

# Optimal Weed Control in Citrus

- *Latest on Chemical Strategies and Non-chemical Alternatives*

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# Talk outline: Optimal Weed Control in Citrus – Updates on

## Chemical strategies

- Effective herbicide use
- Tree-safe herbicide use

## Non-chemical alternatives

- Cover-cropping

# Talk outline: Optimal Weed Control in Citrus – Updates on

## Chemical strategies

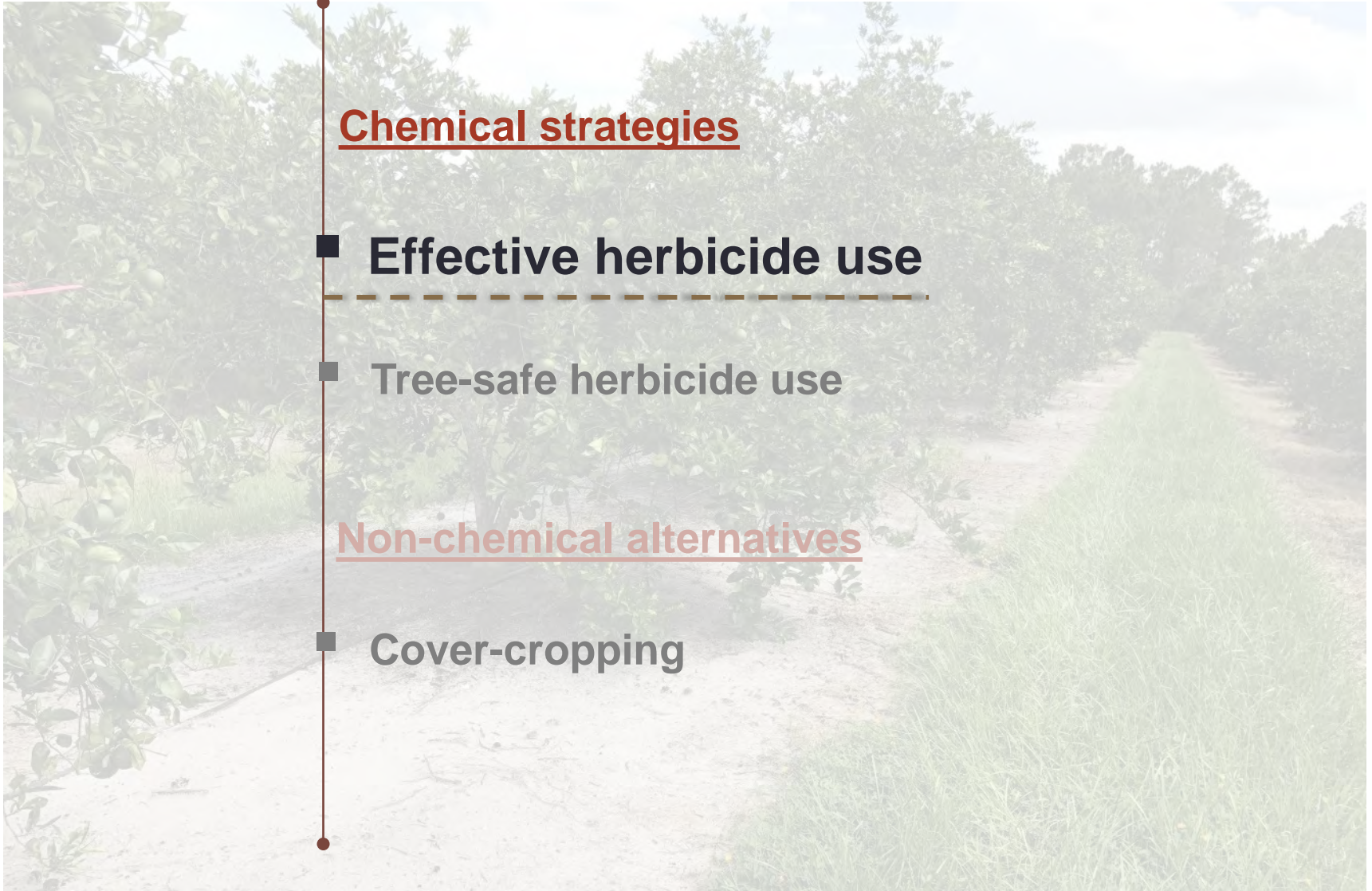
- **Effective herbicide use**

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- **Tree-safe herbicide use**

