

# UPDATE ON TRUNK INJECTION

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**University of Florida/IFAS**

Southwest Florida Research and Education Center, FL, USA

Citrus Institute, Avon Park, 4 April 2023

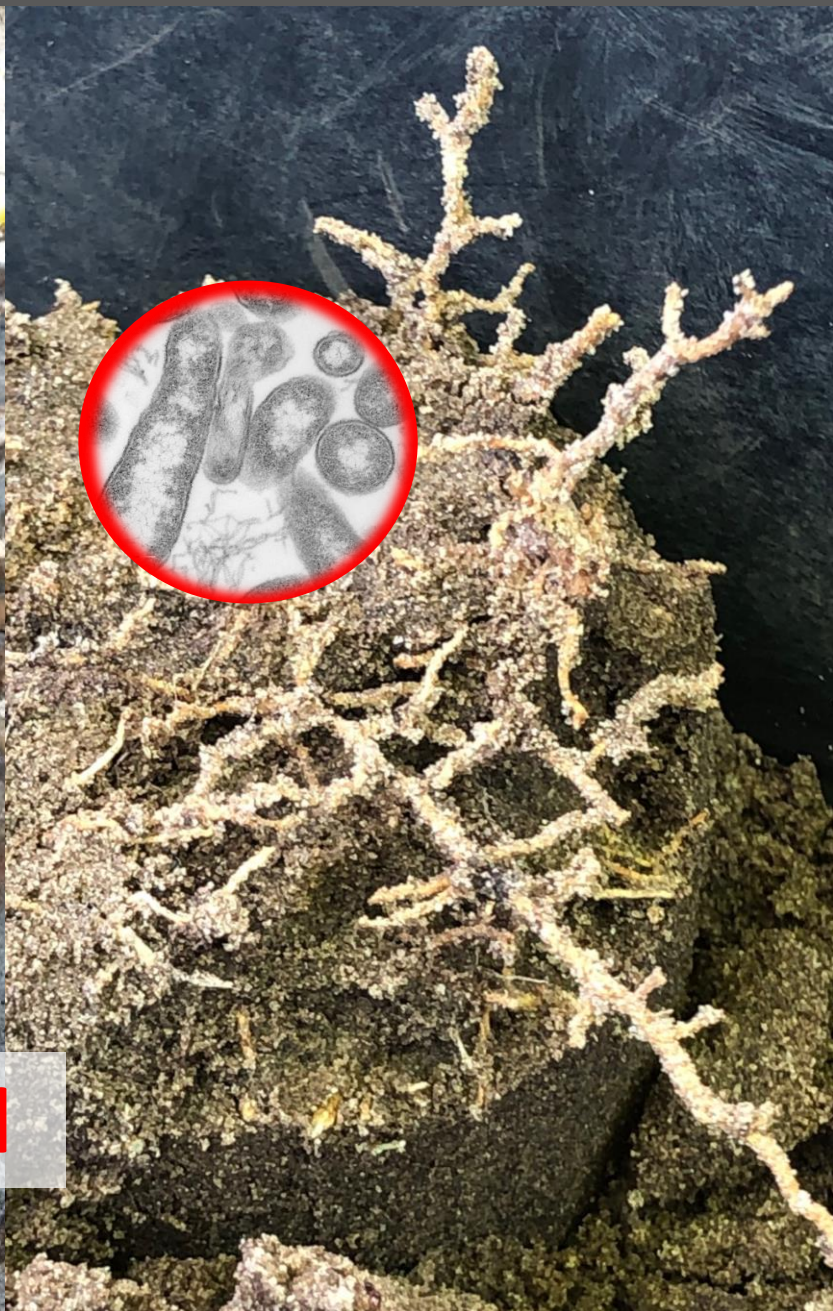


# REMINDERS





# HLB IS A VASCULAR (SYSTEMIC) DISEASE

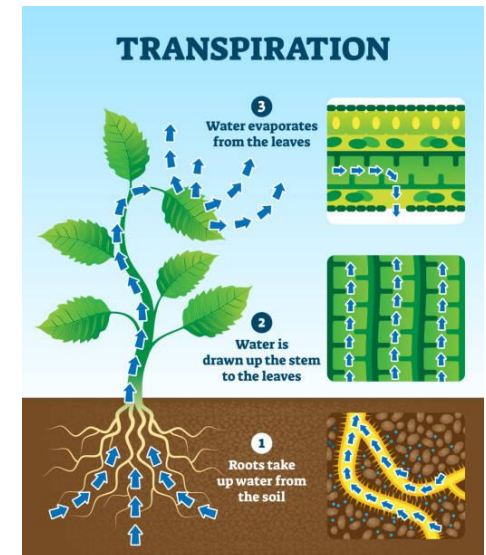


**CLas is phloem-limited**



# WHAT IS TRUNK INJECTION?

- ❖ The targeted (vascular) delivery of crop protection materials into the stem or trunk of a woody plant as an alternative to spraying or soil drenching
- ❖ Injection occurs into the xylem from where the materials are distributed throughout the plant with the transpiration stream





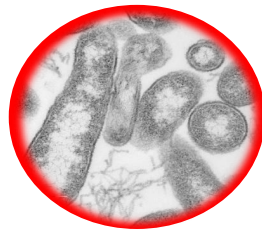
# THE PLANT VASCULAR SYSTEM

## Xylem

- Passive transport
- Unidirectional – from roots to leaves ↑
- Driving force is transpiration

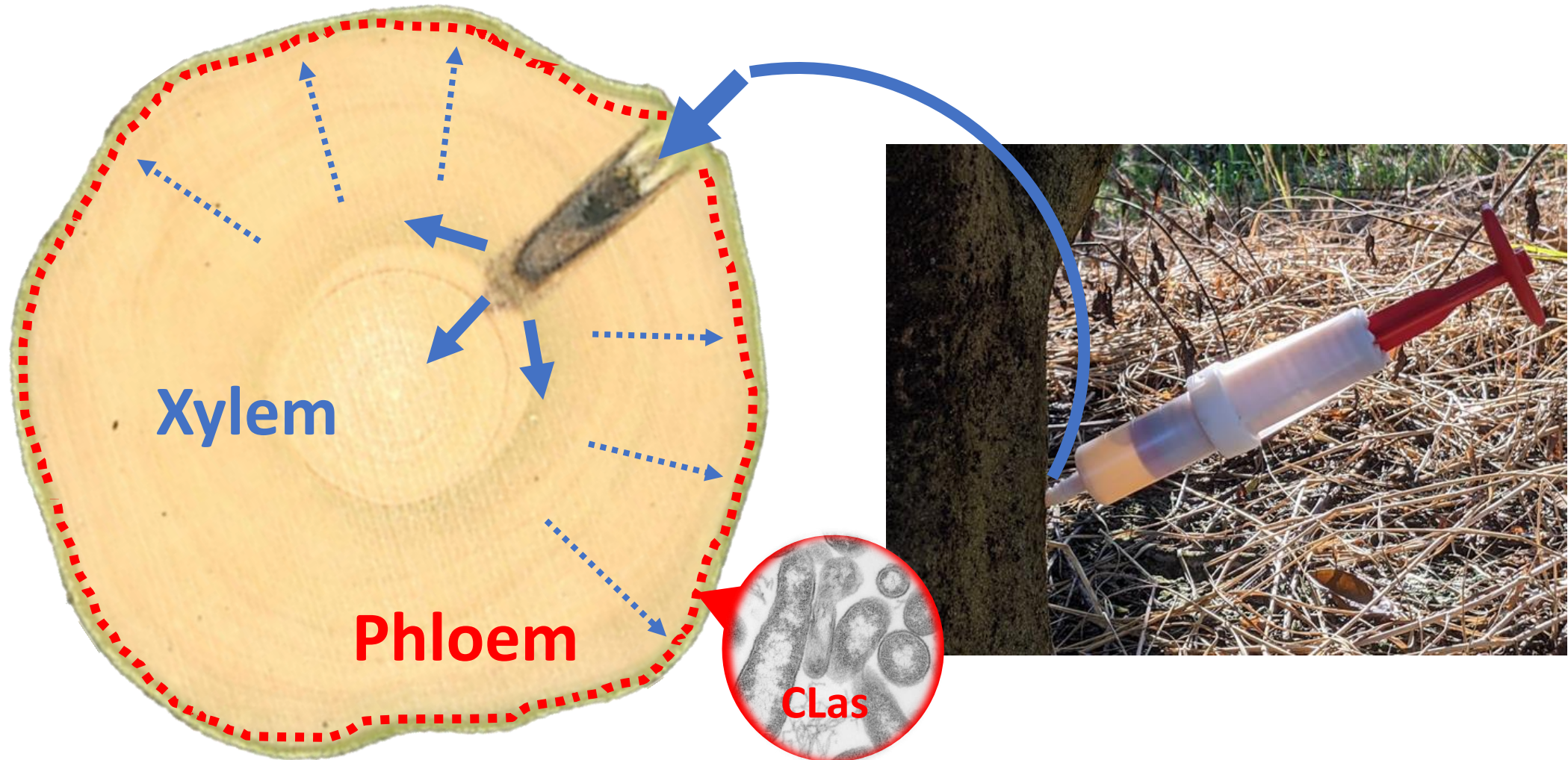
## Phloem (→CLas)

- Active transport
- Bidirectional - from source to sink tissue ⇕





# PRINCIPLES





# ADVANTAGES

- Precise delivery of materials
- Elimination of spray drift
- Reduced risk for worker exposure
- Reduced risk for non-target organisms
- Reduced pesticide load into the environment
- Potentially longer residual activity of materials





# HLB RESEARCH





# 1970s – 1980s



358

Vol. 61, No. 5--PLANT DISEASE REPORTER--May 1977

## PRELIMINARY REPORT ON EXTENDED TREATMENT OF CITRUS GREENING WITH TETRACYCLINE HYDROCHLORIDE BY TRUNK INJECTION

S. P. van Vuuren, J. N. Moll, and J. V. da Graca

Virology Section, Citrus and Subtropical Fruit Research Institute, Nelspruit, South Africa.

Plant Dis. Repr. 61: 358-359.

Table 1. Uptake of tetracycline hydrochloride solution (1000 mg/liter) under pressure by greening-infected citrus trees over extended periods and the resultant decreases in fruit symptoms.

Duration of injection	Replicate	Uptake (liter)	Percentage fruit with greening symptoms		% Increase/ decrease
			Before treatment	After treatment	
Control	1	0	22	37	+68
	2	0	38	25	-34
	3	0	30	23	-23
3 days	1	2.60	32	15	-53
	2	6.45	33	12	-64
	3	5.55	24	3	-88
7 days	1	5.60	34	1	-97
	2	6.00	21	1	-95
	3	7.30	33	0	-100

FIGURE 1. Citrus tree with trunk injection apparatus attached. The position of the valve is indicated by an arrow.





Fig. 1. Modified blowlamp injector.

## Control of Citrus Greening and its Psylla Vector by Trunk Injections of Tetracyclines and Insecticides

R. E. Schwarz, J. N. Moll, and S. P. van Vuuren

*Stubborn, Greening, and Related Diseases*

27

TABLE 1

PERCENTAGE OF SEVERE FRUIT GREENING IN SEVEN-YEAR-OLD VALENCIA ORANGE TREES BEFORE AND AFTER TREATMENT WITH VARIOUS TETRACYCLINES AND INSECTICIDES

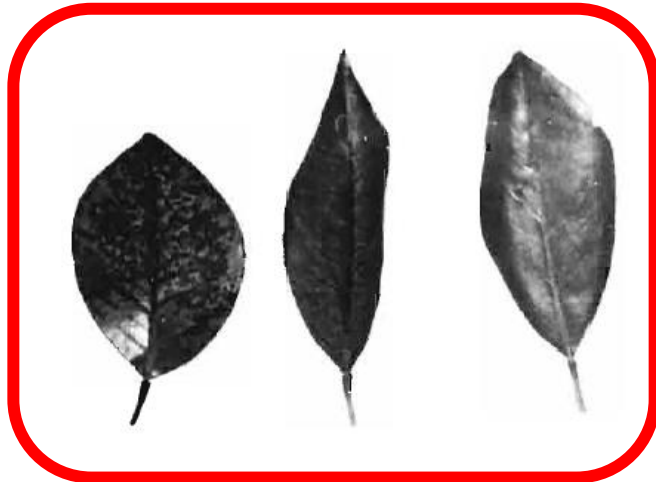
Treatment and amount*	Mean % fruit greening in five trees in:		
	1970 Before treat.	1971 After treat.	1972 After treat.
Tetracycline hydrochloride:			
250 ppm .....	60.3	22.5	19.7
500 ppm .....	62.7	13.0	11.0
750 ppm .....	63.2	15.3	21.2
Oxytetracycline hydrochloride, animal formula:			
250 ppm .....	61.2	32.3	32.1
500 ppm .....	62.7	42.8	43.8
Chlortetracycline, 750 ppm .....	61.6	46.7	39.6
Tetracycline/chloramphenicol, 750 ppm/750 ppm .....	61.7	40.4	47.2
Cycocel (2-chloroethyl trimethyl-ammonium hydrochloride), 1,000 ppm .....	63.6	66.3	54.2
Control, water .....	63.4	59.0	48.7

\* All materials were injected in 1 liter aqueous solution.

