Ilmu Pertanian (Agricultural Science)
Vol. 4 No. 3 December, 2019: 98–102
Available online at http://journal.ugm.ac.id/jip
DOI: doi.org/10.22146/ipas.46129

The Effects of Silica on Growth and Yield of Chrysanthemum Plants (*Dendranthema* sp.) Cultivar Sheena and Snow White

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Received: 22nd May 2019; Revised: 18th July 2019; Accepted: 15th August 2019

ABSTRACT
Silica is one of beneficial nutrients in plants. Silica functions to strengthen epidermal wall and vascular tissues so as to affect the stems that are getting bigger and stronger. The present study was conducted to determine the effects of silica fertilizers on growth and yield of chrysanthemum plants in Sheena and Snow White varieties with different anatomies. This study used Split Plot Design. The main plot was the concentration of silica with 4 levels, i.e. 0, 31.1, 62.2, and 93.3 $mg.L^{-1}.m^{-2}$. The subplots were two varieties, Sheena and Snow White. It was revealed that Si fertilizers with 62.2 $mg.L^{-1}$ concentration could accelerate harvest age and the stem hardness in Snow White aged 45 days. The Snow White which has bark stem anatomy was more responsive to silica fertilizers than to Sheena with the woody stem anatomy. This research benefits researchers, farmers and policy stakeholders in a way of increasing yield and quality for local and international market competition.

Keywords: chrysanthemum, sheena, silica, snow white, stem

INTRODUCTION

The chrysanthemum as an ornamental cut flowers is increasingly popular in various countries (Hajipour and Jabbarzadeh, 2016; Sanjaya *et al*., 2018), including Indonesia. Yogyakarta is one of the centers for chrysanthemum cultivation in Indonesia with the rapidly increasing demand of cut flowers . A very high temperature (more than 28ºC) has become a limiting factor for chrysanthemum growth. Chrysanthemum grows well at the altitude of 700 meters above sea level (Pusat Penelitian dan Pengembangan Hortikultura, 2006), but one of the centers for chrysanthemum cultivation in Yogyakarta is located only at an altitude of 650 meters above mean sea level. The lower the altitude of the place, the higher the temperature of the environment, so that it can lead to the less optimal conditions for the growth of chrysanthemum plants. One of them is small chrysanthemum plants that can easily fall. In order to optimize the plant conditions silica (Si) as the nutrient was provided (Pozo *et al*., 2015). Silica has never been given to the cultivation of chrysanthemum plants since it does not belong to essential nutrients, but beneficial ones in plants. The use of Si affects the plant growth and production, which then strengthens the plant stems to reduce the plants breakdown (Yavas and Unay, 2017). Furthermore, silica can increase growth and yield of rice plant (Amrullah *et al*., 2014), anthurium (Dias *et al*., 2017), cucumber (Alsaeedi *et al*., 2019), and passion fruit (Costa *et al*., 2018)

Silica functions to strengthen epidermal wall and vessel tissues (Yavas and Unay, 2017). It is absorbed by plants in the form of monosilicate acids [$Si(OH)_4$] which enter the plant through xylem (Pozo *et al*., 2015). Silicic acids will polymerize silica gel (SiO_2nH_2O) and transport it together with water. Si's translocation runs due to the process of transpiration and polymerization. Polymerization converts silicic acids into colloidal silicic acids and eventually becomes silica gel that attaches to the epidermis (Currie and Perry, 2007). The absorbed silica will accumulate on the surface of epidermal cell wall in the form of a silica gel layer to become thicker and stronger (Currie and Perry, 2007). Plants have a layer of silica gel or often known as phytolith with hard compositions like a rock (Smis *et al*., 2014). Si improves the structural stability of cell walls during cell elongation and division and thereby maintaines the cell shape (Sivanesan and Park, 2014). Plant without Si can inhibit the plant growth and yield as the plant tissue is not protected by silica layer (Vasanthi *et al*., 2014)

Chrysanthemum varieties planted in Yogyakarta are mostly introduced from abroad, including Snow White, Sheena, Lolipop Ungu, Lolired and Bakardi. The varieties used in the present study were Sheena and Snow White. The former has a woody anatomy, while the latter has a stem anatomy. The present study was conducted to determine the effects of silica fertilizers on the growth and yield of chrysanthemum plants of Sheena and Snow White varieties that have different anatomies.