## Non-chemical alternatives

- **Cover-cropping**



# POST-emergence: What to Mix and What Not to Mix!



## Glyphosate + 2,4-D (Embed Extra®)



clogged sprayer filter

*Mixing issues - Dilution is the solution!*

- Increase water application volumes (e.g., 20+ GPA)
- Only add glyphosate when the spray tank is full

# POST-emergents: What to Mix and What Not to Mix!



## Glyphosate + 2,4-D (Embed Extra®)



Survival of grass seedlings to glyphosate + 2,4-D mixture (right)

e.g., Johnson grass, Guinea grass, Barnyard grass etc.

# POST-emergents: What to Mix and What Not to Mix!



These POST- herbicide mixes will NOT have favorable outcomes

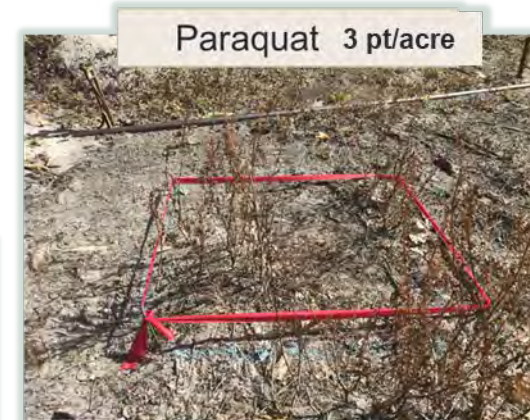
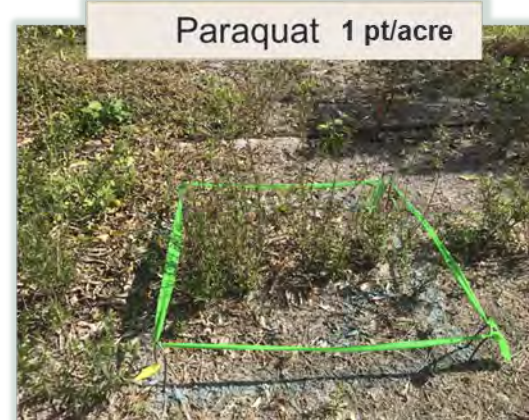
- ❌ Fluazifop-butyl (Fusilade) + 2,4-D (Embed Extra<sup>®</sup>)
- ❌ Glyphosate + Carfentrazone (Aim)
- ❌ Glyphosate + Glufosinate (Scout, Rely 280 etc.)

# Improving herbicide application outcomes

Use optimum **rates**

Use high labeled rates

- Heavy weed infestation
- Weeds in mature growth stage



Effect of paraquat application rates on goatweed control

# Strategies for getting the best out of POST-emergents

*–tips for improving efficacy*

## Use an appropriate surfactant

- Helps improve the herbicide retention, coverage and efficacy



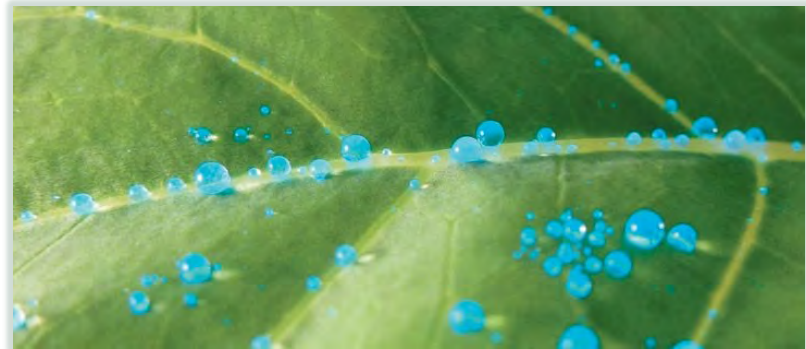
Saflufenacil (Treevix) + NIS



Saflufenacil (Treevix) + Methylated seed oil (MSO)



