Silicon (Si): A Beneficial Nutrient for Citrus Production

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Today's talk……

- Introduction
- Benefits
- Si sources, application methods / rate
- Si related research at UF/IFAS NFREC

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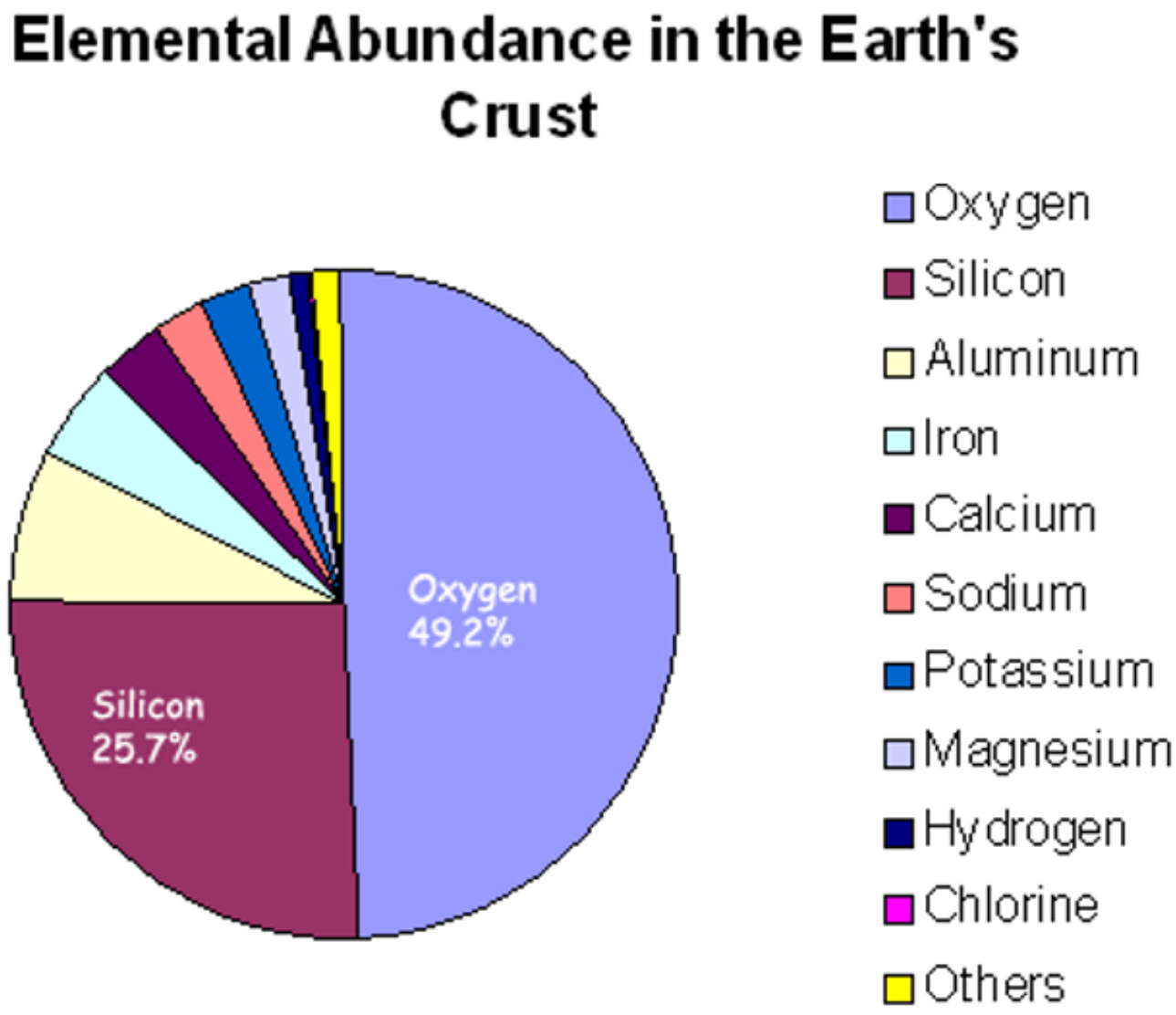
Introduction



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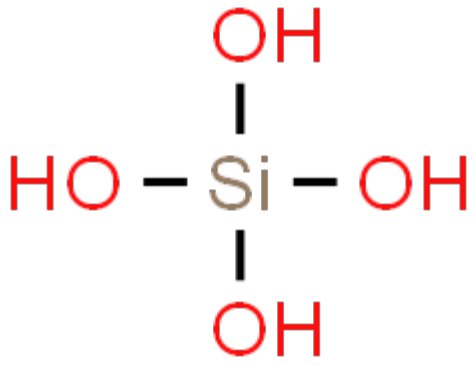
Silicon not Silicone

- **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

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

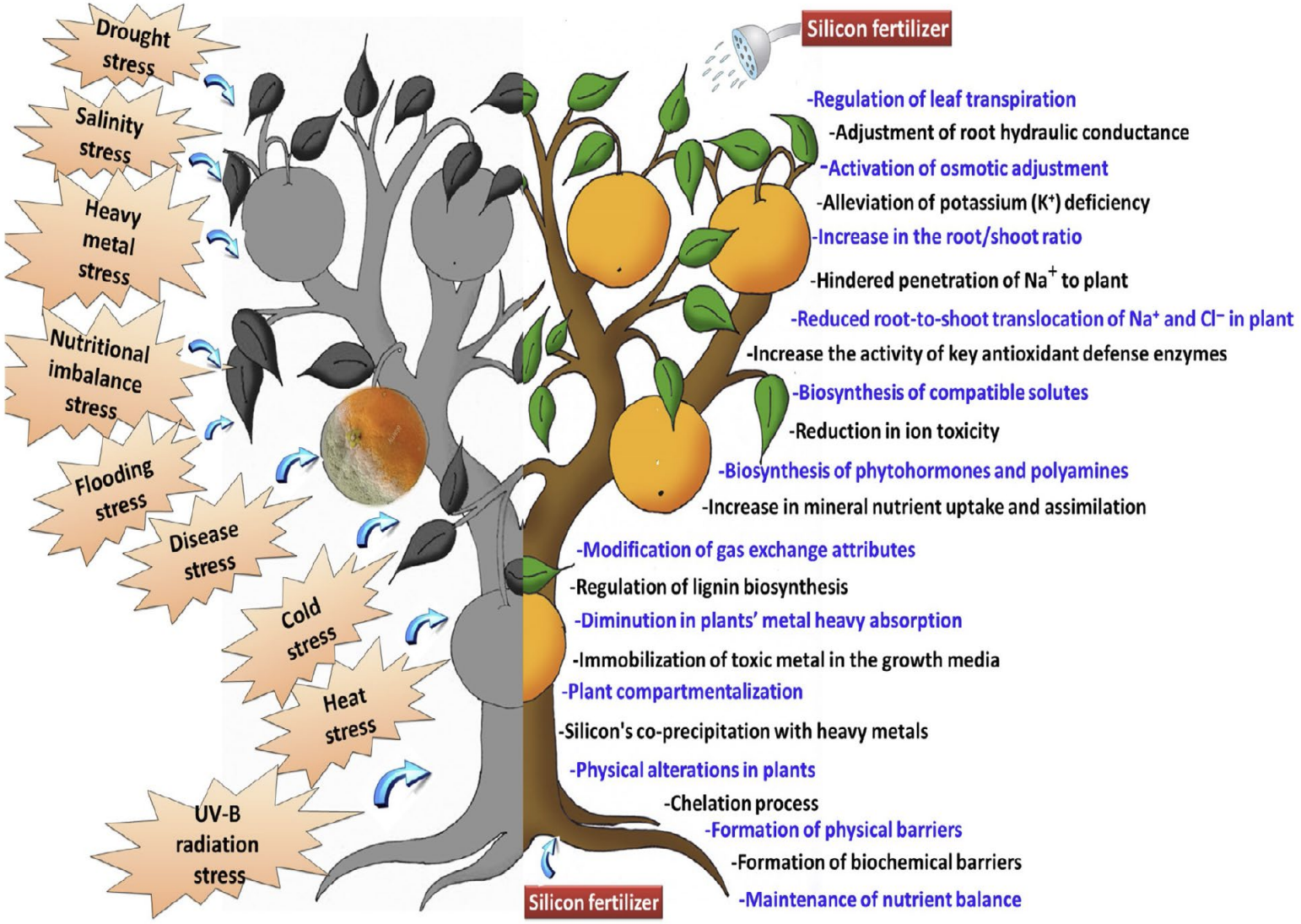
Arnon and Stout, 1939

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 plants with silicon???