# 1970s – 1980s



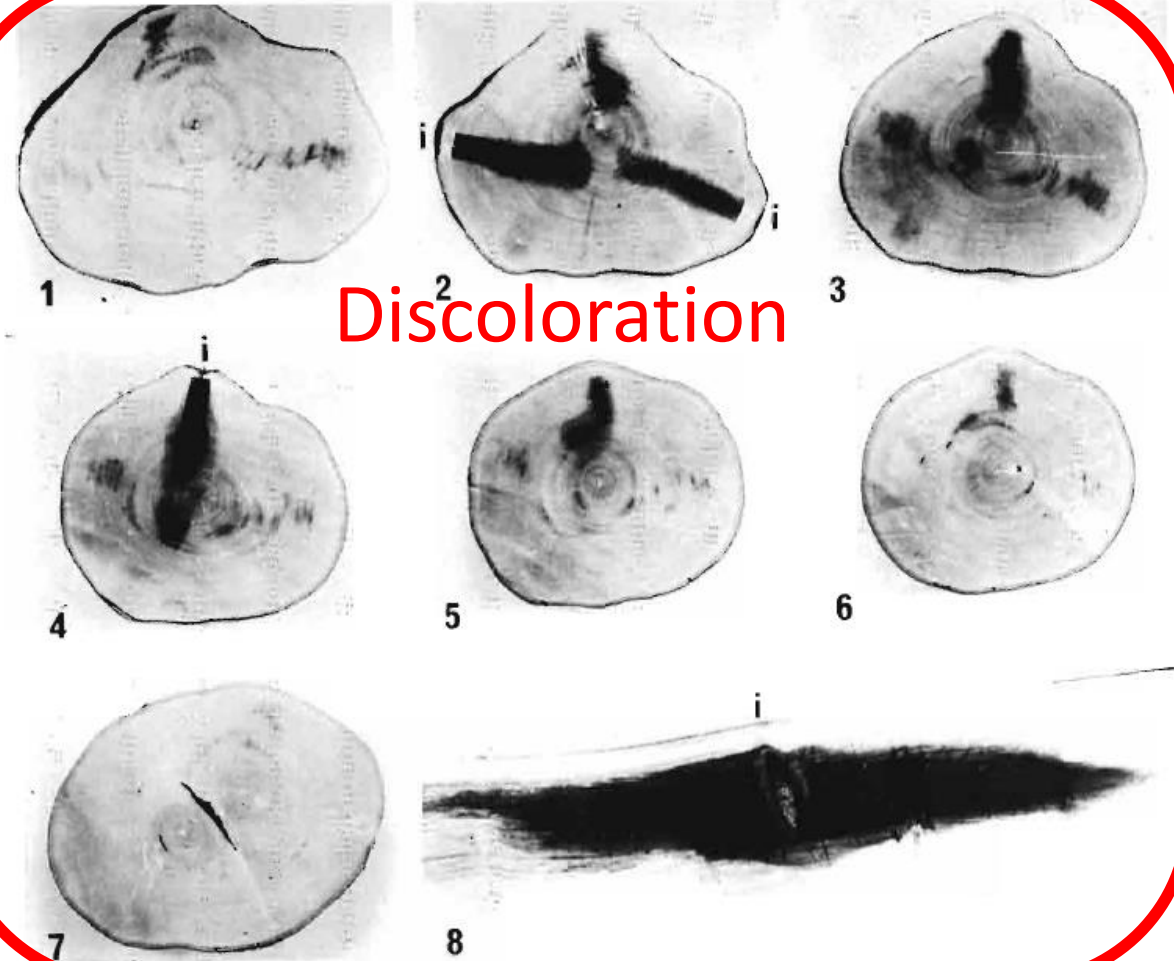
Phytotoxicity



*Phytophylactica* 9, 77-81 (1977)

## THE DETERMINATION OF OPTIMAL CONCENTRATION AND pH OF TETRACYCLINE HYDROCHLORIDE FOR TRUNK INJECTION OF GREENING-INFECTED CITRUS TREES

S. P. VAN VUUREN, Citrus and Subtropical Fruit Research Institute, Nelspruit, 1200





# PUBLISHED INFORMATION



horticulturae




agriculture



Review

## Trunk Injection as a Tool to Deliver Plant Protection Materials—An Overview of Basic Principles and Practical Considerations

Leigh Archer<sup>1</sup>, Jonathan H. Crane<sup>2</sup> and Ute Albrecht<sup>1,\*</sup> 

*Horticulturae* **2022**, *8*(6),  
552; <https://doi.org/10.3390/horticulturae8060552>

UF | IFAS Extension  
UNIVERSITY of FLORIDA



What can we help you with?


TRUNK INJECTION TO DELIVER CROP PROTECTION  
MATERIALS: AN OVERVIEW OF BASIC PRINCIPLES AND  
PRACTICAL CONSIDERATIONS

Leigh Archer, Ute Albrecht, and Jonathan Crane

<https://edis.ifas.ufl.edu/publication/HS1426>


Article

## Efficacy of Trunk Injected Imidacloprid and Oxytetracycline in Managing Huanglongbing and Asian Citrus Psyllid in Infected Sweet Orange (*Citrus Sinensis*) Trees

Leigh Archer<sup>1</sup>, Jawwad Qureshi<sup>2</sup> and Ute Albrecht<sup>1,\*</sup> 

*Agriculture* **2022**, *12*(10),  
1592; <https://doi.org/10.3390/agriculture12101592>



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## Trunk injection of oxytetracycline for huanglongbing management in mature grapefruit and sweet orange trees

Leigh Archer, Sanju Kunwar, Fernando Alferez, Ozgur Batuman, and Ute Albrecht 

Published Online: 6 Dec 2022 | <https://doi.org/10.1094/PHYTO-09-22-0330-R>

<https://doi.org/10.1094/PHYTO-09-22-0330-R>

# 2020-2022 STUDIES





# METHODOLOGY



- Use of spring-loaded syringes (Chemjets)
- Injection on two opposite sides of the trunk (20 ml/side)
- Injection in the scion (mostly)
- Active ingredient/tree: **0.79 g** (18,000 ppm)

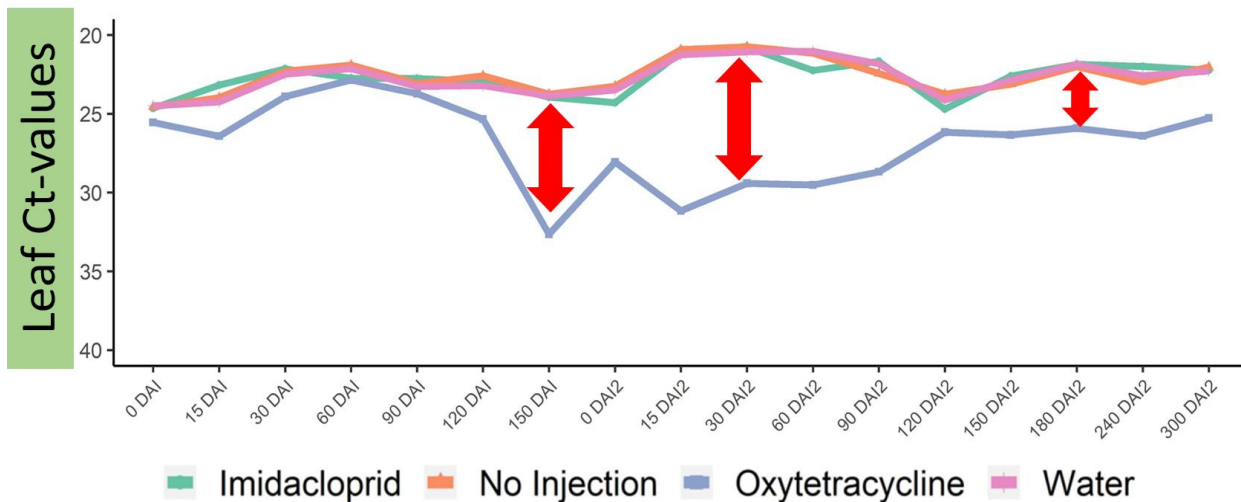
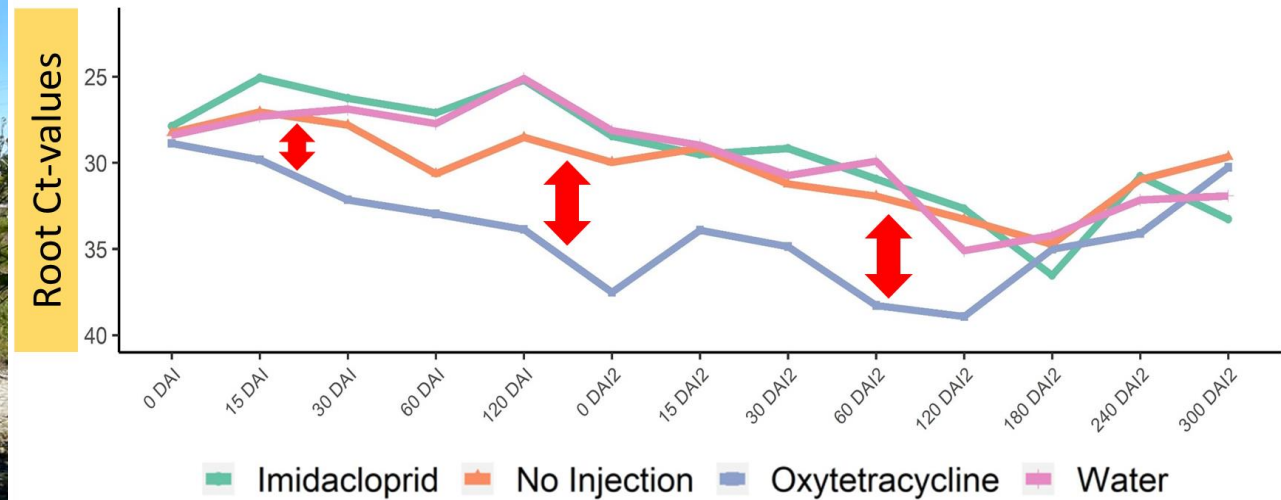


# OTC EFFICACY





# OTC EFFICACY



# NEW STUDIES





# ONGOING - STUDY 1

planted in 2014 - injected in 2022





# ONGOING - STUDY 1

planted in 2014 - injected in 2022

Southwest Florida  
Valencia/Carrizo  
Planted in 2014  
Av. Trunk diam. - 5.4"

