

Effect of Root or Foliar Application of Soluble Silicon on Plant Growth, Fruit Quality and Anthracnose Development of Capsicum

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ABSTRACT. This study was conducted to investigate the root and foliar application of soluble silicon on plant growth, fruit quality parameters and anthracnose disease development in fruits of *Capsicum annuum* L. 'Muria F1'. Silicon as potassium silicate (75 mg/l) was provided to root by amending the nutrient solution (T Root) at weekly interval or to foliage by spraying (T Foliar) daily, as two separate treatments. Control plants were not treated with Si. Disease resistance in fruits was assessed by artificial inoculation of *Colletotrichum gloeosporioides*. Plant growth and fruit quality parameters were not significantly affected by Si treatments except firmness and cuticle thickness of fruits which were significantly greater in both T Root and T Foliar treated fruits than the control. This increase in fruit firmness and cuticle thickness possibly may be attributed to mechanical strength occurred by Si treatment. Sensory evaluation was carried out by a trained panel and there was no significant difference in sensory properties among the Si treated and control fruits. The fruits harvested from T Root or T Foliar treated plants developed significantly smaller lesions (67% and 39% respectively) as compared to the control. Further, the disease incidence was delayed by 2 days in both root and foliar treatments compared to the control. However, the effect of Si root treatment was significantly higher than the foliar spray against the disease.

Keywords: Anthracnose, *Capsicum annuum* L., *Colletotrichum gloeosporioides*, silicon

INTRODUCTION

Capsicum (*Capsicum annuum* L.) is one of the important spice/vegetable crops. Anthracnose disease caused by fungi *Colletotrichum* species is one of the major diseases in capsicum (*Capsicum annuum* L.) in tropical and sub tropical climates causing postharvest losses (Oanh *et al.*, 2004). The disease is controlled by seed treatment and foliar spray with fungicides. However, longer use of fungicides leads to environmental and health hazards and development of fungicide resistance pathogen populations. Therefore, alternative environmental friendly control methods are needed to be investigated. The potential of soluble silicon in enhancing plant disease resistance has proven to be effective particularly, in hydroponic systems where Si availability is limited for plants (Epstein, 1994). Mainly two different application methods have been practiced to supply Si for plants; root application and foliage application. Root supplement of Si has been reported to cause significant reductions of powdery mildew (Adatia and Bestford, 1986) and *Pythium* root rot (Cherif and

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Belanger, 1992) of cucumber and *Phytophthora* blight disease of bell pepper (French-Monar *et al.*, 2010). In a recent study, application of soluble Si, either 100 mg/l or 75 mg/l showed highest resistance against the anthracnose disease of Capsicum 'Awlegama' (Jayawardana *et al.*, 2014).

On the other hand, foliar application of soluble Si has been reported to reduce powdery mildew of cucumber, mask melon, zucchini squash (Menzies *et al.*, 1992) and grapes (Bowen *et al.*, 1992) and angular leaf spot of beans (Rodrigues *et al.*, 2010). However, foliar spraying of Si, if effective, may offer practical and viable mean of reducing plant diseases with low cost.

In addition to development of disease resistance, plant growth and yield have also been improved by silicon application in plants such as, cucumber (Adata and Bestford, 1986), rice (Ma *et al.*, 1989), and broad bean (Ghasemi *et al.*, 2013). The objective of this study was to investigate the effect of silicon application method, either as a foliar spray or as an amendment of nutrient solution, on plant growth, fruit quality parameters and anthracnose disease development of capsicum.

MATERIALS AND METHODS

Plant material

Seeds of capsicum 'Muria F1' (East-West seed International Ltd. of Thailand) were sown on coir dust and compost medium (1:1) and were maintained in the nursery for six weeks. Healthy seedlings were transferred to non circulating liquid hydroponic system in a mesh house at 28-30 °C temperature and 80-85% relative humidity.

Treatments and experimental design

Three treatments, including the control were applied. Silicon (75 mg/l) was supplied in the form of potassium silicate which was added into the nutrient solution of the hydroponic system (T Root) or was sprayed on plant foliage (T Foliar) separately. Administration of silicon to the nutrient solution was practiced once a week while foliar spraying was practiced daily to fully wet the foliage. The plants of control treatment were not supplied with Si either through root or foliage. Treatments were arranged in Complete Randomized Design (CRD) with three replicates each with four plants. The experiment was repeated and the data were analyzed using one way ANOVA in SPSS 16 statistical package.

