniformity of seeds and gave the good seedling. It can be improve the growth rate and yield in pepper production. Now, utilization of Si fertilizer has many variants. Kunlinda *et al.*, (2014) reported that sweet pepper "vega 1288" seeds were primed with Ca_2SiO_4 at 2 g L^{-1}gave the highest of germination index (GI) and germination percentage. While, seed-primed with Ca_2SiO_4 at 4 g L^{-1} by foliar application gave the good of sweet pepper seedling. From the above, thus purpose of this research was to study the rate and application method of Ca_2SiO_4 fertilizer appropriated for pepper seedling production.

2. Methods

The experiment was conducted in greenhouse at soil science experimental field, Department of Soil Science, Faculty of Agriculture at Kamphaeng Saen, Kasetsart University, Nakhon Pathom, Thailand. The each experiment was used peat for cultivated. In addition, Si fertilizer is a calcium silicate (Ca_2SiO_4) and calcium silicate used in this experiment was component as silicon (25%SiO_2), calcium (40%CaO) and magnesium (2%MgO). This study was divided into two experiments. The effect of Ca_2SiO_4 fertilizer application in pepper seedling by mixed in growing media (experiment 1) was used 2x6 factorials in Completely Randomized Design (CRD) with 4 replications. Factor A was seed preparation methods (seed primed with Ca_2SiO_4 fertilizer at a rate 2 g L^{-1} and non-seed primed) and factor B was application rates of Ca_2SiO_4 fertilizer at 0, 30, 60, 120, 240 and 480 kg ha^{-1}. The effect of Ca_2SiO_4 fertilizer application in pepper seedling by foliar method (experiment 2) was used 2x6 factorials in CRD with 4 replications. Factor A was seed preparation methods (seed primed with Ca_2SiO_4 fertilizer at a rate 2 g L^{-1} and non-seed primed) and factor B was application rates of Ca_2SiO_4 fertilizer at 0, 2, 4, 6, 8 and 10 g L^{-1}. All treatments used foliar Ca_2SiO_4 fertilizer for pepper seedling at 14 and 21 days after sowing (DAS).

2.1 Seed Preparation Methods

Chilli pepper seeds were primed with Ca_2SiO_4 fertilizer at a rate 2 g L^{-1} for 5 hours at temperate room (Kunlinda *et al.*, 2014).

2.2 Data Collection

The plant samples were measured at 28 DAS. All experiments data were collected such as plant height, leaf number (larger than 1 centimeter), fresh and dry weight (Kunlinda *et al.*, 2014). Total Si content in plant was using Nayer *et al.,* (1975) method.

2.3 Statistical Analysis

The data were analyzed for Statistical analyses carried out using the R program. By method of analysis of variance (ANOVA) and Comparisons of the means among treatments were done using LSD at a significance level of $P < 0.01$.

3. Results

3.1 Effect of Ca_2SiO_4 fertilizer application in pepper by mixed in growing media (Experiment 1)

3.1.1 Plant Height of Pepper Seedling

Seed preparation methods showed that seed primed with Ca_2SiO_4 fertilizer application at a rate 2 g L^{-1} was significantly different and gave the plant height higher than non-seed-primed (Table1). In addition, Ca_2SiO_4 fertilizer application by mixed in growing media at a rate 120 kg ha^{-1} was significantly different and gave to trend the plant height of pepper seedling (Table1). While, relationship between factor A (seed preparation methods) with factor B (application rate of Ca_2SiO_4 fertilizer) were significantly different that seed-primed with application rate of Ca_2SiO_4 fertilizer at 120 kg ha^{-1} gave to trend the high of plant height (Table1).

Table 1. Plant height (cm) of pepper seedling at 28 day after sowing (experiment 1)

Factors	Seed preparation methods (A)		Average (A)
	Non- seed primed	seed primed	
Ca_2SiO_4 fertilizer application (kg ha^{-1}) (B)			
0	9.04e	10.56cd	9.80D
30	9.53de	11.97ab	10.75C
60	11.07bc	12.67a	11.87A
120	10.40cd	12.85a	11.63AB
240	11.11ab	10.37cd	10.74C
480	10.84c	11.27bc	11.06BC
Average (B)	10.33B	11.62A	
F-test : A	**		
B	**		
A×B	**		
CV. (%)	6.39		

Note. ** = significantly different at P<0.01

3.1.2 Leaf Number of Pepper

The results showed that seed preparation methods and Ca_2SiO_4 fertilizer application by mixed in growing media were non significantly different of the leaf number of pepper (Table 2)

Table 2**.** Leaf number of pepper seedling at 28 day after sowing (experiment 1)