Grass killers + Crop oil conc. (COC)



UV light showing herbicide spray-retention on cabbage leaf-surface when surfactant was used



# Strategies for getting the best out of POST-emergents

*—tips for improving efficacy*

## *The half-life of selected herbicides at different solution pH values*

### Use suggested adjuvants

- **AMS, Buffers, etc.**
- Most herbicides work best when the pH of mixing water is 4-6

*(Read specific product labels for requirement)*

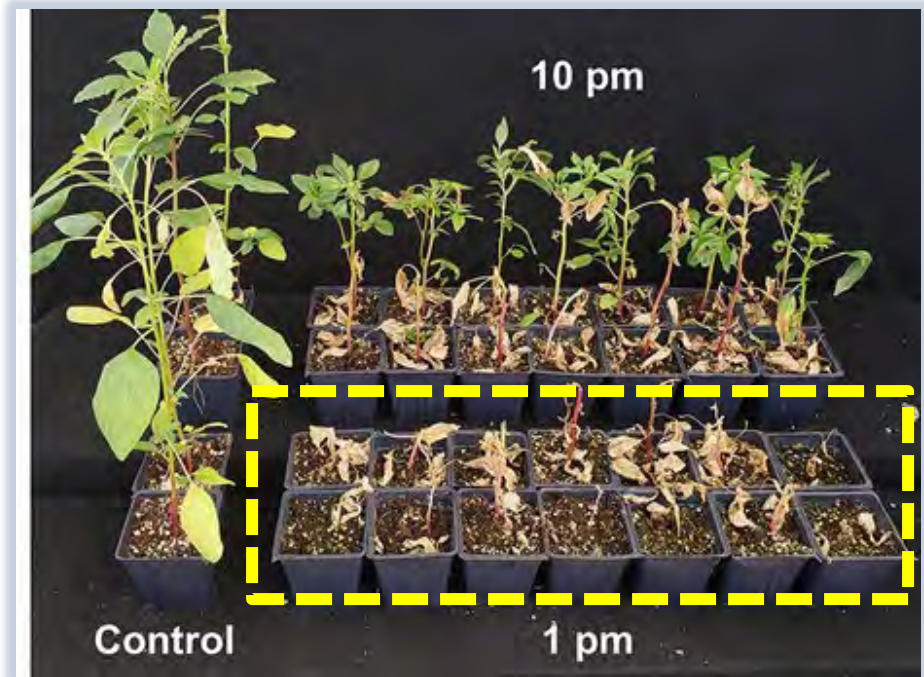
<i>Herbicide a.i</i>	pH 5	pH 6	pH 7	pH 8	pH 9
Sethoxydim	Stable	Stable	Stable	Stable	Stable
Paraquat	Stable	Stable	Stable	Unstable	Unstable
2,4-D	Stable	Stable	Stable	Unstable	Unstable
Glyphosate	Stable	Stable	Unstable	Unstable	Unstable

# When to spray herbicides? – dawn, noon or dusk

Apply when there **is ample sunlight**

- **Mid-day applications** enhance effectiveness of *Glufosinate*
- Broad-leaf weeds tended to be more sensitive to the time-of-day effect than grasses

## Impacts of 'application time' on glufosinate efficacy




# Spraying during rainy season – *give at least 6 hrs. dry period*

## Rainfast periods of burndown herbicides

- Time required between application and rain for the product to perform effectively
- Generally, rainfall within 6 hrs. after application may reduce effectiveness

### E.g., of Rainfast ratings for citrus herbicides

Herbicide products	Hours until rainfast
Aim	1
Gramoxone SL	0.5
Roundup PowerMax	0.5
Roundup WeatherMax	0.5
Scout	4
Embed extra	6+ 
Poast	1
Fusilade DX	1
Treevix	1

Source: Product Labels

## Spraying during summer— *apply during the cooler part of the day*



Efficacy of these POST-emergent systemic herbicides reduces when temperatures are **above 95°F**

