Citrus Trunk Injection Research Update

Ute Albrecht
University of Florida/IFAS
Southwest Florida Research and Education Center, Immokalee, FL

Virtual Seminar, 22 July 2022

UF | IFAS
UNIVERSITY *of* FLORIDA

Thank You

USDA-NIFA-SCRI #2019-70016-29096

CRDF 22-001

Grower Collaborators

Dr. Leigh Archer

OUTLINE

- Background Information
- Preliminary Research
- Field Trials
- Tree Injury

✓ **Background Information**

- Preliminary Research
- Field Trials
- Tree Injury

"Trunk injection"

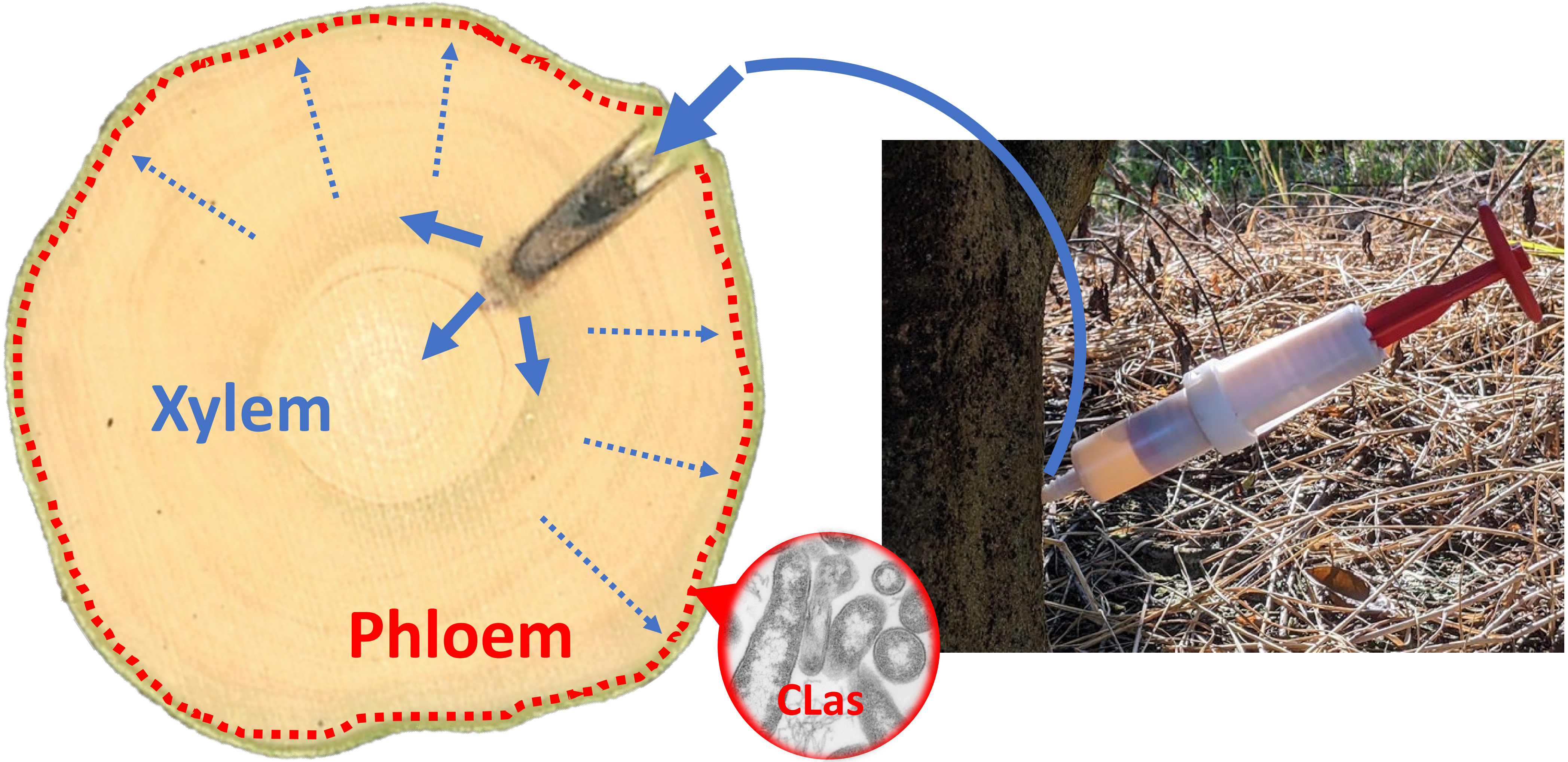
- First evidence (12th century) → Arabic horticulturists applied perfumes, spices, dyes, and other things to wounds to affect the smell, color, or other attributes of flowers and fruits (solid "injection")
- First documented experimentation (15th century) → Leonardo da Vinci injected arsenic and other poisonous solutions through bore holes into apple trees to make the fruit poisonous (liquid injection)

Trunk injection – modern definition

- The targeted delivery of crop protection materials into the stem or trunk of a woody plant as an alternative to spraying or soil drenching ("endotherapy")

- Injection occurs into the **xylem** (not phloem) from where the materials are then distributed throughout the plant with the transpiration stream

Trunk injection in citrus trees



Modern areas of use

- Forest trees, non-crop-bearing ornamental trees, large woody shrubs, and palms in residential and commercial landscapes
- Some crop-bearing agricultural crops (e.g., avocado, peach, pear)

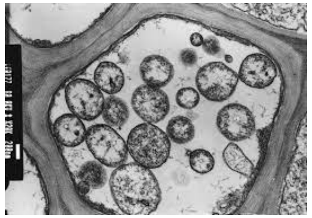
→ *20% of the commercial avocado acreage (~6000 acres) in Florida is managed for laurel wilt by trunk injections*

Targets

- *Insects* (stem and leaf feeding, bark boring)
- *Nematodes* (wood nematodes)
- *Fungi* (e.g., vascular wilt, powdery mildew, phytopthora)
- *Bacteria* (e.g., fire blight, blossom blight, bacterial blast)
- *Phytoplasmas* (lethal yellows/bronzing)
- *Other* (delivery of nutrients, growth regulators, etc.)





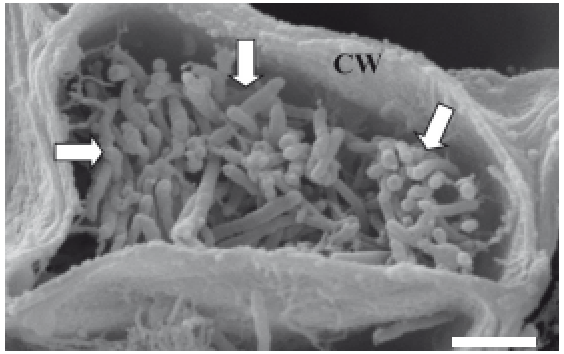



Advantages

- 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

Trunk injection – HLB

CLas is phloem-limited

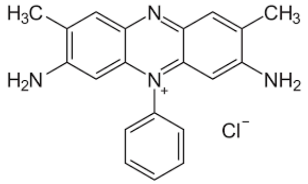


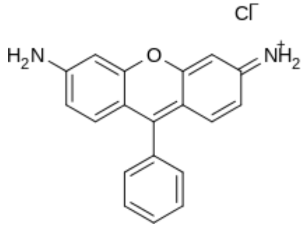
Martinez et al. 1970
Schwarz and Van Vuren 1970
Moll and Van Vuuren 1977
Chiu et al. 1979
Aubert and Bove 1980
Cheema et al. 1986

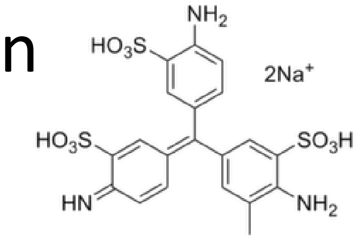
Hu and Wang 2016
Hu et al. 2018
Zhang et al. 2019
Li et al. 2019
Li et al. 2021

- ✓ Background Information
- ✓ **Preliminary Research**
- Field Trials
- Tree Injury

Compound mobility

Safranin 

Rhodamine 

Acid Fuchsin 

Formulation matters!

Methods of injection





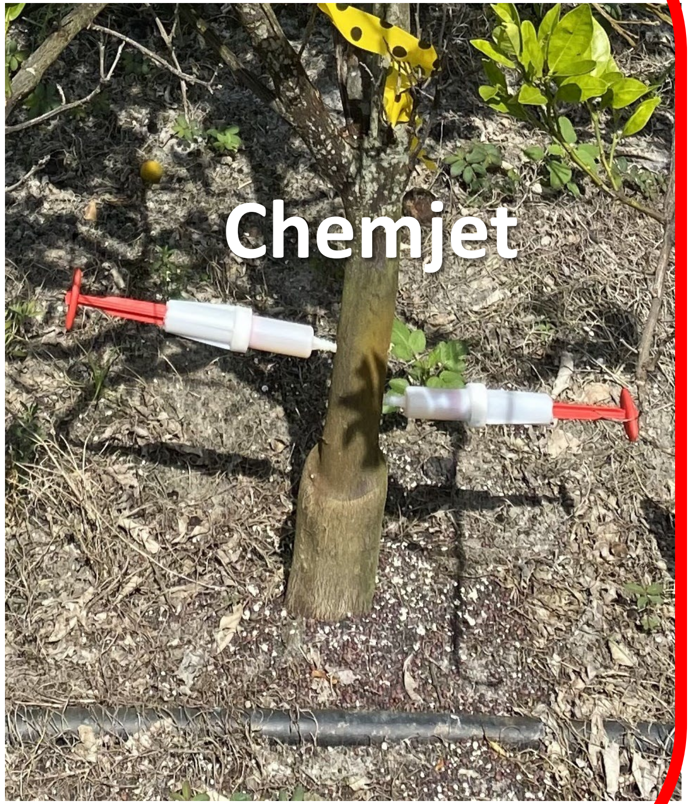



Most technologies are drill-based. Few are no-drill (needle)-based.
All require relatively large injection holes.

