Use of Silicon Fertilizer in Citrus Production

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Florida Citrus Growers Institute,

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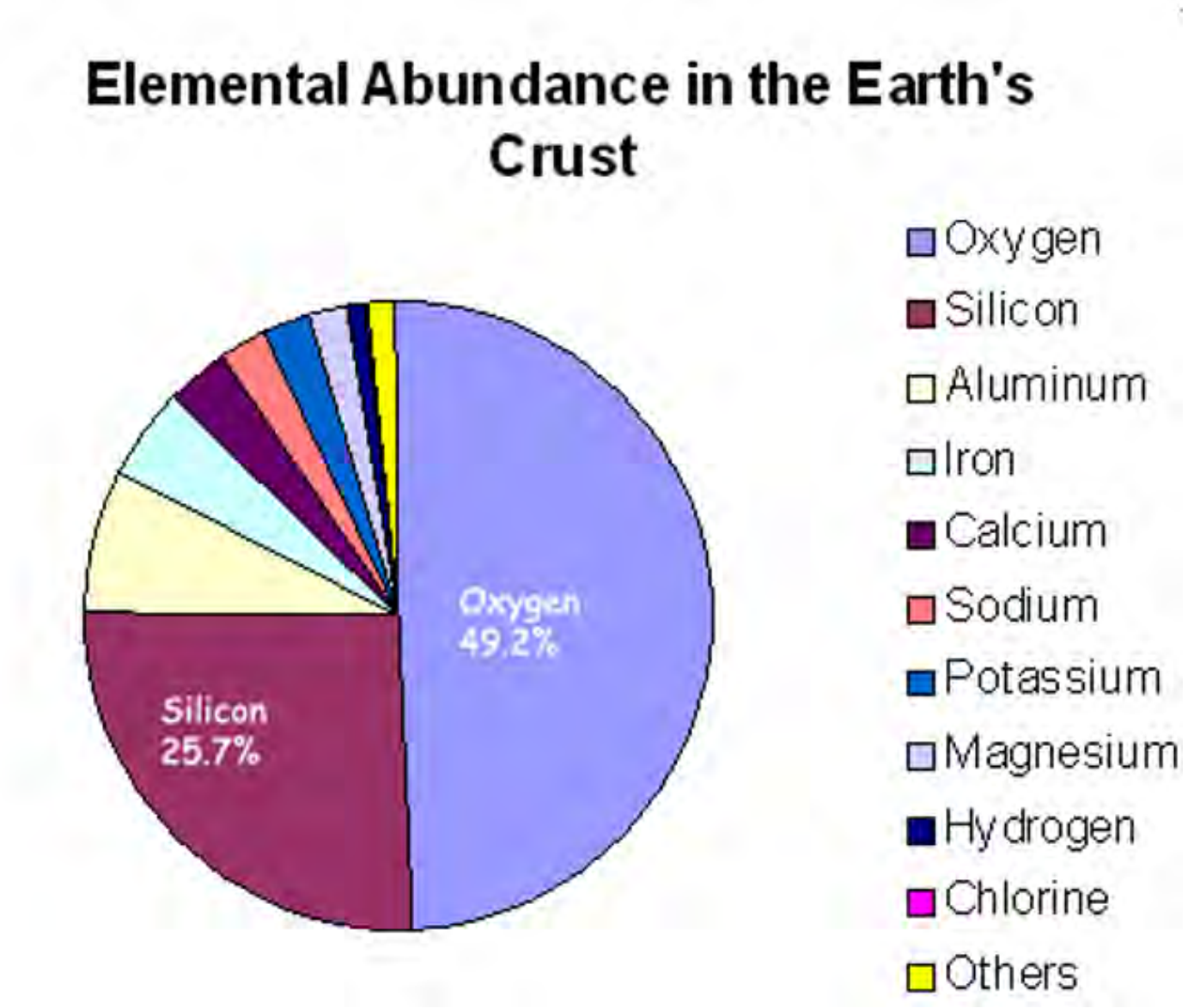
Introduction



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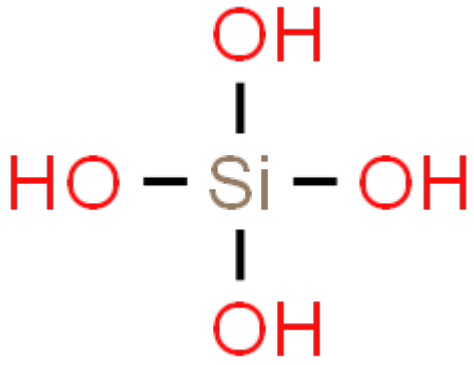
Silicon not Silicone

- **Silicon:**
- Orthosilicic acid: H_4SiO_4
  - Form absorbed by plants
- Silica, 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

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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

  Legumes < fruits < vegetables < grasses < grain crops

- Concentration of Si in a plant varies from organ to organ, with higher amount in mature leaves

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Is Si beneficial or Essential???

Essential Element	Beneficial Element
Plant must be unable to complete its life cycle in absence of mineral element	Not required to complete the life cycle
The function of the element must not be replaceable by another mineral element	Compensate toxic effects of other elements or replace mineral nutrients in some other less specific functions
The element must be directly involved in plant metabolism	Don't directly involved in plant metabolism
N, P, K,C, H, O, Mg, S	Si, Se, Co

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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

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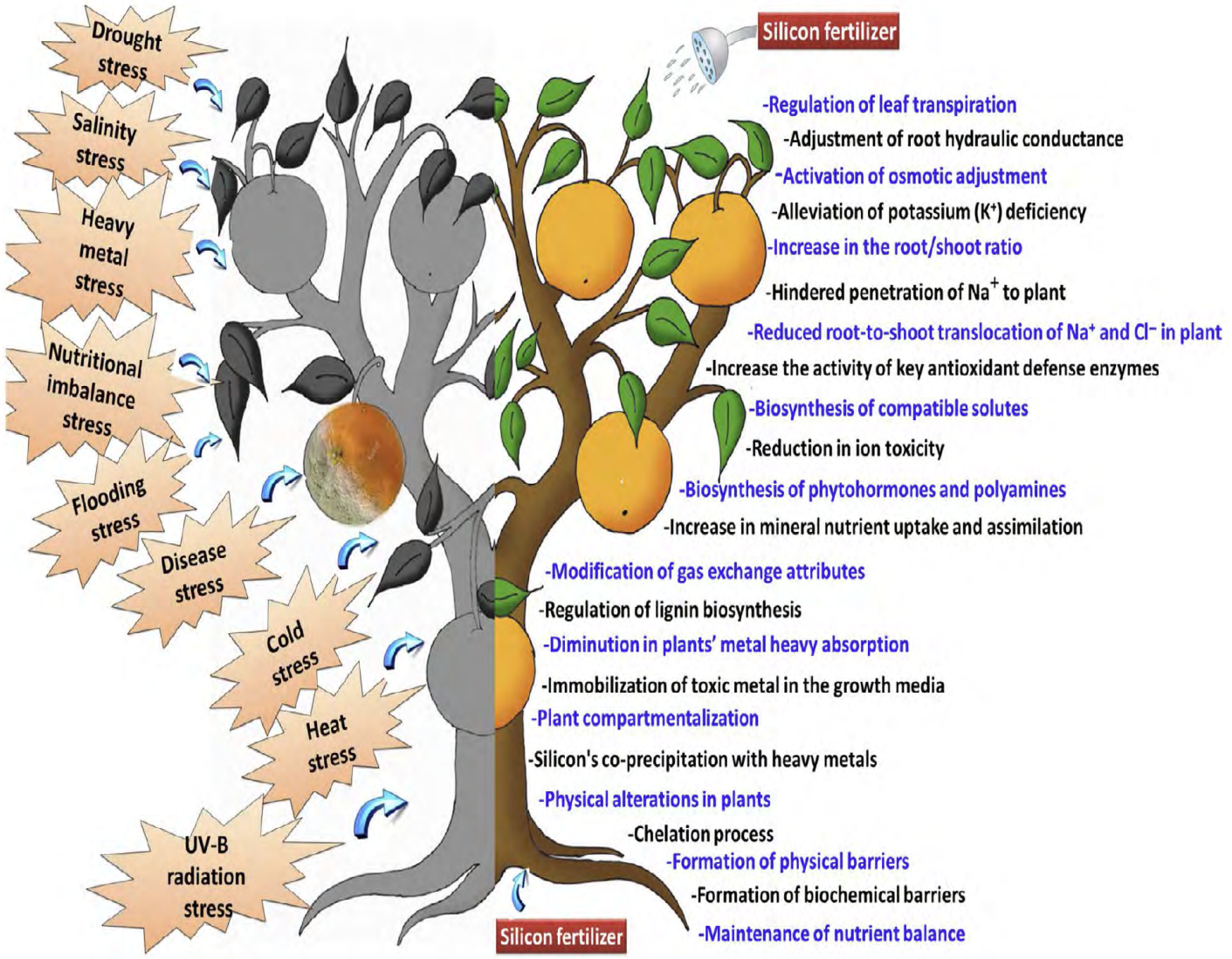
Why should you supplement your Citrus with silicon???