- Glyphosate
- 2,4-D – Embed Extra
- Sethoxydim - Poast

Injury potential to tree is also high

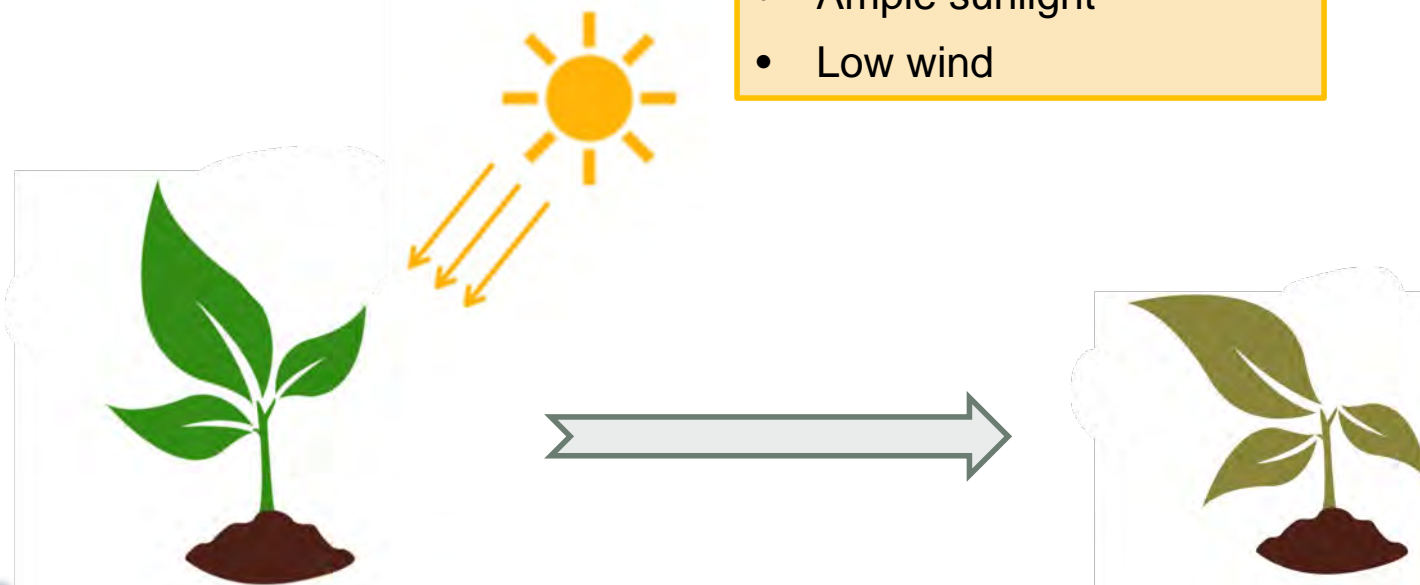
# POST-emergent herbicide application

## ✓ Do use

- Surfactants/AMS
- Optimum spray volume
- Good spray coverage

## ✓ Do spray when there is

- Ample sunlight
- Low wind



## ✓ Do apply when weeds are

- Non-stressed
- Actively growing
- Early growth stage

- Effective POST-emergent weed control

# Suppressing weed germination – *prevention is better than cure*



**Do** bring in PRE-emergent herbicides into the program

- ***A square foot of soil, 6 inches deep, can have ~3000 viable weed seeds***
- ***~130 million viable seeds per acre***



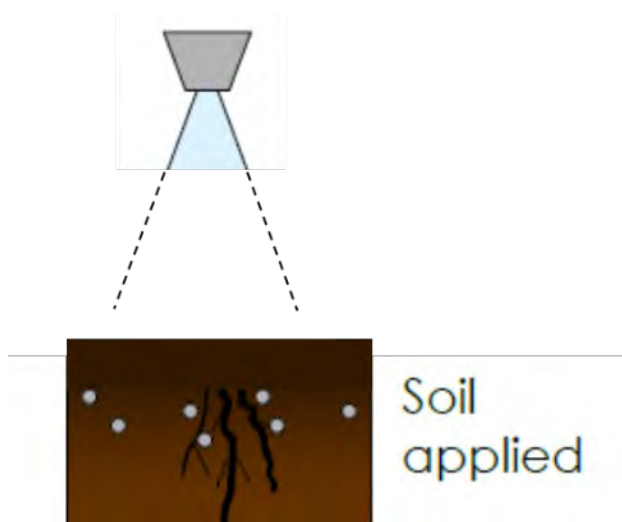
After 30 days



# Major PRE-emergence herbicides used in FL citrus

- Active ingredient – E.g., Brand name(s)