MATERIALS AND METHODS

The research was conducted from November 2018 to March 2019, located at chrysanthemum plantations owned by ASTHABUNDA on Jalan Kaliurang km 21, Panggeran, Hargoninangun, Pakem, Sleman, Yogyakarta, Indonesia at an altitude of 650 meters above mean sea level, and the Faculty of Agriculture, Gadjah Mada University, Yogyakarta, Indonesia. The research instruments included agricultural equipment, stationeries, enforcement net, incandescent lamp, digital scale, timer, caliper, and pnetrometer. Soil type on land research is Regosol. The materials were chrysanthemum seeds of Sheena and Snow White which were available in the field, cow manure, NPK fertilizers, dolomite, SiO_2 fertilizers, 80% acetone, sand, fungicides (Antracol, Bion m, Nativo, and Detaine), akarisida (Samidte), insecticides (Confidor, Topdor, Proclim and Abamectin), aquadest, and 80% of acetone. This study applied Split Plot Design. The main plot was the concentration of silica with 4 levels, i.e. 0, 31.1, 62.2, and 93.3 $mg.l^{-1}.m^{-2}$. The subplots were two varieties, Sheena and Snow White. The combination of treatments was eight with three replications. SiO2 fertilization was performed once a week until the third week, which was applied by spraying it on the canopy part of the plants. The Si fertilizer volume for each plot (1 m^2) was 1 L per each spray. Chrysanthemum spacing was 10×10 cm. The observational variables were plant height, stem diameter, stem hardness, harvest age, number of petals per flower, and flower diameter. The data analysis used variance analysis (ANOVA), and the Tukey test with a level of α= 5% was then carried out.

RESULTS AND DISCUSSION

Plant height and stem diameter

Plant height was the variable of plant growth that was most frequently observed since it could be simply measured and becomes the determinant for the yield quality. Chrysanthemum plants which could be sold were those with a height of more than 70 cm. Stem diameter was also one of the determinants for chrysanthemum quality. Cut chrysanthemum used as a bucket or decoration requires a large stem diameter to make it look sturdy and upright.

Table 1 presents the plant height and stem diameter

Table 1. Plant height (cm) while harvesting two chrysanthemum varieties on various silica fertilizers

Treatment	Plant height (cm)	Stem diameters (mm)
Varieties		
Sheena	79.06 a	4.67 a
Snow White	74.31 b	4.70 a
Silica Fertilization ($mg.l^{-1}$)		
0	73.54 b	4.4 b
31.1	75.29 ab	4.54 b
62.2	78.75 ab	4.79 ab
93.3	79.17 a	5.01 a
Mean	76.68	4.69
CV	3.93	5.89
Interaction	-	-

Remark: Numbers followed by the same letters in one colomn indicate no significant differences based on Tukey test of α= 5%. Sign (-) shows no interaction between silica fertilization and varieties.

Table 2. Stem hardness (N) two chrysanthemum varieties 45 days on various silica fertilizers

Cultivars	Silica Fertilization (mg.l^{-1})				Mean
	0	31.1	62.2	93.3	
Sheena	78.55 ab	77.33 ab	74.37 ab	66.73 b	74.23
Snow White	65.51 b	74.73 ab	83.68 a	69.28 b	73.30
Mean	72.03	76.01	79.02	68.00	+
CV	6.76				

Remark: Numbers followed by the same letters in one colomn indicate no significant difference based on Tukey test of α= 5%. Sign (+) shows interaction between silica fertilization and cultivars.

of two chrysanthemum varieties with Si fertilizer. It did not show any interaction between the Si fertilizers and the tested chrysanthemum varieties. There were effects of variety and Si fertilization on plant height and stem diameter. Sheena and Snow White produced significant differences in plant height, and Sheena was higher than Snow White. The application of Si fertilizers up to 62.2 mg.L^{-1} concentration had not significantly increased plant height. The increase in plant height could be seen if the chrysanthemum plants were fertilized with Si fertilizers in 93.3 mg.L^{-1} concentration. According to the research conducted by Pozo *et al*. (2015), some horticultural plants with silica fertilizers had higher stems.The increase in plant size refers to the development of plant organs, particularly the development or elongation of cells. The increase in plant height is a form of increased cell division due to increased assimilation. As a whole, the plant height was more than 70 cm so that it met the consumer standards. Sheena and Snow White stem diameters did not have any real differences. The application of Si fertilizers to 62.2 mg.L^{-1} concentration had not significantly increased the stem diameter. It was greater if the chrysanthemum plants were fertilized with Si fertilizers in 93.3 mg.L^{-1} concentration. Silica absorbed by plants will accumulate on the surface of the epidermal cell wall in the form of a layer of silica gel so that the stem becomes thicker and stronger. According to Pozo *et al*. (2015), silica fertilization can increase stem diameter.