Injection pressure

INJECTION

High pressure



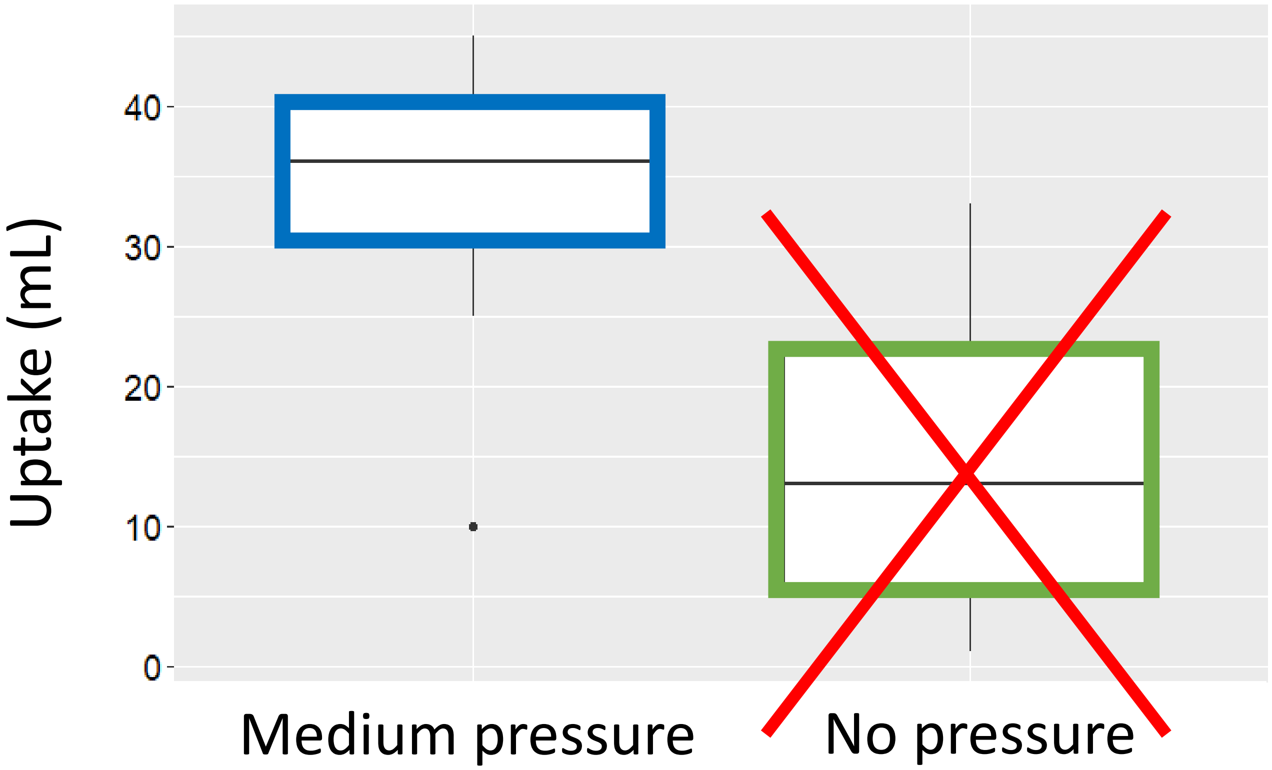
Medium pressure

INFUSION

Low pressure

No pressure

Efficacy



High pressure vs. medium pressure

HIGH PRESSURE INJECTION

Water | Oxytetracycline | Imidacloprid

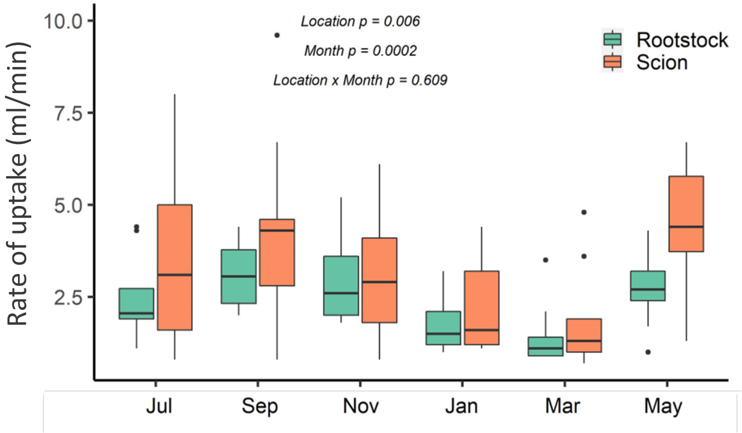
MEDIUM PRESSURE INJECTION

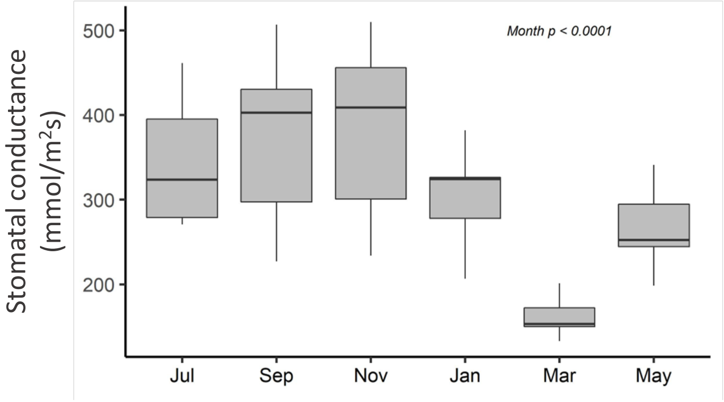
Water | Oxytetracycline | Imidacloprid

High pressure injection in combination with plugs causes greater injury

Other results

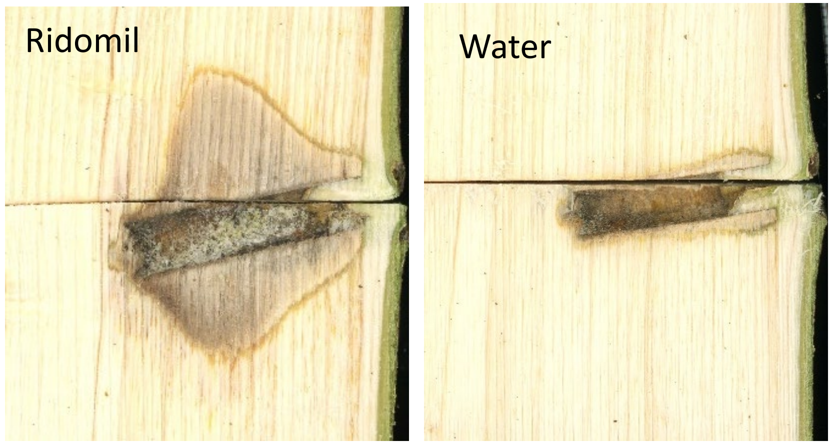
- The speed of uptake and distribution depends on the transpiration rate of the tree (which depends on weather, season, time of day, etc., and the physiological state of the tree)
- The uptake and distribution of injected compounds may vary between rootstock and scion

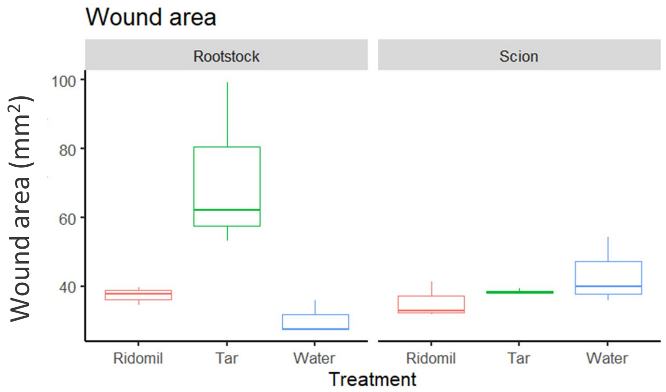


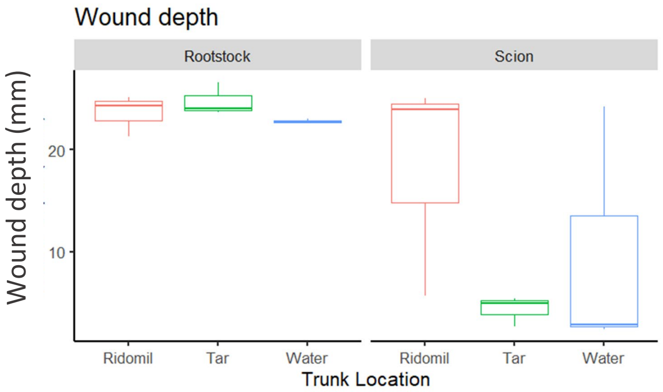


Other results

- It is better to leave wounds alone as post-injection treatments may interfere with wound healing
- Wound closure is faster when injections occur in the spring than in the fall
- Wound closure efficiency may differ in rootstock and scion







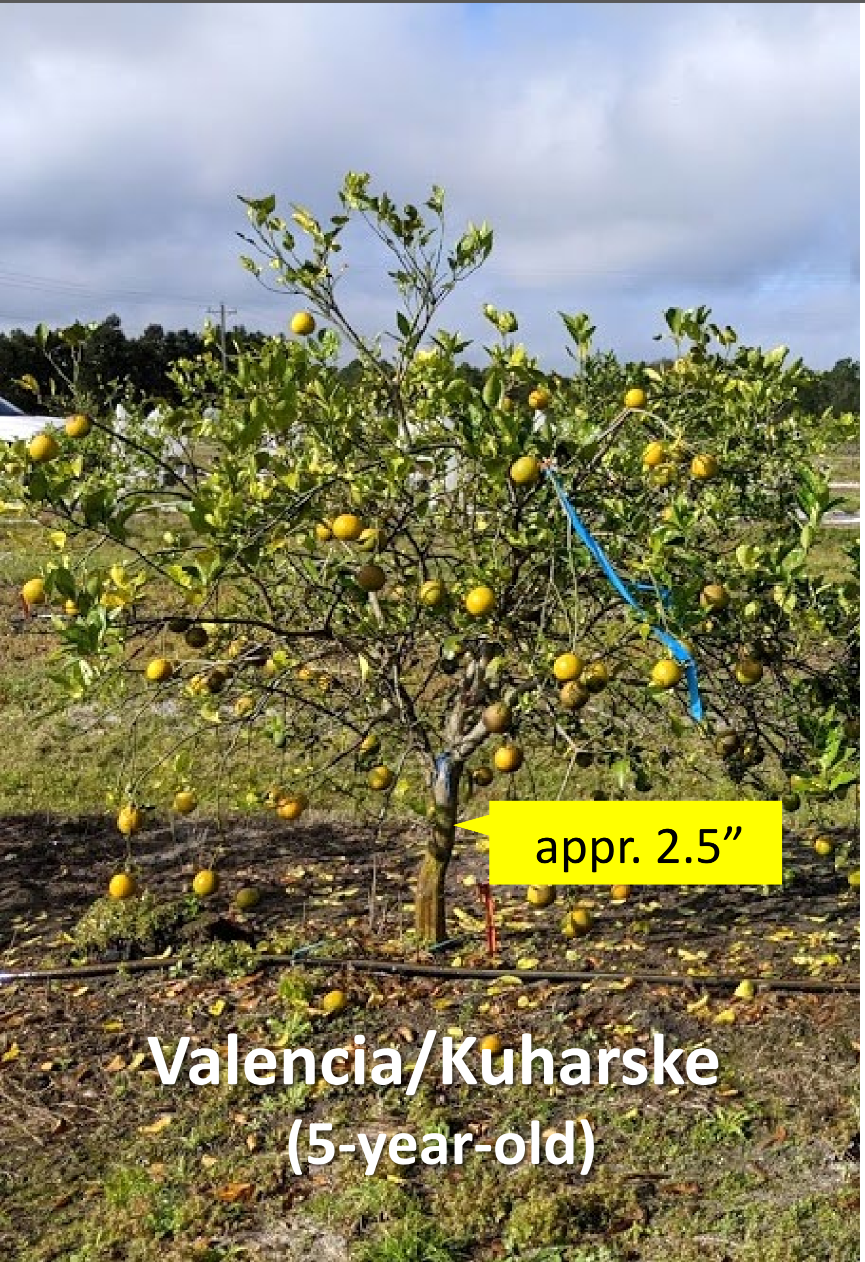
✓ Background Information

✓ Preliminary Research

✓ **Field Trials**

- Tree Injury

Valencia trial



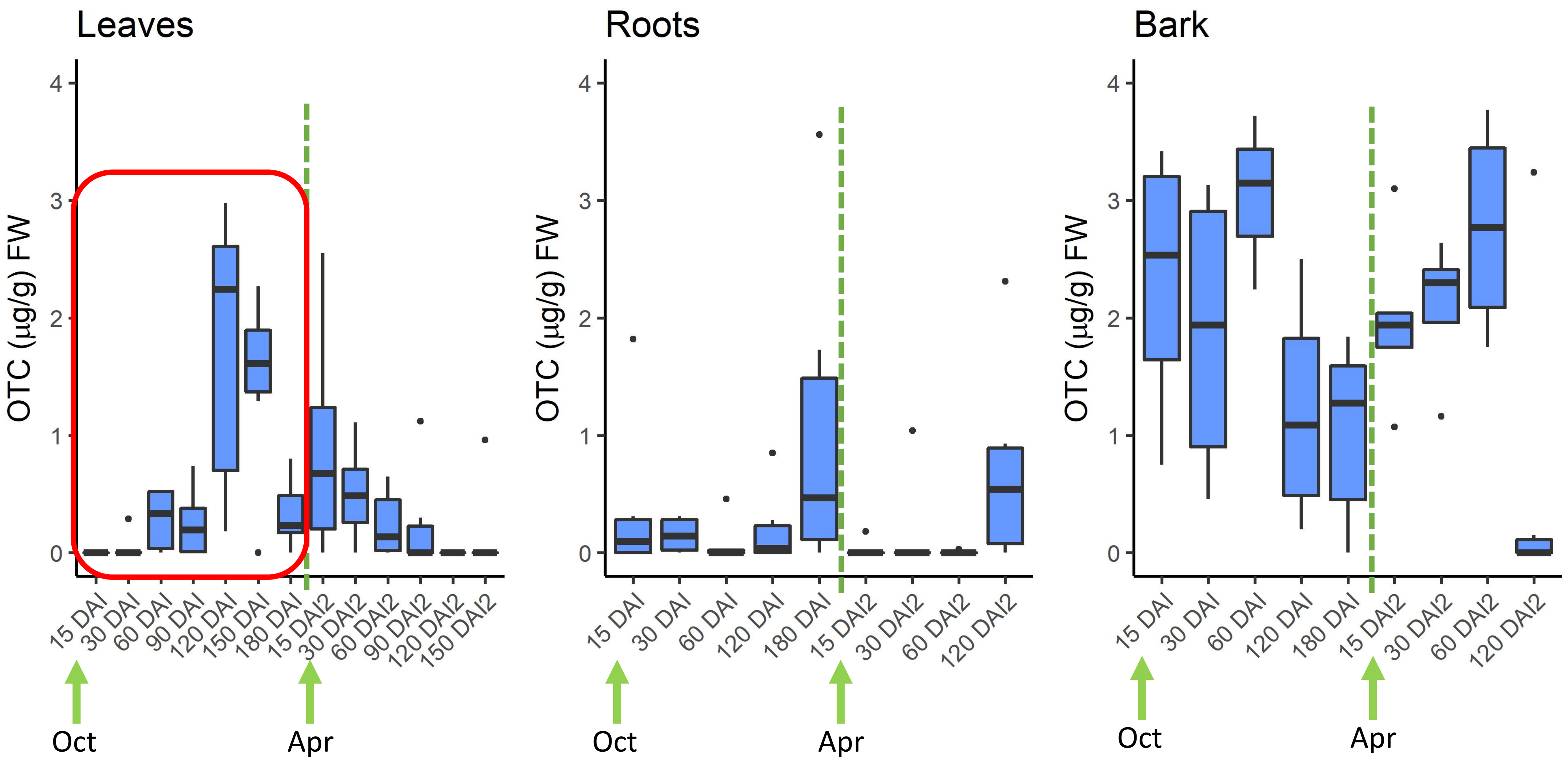
Injections performed in Oct 2020 and April 2021:

1. Oxytetracycline (OTC)
   - ✓ Arbor-OTC (Arborjet Inc.) @ 0.79g a.i./tree
2. Imidacloprid (IMI)
   - ✓ Xytect (Rainbow Ecoscience) @ 0.4 g a.i./tree
3. Water injection
4. No Injection

Injections were performed into the scion using 2 chemjets (1 each on opposite sides). Each chemjet holds a volume of 20 ml. Trunk diameters at injection site were approximately 2.5 “.

