

# Enhancing Citrus Growth: Harnessing Silicon as a Plant Beneficial Nutrient

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**UF | IFAS**  
UNIVERSITY of FLORIDA

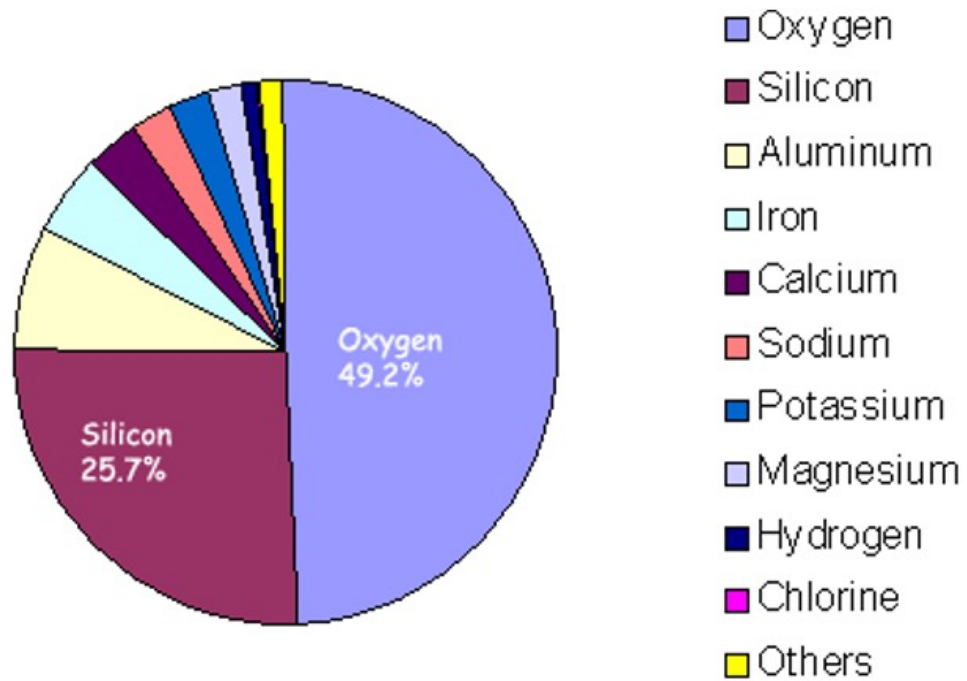
Citrus Nutrition Day, January 22, 2025  
CREC, Lake Alfred

# Today's talk.....

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

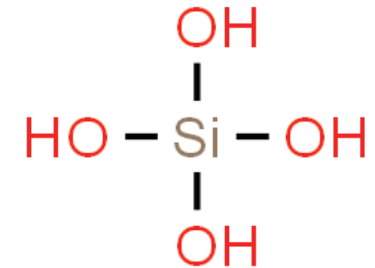
# Introduction

## Elemental Abundance in the Earth's Crust



## 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  
*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???

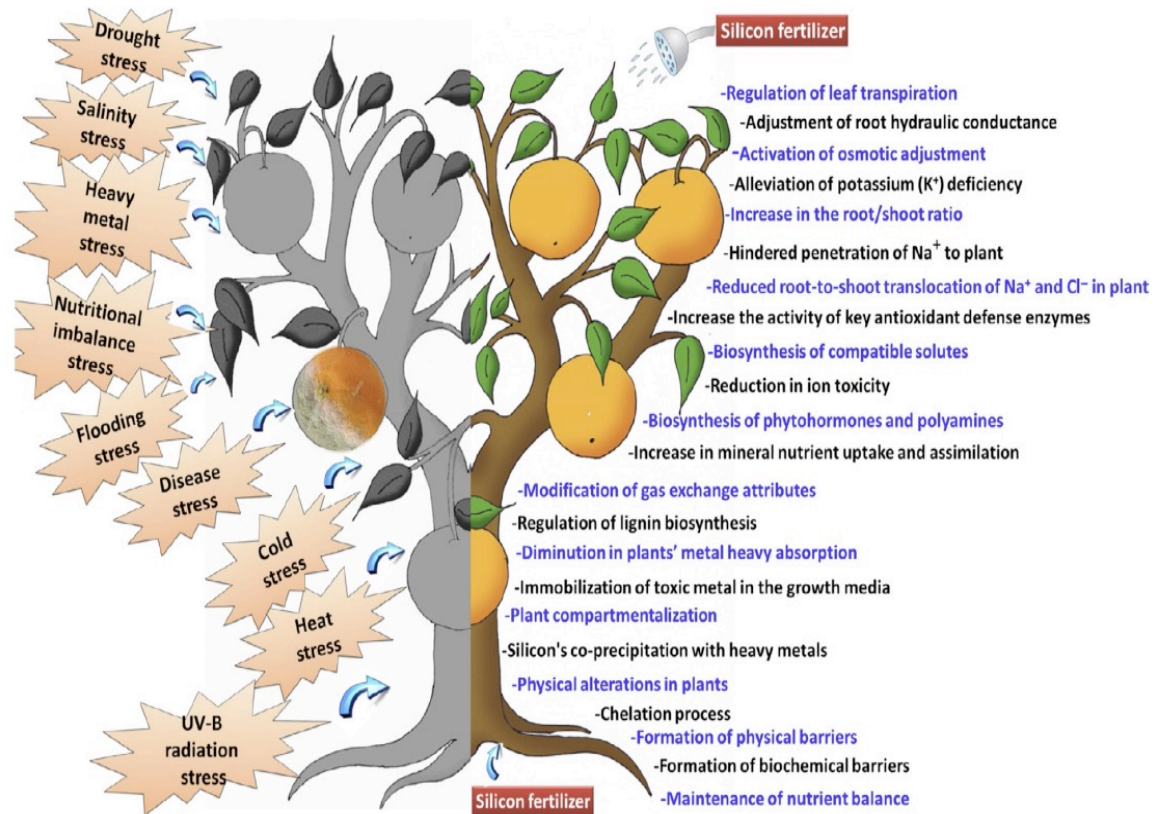
Essential Element	Beneficial Element
Plant must be unable to complete its life cycle in absence of mineral element	Not required to complete the life cycle
The function of the element must not be replaceable by another mineral element	Compensate toxic effects of other elements or replace mineral nutrients 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

## 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 stress





# **Pictorial : Silicon Results**

## **Si improves shelflife**

- Reduces internal decomposition (stone and pome fruits)
- Increases fruit firmness (citrus quality)
- Reduces cracking and pitting
- Increases skin hardness
- 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

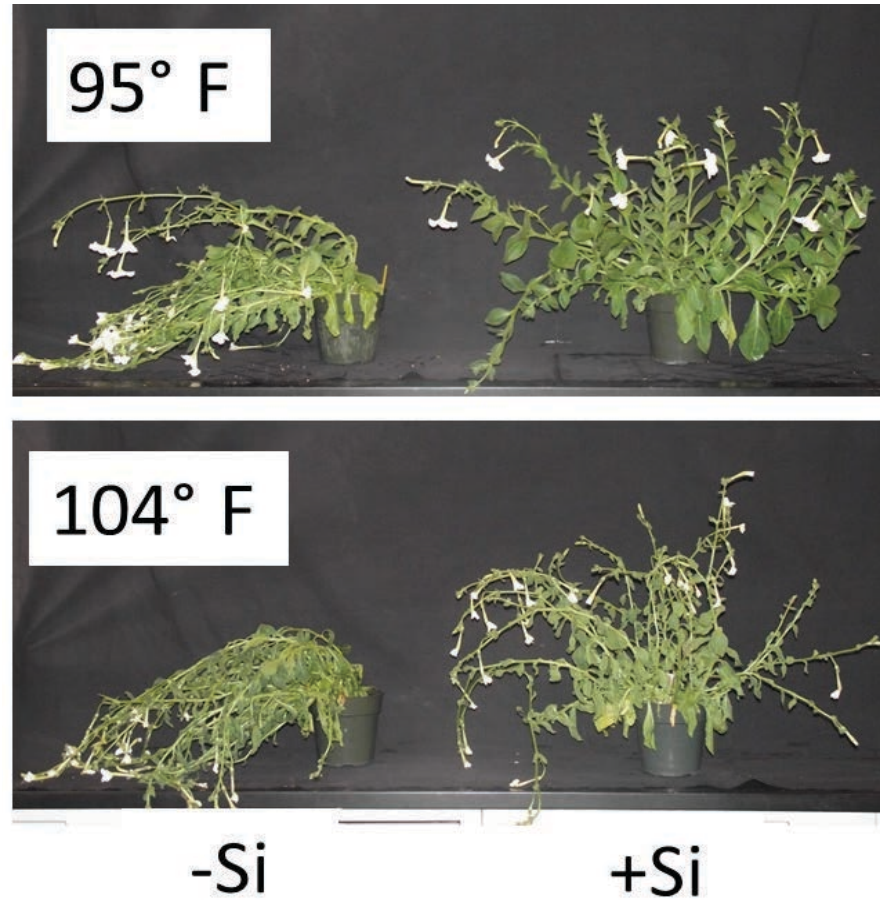
# Si improved postharvest life in grapes

