# What are the benefits of using silicon as a nutrient for strawberry growth?

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## Introduction

- Strawberries produced in substrate (e.g. coir) are grown in the presence of very low levels or no bioavailable silicon (Liu, 2017)
- Silicon has been shown to reduce strawberry powdery mildew epidemics, caused by *P. aphanis,* in consecutive field trials (2013-2016) (Liu, 2019)
- Reduction in disease levels may be a result of deposition of silicon within leaves and petioles, which enhances the passive defence pathway
- Deposition of silicon occurs in the cuticle, epidermis, palisade layers and stomata of the leaves (Figure 1); xylem and epidermis of the petioles and xylem of the roots
- Silicon enhances the passive defence pathway by modifying the wax and cuticle thickness of leaves (Jin 2016)

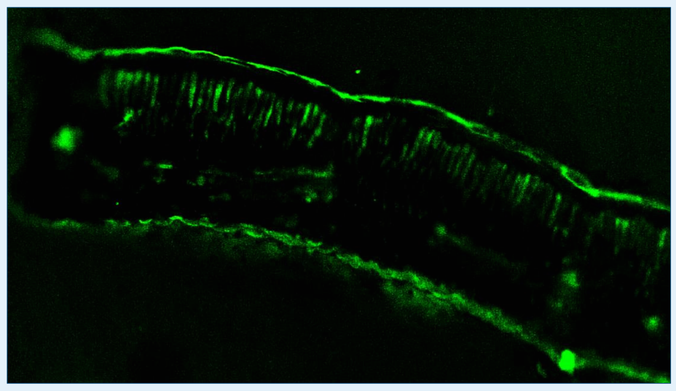

Figure 1: Silicon deposition in a strawberry leaf cross section, stained with lyso-tracker HCK-123 yellow dye, visualised using a LED fluorescent microscope.

Aim: To evaluate additional benefits of the use of silicon and to determine any deficiency and toxicity effects of silicon in strawberry growth.

## Methods

Two glasshouse hydroponic experiments were set up in 2018 & 2019, in 5L plastic containers with aeration pumps providing an air supply (Figure 2). These contained Hoagland's solution, comprised of deionised water, macronutrients and micronutrients essential for plant growth (no silicon) (Jones, 2016). Plastic was used throughout the experiments to eliminate silicon. Bare root Malling Centenary™ strawberry crops were planted for both experiments.

Deficiency experiment: this contained two treatments,

1. Silicon treatment: 50 ml treatment of "Sirius" (a commercial bioavailable form of silicon) at 0.017% (v/v) - applied weekly
2. Untreated control: 50ml treatment of deionised water - applied weekly

Toxicity experiment: this contained four treatments,

1. Silicon treatment: 50ml treatment of "Sirius" at 0.017% (v/v) (normal field rate) - applied weekly
2. Silicon treatment: 50ml treatment of "Sirius" at 0.17% (v/v) - applied weekly
3. Silicon treatment: 50ml treatment of "Sirius" at 1.7% (v/v) - applied weekly
4. Untreated control: 50ml treatment of deionised water - applied weekly

Figure 2: Hydroponic tubs containing strawberry plants in Hoagland's solution on glasshouse bench four weeks after planting (2018).

## Results

**Deficiency Experiment**

There were no classic deficiency symptoms observed in untreated plants, however the plants were smaller compared to silicon treated plants. The wet biomass of the untreated plants was significantly lower than the silicon treated plants ($p<0.05$).

Results in Table 1 found that there were significantly fewer leaves and chlorophyll content ($P<0.05$) and significantly less fruits and higher Brix$^{o}$ levels in the fruit ($P<0.05$), in untreated plants, compared to silicon treated plants. Flowering was a week later in untreated plants compared to silicon treated plants. Data was analysed using ANOVA, regression statistics and the dependant "paired" t test.

Table 1: Results from hydroponic deficiency experiment (January-June 2018)

| | Untreated Control | Silicon rate: 0.017% |
|---|---|---|
| Average number of leaves at end of treatment | 20 | 29 |
| Average chlorophyll content of leaves (throughout experimental period) | 665.1µmol/m$^2$ | 813.5µmol/m$^2$ |
| Initial flowering date | 22$^{nd}$ May 2018 | 15$^{th}$ May 2018 |
| Total number of fruits counted during fruiting period | 8 | 16 |
| Average Brix$^{o}$ content of fruit | 9 | 17 |
| Total number of runners at end of treatment | 24 | 37 |

**Toxicity Experiment**

The silicon treatments of 0.017% and 0.17% showed no detrimental effects to the plants treated, however, the silicon treatment of 1.7% gave toxicity symptoms and caused plant death. As shown in Table 2, the 1.7% silicon treatment reduced leaf number and plant biomass. The silicon treatment of 1.7% caused a reduction in the total number of fruit, average weight and size of fruit (Table 2).