INJECTORS: Chemjets

INJECTION TIME: April or June

OTC DOSE: **0.79 g** or **1.2g** a.i. per tree





# TREE HEALTH





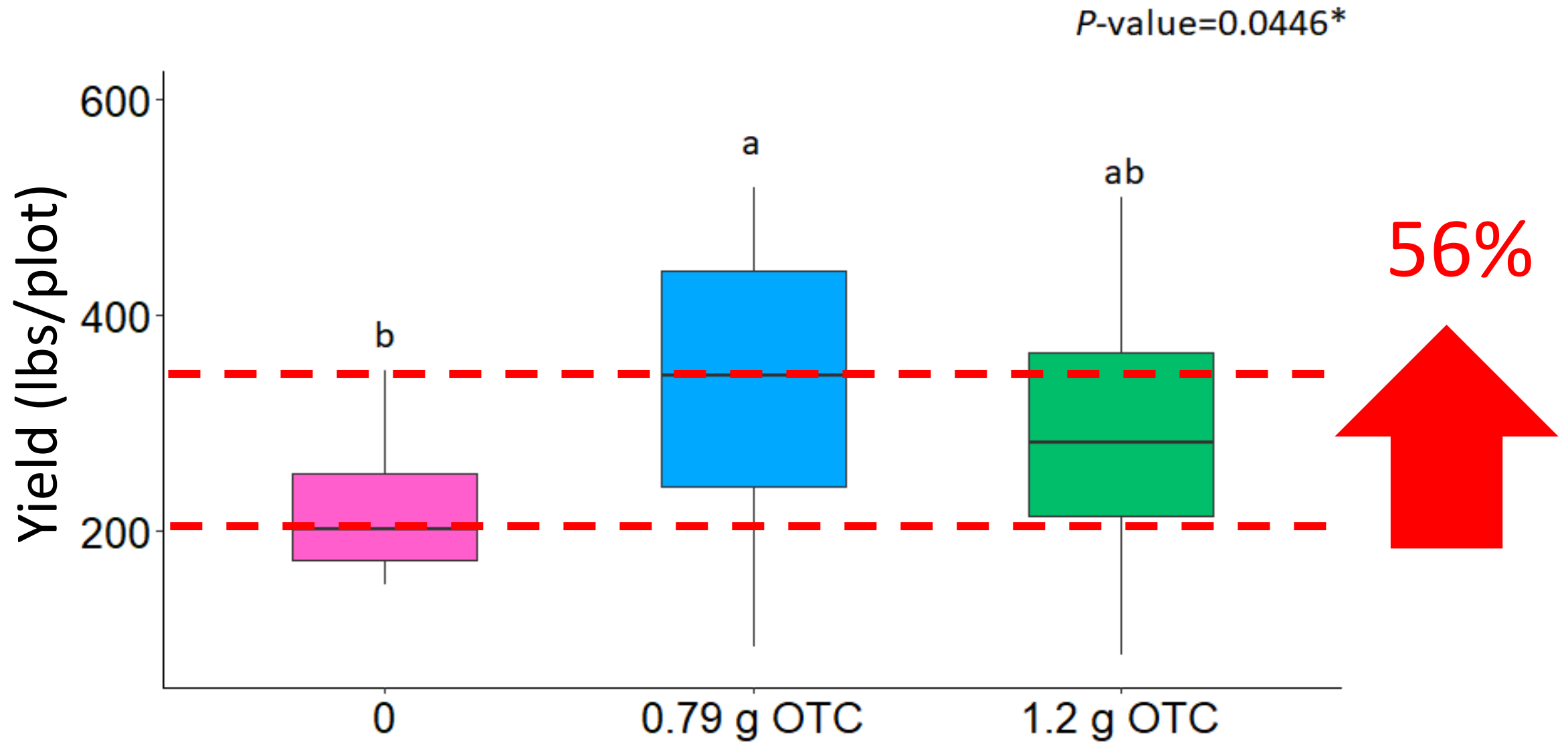
# TREE HEALTH

But... results can be variable, even for the same tree





# YIELD



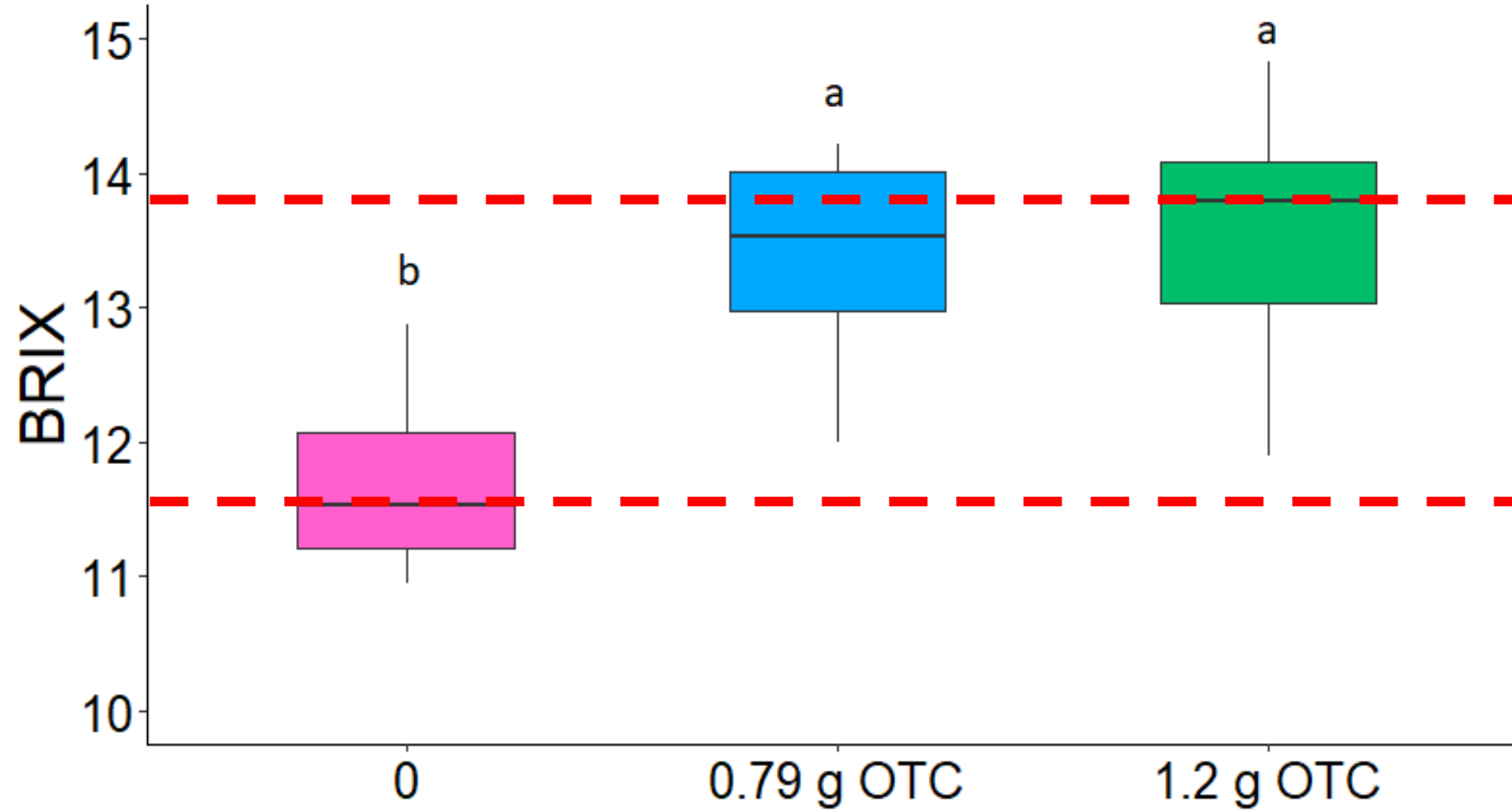
# FRUIT QUALITY



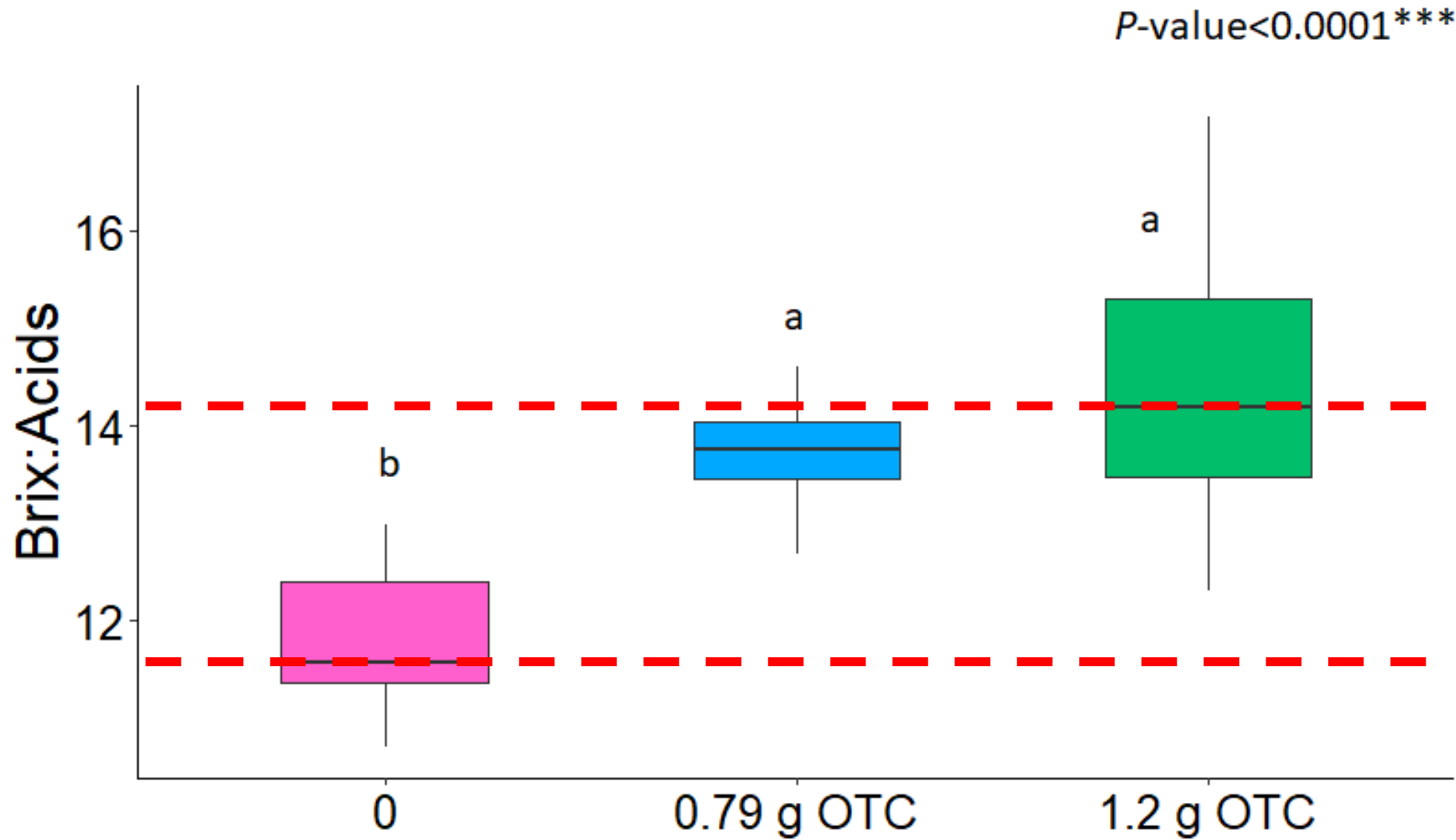


# JUICE BRIX

$P\text{-value} < 0.0001^{***}$

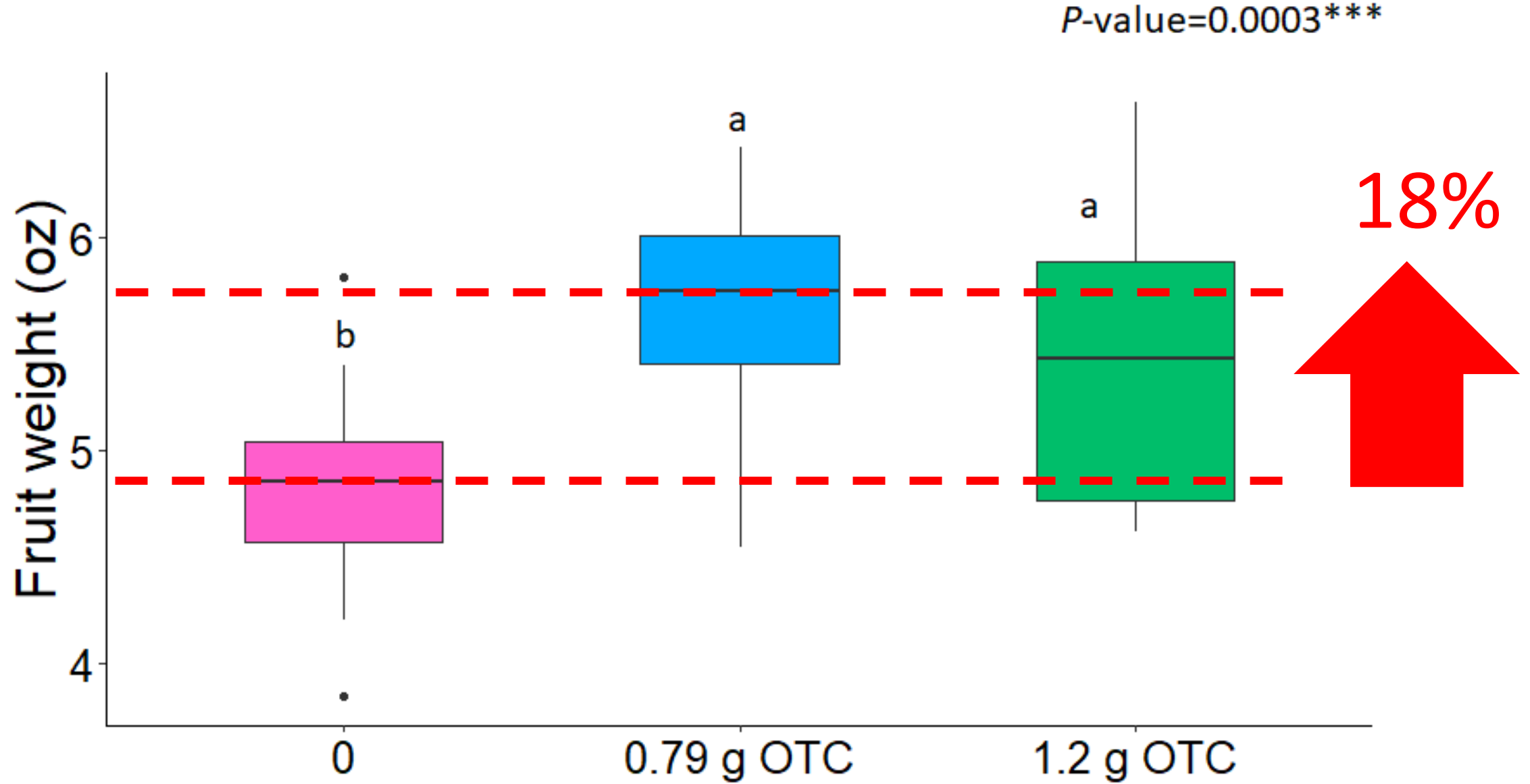


# BRIX:ACID





# FRUIT SIZE / WEIGHT



# ONGOING - STUDY 2

planted in 2018 - injected in 2022

East Coast (near Fort Pierce)

**Valencia/X639**

Planted in Nov 2018

Av. trunk diam = 2.8"



Central Ridge (near Venus)

**OLL-8/X639**

Planted in May 2018

Av. trunk diam = 2.6"





## Eight treatments: T1-T8

- OTC RATES
  - ✓ 140 mg, 330 mg, 750 mg
- TIME OF INJECTION
  - ✓ May and/or August
- OTHER
  - ✓ Device, injection location