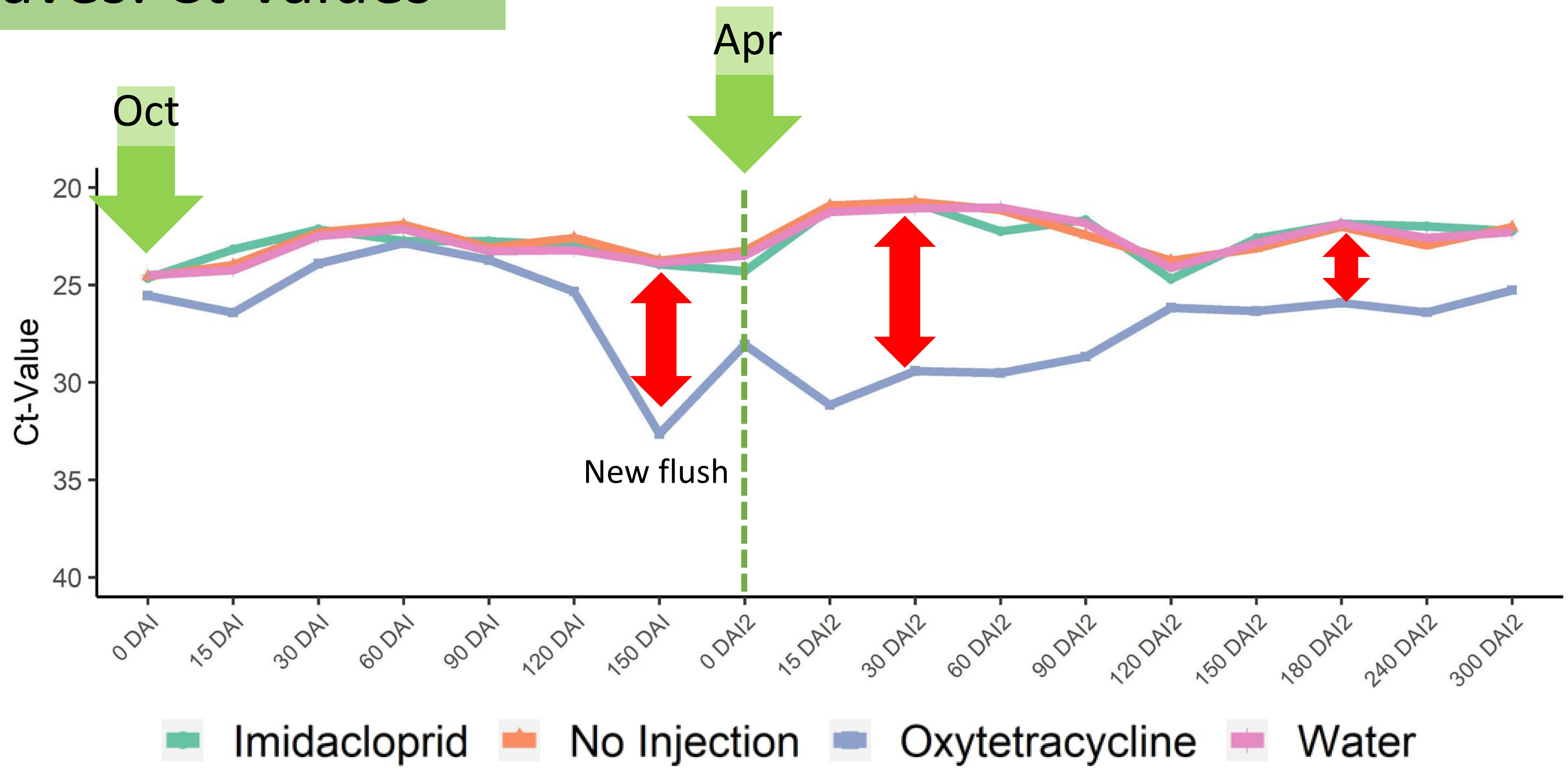

DEWALT

OTC Residues



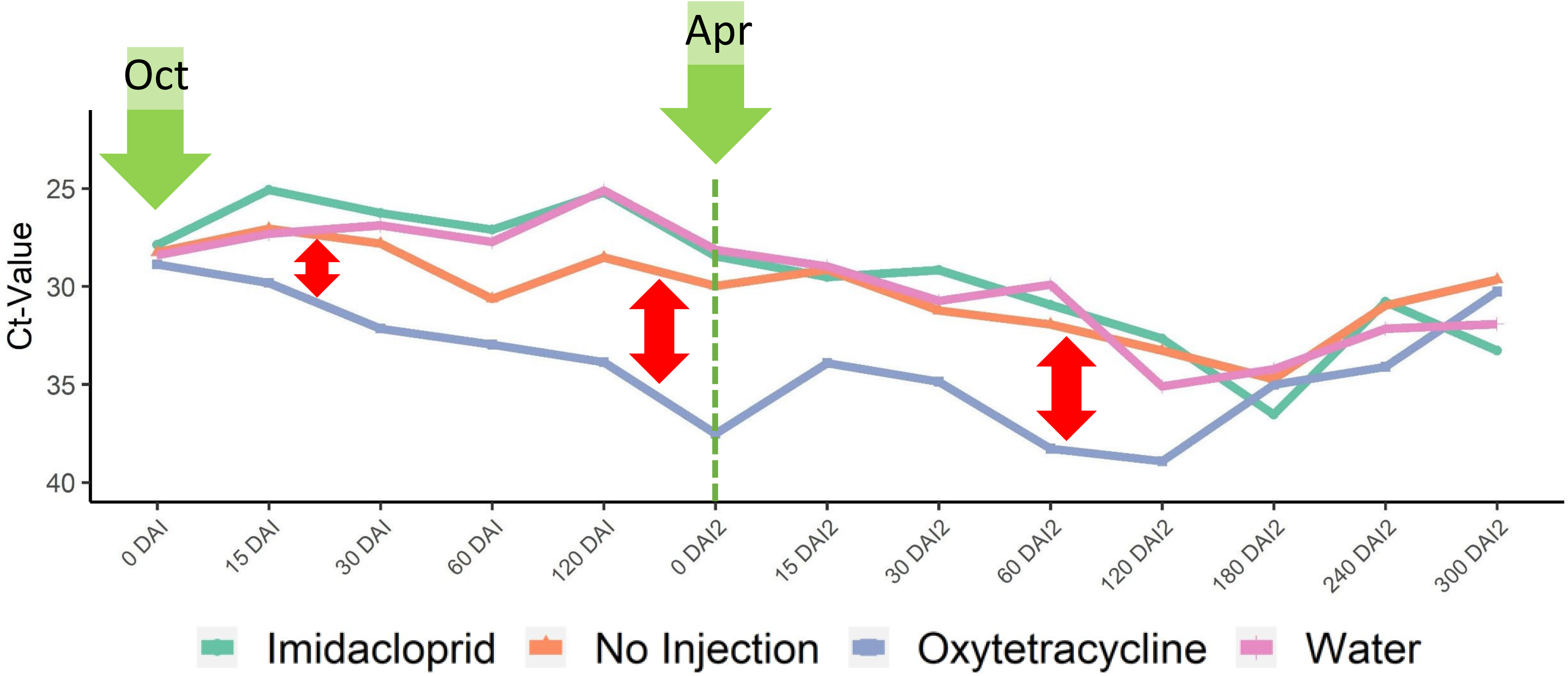
CLas titer

Leaves: Ct-values

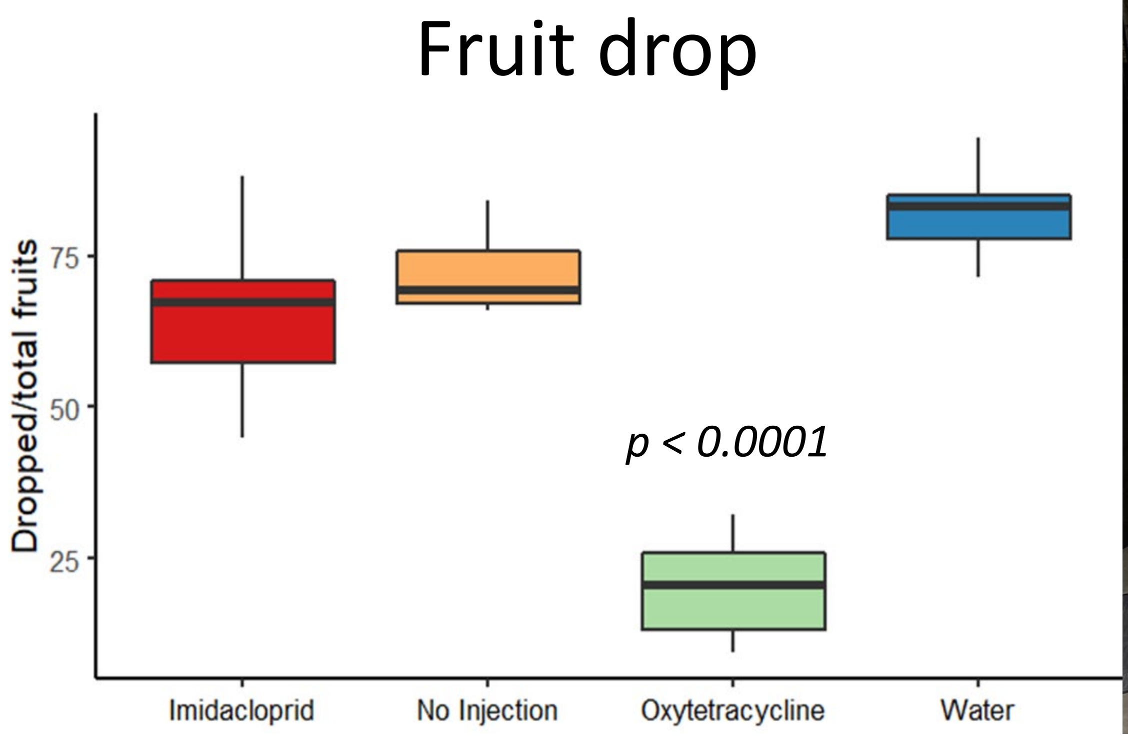


CLas titer

Roots: Ct-values

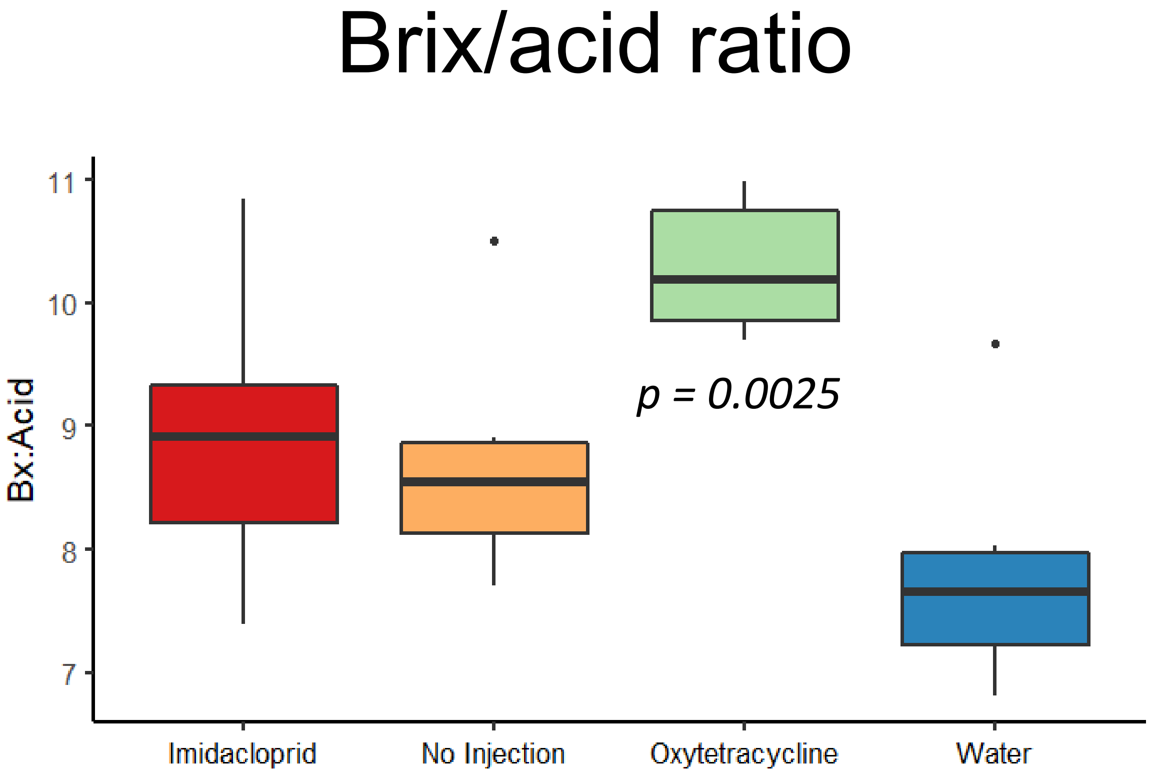


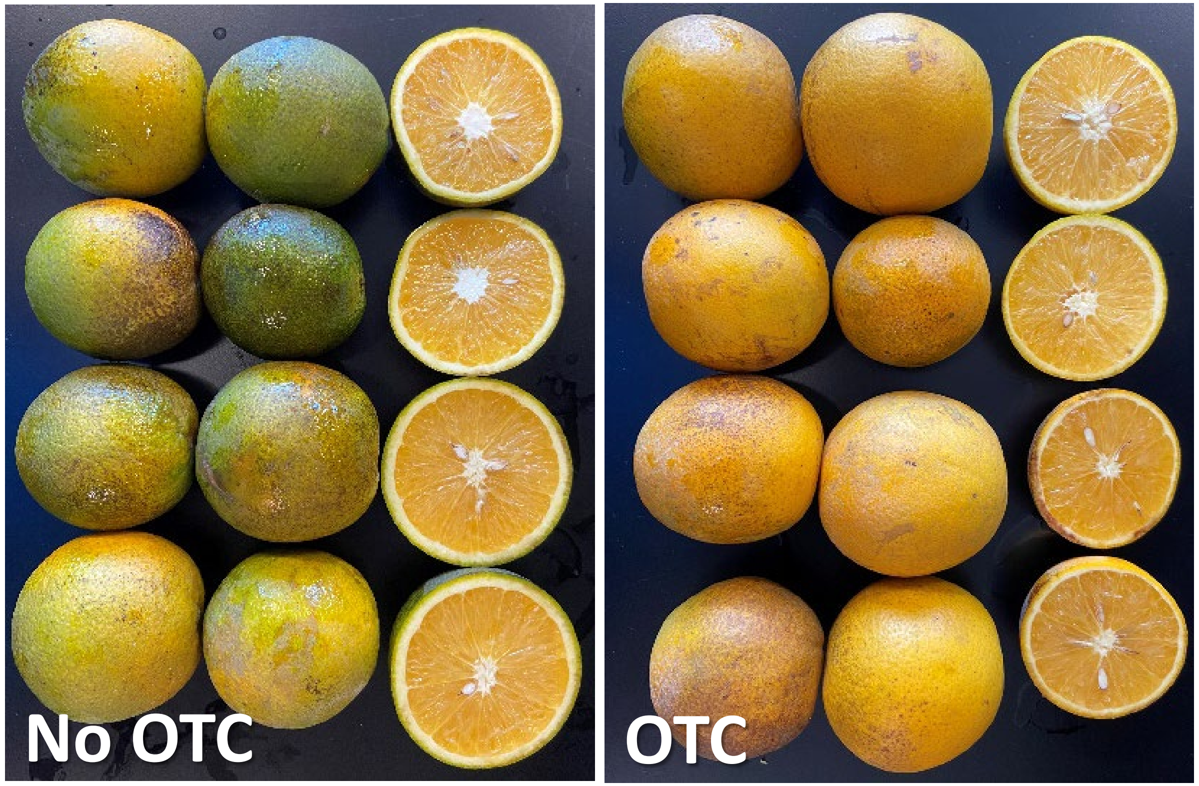
Fruit drop and yield



OTC reduced fruit drop and increased yield significantly

Fruit quality

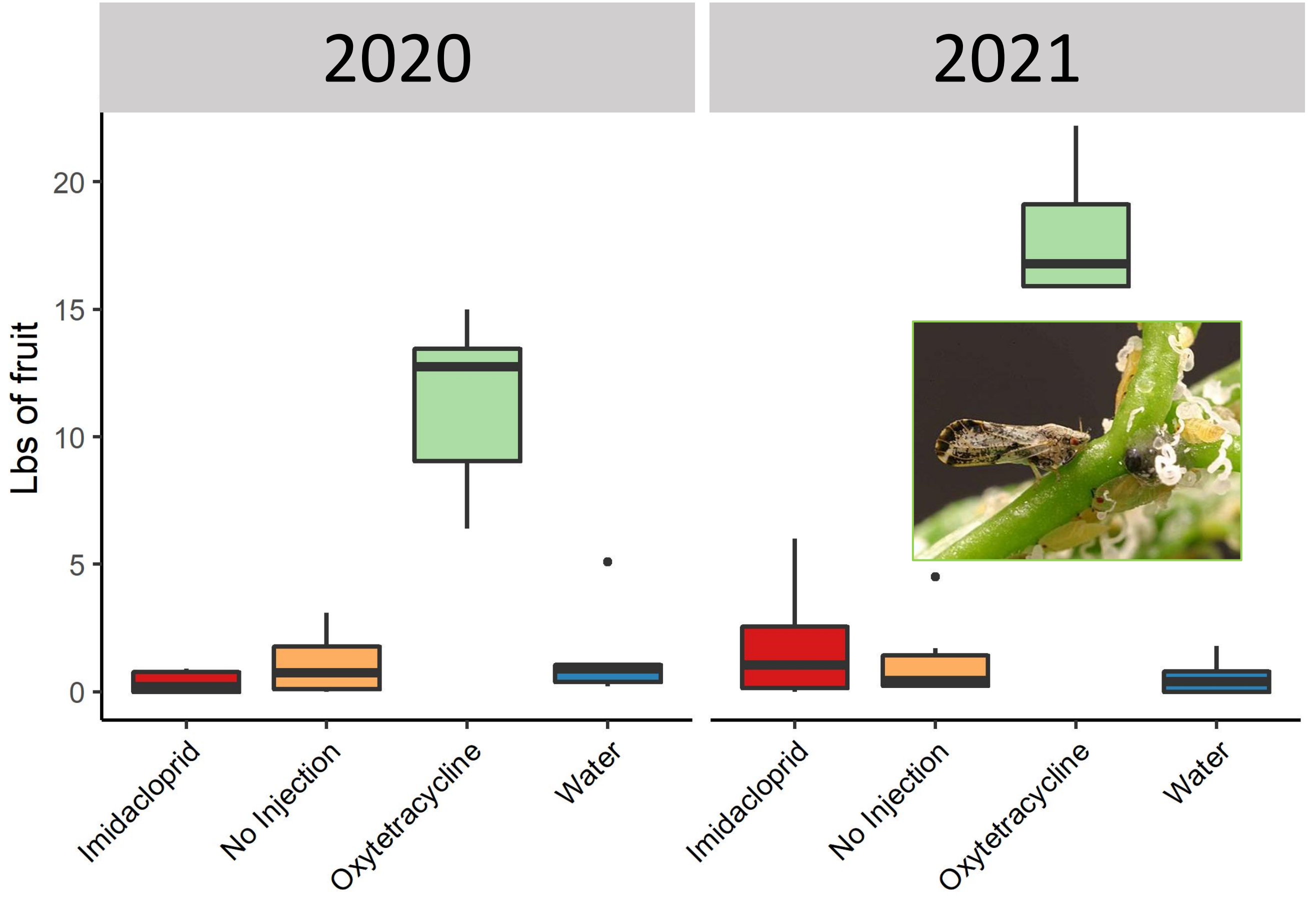




OTC improved internal and external fruit quality significantly

Tree health

Midsweet study



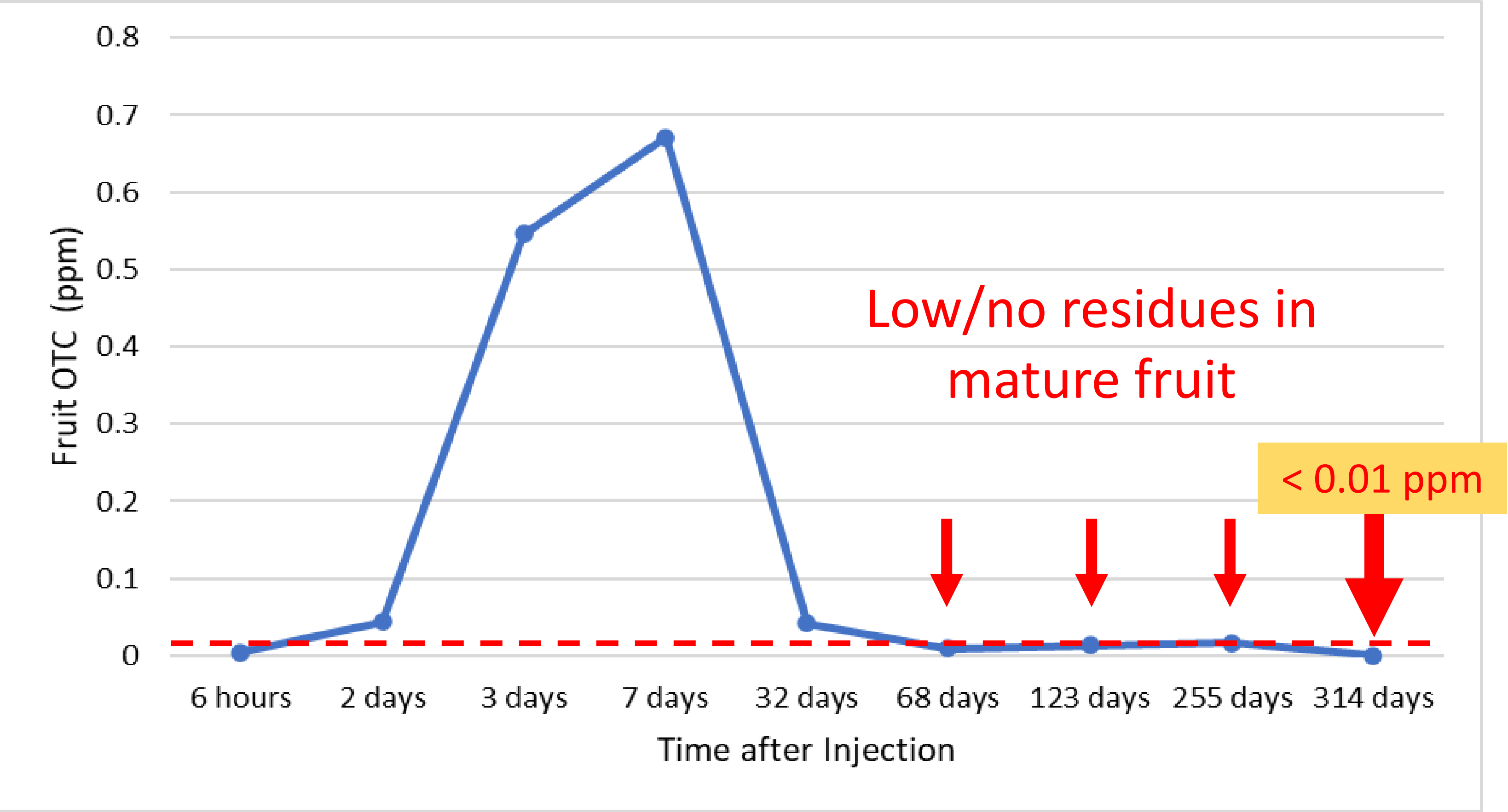