Potassium silicate and nutrient solution

Potassium silicate and the nutrient solution were prepared with commercial grade chemicals. Potassium silicate was prepared according to Brauer (1965) and was analyzed for molybdo reactive silica concentration using colorimetry (Clesceri *et al.*, 1998). Two different nutrient formulations were used in growing stage (NFG) and blooming stage (NFB). The composition of NFG (mg/l) was N- 313, P- 80, K- 202, Ca- 300, Mg- 78, and the composition of NFB was N- 366, P- 80, K- 650, Ca- 169, Mg- 78 and both formulas included Cu- 0.01, Fe- 3.90, Zn- 0.13, Mn- 1.20, B- 1.00 and Mo- 0.13 (Saparamadu, 2008). Proper adjustments were made in the composition of nutrient formulas to compensate the additional input of K when Potassium silicate was added (T Root). The pH of the nutrient solutions was adjusted to 6.3 using 1M HNO₃. Nutrient solution was renewed at weekly interval.

Pathogen isolation and identification

Capsicum fruits with anthracnose lesions caused by *Colletotrichum gloeosporioides* were collected, surface sterilized with 1 % NaOCl for 1 minute followed by washing with sterile distilled water, cultured on PDA (Potato Dextrose Agar) media and incubated at 27-30°C. *C. gloeosporioides* was isolated by sub culturing and identified by typical ovoid shape of conidia (Du *et al.*, 2005). Fruits harvested at the colour break stage were used for the following experiments.

Fruit inoculation and disease assessment

A suspension of conidia (10^5 conidia per ml) of *C. gloeosporioides* was prepared by using 7 days old pure cultures. Three sets, each containing 10 fruits from each treatment were artificially inoculated. Each fruit was inoculated by placing drops of (20 μ l) conidia suspension at three different places on the surface of freshly harvested fruits. Inoculated fruits were maintained in moist chambers (95-100% relative humidity) at 28 ± 2 °C. The lesion area was recorded daily for 10 days. The average lesion area was calculated for each fruit.

Plant growth and fruit parameters

The shoot length, root length, internodes diameter (3rd - 4th nodes from base), number of leaves, average leaf area and number of fruits per plant were recorded at 12 weeks after transplanting. Fruit length and fruit fresh weight of each harvested fruit were measured. Fruit width and fruit pericarp thickness were measured by a vernier caliper. Diameter at the maximum width was taken as the fruit width. Fruits were cross sectioned at the maximum width and three measurements of pericarp thickness were taken per cross section. Cross sections of fruits were mounted on a slide and cuticle thickness was measured with a calibrated ocular micrometer at 400X. Fruit dry weight was measured after being placed in a dry oven (80 °C for 72 hrs). Fruit firmness was measured by penetrometer (Model FT 40, Wagner Instruments, Greenwich CT). Fruit extracts were prepared by crushing the fruits separately using a blender and squeezing the pulp through a muslin cloth. Total soluble solids (TSS) of fruit extracts were measured by a refractometer (Model WZ-113, China) within the range of 0-32%. Brix and pH of the extracts was measured using pH meter (Model IQ150, USA). Aliquots (5 ml) of fruit extracts were titrated against 0.1 M NaOH in the presence of phenolphthalein as an indicator and titratable acidity (%TA) for each sample was determined according to Askar and Trepow (1993). A sensory evaluation was carried out by a trained panel to test sensory properties of harvested fruits; colour, hardness, smell, pungency and overall appearance using hedonic scale.

RESULTS AND DISCUSSION

Lesion area of capsicum fruits inoculated with *C. gloeosporioides*

The average lesion areas recorded after 10 days of pathogen *C. gloeosporioides* inoculation were 54.5 mm², 99.2 mm² and 163.6 mm² in fruits of T Root, T Foliar and control treatments, respectively (Figure 1). The fruits obtained from T Root treated plants showed the highest disease (lesion area) reduction (67%) compared to the control. However, the

disease reduction observed in fruits obtained from foliage treated plants was 39% compared to control. This was significantly lower compared to that of root treated plants.