## PRE-emergent herbicides



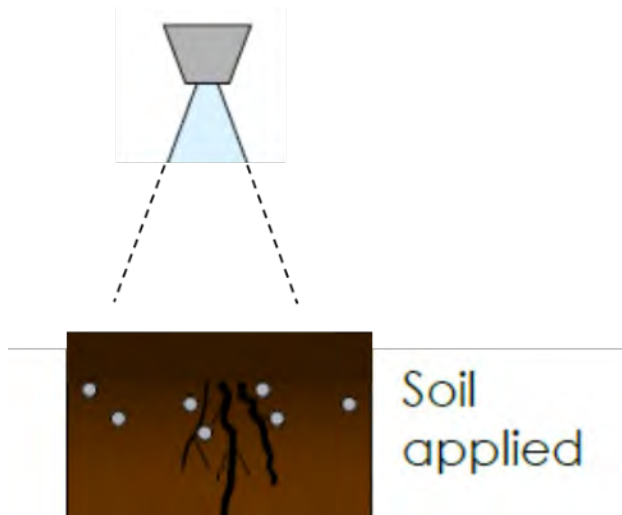
- **Simazine** – Princep, Caliber 90, etc.
- **Diuron** – Direx, Karmex, etc.
- **Norflurazon** - Solicam
- **Pendimethalin** - Prowl
- **Indaziflam** - Alion
- **Flumioxazin** – Chateau EZ

- See 'Florida Citrus Production Guide: Weed Chapter' for a complete listing of herbicides used in citrus  
- Consult specific product label for rate suggestion and other usage restrictions

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- **Norflurazon** - Solicam
- **Pendimethalin** - Prowl
- **Indaziflam** - Alion
- **Flumioxazin** – Chateau EZ
- **Rimsulfuron** – Pruvix, Matrix
- **Flazasulfuron** – Mission (*5+ years old trees*)

- See 'Florida Citrus Production Guide: Weed Chapter' for a complete listing of herbicides used in citrus  
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**Tank mixing pre-emergence/residual herbicides** helps cut-down the rates and manages herbicide tolerance issues



### *Evaluated PRE tank mixes*

<b>Active ingredient(s)</b>	<b>Herbicide product(s)</b>	<b>Product Rate (per acre)</b>
<b>Flumioxazin + Indaziflam</b>	<b>Chateau + Alion</b>	<b>6 oz 3 oz</b>
<b>Flumioxazin + Diuron</b>	<b>Chateau + Karmex</b>	<b>6 oz 4 lb</b>
<b>Flumioxazin + Norflurazon</b>	<b>Chateau + Solicam</b>	<b>8 oz 3 lbs.</b>
<b>Rimsulfuron + Indaziflam</b>	<b>Pruvin or Matrix + Alion</b>	<b>2 oz 3.5 oz</b>