# ONGOING - STUDY 2

planted in 2018 - injected in 2022



**East coast trial - March 2023**

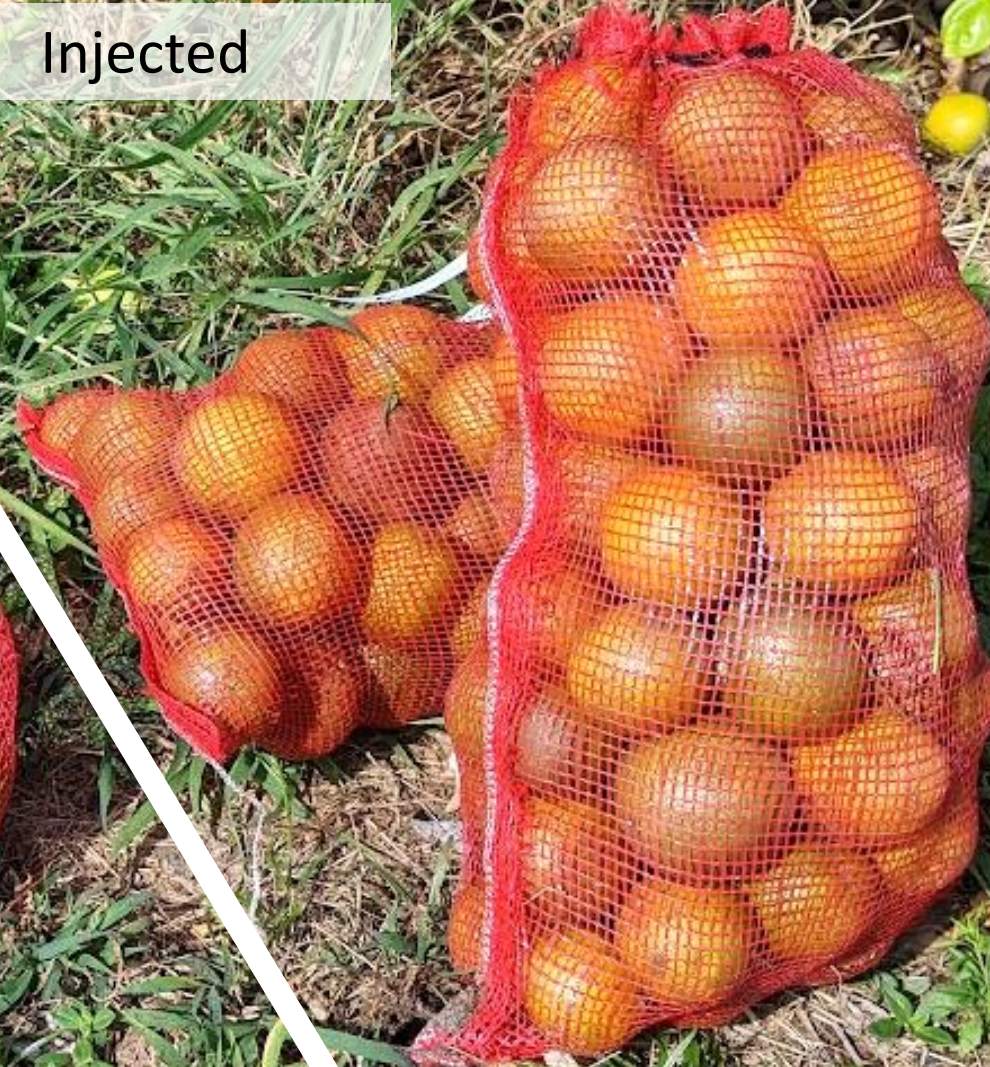


# YIELD

Not injected



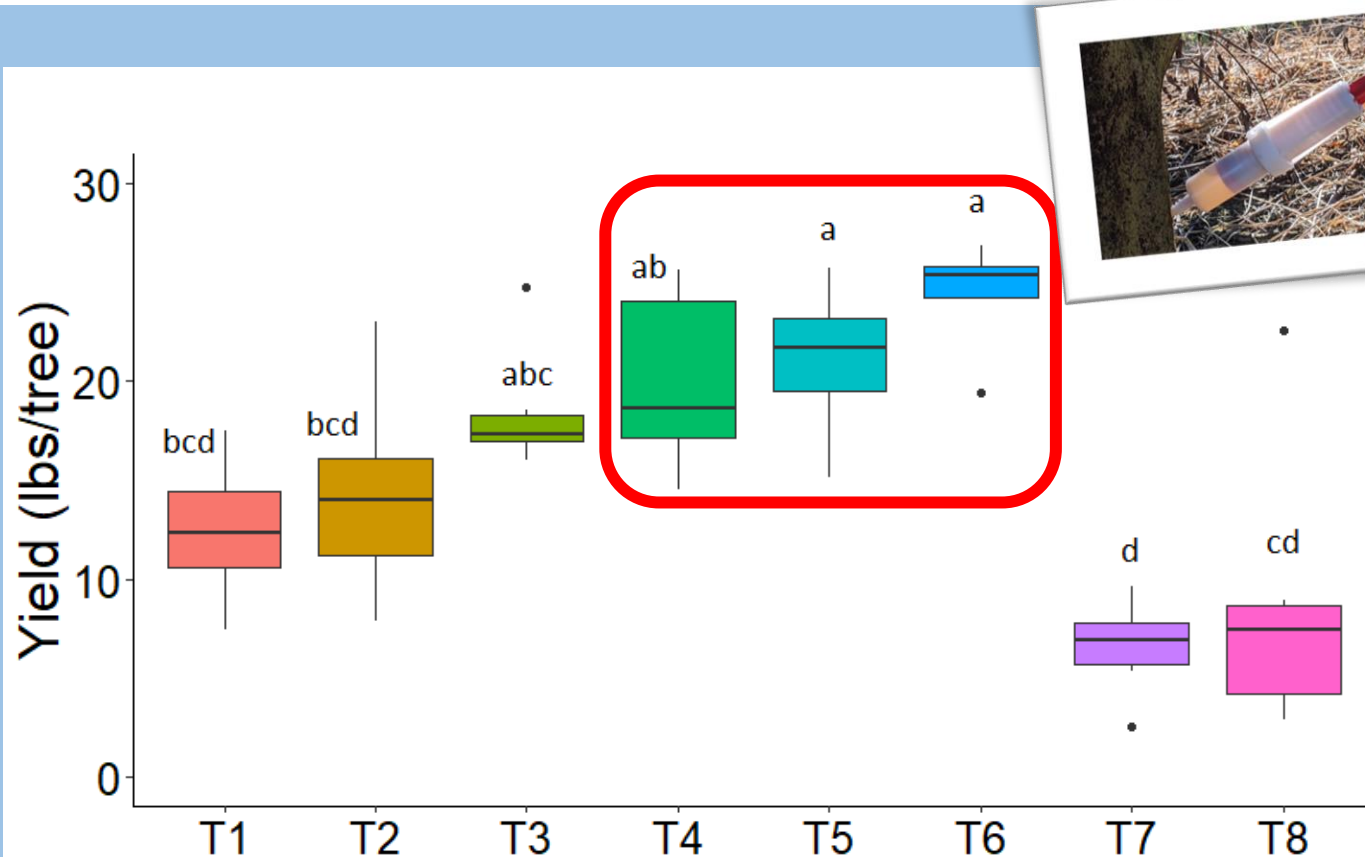
Injected





# YIELD

## EAST COAST TRIAL



T1 = 140 mg: May+Aug\* - Rootstock

T2 = 330 mg: May+Aug\* - Rootstock

T3 = 330 mg: May+Aug\*\* - Rootstock

T4 = 750 mg: May\*\* - Scion

T5 = 750 mg: May\*\* - Rootstock

T6 = 750 mg: Aug\*\* - Rootstock

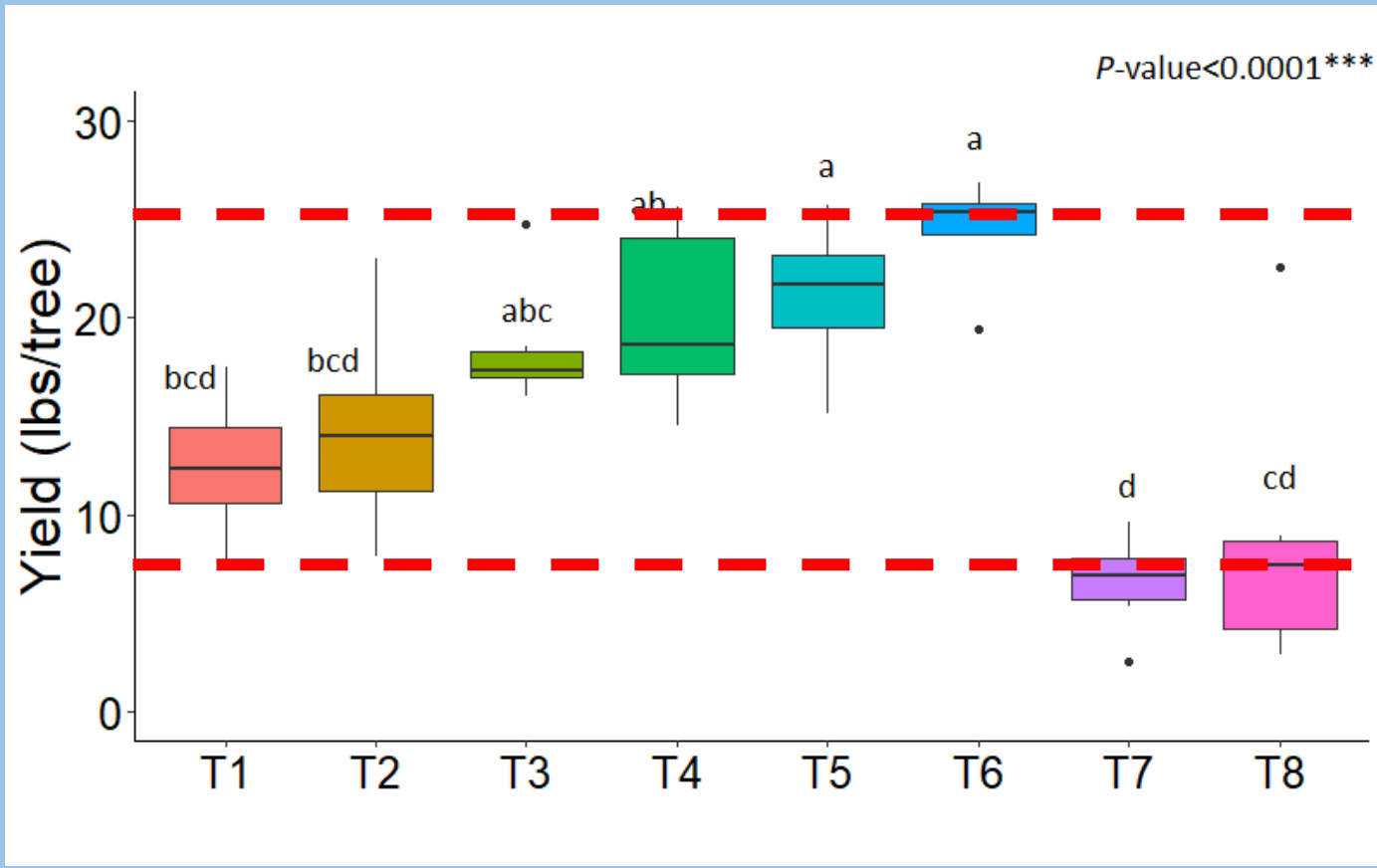
T7 = OTC Spray

T8 = Untreated control

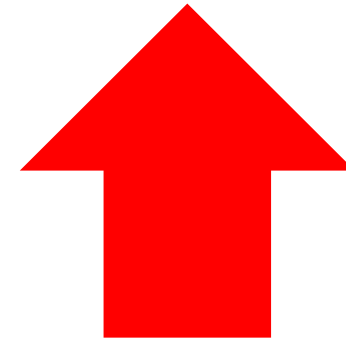


