Alternative Strategies to Manual Weeding and Conventional Pesticide-Based Weed Control

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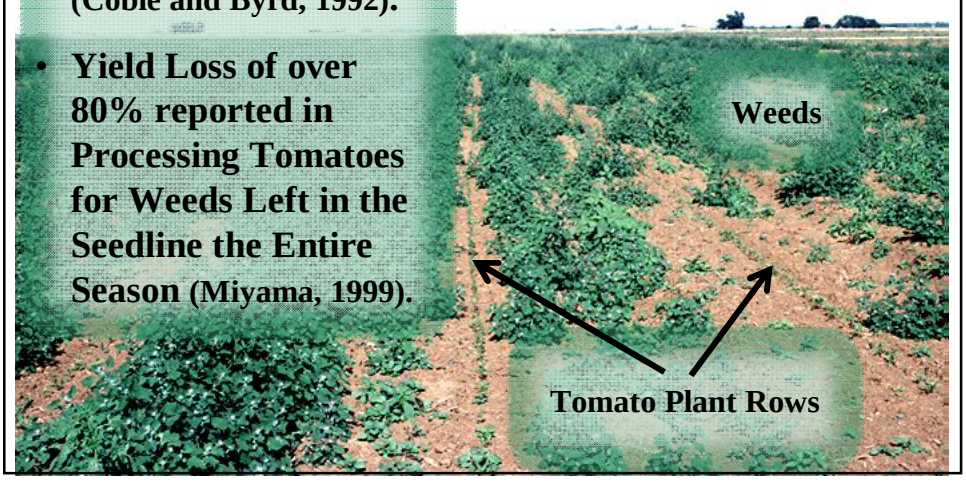
Weeds Reduce Yields

- **Yield Loss of 0.26% to 8.85% reported for Each Single Weed in a 10-m Row of Cotton (Coble and Byrd, 1992).**
- **Yield Loss of over 80% reported in Processing Tomatoes for Weeds Left in the Seedline the Entire Season (Miyama, 1999).**



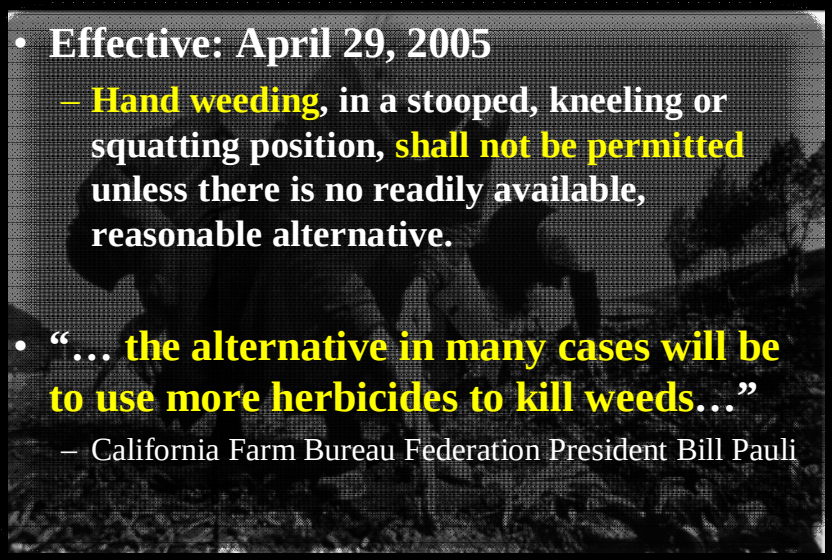
Health Risks of Weed Control

- 1975: California banned the use of short handled tools (Title 8, Section 3456) based upon:
  - Medical evidence relating short tool usage and irreparable spinal injury and permanent disability.
- Hand weeding without tools was allowed until 2002.