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



Etesami and Jeong 2018

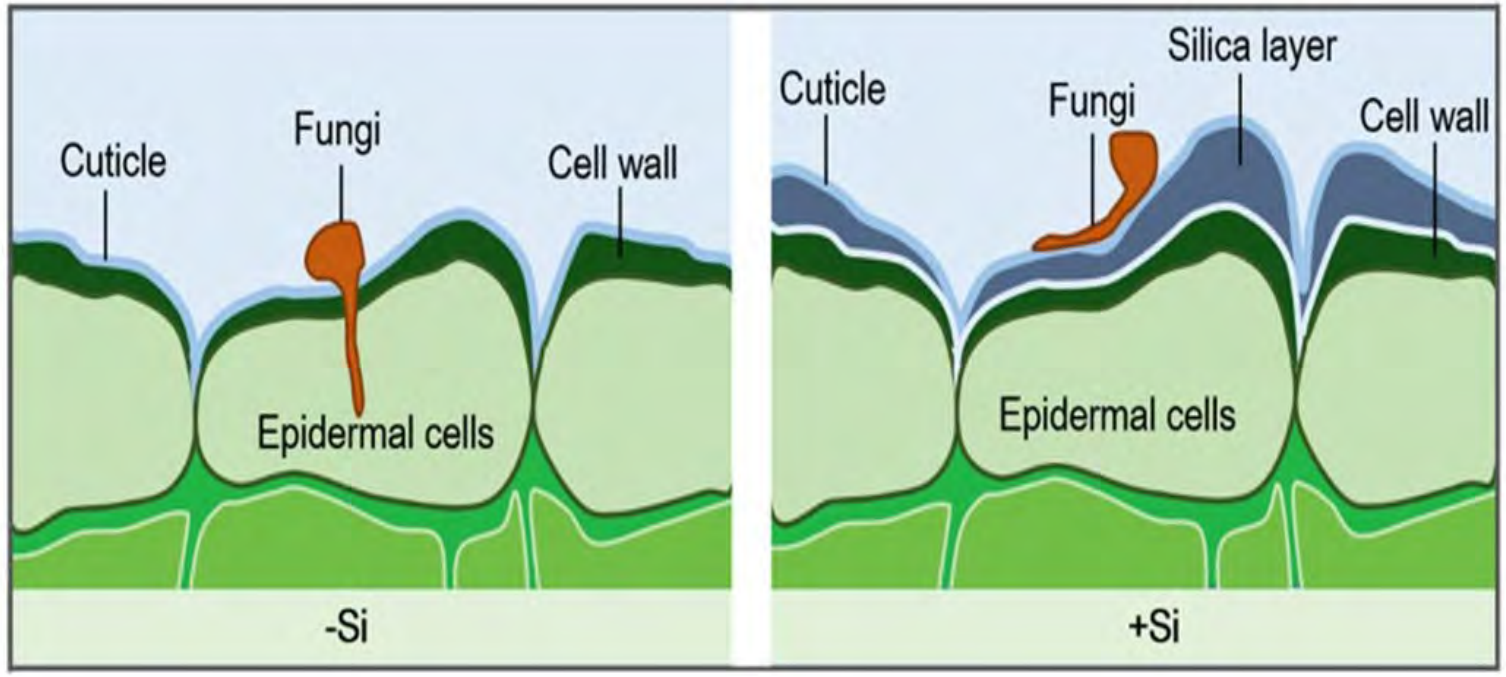
Silicon in Plant Disease Management

Mode of Action of Silicon

Biochemical Resistance

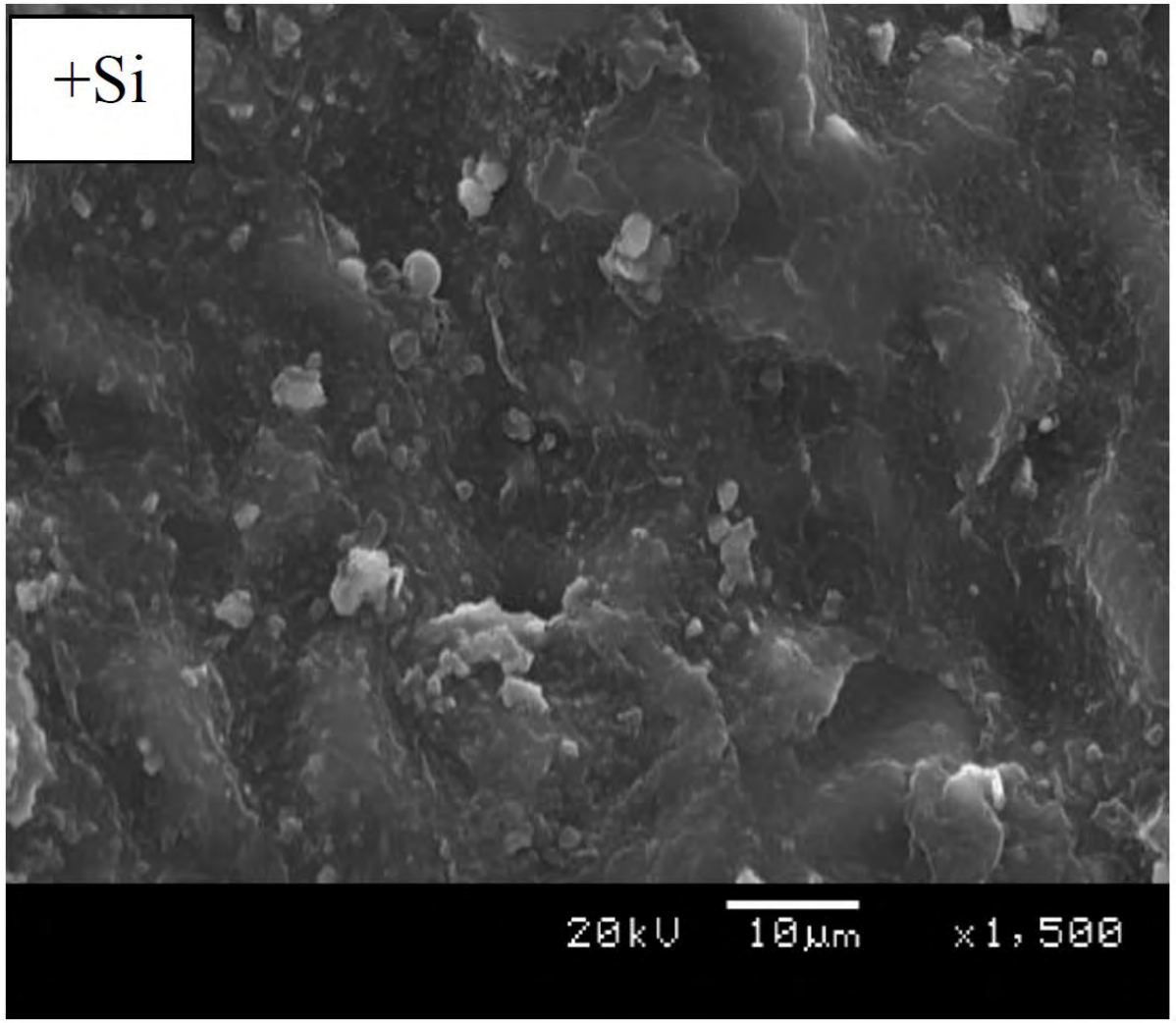
- Defense-related enzymes
- Antimicrobial compounds
- Regulating systemic signals