Stem hardness and harvest time

Stem hardness was used as an indicator of the resistance of the stem to fall. Chrysanthemum plants needed hard stems so they would not be easily broken down and could be harvested based on harvest criteria. It could not be, thus, harvested together.

The hardness of chrysanthemum stem was influenced by the interaction of Si fertilization and the varieties. Table 2 shows that the stem hardness of Sheena was not significantly affected by Si fertilization, but Snow White was significantly affected. Si fertilization at 31.1 mg.L^{-1} concentration in Snow Shite variety had not increased the stem hardness. A significant increase occured when the concentration was increased to 62.2 mg.L^{-1}. The increase in the concentration of Si which was higher up to 93.3 mg.L^{-1} actually decreased the the stem hardness so that it was not different from the stem hardness of the plants with no fertilization. A study conducted by Ma and Takahashi (2002) showed that the use of Si fertilizers greatly affects plant growth, which has an impact on strengthening plant stems. Silica is accumulated in the cell wall of the stem epidermis to produce harder stems. The Snow White has a sticky anatomy, while Sheena has a woody anatomy. The bark stem responds more to sticky anatomy with higher stem hardness than the woody anatomy with tender stems. According to Melo *et al*. (2015), Si increases hardness of plant tissue.

Table 3 shows that there was no interaction between silica fertilization and the variety tested on the hardness of the harvest stem. Both varieties produced significant differences; the Snow White had a harder stem than Sheena. However, silica fertilization did not produce significant differences in stem hardness variables at harvest time. Table 3 also shows that there was no interaction of varieties and fertilization of Si against harvest time. Snow White had shorter harvest time than Sheena. Silica fertilization in 31.1 mg.L^{-1} concentration had not been able to accelerate the harvest time. It would be faster if Si fertilizers was given by more than 62.2 mg.L^{-1} concentration. According to Amrullah *et al*. (2014), silica can make the harvest time of rice plant more quickly

The number of petal dan flower diameter

The number of petals per flower could describe the volume of a flower. Chrysanthemum petal variations could be single or overlapping. Both varieties had overlapping types of petals. Flower diameter was

Table 3. Stem hardness while harvesting (N) and harvest ages two chrysanthemum varieties on various silica fertilizers

Treatment	Stem Hardness	Harvest Time
Varieties		
Sheena	66.78 b	112.33 a
Snow White	82.59 a	107.00 b
Silica Fertilization (mg.l^{-1})		
0	73.13 a	112.00 a
31.1	71.80 a	110.83 ab
62.2	76.35 a	108.33 bc
93.3	77.47 a	107.50 c
Mean	74.68	109.67
CV	11.70	1.93
Interaction	-	-

Remark: Numbers followed by the same letters in one colomn indicate no significant difference based on Tukey test of α= 5%. Sign (-) shows no interaction between silica fertilization and varieties.

Table 4. Number of petal per flower dan flower diameter (cm) two chrysanthemum varieties on various silica fertilizers

Treatment	Number of petal per Flower	Flower diameter
Varieties		
Sheena	545.46 a	12.23 a
Snow White	200.04 b	9.48 b
Silica Fertilization (mg.l^{-1})		
0	371.75 a	10.59 a
31.1	350.25 a	10.79 a
62.2	375.75 a	11.14 a
93.3	393.25 a	10.91 a
Mean	372.75	10.84
CV	9.56	6.35
Interaction	-	-

Remark: Numbers followed by the same letters in one colomn indicate no significant difference based on Tukey test of α= 5%. Sign - shows no interaction between silica fertilization and varieties.

one indicator of chrysanthemum plants to be harvested. Chrysanthemum used in the present study was a standard type, so it had one flower petal only.

There was no interaction between the effects of silica fertilization and the tested varieties on the number of petals per flower and flower diameter (table 4). Sheena only had greater number of petals per flower and larger flower diameter than Snow White, but silica fertilization with different concentrations had not been able to produce the number of petals per flower, and its diameter was significantly different. Kamenidou's study (2005) revealed that sunflowers given by silica can increase the diameter of flowers. Although the analysis did not produce significant differences, the flower diameter had a value that tended to increase when it was given by additional silica fertilizers.

CONCLUSIONS

The above description revealed that Si fertilizers with 62.2 mg.L^{-1} concentration could accelerate the harvest age of chrysanthemum plants and increase the stem hardness in Snow White aged 45 days. The Snow White which had the bark stem anatomy was more responsive to silica fertilizers than the Sheena with the woody stem anatomy. This research benefits the researchers, farmers and policy stakeholders in a way of increasing the yield and quality for local and international market competition.

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