# YIELD

## EAST COAST TRIAL



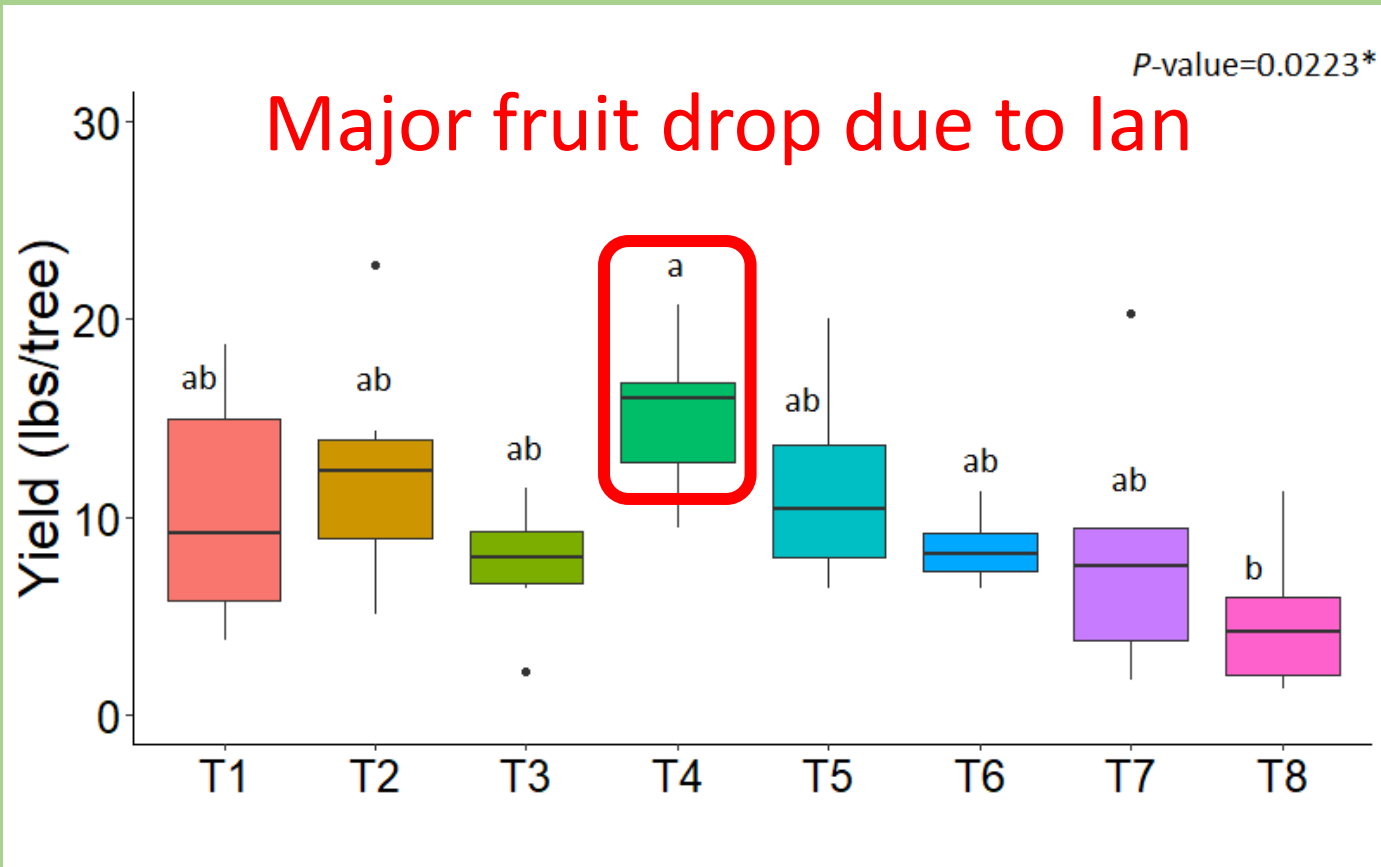
300-400%





# YIELD

## RIDGE TRIAL



T1 = 140 mg: May+Aug\* - Rootstock

T2 = 330 mg: May+Aug\* - Rootstock

T3 = 330 mg: May+Aug\*\* - Rootstock

T4 = 750 mg: May\*\* - Scion

T5 = 750 mg: May\*\* - Rootstock

T6 = 750 mg: Aug\*\* - Rootstock

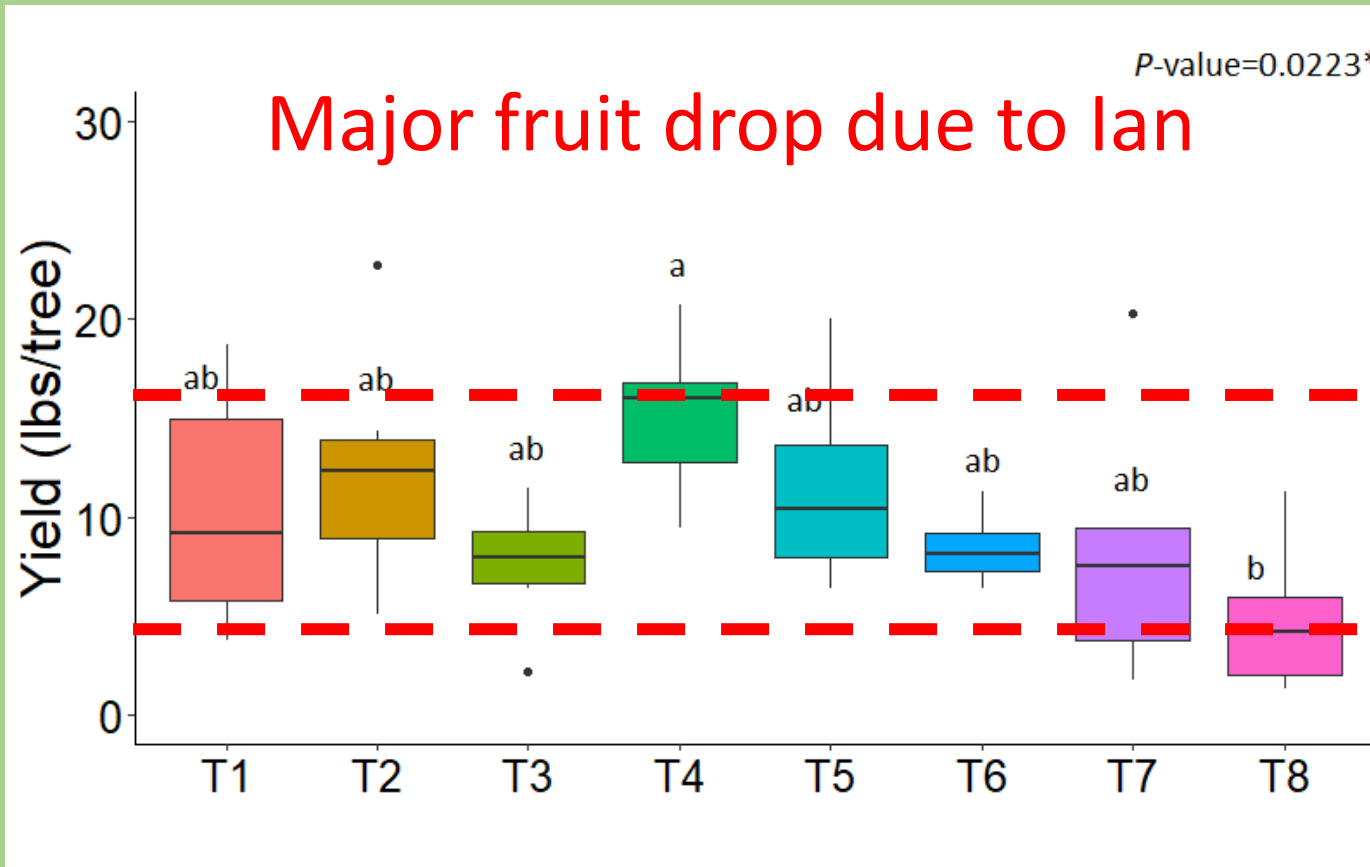
T7 = OTC Spray

T8 = Untreated control

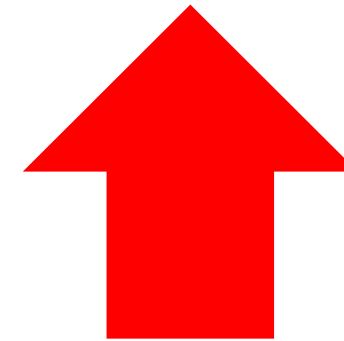


# YIELD

## RIDGE TRIAL



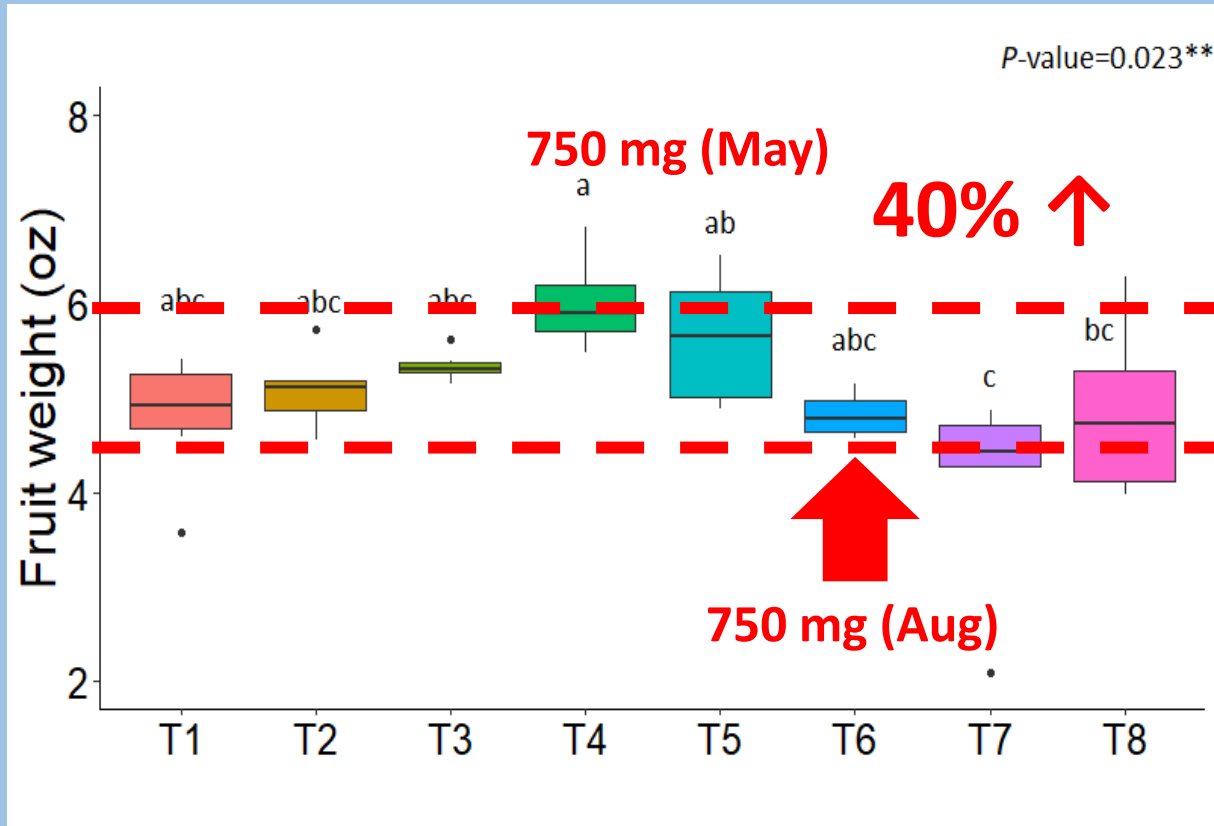
300%





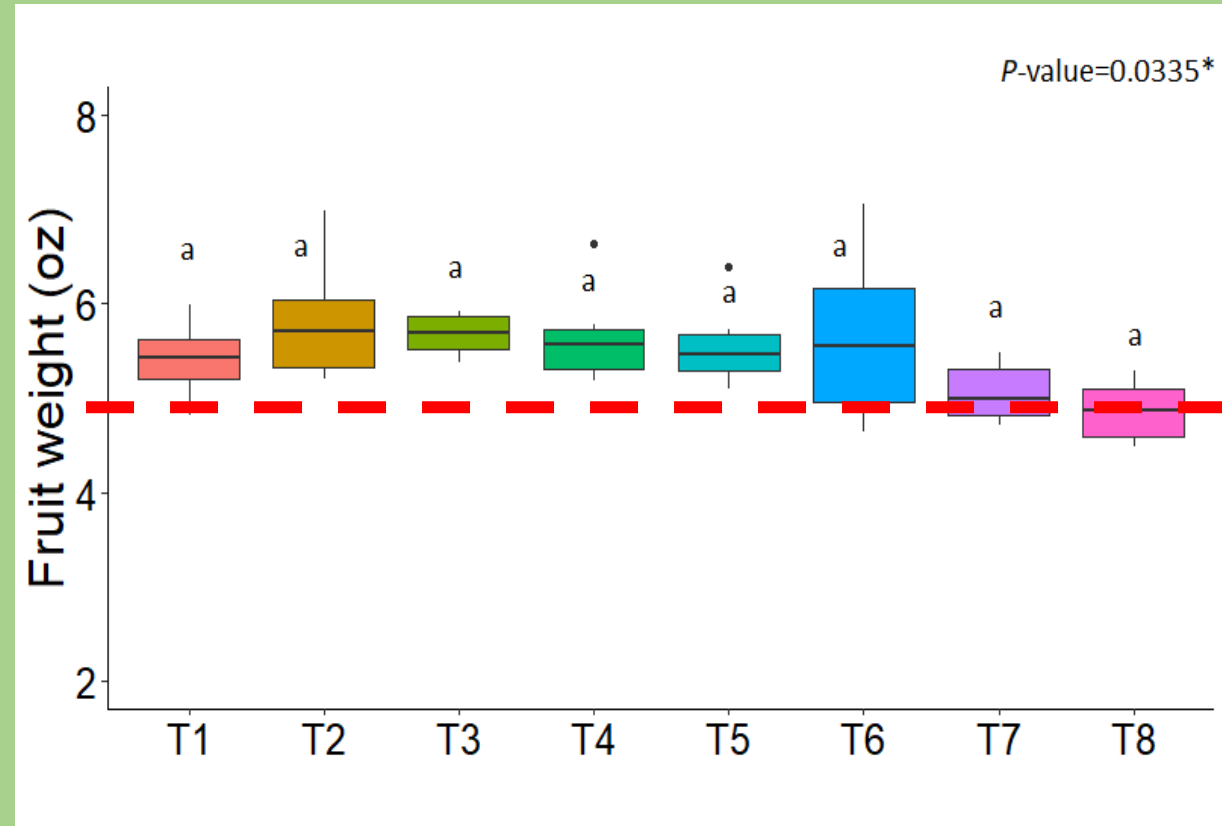
# FRUIT SIZE / WEIGHT

## EAST COAST TRIAL



Valencia/X639