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



Etesami and Jeong 2018

Pictorial : Silicon Results

Si improves shelflife

- Reduces internal decomposition (stone and pome fruits)
- Increases fruit firmness (citrus quality)
- Reduces cracking and pitting
- Increases skin hardiness
- Keeps stalks green (for cherries)
- Keeps rachises green (grapes)
- Reduced deterioration during cold storage
- Extend shelflife

Si improved postharvest life in blueberry

Control

Silicon

1 month after cold storage conditions

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Si improved postharvest life in grapes

Control

Silicon

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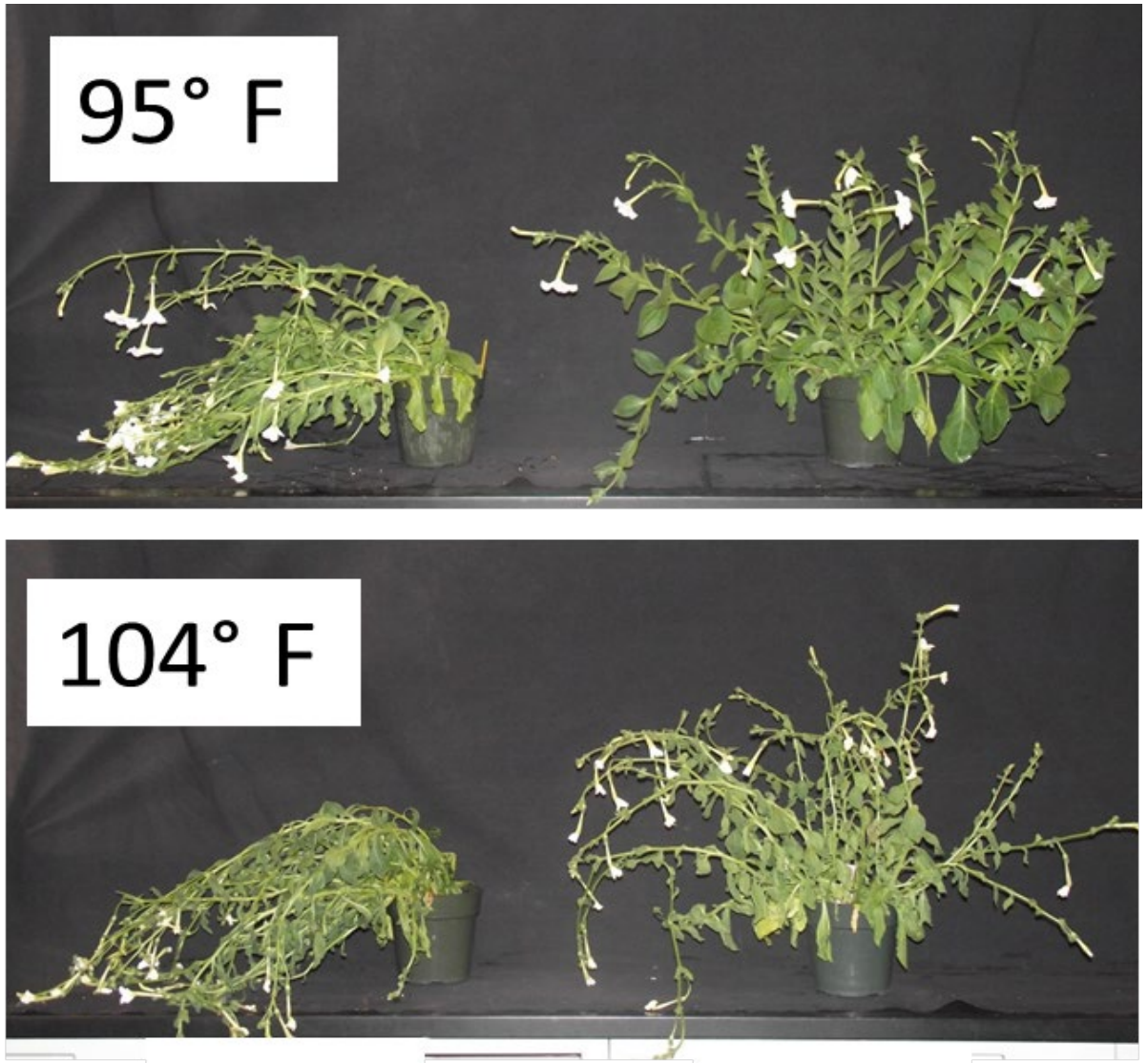
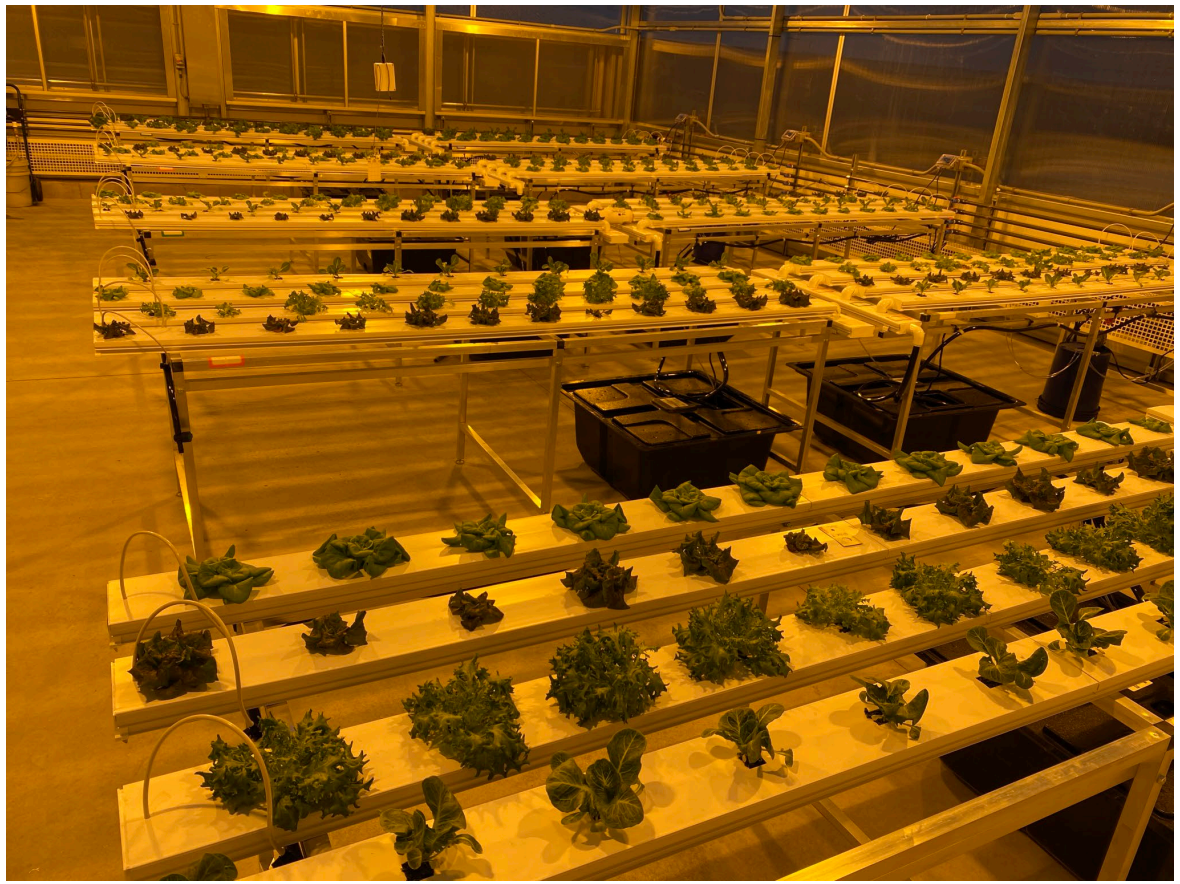
Improved Heat Tolerance in Petunia