Control

Silicon



# Improved Heat Tolerance in Petunia



# Si in hydroponic lettuce production



## Si improved head size lettuce



# Si mitigated tip burn/necrosis in lettuce



Contol (wihout Silicon)

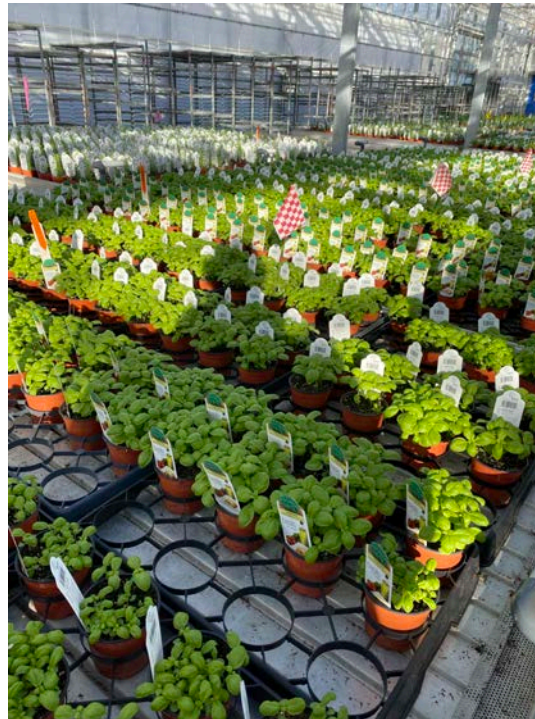


Silicon





# Si improved drought tolerance and resistance to lodging in ornamentals



# Cyclamen Synchro Sierra White

7 days after drought stress (no watering)

Control

25ppm

Foliar

25ppm

Drenched

50ppm

Foliar

50ppm

Drenched

25ppm

Foliar+Drenched



# New Guinea Impatiens Infinity White

3.5 days after drought stress (no watering)

**Control**

**25ppm  
Foliar**

**25ppm  
Drenched**

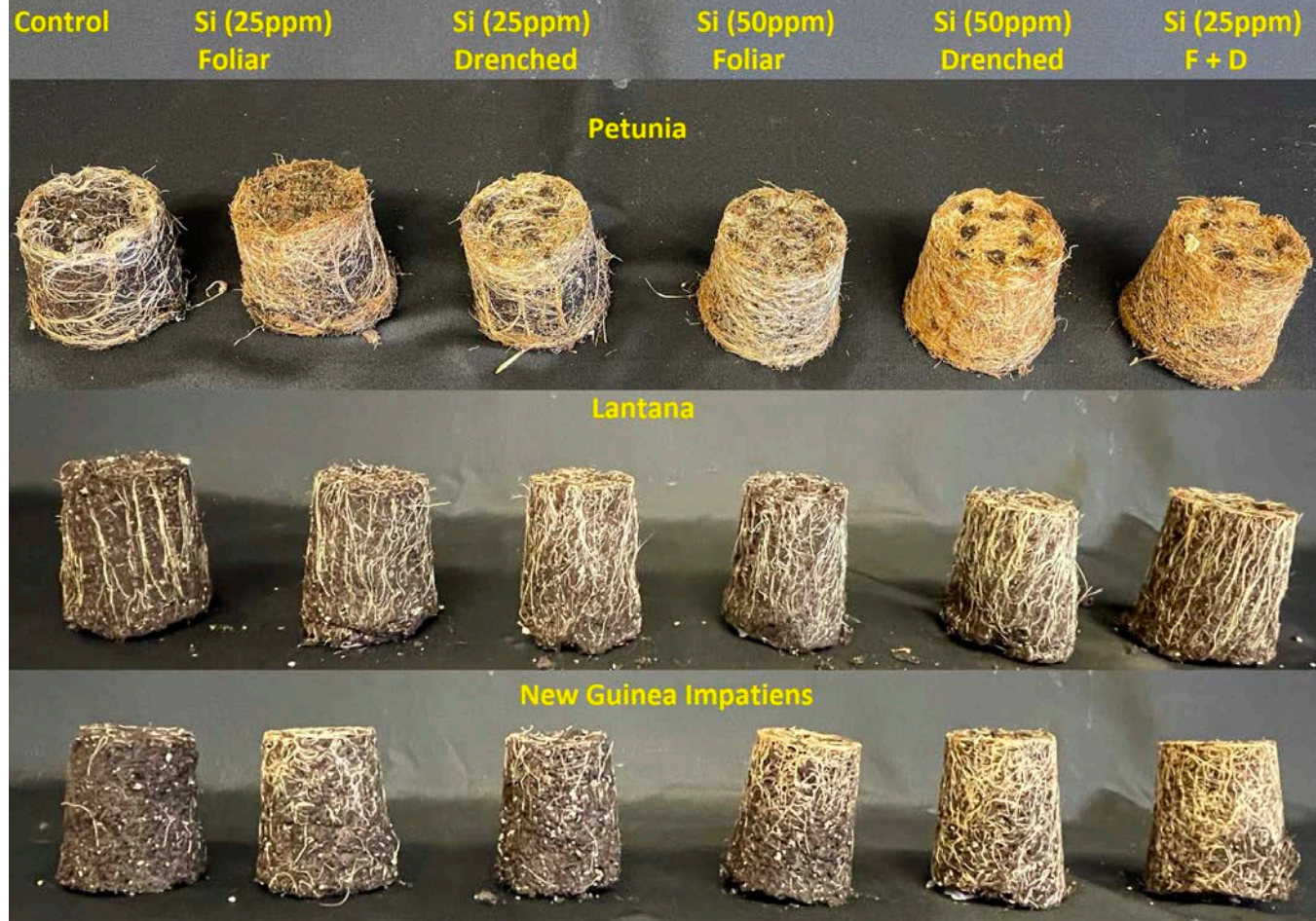
**50ppm  
Foliar**

**50ppm  
Drenched**

**25ppm Foliar  
+ 25 Drenched**



# Effect of Silicon on Root Formation



## Lodging in cut flowers



## Si reduced lodging in snapdragon

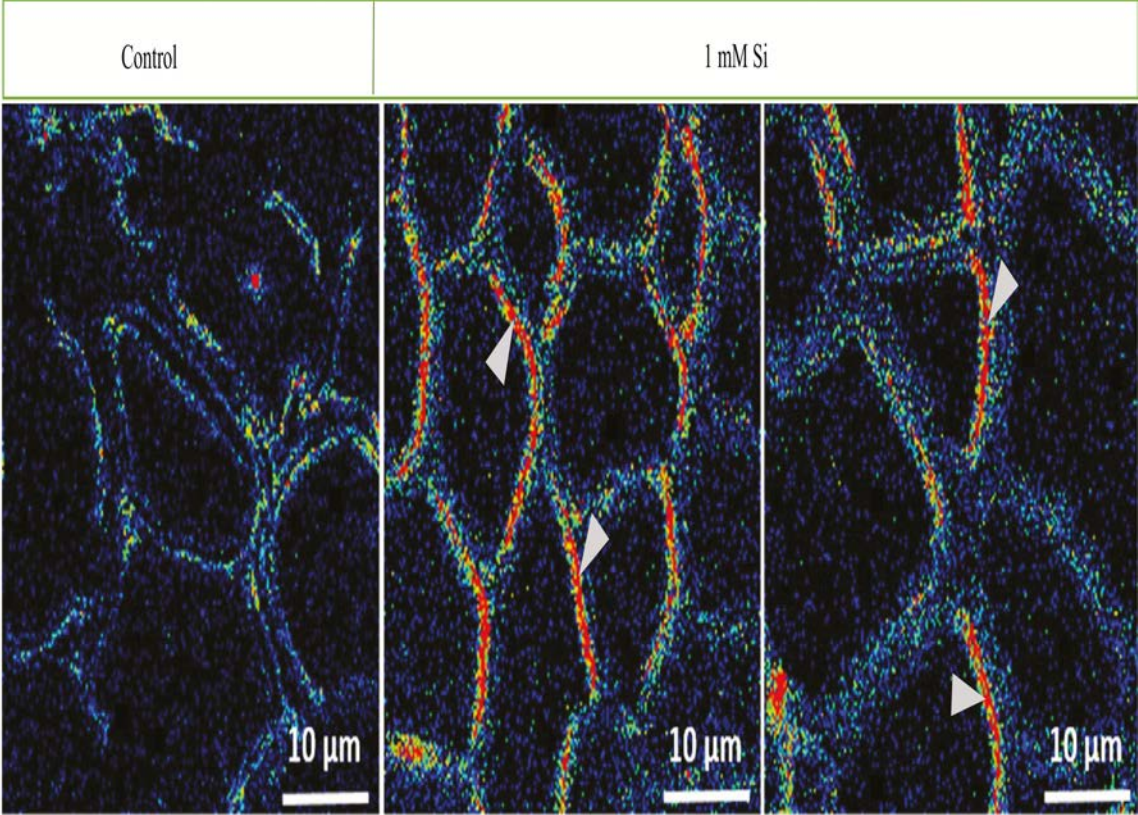


Control (distilled water)



