

# Development of a Robotic Laser Weeding System for Precision Weed Management in Vidalia Onions

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## INTRODUCTION

“For South Georgia, the first challenge is weed control”, Aries Haywood, Vidalia Onion Grower<sup>1</sup>

### Cost Penalty of Transplants:

- Vidalia Onion growers spend \$5000 - \$7000 per acre for growing transplanted onions, largely due to transplanting costs<sup>2</sup>.
- Nearly all commercial onions in Vidalia are grown from transplants because of weed problems in direct seeding.

### Challenges in Direct Seeding:

- Mechanical cultivators injure onions' shallow roots
- Post-emergence options are narrow and impractical at field scale



### Laser Weeding Benefits:

- Chemical-Free
- High-Precision
- Saves growers \$1000 - \$2000 per acre
- Automated
- Organic-Ready

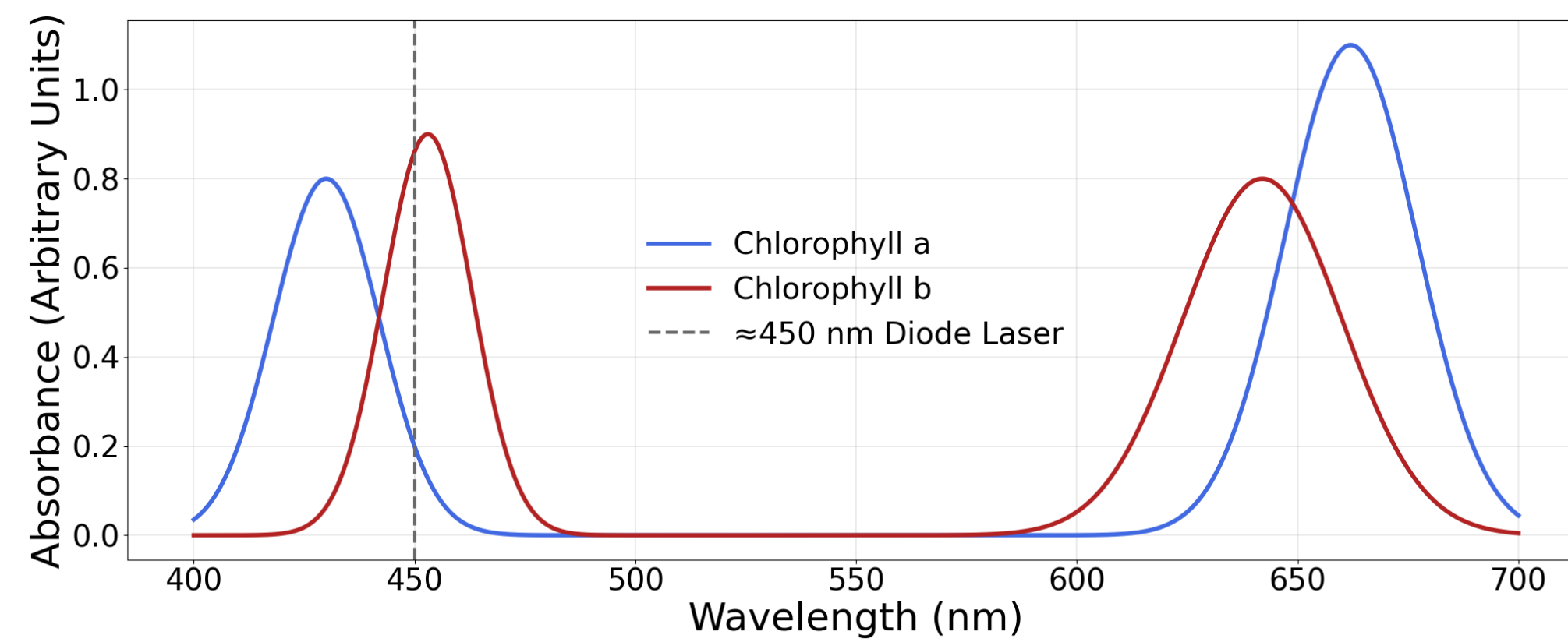


Figure 1. Absorbance spectra of Chlorophyll a & b and laser wavelength<sup>4</sup>

## GOAL & OBJECTIVES

Targeting weeds with a delta-robot-mounted high-power diode laser will lower weeding costs and enhance sustainability in direct-seeded Vidalia onion fields.

