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Effect of silicon application on growth and yield of tomato (*Lycopersicon esculentum* Mill.*)* Var. Rajitha grown under water stress

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Abstract

This experiment was aimed to determine the effect of application of silicon on the growth and yield of tomato (var. Rajitha) under water stress condition. Treatments of the experiment were 75 mg of Si and no water stress (T1), 75 mg of Si and 50% water stress (T2), 150 mg of Si and no water stress (T3), 150 mg of Si, and 50% water stress (T4), no Si and no water stress (T5), and no Si and 50% water stress (T6). A pot experiment was conducted at a plant house in Horticultural Crop Research and Development Institute, Gannoruwa in 2019. The experiment was conducted as a Complete Randomized Design with a factorial treatment structure. There were 5 replicates in each treatment. Water stress and silicon were taken as main factors. Silicon was added as magnesium silicate and water stress was imposed by maintaining a moisture level equivalent to 50% of field capacity. According to the results, the significantly highest

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($p \leq 0.05$) mean height of plants (132.6 cm) in (13 weeks after planting) was observed in plants of T3 treatment, and the lowest mean height (107cm) was observed in plants of T6 treatment. Among the water stress treatments, T4 treatment reported significantly highest ($p \leq 0.05$) shoot/root ratio followed by T2 treatment. The application of magnesium silicate had improved yield parameters such as number of flowers, number of fruits, fruit weight, and fruit yield. In water stress treatments, T4 plants showed the highest flowering. Among the water stress treatment plants T4 resulted in the highest number of fruits per plant (13.6). Water stress negatively affects fruit weight but compared to T6 treatment plants (54.4 g) T2 treatment plants (55.7 g) and T4 treatment plants (56.3 g) showed higher fruit weight, but the treatments were not significantly different from each other. Lower fruit yield was observed in T6 treatment plants (0.707 kg) but T2 treatment plants (0.77 kg) and T4 treatment plants (0.967 kg) have shown higher fruit yield. The results of this experiment showed that the water stress reduced the growth of tomato plant and yield. But the application of magnesium silicate has a positive influence on growth and yield by enhancing the water tolerance of tomato under water stress conditions.

Keywords: growth parameters, nutritional parameters, silicon, tomato, water stress, yield parameters

INTRODUCTION

Global agricultural production is threatened by rapidly changing unpredictable climate conditions. Water deficiency is the most vital factor limiting agricultural activity in Sri Lanka. Temperature related extreme records have expanded over most areas in Sri Lanka. Yearly normal precipitation over Sri Lanka has been decreased throughout the previous 57 years at a rate of around 7 mm for each year. Temperature and water stress will have huge effects on soil moisture deficits and need additional irrigation water and water conservation is important in dry and intermediate zones in Sri Lanka for sustainable agricultural productivity (De Silva, 2006; Easwaran, 2018). Plant response to water stress involves different mechanisms ranging from stomatal closure, increase in root/shoot ratio, leaf area reduction, and osmotic adjustment. In the physiological mechanism of drought avoidance, maintenance of favorable water status in plants is achieved through either efficient stomatal regulation or high root activity (Kaya *et al*., 2006). Tomato production in Sri Lanka is much lower than the world's normal as the regular climate changes unfavorably influence normal production (Dishani and De Silva, 2016). Silicon (Si) is the second most abundant element in the earth crust after oxygen (Shi *et al*., 2016). Silicon is most commonly found in lithosphere in form of solution as silicic acid and all plant uptake directly as silicic acid (Ma *et al*., 2001). Si assumes an essential part in plant tolerance to environmental stresses. There are two types of resistance; (i) Stress avoidance-in the whole growth process does not meet with the face of adversity and (ii) Stress tolerance-plant has a capacity for environmental processes to remain normal. The effect of Si on the greater tolerance of higher plants to drought could be associated with an increase in the action of antioxidant defences, reduction in the oxidative damage to functional molecules and membranes, and maintenance of many physiological as well as photosynthetic processes under water stress conditions (Mauad *et al*., 2016). This study was conducted to investigate the effectiveness of Si in reducing the adverse effects of water stress and thereby increasing the growth and yield of tomato.