50ppm Si (foliar weekly)

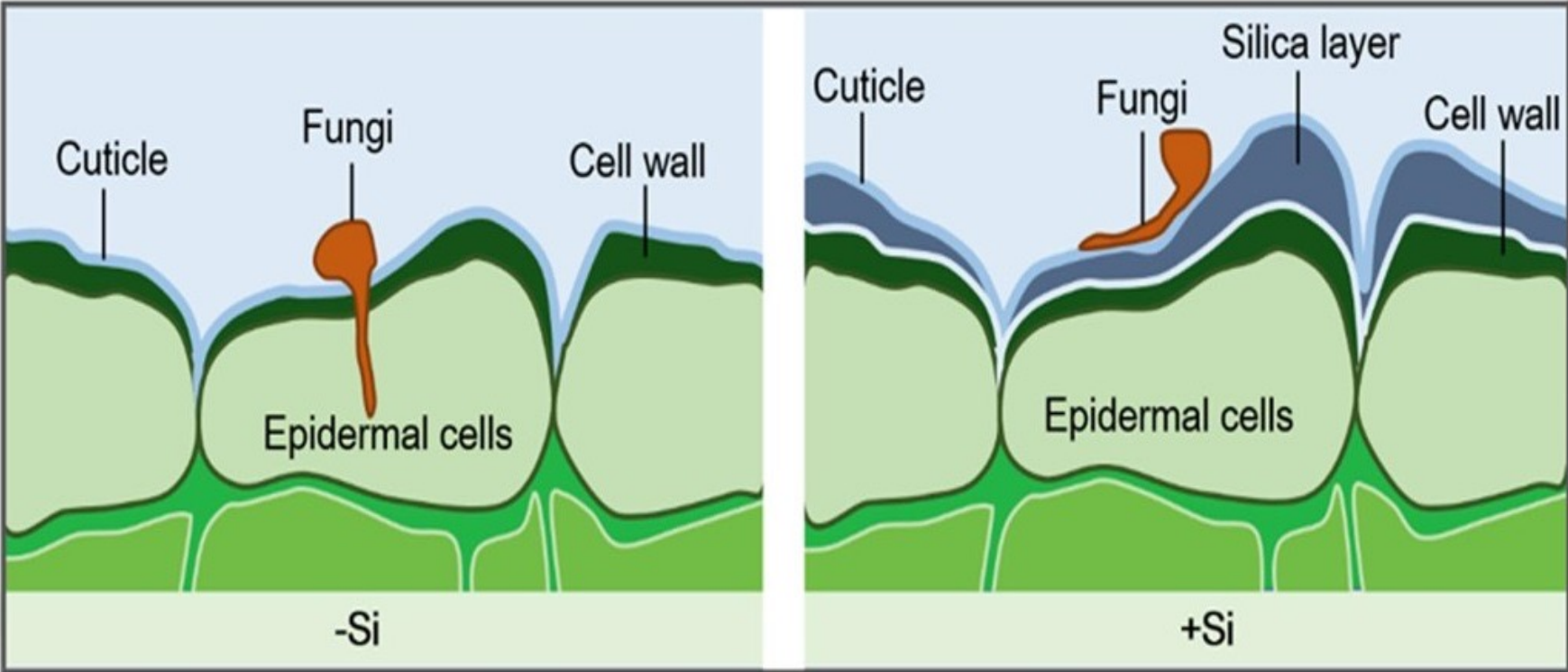
# Silicon deposition in xylem cell walls leads to reduced lodging



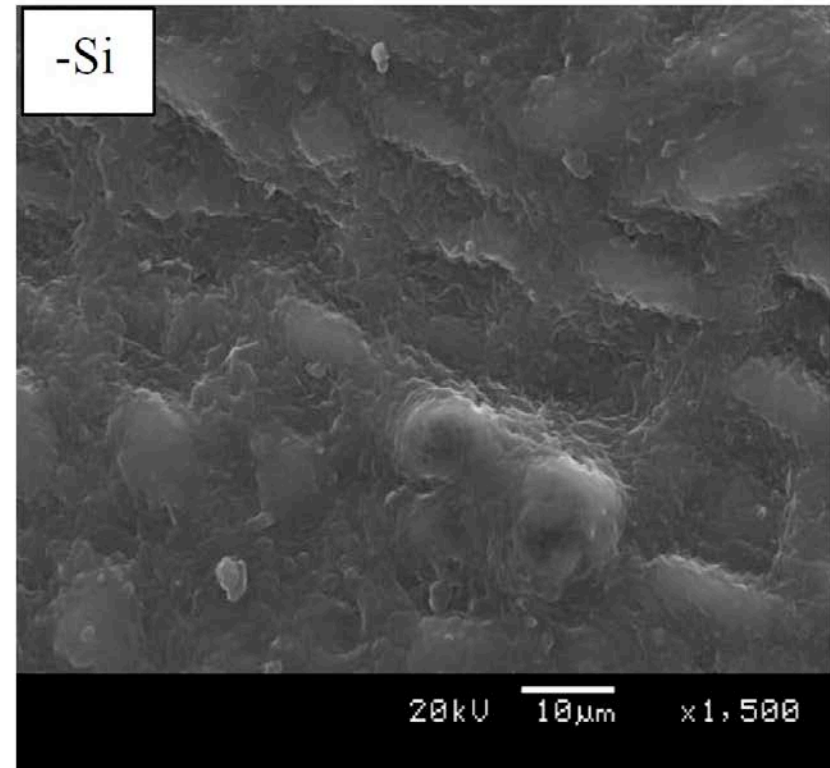
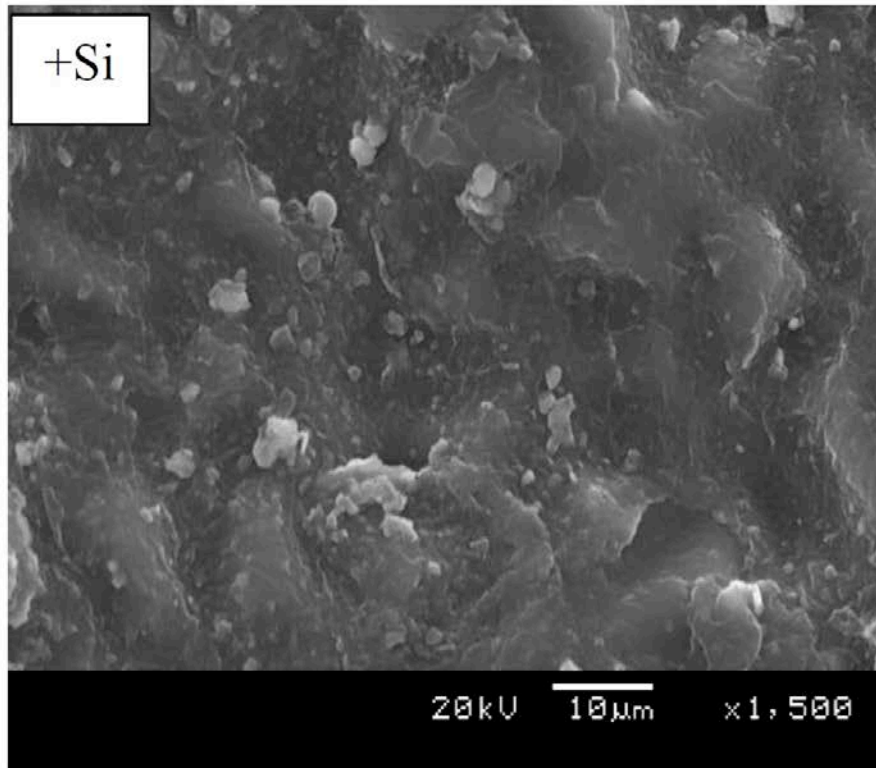
# **Silicon in Plant Disease Management**



