Use of Silicon Fertilizer in Citrus Production

Muhammad Adnan Shahid., PhD
Assistant Professor of Horticulture
North Florida Research and Education Center, Quincy
mshahid@ufl.edu

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Introduction

Elemental Abundance in the Earth's Crust

- Oxygen: 49.2%
- Silicon: 25.7%
- Aluminum
- Iron
- Calcium
- Sodium
- Potassium
- Magnesium
- Hydrogen
- Chlorine
- Others
Silicon not Silicone

• **Silicon:**
  - Orthosilicic acid: \( \text{H}_4\text{SiO}_4 \)
    - Form absorbed by plants
  - Silica, \( \text{SiO}_2 \), Quartz amorphous glass
    - Form deposited into plant tissues

• **Silicone:**
  - Polymer of Si, C, H, and O
  - Rubber-like consistency
  - Commonly used in cookware, sealant, adhesive, lubricant
Si concentration in plants

• Si concentration ranges 0.1 to 10% (dry weight basis)

• Monocots present higher level than dicots

• Si level increased in the following pattern
  \[ \text{Legumes} < \text{fruits} < \text{vegetables} < \text{grasses} < \text{grain crops} \]

• Concentration of Si in a plant varies from organ to organ, with higher amount in mature leaves
<table>
<thead>
<tr>
<th>Essential Element</th>
<th>Beneficial Element</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant must be unable to complete its life cycle in absence of mineral element</td>
<td>Not required to complete the life cycle</td>
</tr>
<tr>
<td>The function of the element must not be replaceable by another mineral element</td>
<td>Compensate toxic effects of other elements or replace mineral nutrients in some other less specific functions</td>
</tr>
<tr>
<td>The element must be directly involved in plant metabolism</td>
<td>Don’t directly involved in plant metabolism</td>
</tr>
<tr>
<td>N, P, K, C, H, O, Mg, S</td>
<td>Si, Se, Co</td>
</tr>
</tbody>
</table>

Arnon and Stout, 1939
Is Si beneficial or essential???

• In 2012, Si was categorized as a plant “beneficial substance” by Association of American Plant Food Control Officials (AAPFCO)

• Prior to AAPFCO approval, all Si products were listed on fertilizer labels as “non-plant food ingredient”

• Now, manufacturers can identify qualifying formulations of Si as “plant beneficial substance”

• Si products are also approved by Organic Materials Review Institute (OMRI) for use in organic production
Why should you supplement your Citrus with silicon???

- Improvement in
  - Yield
  - Rooting
  - Fruit size and number
  - Postharvest life
  - Resistance to plant pathogens
  - Tolerance to abiotic stresses

Etesami and Jeong 2018
Silicon in Plant Disease Management
Mode of Action of Silicon

Biochemical Resistance

• Defense-related enzymes
• Antimicrobial compounds
• Regulating systemic signals

Mechanical Resistance
Upper Epidermal Surface of Si-treated Citrus
## Silicon for Disease Control in Horticultural Crops

<table>
<thead>
<tr>
<th>Disease</th>
<th>Fruit Crop</th>
<th>Pathogen</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown Spot</td>
<td>Citrus</td>
<td><em>Alternaria alternata</em></td>
<td>Asanzi et al. (2015)</td>
</tr>
<tr>
<td>Green mold</td>
<td>Citrus</td>
<td><em>Penicillium digitatum</em></td>
<td>Liu et al. (2010)</td>
</tr>
<tr>
<td>Green mold</td>
<td>Lemon</td>
<td><em>P. digitatum</em></td>
<td>Mkhize et al. (2012)</td>
</tr>
<tr>
<td>Root rot disease</td>
<td>Banana</td>
<td><em>Cylindrocladium spathiphylli</em></td>
<td>Vermeire et al. (2011)</td>
</tr>
<tr>
<td>Fusarium wilt</td>
<td>Banana</td>
<td><em>Fusarium oxysporum f. sp. cubense</em></td>
<td>Fortunato et al. 2012</td>
</tr>
<tr>
<td>Powdery mildew</td>
<td>Grapevine</td>
<td><em>Uncinula necator</em></td>
<td>Bowen et al. (1992)</td>
</tr>
<tr>
<td>Disease</td>
<td>Fruit Crop</td>
<td>Pathogen</td>
<td>Reference</td>
</tr>
<tr>
<td>--------------------------</td>
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</tr>
<tr>
<td>Root root</td>
<td>Tomato</td>
<td><em>Pythium aphanidermatum</em></td>
<td>Heine et al. (2011)</td>
</tr>
<tr>
<td>Powdery mildew</td>
<td>Pumpkin</td>
<td><em>Podosphaera xanthii</em></td>
<td>Lepolu Torlon et al (2016)</td>
</tr>
<tr>
<td>Powdery mildew</td>
<td>Zucchini</td>
<td><em>Podosphaera xanthii</em></td>
<td>Menzies et al.(1992)</td>
</tr>
<tr>
<td>Downy mildew</td>
<td>Lettuce</td>
<td><em>Bremia lactucae</em></td>
<td>Garibaldi et al. (2011)</td>
</tr>
<tr>
<td>Crown and root root root</td>
<td>Cucumber</td>
<td><em>Pythium ultimum</em></td>
<td>Cherif et al. (1994)</td>
</tr>
</tbody>
</table>
Silicon in Plant Pest Management
Silicon as a natural plant guard against insect-pests