PC: Neil Mattson

Si in hydroponic lettuce production



Si improved head size lettuce

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Si mitigated tip burn/necrosis in lettuce

Contol (wihout Silicon)

Silicon

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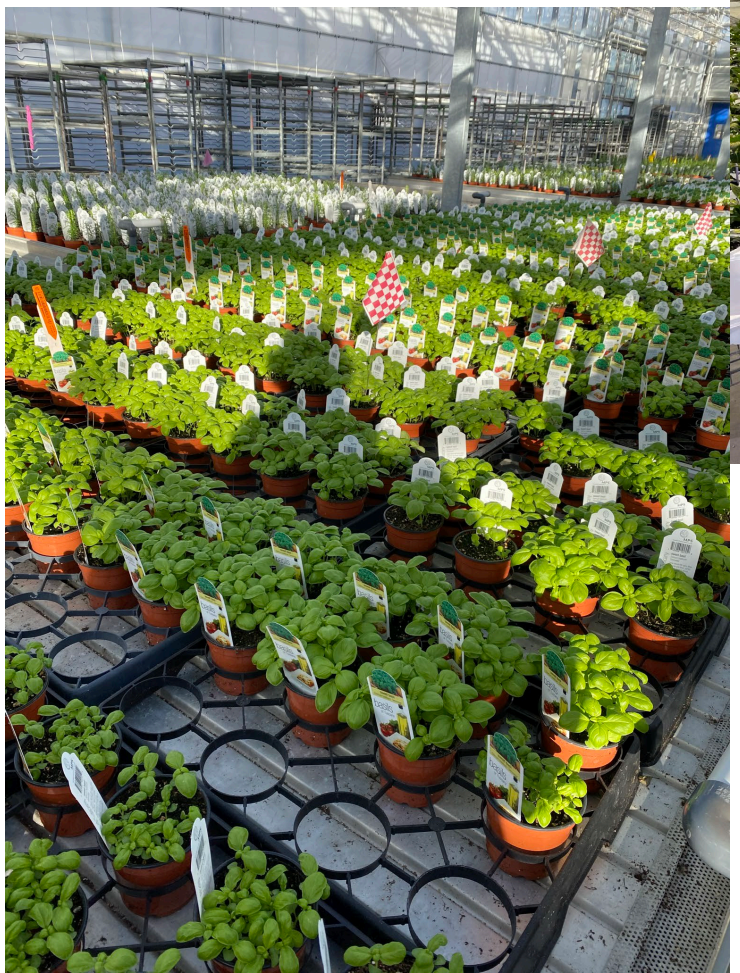
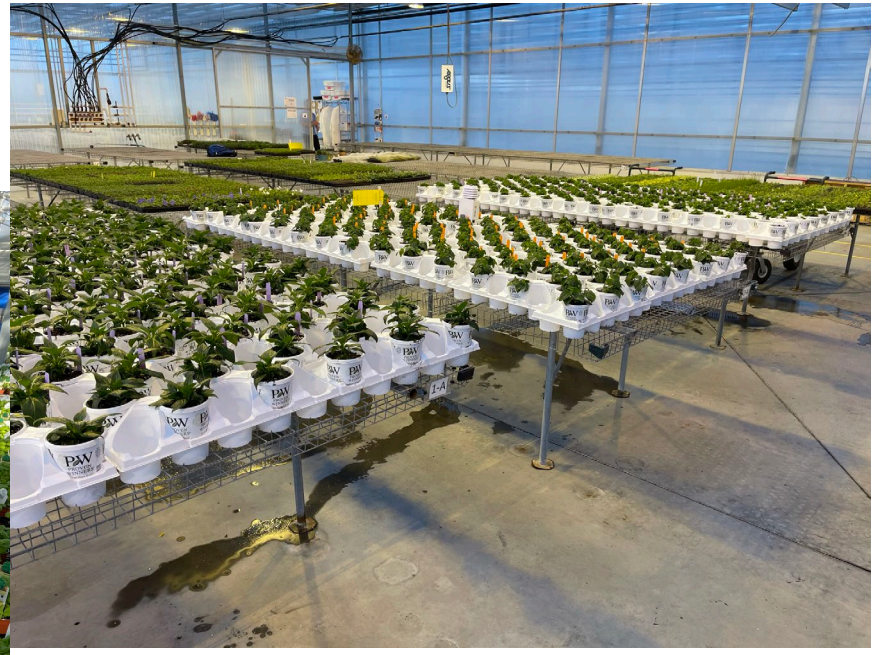
Si improved drought tolerance and resistance to lodging in ornamentals





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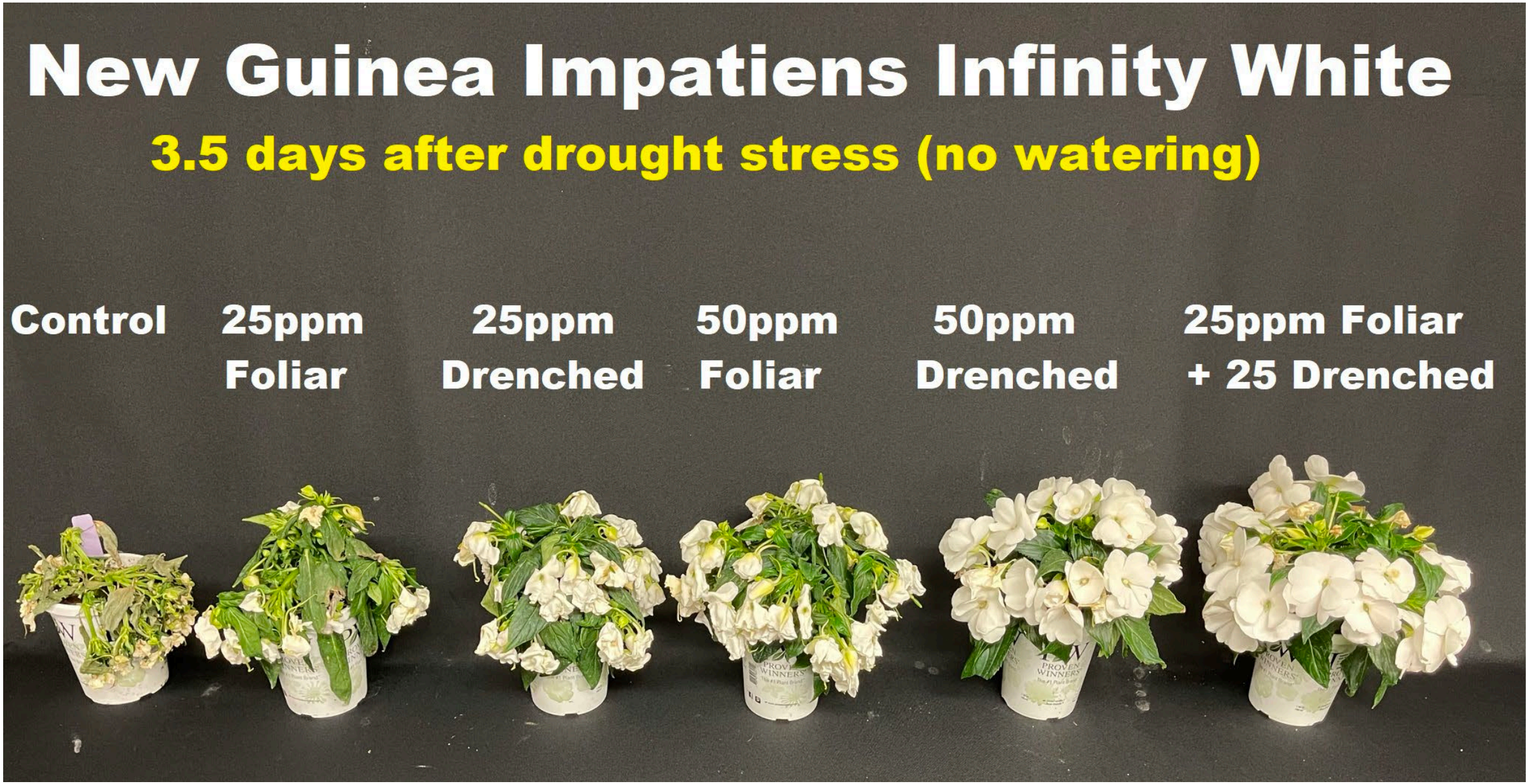
New Guinea Impatiens Infinity White

