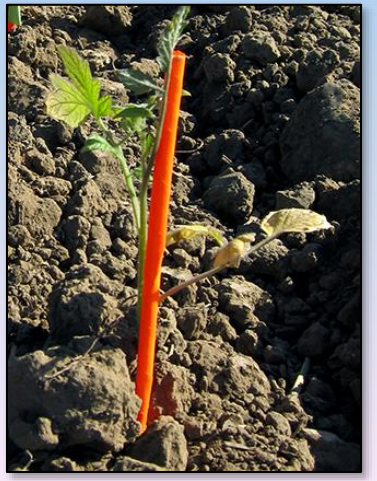
AUTOMATED WEEDING IN LETTUCE AND TOMATO USING A CROP MARKING SYSTEM

STEVE FENNIMORE,

UNIVERSITY OF CALIFORNIA, DAVIS



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- CA Tomato Research Institute

ISSUES WITH ROBOTIC WEEDERS

- Cost and complexity
- The 2-D detection system gets “lost” in heavy weed infestations
- Need better crop/weed differentiation

ACTUATOR – CULTIVATOR KNIFE

ROBOVATOR ON 80 INCH BEDS

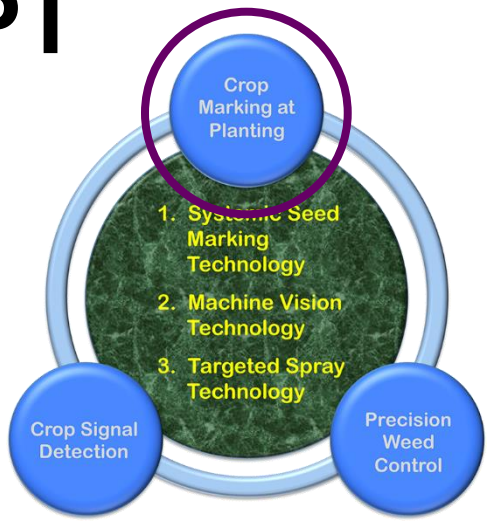
HOW TO IMPROVE CROP/WEED DIFFERENTIATION?

- Identify the crop
  - Machine learning
- Mark the crop “crop signaling”
  - Systemic marker
  - Topical markers
  - Plant labels

CRITICAL POINTS

- ❖Weed control in vegetables is complex and multiple tools are used
- ❖There are few (near zero) new herbicides for vegetables
- ❖Hand weeding is important, but is not long-term sustainable
- ❖New weed technologies besides herbicides are needed for vegetable crops

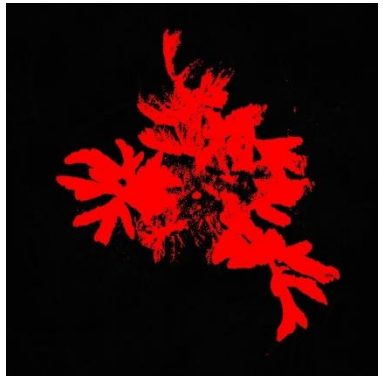
CROP SIGNALING CONCEPT



- Crop Signaling is a method by which the crop plant can signal its identity to an automated weeding machine.

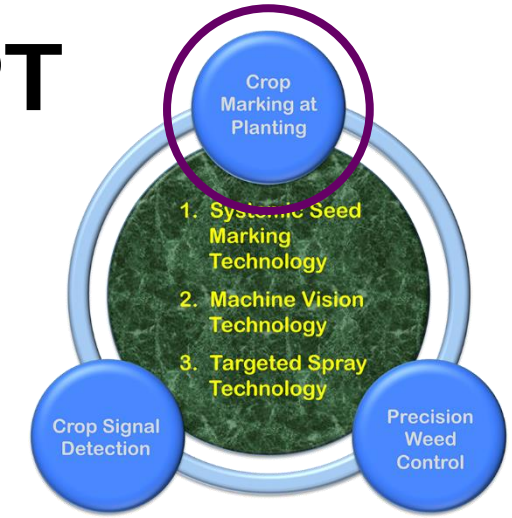
Three Methods of Crop Signaling were tested:

1. Systemic Markers
2. Topical Markers
3. Plant Labels



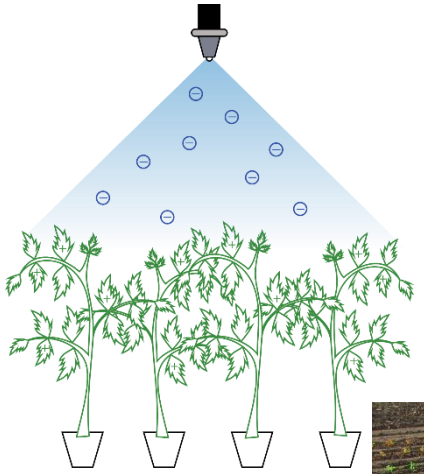
CROP SIGNALING CONCEPT

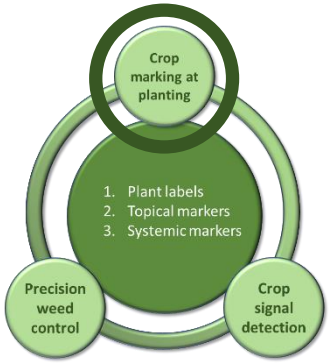
- Topical Markers



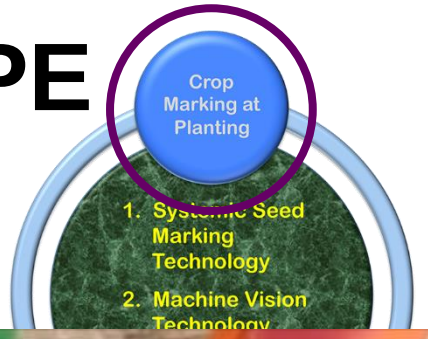
TOPICAL MARKERS

- Several formulations have been investigated
  - Water based
  - Biodegradable
  - Washes off before maturity
- Topical application is done just prior to planting
- The label is detected by the weeder during cultivation