There was a delay in symptom development observed (6 days after inoculation) in Si treated fruits (T Root or T Foliar) compared to control fruits (4 days after inoculation) (Figure 2). In addition, the fruits from control plants showed the highest rate of lesion development while the lowest rate of lesion development was recorded in fruits obtained from T Root treatment (Figure 2). Similarly, the anthracnose disease severity was reduced by Si root supplement in beans with a delay in disease initiation (Polanco *et al.*, 2012). Further, the anthracnose disease of common bean has been reduced by 41% by foliar application of potassium silicate together with sodium molybdate (Polanco *et al.*, 2014).

However, it was reported that foliar application of Si was less effective in controlling the powdery mildew of wheat than the root application (Guevel *et al.*, 2007).

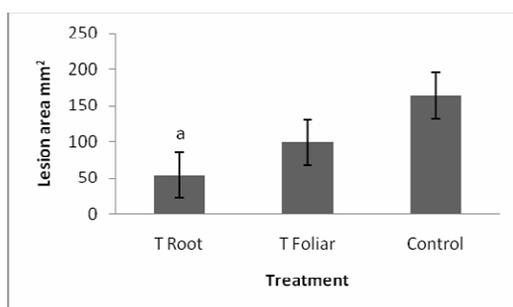


Fig. 1. Lesion area (mm²) of capsicum fruits at 10 days after inoculation of *Colletotrichum gloeosporioides*. Bars with the same letter are not significantly different ($P \leq 0.05$) as determined by Tuckey HSD test.

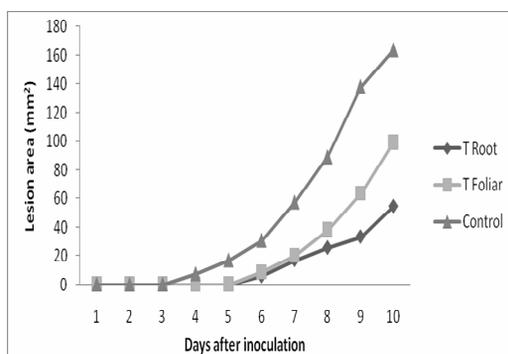


Fig. 2. Lesion development of capsicum fruits inoculated with *Colletotrichum gloeosporioides*.

It is also reported that application of potassium silicate to soil at 1.7 mM (100 mg/l) did not reduce the number of powdery mildew colonies on grape leaves, while foliar sprays of potassium silicate at 17 mM concentration reduced the number of powdery mildew colonies by over 60% (Bowen *et al.*, 1992). However, 17 mM concentration far exceeds the standard 1.7 mM in root application (Guevel *et al.*, 2007). It has been reported that there was no difference of Si concentration in bean leaf tissues when the plants subjected to Si spray compared to that of control plants (Rodriguez *et al.*, 2010). Also, wheat plants treated with

root application of Si had higher level of Si deposition in comparison with foliar application which accumulated very little Si. The above findings suggest that amount of soluble Si absorbed through foliage is lesser than root.

The mechanism underlying with disease resistance caused by Si in plants has been explained in different ways, *i.e.* Si acts as a physical barrier and induces biochemical defence responses similar to systemic acquired resistance in plants (Cai *et al.*, 2009). The mechanism underlying the disease reduction by foliar Si treatments possibly could be the physical barrier formed due to coating of crystals on the leaf surface by the spray (Guevel *et al.*, 2007). Liang *et al.* (2005) suggested that foliar application of Si gave a satisfactory disease control probably through a physical barrier caused by deposited Si on leaf surfaces or an osmotic effect of the silicates, but was not able to enhance the enzymes involved in host defence responses. On the other hand, continuous root application of Si induced systemic acquired resistance. It could be suggested that Si applied on both root and foliage has ability to delay the disease initiation while, Si supplied through root has a further inhibitory action on fungal development that showed lowest growth of lesion area with time.

Plant growth and fruit parameters

There was no significant effect on growth parameters in crops treated with Si compared to the control (Table 1). Among the fruit parameters, fruit firmness and cuticle thickness were significantly greater in both root and foliage treatments compared to control whereas other tested fruit parameters were not affected by Si application (Table 1).