3.5 days after drought stress (no watering)



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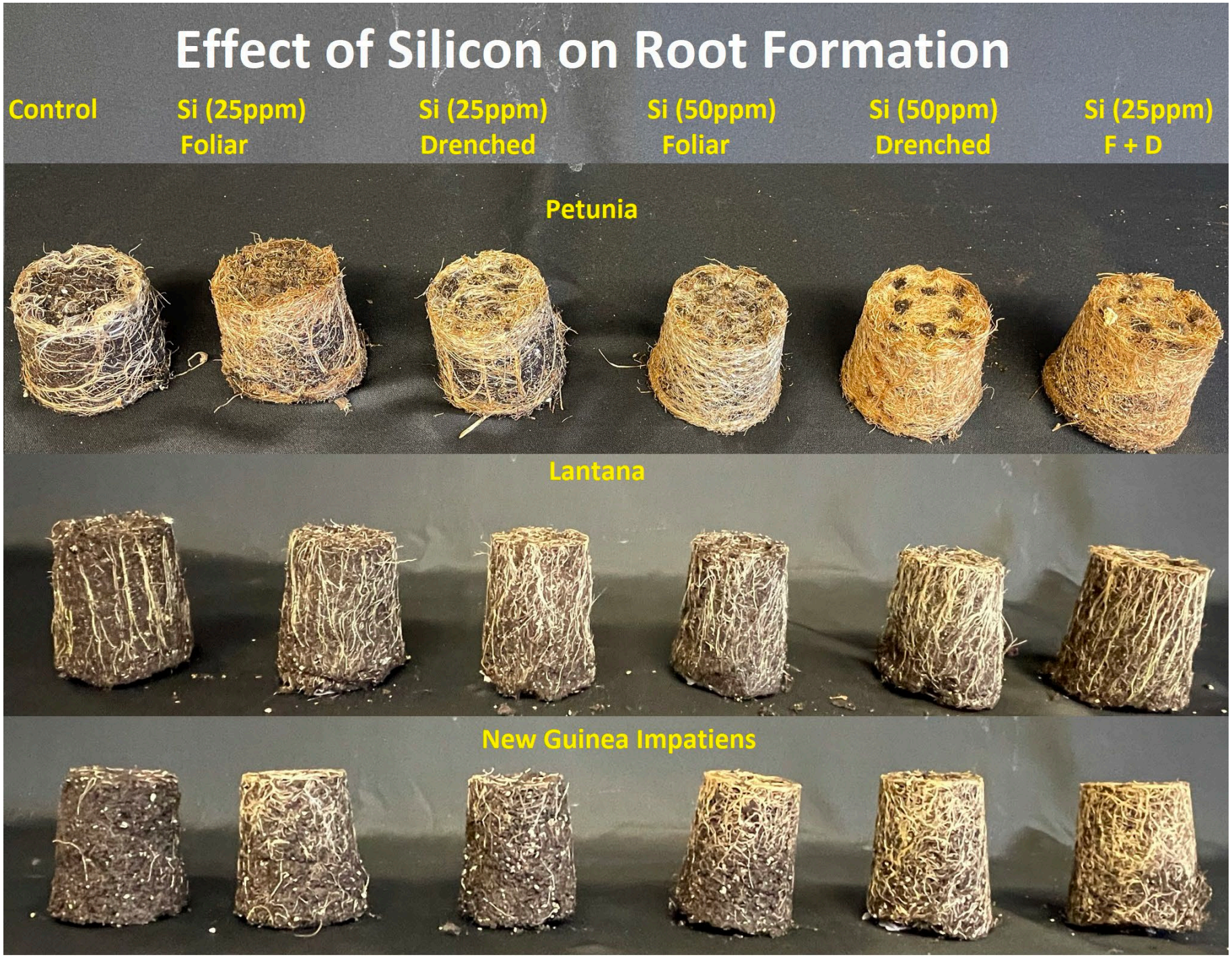
Effect of Silicon on Root Formation



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Lodging in cut flowers

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Si reduced lodging in snapdragon

Control (distilled water)

50ppm Si (foliar weekly)