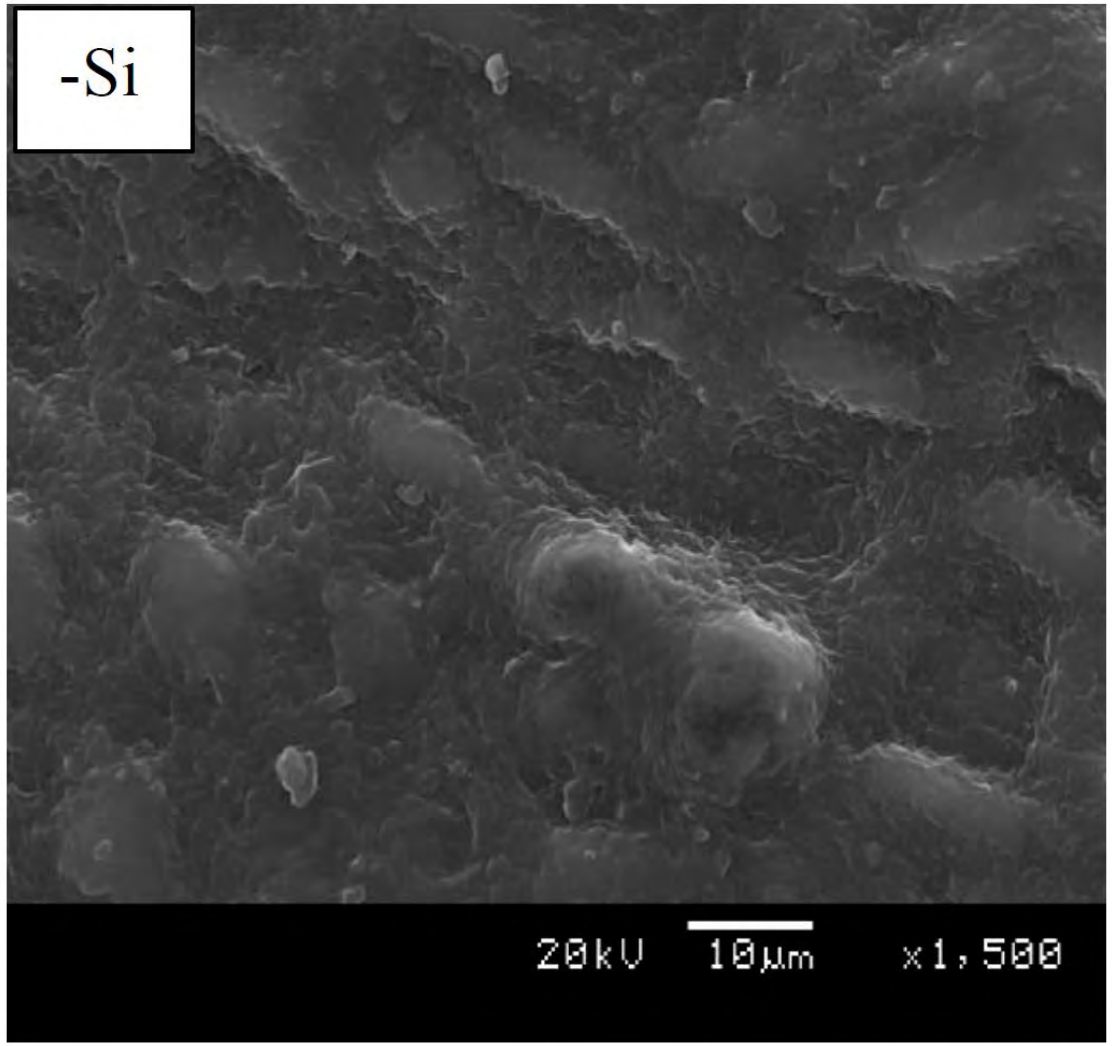
Mechanical Resistance



Wang et al., 2017

Upper Epidermal Surface of Si-treated Citrus





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Mvondo-She and Marais, 2019

Silicon for Disease Control in Horticultural Crops

Disease	Fruit Crop	Pathogen	Reference
Brown Spot	Citrus	*Alternaria alternata*	Asanzi et al. (2015)
Green mold	Citrus	*Penicillium digitatum*	Liu et al. (2010)
Green mold	Lemon	*P. digitatum*	Mkhize et al.(2012)
Root rot disease	Banana	*Cylindrocladium spathiphylli*	Vermeire et al.(2011)
Fusarium wilt	Banana	*Fusarium oxysporum f. sp. cubense*	Fortunato et al. 2012
Powdery mildew	Grapevine	*Uncinula necator*	Bowen et al. (1992)

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Silicon for Disease Control in Vegetable Crops

Disease	Fruit Crop	Pathogen	Reference
Root root	Tomato	*Pythium aphanidermatum*	Heine et al. (2011)
Powdery mildew	Pumpkin	*Podosphaera xanthii*	Lepolu Torlon et al (2016)
Powdery mildew	Zucchini	*Podosphaera xanthii*	Menzies et al.(1992)
Downy mildew	Lettuce	*Bremia lactucae*	Garibaldi et al. (2011)
Crown and root root	Cucumber	*Pythium ultimum*	Cherif et al. (1994)