Effect of OTC on fruit production remained in year 2 without any additional injection (but CLas titers increased again)

→ Injections may not need to be performed every year

Fruit size

Fruits are larger after spring injection than after fall injection

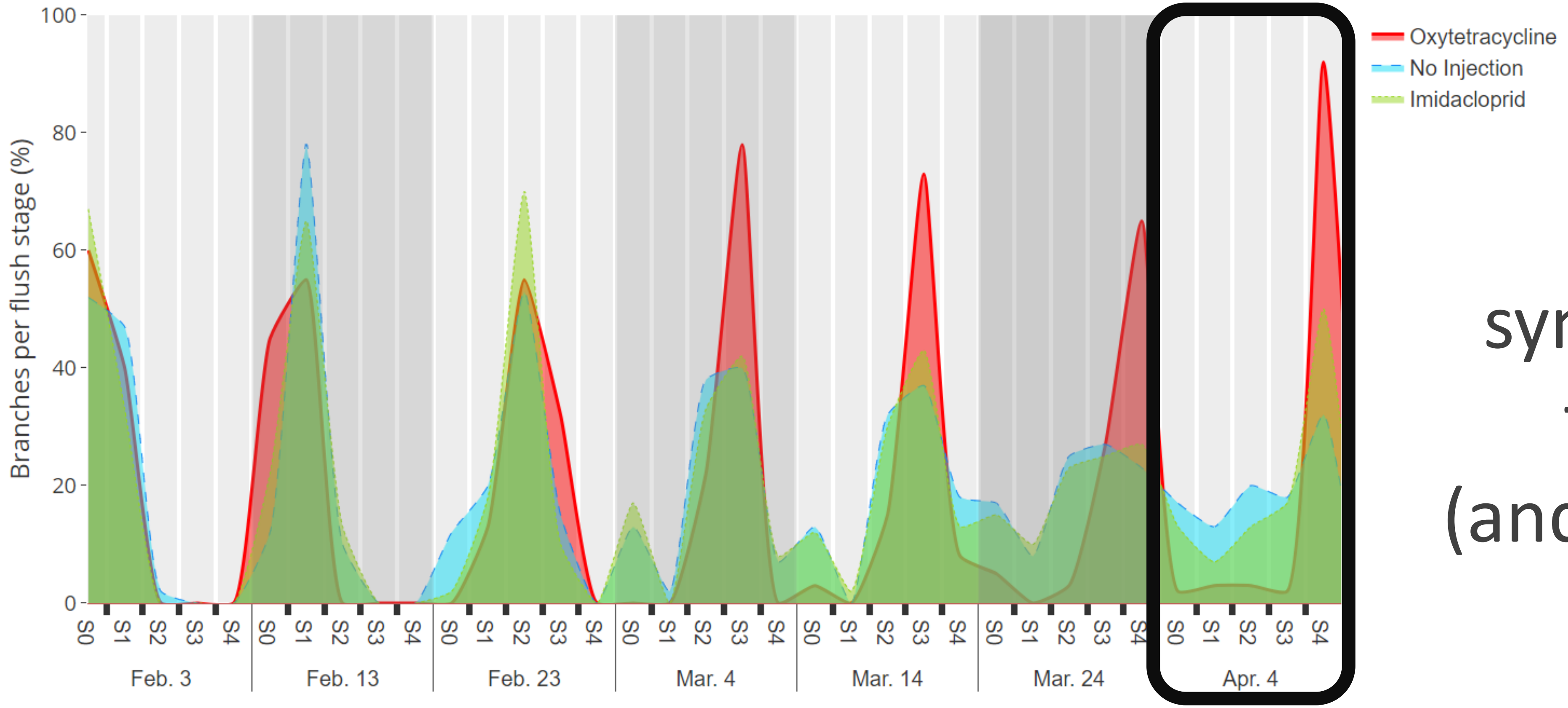
Fruit residues



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

Flushing phenology

Stage 0: No Flush | Stage 1: Feather Flush | Stage 2: Flush Elongation | Stage 3: Leaf Expansion | Stage 4: Leaf Hardening



OTC synchronizes flushing (and flowering)