# Mode of Action of Si



## Upper Epidermal Surface of Si-treated Citrus



# Silicon for Disease Control in Fruit Crops

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

## Silicon for Disease Control in Fruit Crops

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

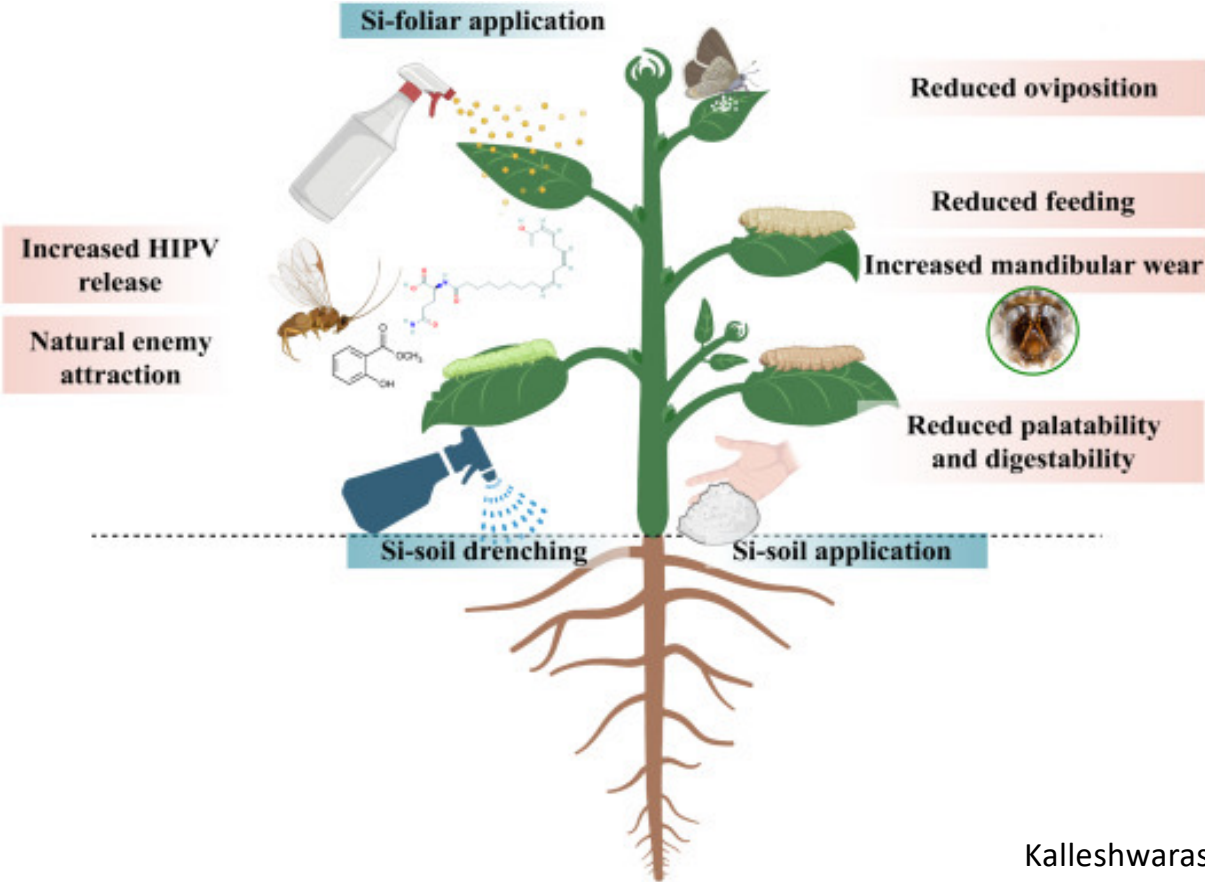
## **Si for disease control: Important points**

- As Si concentration increases in plant tissues, plant disease suppression dramatically improves
- For disease suppression, Si supply should be continuous
- Si may 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.

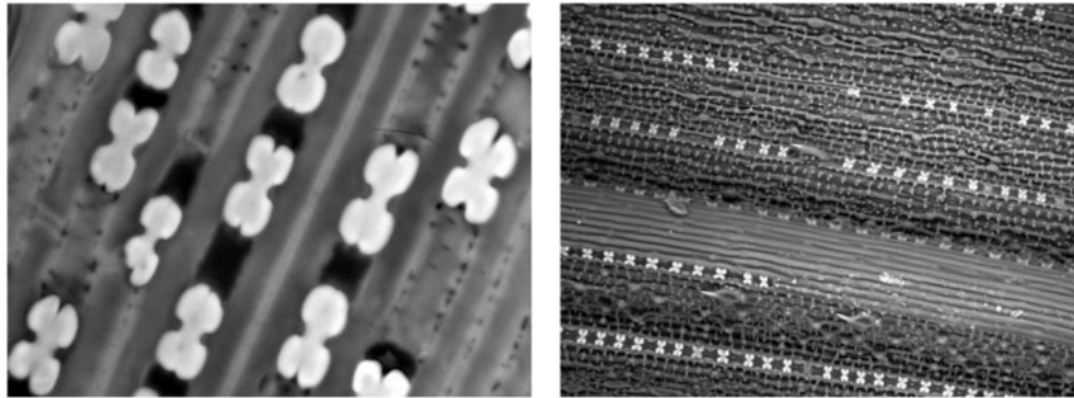
***Clearly, more research is needed.....***

# **Silicon in Plant Pest Management**

# Silicon as a natural plant guard against insect-pests

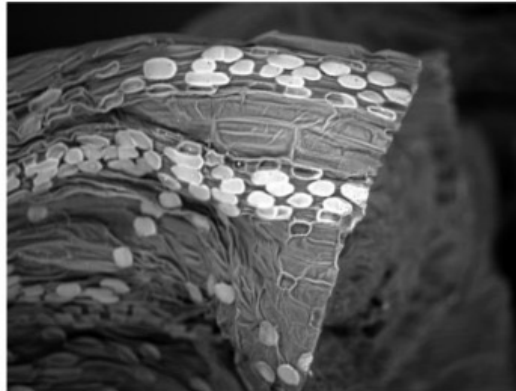


# Silicon develops a silica bilayer in leaf providing resistance to herbivory



(a)

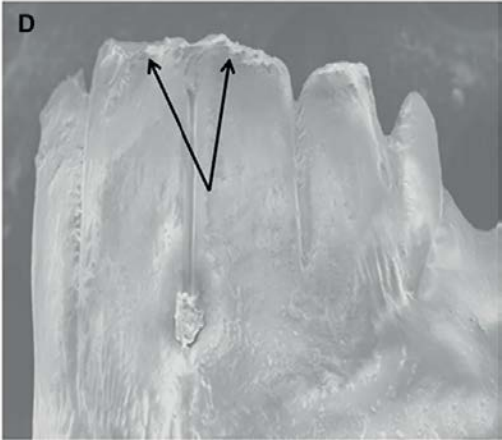
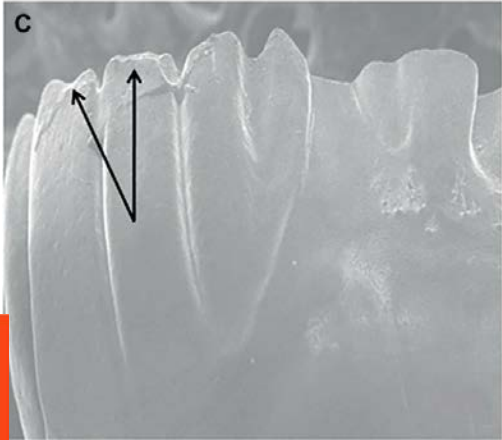
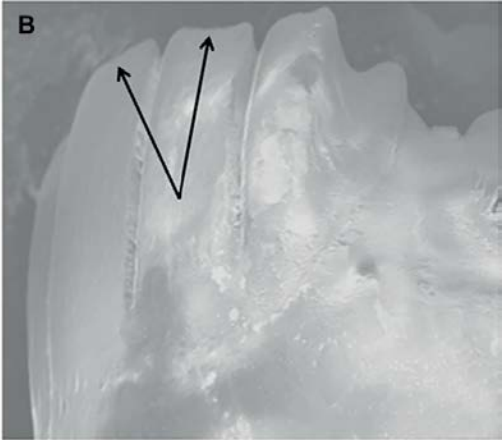
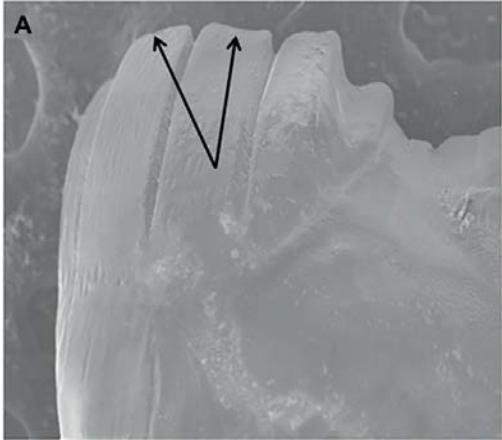
(b)