The number of leaves in silicon treatment of 1.7% is significantly reduced compared to untreated, 0.017% and 0.17% silicon treated ($p<0.05$), by two-way ANOVA test.

Table 2: Results from hydroponic toxicity experiment (January-June 2019)

| | Untreated Control | Silicon rate: 0.017% | Silicon rate: 0.17% | Silicon rate: 1.7% |
|---|---|---|---|---|
| Average number of leaves at end of treatment | 15 | 15 | 18 | 7 |
| Average Total dry biomass (g) | 28.42 | 23.90 | 26.67 | 9.06 |
| Average Total number of fruits | 55 | 75 | 73 | 25 |
| Average weight of fruit (g) | 13.97 | 13.46 | 13.71 | 7.98 |
| Average size of fruit (LxW) (mm) | 27.42 x 28.6 | 27.37 x 29.5 | 29.3 x 30.0 | 22.7 x 23.2 |

The pH and EC of all hydroponic tubs was measured each week, the optimal pH for strawberry growth is 6-6.5 and the EC is 1.8-2.0. The pH gradually increased in the 1.7% silicon treatment through the duration of the experiment, from 6.42 to 8.59. In week 10 (4$^{th}$ April 2019) some of the 1.7% silicon treated plants started to show deterioration, the pH was 7.5 and the concentration of silicon in the tubs was 33.28mg/L.

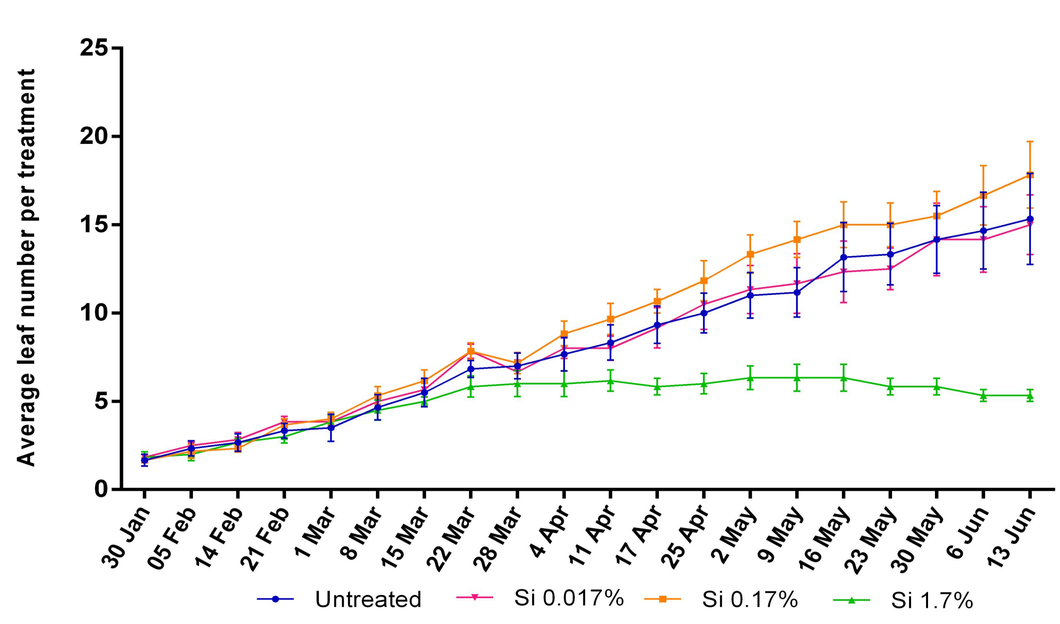


Figure 2: Average leaf number each week for duration of experimental period (January- June 2019)

## Discussion

Whilst the results from the hydroponic deficiency experiment showed no classic deficiency symptoms, the number of leaves, runners, fruits and chlorophyll content of untreated plants were significantly lower than the silicon treated plants. Therefore, using a silicon treatment "Sirius" at a rate of 0.017% (normal field rate), significantly increases productivity.

However, in the toxicity experiment, the silicon treatment at the rate of 1.7% greatly reduced productivity; this may be due to the increased concentration of silicon within the growing system. The level of silicon measured in the 1.7% silicon treatment is above maximum level (22mg/L) recommended for water sources in strawberry irrigation (AHDB, 2011). The silicon content in 0.017% and 0.17% silicon treatments are both below 22mg/L. The pH measured (7.5) was also higher than the recommended pH of 6-6.5. The rate of 0.17% was not toxic to the plants, instead increased productivity, however this was not significantly different to the untreated plants.

The results suggest that though silicon is not an essential element it is probably a limiting factor in strawberry productivity, but at very high levels can be toxic. It is therefore recommended that growers use silicon at a rate of 0.017% throughout the growing season, particularly when growing in coir.

## References

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