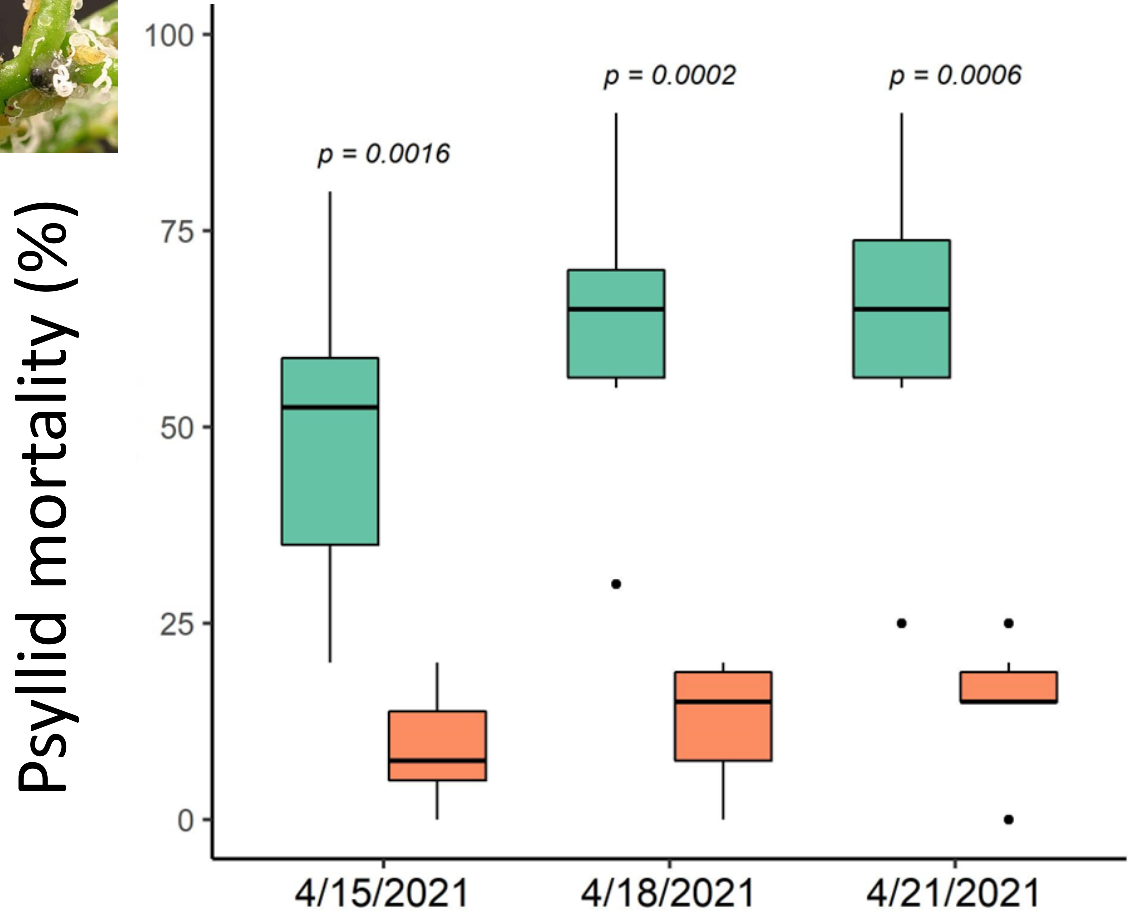
Flushing phenology

Oxytetracycline

Water Control

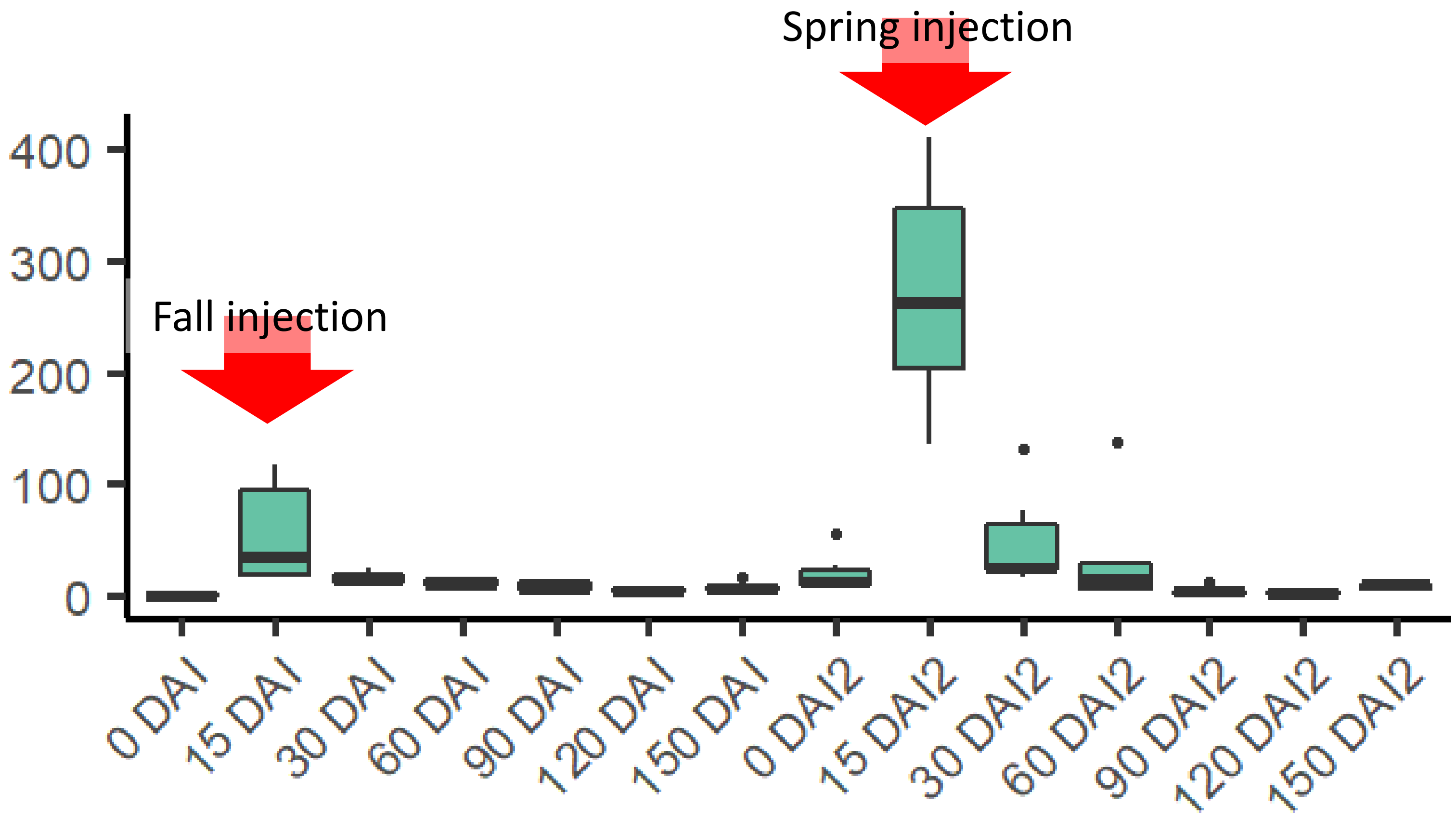
Imidacloprid efficacy

Imidacloprid efficacy



IMI significantly increased psyllid mortality 2 weeks after injection (4/5/2021), but not after 2 months

Leaf residue levels



Higher leaf residues were found after spring injection. But residue levels were low within 1-2 months after injection

Other Trials

Trees

Mature Hamlin, Valencia, and Duncan

Scion trunk diam. 4.0-5.5”

Treatments

OTC injected in April, October, or both

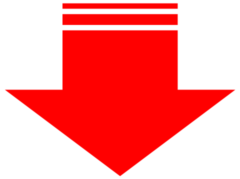
The rate of OTC was the same as for the smaller trees (0.79g a.i. per tree)

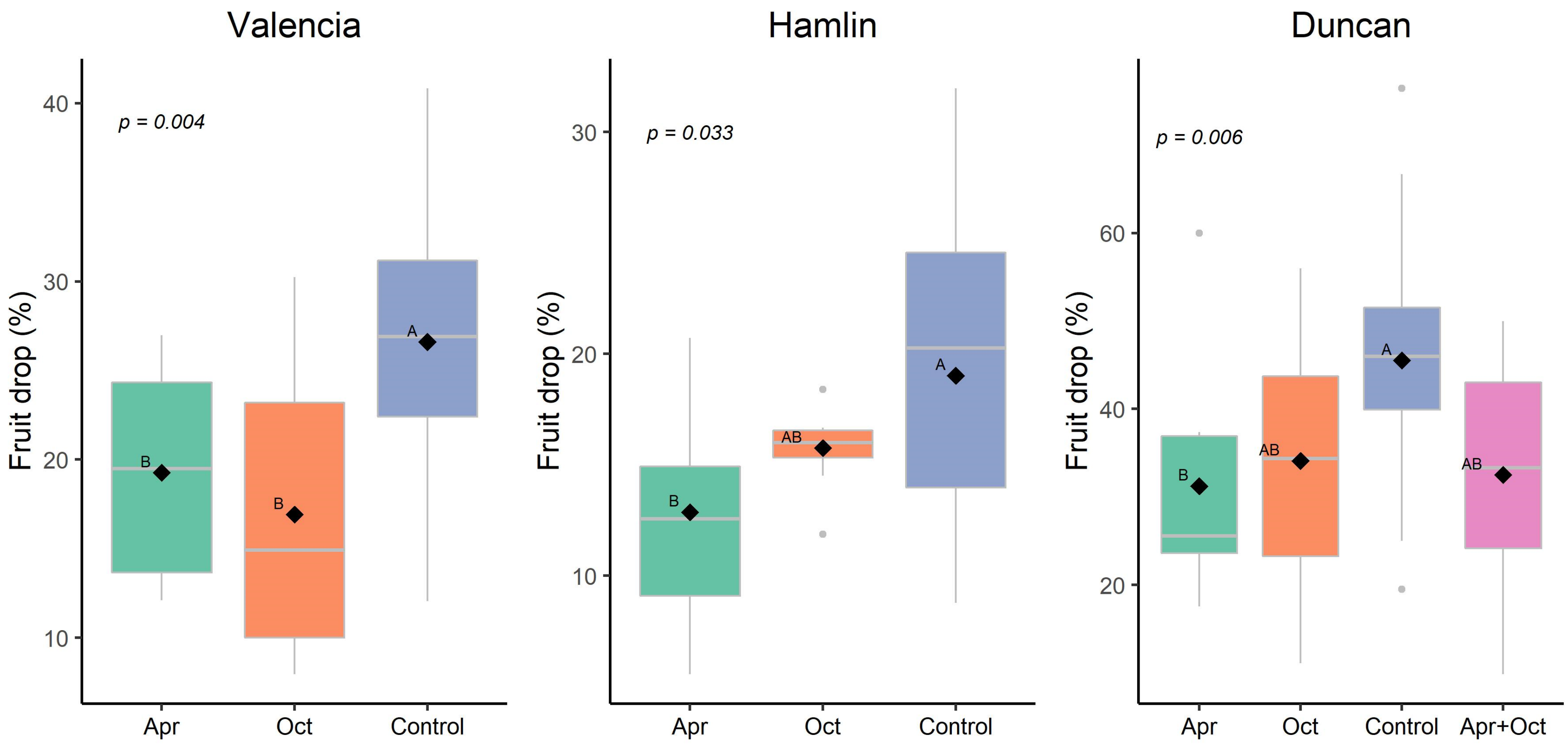





Other Trials

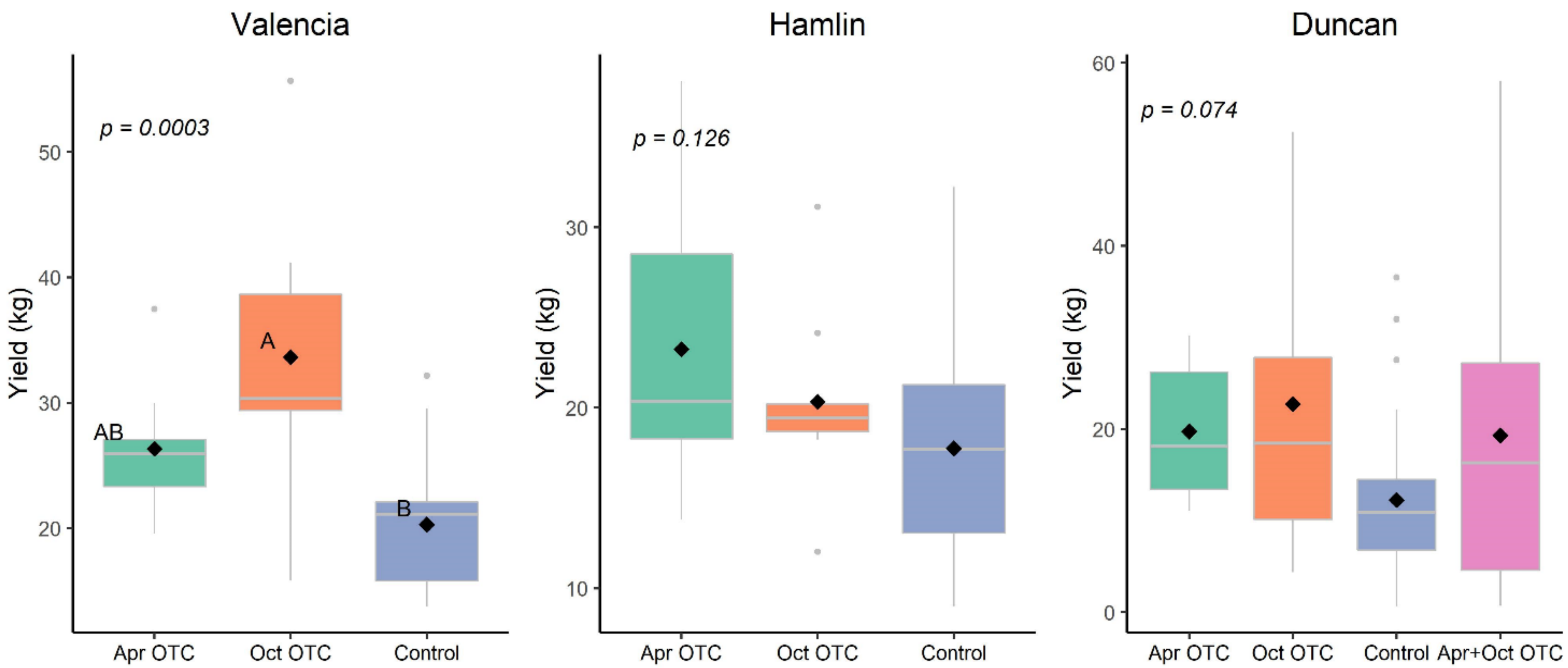
FRUIT DROP





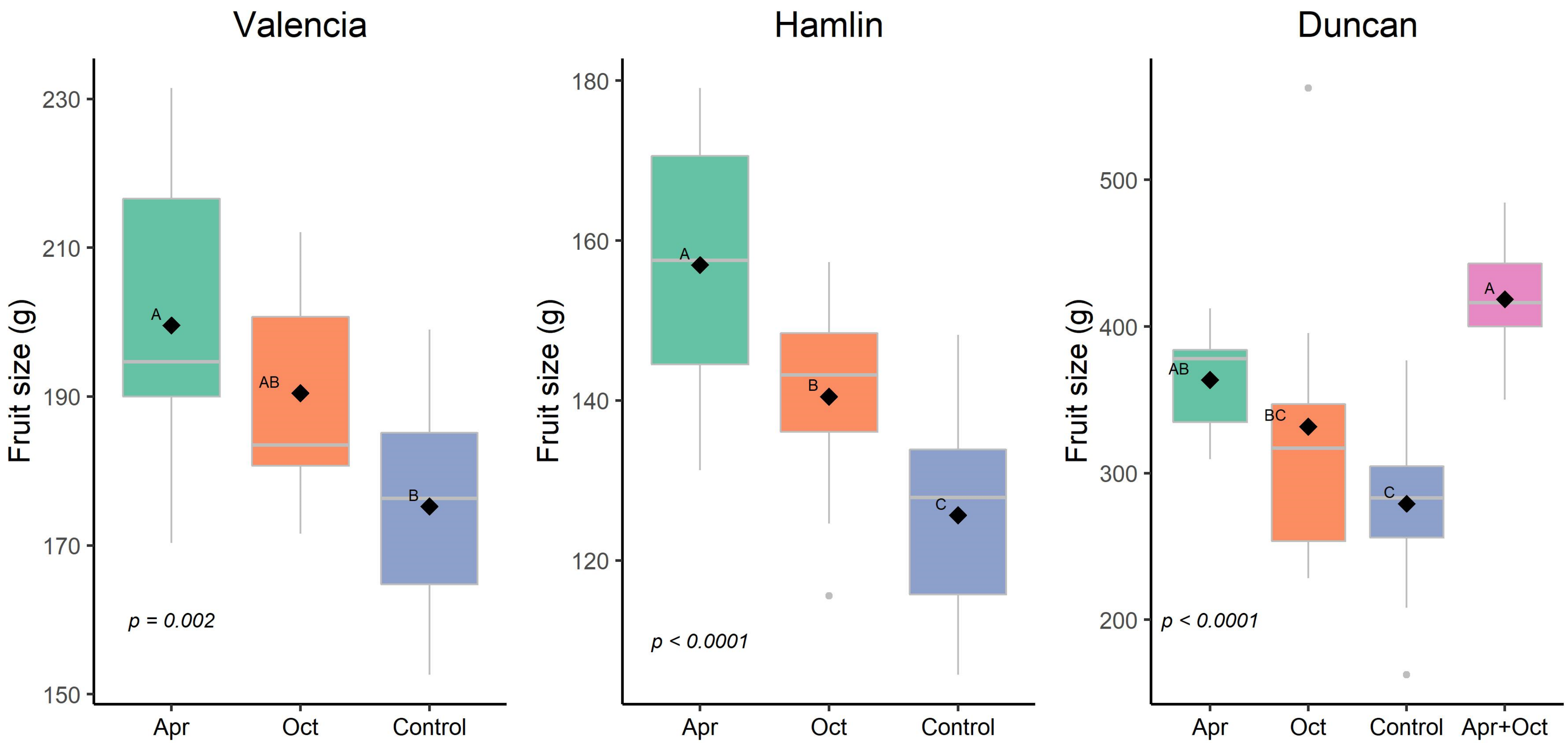
Other Trials

YIELD



Other Trials

FRUIT SIZE



Duncan Grapefruit

Ongoing Trials

1. **Valencia/Carrizo – 8?-yrs-old – SW Florida**
   - Different OTC rates
   - Timing of injections