MATERIALS AND METHODS

Treatments and experimental design

A pot experiment was conducted for a period of 6 months at a plant house located in Horticultural Crop Research and Development Institute (HORDI), Peradeniya, Sri Lanka. As shown in Table 1, treatments of the experiment were 75 mg Si and no water stress (T1), 75 mg Si and 50% water stress (T2), 150 mg Si and no water stress (T3), 150 mg Si and 50% water stress (T4), no Si and no water stress (T5), and no Si and 50% water stress (T6). The experimental design was a Complete Randomized Design (CRD) with a factorial treatment structure. There are 6 treatments and 5 replicates. Stress and silicon were taken as factors. The total population is 30 plants.

Table 1: Treatments of the experiment

Treatment	Composition
T1	75 mg Si+ no water stress
T2	75 mg Si + water stress (50%)
T3	150 mg Si + no water stress
T4	150 mg Si + water stress (50%)
T5	No Si +No water stress
T6	No Si+ water stress (50%)

The plant house was maintained at a temperature of 28 °C with a thermostat and air circulation fans. Relative humidity was measured daily with a Relative Humidity meter. Recommended tomato seeds (var. Rajitha) was obtained from the vegetable division in HORDI. Silicon was added as $MgSiO_3$ (Magnesium silicate). According to the treatment order, magnesium silicate was added to the soil surface and mixed. The water stress plant root zone was covered using a transparent polyethylene sheet. Continue fertilizing tomato plants about every 3-4 weeks.

Water management

Water stress was imposed by maintaining a soil moisture level equivalent to 50% of field capacity, whereas the well-watered pots were maintained as control at full field capacity (100%) level. Field capacity was measured by volume basis. Plant available water for the water stress of 50% soil moisture deficit level was calculated by the difference between field capacity and permanent wilting point moisture content and divided by 2. The plant receives irrigation only when plant available water is depleted by 50% in water stress plants (Dishani and De Silva, 2016). The water-deficit treatments were applied for 3-week age tomato plants. Every day the water stress and plant water stress levels were measured using tensiometers.

Growth parameters

Plant height (cm) was recorded by using centimetre rod and the average height of tomato plant was calculated. The dry weight of the tomato plant shoots, and roots samples were determined separately in each replicate using a weighing balance. The samples were placed 60 °C for 72 hours (Mohammed *et al*., 2018).

Yield parameters

Flowering was measured in each replicate at weekly interval and the average flowering of tomato plant was measured. The number of fruits per plant was recorded in each replicate at weekly interval and the average number of fruits of tomato plant was measured. Fruit weight (g) was measured in each replicate of tomato plants by using weighing balance and average fruit weight was measured. Fruit yield (kg) was measured in each replicate by using a weighing balance and average fruit yield was measured.

Statistical analysis

Data analysis was done by Analysis of Variance (ANOVA) and mean separation was done by LSD using appropriate SAS (University version) procedures.

RESULTS AND DISCUSSION

Growth parameters

Plant height

As shown in Figure 1, the significantly highest mean height of plants (132.6 cm) in (13 weeks after planting) was observed in plants with 150 mg Si and no water stress condition (T3) and the lowest mean height (107cm) was observed in plants with no silica and 50% water stress treatment (T6). These results indicate that the water stress affects significantly to reduce the vegetative growth of tomato plant. Water stress has several effects on tomato plant growth and the results of this experiment agree with the findings of Mohammed *et al*. (2018) that the tomato plants height and the number of leaves were reduced under different deficit irrigation levels. However, under water stress condition, Si added treatment showed higher plant height than that of no Si added treatment. Retarded plant growth and developmental processes are often observed in plants under water stress over time because photosynthesis and transpiration are inhibited