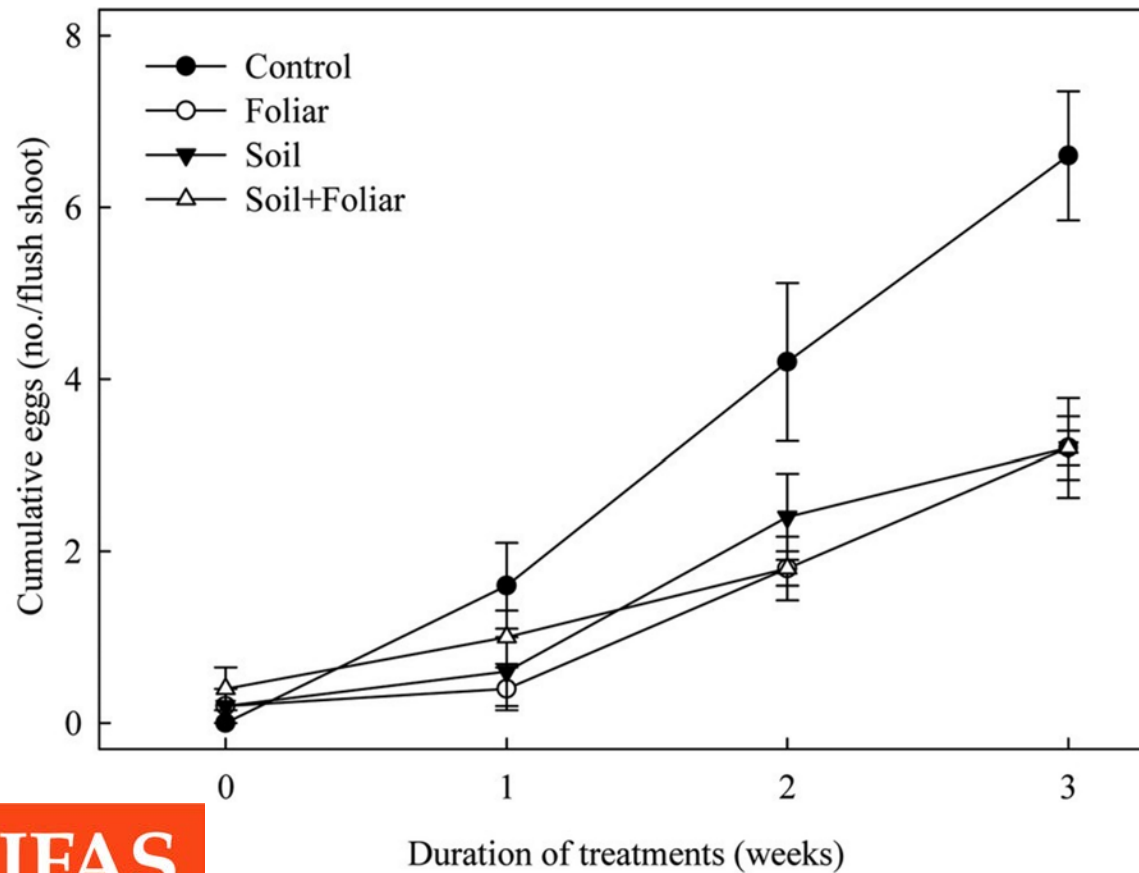
(c)



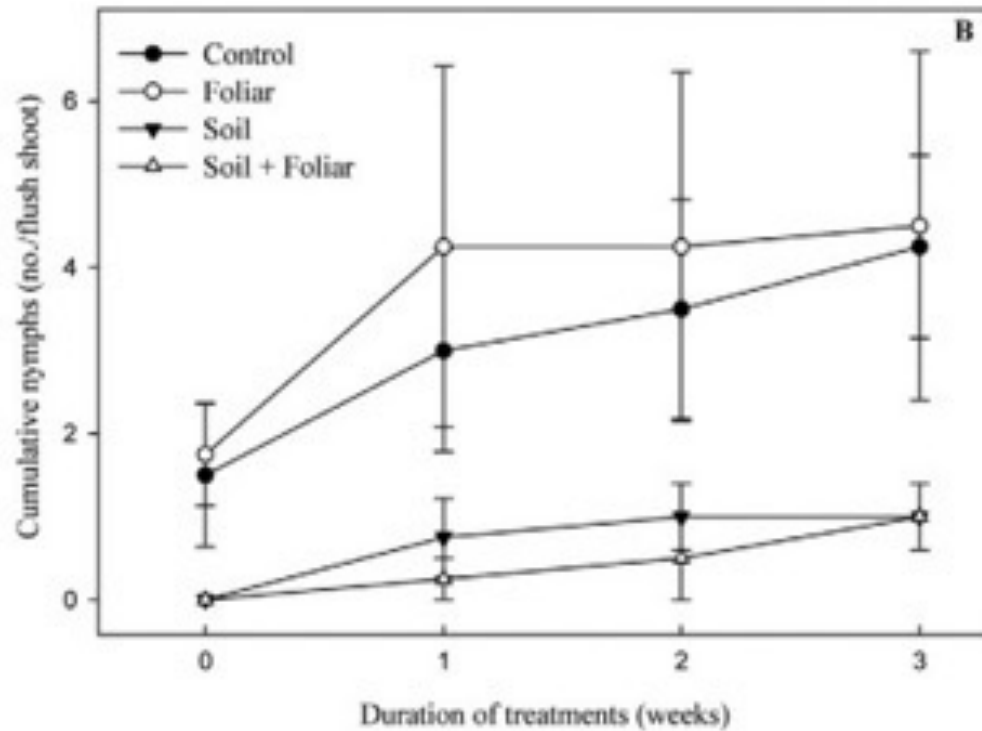
# Silicon as a natural plant guard against insect-pests



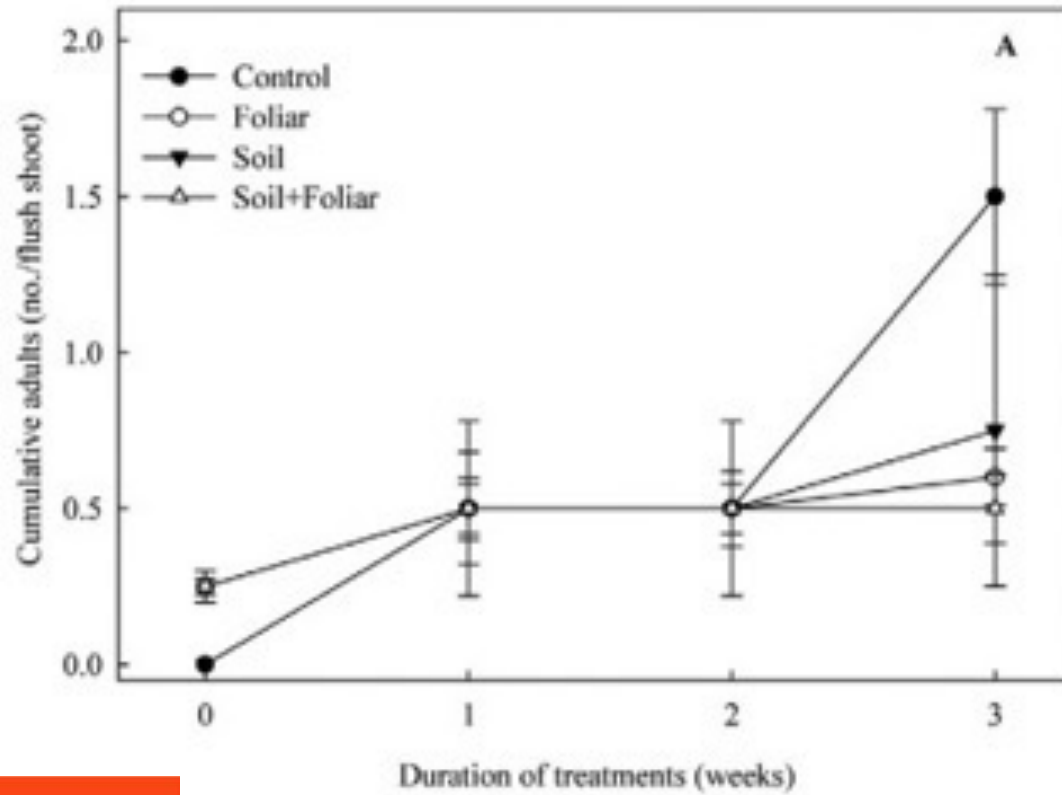
# Silicon reduced ACP population in Tahiti Lime



# 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,  $\text{CaSiO}_3$ ) 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

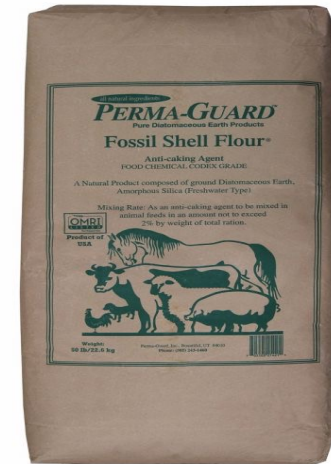
- Silicon fertilizers can be applied to....
  - **Soil**
    - Incorporated directly like wollastonite or steel slag
    - Dissolved in water to make solution and then apply to soil
      - Sprinkler, drip or overhead irrigation
  - **Soilless mixes**
    - Pre-mix with substrate
    - Fertigation
 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



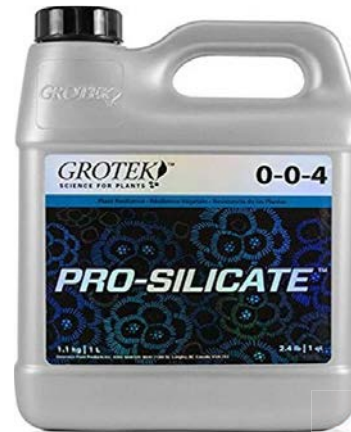
## Si Application Rate

- 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

# Commercially Available Si Products



# Commercially Available Si Products



# **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<sup>th</sup>, 2022)



After Freeze (January 7<sup>th</sup>, 2023)



Recovering from freeze (April 11<sup>th</sup>, 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.

