Weed Control in Horticultural Crops
- Novel Approaches for Improving Efficacy, Sustainability and Crop-Safety

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Immokalee, FL

https://swfrec.ifas.ufl.edu/programs/weed-science/
The big picture
Weed management challenges for future:

- Increasing demand for food production
  - Herbicide tolerance
  - Lack of new chemistries
  - Farm labor shortages
  - Rising interest in organic production
Demand for food production is always rising

- World population is always increasing

*Image and information credits: Westwood et al. 2018*
Demand for food production is always rising

- World population is always increasing
- Food production is short now

*Image and information credits: Westwood et al. 2018*
Future

Present

Past

- Food production is short now and will continue in the future

Demand for food production is always rising

Image and information credits: Westwood et al. 2018
Weed management challenges for future.....

- Increasing demand for food production
- **Herbicide tolerance**
- **Lack of new chemistries**
- Farm labor shortages
- Rising interest in organic production
Herbicide resistance and tolerance in weeds is becoming a global threat. Approximately 100 weeds resistant to any herbicide documented in the US.
New herbicide chemistry development is lacking

- Increase in herbicide resistant weeds
- Lack of any new herbicide chemistries / mode of actions since 1980’

Image and information credits: Westwood et al. 2018
Weed management challenges for future...

- Increasing demand for food production
- Herbicide tolerance
- Lack of new chemistries
- Farm labor shortages
- Rising interest in organic production
The need... Novel and alternative approaches in weed management

**Efficacy**
- Precision weed management
  - Machine vision weed detection
  - UAS / Drone imaging

**Sustainability**
- Non-chemical/alternative approaches
  - Steam weeding
  - Natural herbicides
  - Cover-crops (citrus)

**Crop-safety**
- Herbicide placement
  - Slow-release carriers
Novel and alternative weed management strategies

- **Efficacy**
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- **Sustainability**
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- **Crop-safety**
  - Herbicide placement
    - Slow-release carriers
- **Trends in computational power & communication networking has been always rising**

Precision weed management (PWM)
Precision weed management (PWM)

“Three Rs of precision weed management”

Right amount

Right target/weed

Right time
Precision weed management (PWM)

“place the right amount of inputs [herbicides] on the right target [weeds] at the right time”
Precision weed management (PWM)

**Techniques**

- Automation / Machine Learning
- **UAS/ Drone imaging**
Precision weed management (PWM)

- **Automation / Machine Learning**
  - Synergy b/w
    - Man
    - Machine
    - Sprayer

**Techniques**
Precision weed management (PWM)

- Automation / Machine Learning
- Machine vision-based applicators - “See & Spray”
  - Precision / targeted application
  - Site specific / “need only based” sprays
  - Reduce inputs up to 90%

Source(s): Zijlstra et al. 2011
Sharpe et al. 2019
http://www.bluerivert.com
Precision weed management (PWM)

Automated/Machine Learning

Machine vision based applicators - “See & Spray”

Techniques

Sensors – critical component weed species discrimination

Source(s): Zijlstra et al. 2011
Sharpe et al. 2019
http://www.bluerivert.com
Precision weed management (PWM)

- Automation / Machine Learning
- Machine vision based applicators - “See & Spray”

Techniques

- Sensors – critical component
- Weed species discrimination
  - Hyperspectral – high accuracy
  - Multispectral
  - Digital Color Images

Source(s): Zijlstra et al. 2011
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Precision weed management (PWM)

- Automation / Machine Learning
  - Machine vision based applicators - “See & Spray”
  - Sensors – critical component
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    - Digital Color Images

Source(s): Zijlstra et al. 2011
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           http://www.bluerivert.com
Color Image based weed detection

“Geranium weed” growing in the strawberry crop plasticulture beds

Image and information credits: Sharpe et al. 2019
‘Weed detection’ boxes generated on images for *Geranium weed* growing with the strawberry crop plasticulture

*Image and information credits: Sharpe et al. 2019*
Color Image based weed detection – **drawbacks**

- False-positive identifications
Automation / Machine Learning

**Pros**
- Potentially reduce chemical use

**Cons**
- Lack of a robust weed sensor
- Commercial-scale applicability to all crops, weed species, and growing conditions is challenging
Techniques