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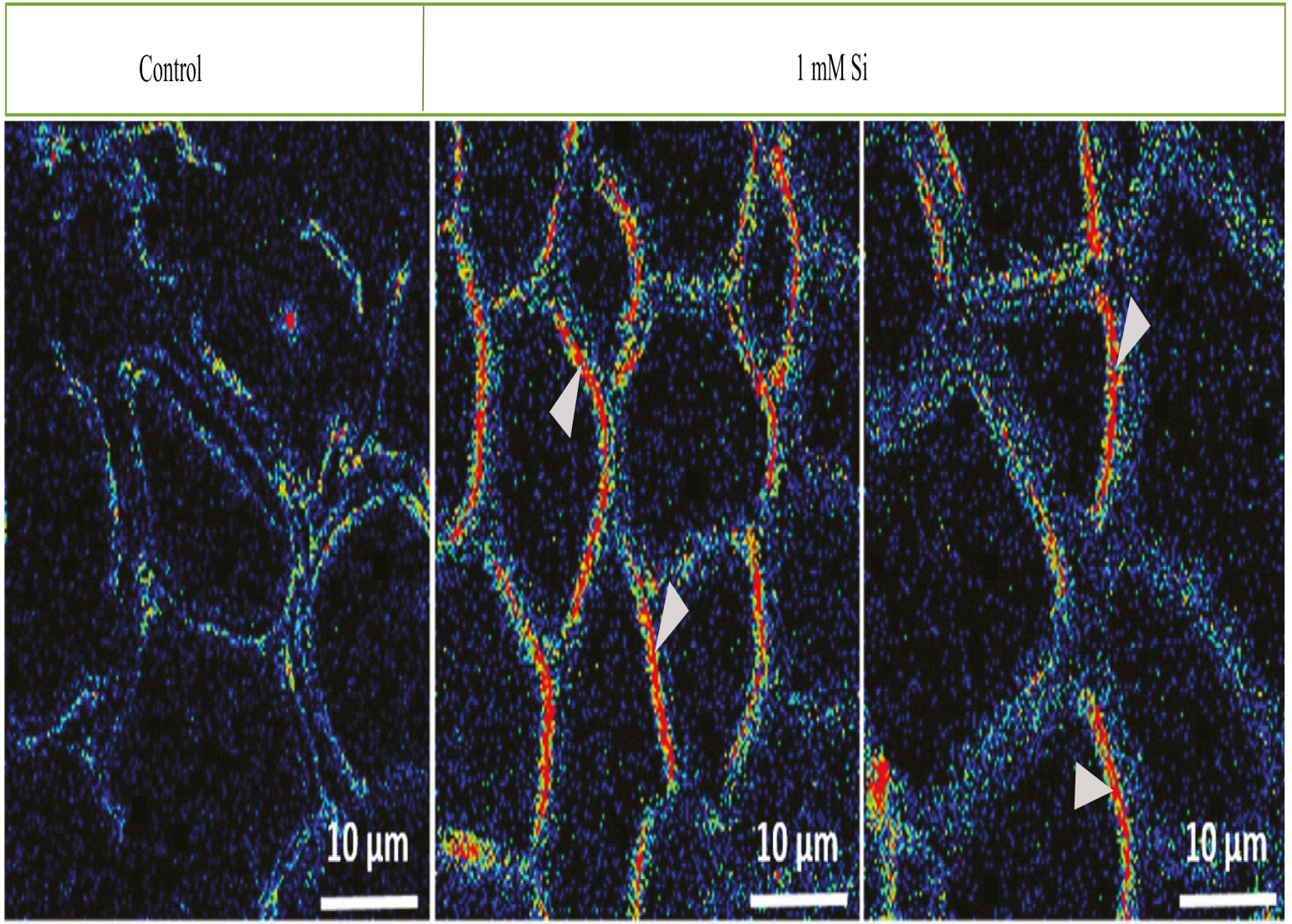
Silicon deposition in xylem cell walls leads to reduced lodging



Mandlik et al., 2020

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Si improved number of florets

Control

50ppm Si

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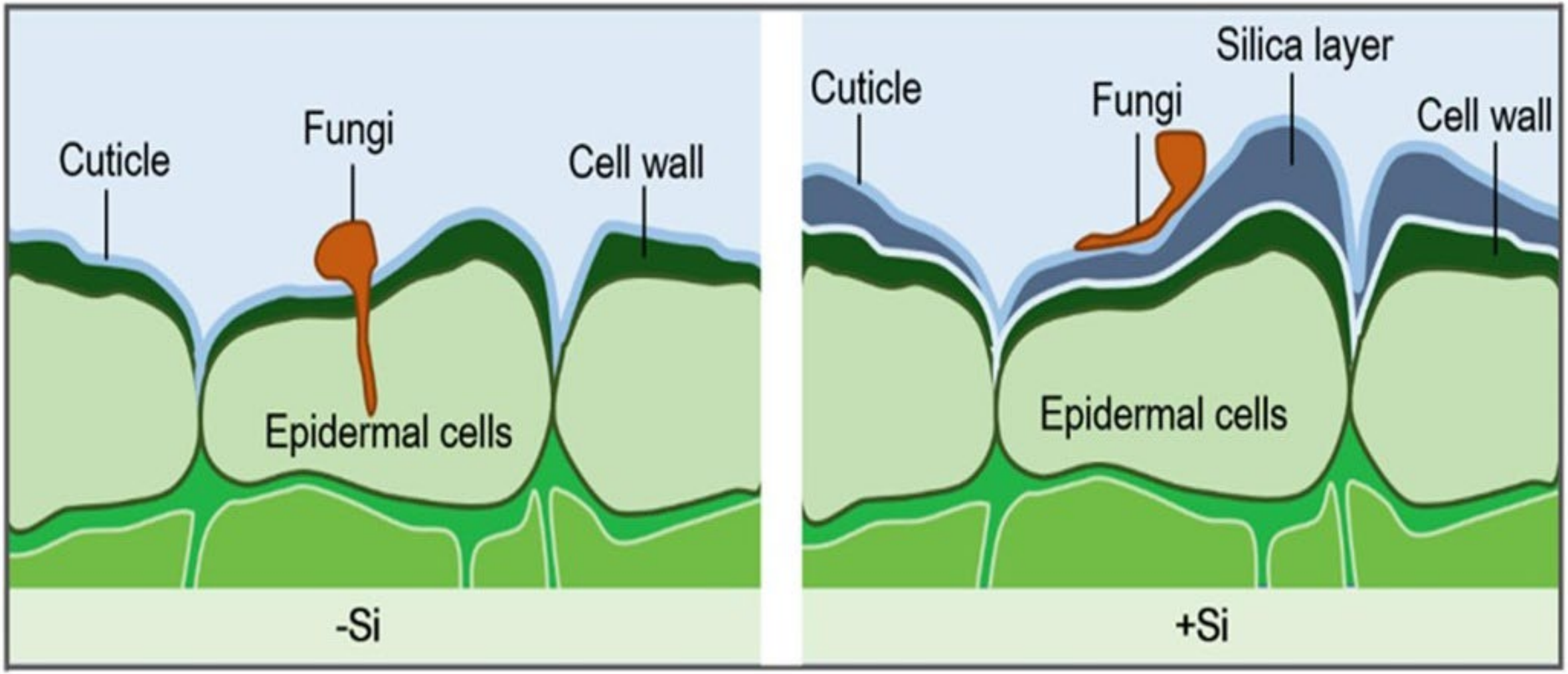
Silicon in Plant Disease Management