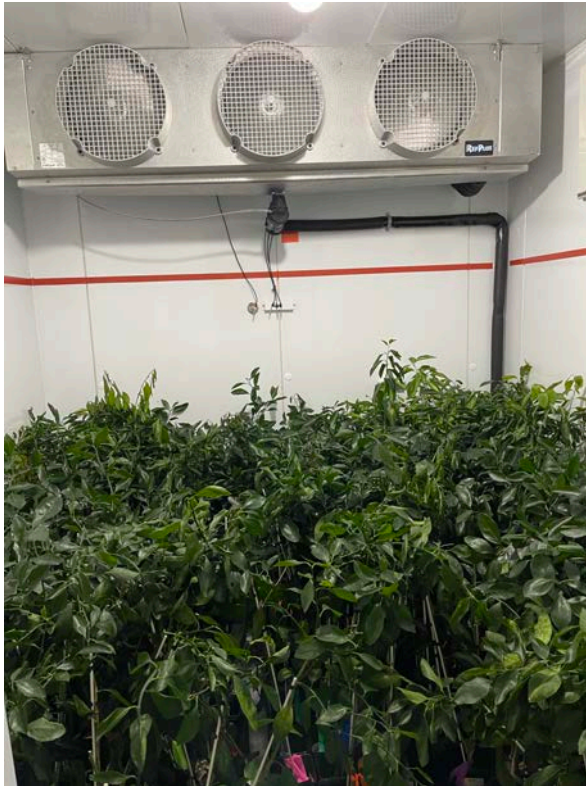
## Application time:

- Biweekly
- Monthly

# Silicon Therapy to Improve Cold Tolerance



# Silicon Therapy to Improve Cold Tolerance





# Silicon Therapy to Improve Cold Tolerance

After 48 hours of freezing stress (-6 C)



No Si (distilled water)



100ppm Silicon

# Silicon Therapy to Improve Cold Tolerance

After 48 hours of freezing stress (-6 C)

100ppm Silicon

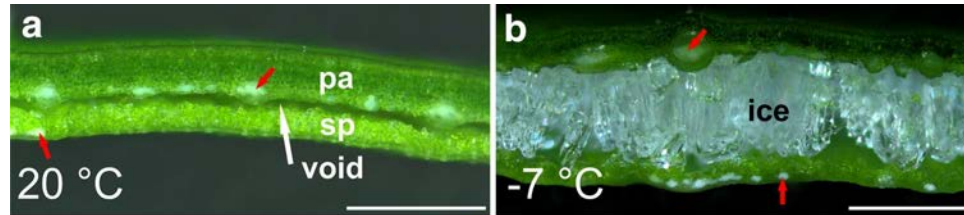


No Si (distilled water)

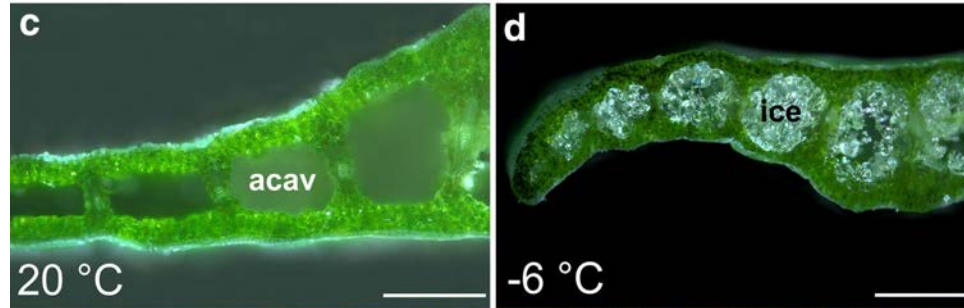


# Why water-soaked leaves after freeze damage?

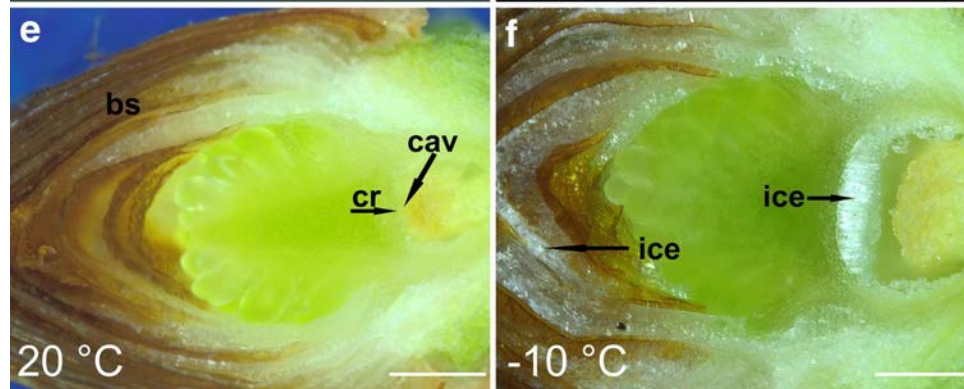
American Boxwood  
(*Buxus sempervirens*)



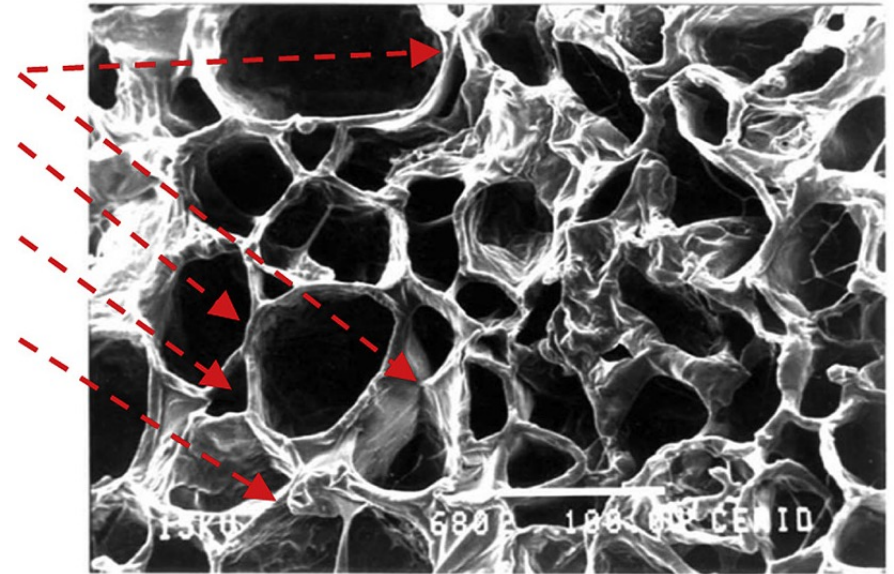
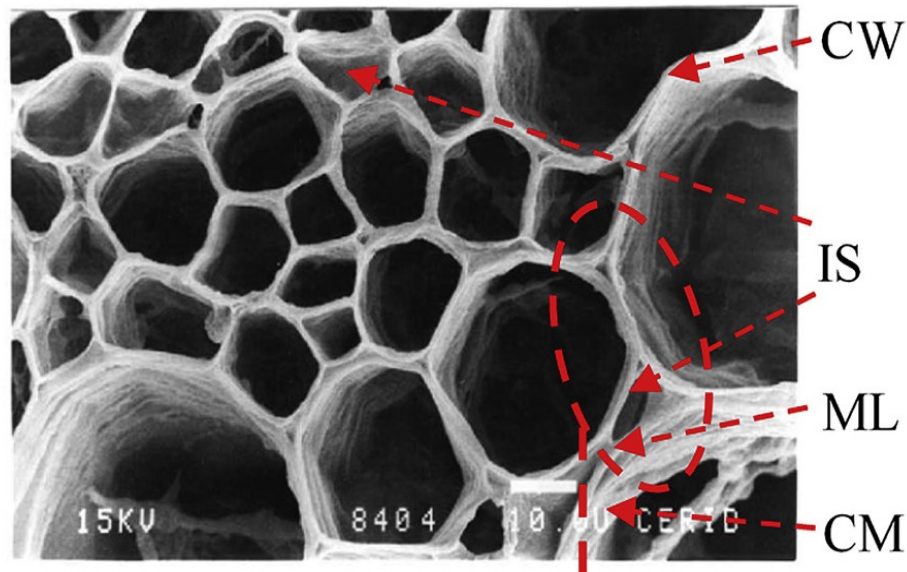
Snowdrop  
(*Galanthus nivalis*)



European spruce  
(*Picea abies*)