- **Unmanned aerial systems (UAS) / Drones**
  - Images can be used for inferring weed management decisions
Heavy parthenium infestation in a cucumber farm
Immokalee, FL
Parthenium weed control study in cucumber crop
Immokalee, FL - 2017
Unmanned Aerial System (UAS) based model to quantify herbicide efficacy

Visual Sensor: Drone image showing the efficacy of herbicide treatments
Unmanned Aerial System (UAS) based model to quantify herbicide efficacy

Multispectral Sensor shows photosynthetic activity of weeds
Unmanned Aerial System (UAS) based model to quantify herbicide efficacy

Multispectral Sensor shows photosynthetic activity of weeds

1 high weed activity
2 low or no activity
Unmanned Aerial System (UAS) based model to quantify herbicide efficacy

Vegetation vigor

Weed Mortality

Multispectral Sensor shows photosynthetic activity of weeds
Unmanned Aerial System (UAS) based model to quantify herbicide efficacy

- To help growers optimally schedule their spray applications
- To avoid any redundant follow-up herbicide application in areas where weed control has been achieved to a large degree.

Kanissery, Singh and Fletcher, 2018
Unmanned Aerial System (UAS) based model to quantify herbicide efficacy

Model fit ($R^2$) = 0.96

Pros
- Evaluating herbicide injury
- Calculating spray thresholds
- Planning site-specific application of herbicide

Cons
- Work with large data sets
- Hardware & Software knowhow
Novel approaches - *Weed Management in Horticulture Productions*

**Efficacy**
- Precision weed management
- Machine vision weed detection
- UAS / Drone imaging

**Sustainability**
- Non-chemical/alternative approaches
- Steam weeding
- Natural herbicides
- Cover-crops (citrus)

**Crop-safety**
- Herbicide placement
- Slow-release carriers
**Steaming** – as a tool in weed management

- *Thermal weed management strategies*
  - E.g., steam, hot water, flame etc.

- Non-chemical weed management strategy in commercial horticulture production

![Image of Mobile boom connected to steamer]
Steaming – in citrus weed management

- Steam generating system

[Image of steam generating system with labeled parts: Water tank, Electric generator, Flow meter, Water Pump]
Steaming – in citrus weed management

- Non-chemical weed management
- Sustainable

Steamer pulled by tractor
Steaming – in citrus weed management

Treatments

combination of
- Steam pressure levels
- Tractor speed levels

~2 weeks after treatment

Weed control (%)

Untreated check  Paraoquat  Steam Trt 1  Steam Trt 2  Steam Trt 3  Steam Trt 4

High pressure (53 L hr\(^{-1}\)) + Low tractor speed (1.7 km hr\(^{-1}\))

Abdulridha et al. 2019; doi: 10.13031/aea.13494
Steaming – in citrus weed management

E.g., of weeds controlled by steam

Sedges

Goatweed

Guinea grass

Abdulridha et al. 2019; doi: 10.13031/aea.13494
Steaming – in citrus weed management

- For weed management in the citrus rows

Steam application for citrus row weed control

~ 6 hrs. after steam application
Steaming – in citrus weed management

- For weed management in the citrus rows
Goat weed

- Slow response to glyphosate & paraquat application
Goat weed control in citrus

- Steam was applied followed by a contact herbicide.

<table>
<thead>
<tr>
<th>Paraquat rate (pt. / acre)</th>
<th>No steam</th>
<th>With Steam</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Goat weed control in citrus**

- Steam was applied followed by a contact herbicide
- Contact herbicide found effective even at lower application rate when combined with steam application

<table>
<thead>
<tr>
<th>1 week after treatment</th>
<th>No steam</th>
<th>With Steam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paraquat rate (pt. / acre)</td>
<td>% weed control</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0&lt;sup&gt;c&lt;/sup&gt;</td>
<td>54&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>1</td>
<td>51&lt;sup&gt;b&lt;/sup&gt;</td>
<td>92&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>95&lt;sup&gt;a&lt;/sup&gt;</td>
<td>96&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