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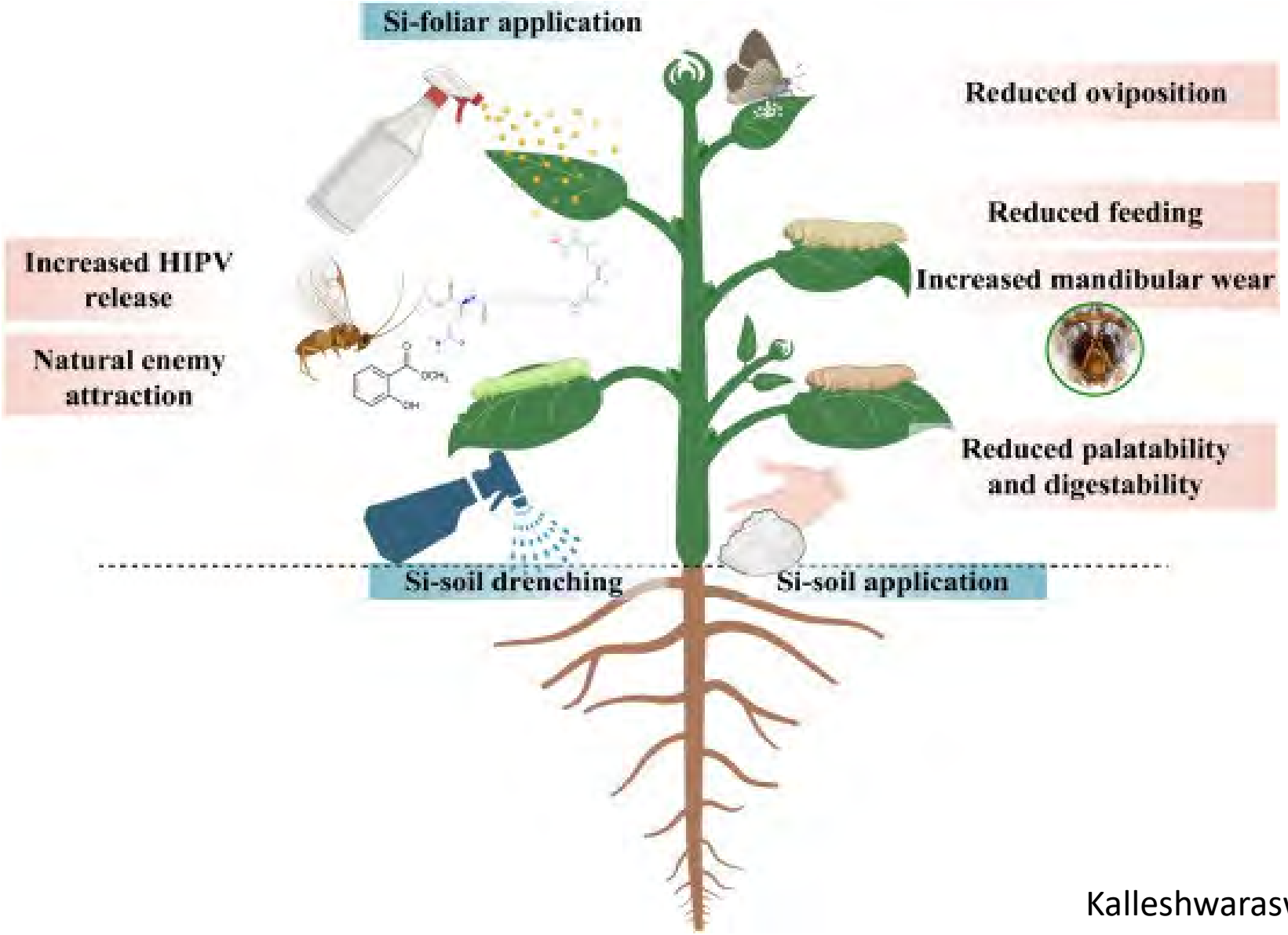
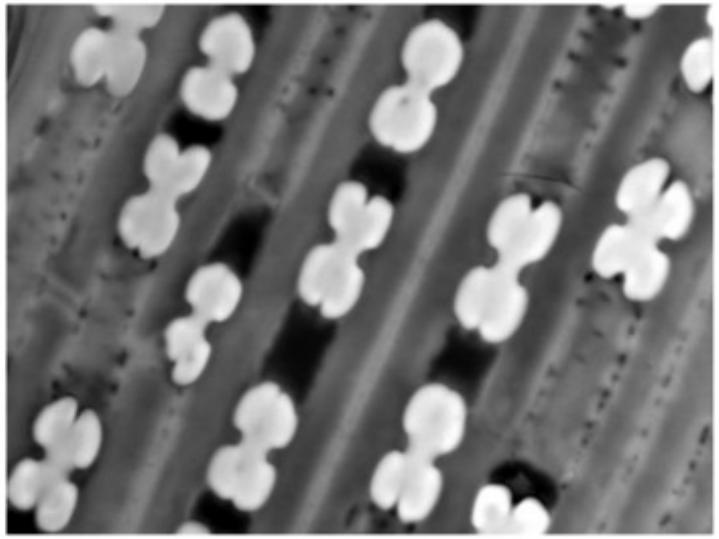
Silicon in Plant Pest Management

Silicon as a natural plant guard against insect-pests



Kalleshwaraswamy et al. 2022

Silicon develops a silica bilayer in leaf providing resistance to herbivory



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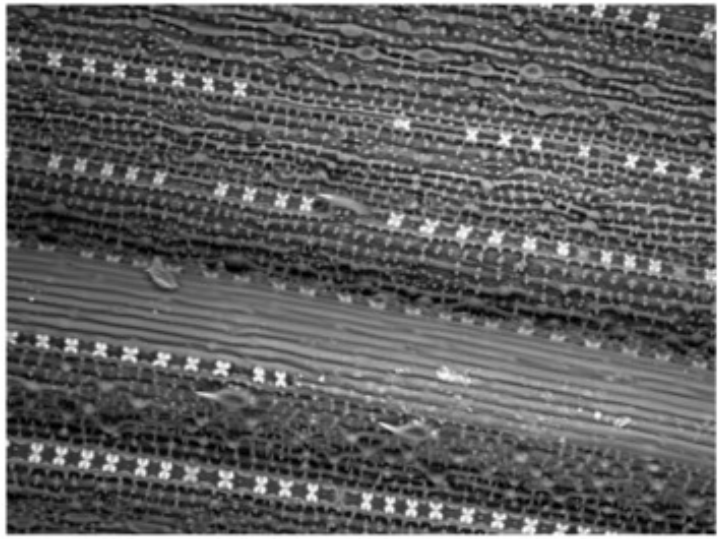

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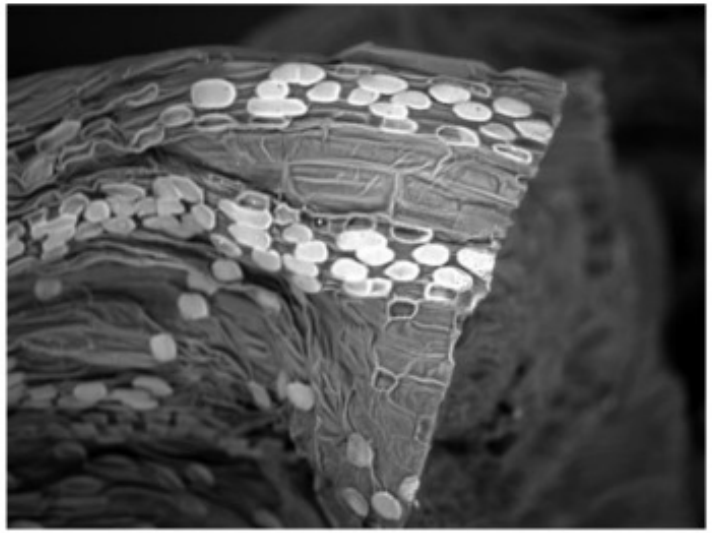

(c)