   5.5”

2. **Valencia/Kuharske – 8-yrs-old – SW Florida**
   - Different OTC rates
   - Different volumes

   5”

3. **Valencia/SO – 9-yrs-old – East Coast**
   - Different OTC rates
   - Different OTC formulations
   - Different technologies/methodologies

   4.5”

4. **Valencia/X639 – 4-yrs-old – East Coast**
   - Different OTC rates
   - Timing of injection
   - Different technologies/methodologies
   - Rootstock vs. scion

   2.5 – 3”

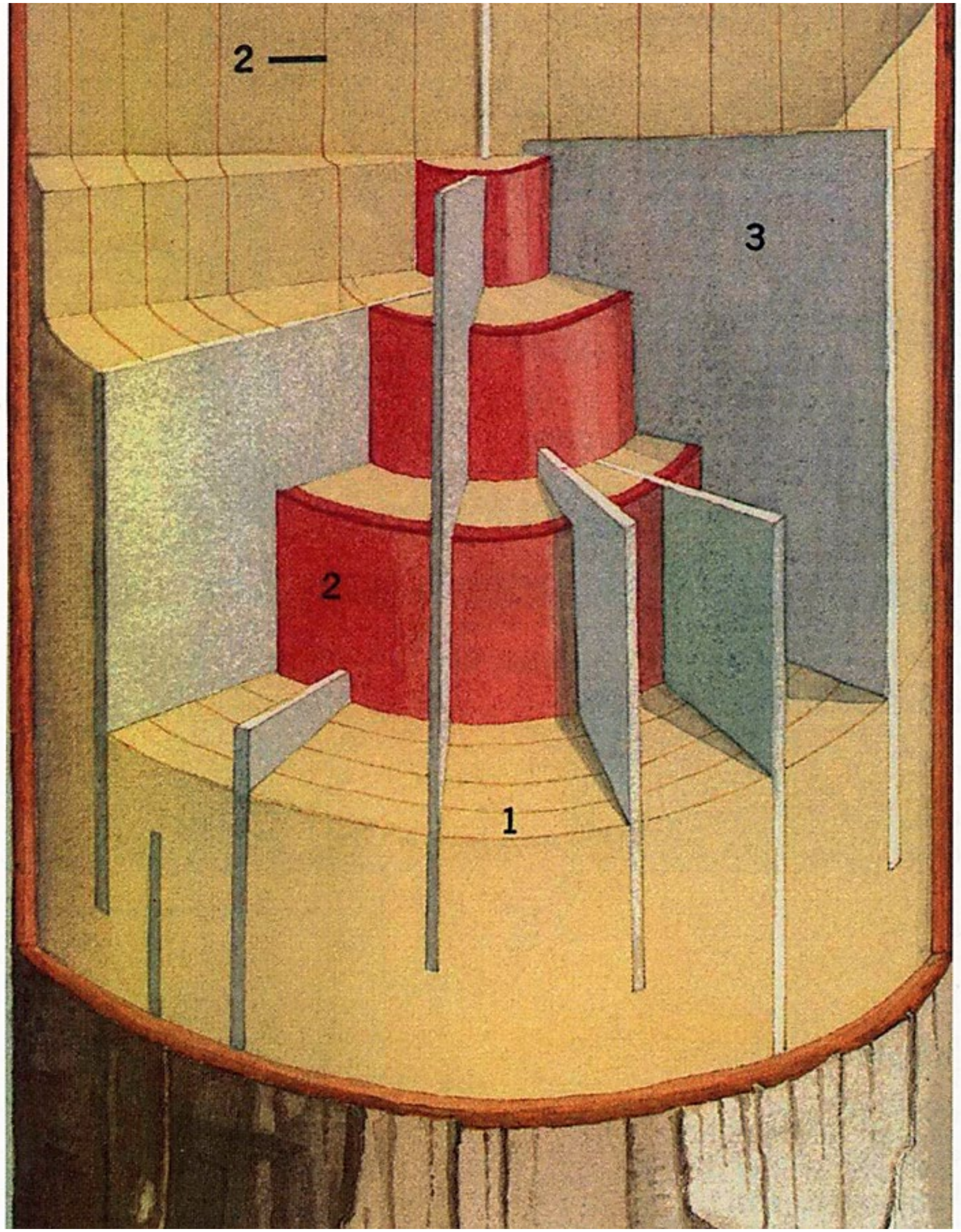
5. **OLL-8/X639 – 4-yrs-old – Central Ridge**
   - Same as trial 4

All crop will be destroyed

- ✓ Background Information
- ✓ Preliminary Research
- ✓ Field Trials
- ✓ **Tree Injury**

Tree injury

Wound compartmentalization



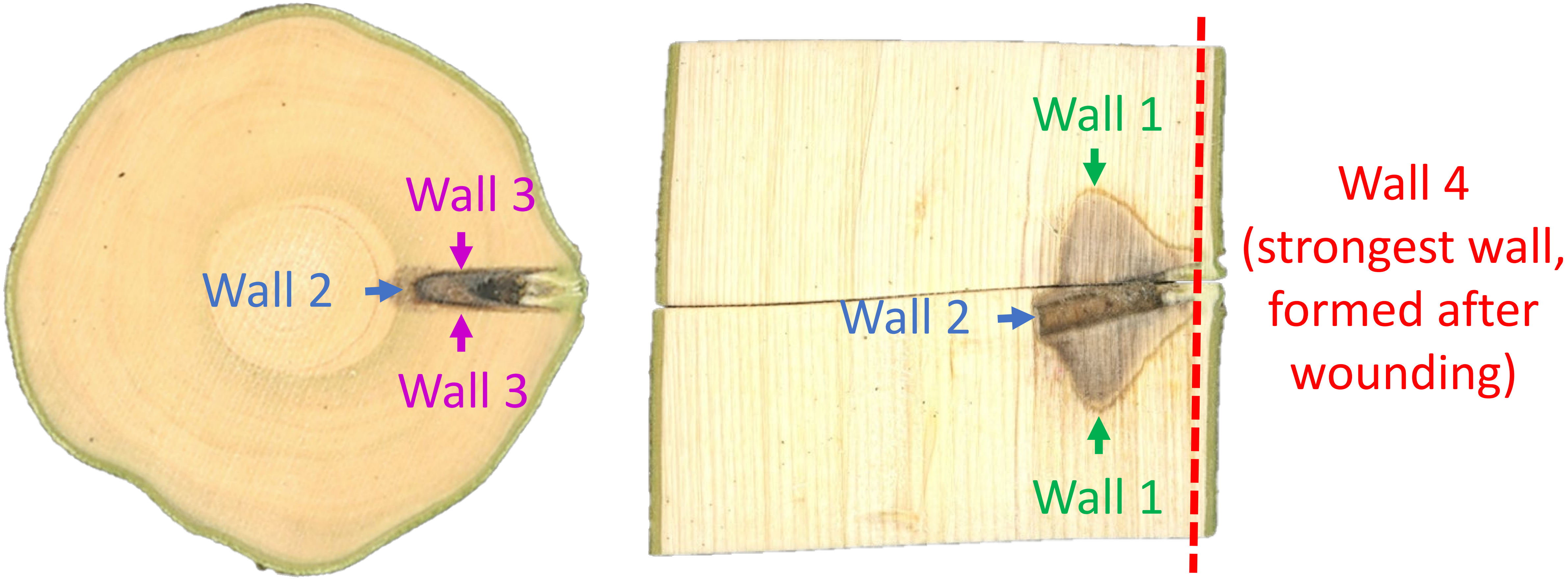
Compartmentalization of Decay in Trees (CODIT)

Shigo and Marx (1977)

Wall 1 (weak) → Wall 3 (strong)

Fig. 64: The CODIT Model depicts the tree as a chambered organism in which there are structural walls that can react to decay by compartmentalization. Wall 1 occurs in the axial direction. Wall 2 provides barriers in the radial direction (toward the center of the trunk) and wall 3 in the tangential direction (to the sides). In the model, wall 1 represents the weakest compartment and wall 3 is the strongest (Shigo & Marx 1977).

Wound compartmentalization

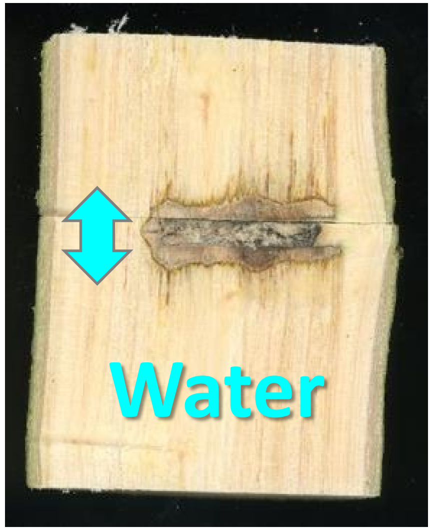


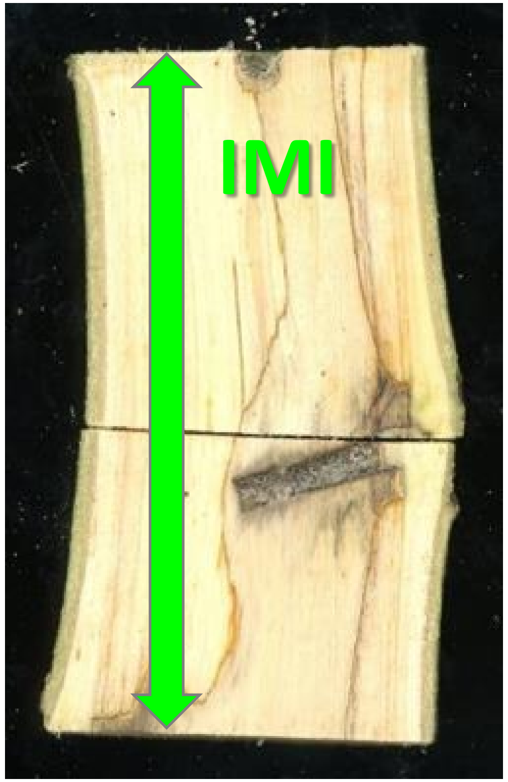
Effective wound compartmentalization in citrus trunks after water injection