## RIDGE TRIAL

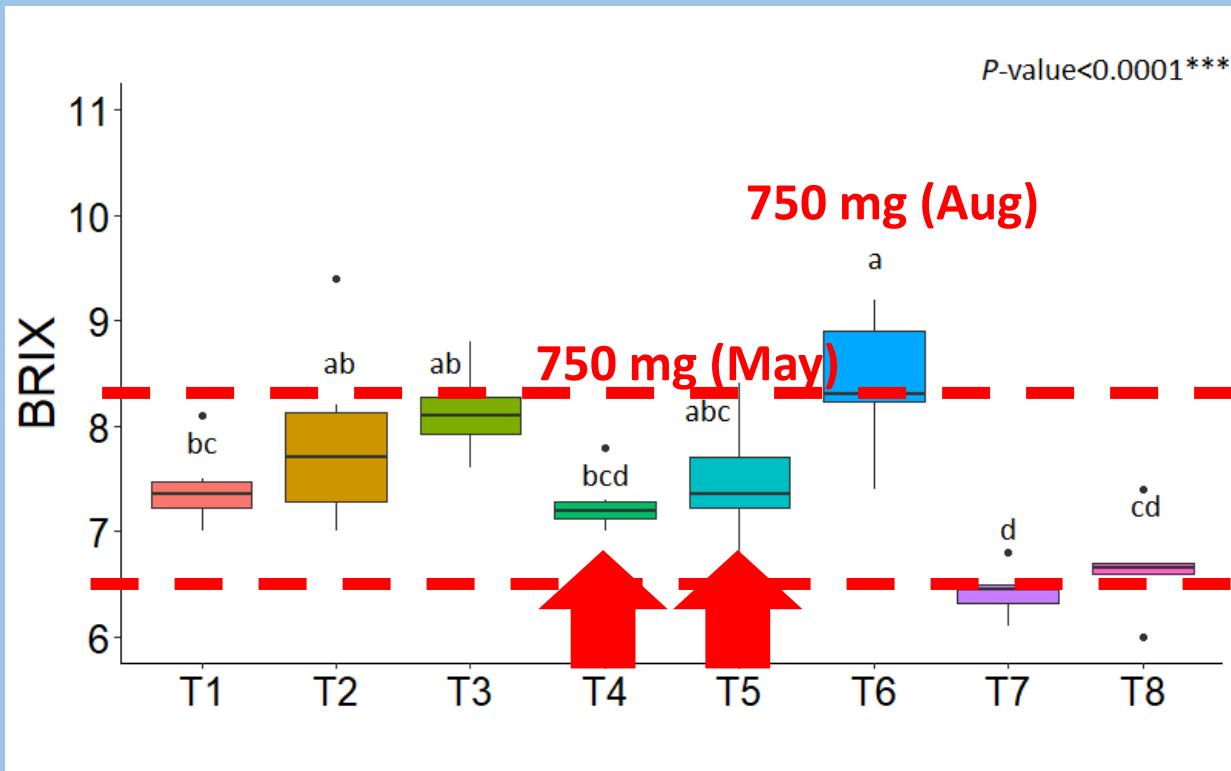


OLL-8/X639



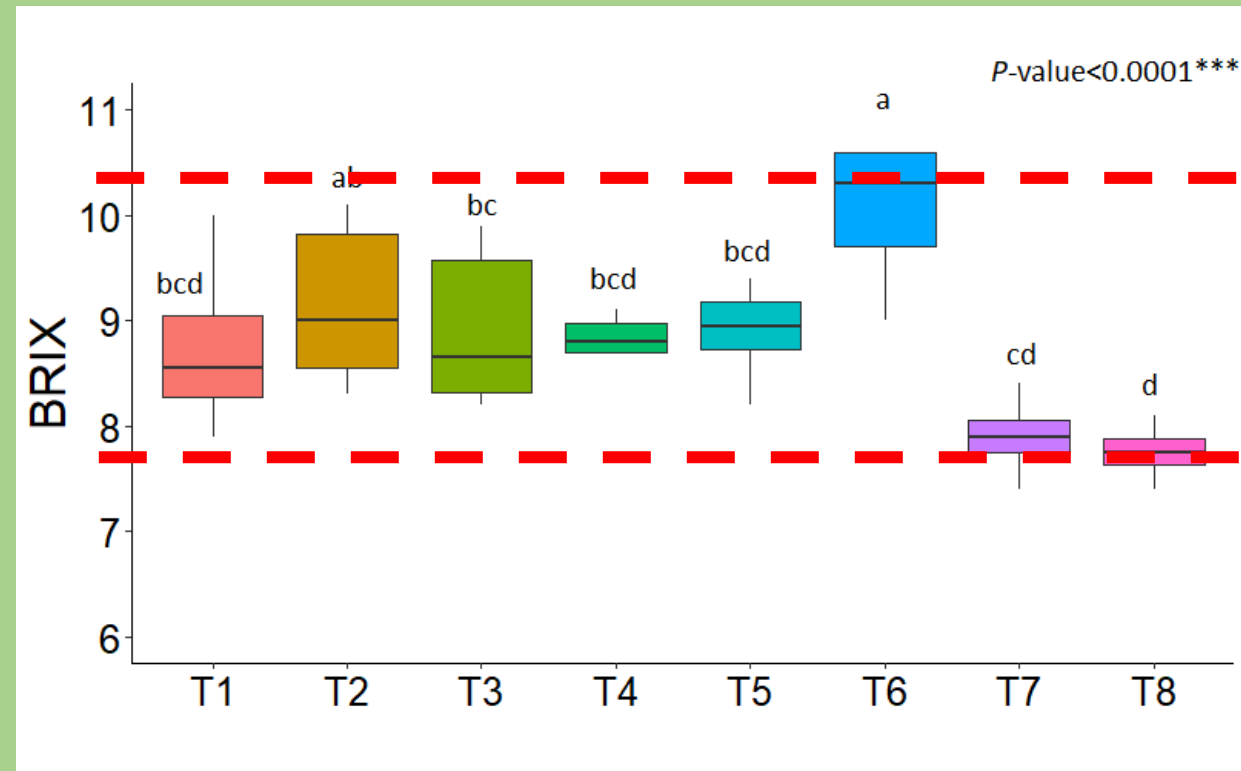
# JUICE BRIX

## EAST COAST TRIAL



Valencia/X639

## RIDGE TRIAL



OLL-8/X639



# TREE INJURY





# TREE INJURY



OTC delays wound closure and increases the wound size







# TREE INJURY



Other injection technology



# TREE INJURY NOT RELATED TO INJECTIONS





# SEASONALITY

Percentage of fully closed wounds 4, 8, and 12 months after injection

Month	Compound	4 MAI	8 MAI	12 MAI
June	Water	100%	100%	100%
October	Water	25%	58%	100%
June	OTC	0%	36%	83%
October	OTC	0%	0%	58%
		***	***	*

