Advancements in Automated Trunk Injection of Citrus Trees

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Existing Tree Trunk Injection Methods

- Manually operated; physical strain and undesirable working conditions
- Tree wounding
- Mostly drill based; drilling damages the xylem vessels
- Long duration to complete the injection process (up to 24 hours)
- Mostly one-sided injection

Development of an automated delivery system for therapeutic materials to treat HLB infected citrus

CDRE, USDA. Budget: $3.4M

PI: Dr. Batuman
Co-PIs: Dr. Ampatzidis, Dr. Albrecht, Dr. Alferez, etc.

Duration: 01/01/2019 – 12/31/2024.

EXPLORATORY PROTOTYPES

Prototype 1

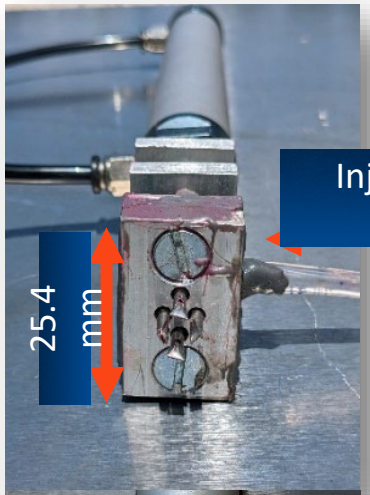
Prototype 2

Observations

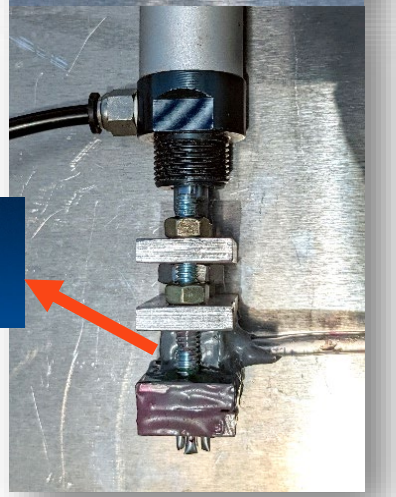
- Uneven clamping force and trunk centering problems
- Excessive deflection of the positioning arm
- Insufficient needle penetration
- Clogging, excessive leaks and zero flow