Health Risks of Weed Control

- **1993: Division of Occupational Safety and Health reported that hand weeding is more damaging than short handled weeding**
  - **6-12 inches more bending than with a short handed hoe.**
  - **Extreme bending causes an exponential increase in forces on the back.**

Health Risks of Weed Control



- **Effective: April 29, 2005**
  - **Hand weeding, in a stooped, kneeling or squatting position, shall not be permitted unless there is no readily available, reasonable alternative.**
- **"… the alternative in many cases will be to use more herbicides to kill weeds…"**
  - California Farm Bureau Federation President Bill Pauli

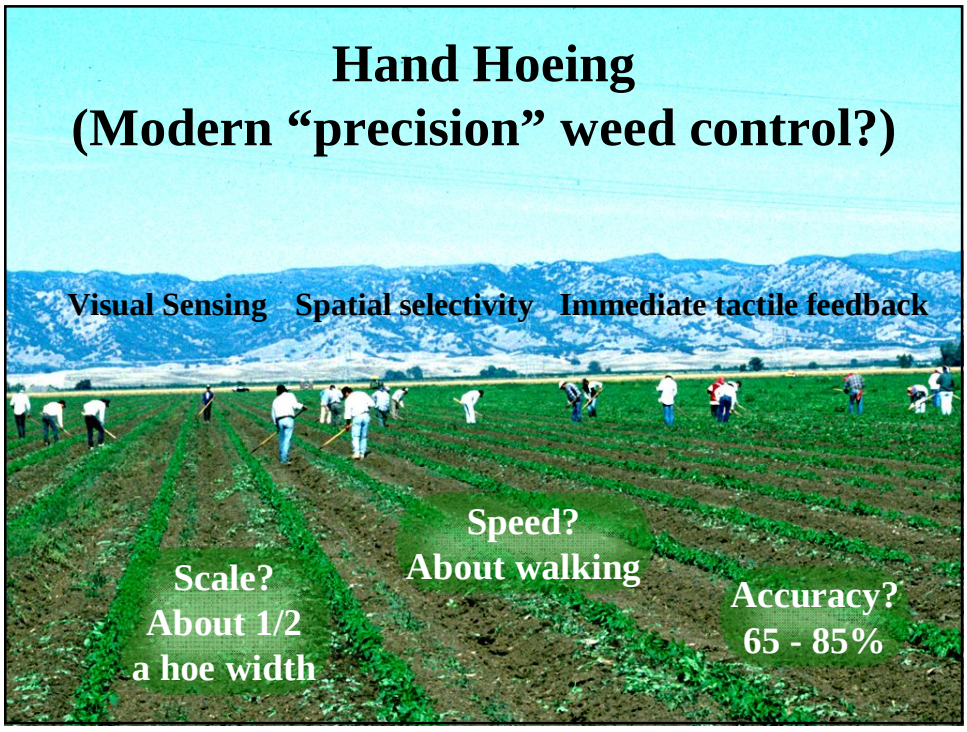
Herbicide use in California

- **From 1996 to 2006, over 1.2 billion lbs of herbicides were used in California (Includes non-Ag uses, CDPR 2008).**
- The introduction of herbicide tolerant crops has allowed some growers to switch to herbicides that are effective at lower rates of usage per acre. (USDA, ERS, 2006).
- "However, statistical analyses from 1992 to 2005 do not indicate a significant trend of either increase or decrease in pesticide use" (CDPR 2005).
- The majority (60%) of herbicides detected in California surface water were applied during November to March as a preemergent application on bare soil (CDPR 2008).

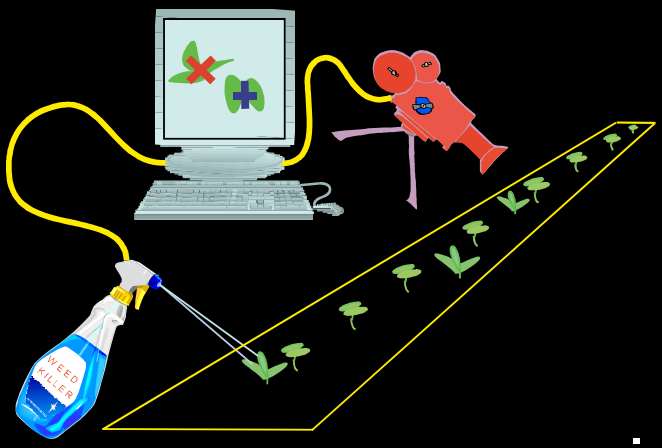
Importance of Weed Control in Organic Farming

- National Organic Farmers' Survey: -(Walz, 2004)
  - Respondents ranked weed management as their number one research priority.
  - Weed-related production losses and high labor costs were ranked in the top eight problems for organic farmers.

