Introduction
Weed management is a major challenge in crop production and weed control expenses rank among the top of any agricultural input. Industrial agriculture heavily relies upon herbicides, which contribute 68% to the total pesticide usage in the US (NASS 2010). Heavy and injudicious use of herbicides has led to herbicide-resistant weeds and environmental health concerns. Mechanical tools have limitations under wet soil conditions and accessing near- or intra-row weeds, in addition to their negative impact on soil health. Therefore, there is an urgent need to develop new and more precise tools to control weeds, especially to address problematic weeds that plague crop production.

Our team aimed at developing a robotic platform that supports precision weed management by integrating a high-power laser and a computer-vision-based weed detection system. While towing the system on the back of a tractor, a stereo camera along with onboard image processing algorithm identifies and localizes the weeds, signaling the high-power laser to take action. This project went through multiple iterations and its feasibility and effectiveness have been thoroughly tested in this research.

Methods and Results
An important focus of our project has been making a stationary prototype to illustrate the functionality and test the capabilities of the system:
- The basic framework of the system is a laser mounted on a motorized gimbal system attached to a microcontroller which interfaces with the stereo camera (Figure 1a).
- Laser power supply, gimbal, Nvidia Jetson microcontroller and Intel RealSense stereo camera were integrated onto the frame.
- The system aims weeds radially based on their locations calculated from the depth data generated by the stereo camera (Figures 1b).

Another focus has been developing a machine-learning-based weed detection algorithm:
- An algorithm called FasterRCNN (Ren et al. 2015) implemented in Tensorflow is used.
- The algorithm uses the stereo camera to capture an image of weeds beneath the frame. Using the trained machine learning algorithm, weeds in the captured image are detected and bounding boxes are drawn around each weed (Figure 2).
- Using the LiDAR in the stereo camera, the distance of a weed from the camera is determined. Each weed is given a specific coordinate which is sent to the motor to control laser movement.

Figure 1: a) Sketch of the framework used to prototyping the laser-based robotic weed control system. The frame consists of a gimbal system that controls laser rotation, a Nvidia Jetson microcontroller, a Intel RealSense stereo camera and a power supply system (not shown in the sketch); b) Top and side view of the laser and plants showing laser targeting mechanism.

Figure 2: An example of weed detection result using the trained FasterRCNN algorithm. Weeds in the image are outlined by a bounding box with prediction confidence annotated at the top left corner of each box.

Conclusion
The results showed that laser is a powerful tool for weed management, especially for controlling weed seedlings when laser is focused on the stems. This result provides valuable information in determining the best design solution of our robotics platform. With current progress that has been made in image processing algorithm and laser control mechanism, a fully functional prototype that can be tested in field will be soon developed.

References