CROP SIGNALING PROTOTYPE

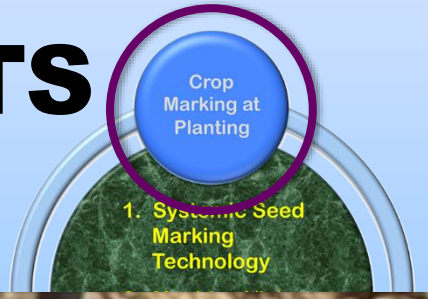


- Topical Markers

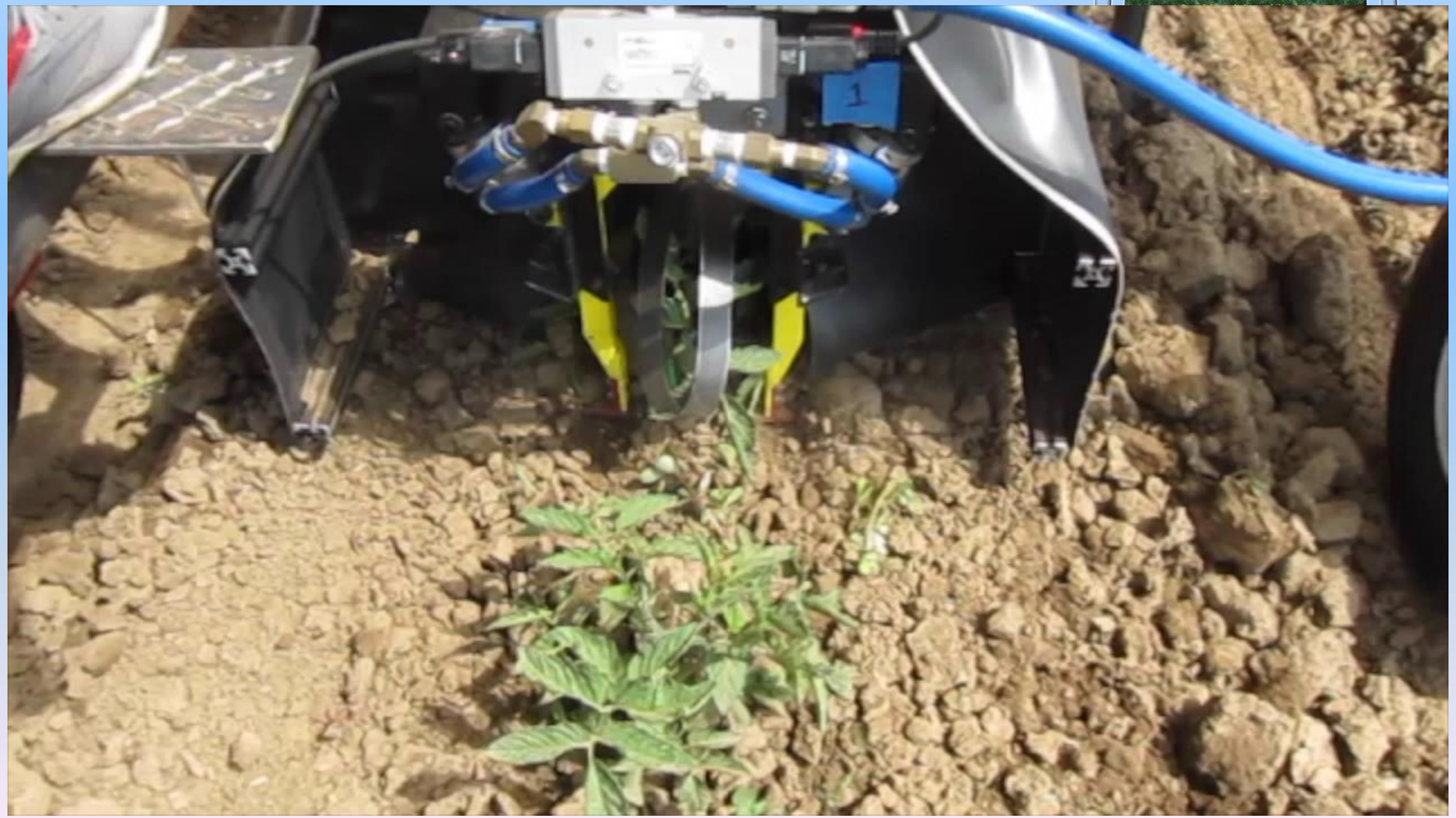
CROP SIGNALING PROTOTYPE

- Plant Labels

CROP SIGNALING RESULTS



Plant Labels



CROP SIGNAL EVALUATIONS

- 14 trials were conducted during 2016 to 2018
  - 8 in processing tomato at Davis, CA
  - 6 in lettuce at Salinas, CA
- All trials were replicated 4 times and arranged in a RCB design
- Statistical analysis was conducted using R Studio
- Data were weed densities, hand weeding times and crop harvest

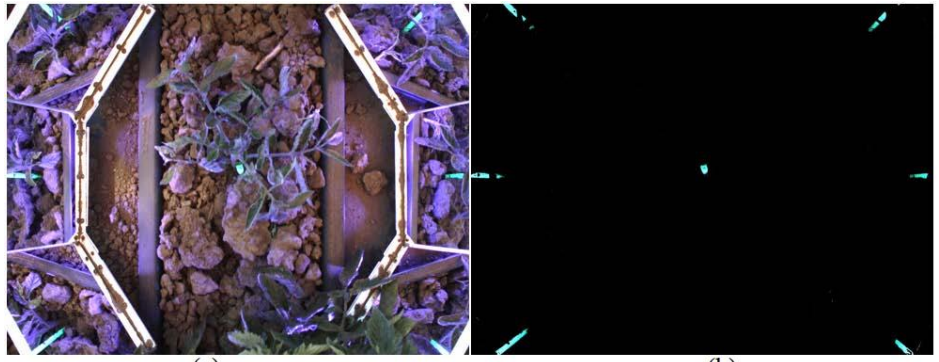
DETECTION SYSTEM

- Detector – color digital camera Scout scA 1600 Basler Inc. Germany
- Lighting system consisted of UV LED

- Detection of marked crops was near 100% (Raja et al. 2019)
- Topical marker was “Wildfire” theatrical paint

ROBOTIC WEEDER COMPONENTS

- Detection system identifies the crop/weed



- Actuator – device that kills weed – cultivator knife

TOMATO

Cultivator	Weeds after cultivation	Time to hand weed	Yield
	1,000/A	Hr/A	Tons/A
Robotic	45.3 a	7.8 a	22.0 a
Standard	458.1 b	14.9 b	25.1 a

LETTUCE

Cultivator	Weeds after cultivation	Time to hand weed	Yield
	1,000/A	Hr/A	Tons/A
Robotic	72.8 a	16.0 a	20.4 a
Standard	213.7 b	29.1 b	16.9 a

CONCLUSIONS

- The robotic weeder removed 90% more weeds in tomato and 66% more weeds in lettuce than the standard cultivator
- The robotic weeder reduced hand weeding times 48% in tomato and 45% in lettuce compared to the standard cultivator
- The robotic weeder did not reduce tomato or lettuce yields compared to the standard cultivator

OWNERSHIP & OPERATING COSTS

Category	Traditional	Steketee IC	Robovator	Signaling
	---------- $/A ----------			
Ownership	--	53	73	67
Auto cultivation	--	165	199	190
Hand weed	161	100	100	88
Total	161	318	372	345

Tourte et al. CA Ag in review

SUMMARY

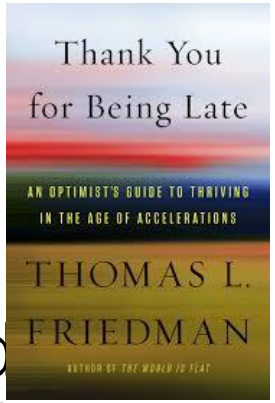
- Topical markers and plant labels resulted in crop recognition >99%
- Weed removal with the plant signaling system was more efficient than standard inter-row cultivation

1. WEED AUTOMATION NEEDS

- Train students in multiple disciplines needed for weed control automation
  - technology, engineering, weed science
- Research needed for high-risk high-gain technologies
  - Lasers
  - Abrasives (sand blasting)
  - Thermal methods (hot oil, serial flaming)
  - High pressure water
  - Crop/weed identification

2. WEED AUTOMATION NEEDS

- Joint ventures between industry and public sector will create opportunities
  - Create new companies and jobs
  - Student internships and real world mentoring
  - Ensure that students are being trained with skills relevant for a workplace with continuously changing technology

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