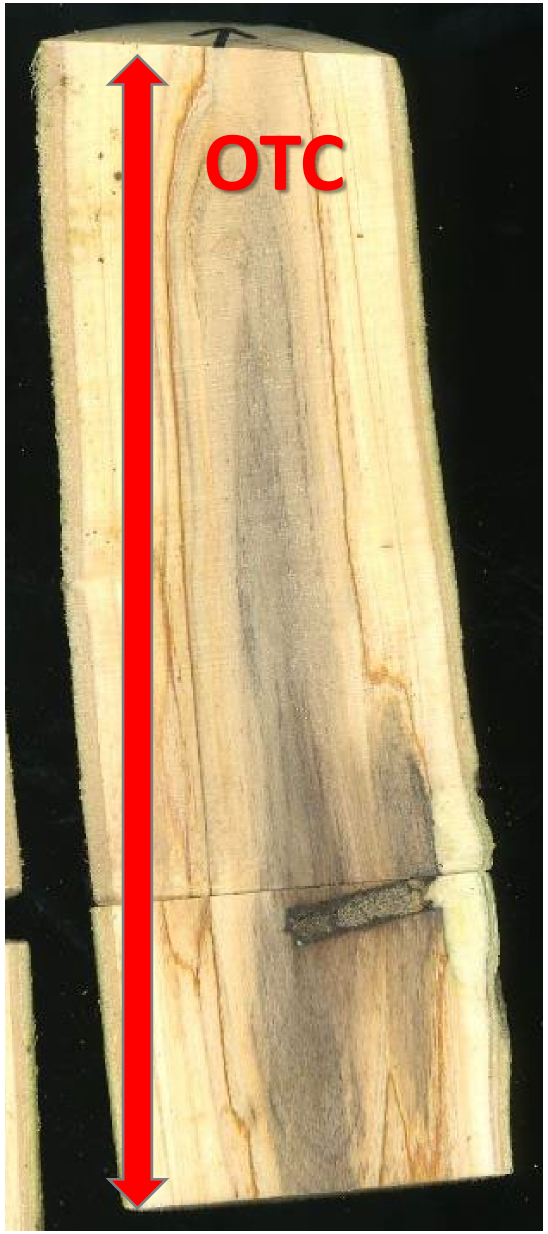
Wound compartmentalization

Compartmentalization is less effective after injection of chemicals

Wound compartmentalization

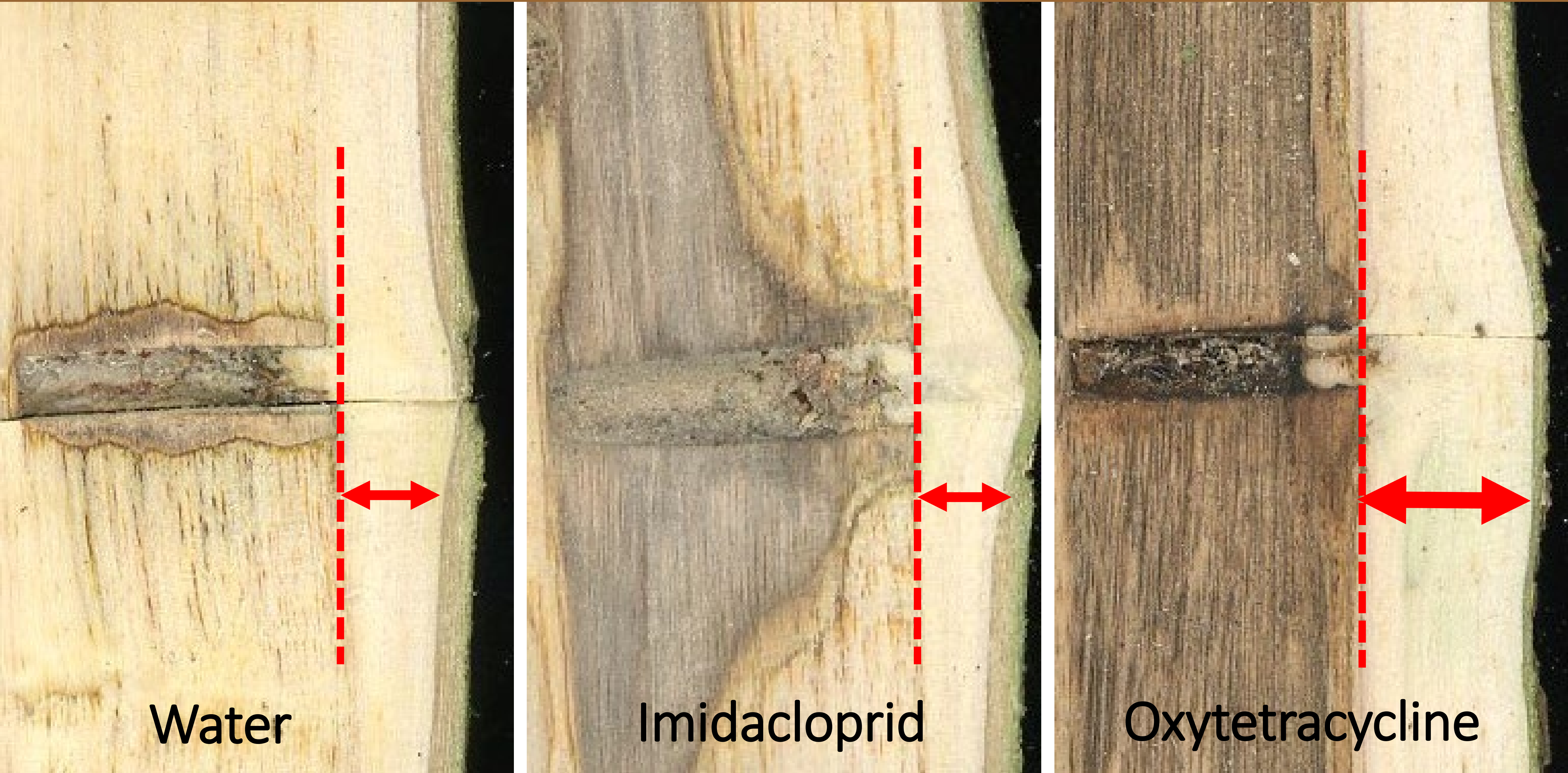






…, especially in the axial direction

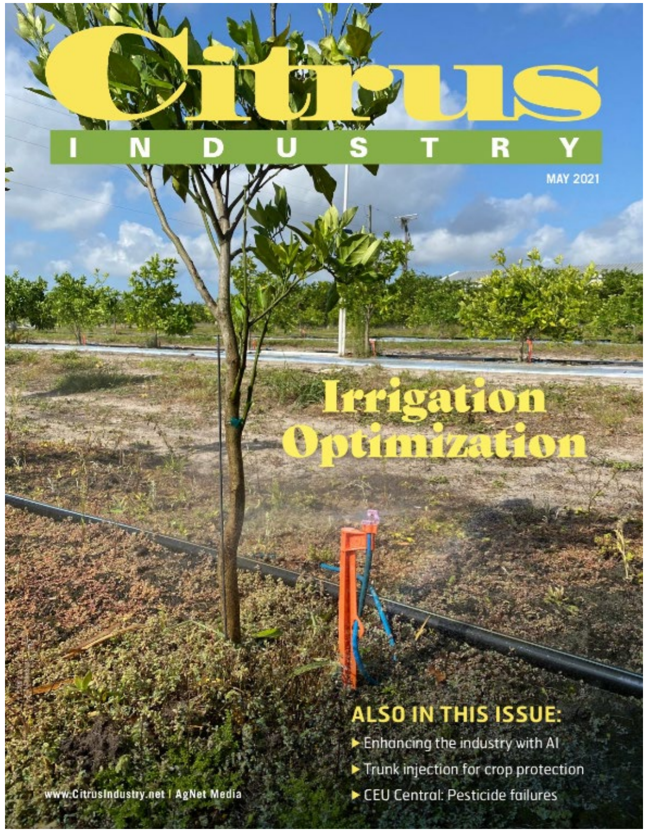
Wound compartmentalization



Summary

- Trunk injection can effectively and systemically deliver crop protection materials to target pests and diseases
- Injected OTC appears to move to the phloem, reduces CLas titers, and improves tree health, fruit quality, and yield
- Imidacloprid did not show long-term efficacy
- Trunk injections cause injury and long-term effects need to be evaluated
- USDA-NIFA-SCRI #2021-70029-36056 → new chemistries

Further information



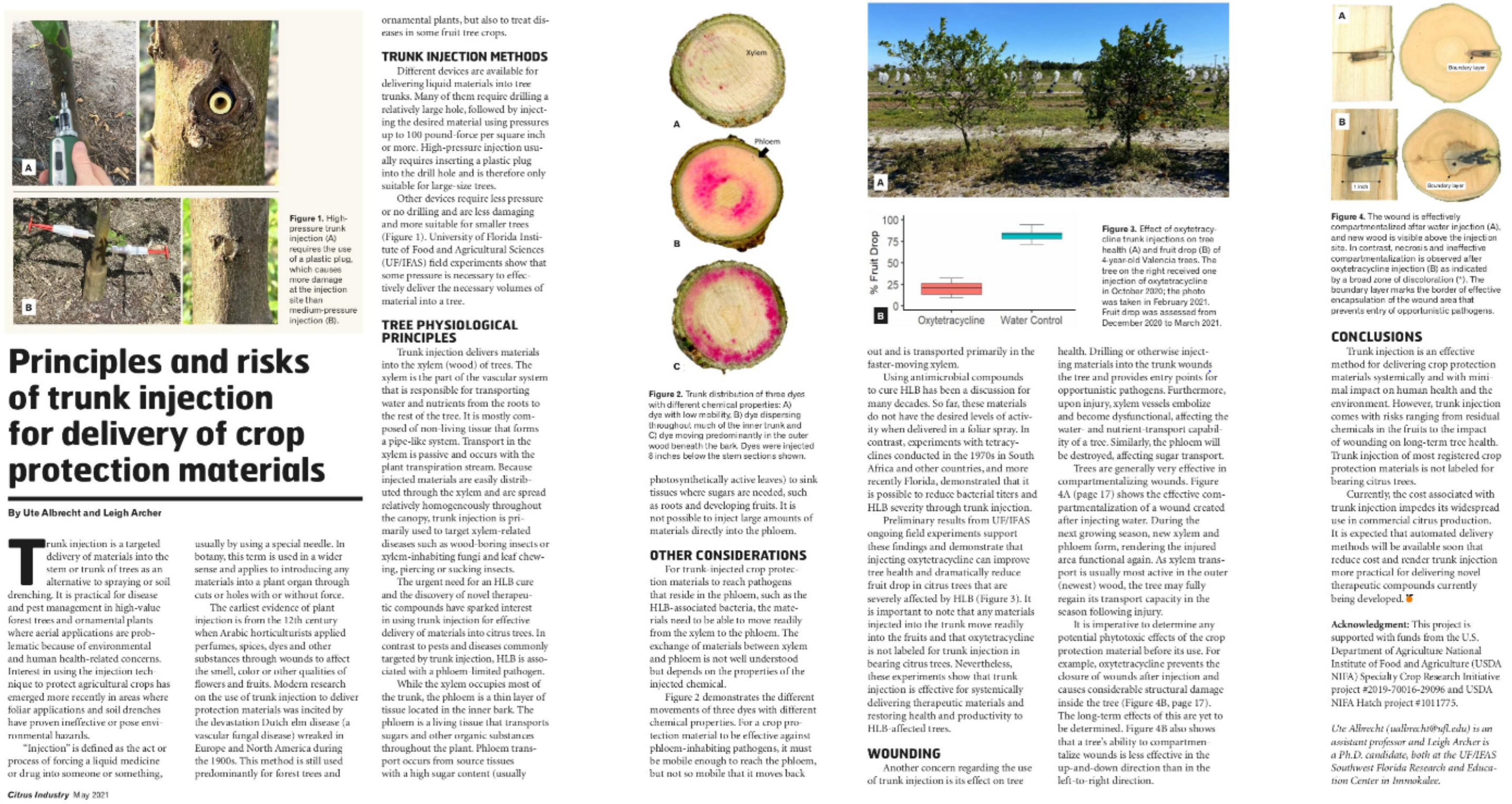


Figure 1. High-pressure trunk injection (A) requires the use of a plastic plug, which causes more damage at the injection site than medium-pressure injection (B).

Principles and risks of trunk injection for delivery of crop protection materials

By Ute Albrecht and Leigh Archer

Trunk injection is a targeted delivery of materials into the stem or trunk of trees as an alternative to spraying or soil drenching. It is practical for disease and pest management in high-value forest trees and ornamental plants where aerial applications are problematic because of environmental and human health-related concerns. Interest in using the injection technique to protect agricultural crops has emerged more recently in areas where foliar applications and soil drenches have proven ineffective or pose environmental hazards.

"Injection" is defined as the act or process of forcing a liquid medicine or drug into someone or something, usually by using a special needle. In botany, this term is used in a wider sense and applies to introducing any materials into a plant organ through cuts or holes with or without force.

The earliest evidence of plant injection is from the 12th century when Arabic horticulturists applied perfumes, spices, dyes and other substances through wounds to affect the smell, color or other qualities of flowers and fruits. Modern research on the use of trunk injection to deliver protection materials was incited by the devastation Dutch elm disease (a vascular fungal disease) wreaked in Europe and North America during the 1900s. This method is still used predominantly for forest trees and ornamental plants, but also to treat diseases in some fruit tree crops.

TRUNK INJECTION METHODS

Different devices are available for delivering liquid materials into tree trunks. Many of them require drilling a relatively large hole, followed by injecting the desired material using pressures up to 100 pound-force per square inch or more. High-pressure injection usually requires inserting a plastic plug into the drill hole and is therefore only suitable for large-size trees.

Other devices require less pressure or no drilling and are less damaging and more suitable for smaller trees (Figure 1). University of Florida Institute of Food and Agricultural Sciences (UF/IFAS) field experiments show that some pressure is necessary to effectively deliver the necessary volumes of material into a tree.

TREE PHYSIOLOGICAL PRINCIPLES

Trunk injection delivers materials into the xylem (wood) of trees. The xylem is the part of the vascular system that is responsible for transporting water and nutrients from the roots to the rest of the tree. It is mostly composed of non-living tissue that forms a pipe-like system. Transport in the xylem is passive and occurs with the plant transpiration stream. Because injected materials are easily distributed through the xylem and are spread relatively homogeneously throughout the canopy, trunk injection is primarily used to target xylem-related diseases such as wood-boring insects or xylem-inhabiting fungi and leaf chewing, piercing or sucking insects.

The urgent need for an HLB cure and the discovery of novel therapeutic compounds have sparked interest in using trunk injection for effective delivery of materials into citrus trees. In contrast to pests and diseases commonly targeted by trunk injection, HLB is associated with a phloem-limited pathogen.

While the xylem occupies most of the trunk, the phloem is a thin layer of tissue located in the inner bark. The phloem is a living tissue that transports sugars and other organic substances throughout the plant. Phloem transport occurs from source tissues with a high sugar content (usually photosynthetically active leaves) to sink tissues where sugars are needed, such as roots and developing fruits. It is not possible to inject large amounts of materials directly into the phloem.

Figure 2. Trunk distribution of three dyes with different chemical properties: A) dye with low mobility, B) dye dispersing throughout much of the inner trunk and C) dye moving predominantly in the outer wood beneath the bark. Dyes were injected 8 inches below the stem sections shown.

OTHER CONSIDERATIONS

For trunk-injected crop protection materials to reach pathogens that reside in the phloem, such as the HLB-associated bacteria, the materials need to be able to move readily from the xylem to the phloem. The exchange of materials between xylem and phloem is not well understood but depends on the properties of the injected chemical.

Figure 2 demonstrates the different movements of three dyes with different chemical properties. For a crop protection material to be effective against phloem-inhabiting pathogens, it must be mobile enough to reach the phloem, but not so mobile that it moves back out and is transported primarily in the faster-moving xylem.

Using antimicrobial compounds to cure HLB has been a discussion for many decades. So far, these materials do not have the desired levels of activity when delivered in a foliar spray. In contrast, experiments with tetracyclines conducted in the 1970s in South Africa and other countries, and more recently Florida, demonstrated that it is possible to reduce bacterial titers and HLB severity through trunk injection.

Preliminary results from UF/IFAS ongoing field experiments support these findings and demonstrate that injecting oxytetracycline can improve tree health and dramatically reduce fruit drop in citrus trees that are severely affected by HLB (Figure 3). It is important to note that any materials injected into the trunk move readily into the fruits and that oxytetracycline is not labeled for trunk injection in bearing citrus trees. Nevertheless, these experiments show that trunk injection is effective for systemically delivering therapeutic materials and restoring health and productivity to HLB-affected trees.

Figure 3. Effect of oxytetracycline trunk injections on tree health (A) and fruit drop (B) of 4-year-old Valencia trees. The tree on the right received one injection of oxytetracycline in October 2020; the photo was taken in February 2021. Fruit drop was assessed from December 2020 to March 2021.

WOUNDING

Another concern regarding the use of trunk injection is its effect on tree health. Drilling or otherwise injecting materials into the trunk wounds the tree and provides entry points for opportunistic pathogens. Furthermore, upon injury, xylem vessels embolize and become dysfunctional, affecting the water- and nutrient-transport capability of a tree. Similarly, the phloem will be destroyed, affecting sugar transport.

Trees are generally very effective in compartmentalizing wounds. Figure 4A (page 17) shows the effective compartmentalization of a wound created after injecting water. During the next growing season, new xylem and phloem form, rendering the injured area functional again. As xylem transport is usually most active in the outer (newest) wood, the tree may fully regain its transport capacity in the season following injury.

It is imperative to determine any potential phytotoxic effects of the crop protection material before its use. For example, oxytetracycline prevents the closure of wounds after injection and causes considerable structural damage inside the tree (Figure 4B, page 17). The long-term effects of this are yet to be determined. Figure 4B also shows that a tree's ability to compartmentalize wounds is less effective in the up-and-down direction than in the left-to-right direction.

Figure 4. The wound is effectively compartmentalized after water injection (A), and new wood is visible above the injection site. In contrast, necrosis and ineffective compartmentalization is observed after oxytetracycline injection (B) as indicated by a broad zone of discoloration (*). The boundary layer marks the border of effective encapsulation of the wound area that prevents entry of opportunistic pathogens.

CONCLUSIONS

Trunk injection is an effective method for delivering crop protection materials systemically and with minimal impact on human health and the environment. However, trunk injection comes with risks ranging from residual chemicals in the fruits to the impact of wounding on long-term tree health. Trunk injection of most registered crop protection materials is not labeled for bearing citrus trees.