Factors	Seed preparation methods (A)		Average (A)
	Non- seed primed	seed primed	
Ca_2SiO_4 fertilizer application (kg ha^{-1}) (B)			
0	8	8	8
30	8	8	8
60	8	8	8
120	8	8	8
240	8	8	8
480	8	8	8
Average (B)	8	8	
F-test : A	ns		
B	ns		
A×B	ns		
CV. (%)	2.44		

Note. ns = non-significantly different at P>0.01

3.1.3 Fresh Weight of Pepper Seedling

The results showed that seed preparation methods were significantly different and seed primed gave the fresh weight higher than non-seed primed **(**Table3). Ca_2SiO_4 fertilizer application at a rate 240 kg ha^{-1} was significantly different and gave to trend the fresh weight of pepper seedling (Table3). While, relationship between factor A with factor B were significantly different that seed primed with application rate of Ca_2SiO_4 fertilizer at 120 kg ha^{-1} gave to trend the high of Fresh weight of pepper seedling (Table3).

Table 3. Fresh weight (g) of pepper seedling at 28 day after sowing (experiment 1)

Factors	Seed preparation methods (A)		Average
	Non- seed primed	seed primed	(A)
Ca_2SiO_4 fertilizer application (kg ha^{-1}) (B)			
0	2.54c	2.58c	2.56B
30	2.86abc	2.84abc	2.83A
60	2.81abc	1.97d	2.39B
120	2.73bc	3.16a	2.94A
240	3.01ab	2.94abc	2.97A
480	2.86abc	3.02ab	2.94A
Average (B)	2.66B	2.89A	
F-test : A	**		
B	**		
A×B	**		
CV. (%)	8.72		

Note. ** = significantly different at P<0.01

3.1.4 Dry Weight of Pepper Seedling

The results showed that seed preparation methods was gave the same as the fresh weight (Table4), but Ca_2SiO_4 fertilizer application at a rate 120 kg ha^{-1} was significantly different and gave to trend the dry weight of pepper seedling (Table4). While, relationship between factor A with factor B were significantly different that seed primed with application rate of Ca_2SiO_4 fertilizer at 120 kg ha^{-1} gave to trend the high of dry weight of pepper seedling (Table4).

Table 4. Dry weight (g) of pepper seedling at 28 day after sowing (experiment 1)

Factors	Seed preparation methods (A)		Average
	Non- seed primed	seed primed	(A)
Ca_2SiO_4 fertilizer application (kg ha^{-1}) (B)			
0	0.25b	0.25b	0.24B
30	0.26b	0.28ab	0.26AB
60	0.24b	0.26ab	0.21C
120	0.17c	0.31a	0.28A
240	0.29ab	0.25b	0.27AB
480	0.35b	0.27ab	0.25AB
Average (B)	0.24B	0.27A	
F-test : A	**		
B	**		
A×B	**		
CV. (%)	11.31		

Note. ** = significantly different at P<0.01

3.1.5 Total Silicon Content in Pepper Seedling

Our treatments results demonstrated that in total silicon, seed preparation methods the results showed that was non significantly different of total silicon in pepper seedling (Table5). In addition, Ca_2SiO_4 fertilizer application at a rate 480 kg ha^{-1} was significantly different and gave to trend the total silicon in pepper seedling (Table5). While, relationship between factor A with factor B were significantly different that seed primed with application rate of Ca_2SiO_4 fertilizer at 480 kg ha^{-1} gave to trend the total silicon in pepper seedling (Table5).

Table 5. Total silicon content (mg kg^{-1}) in pepper seedling at 28 day after sowing (experiment 1)

Factors	Seed preparation methods (A)		Average
	Non- seed primed	seed primed	(A)
Ca_2SiO_4 fertilizer application (kg ha^{-1}) (B)			
0	1.00c	2.00c	1.00b
30	24.00ab	17.00b	21.00a
60	25.00ab	16.00b	20.00a
120	20.00b	22.00b	20.00a
240	21.00b	24.00ab	22.00a
480	17.00b	34.00a	25.00a
Average (B)	18.00	19.00	
F-test :A	ns		
B	**		
A×B	**		
CV. (%)	27.27		

Note. = non-significantly different at P>0.01, ** = significantly different at P<0.01

3.2 The effect of Ca_2SiO_4 fertilizer application in pepper by foliar method (Experiment 2)

3.2.1 Plant Height of Pepper Seedling

Seed preparation methods the results showed that seed primed with Ca_2SiO_4 fertilizer application at a rate 2 g L^1 was significantly different and gave the plant height higher than non-seed primed (Table6). In addition, Ca_2SiO_4 fertilizer application by foliar method was non-significantly different of the plant height of pepper seedling (Table6). While, relationship between factor A with factor B were non-significantly different of plant height of pepper seedling (Table6).