Kalleshwaraswamy et al. 2022

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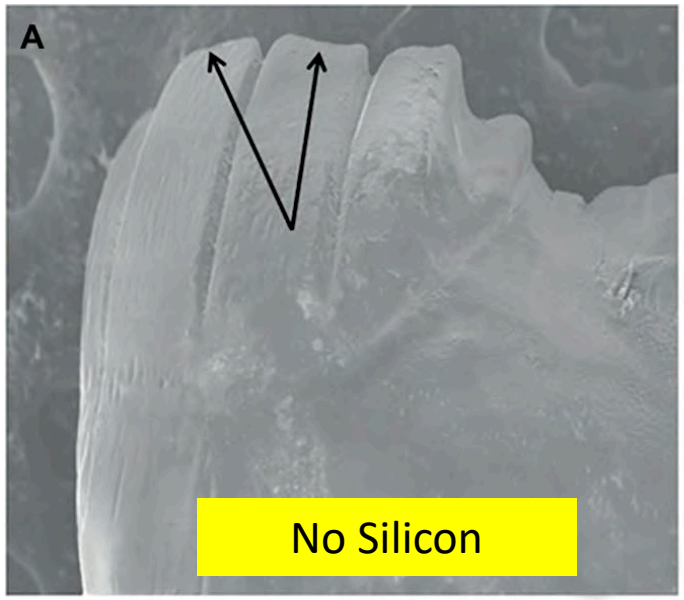