- Replication (n) = 4
- Mean comparison: Tukey’s hsd (p < 0.05)
Steaming in combination with herbicide application

**Goat weed control in citrus**

- Steam was applied followed by a contact herbicide

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<tr>
<td>0</td>
<td>0&lt;sup&gt;c&lt;/sup&gt;</td>
<td>37&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>1</td>
<td>25&lt;sup&gt;b&lt;/sup&gt;</td>
<td>53&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>85&lt;sup&gt;a&lt;/sup&gt;</td>
<td>81&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

~1 month after treatment

- CV 15.36
- P-value <0.0001

- Replication (n) = 4
- Mean comparison: Tukey’s hsd (p < 0.05)
Steaming for weed control in ditch banks

2 days after steam application
Steam weeding

**Pros**
- Reduce chemical foot-print
- An option for organic production

**Cons**
- Potential weed re-growth
- Relatively slower application process than herbicide sprays
  - *E.g., Tractor speed should be ~1 mph for successful steam weeding*
Utilizing **aquatic weeds** as potential ‘natural’ or ‘bio’ herbicide towards promoting sustainable agriculture

- Natural herbicides: ‘green’ products
- Plant-based herbicides
- Examples:
  - Botanical oils (Clove oil, eugenol)
  - Soaps (pelargonic acid)
  - Vinegar

**Recycling aquatic weeds** for suppressing terrestrial weeds

- novel and environmentally-friendly approach
Recycling aquatic weeds for suppressing terrestrial weeds

Muskgrass *Chara* spp.

Filamentous algae *Lyngbya wollei*

Aquatic weed powder

Aquatic weed extracts

- Fu et al (2020) - MS student project
Aquatic weed extracts suppressed the germination and growth of Pigweed (Amaranth)

Possible allelopathic effects

Aquatic weeds

- a problem weed in vegetables and other crops

Fu et al., 2020
https://journals.plos.org/plosone/article/figure?id=10.1371/journal.pone.0237258.g006
Use of cover crops as a weed control strategy

Cover crops for row-middle management in citrus

- Emerging practice in citrus production
- Soil quality improvement
- *Weed control* is an added benefit
- Possible allelopathic effects

Cove crop mix planted in citrus row middles
Use of cover crops as a weed control strategy in citrus

- Cover crops significantly reduced the weed pressure in treated row-middles when compared to non treated controls

- E.g., of Cover crops planted: Daikon radish, White Clover, Crimson Clover & Buckwheat

- No. of observations per treatment (n) = 18
- Bars with the same letters do not significantly differ (Tukey’s HSD, P<0.01)
Novel and alternative weed management strategies

**Efficacy**
- Precision weed management
  - Machine vision weed detection
  - UAS / Drone imaging

**Sustainability**
- Non-chemical/alternative approaches
  - Steam weeding
  - Natural herbicides
  - Cover-crops (citrus)

**Crop-safety**
- Herbicide carriers
  - Slow-release polymers
  - Fertilizers as herbicide carriers
- **Nutsedge** infestation in plasticulture production

Yellow Nutsedge taking over the plastic beds
Immokalee, FL
Nutsedge control is one of the main challenges faced by producers

**Spraying herbicides on raised beds** before installation of plastic mulch is among the control options

- S-metolachlor (Dual Magnum)
- Fomesafen (Reflex)
Residual herbicide persistence in vegetables is a great concern for growers

- **S-metolachlor** sprays on beds manage nutsedge effectively

- However, potentially injure the transplants

*S-metolachlor (Dual Magnum)*: injured pepper transplant from metolachlor application under the plastic beds
The concept of **herbicide carriers**

- For **crop-safe placement** of herbicide under the plastic mulch on raised beds
  - Placing herbicide in the weed activity zone
  - Keeping the chemicals out of crop root zone
  - Utilizing slow-release technology

- Slow-release polymer granules (also known as *hydrogels*)

- Fertilizers, manures, compost etc. are also being evaluated as carriers
How **herbicide carriers** works?

- Side dress application on raised beds before installing plastic mulch
How **herbicide carriers** works?