Table 6. Plant height (cm) of pepper seedling (experiment 2)

Factors	Seed preparation methods (A)		Average
	Non- seed primed	seed primed	(A)
Ca_2SiO_4 fertilizer application (g L^{-1}) (B)			
0	11.86	11.80	11.83
2	11.98	12.89	12.43
4	12.29	16.37	14.33
6	12.09	14.23	13.16
8	12.00	14.00	13.00
10	12.39	13.54	12.96
Average (B)	12.10B	13.80A	
F-test : A	**		
B	ns		
A×B	ns		
CV. (%)	12.98		

Note. ns = non-significantly different at P>0.01, ** = significantly different at P<0.01

3.2.2 Leaf Number of Pepper

The results showed that seed preparation methods and Ca_2SiO_4 fertilizer application by foliar method were non-significantly different of the leaf number of pepper (Table 7).

Table 7. Leaf number of pepper seedling (experiment 2)

Factors	Seed preparation methods (A)		Average
	Non- seed primed	seed primed	(A)
Ca_2SiO_4 fertilizer application (g L^{-1}) (B)			
0	8	8	8
2	8	8	8
4	8	8	8
6	8	8	8
8	8	8	8
10	8	8	8
Average (B)	8	8	
F-test : A	ns		
B	ns		
A×B	ns		
CV. (%)	2.44		

Note. ns = non-significantly different at P>0.01

3.2.3. Fresh Weight of Pepper Seedling

The results showed that seed preparation methods were significantly different and seed primed gave the fresh weight higher than non-seed primed (Table8). Ca_2SiO_4 fertilizer application at a rate 4 g L^{-1} was significantly different and gave to trend the fresh weight of pepper seedling (Table8). While, relationship between factor A with factor B were significantly different that seed-primed with application rate of Ca_2SiO_4 fertilizer at 4 g L^{-1} gave to trend the high of fresh weight of pepper seedling (Table8).

Table 8. Fresh weight (g) of pepper seedling (experiment 2)

Factors	Seed preparation methods (A)		Average
	Non- seed primed	seed primed	(A)
Ca_2SiO_4 fertilizer application (g L^{-1}) (B)			
0	2.61d	2.73d	2.67C
2	3.58ab	3.79ab	3.69A
4	3.52ab	3.88a	3.70A
6	3.64ab	3.47b	3.56AB
8	3.08c	3.66ab	3.37B
10	3.52ab	3.73ab	3.62A
Average (B)	3.32B	3.54A	
F-test : A	**		
B	**		
A×B	*		
CV. (%)	6.69		

Note. ** = significantly different at P<0.01, * = significantly different at P<0.05

3.2.4 Dry Weight of Pepper Seedling

The results showed that seed preparation methods significantly different and seed primed gave the dry weight higher than non-seed primed (Table9). Ca_2SiO_4 fertilizer application at a rate 2 g L^{-1} was significantly different and gave to trend the dry weight of pepper seedling (Table9). While, relationship between factor A with factor B were non significantly different of dry weight of pepper seedling (Table9).

Table 9. Dry weight (g) of pepper seedling (experiment 2)

Factors	Seed preparation methods (A)		Average
	Non- seed primed	seed primed	(A)
Ca_2SiO_4 fertilizer application (g L^{-1}) (B)			
0	0.25c	0.25c	0.25C
2	0.34a	0.34a	0.34A
4	0.30ab	0.32ab	0.31AB
6	0.33a	0.31ab	0.32AB
8	0.27bc	0.32ab	0.29B
10	0.31ab	0.34a	0.32AB
Average (B)	0.30	0.31	
F-test : A	ns		
B	**		
A×B	ns		
CV. (%)	10.74		

Note. ns = non-significantly different at P>0.01, ** = significantly different at P<0.01

3.2.5 Total Silicon Content in Pepper Seedling

Our treatments results demonstrated that in total silicon, seed preparation methods the results showed that was non significantly different of total silicon in pepper seedling (Table10). In addition, Ca_2SiO_4 fertilizer application at a rate 2 g L^{-1} was significantly different and gave to trend the total silicon in pepper seedling (Table10). While, relationship between factor A with factor B were non-significantly different of the Total silicon in pepper seedling (Table10).

Table 10. Total silicon content (mg kg^{-1}) in pepper seedling (experiment 2)

Factors	Seed preparation methods (A)		Average
	Non- seed priming	seed priming	(A)
Ca_2SiO_4 fertilizer application (g L^{-1}) (B)			
0	0.54e	3.10de	1.80c
2	11.10ab	0.13.30a	12.00a
4	0.69bcd	8.60abc	7.80b
6	5.9cd	8.50abc	7.20b
8	7.9bc	8.80abc	8.40b
10	8.7abc	9.10abc	8.90b
Average (B)	6.90	8.60	
F-test : A	ns		
B	**		
A×B	ns		
CV. (%)	28.62		

Note. ns = non-significantly different at P>0.01, ** = significantly different at P<0.01