Mode of Action of Si



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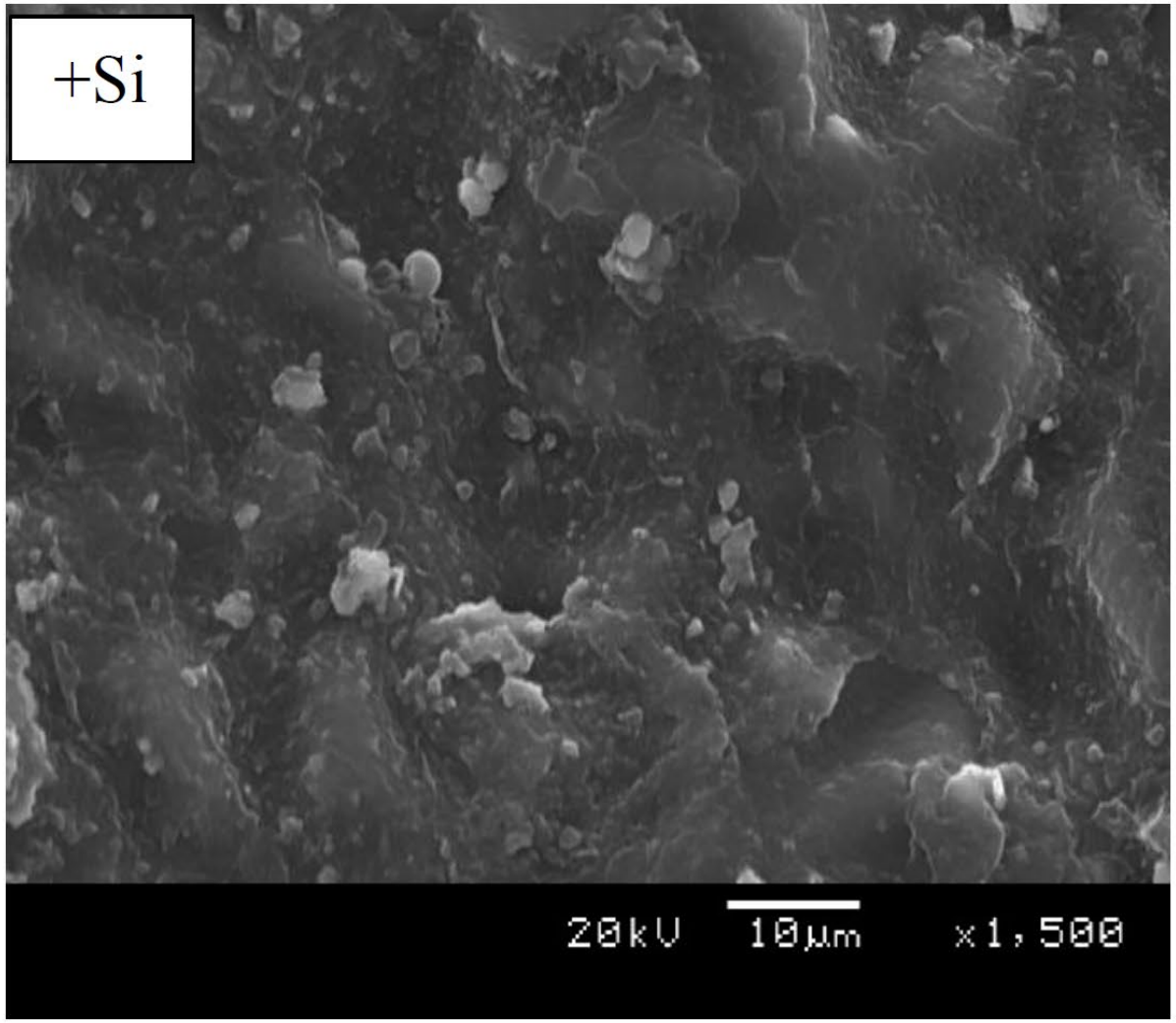
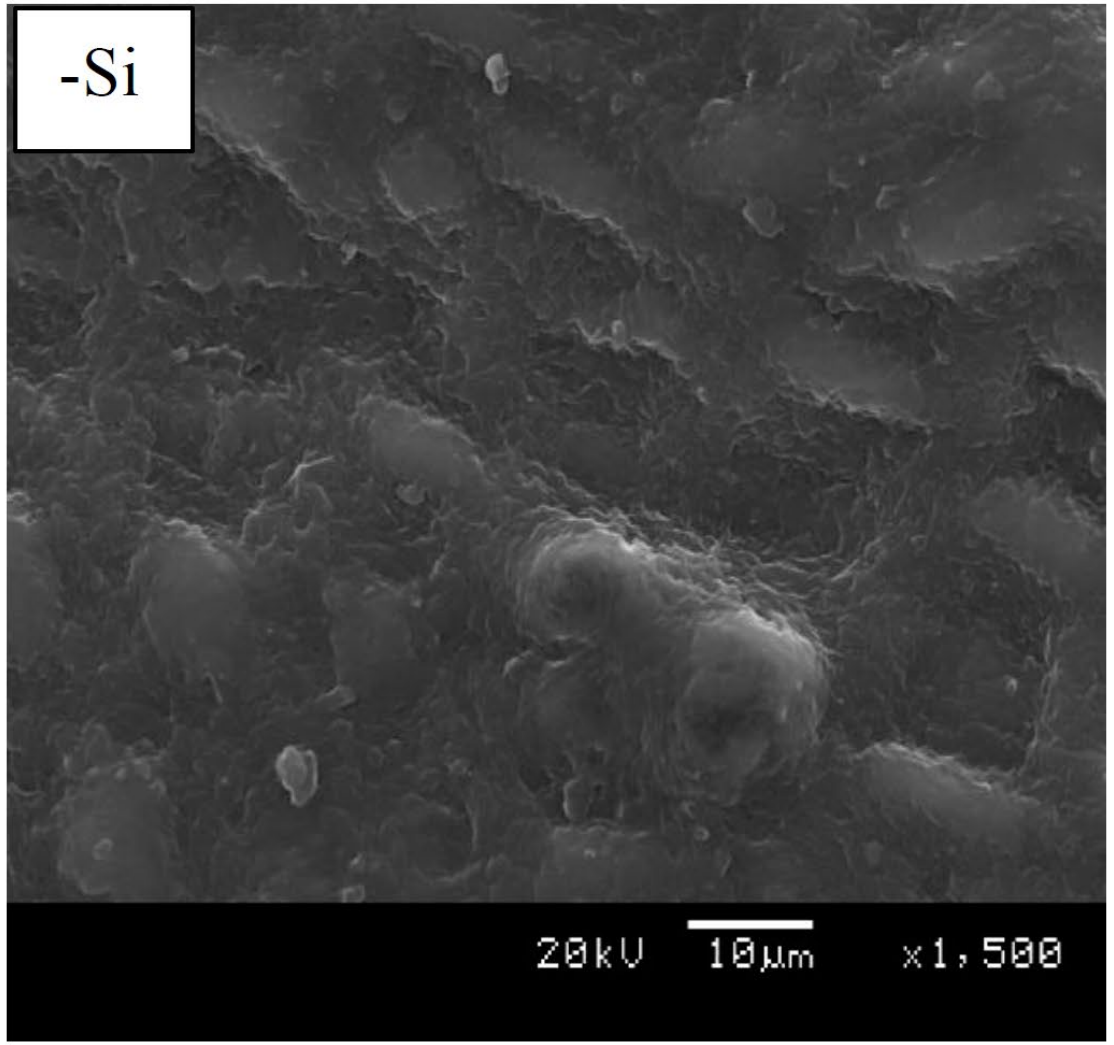
Wang et al., 2017