## Challenges with Florida soils



Typical Crop  
production soils



Florida  
Citrus production soils

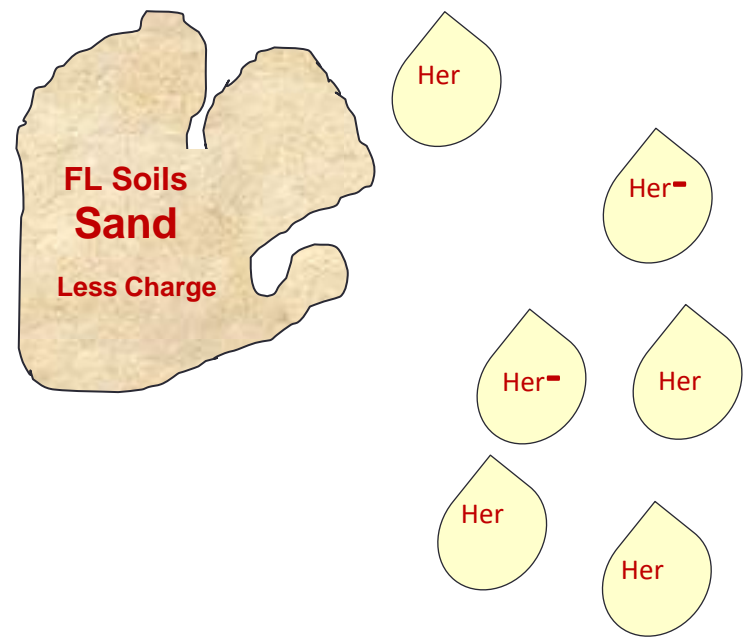
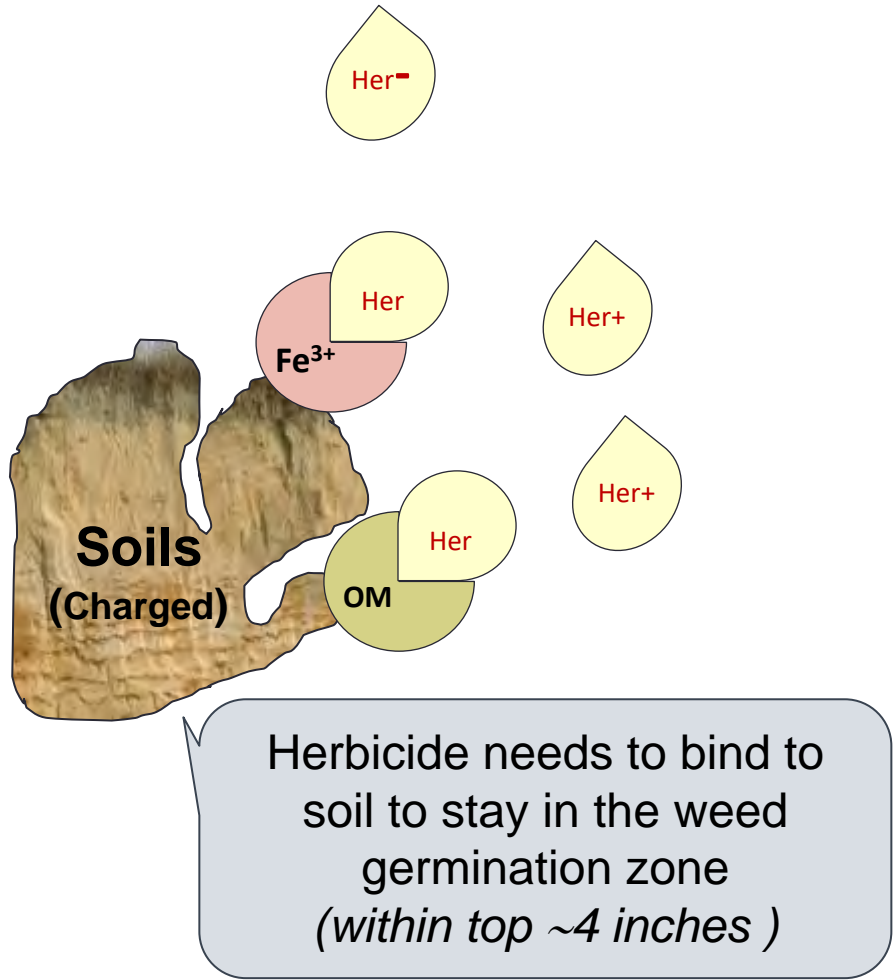
Sand >95%