4. Discussion

Experiment 1, the effect of Ca_2SiO_4 fertilizer applied in pepper by mixed in growing media. The results showed that seed-primed with Ca_2SiO_4 fertilizer application at a rate 2 g L^{-1} was significantly different and gave the plant height, fresh weight and dry weight higher than non-seed-primed. In addition, Ca_2SiO_4 fertilizer application in soil was significantly different plant height, fresh and dry weight and Si content in plant. By the time, Ca_2SiO_4 fertilizer application at a rate 120 kg ha^{-1} gave to trend the high of plant height, fresh and dry weight and Si content in plant. While, relationship between seed preparation methods with application rate of Ca_2SiO_4 fertilizer were significantly different that seed-primed with application rate of Ca_2SiO_4 fertilizer at 120 kg ha^{-1} gave to trend the high of plant height, fresh and dry weight and Si content in plant. In addition, experiment 2, the effect of Ca_2SiO_4 fertilizer application in pepper by foliar method the results showed that seed-primed by Ca_2SiO_4 fertilizer application at a rate 2 g L^{-1} was significantly different and gave the plant height, and fresh weight

higher than non-seed primed. In addition, seed-priming and non-seed priming was not significantly different of plant leaf number, dry weight and total Si content in plant. Ca_2SiO_4 fertilizer application by foliar method was significant different of seedling fresh weight, seedling dry weight and total Si content in plant. Ca_2SiO_4 fertilizer application by foliar method at a rate 2 g L^{-1} gave to trend the seedling fresh weight, seedling dry weight and total Si content in plant. However, relationship between seed preparation methods with application rate of Ca_2SiO_4 fertilizer application by foliar method were not significantly different at $P<0.01$. Seed-primed with Ca_2SiO_4 fertilizer application at a rate 2 g L^{-1} by foliar method gave to trend the high of plant height, leaf number, seedling fresh weight, seedling dry weight and total Si content in plant. Each experiment, it was found that seed primed increased the growth rate of pepper seedling higher more than non-seed primed. Which was in accordance with the finding of primed seeds stimulate and enhanced germination speed and uniformity of seeds (McDonald, 2000). In additions, Hanson (1984) reported the Ca stimulated seed germination and is the cofactor of amylase enzyme. It helped digestion of starch in sperm seeds of a smaller and to promoted seed germination. In addition, Korhmaz (2005) reported that primed sweet pepper seed with KNO_3 with 0.1 mM acetylsalicylic acid gave the good seedling more than non-primed seed. All of above seed primed gave the growth rate and total Si content more than non-seed primed. Moreover, each experiments the results showed that seed primed by Ca_2SiO_4 fertilizer application at a rate 120 kg ha^{-1} (mixed in growing media) and Ca_2SiO_4 fertilizer application at a rate 2 g L^{-1} (foliar method) were gave to trend the growth rate of pepper seedling. It found that Ca_2SiO_4 fertilizer used in this experiment was component as Si and Ca. Then, Si and Ca gave the cell membrane is strong (Epstein & Bloom, 2005) and Si fertilizer is applied to crops in several countries for increased productivity and sustainable production. Which, plants uptake Si in the form of silicic acid, which is transported to the shoot, and after loss of water, it is polymerized as silica gel on the surface of leaves and stems. enhance the strength of the tissue (Ma & Takahashi, 2002) consist of Si accumulated in the cell wall there is characteristic lamination (Silica layer) influence to plant leaves are strong (Epstein & Bloom, 2005). Due to plants uptake Si to cell, Si changes to the solid from of Si in cell wall of plant. It can be improve the structure of cell wall and stronger resistance to disease and insect infestation (Marschner, 1995). In addition, Si can increase watering conditions, and it can also improve the growth of this crop in drought conditions by maintaining high leaf areas to insure high assimilatory capability, thickening leaves which are beneficial to reduce the transpiration loss of water (increasing the thickness of leaves) leaf erectness, haulm stability and lodging. Also, Ca_2SiO_4 used in this experiment was component as magnesium (Mg). Thus, Mg is composition of photosynthesis in plants as a result increased efficiency of photosynthesis (Gong *et al*., 2003). Then, plant also encourages the highest pepper seedlings growth. However, the utilization of Ca_2SiO_4 fertilizer application at a high dose in the pepper seedling could decrease plant growth.

5. Conclusion

Utilization of Ca_2SiO_4 fertilizer application by seed primed with Ca_2SiO_4 fertilizer application by mixed in growing media at a rate 120 kg ha^{-1} gave the good plant growth and total silicon in plant. And Ca_2SiO_4 fertilizer application by seed primed with Ca_2SiO_4 fertilizer application by foliar at a rate 2 g L^{-1} gave the highest of plant growth and total silicon in plant. By the time, Ca_2SiO_4 fertilizer application can be employed for enhancing plant growth of pepper seedling and increasing Si content in plant.

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