Fall injections delay wound closure compared with summer injections

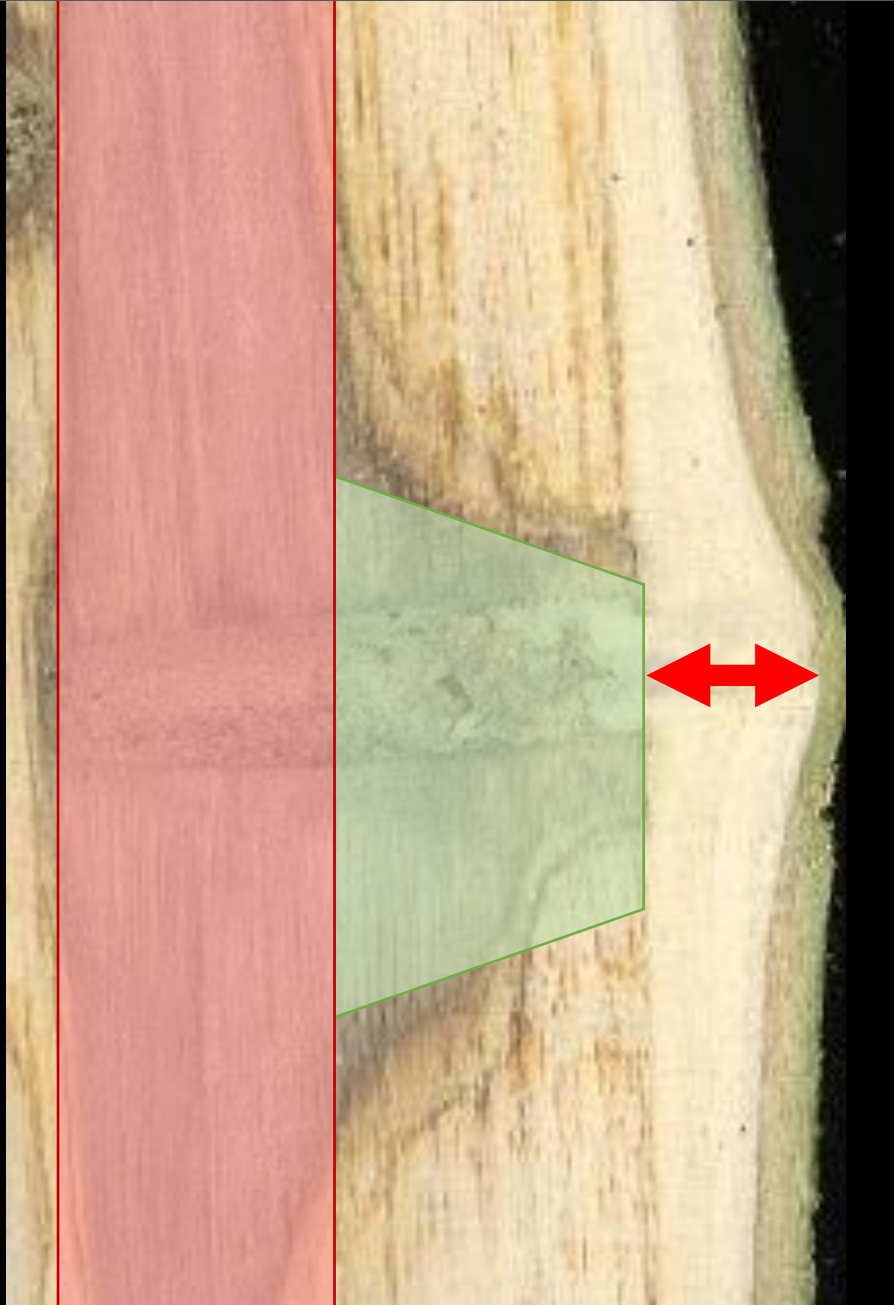


# INTERNAL WOUND COMPARTMENTALIZATION

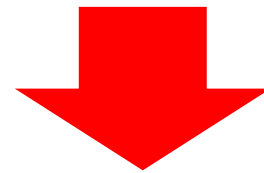




# OLD VS. NEW WOOD



Injection into the **older wood** causes more wounding than injection into the **newer wood** (metabolically more active)



The shallower the injection, the better



# OTHER CONCERNS



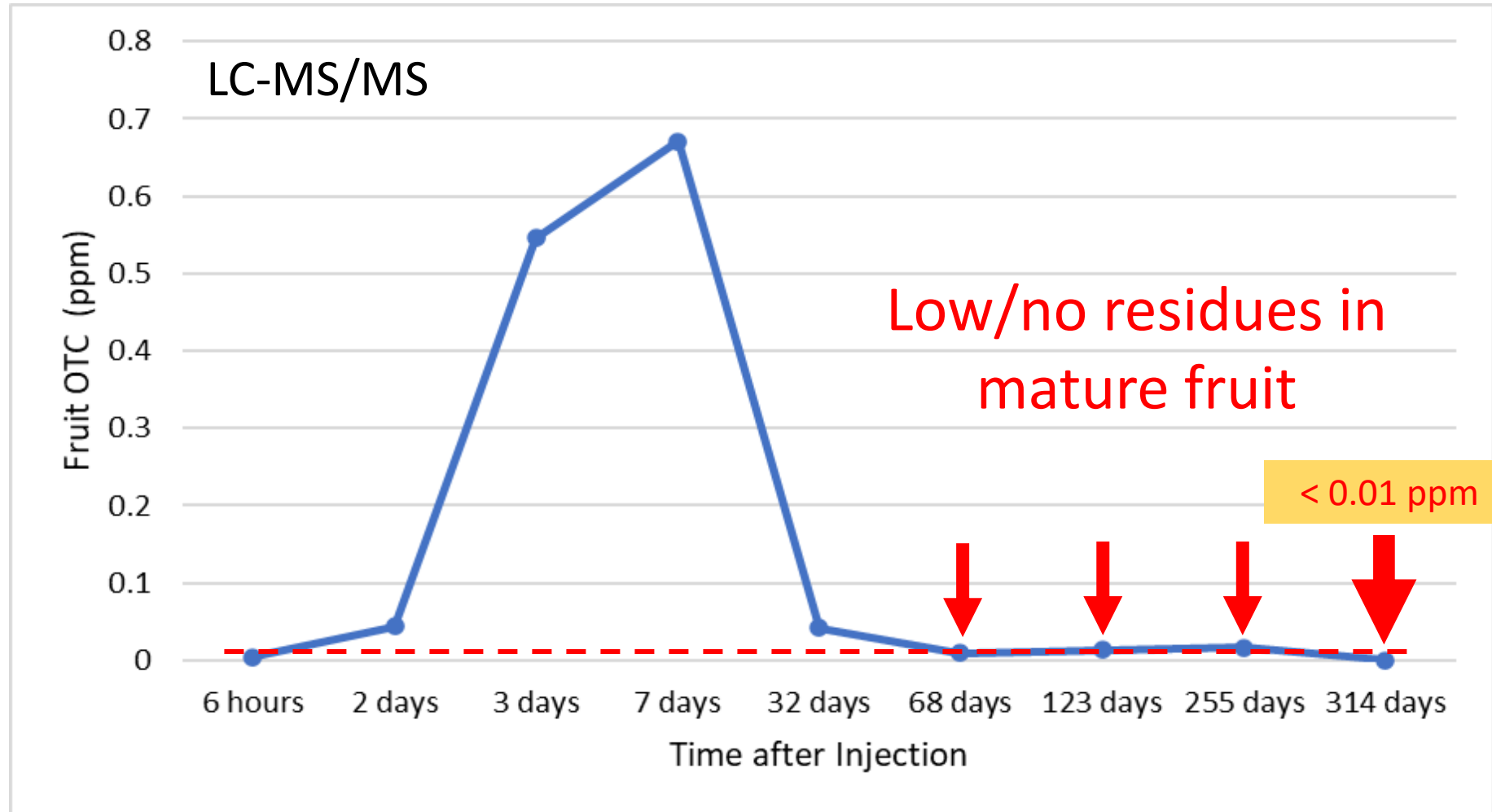


# CONSUMER ACCEPTANCE





# OXYTETRACYCLINE – FRUIT RESIDUES



OTC residues in fruit decreases dramatically within 30-60 days after injection



# ANTIBIOTIC USE IN AGRICULTURE

## 2021 Domestic Sales of Antibiotics for food-producing animals

	<i>Not Medically Important (kg)</i>	<i>Medically Important (kg)</i>	<b>Total (kg)</b>
<b>Commodity</b>			
<b>CATTLE</b>	3,290,231	2,460,766	5,750,997
<b>SWINE</b>	612,622	2,529,800	3,142,422
<b>CHICKEN</b>	983,331	158,342	1,141,673
<b>TURKEY</b>	226,721	659,431	886,152
<b>OTHER</b>	2,205	181,383	183,588
<b><i>TOTAL</i></b>	<b><i>5,115,111</i></b>	<b><i>5,989,721</i></b>	<b><i>11,104,832</i></b>



# ANTIBIOTIC USE IN AGRICULTURE

## 2021 Bearing Applications of Antibiotics in Tree Crops

	<i>Oxytetracycline<sup>1</sup> (kg)</i>	<i>Streptomycin<sup>2</sup> (kg)</i>	<i>Total (kg)</i>
Commodity			
APPLES	14,286	19,229	33,515
GRAPEFRUIT	--	(D)	--
ORANGES	(D)	3,991	3,991
PEACHES	544	(D)	544
PEARS	3,175	2,313	5,488
<b>TOTAL</b>	<b>18,005</b>	<b>25,533</b>	<b>43,538</b>



# THE LABEL





# THE LABEL(S)

FIFRA Section 24(c)  
Special Local Need Label

KW 10/28/2022

ReMedium TI®

**For distribution and use only within Florida.**

ReMedium TI® is a systemic injectable antimicrobial for the control or suppression of Huanglongbing (HLB, Citrus Greening) for Citrus Group 10-10.

OXYTETRACYCLINE GROUP	41	FUNGICIDE/BACTERICIDE
-----------------------	----	-----------------------

**Active Ingredient**

Oxytetracycline Hydrochloride*	95.0%
Other Ingredients	5.0%
Total	100.00%

\*Equivalent to 87.9% Oxytetracycline

**KEEP OUT OF REACH OF CHILDREN**

## CAUTION

See inside booklet for Additional Precautionary Statements,  
Directions for Use and Restrictions.

Si usted no entiende la etiqueta, busque a alguien para que se la  
explique a usted en detalle.

(If you do not understand the label, find someone to explain it to you in detail.)

Sec 24(c) Registrant:

EPA SLN FL220005

Exp. 12/4/2025

Net Contents: 165 Grams

Produced for:

TJ BioTech LLC

PO Box 21

Buffalo, SD 57720

EPA Est. No. 100305-IND-1

Lot No. XXXX

page 1 of 9

FIFRA Section 24(c)  
Special Local Need Label

RECTIFY™

1/30/2023

**For distribution and use only within Florida**

This labeling must be in the possession of the user at the time of the pesticide application

Rectify™ is a systemic injectable bactericide for the control of *Candidatus* *Liberibacter asiaticus* (CLas) or suppression of Huanglongbing (HLB, Citrus Greening) for Citrus Group 10-10.

OXYTETRACYCLINE GROUP	41	FUNGICIDE/BACTERICIDE
-----------------------	----	-----------------------

**Active Ingredient:**

Oxytetracycline Hydrochloride*	95.0%
• Other Ingredients	5.0%
Total	100.0%

\*Equivalent to minimum 88.0% Oxytetracycline

**KEEP OUT OF REACH OF CHILDREN**

## CAUTION

See inside booklet for Additional Precautionary Statements,  
Directions for Use and Restrictions.