# How freezing cause damage to the plants?



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



Florida



# 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



## Silicon improved freezing tolerance



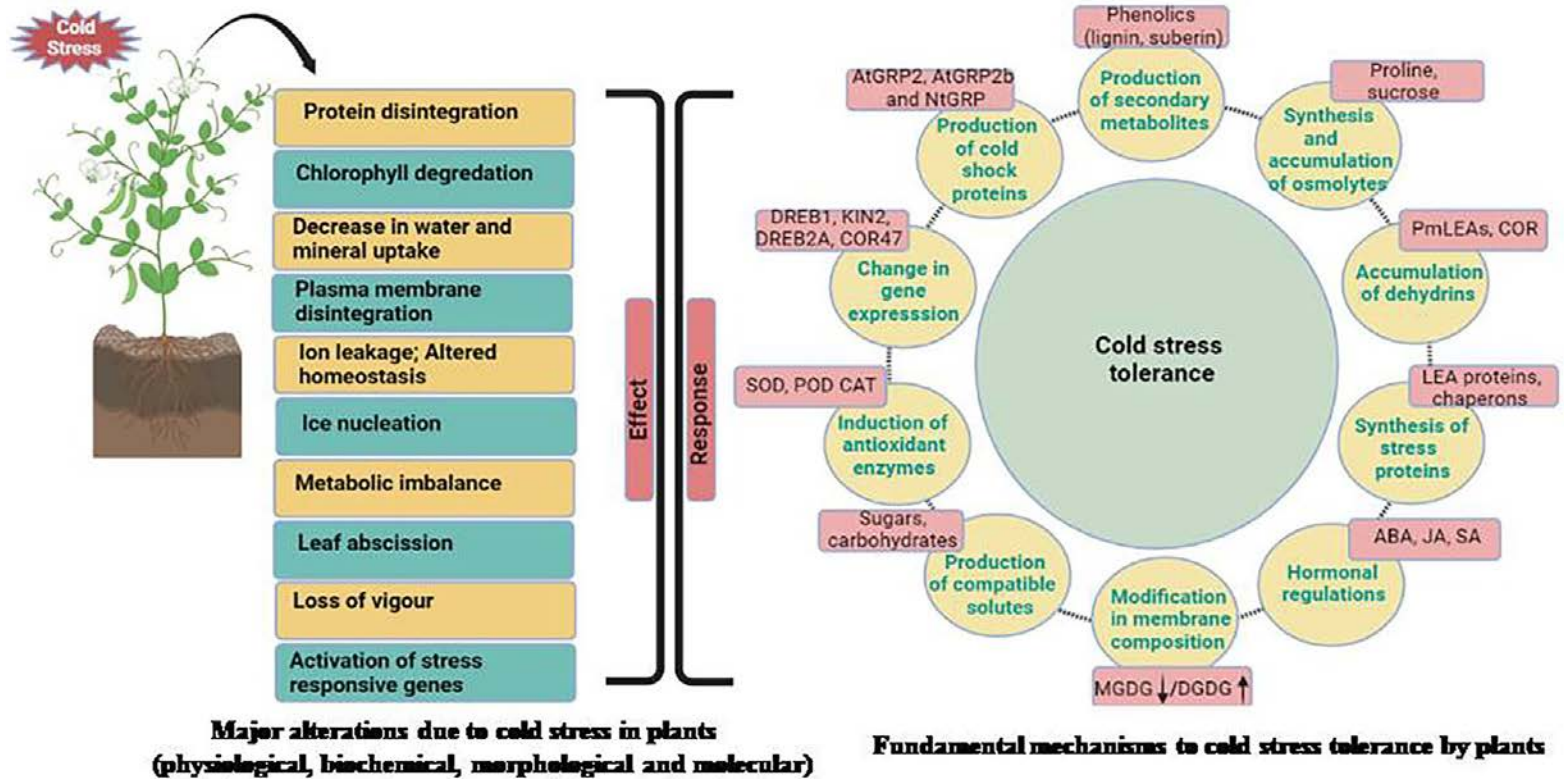
Without Si



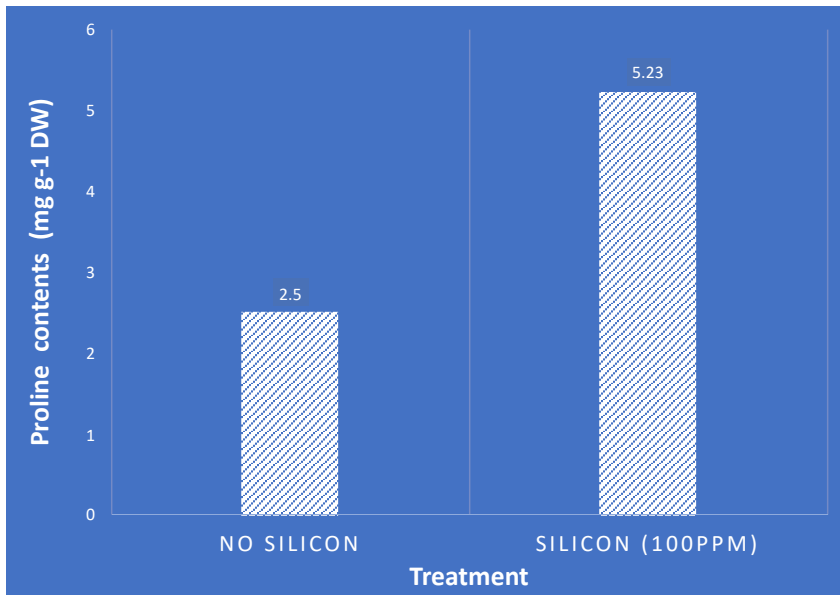
100ppm ( 4 weekly)



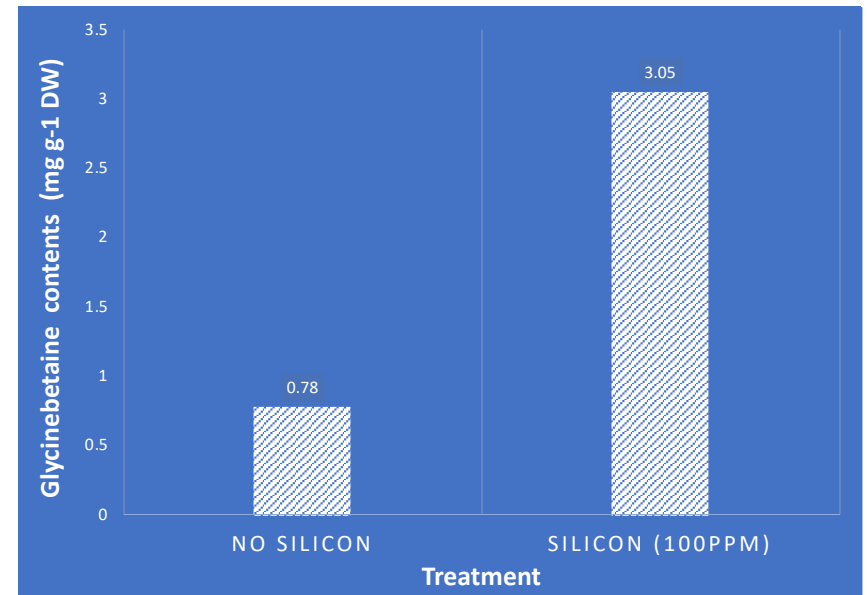
# What makes Si-treated plants freeze tolerant



# What makes Si-treated plants freeze tolerant

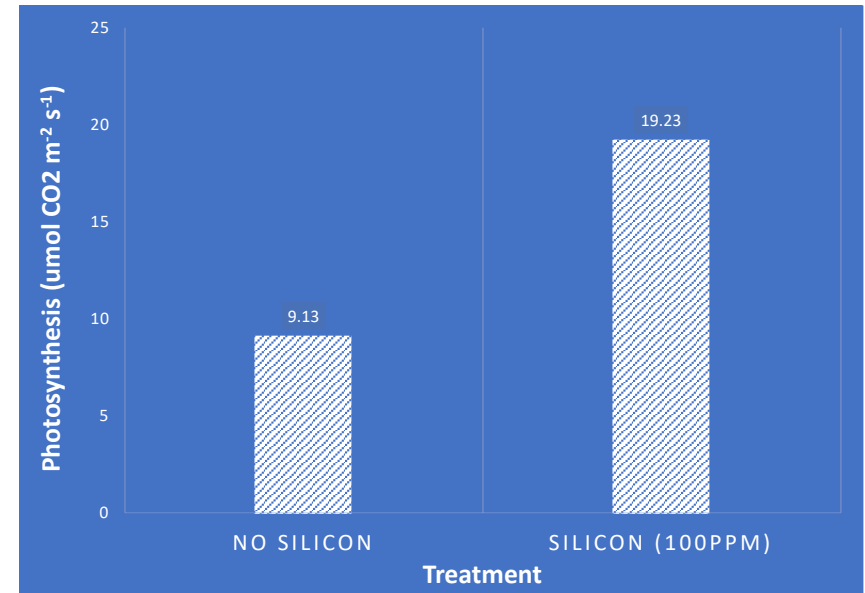
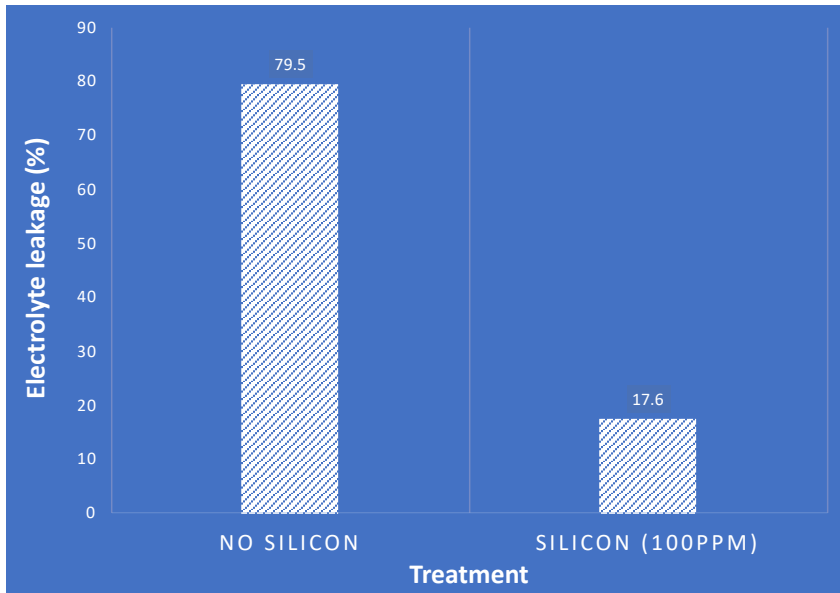