- Real-time weed detection and localization using RGB-D data
- Integrated Robotic system for precision laser targeting, validated in both lab and field environments

## MATERIALS AND METHODS

### Real-time weed detection and localization using RGB-D data

- Study Site and Experimental Design:**
  - Location: UGA Vidalia Research Center, Lyons (GA).
  - Design: Randomized complete block with three subfield blocks and two replicates per onion row.
- Data Collection**
  - Timing: Feb-Mar 2025, onions 3-5 true leaf stage.
  - Sensor: Zed-2i Stereo vision camera.
  - Capture format: 15 fps recordings for uninterrupted spatial-temporal coverage, ~95 % faster than 15s per static depth image.
  - Data Extraction: FFmpeg losslessly extracts raw MKV streams into RGB + 16-bit depth frames at 2.3 fps with 66 % FOV overlap.

## MATERIALS AND METHODS (Cont.)

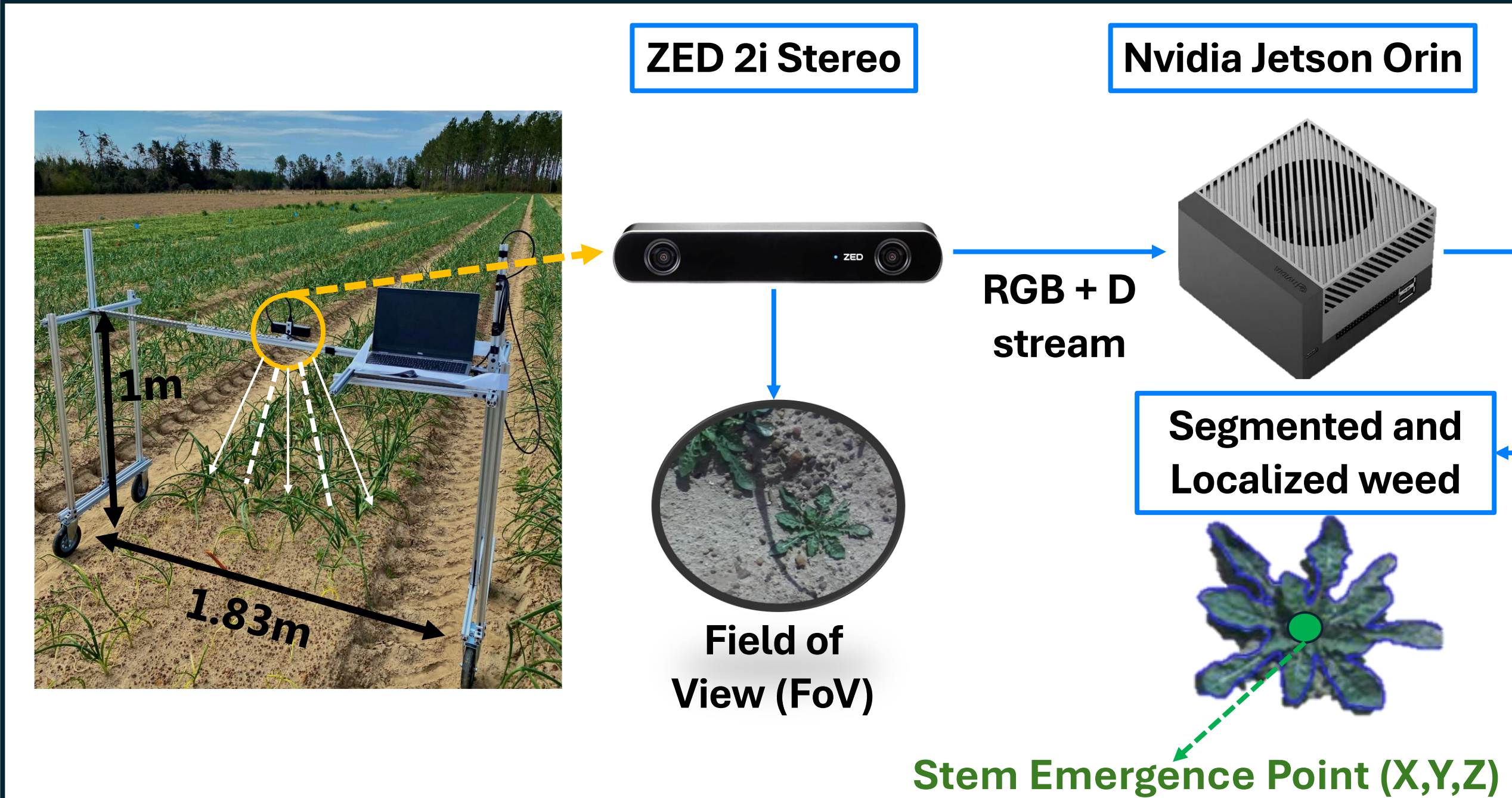


Figure 2. ZED 2i stereo camera streams RGB-D frames to an NVIDIA Jetson Orin for real-time 3D weed detection & localization via deep-learning inference.