Si usted no entiende la etiqueta, busque a alguien para que se la  
explique a usted en detalle.

(If you do not understand the label, find someone to explain it to you in detail.)

Sec 24(c) Registrant:

AgroSource, Inc.

PO Box 3091

Tequesta, FL 33469

EPA SLNFL230001

Expires 12/04/2025

Net Contents:

2.75 lbs. (1248 grams)

EPA Est. No. 65387-AR-2

Lot No. XXXX

Page 1 of 10



# THE LABEL

## 5. Future Injections in the Same Tree

Future injections in the same tree are applied into new holes placed intermediate to the old injection sites. Drill new sites either above or below (by 2" vertically) to the old sites and 2 to 3" horizontally from them. Applied correctly, this will form a triangular pattern with the old sites.

Injecting small, non-bearing trees may cause more harm than benefits, especially when done twice per year

### Non-Bearing Citrus (1,100 ppm Solution)

Trunk Diameter (Inches)	Volume of Solution to Inject
<1.25"	Too small: Do no inject
1.25" – 1.75"	25 mL
1.75" – 2.125"	50 mL

For Non-Bearing Citrus, make up to two applications throughout the growing season, spaced at least 4 months apart.



Use of IPCs is the most effective way to protect young trees from HLB





# THE LABEL

## Label rates

Volume	BEARING TREES			NON-BEARING TREES	
	Trunk diam.	5,500 ppm	11,100 ppm	Trunk diam.	1,100 ppm
25 ml	2.15" – 3"	0.138 g	0.275 g	1.25" - 1.75"	0.0275 g <sup>1</sup>
50 ml	3" - 4.25"	0.275 g	0.55 g	1.75" - 2.125"	0.055 g <sup>1</sup>
100 ml	4.25" – 6"	0.55 g	1.1 g	May cause too much damage	
150 ml	> 6"	0.825 g	1.65 g		

<sup>1</sup> can be injected twice a year

*This document is a suggested use pattern of injectable antimicrobials in Florida citrus. This is not an official University of Florida recommendation. Information is based on FIFRA Section 24(c) Special Local Need Label for ReMedium TI<sup>®</sup> (10/28/2022) and Rectify™ (01/30/2023).*

## Antibacterial Product Application Schedule

Application schedule should be adjusted based on expected harvest time and flowering. The red boxes indicate possible timing of injection. Note that only one application per year is recommended, although non-bearing trees are allowed to be injected up to twice annually with a 4-month interval.

Citrus Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Early Season Varieties (Ex. Hamlin, Navel, Fallglo)												
Mid Season Varieties (Ex. Murcott, Pineapple, Midsweet)												
Late Season Varieties (Ex. Valencia)												
Grapefruit (Ex. Ray Ruby, Flame, Ruby Red)												

The latest possible injection application should be determined based on the 180-day PHI from the expected harvest date.  
Color scale from most desirable (dark) to least desirable (light)

### Application

- DO NOT apply during bloom.
- Recommended use after harvest and during spring.
- Recommended to apply when leaves are fully expanded for efficient uptake and distribution within tree.
- Phytotoxicity can occur in the hottest months of the year.
- ONLY inject once product is fully dissolved.
- ONLY use freshly prepared solution and protect solution from sunlight.

### THE LABEL IS THE LAW!

Refer to the label for additional information.  
This guide does not supersede the label.

### Injection Sites

- Do not re-use injection sites.
- The rootstock is the recommended location for injection, but it may not always be possible.
- Subsequent injections should be above or below the initial site by 2 inches and to the right or left by 2 to 3 inches.
- Do NOT use any post-wounding treatments as these may interfere with wound healing.

**ANTIBACTERIAL PROGRAMS DO NOT  
REPLACE ASIAN CITRUS PSYLLID  
MANAGEMENT PROGRAMS.**



Trunk damage from injections

### Considerations

- Injection into the trunk can cause significant damage to the tree.
- In all trees, it is best to minimize hole diameter.
- Trees with a trunk diameter of less than 2.5 inches are best not injected.
- Minimizing the hole size will minimize tree damage.



ReMedium TI® (EPA # SLN FL220005) Rectify™ (EPA # SLN FL230001)		
Pre-harvest Interval (days)		180
Bearing trees	Max. Number of Applications per Calendar Year	1
	Min. Re-treatment Interval (days)	365
Non-bearing trees	Max. Number of Applications per Calendar Year	2
	Min. Re-treatment Interval (days)	120
Re-entry Interval (hours)		12
Maximum amount of product per tree per year		1.65 g
FRAC Group		41

ReMedium TI® and Rectify™ Personal Protective Equipment (PPE) for Applicators and Handlers	
Coveralls over short sleeved shirt and shorts	Yes <sup>1</sup>
Long sleeve shirt and pants	Yes <sup>2</sup>
Chemical-resistant gloves	Yes <sup>1,2</sup>
Shoes and socks	Yes <sup>1,2</sup>
Protective eyewear	Yes <sup>1,2</sup>
Respirator	Yes <sup>1,3</sup>
Application Method	Injection
<sup>1</sup> Mixers and injection device fillers	
<sup>2</sup> Applicators	
<sup>3</sup> At least a particulate respirator with any N,R, or P filter, NIOSH approval prefix TC-84-A	

ReMedium TI® or Rectify™ Dose per Tree by Trunk Diameter <sup>1</sup>					
Volume	Bearing			Non-bearing	
	Trunk Diameter	5,500 ppm	11,100 ppm	Trunk Diameter	1,100 ppm
25 ml	2.15" – 3"	0.138 g	0.275 g	1.25" – 1.75"	0.0275 g <sup>1</sup>
50 ml	3" – 4.25"	0.275 g	0.55 g	1.75" – 2.125"	0.055 g <sup>1</sup>
100 ml	4.25" – 6"	0.55 g	1.1 g	–	–
150 ml	> 6.0"	0.825 g	1.65 g	–	–
<sup>1</sup> can be injected twice per year but may cause more harm than benefit					

Crop Type
Citrus (group 10-10): Grapefruit, lemon, lime, orange, tangelo, tangerine, citron, kumquat, pummelo, and hybrids of these.

### **DANGER**

Muriatic acid is highly corrosive and can cause severe skin burns and eye damage. Do not inhale fumes.






### **CAUTION**

Injection of oxytetracycline dissolved in acidified solution may cause trunk damage with long-term effects not yet established.

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***Muriatic acid, also known as Hydrochloric Acid or Hydrogen Chloride (HCl), is a highly caustic liquid. To protect workers from burns and other injuries, it is important to use appropriate safety precautions.***

<b>Personal Protective Equipment (PPE) for Handlers</b>	
<b>Protective clothing</b> – Chemical resistant apron or Tyvek (OSHA level C)	
<b>Chemical-resistant gloves</b> – gauntlet-style, neoprene, nitrile, butyl rubber, PVC	
<b>Rubber boots</b>	
<b>Protective eyewear</b> – Tightly fitting safety goggles (NIOSH rating D3) and 8-inch face shield. DO NOT wear contact lenses	
<b>Ventilation</b>	Good room ventilation and local exhaust required if used in an enclosed space
<b>Respirator for enclosed spaces with insufficient ventilation</b> - NIOSH-Approved air-purifying respirator with acid gas cartridge and HEPA filter	
<b>Other protective equipment</b>	Eye wash station, safety shower, spill kit

## **DANGER**

Muriatic acid is highly corrosive and can cause severe skin burns and eye damage. Do NOT inhale fumes.



The GHS hazard pictograms for free download ([reach-compliance.ch](http://reach-compliance.ch))

- Keep in original container
- Always add acid to water NOT water to acid
- Wash thoroughly after handling
- Do NOT eat, drink, or smoke when using product

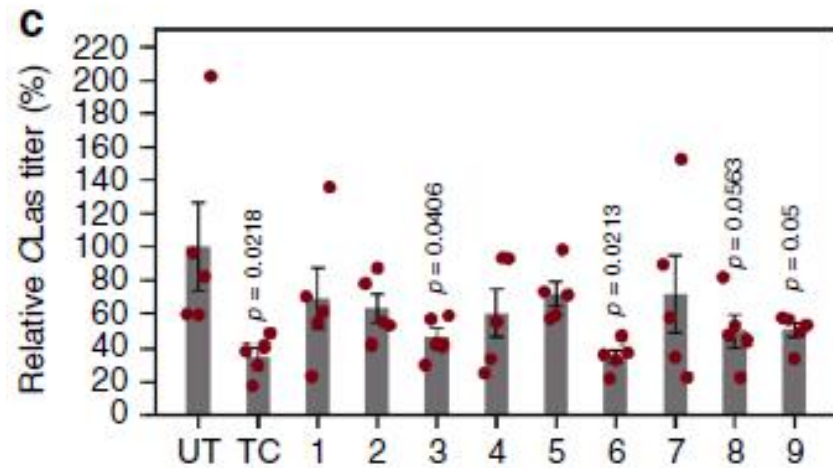
1. U. Albrecht, associate professor, Department of Horticulture Sciences, Southwest Florida Research and Education Center, O. Batuman, assistant professor, Department of Plant Pathology, Southwest Florida REC, and Megan M. Dewdney, associate professor, Department of Plant Pathology, Citrus REC; UF/IFAS Extension; Gainesville, FL 32611.

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# NEED FOR NEW THERAPIES

CLas-citrus hairy roots

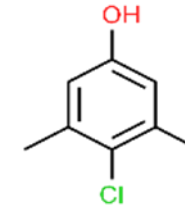


Irigoyen et al. 2020

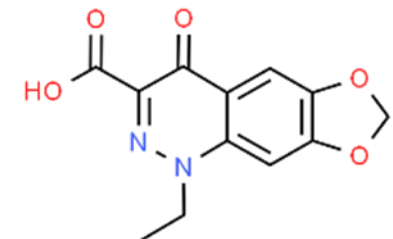


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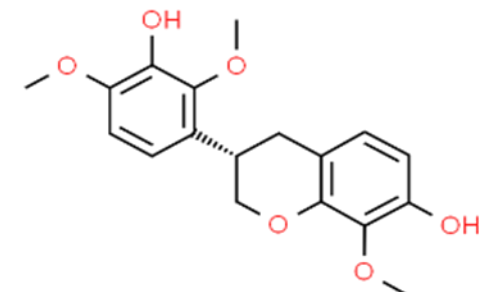
3



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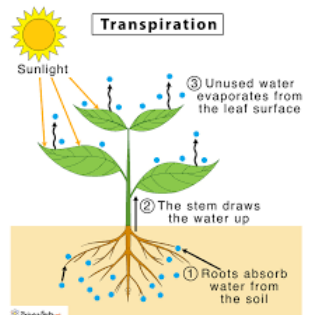
# BEST PRACTICES





# BEST PRACTICES

- Inject after harvest and after the main flowering period to prevent exposure to pollinators
- Uptake and distribution of injected materials is driven by transpiration, therefore:
  - Inject when leaves are fully expanded (not during leaf flush) to ensure efficient uptake and distribution of injected materials.
  - Inject during mid- to late morning when trees are actively transpiring. Injections in the afternoon are likely less effective and may also increase the risk for phytotoxicity.
  - Uptake is better when trees are well watered



# BEST PRACTICES

- Avoid injecting during the hottest time of the season (and day). There have been reports of phytotoxicity (leaf bronzing) when injections were conducted in August
- Use a sharp brad-point drill bit for drilling the hole to minimize injury
- Drill the hole no deeper than necessary → the deeper the drill bit, the more damage occurs in the trunk
- Do not use any wound sealants or plugs to seal the wounds – these inhibit the trees' ability to heal





# BEST PRACTICES

- Remember that trees will become re-infected → **Oxytetracycline injections are no replacement for psyllid control**
- Injecting non-bearing trees with a small trunk diameter may cause more harm than benefit
- Inject trees only once annually and leave a pre-harvest interval of at least 180 days
- Follow label directions. The label is the law.



# Thank You

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CRDF #22-001

Grower Collaborators







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