**Proline**



**Glycinebetaine**

# What makes Si-treated plants freeze tolerant



## Si reduced leaf minor attack



## Si reduced leaf minor attack

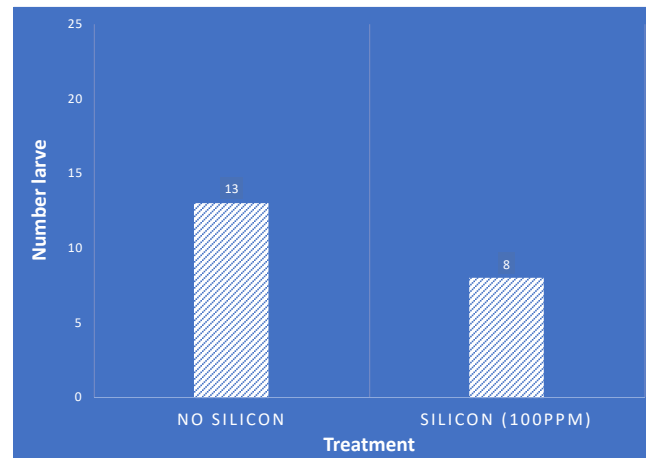
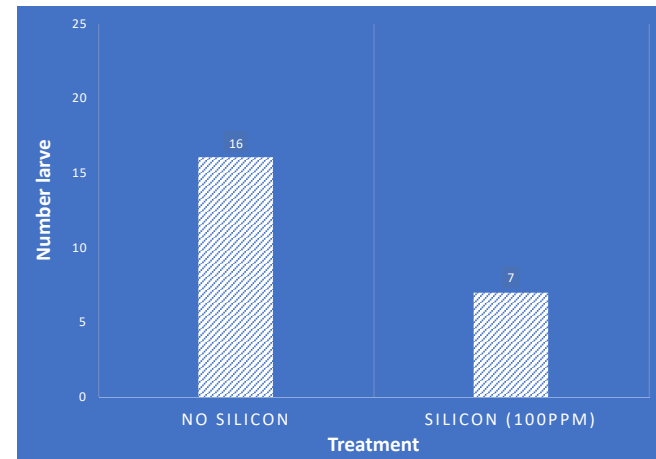
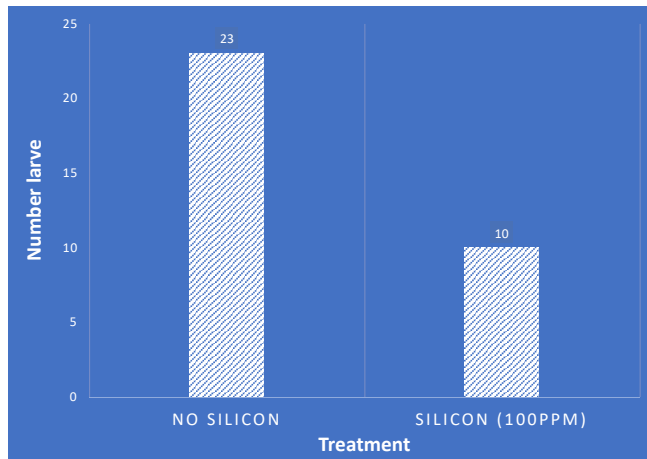


Si (0 ppm)



Si (100ppm)

# Si reduced leaf minor attack



## **Si improved fruit quality**

**Firmness**

**Shelf life**

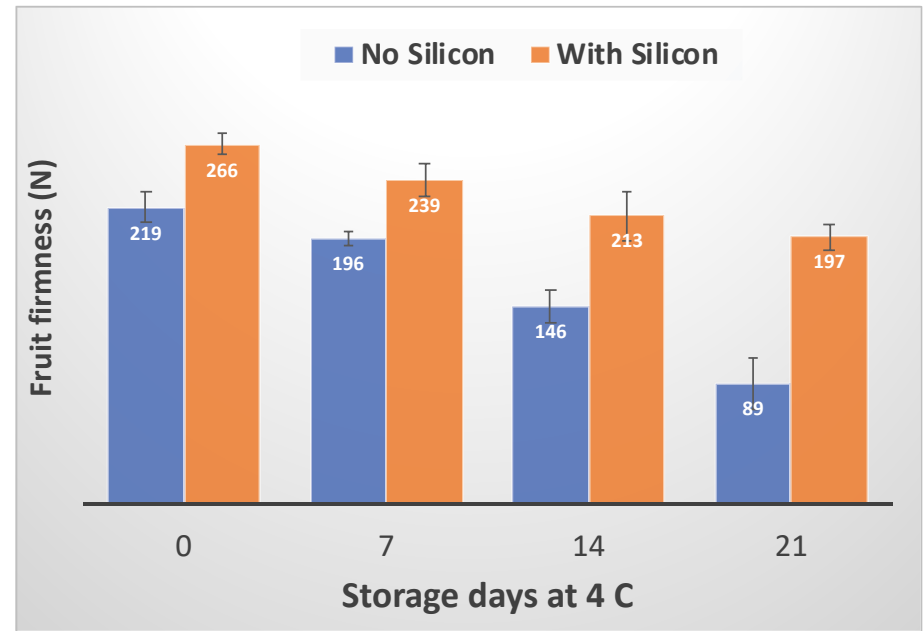
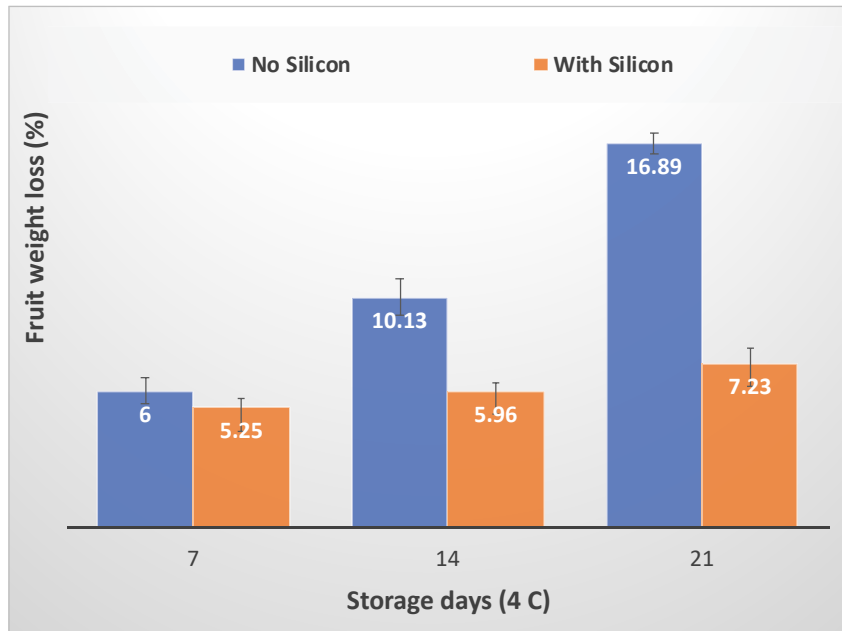
**Fruit drop**

**Respiration**

**Fruit weight loss**



# Si improved fruit quality





## Si improved fruit freeze tolerance



Control



Silicon treated

## Take-home message

- Si is effective in improving plant growth and shelf life in variety of plant species including 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
- ***More research on molecular physiology is needed to understand the stress tolerance mechanism in Si treated plants***



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# Questions