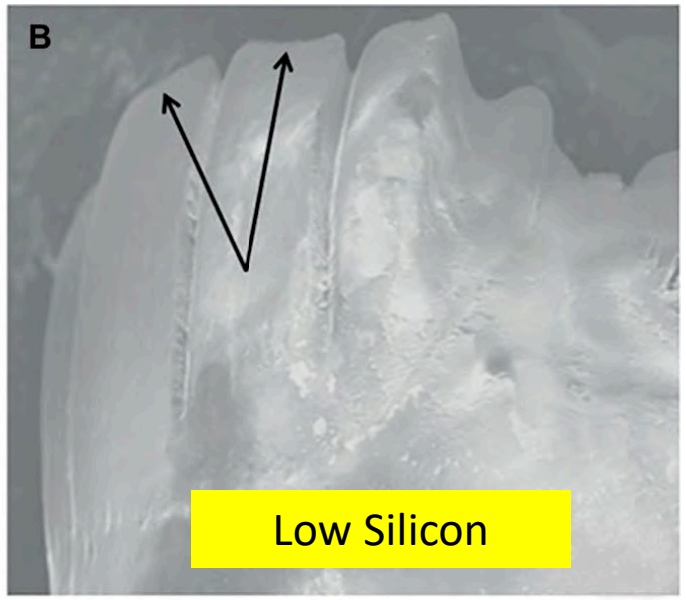

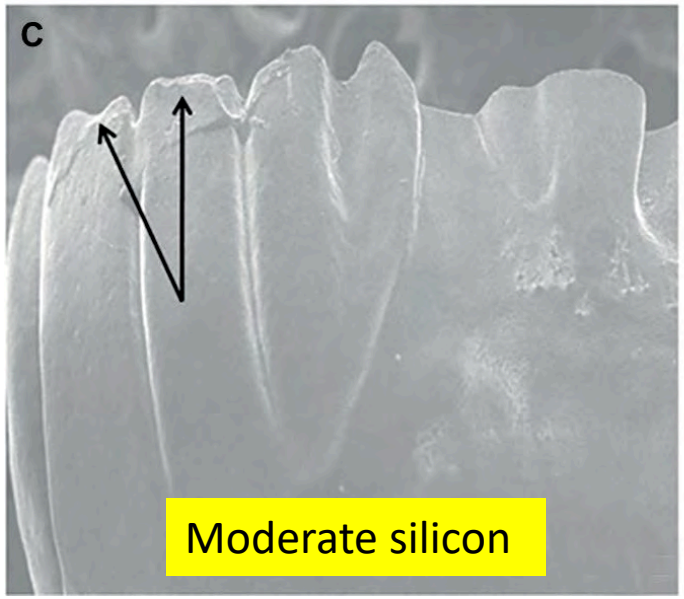

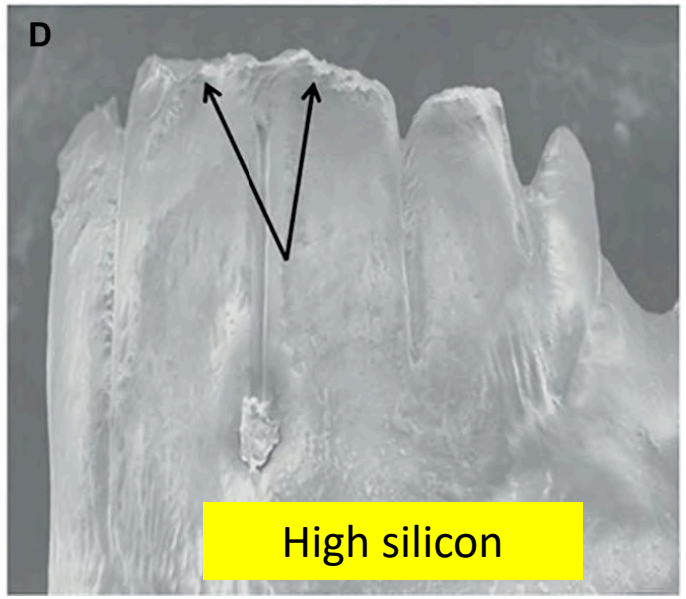

Mir et al. 2019

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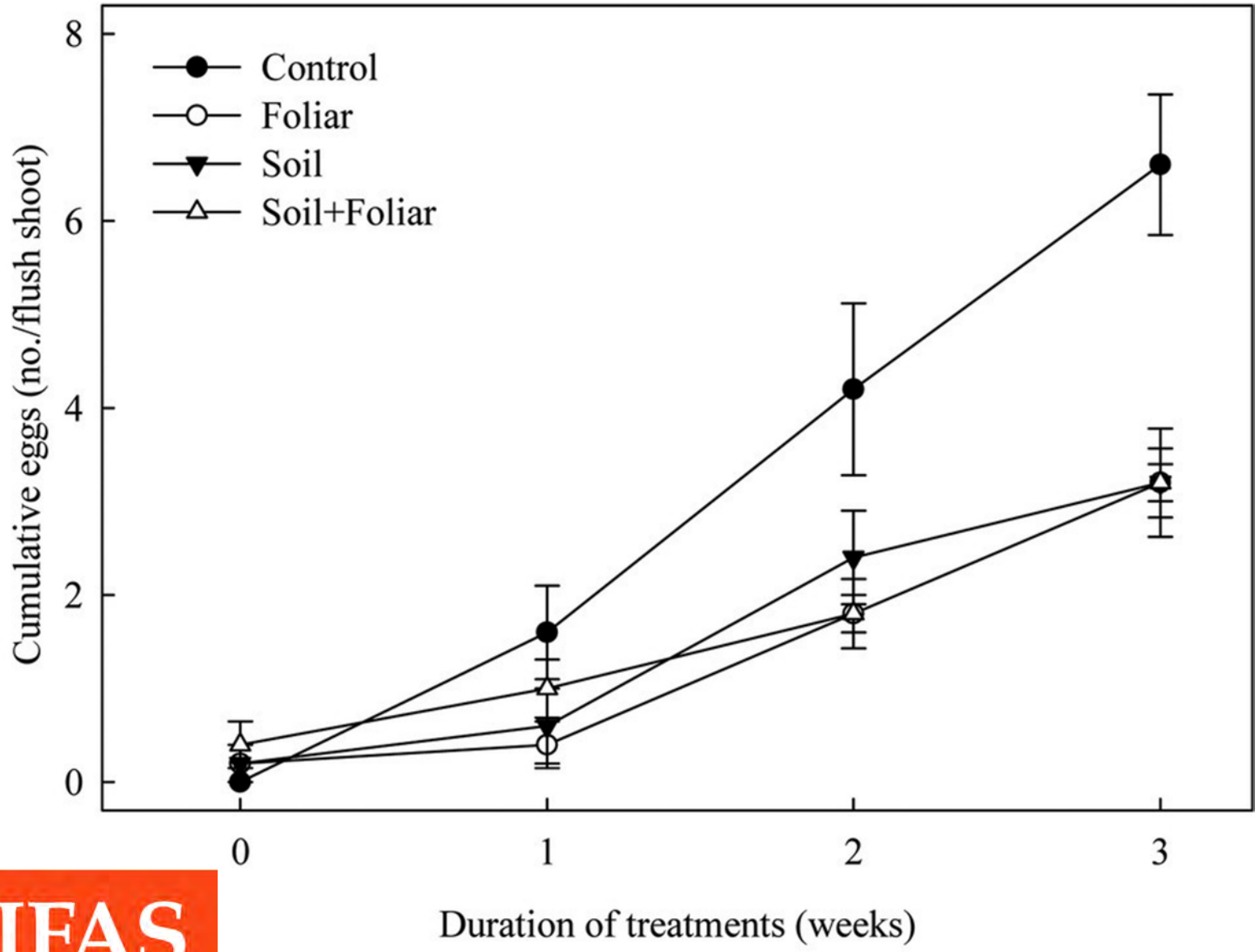
Silicon reduced ACP papulation in Tahiti Lime



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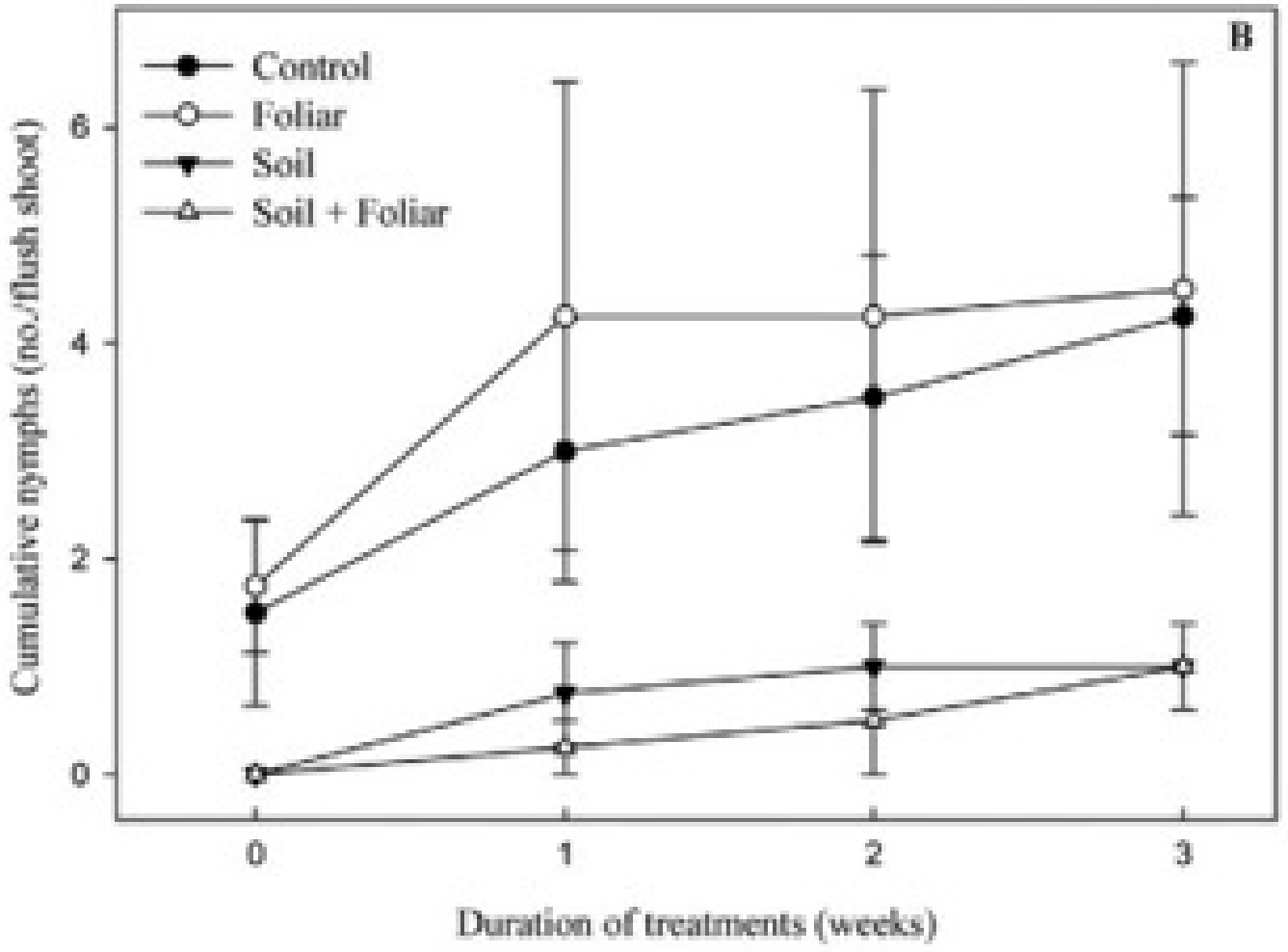
Augusto Ramírez-Godoy et al 2018