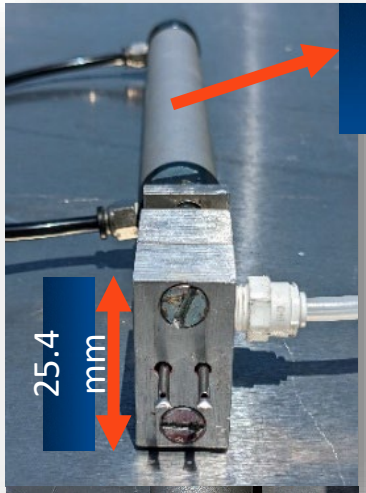
END EFFECTOR INJECTION TOOL

ABS Plastic Manifold



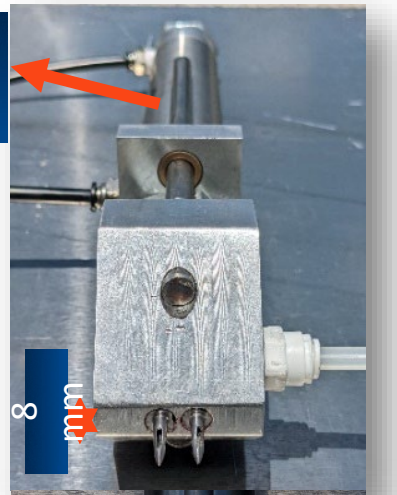
Injectate inlet

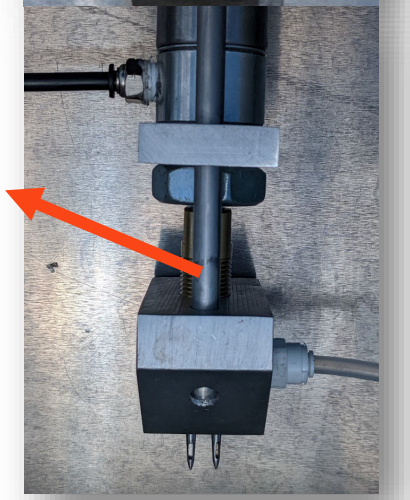




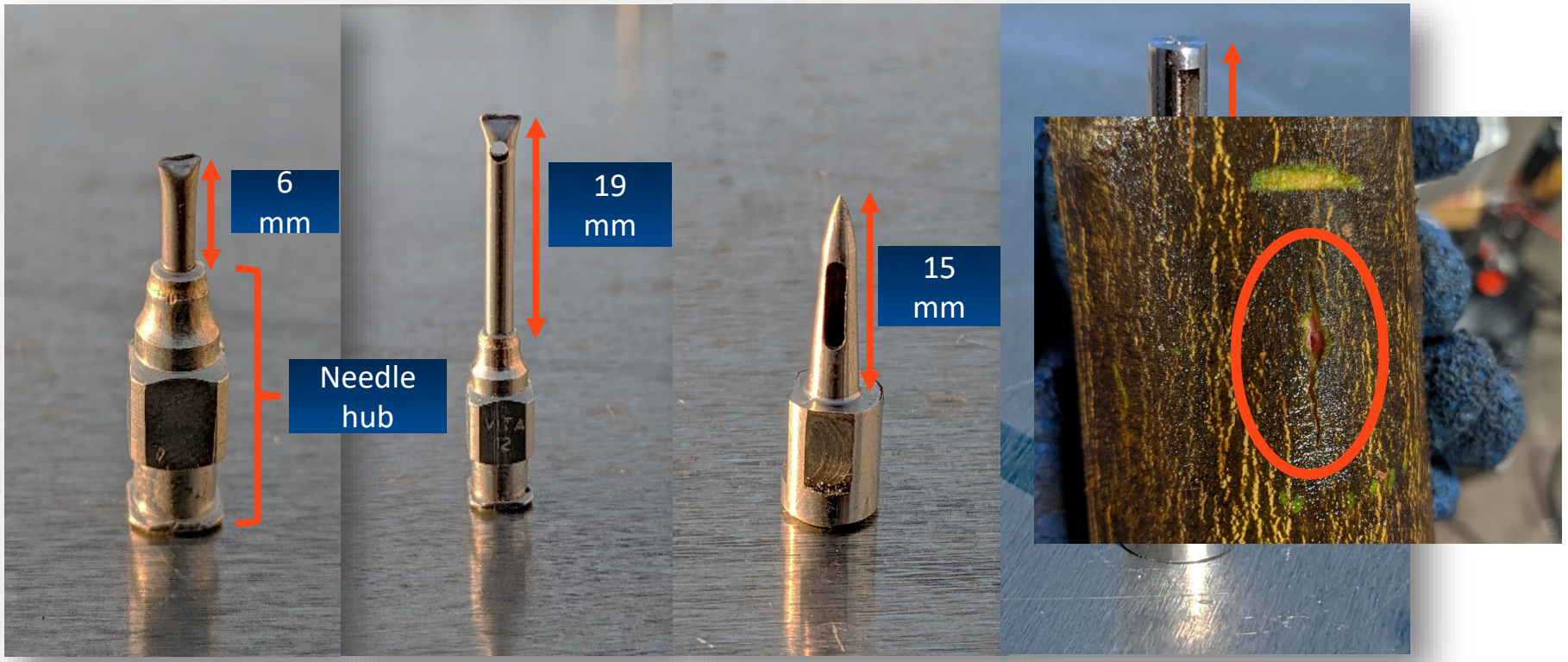
Pneumatic actuators