### Integrated Robotic system for precision laser targeting, validated in both lab and field environments

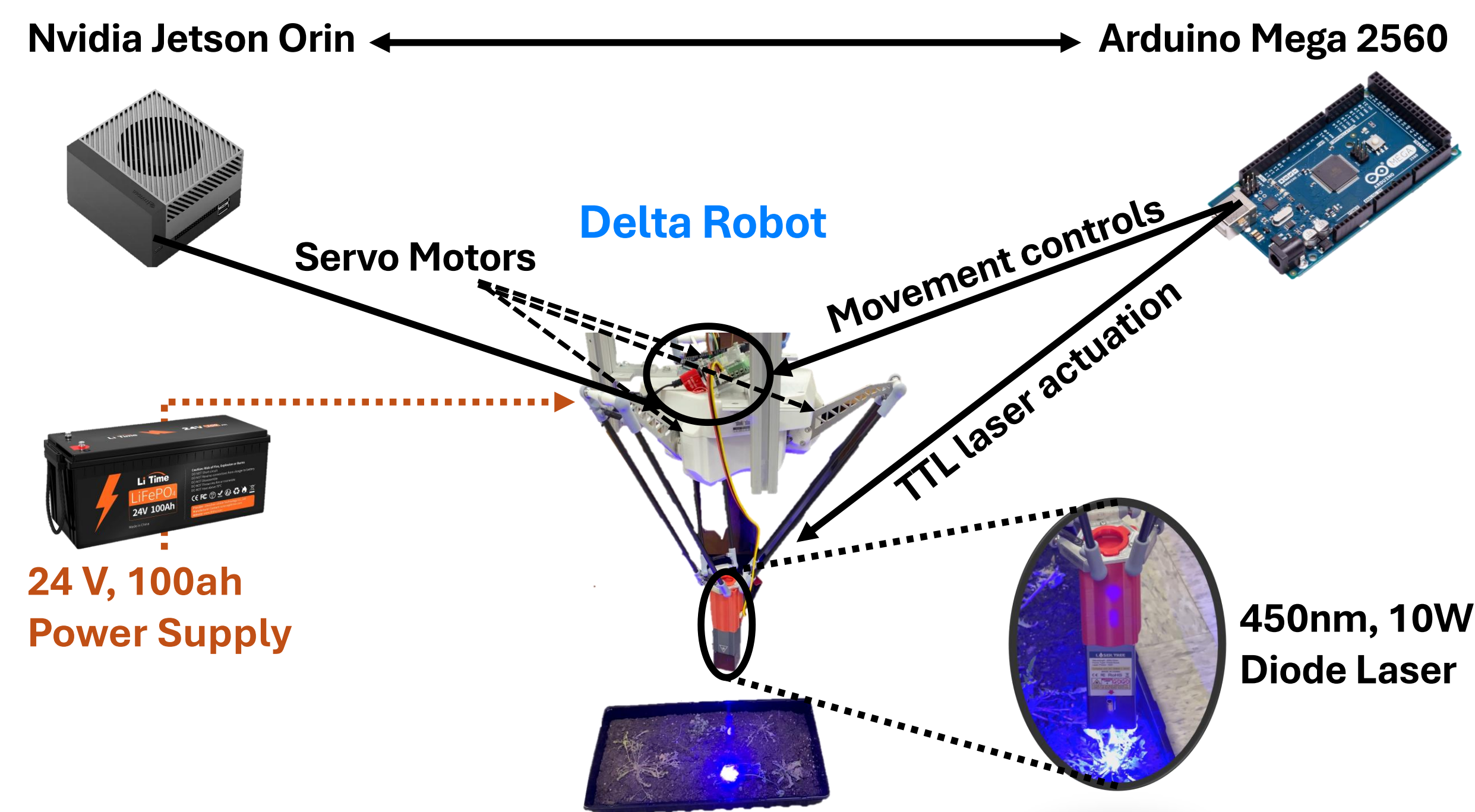


Figure 3. A Parallel Delta robot with a 10 W 450 nm diode laser end-effector, guided by 3D weed coordinates from Jetson and controlled via an Arduino 2560.