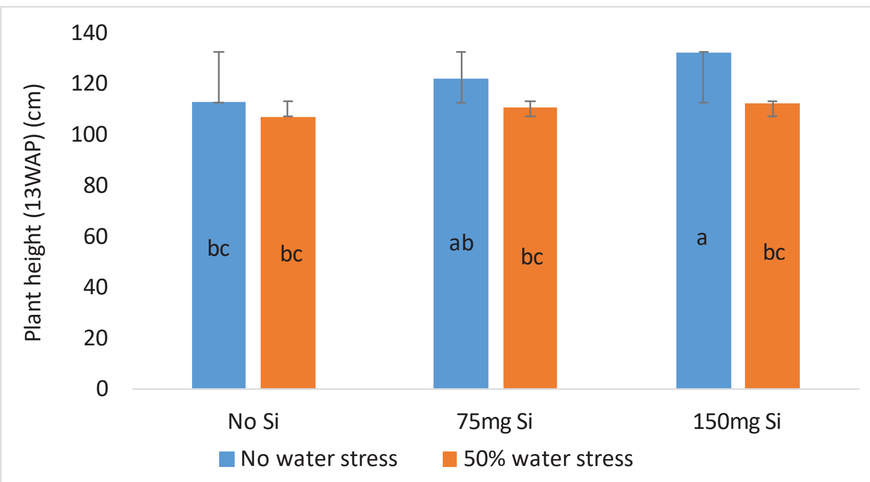

Figure 1: Effect of treatments on 13 Weeks after planting (WAP) plant height (letters inside the bar show the significance between treatments)

immediately after receiving the water stress (Sibomana *et al.,* 2013). However, study results revealed that the addition of Magnesium Silicate improved the water stress tolerance in tomato plants. Magnesium Silicate had a positive effect on growth because it might have been attributed due to increased photosynthetic activity of the plant, water metabolism, and membrane lipid peroxidation, more formation of carbohydrates, chlorophyll content, and increase enzymes under water stress condition, and more uptake of essential nutrients under the water stress condition.

Pulz (2008) found similar results by utilizing calcium and magnesium silicates in the place of dolomitic limestone which increased potato plant height. Similar results were also noticed by Dattatray (2018), Ullah *et al.* (2016) and Lu *et al.* (2016). Further, the Silicon applied plants have shown better performance in both water stress and no water stress condition. Silicon has great resistance to alleviate water stress and influenced tomato growth in addition to their effects on physiological characteristics.

Shoot / root ratio

As shown in Figure 2, the significantly highest ($p \leq 0.05$) shoot / root ratio of tomato was observed in 150 mg Si / no waters stress treatments (T3) plants (6.4) followed by 75 mg Si / no water stress treatment (T1) plants (5.4) and then no Si / no water stress treatments (T6) plants (5.2). Among the water stress treatments, 150 mg Si treatment (T4) reported significantly highest shoot/root ratio followed by 75 mg Si (T2) and no Si treatments (T6). This ratio increased in plants with no water stress treatment but decreased in plants in water stress treatment. The results between water stress and no water stress are in line with the findings of Mohammed *et al*. (2018). However, no difference in shoot/root ratio was observed between the magnesium silicate applied plants and no silicon applied plants. The application of magnesium silicate increases plant growth in both water stress and no water stress treatments in this experiment. Similar results were noticed by Sandoval and Blanco (2017) in rice plant, the application of increasing doses of magnesium silicate significantly helped the growth variables compared to no silicon applied treatments, and similar observations were made by Dattatray (2018). Calcium Silicate and Potassium Silicate through modification of plant water relation stimulates sweet orange cell division and cell elongation boosts in plant immune system and enhances sweet orange plant growth.

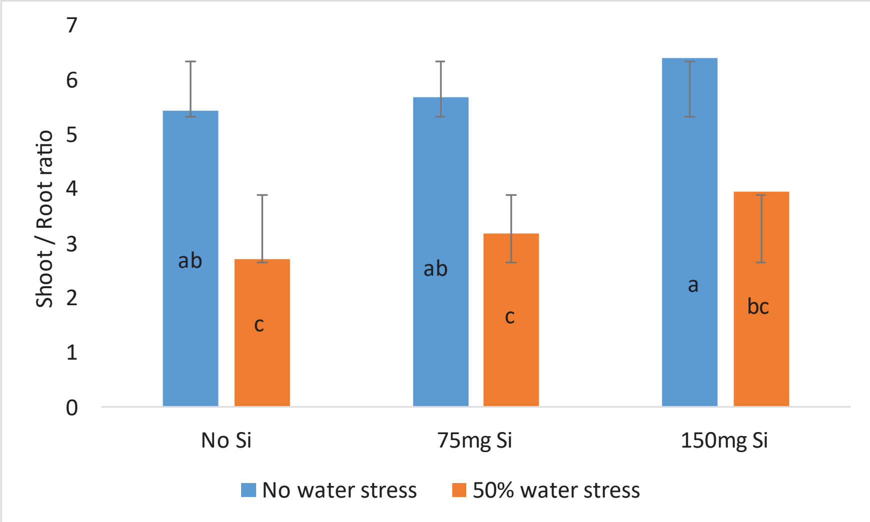

Figure 2: Effect of treatments on shoot/root ratio (letters inside the bar show the significance between treatments).