Guide rod





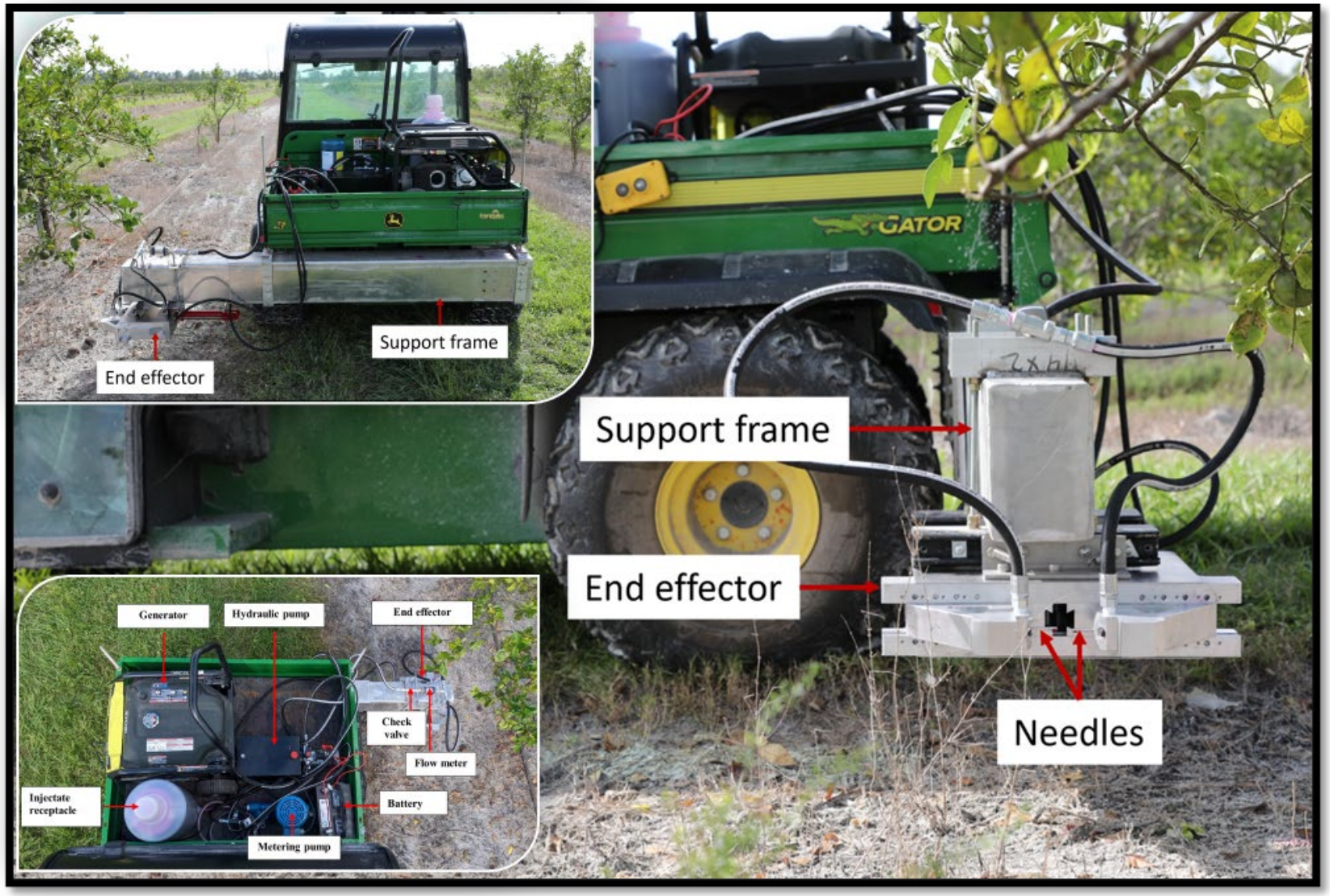
NEEDLE DESIGNS



Observations

- Pointed needle tips splits the trunk
- Larger outlet surface area prevents clogging but leads to excessive leaks
- Shallow penetration depths leads to excessive leaks