Hand Hoeing (Modern "precision" weed control?)

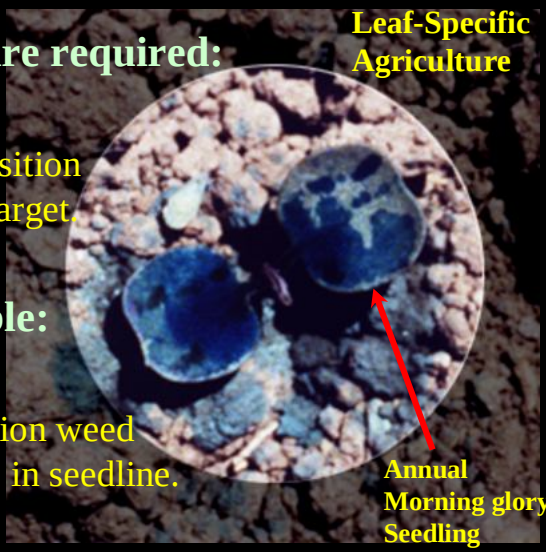


Robotic Weed Control System (Concept Picture)



Basic Concepts:

- **When herbicides are required:**
  - Sense the target.
  - Focus optimal deposition exclusively on the target.
- **When mechanical methods are feasible:**
  - Sense the crop.
  - Automatically position weed knives to kill weeds in seedline.