## RESULTS



Figure 4. (Left) Manual annotation of Cutleaf Evening Primrose for training. (Right): Preliminary detection with stem emergence point.

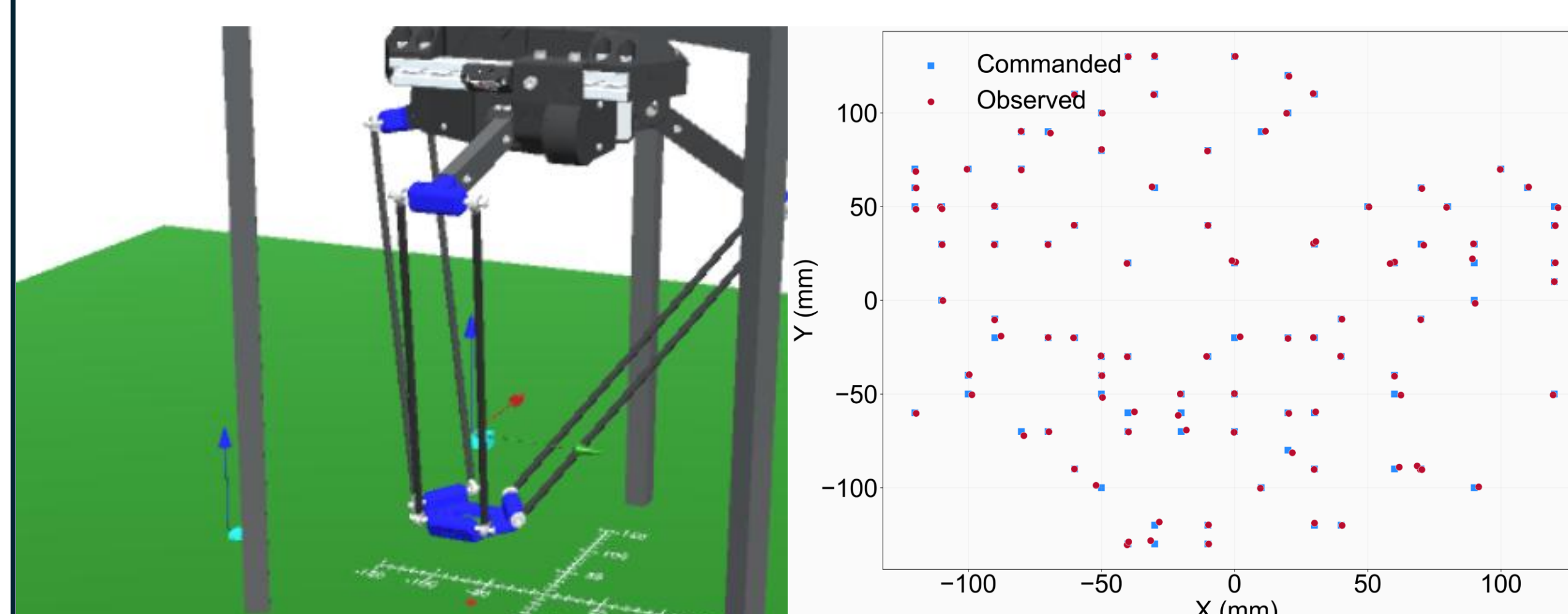


Figure 5: (Left) Simulated Clavel-style delta robot positioned over the XY workspace grid. (Right) Positional accuracy illustrated by a scatter plot