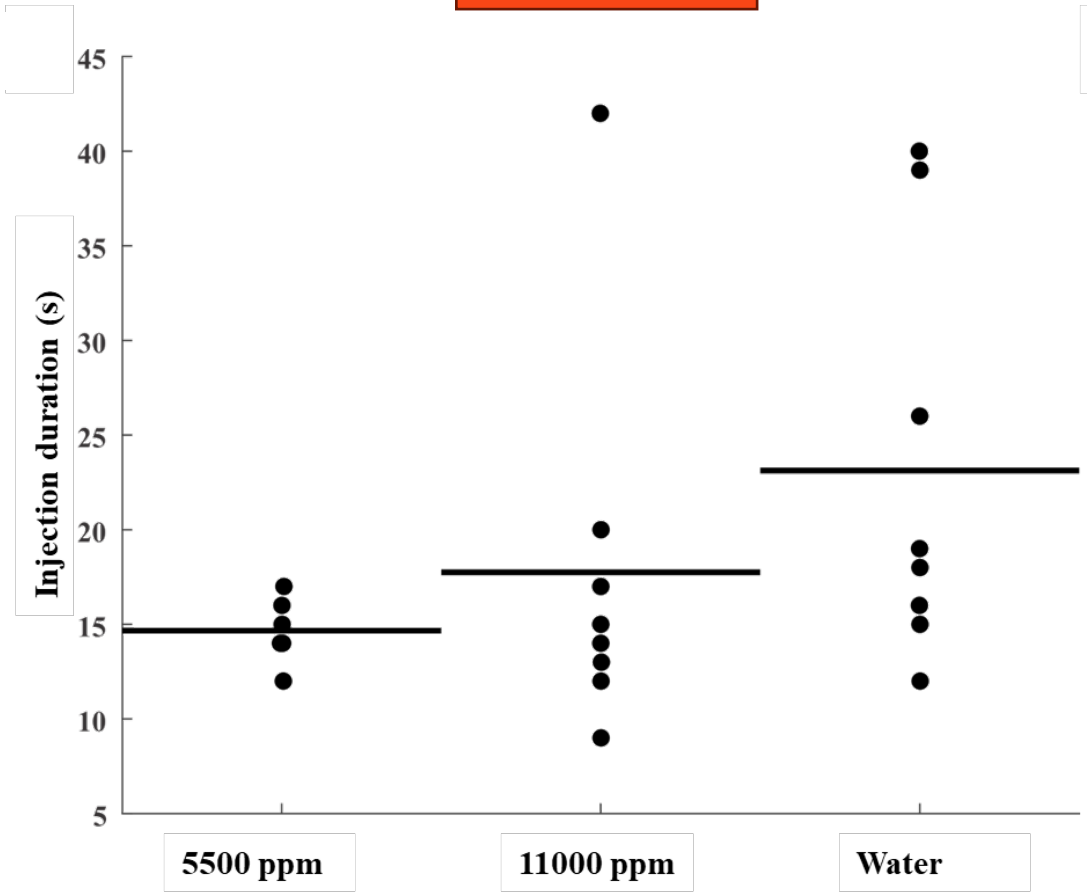
Automated Delivery System



Automatic Delivery System

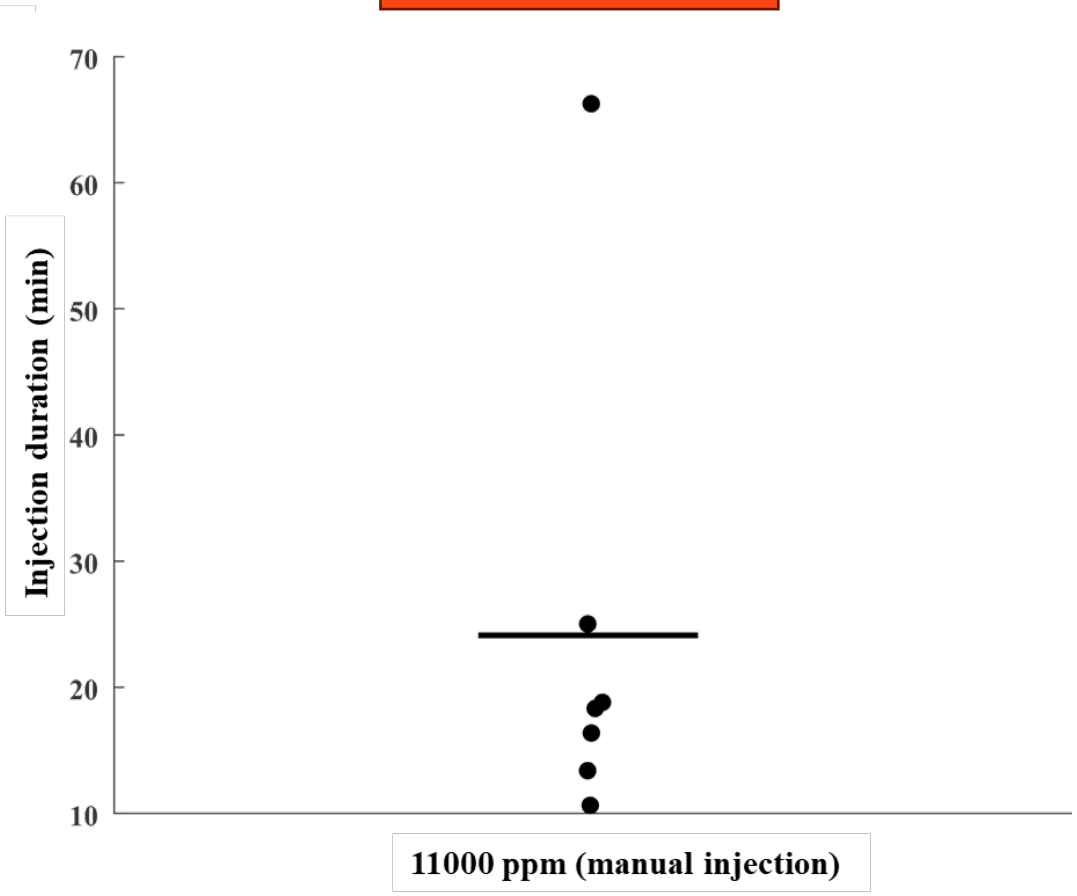
COMPARING INJECTION DURATION

ATIS



Average duration: 18 s

Manual Injection

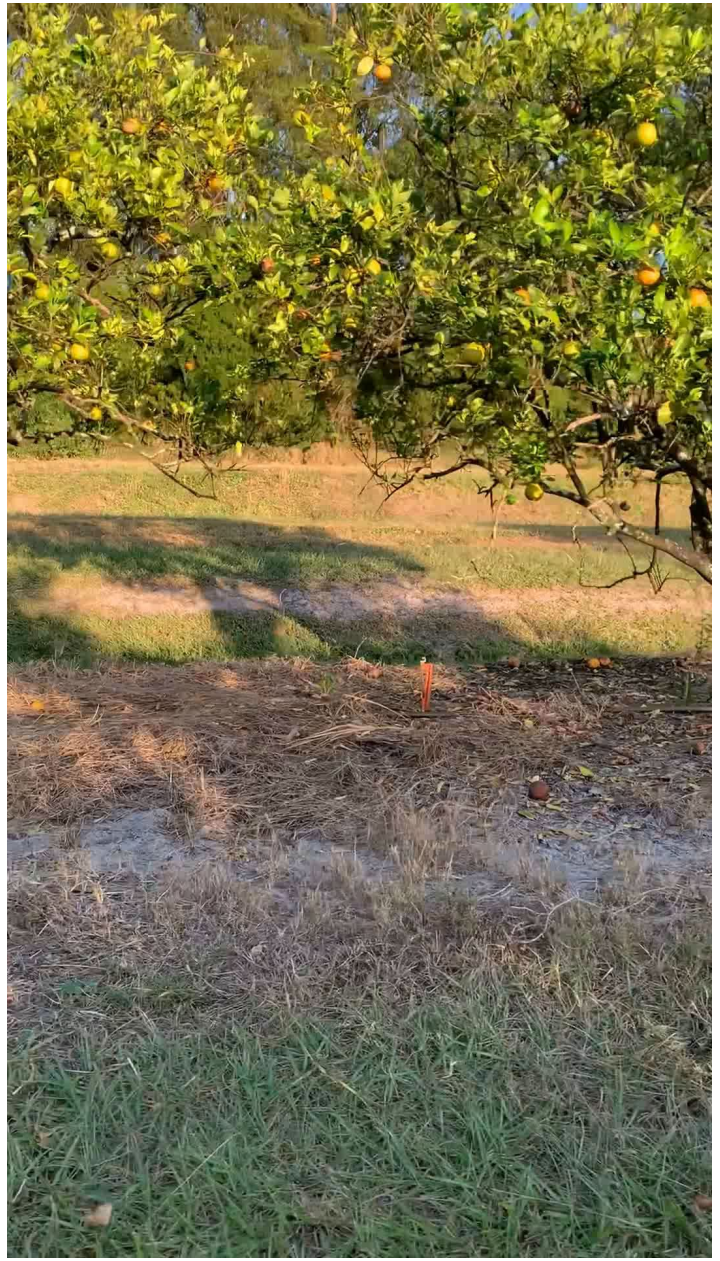


Average duration: 24 min

COMPARING WOUNDING

Manual system

Automated system

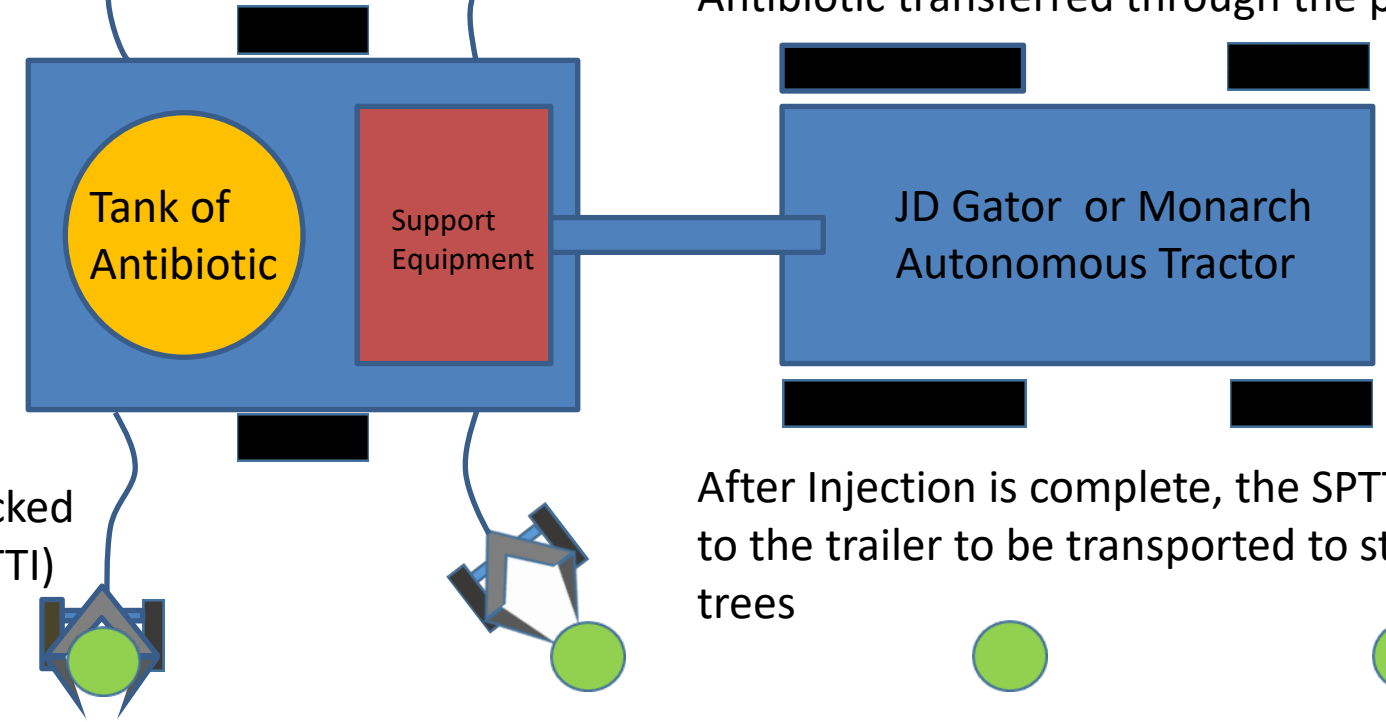


Zhou C. and Ampatzidis Y., 2024. AI-enabled 3D vision system for rapid and accurate tree trunk detection and diameter estimation. 16th International Conference on Precision Agriculture (ICPA), Manhattan, Kansas, USA, July 21-24.

The SPTTI are guided to the trees by intelligence on the trailer

Orchard Trees

Once clamped on the tree, the SPTTI inject the tree with Antibiotic transferred through the power umbilical



Self Propelled Tracked Tree Injectors (SPTTI)

After Injection is complete, the SPTTI are rapidly reeled back to the trailer to be transported to stage up to next set of trees

Orchard Trees

Conclusion – Take Home Message

✅ **Proven effectiveness**: Automated trunk injection delivers oxytetracycline efficiently to HLB-affected citrus trees.
✅ **Key advantage**: Reduces labor needs, improves consistency, and has potential for large-scale adoption in commercial groves.

⚙️ **Current challenges**:

- System mobility and deployment efficiency
- Speed of injection and repositioning
- Reliability of injector clamping and antibiotic delivery

🚀 **Next steps**:

- **New design** integrates **AI-driven guidance** and **four robotic self-propelled injectors** to improve speed, efficiency, and precision.
- Collaborative proposal with **industry partners and robotics experts** to advance development and field testing.

🌱 **Take-home message**: Automated, AI-enabled trunk injection systems hold strong promise for **scalable, precise, and efficient management of HLB**.

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THANK YOU

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