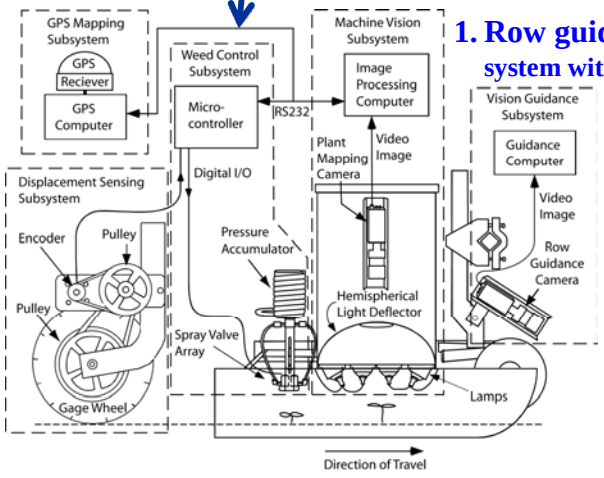
Autonomous Weed Control System

3. Weed Control System

4. Location Sensor

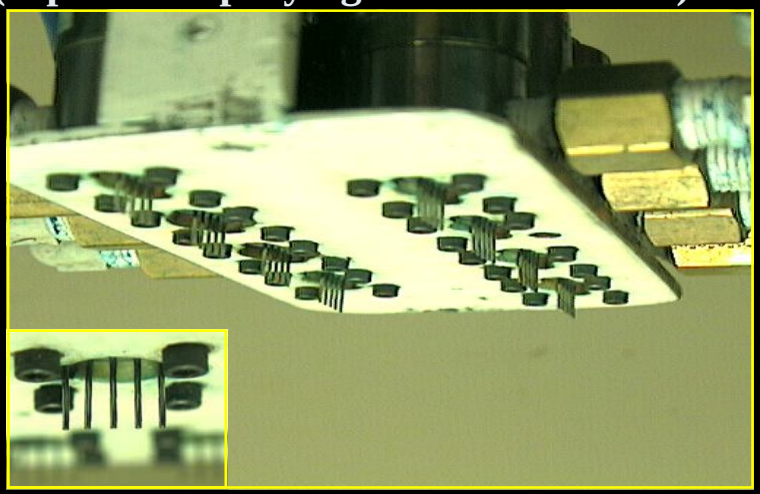
2. Plant Sensor

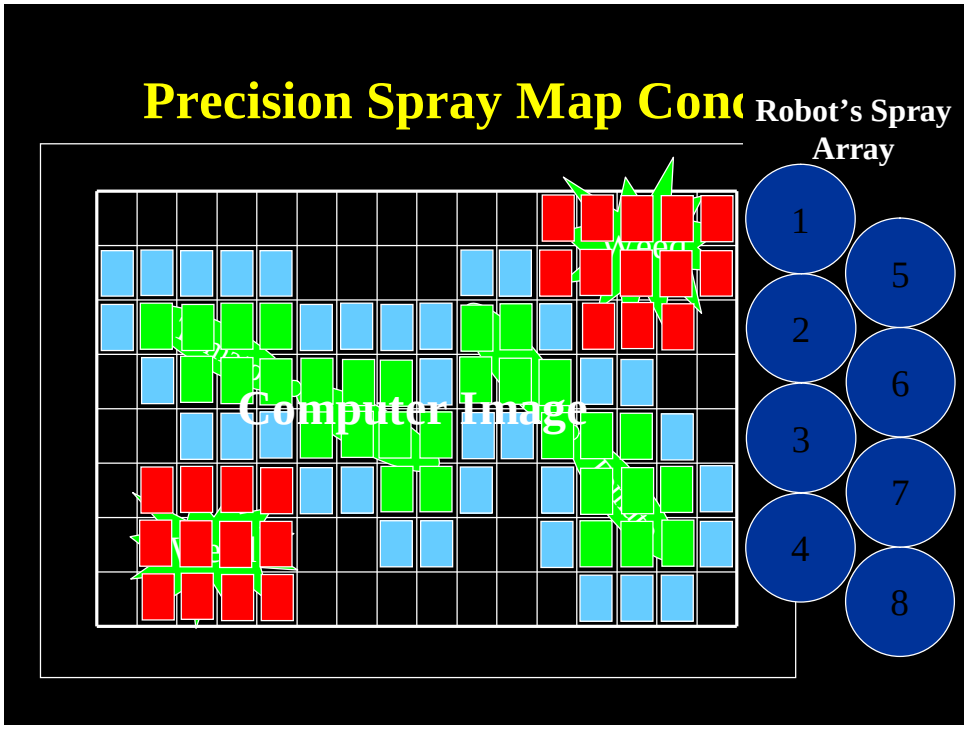
1. Row guidance to align system with crop row



UC Davis Precision Micro-sprayer

(capable of spraying individual leaves)




Precision Spray Map Con
Robot's Spray Array
Weed
Computer Image
1
2
3
4
5
6
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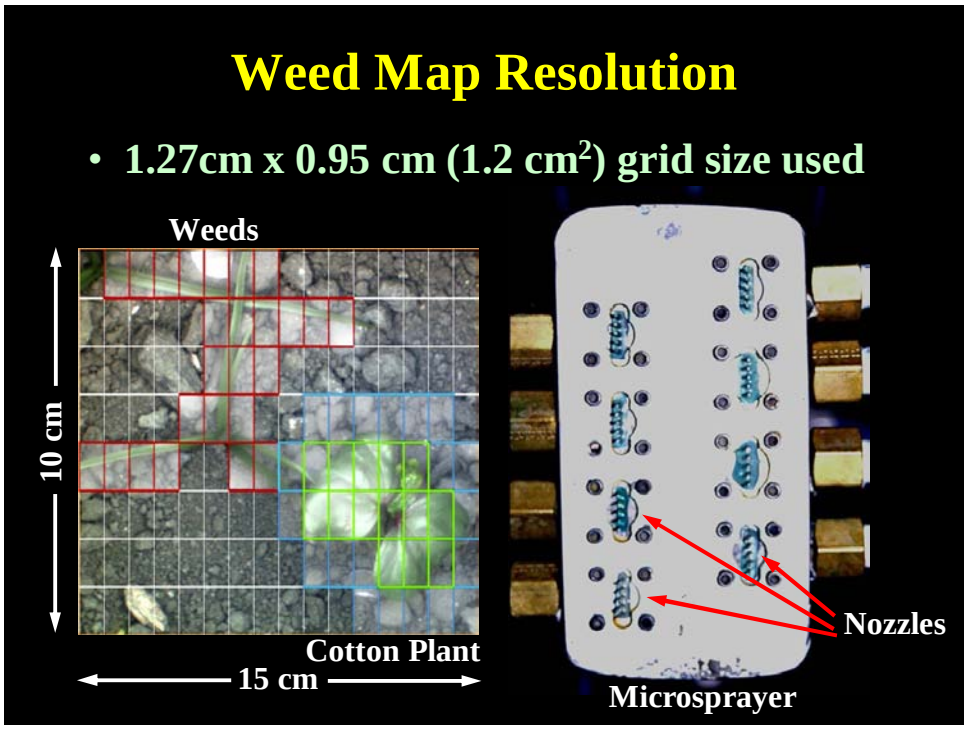