Yield parameters

Flowering in weeks after planting (WAP)

Flowering was observed in 5 WAP only in certain plants. Flowering data were collected from 5 WAP to 16 WAP. Early flowering was observed at 5 WAP in plants with water stress, no Si and from 8WAP to 13 WAP increasing in the flowering rate was observed. When considering the 11 WAP flowering mean values (Figure 3), they were significantly different between treatments. Significantly highest ($p \leq 0.05$) flowering showed in no water stress plants no Si (T5) and no water stress 75 mg Si (T1) plants. In water stress treatments 150 mg Si applied plants (T4) showed significantly highest flowering. Water stress badly affects flower formation. Results from this study agree with the finding of Olaniyi *et al.* (2010) in tomato plants. He reported that the water deficit stress increases the flower abortion. Water stress decreasing the tomato fruits settings, tomato fruit yield, and low-quality fruits might be due to the non-development of flowers. A similar result was observed by Sibomana (2013) as reported several changes in plant growth and developmental processes when plants are exposed to slow water stress over time because photosynthesis and transpiration are inhibited immediately after receiving the water stress. Water stress in the early growth period decreased the number of flowers

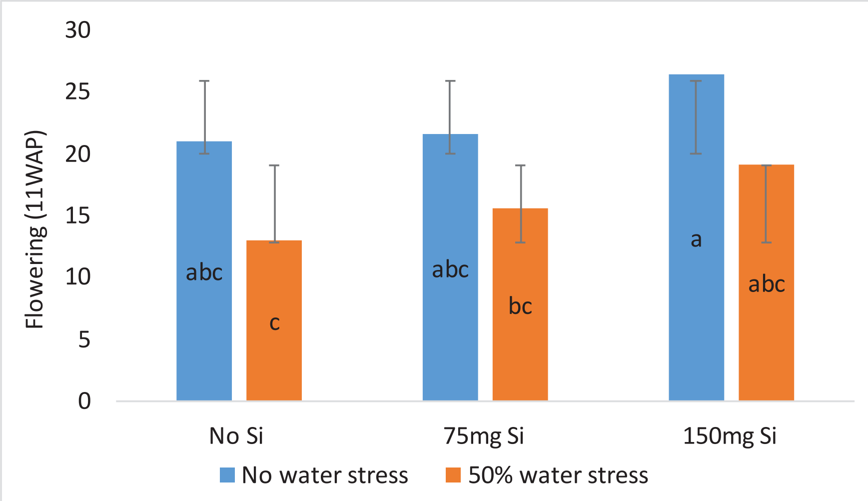

Figure 3: Effect of treatments on 11 weeks after planting (WAP) flowering (letters inside the bar show the significance between treatments)

leading to a reduction in the number of fruits and yield. However, in this experiment results showed (Figure 4) the application of magnesium silicate in water stress treatment has increased the flower formation than no Silicon applied water stress treatment plants.

Number of fruits per plant

The number of fruits per plant data was collected from 8 WAP to 16 WAP (Figure 4). Fruits started to appear in 8 WAP in several plants but 10 WAP fruits appeared in all plants. Results showed no water stress plant produced the highest number of fruit than the water stress plants. Based on the results significantly ($p \leq 0.05$) highest number of fruits was collected in no water stress 150 mg Si treatment plants (19.6), followed by no water stress 75 mg Si treatment plants (16.4) and no water stress no Si treatment plants (16). The lower number of fruits was collected in water stress no Si treatment plants (12), water stress 75 mg Si treatment plants (10.8), and water stress 150 mg Si treatment plants (13.6). However, among the water stress treatment plants 150 mg Si application treatment has shown significantly highest ($p \leq 0.05$) number of fruits per plant. These results indicate that water stress negatively affects fruit production and the results from this study are similar to those found by Mohammed (2018) in tomato plants. Jarosz (2014) indicates that silicon is the only element that does not harm plants when taken up in higher amount and it improves plant fertilization, plant growth, and yield. Silicon application helped in improving fruit set and minimizing fruit drop of tomato as same as the result found by Dattatray (2018).