Upper Epidermal Surface of Si-treated Citrus





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Mvondo-She and Marais, 2019

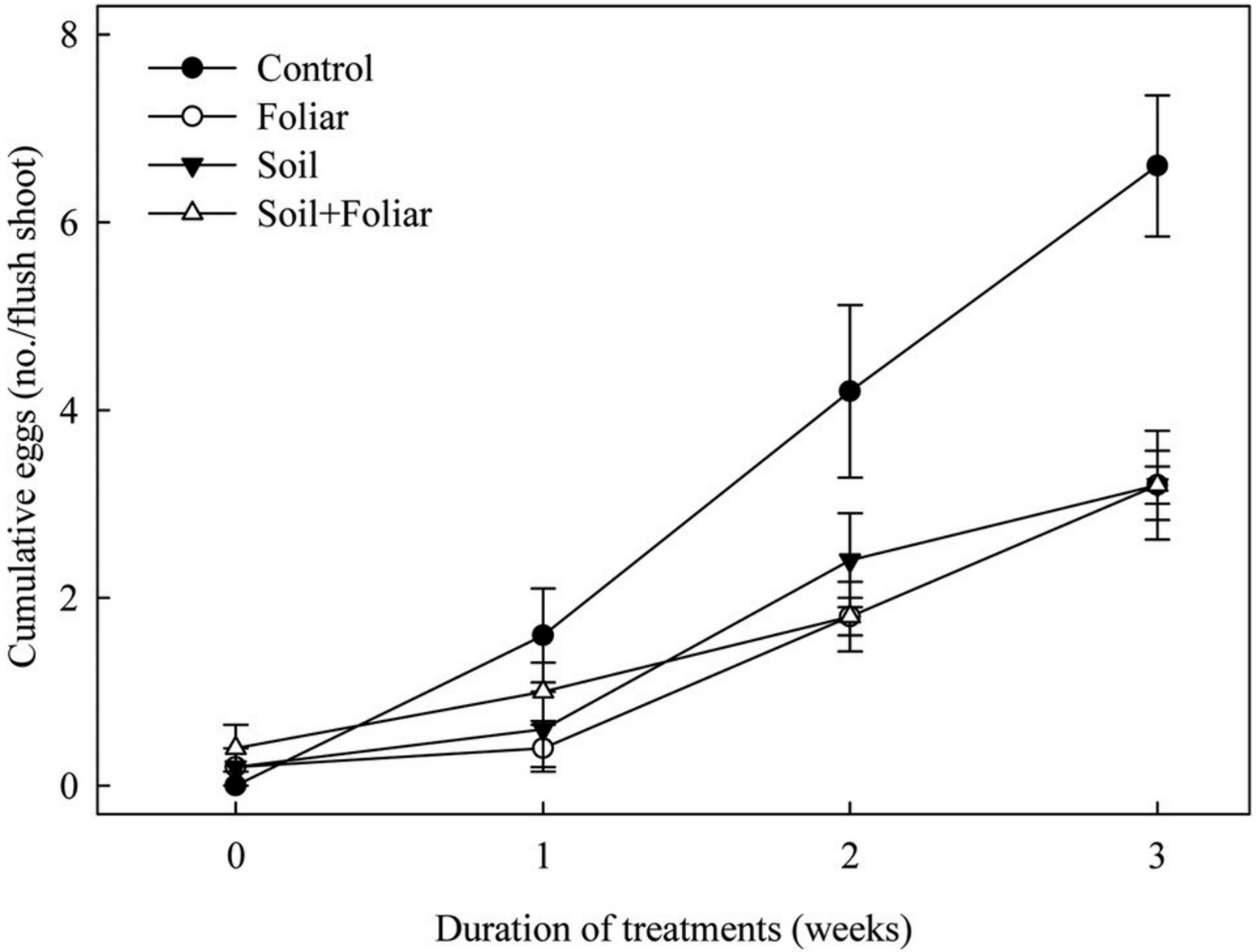
Silicon for Disease Control in Fruit Crops

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)

Silicon for Disease Control in Fruit Crops

Disease	Fruit Crop	Pathogen	Reference
Anthracnose	Avocado	*Colletotrichum gloeosporioides*	Anderson et al. (2005)
Black root rot	Avocado	*Calonectria ilicicola*	Dann and Le (2017)
Phytophthora root rot	Avocado	*Phytophthora cinnamomi*	Mkhize et al.(2012)
Powdery mildew	Strawberry	*Sphaerotheca aphanis*	Kanto et al. (2006)
Fruit decay	Cherry	*Penicillium expansum*	Qin and Tian (2005)

Silicon reduced ACP papulation in Tahiti Lime



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Augusto Ramírez-Godoy et al 2018

Si for disease control: Important points

- As Si concentration increases in plant tissues, plant disease suppression dramatically improves
- For disease suppression, Si supply should be continuous
- Si may augment susceptible or partial resistance to complete resistance
- Si may suppress plant disease as effectively as fungicide, and way well suited for adding in IMP strategies
- Identification of good silicon sources, and their optimal dosages for effective pest and disease control in different crops is needed
- Si has potential for integration with biological control for ecologically sustainable pest and disease management.

Clearly, more research is needed……

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Si is also important for our growers

- Strengthen bones
- Treats Alopecia (Baldness or thinning of hairs)
- Skin care – increases elasticity and strength of connective tissues
- Prevents brittle nails
- Promotes healing
- Tuberculosis and cardiovascular diseases

Sources:

- Apples, cherries
- Carrots, onions, pumpkins and cucumber
- Peanut and almond

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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**

Factors Affecting Si Uptake/Availability

- Soil type
  - Sandy and muck soils contain least amount of Si
  - Soilless substrate
  - Peat-based substrates contain very little Si
- Plant type
- Si form
- Application method

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

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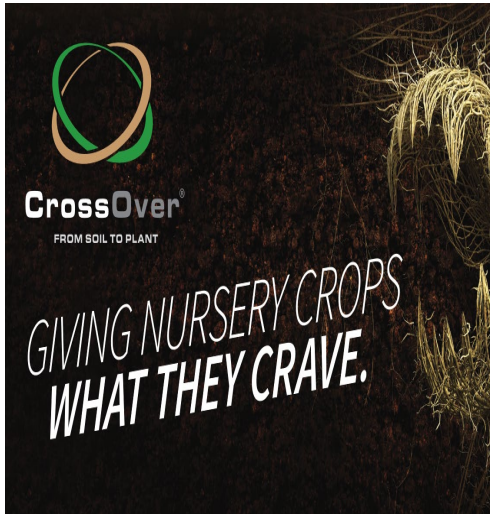
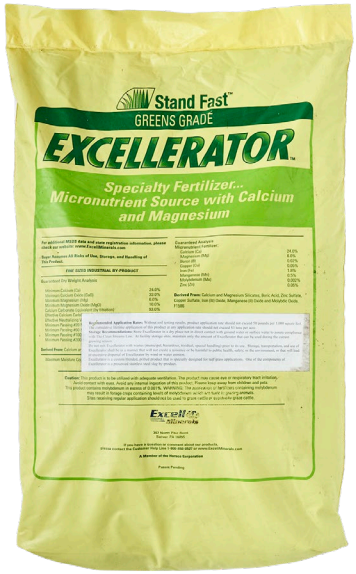
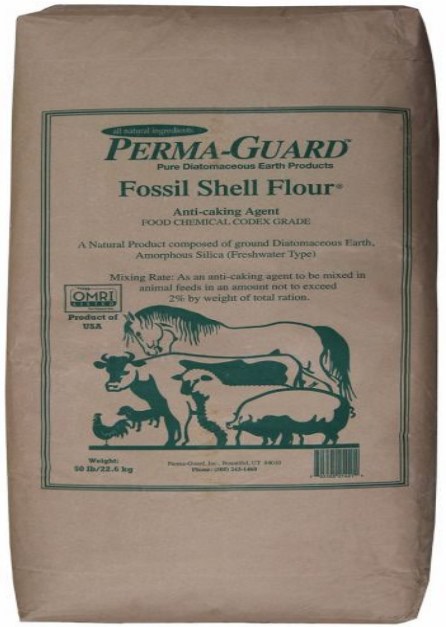
Commercially Available Si Products

AgrowSil®







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Commercially Available Si Products

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Important point for Si Supplements

- Potassium silicate is formed by dissolving silica (SiO_2 or sand) in lye
  - So, final solution is very alkaline with pH 11-12
- Concentrated silicate solution should not be mixed with fertilizers
  - Silicates will polymerize to form a gel like material
- For Dosatron, fertilizer and silicon application should be done alternately
- Do not make solution extra than quantity you are going to apply that day
  - Because silicate products are denser than water, so it normally tends to settle to the bottom, so always keep the solution agitated
- Si is always combined with nutrients, so nutrient value of these elements in product should be considered

Silicon related research at UF/NFREC

- Evaluating beneficial effects of silicon in citrus and blackberry production in north Florida

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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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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Silicon Therapy to Improve Cold Tolerance

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Silicon Therapy to Improve Cold Tolerance

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Silicon Therapy to Improve Cold Tolerance

After 48 hours of freezing stress (-6 C)

No Si (distilled water)

100ppm Silicon

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Silicon Therapy to Improve Cold Tolerance

After 48 hours of freezing stress (-6 C)

100ppm Silicon

No Si (distilled water)