Silicon reduced ACP Nymphs in Tahiti Lime



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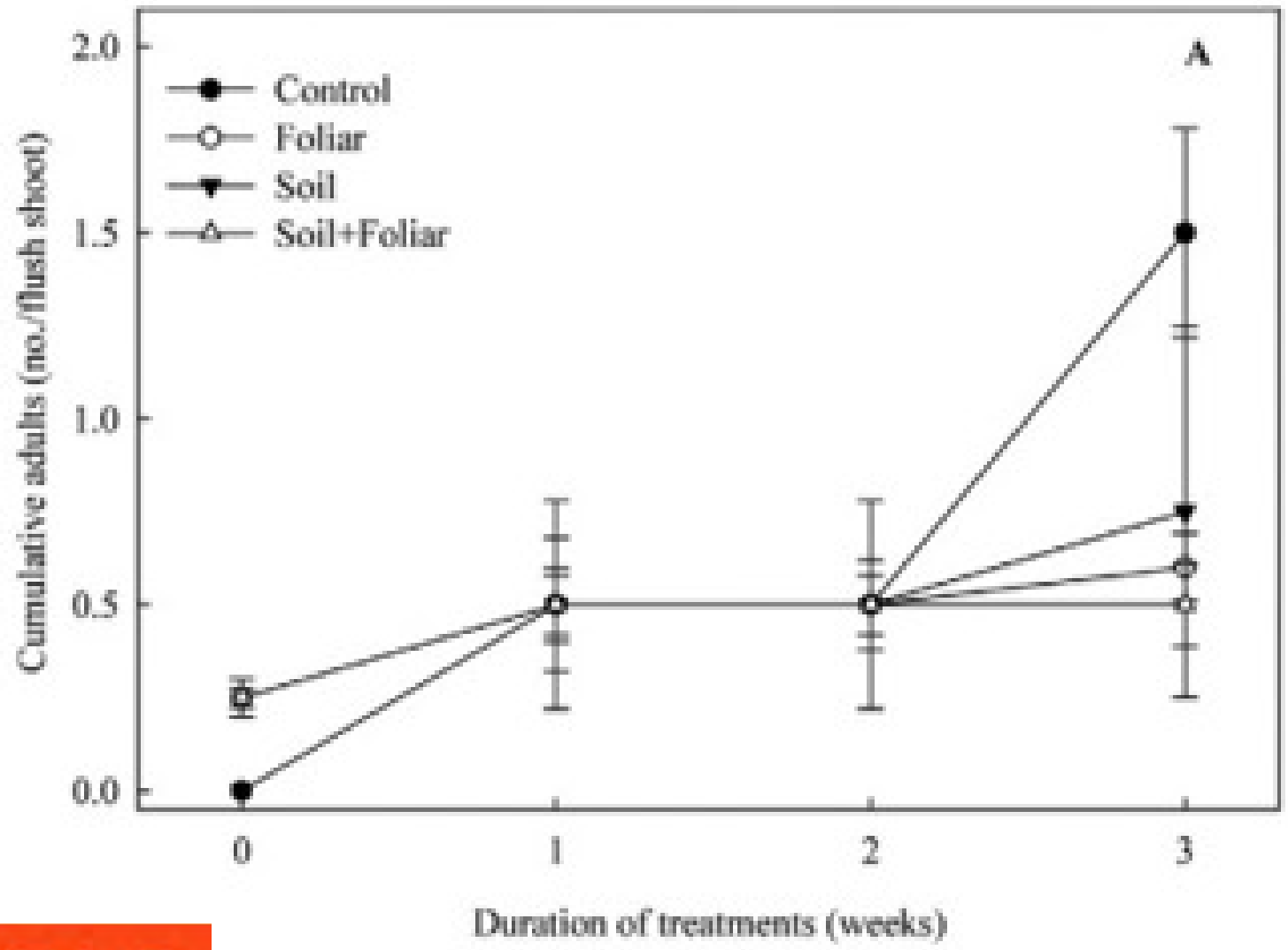

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Augusto Ramírez-Godoy et al 2018

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

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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

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Commercially Available Si Products

AgrowSil®

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Commercially Available Si Products

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Silicon Product Selection

Silicon oxide (SiO_2) = 44.2%
Silicon= 15%

Water soluble silicon = 13.5 %
Silicon= 4.8%

These numbers are just as an example

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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

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Christmas & Late Freeze Events

Before Freeze (December 15th, 2022)

After Freeze (January 7th, 2023)

Recovering from freeze (April 11th, 2023)

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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

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Si to improve cold tolerance in citrus: large scale on farm project

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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

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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

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Silicon improved freezing tolerance

Without Si

100ppm (4 weekly)

Si reduced leaf minor attack

Si reduced leaf minor attack

Si (0 ppm)

Si (100ppm)

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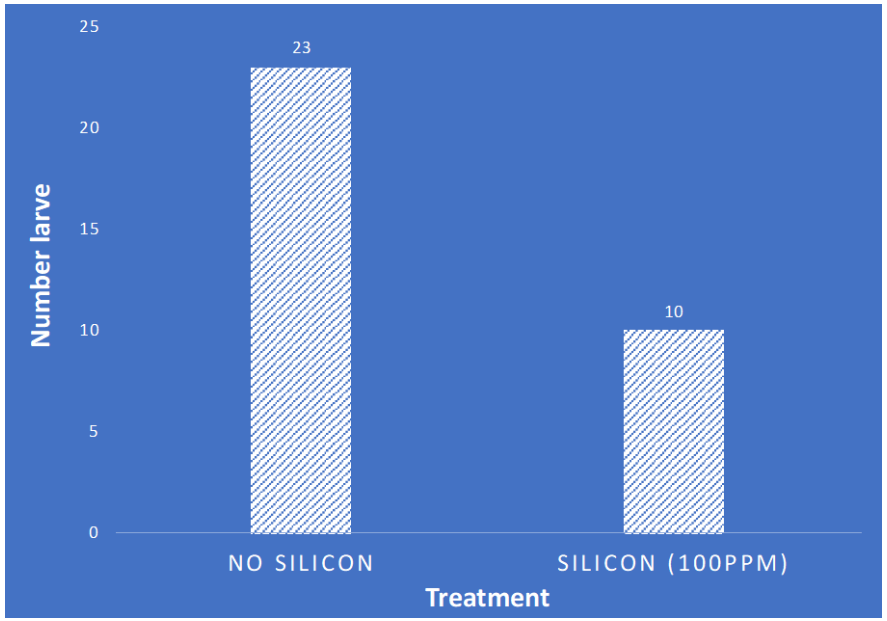
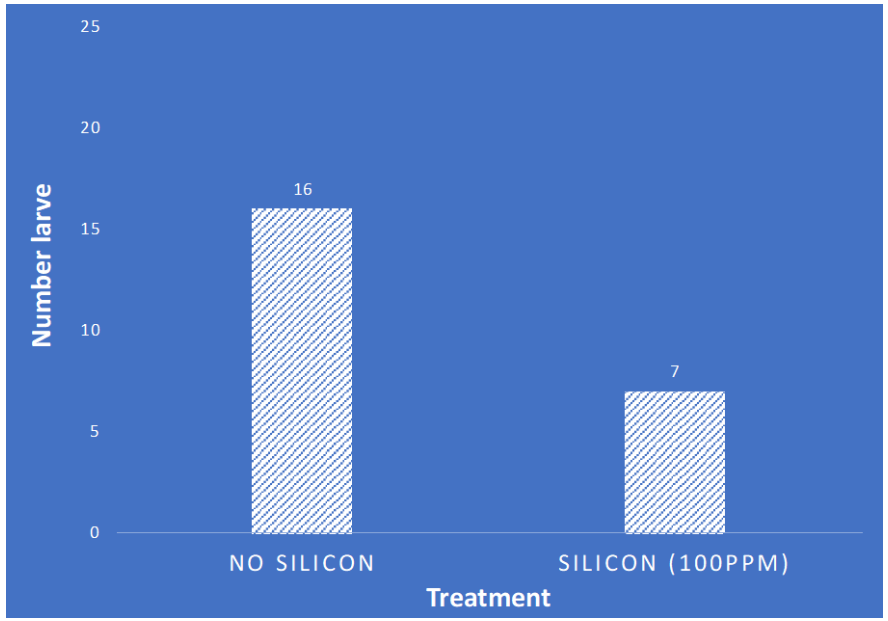
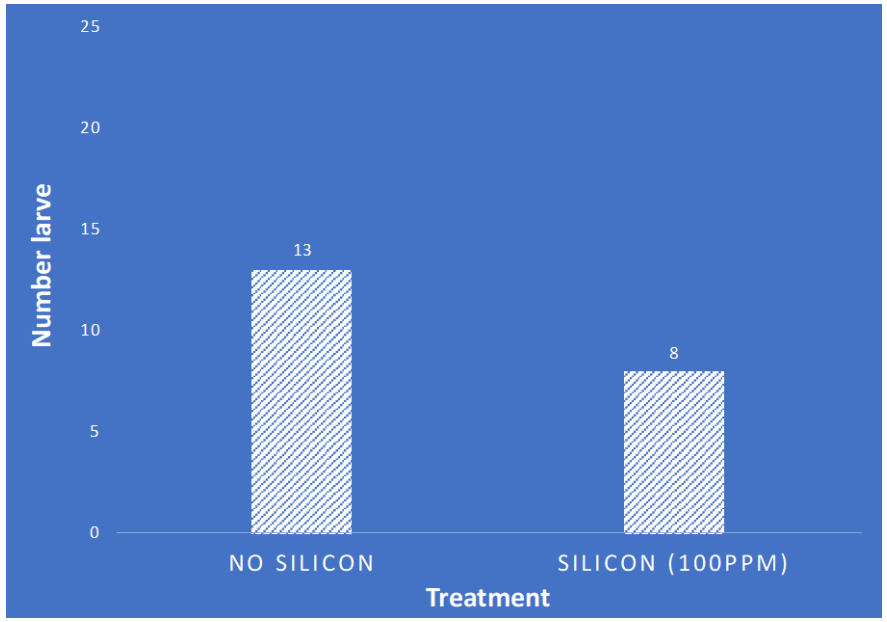
Si reduced leaf minor attack