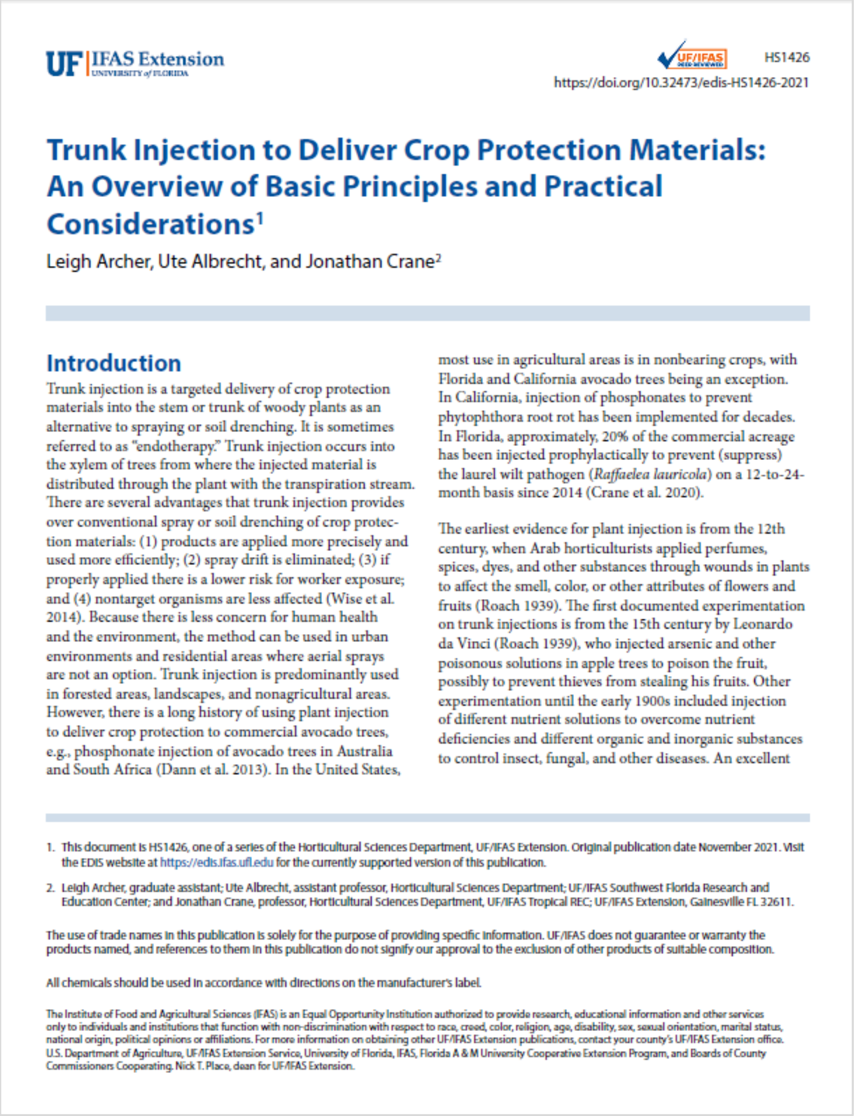
Currently, the cost associated with trunk injection impedes its widespread use in commercial citrus production. It is expected that automated delivery methods will be available soon that reduce cost and render trunk injection more practical for delivering novel therapeutic compounds currently being developed.

Acknowledgment: This project is supported with funds from the U.S. Department of Agriculture National Institute of Food and Agriculture (USDA NIFA) Specialty Crop Research Initiative project #2019-70016-29096 and USDA NIFA Hatch project #1011775.

Ute Albrecht (ualbrecht@ufl.edu) is an assistant professor and Leigh Archer is a Ph.D. candidate, both at the UF/IFAS Southwest Florida Research and Education Center in Immokalee.

https://citrusindustry.net/2021/05/17/principles-and-risks-of-trunk-injection-for-delivery-of-crop-protection-materials/

Further information



UF | IFAS Extension
UNIVERSITY of FLORIDA

UF/IFAS PEER REVIEWED

HS1426

https://doi.org/10.32473/edis-HS1426-2021

Trunk Injection to Deliver Crop Protection Materials: An Overview of Basic Principles and Practical Considerations[1]

Leigh Archer, Ute Albrecht, and Jonathan Crane[2]

Introduction

Trunk injection is a targeted delivery of crop protection materials into the stem or trunk of woody plants as an alternative to spraying or soil drenching. It is sometimes referred to as "endotherapy." Trunk injection occurs into the xylem of trees from where the injected material is distributed through the plant with the transpiration stream. There are several advantages that trunk injection provides over conventional spray or soil drenching of crop protection materials: (1) products are applied more precisely and used more efficiently; (2) spray drift is eliminated; (3) if properly applied there is a lower risk for worker exposure; and (4) nontarget organisms are less affected (Wise et al. 2014). Because there is less concern for human health and the environment, the method can be used in urban environments and residential areas where aerial sprays are not an option. Trunk injection is predominantly used in forested areas, landscapes, and nonagricultural areas. However, there is a long history of using plant injection to deliver crop protection to commercial avocado trees, e.g., phosphonate injection of avocado trees in Australia and South Africa (Dann et al. 2013). In the United States, most use in agricultural areas is in nonbearing crops, with Florida and California avocado trees being an exception. In California, injection of phosphonates to prevent phytophthora root rot has been implemented for decades. In Florida, approximately 20% of the commercial acreage has been injected prophylactically to prevent (suppress) the laurel wilt pathogen (*Raffaelea lauricola*) on a 12-to-24-month basis since 2014 (Crane et al. 2020).

The earliest evidence for plant injection is from the 12th century, when Arab horticulturists applied perfumes, spices, dyes, and other substances through wounds in plants to affect the smell, color, or other attributes of flowers and fruits (Roach 1939). The first documented experimentation on trunk injections is from the 15th century by Leonardo da Vinci (Roach 1939), who injected arsenic and other poisonous solutions in apple trees to poison the fruit, possibly to prevent thieves from stealing his fruits. Other experimentation until the early 1900s included injection of different nutrient solutions to overcome nutrient deficiencies and different organic and inorganic substances to control insect, fungal, and other diseases. An excellent

1. This document is HS1426, one of a series of the Horticultural Sciences Department, UF/IFAS Extension. Original publication date November 2021. Visit the EDIS website at https://edis.ifas.ufl.edu for the currently supported version of this publication.

2. Leigh Archer, graduate assistant; Ute Albrecht, assistant professor, Horticultural Sciences Department; UF/IFAS Southwest Florida Research and Education Center; and Jonathan Crane, professor, Horticultural Sciences Department, UF/IFAS Tropical REC; UF/IFAS Extension, Gainesville FL 32611.

The use of trade names in this publication is solely for the purpose of providing specific information. UF/IFAS does not guarantee or warranty the products named, and references to them in this publication do not signify our approval to the exclusion of other products of suitable composition.

All chemicals should be used in accordance with directions on the manufacturer's label.

The Institute of Food and Agricultural Sciences (IFAS) is an Equal Opportunity Institution authorized to provide research, educational information and other services only to individuals and institutions that function with non-discrimination with respect to race, creed, color, religion, age, disability, sex, sexual orientation, marital status, national origin, political opinions or affiliations. For more information on obtaining other UF/IFAS Extension publications, contact your county's UF/IFAS Extension office. U.S. Department of Agriculture, UF/IFAS Extension Service, University of Florida, IFAS, Florida A & M University Cooperative Extension Program, and Boards of County Commissioners Cooperating. Nick T. Place, dean for UF/IFAS Extension.

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

horticulturae MDPI

Review

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

Leigh Archer [1], Jonathan H. Crane [2] and Ute Albrecht [1,*]

1 Southwest Florida Research and Education Center, Horticultural Sciences Department, Institute of Food and Agricultural Sciences, University of Florida, Immokalee, FL 34142, USA; larcher1@ufl.edu
2 Tropical Research and Education Center, Horticultural Sciences Department, Institute of Food and Agricultural Sciences, University of Florida, Homestead, FL 33031, USA; jhcr@ufl.edu
* Correspondence: ualbrecht@ufl.edu

Abstract: Trunk injection is a targeted delivery of pesticides, insecticides, nutrients, or other plant protection materials into the stem or trunk of woody plants as an alternative to spraying or soil drenching. Trunk injection has historically been used for disease and pest management of high-value forest tree species or ornamental plants when aerial applications are problematic due to spatial problems and health-related concerns. An interest in using the injection technique for protection of agricultural crops in commercial production systems has emerged more recently, where foliar applications and soil drenches have proven ineffective or pose environmental hazards. This review provides an overview of the basic principles of trunk injection and the plant physiological implications, its current use in commercial agriculture and other plant systems, and associated risks.

Keywords: horticultural crops; crop protection; endotherapy; chemotherapy; systemic delivery

check for updates

Citation: Archer, L.; Crane, J.H.; Albrecht, U. Trunk Injection as a Tool to Deliver Plant Protection Materials—An Overview of Basic Principles and Practical Considerations. *Horticulturae* 2022, *8*, 552. https://doi.org/10.3390/horticulturae8060552

Academic Editor: Giovanni Bubici

Received: 31 May 2022
Accepted: 16 June 2022
Published: 19 June 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Trunk injection is a technique for applying plant protection materials that offers an alternative to foliar sprays or soil drenches. Among the main advantages that trunk injection provides over conventional methods are a higher efficiency of product delivery, reduced risk for worker exposure, reduced risk to the environment, reduced harm to non-target organisms, and the possibility for use in populated areas where other methods are not an option [1,2]. Trunk injection techniques have not been optimized for use in commercial crop production; however, there is a long history of using the method in a variety of crop and non-crop species.

According to the dictionary, the term "injection" is the act or process of forcing a liquid medicine or drug into someone or something, usually by using a special needle. In botany, this term is used in a wider sense and includes any introduction of materials into a plant organ by cutting or through holes with or without force. In this sense, the earliest evidence for plant injection is from the 12th century, when Arabic horticulturists applied perfumes, spices, dyes, and other substances through wounds in plants to affect the smell, color, or other attributes of flowers and fruits [3]. The first documented experimentation on trunk injections occurred in the 15th century by Leonardo da Vinci [3], who injected arsenic and other poisonous solutions through bore holes into apple trees to render the fruit poisonous. Other experimentation until the early 1900s included injection of different nutrient solutions such as ferrous sulphate and ferric chloride as remedies for nutritional deficiencies [3]. This was followed by injection of other inorganic substances such as iron pyrophosphate, potassium cyanide, and aluminum sulphate to control insects and plant diseases [3]. In addition to inorganic materials, organic substances including salicylic acid and plant- and microorganism-derived liquids were injected by various methods for the

Horticulturae 2022, *8*, 552. https://doi.org/10.3390/horticulturae8060552 https://www.mdpi.com/journal/horticulturae

Horticulturae 2022, *8*, 552 3 of 21

High-Pressure Injection	Low-Pressure Injection	No-Pressure Injection
Drill-based	Drill-based	Drill-based
Quik-jet Micro-injection System; Quik-Jet AIR Injection System (Arborjet Inc, Woburn, MA, USA) arborjet.com	Chemjet Tree Injectors (Chemjet, Queensland, Australia) chemjet.com.au	Acecap (Creative Sales, Fremont, NE, USA) acecap-medicap.com
ENDOplant (ENDOterapia Vegetal, Girona, Spain) endoterapiavegetal.com	Mauget Smart Shot (Mauget, Arcadia, CA, USA) mauget.com	Mauget Capsules (Mauget, Arcadia, CA, USA) mauget.com
Q-Connect (Rainbow Ecoscience, Minnetonka, MN, USA) rainbowecoscience.com	Manual Macro-Infusion (Rainbow Treecare, Minnetonka, MN, USA) rainbowecoscience.com	Drill-free
Sidewinder Tree Injector (The Australian Made, Loganholme, Australia) australianmade.com.au	Ecoject system (BioForest Technologies, Ontario, Canada) bioforest.ca	EZ Ject Lance (ArborSystems, Omaha, NE, USA) arborsystems.com
	Tree IV Micro-infusion System; Viper Micro-injection System (Arborjet Inc, Woburn, MA, USA) arborjet.com	BITE Tree Infusion (Sorbus, Somerset, UK) sorbus-intl.co.uk/tree-care/bite
	Microinjectors (Tree Tech, Morriston, FL, USA) treetech.net	
	Drill-free	
	Wedgle Direct-Injection System (ArborSystems, Omaha, NE, USA) arborsystems.com	

Figure 1. Some of the currently available trunk injection devices (links accessed 14 June 2022).

2.1. High-Pressure Injection

The Arborjet Quik-Jet Air (Arborjet Inc., Woburn, MA, USA) is one example of a high-pressure application device. Arborjet and similar high-pressure systems, such as ENDOplant (ENDOterapia Vegetal, Girona, Spain), use 7.15 mm or larger diameter plastic plugs as injection ports, which are inserted into the tree after drilling of a hole. This creates a tight seal for injection, prevents leaking, and protects the wound from pathogens and insects. Injection of the compounds occurs though specialized metal injection tips at pressures of 60–100 psi (413–689 kPa) created by using compressed gas. Although the plastic plugs enable the rapid injection of large volumes of material, they can cause more damage to trees than no-plug methods as they increase the size of the injection hole, increase the probability of injury from bark cracking, and may interfere with full wound closure [23]. Dendrology research has shown that plugging tree core wounds does not provide any benefit and can even interfere with the natural healing capabilities of the tree [33]. Other high-pressure systems include the Q-Connect (Rainbow Ecoscience, Minnetonka, MN, USA) and the Sidewinder Tree Injector (The Australian Made, Loganholme, Australia).

2.2. Low-Pressure Injection

An alternative to high-pressure injection are syringe or needle-based methods sold by Chemjet (Kerrville, TX, USA), Mauget (Arcadia, CA, USA), Rainbow Ecoscience (Minnetonka, MN, USA), and other manufacturers, which allow the plug-free injection of materials. Injection using these devices occurs at relatively low pressures (<60 psi) by manual squeezing or use of a spring-loaded syringe system. Most of these systems rely on drilled holes prior to application; however, ArborSystems (Omaha, NE, USA) has developed a low-pressure drill-free system, the Wedgle® Direct-Inject. With this device, a shallow stem core is removed, and liquid is manually pushed into the trunk. The rate of liquid uptake associated with lower-pressure devices is slower than that of higher-pressure

https://doi.org/10.3390/horticulturae8060552

Questions

Ute Albrecht

UF/IFAS, Southwest Florida Research and Education Center

ualbrecht@ufl.edu