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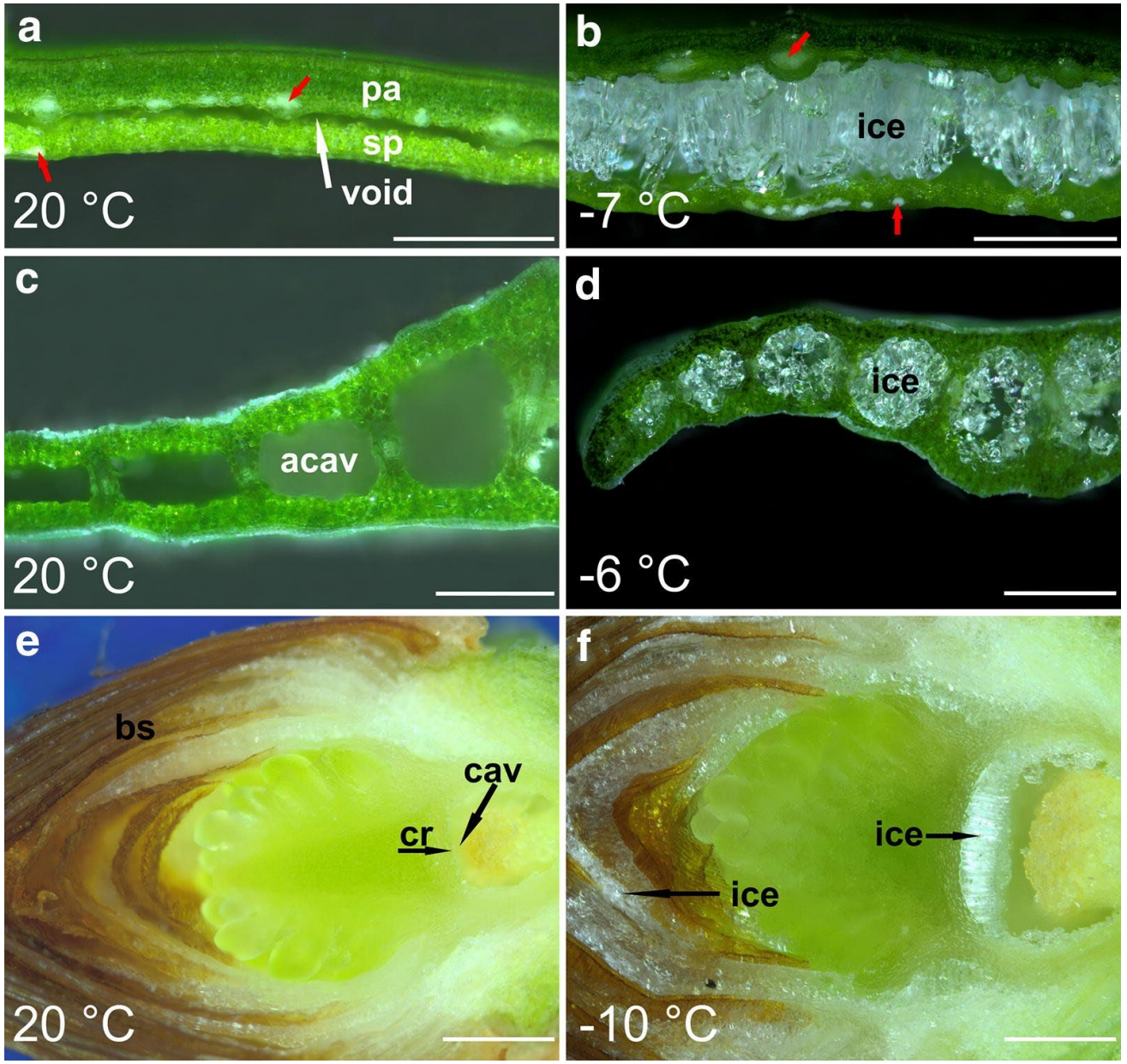
Why water-soaked leaves after freeze damage?

American Boxwood
(Buxus sempervirens)

Snowdrop
(Galanthus nivalis)

European spruce
(Picea abies)



Stegner et al., 2020

Si to improve heat and 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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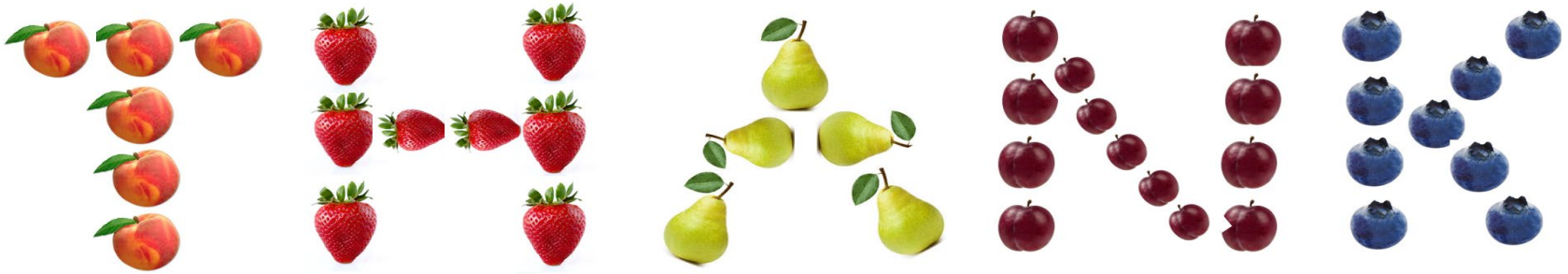
Three weeks after freeze event

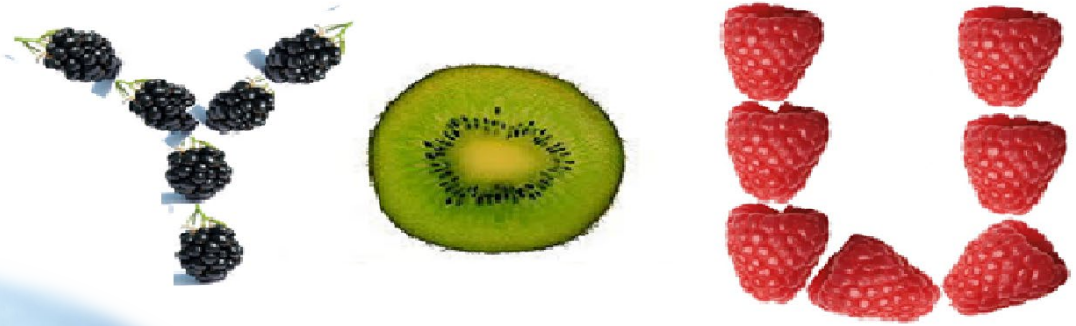
Without Si

100ppm (4 weekly)

Concluding remarks

- Si is effective in improving plant growth and postproduction life in variety of plant species
- Before using silicon supplementation with your crops, conduct small test runs. Several commercial products are available on the market, however rates and application methods can vary between species and cultivars, so testing is important. Reports of damage from high application rates are rare.
- Continuous supply of silicon to plants is more effective than single time application
- Overall, drenching found to be more effective than foliar application, but we have found variations between cultivars within same specie
- Please note silicon fertilizers are very alkaline and greatly increase the pH of the stock solution. This reduces the solubility of micronutrients and silicon can form precipitates in the stock tank. To err on the side of caution, it is best to have separate stock tanks for a silicon fertilizer and your standard fertilizer.
- Response of Si is species dependent, so research for crop wise recommendations is needed
- Since, Si mitigates various environmental stresses and suppress pest and disease attack, so could be beneficial in plant nutrition program
- ***More research on molecular physiology is needed to understand the stress tolerance mechanism in Si treated plants***





Questions

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