- Side dress application on raised beds before installing plastic mulch

Key: 🌱 Herbicide - carrier complex
How slow-release carriers works?

- Side dress application on raised beds before installing plastic mulch
Hydrogel based pre-emergent herbicide application on raised bed plasticulture production

Hydrogels based herbicide application under the plastic in pepper production Immokalee, FL
Hydrogel based pre-emergent herbicide application on raised bed plasticulture production

Pre-emergent herbicide with hydrogel applied on bed under plastic

Untreated control
Hydrogel based pre-emergent herbicide application
Both spraying and hydrogel-based treatments of s-metolachlor were effective in suppressing Nutsedge.
Hydrogel as herbicide carriers in vegetable plasticulture

- Both spraying and hydrogel-based treatments of s-metolachlor were effective in suppressing Nutsedge.
Hydrogel as herbicide carriers in vegetable plasticulture

- **Plant vigor of pepper** plants were periodically measured using a hand-held spad meter.

![Hand-held spad meter](image)

**Plant Vigor - 1.5 Months**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant Vigor (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated Control</td>
<td>A</td>
</tr>
<tr>
<td>Spray</td>
<td>B</td>
</tr>
<tr>
<td>Low rate + Hydrogel</td>
<td>A</td>
</tr>
<tr>
<td>High rate + Hydrogel</td>
<td>A</td>
</tr>
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Mean Separation Tukey’s HSD at P ≤ 0.05
Hydrogel as herbicide carriers in vegetable plasticulture

- Hydrogel based treatments had better plant vigor

Plant Vigor - 1.5 Months

Mean Separation Tukey's HSD at $P \leq 0.05$
Hydrogel as herbicide carriers in vegetable plasticulture

- Pepper yield data was collected

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rate (pt/A)</th>
<th>No. marketable fruits</th>
<th>Wt. marketable fruits (g)</th>
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<tbody>
<tr>
<td>Untreated Control</td>
<td>n/a</td>
<td>12&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1893</td>
</tr>
<tr>
<td>Spray</td>
<td>1.50</td>
<td>23&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3777</td>
</tr>
<tr>
<td>Low rate + Hydrogel</td>
<td>0.75</td>
<td>35&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5461</td>
</tr>
<tr>
<td>High rate + Hydrogel</td>
<td>1.50</td>
<td>30&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>5413</td>
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**P-value**

|                | 0.02       | 0.05       |

Mean Separation Tukey’s HSD at P ≤ 0.05.
**Hydrogel as herbicide carriers in vegetable plasticulture**

- Bell pepper yield improved with carrier-based application

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**P-value**

Mean Separation Tukey’s HSD at $P \leq 0.05$
Several fertilizers and manures are currently being evaluated as herbicide carriers – “weeding by feeding”
- Polymer coated urea
- Chelated Fe EDTA
- Borax
- Compost etc.
Herbicide carriers

**Pros**
- Improved crop-safety
- Potentially increase the herbicide retention in soil

**Cons**
- Risk of carry-over toxicity to subsequent crops
- Techniques / equipment to scale up the application in commercial farms
Summary

Novel and alternative weed management approaches

- Automation / Machine Learning
  - Discriminating the weeds from crop
  - Sensors & training

- UAS / Drone imaging
  - Informed weed management decisions

- Steaming
  - Efficacy comparable to ‘contact’ herbicides
  - Potential weed re-growth possible
Summary

Novel and alternative weed management approaches

- **Natural herbicides**
  - *Screening of aquatic weeds for herbicidal activity*
  - *Allelopathic effects*

- **Cover crops**
  - *Weed suppression in citrus production*

- **Herbicide carriers**
  - *Slow-release techniques*
  - *Scaling up the application - challenge*
Acknowledgements

**SWFREC weed science team (2018-2021)**

From left: **Shea Teems, Biwek Gairhe, Robert Riefer, Ramdas Kanissery**

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Dr. Sarah Strauss
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Dr. Nathan Boyd
Dr. Peter Dittmar
Dr. Jehangir Bhadha
Dr. Aditya Singh
and more..

https://swfrec.ifas.ufl.edu/programs/weed-science
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