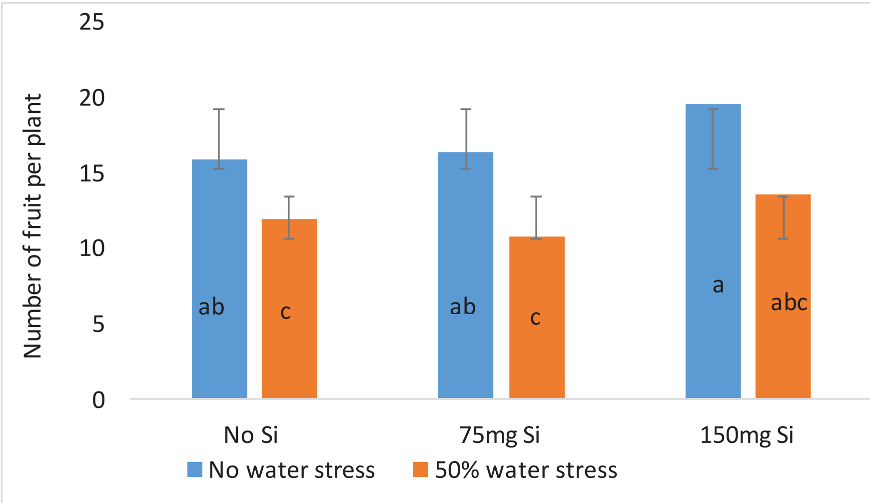

Figure 4: Effect of treatment on number of fruits per plant (letters inside the bar shows the significance between treatments).

Fruit weight

Results revealed that the average fruit weight was significantly different ($p \leq 0.05$) between water stress treatments and no water stress treatments (Figure 5). The highest fruit weight was recorded in no water stress 150 mg Si treatment plants (68.8 g), followed by no water stress 75 mg Si treatment plants (55.7 g), and no water stress no Si treatment plants (66.3 g). The lowest fruit weight was observed in water stress plants. Water stress negatively affect fruit weight but compared to water stress no Si treatment plants (54.4 g) 75 mg Si applied water stress treatment plants (55.7 g) and 150 mg Si applied water stress treatment plants (56.3 g) had higher fruit weight. But these treatments were not significantly different from each other. The tomato plant was most sensitive to water stress condition which reduced the average fruit weight in water stress conditions. The same result was found by Kamal (2013), who reported that the foliar application of potassium silicate improved average fruit weight and total yield of sweet pepper fruits and water use efficiency under water deficit irrigation level. Fruit weight is affected by water stress condition and fruit yield is reduced with a reduction in the amount of water uptake from tomato plants. According to Caroline (2011) plants having sufficient water, form bigger fruits and at the same time get more nutrients under water supplied conditions, thus plants grow well and increase fruit yield and fruit quality. But in this experiment results indicate application of magnesium silicate had a positive effect of tomato fruit weight under water stress conditions. The same results were indicated by Dattatray (2018) that the foliar application of potassium silicate was found to be the best for improving the fruit weight and yield of sweet orange.

Fruit yield

According to the results, the highest fruit yield was reported in no water stress 150 mg Si treatment plants (1.4 kg) followed by no water stress no Si treatment plants (1.146 kg), and no water stress 75 mg Si treatment plants (1.173 kg). The lowest fruit yield was observed in water stress no Si treatment plants (0.707 kg). These results indicate that water stress negatively affects fruit yield.