Table 1. Effect of different Si treatments on plant growth and fruit parameters

Plant growth and fruit parameters		T Root	T Foliar	Control
Plant growth parameters	Shoot length (cm)	62 ^a	58 ^a	60 ^a
	Root length (cm)	20.3 ^a	19.3 ^a	18.7 ^a
	Inter node (3-4) diameter (cm)	3.4 ^a	3.4 ^a	3.1 ^a
	No. of leaves	65 ^a	60 ^a	58 ^a
	Average leaf area (cm ²)	40 ^a	45 ^a	45 ^a
Fruit parameters	No. of fruits	09 ^a	08 ^a	08 ^a
	Fruit length (cm)	14.6 ^a	13.5 ^a	13.3 ^a
	Fruit width (cm)	2.75 ^a	2.67 ^a	2.65 ^a
	Fruit pericarp thickness(mm)	4.0 ^a	4.1 ^a	3.9 ^a
	Fruit fresh weight (g)	30 ^a	28 ^a	25 ^a
	Fruit dry weight (% of fresh weight)	5.5 ^a	6.0 ^a	5.1 ^a
	Cuticle thickness (µm)	37.03 ^b	37.86 ^b	18.51 ^a
	Fruit firmness (N)	23.53 ^b	25.13 ^b	19.6 ^a
	Total soluble solids (°Brix)	7.5 ^a	7.4 ^a	7.0 ^a
	% TA	0.54 ^a	0.53 ^a	0.54 ^a
	pH	5.53 ^a	5.42 ^a	5.70 ^a

Means followed by the same letter within the same row are not significantly different ($P \leq 0.05$) as determined by Tuckey HSD test.

Similarly, fruit fresh and dry weight, TSS, titratable acidity of *Cucumis melo* L. were not affected by root application of Si (Buttaro *et al.*, 2009) and plant growth of wheat was not affected by foliar or root treatments of Si (Guevel *et al.*, 2007). However, increased fruit firmness and cuticle thickness seemed to be involved in disease reduction. The fruits of *C. gloeosporioides* resistant *Capsicum baccatum* 'PBC80' had thicker cuticle than that of susceptible *Capsicum annuum* 'Jejujaerae' revealing that thick cuticle of pepper possibly act

as a pre existing structural barrier to fungal penetration (Kim *et al.*, 2004). It has been also shown that there is a negative correlation between cuticle thickness and disease incidence caused by *C. gloeosporioides* in pepper fruits (Oh *et al.*, 1999).

The penetration of germinating fungal spores in grapes treated with potassium silicate foliar spray was prevented by thick potassium silicate deposits that coated a significant portion of the grape leaf cuticle (Bowen *et al.*, 1992) as well. Therefore, there may be a possibility of involving the physical barrier formation for the disease reduction in fruits of the plants subjected to Si treatments compared to control.

There was no significant difference observed among treatments in tested sensory properties of fruits: fruit colour, fruit hardness, overall appearance, pungency and smell (Table 2). Almost all sensory properties were highly favoured by the panel slightly or moderately or extremely.

Table 2. Mean ranks obtained for the results of sensory evaluation (Hedonic scores^x) as determined by Kruskal Wallis test

Treatments	Fruit colour	Fruit hardness	Overall appearance	Pungency	Smell
T Root	18.30 ^a	16.30 ^a	19.70 ^a	17.10 ^a	16.50 ^a
T Foliar	16.20 ^a	11.90 ^a	14.30 ^a	16.50 ^a	16.50 ^a
control	12.00 ^a	18.30 ^a	12.50 ^a	12.90 ^a	13.50 ^a

^xHedonic scores ranged from 1-7 where 1= Extremely dislike and 7= extremely like.

^aThere was no significant difference among treatments in any sensory property ($P \leq 0.05$) as determined by Kruskal-Wallis test.

CONCLUSIONS

Silicon treatments had no significant effect on consumer preference, plant growth and fruit parameters except fruit firmness and cuticle thickness. However, root supplement of Si was effective over foliar spraying against anthracnose disease development caused by *Colletotrichum gloeosporioides* in *Capsicum annum* L. 'Muria F1'.

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