## RESULTS (Cont.)

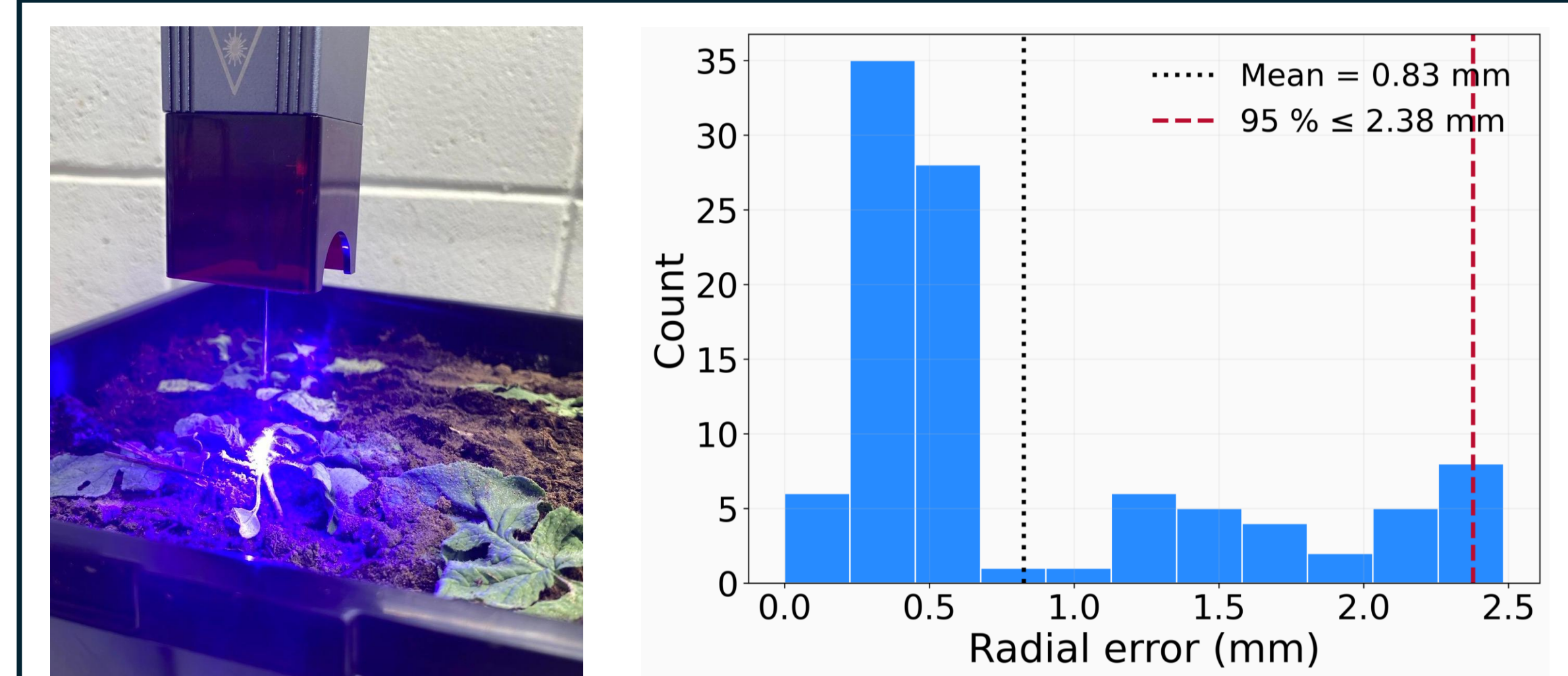


Figure 6. 10 W 450 nm laser targeting a weed (left) and radial error distribution across trials (mean 0.83 mm; 95 % ≤ 2.38 mm) (right).