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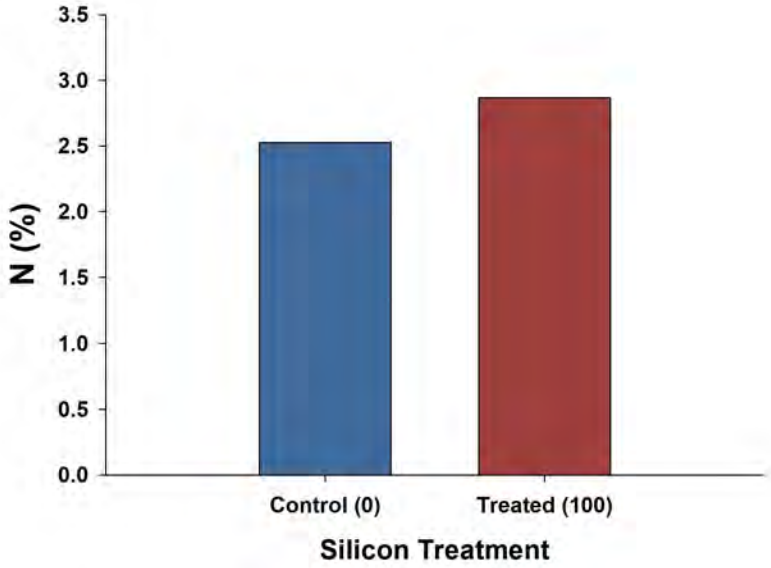
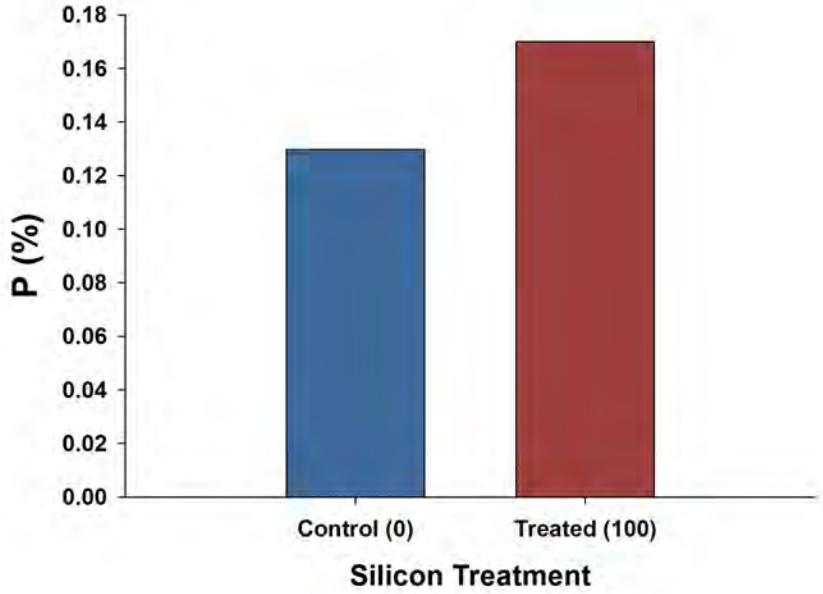
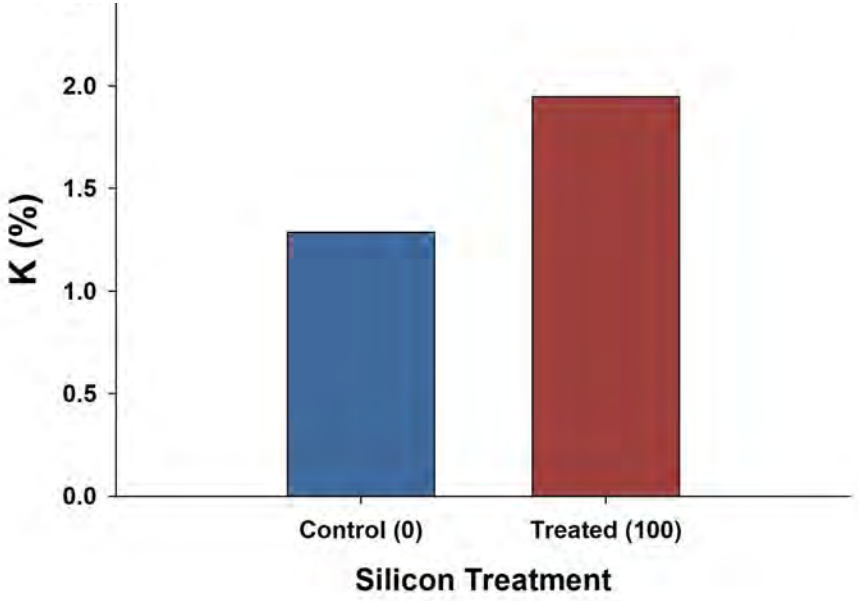
Si improved nutrient uptake







Si improved fruit quality

Firmness

Shelf life

Respiration

Fruit weight loss

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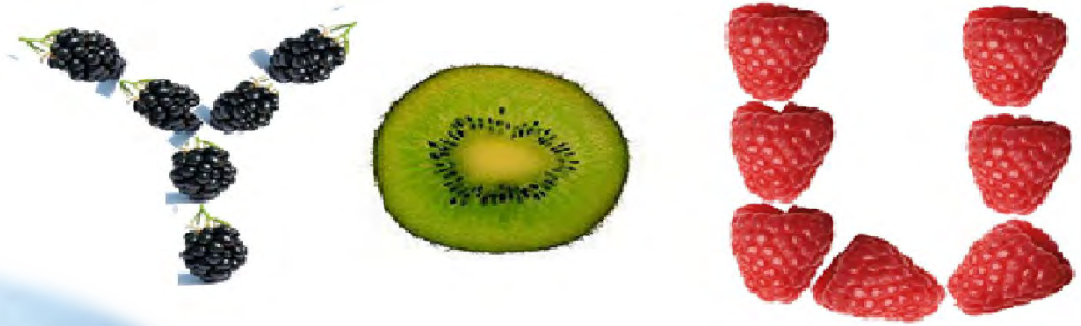
Si application to HLB-affected Citrus

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



Questions

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