Organic matter ≤1%

*Basically, beach sand !*

# PRE-emergence herbicide retention in soil – *important for weed suppression*

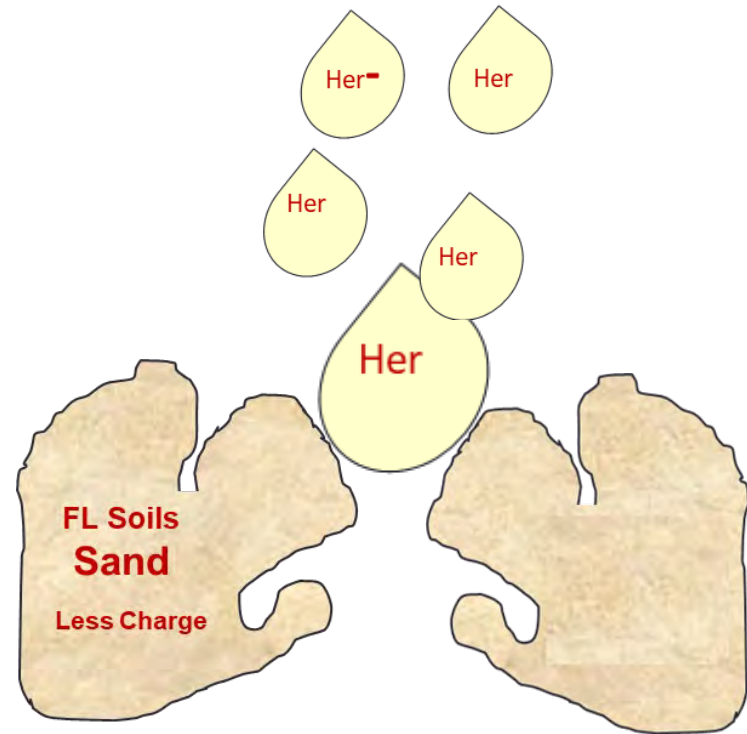
Her PRE-Herbicide



## How can we improve the herbicide retention in sandy soils?

Utilizing adjuvants for improving the efficacy of **PRE-emergence** herbicides

- Herbicide deposition agent – to improve soil retention of herbicides
- E.g., Polyvinyl polymers
- E.g trade names - Hydrovant *fA*®, Grounded® etc.
- Tank-mixed with PRE-emergence herbicides



*Deposition agents increase the herbicide spray droplet size and restricts their movement through the soil pore spaces*

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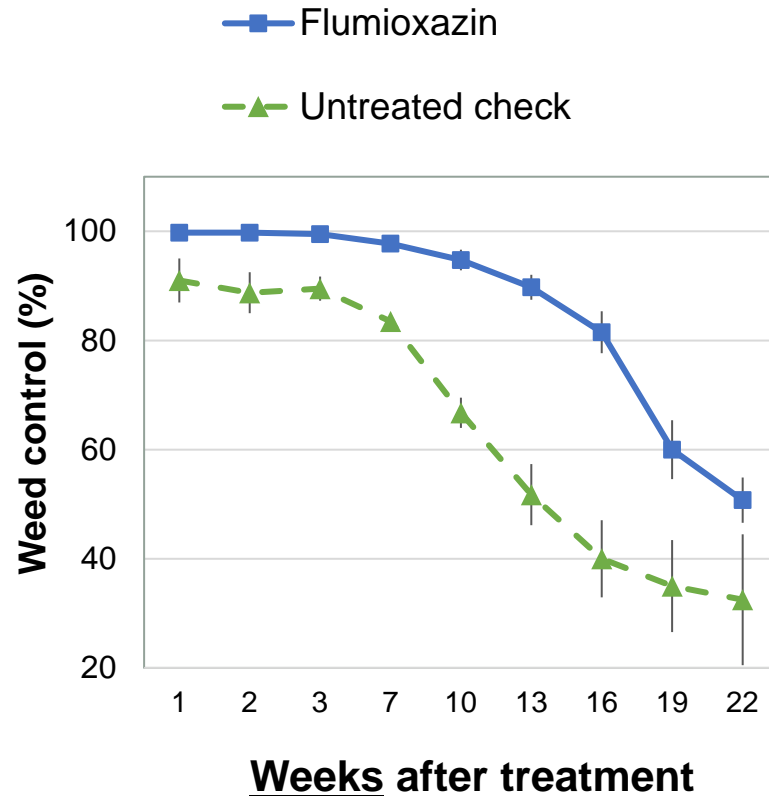
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## Utilizing adjuvants for improving the efficacy of **PRE-emergence** herbicides