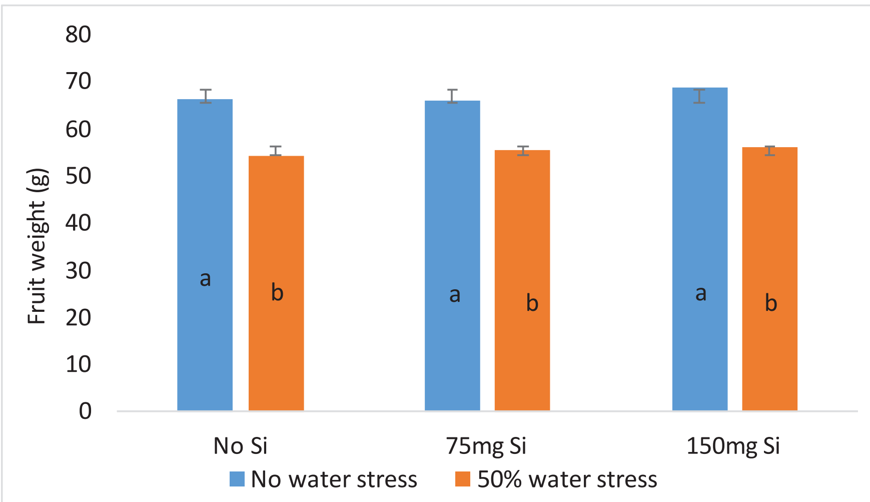

Figure 5: Effect of treatment on average fruit weight (letters inside the bar show the significance between treatments).

However, among the water stress treatment (Figure 6) significantly highest fruit yield was shown in 150 mg Si treatment plants (0.967 kg) followed by 75 mg Si treatment plants (0.77 kg). Results showed tomato plants reproductive processes were negatively affected by the water stress condition and water stress in the early growth period decreased the number of flowers leading to a reduction in the number of fruits and yield. Caroline (2011) showed that the reduction in fruit weight and diameter under stress conditions may contribute to the reduction in fruit yield. And also, there was a reduction in the yield in all water stress treatment plants but magnesium silicate has increased the yield under water stress condition. Similar results were obtained by Jarosz (2014) that the higher total fruit yield in the treatments fertilized with the silicon enriched nutrient solution. Meena (2014) reported that the application of silicon fertilization to increased crop yield in tropical soils and observed that the silicon application may be one of the available resources for increased crop growth and crop yield in arid or semi-arid areas. Magnesium silicate may improve the other nutrient uptake because of that silicon applied plants have shown higher yield than other treatments. This study agrees with the findings of Lalithya *et al.* (2014) that at the time of fruit harvest minimum nutrients were available in the soil and maximum uptake of nutrients was shown in the silicon treated plants with maximum yield of sapota fruits.

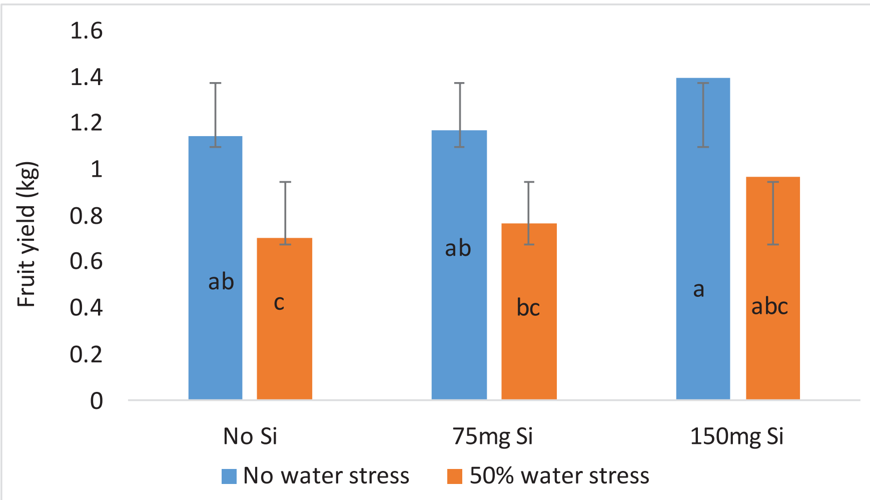

Figure 6: Effect of treatment on fruit yield (letters inside the bar show the significance between treatments).

CONCLUSIONS AND RECOMMENDATIONS

The findings of this experiment showed that the water stress causes a negative effect on the growth and yield parameters of tomato. Under moisture stress condition, a significant reduction of plant height, shoot/root ratio, flowering, number of fruits per plant, fruit weight, and fruit yield were reported. However, the findings of the study showed that the application of magnesium silicate has a positive influence on growth and yield parameters on tomato var. Rajitha under the water stress conditions. Further experiments are needed to find the effect of silicon supplements because in tropical soils silicon application may be one of the available technologies to increase crop growth and yield in dry and intermediate zones of Sri Lanka.

DECLARATION OF CONFLICT OF INTEREST

Authors have no conflict of interest to declare.

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