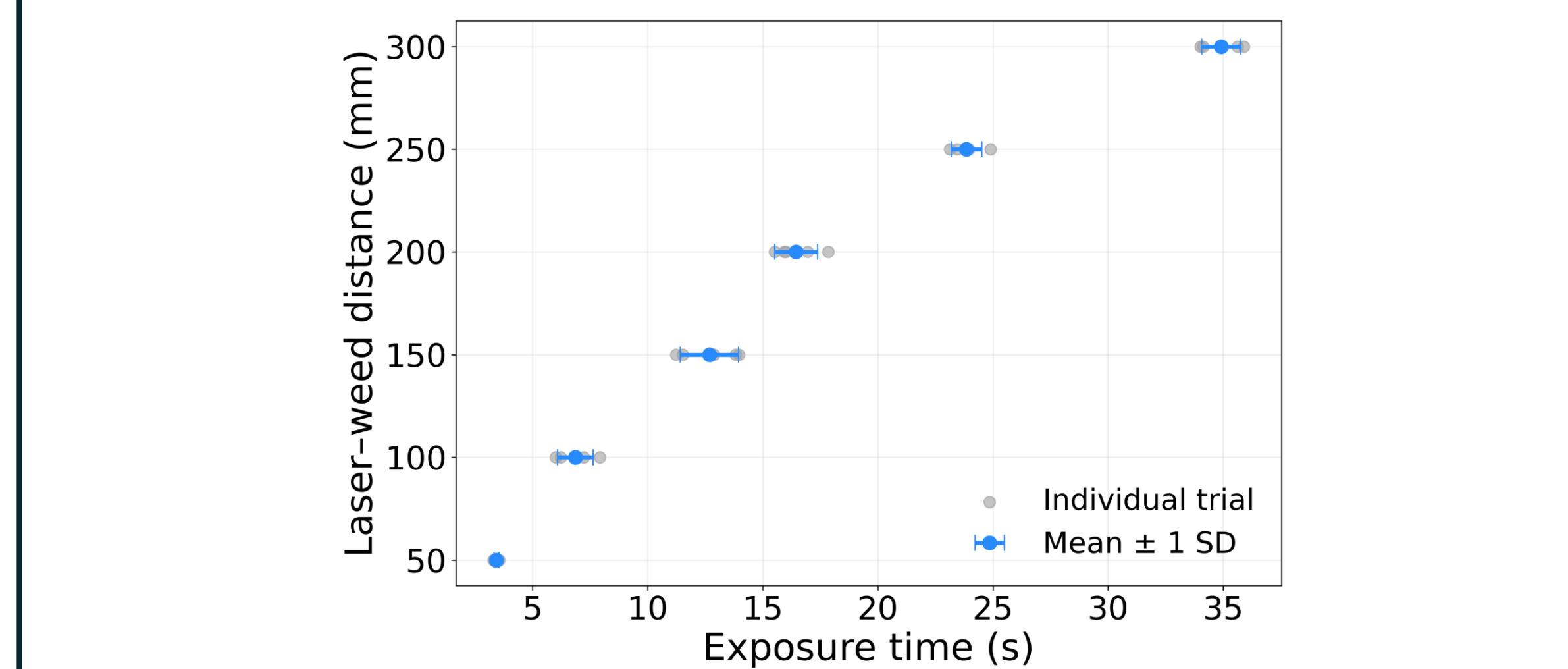


Figure 7. Stand-off distance vs. exposure time: gray dots are individual trials; blue markers with ±1 SD error bars show the mean.

## DISCUSSION AND CONCLUSIONS

### Key Findings:

- Preliminary detection achieved (mAP@50) of 0.94, demonstrating high accuracy for reliable weed perception in real-time.
- Achieved precise laser positioning accuracy with a mean radial error of 0.83 mm.
- For individual stand-off distance trials, the 10W laser performs best till 150 mm distance for maximum laser efficacy.

### Future Directions:

- Integration of the real-time detection system with delta robot for autonomous laser weeding.
- Comprehensive field validations of the integrated system to assess the system's effectiveness.

## REFERENCES

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- [3] W. Bond and S. Burston, “Timing the removal of weeds from drilled salad onions to prevent crop losses,” *Crop Prot.*, vol. 15, no. 2, pp. 205-211, Mar. 1996, doi: 10.1016/0261-2194(95)00127-1.
- [4] “Blue Lasers in Laser Weeding - Opt Lasers.” Accessed: Apr. 28, 2025.

## ACKNOWLEDGMENTS



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