Kalleshwaraswamy et al. 2022
Silicon develops a silica bilayer in leaf providing resistance to herbivory
Silicon as a natural plant guard against insect-pests

A. No Silicon
B. Low Silicon
C. Moderate silicon
D. High silicon

Mir et al. 2019
Silicon reduced ACP papulation in Tahiti Lime

![Graph showing cumulative eggs (no./flush shoot) over duration of treatments (weeks). The graph includes lines for Control, Foliar, Soil, and Soil+Foliar treatments.](image)
Silicon reduced ACP Nymphs in Tahiti Lime
Silicon reduced ACP population in Tahiti Lime
Si Sources, Application Methods, Rate
Sources of Si Fertilizer

- **Wollastonite**: Naturally occurring wollastonite (Calcium silicate, CaSiO$_3$) contains higher amounts of soluble Si
- **Tuff**: Volcanic rock having soluble silicon
- **Byproducts** from industrial procedures such as smelting of wollastonite, iron, magnesium ore are also used Si fertilizers
- **Silicates** of potassium and sodium: commonly used for greenhouse applications
- **Biochar**: Rice husk, bamboo stick, miscanthus
- **Compost**: Cattle, poultry, swine manures
- **Silica nanoparticles**
- **Diatomaceous earth**
Si Application Methods/Approaches

• Silicon fertilizers can be applied to....
  • Soil
    • Incorporated directly like wollastonite or steel slag
    • Dissolved in water to make solution and then apply to soil
      • Sprinkler, drip or overhead irrigation
  • Soilless mixes
    • Pre-mix with substrate
    • Fertigation
    • Foliar
  • Seed Priming
    • Dusting
    • Soaking in solution
  • Cutting treatment
    • Misting
    • Dipping/Soaking
    • Fertigation
Si Application Rate

• Depends upon product type, application method and plant type (Si accumulator or non-accumulator)

• Run small test

• **Foliar spray** 50-100 ppm

• **Fertigation**, 50 ppm for regular fertigation or 100 ppm once in a week

• **Misting**: 25-50 ppm for cuttings

• **Soil Amendment**, 1-6 ton/ac wollastonite or slags

• **Soilless substrate**: It should have minimum 25-35ppm Si
Commercially Available Si Products
Commercially Available Si Products
Silicon oxide (SiO2) = 44.2%
Silicon= 15%

Water soluble silicon = 13.5%
Silicon= 4.8%

These numbers are just as an example
Silicon related research at UF/NFREC

• Evaluating beneficial effects of silicon in citrus production

Objective:

To investigate the effect of Si on....

• Plant growth and development (vegetative and reproductive)
• Fruit yield and quality
• Resistance to pest and disease attack
• Tolerance to different abiotic stresses
• Economics
Christmas & Late Freeze Events

Before Freeze (December 15\textsuperscript{th}, 2022)

After Freeze (January 7\textsuperscript{th}, 2023)

Recovering from freeze (April 11\textsuperscript{th}, 2023)
Experiment layout

Sites:
• Florida Georgia Citrus, Monticello
• Bob & Valinda Root, Lake Byrd
• Rowell Citrus, Perry
• Gram’s Legacy Grove, Perry

Treatments:
• T1: Distilled water
• T2: 50ppm silicon
• T3: 100ppm silicon.

Application time:
• Biweekly
• Monthly
Si to improve cold tolerance in citrus: large scale on farm project
Si to improve heat and cold tolerance in citrus: large scale on farm Study

Application Time:
- Two week
- Four week

Silicon level:
- 50ppm
- 100ppm

Location: Perry FL

Cultivars:
- Satsuma (Owari)
- Red Navel
Three weeks after freeze event

Without Si

100ppm (4 weekly)
Silicon improved freezing tolerance

Without Si

100ppm (4 weekly)

Picture taken on 1/15/2024
Silicon improved freezing tolerance
Si reduced leaf minor attack
Si reduced leaf minor attack

Si (0 ppm)  Si (100ppm)
Si reduced leaf minor attack
Si improved nutrient uptake

![Graphs showing improved nutrient uptake with silicon treatment](image_url)
Si improved fruit quality

Firmness
Shelf life
Respiration
Fruit weight loss
Si application to HLB-affected Citrus
Take-home message

• Si is effective in improving plant growth and shelf life in citrus
• Plants can only uptake Si in the form of Mono-silicic acid (water soluble Si)
• No phytotoxicity - conduct small test runs
• Application rate vary from crop to crop
• Continuous supply of silicon to plants is more effective than single time application
• Drenching found to be more effective than foliar application
• Always select product with maximum % of water-soluble silicon
• Since, Si mitigates various environmental stresses and suppress pest and disease attack, so could be beneficial in plant nutrition program in citrus and other fruit crops
• Research needed on HLB-affected trees
THANK YOU

Questions

mshahid@ufl.edu