Weed Map Resolution
• 1.27cm x 0.95 cm (1.2 cm²) grid size used
Weeds
10 cm
Cotton Plant
15 cm
Nozzles
Microsprayer

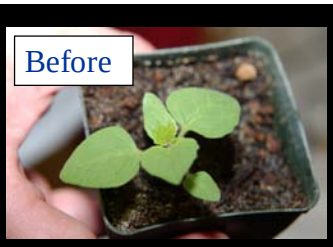
Robotic Weed Control Results

- Field results: 89% of weeds sprayed,
- 79% of cotton plants not sprayed.

Note the “guard” regions

Organic – Hot Oil Microspray

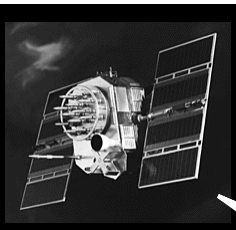
- Canola oil heated to 177 ºC
- Sprayed on top leaves.
- 96% mortality in black nightshade
- 93% mortality in pigweed.



Hyperspectral Species Classification Performance

- Evaluation of seasonal species classification stability between 2005 and 2006 compared to a site-specific calibration done in the 2006.

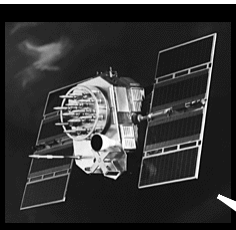
	Species Classification Rate	
Species	2005 -> 2006	2006 Site-Specific
Tomato	87%	95%
Black nightshade	86%	95%
Pigweed	84%	95%
Purselane	Not Available	99%
Lambsquarter	Not Available	92%



RTK GPS Plant Mapping

- Real-time kinematic Global Positioning System (GPS) Technology

- Automatic methods for mechanical weed control.



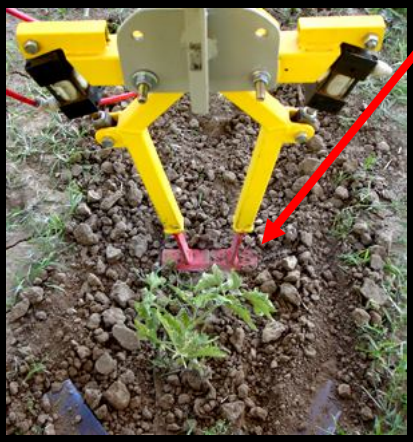
RTK GPS Plant Mapping

- Real-time kinematic Global Positioning System (GPS) Technology

- The Latitude and Longitude of each plant is automatically recorded at planting.
  - within ±1.5 inch accuracy.
- The GPS plant map is used to automatically control a set of mechanical weed knives.

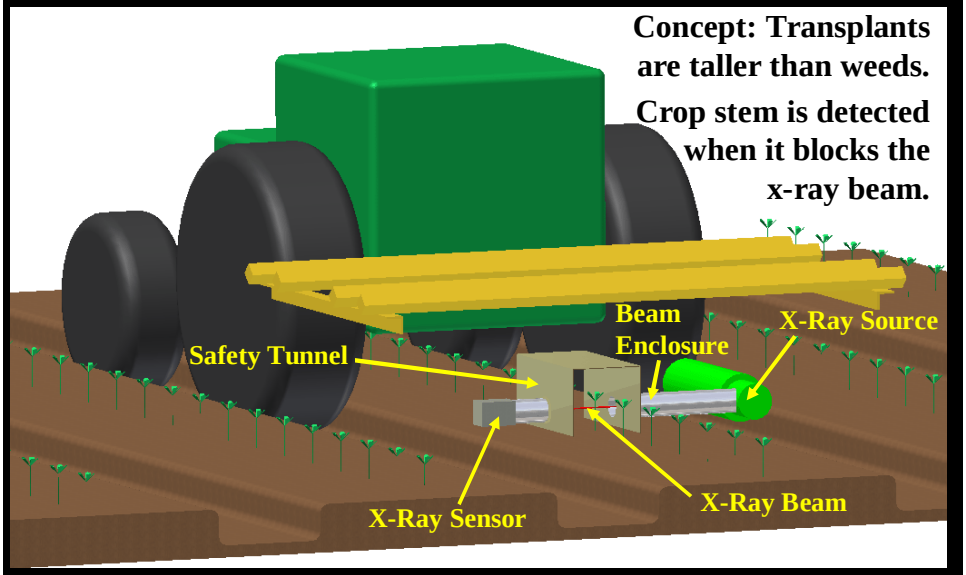
Automatic Weed Control

Before: Weed Knives Closed - killing weeds in seedline



At Plant: Weed Knives Open - avoiding tomato plant

X-Ray Stem Scanning System for Weed Control in Tomato



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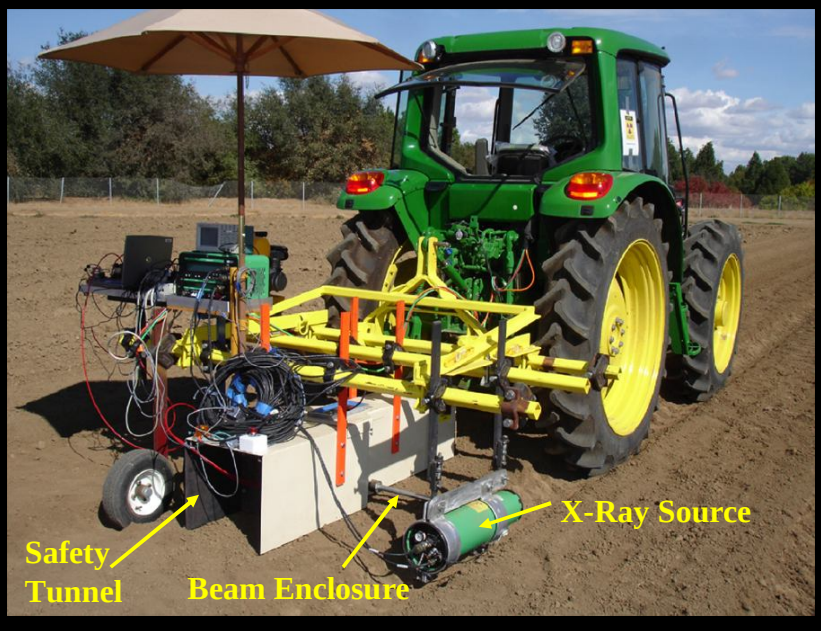

X-Ray Stem Sensor for Automatic Weed Control

- Transplants are detected when the stem blocks the x-ray beam.

Conclusions:

- **Modern sensing and control systems can achieve significant reductions in both manual labor and applied herbicides while maintaining weed control efficacy.**
- **Weed control in close proximity (less than 1 inch) to crop plants may still require some manual labor or herbicide applications.**
- **As is often the case in agriculture, the technology is proven, the barriers may be commercialization and adoption. – Giles (2002)**