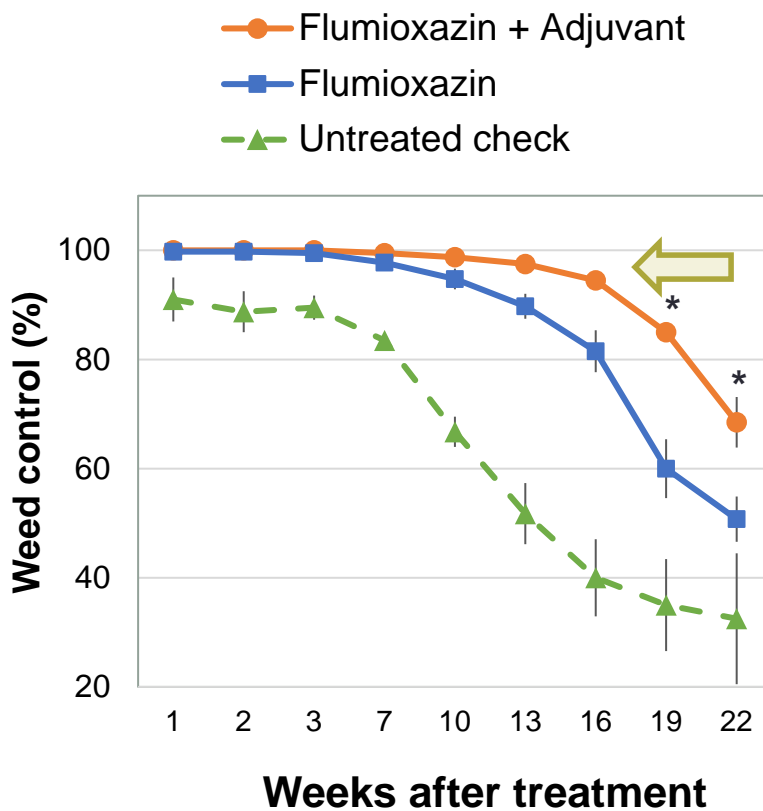
- Herbicide deposition agent or adsorption agent
- E.g., Polyvinyl polymers
- E.g trade name - Hydrovant *fA*®
- Tank-mixed with PRE-emergence herbicide **Flumioxazin** (Chateau)



- Replication (n) = 4
- Mean comparison: Tukey's HSD ( $\alpha = 0.05$ )
- \* Significant difference ( $p \leq 0.05$ )

## Utilizing adjuvants for improving the efficacy of **PRE-emergence** herbicides

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Chateau 8 oz/acre + Hydrovant fA 0.1% v/v

- Replication (n) = 4
- Mean comparison: Tukey's HSD ( $\alpha = 0.05$ )
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Utilizing adjuvants for improving the efficacy of **PRE-emergence** herbicides



Flumioxazin + adjuvant  
~3 months



Untreated control  
~3 months



# POST-emergence: Herbicide tolerance issues reported..

**Parthenium weed..**



# POST-emergence: Herbicide tolerance issues reported..

## Parthenium weed

- Ragweed parthenium, white-top etc.
- 25,000 seeds/plant
- Tolerance / poor efficacy with  
Glyphosate products  
Glufosinate

### Management strategies

- Saflufenacil (Treevix)
- 2,4-D (Embed extra; 24c label) +  
Glyphosate
- Effective pre-emergence  
herbicides
  - Pendimethalin (Prowl)
  - Flumioxazin (Chateau)
  - Indaziflam (Alion)



# POST-emergence: Herbicide tolerance issues reported..

## Spanish needles

- 3,000-6,000 highly viable seeds per plant
- Emerges throughout year
- Tolerance / poor efficacy with  
Glyphosate  
Saflufenacil (Treevix)

### Management strategies

- Rotate with 2,4-D (Embed extra) + Glyphosate
- Follow-up sprays
- Use a pre-emergence herbicide (e.g., Flumioxazin, Indaziflam etc.)



## Herbicide tolerance issues

Spray when they are young

– *never let weeds to grow and adapt!*



**Parthenium – young growth stage**

Credits: Odeiro



**Spanish needles – young plant**

## Common sedge weeds in citrus

### Sedges



**Spray when they are young – never let weeds to grow and adapt!**

*Image Credits PennLive.com*



Nutsedge is more susceptible to herbicides when they are young and has not started producing tubers

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- **Tree-safe herbicide use**

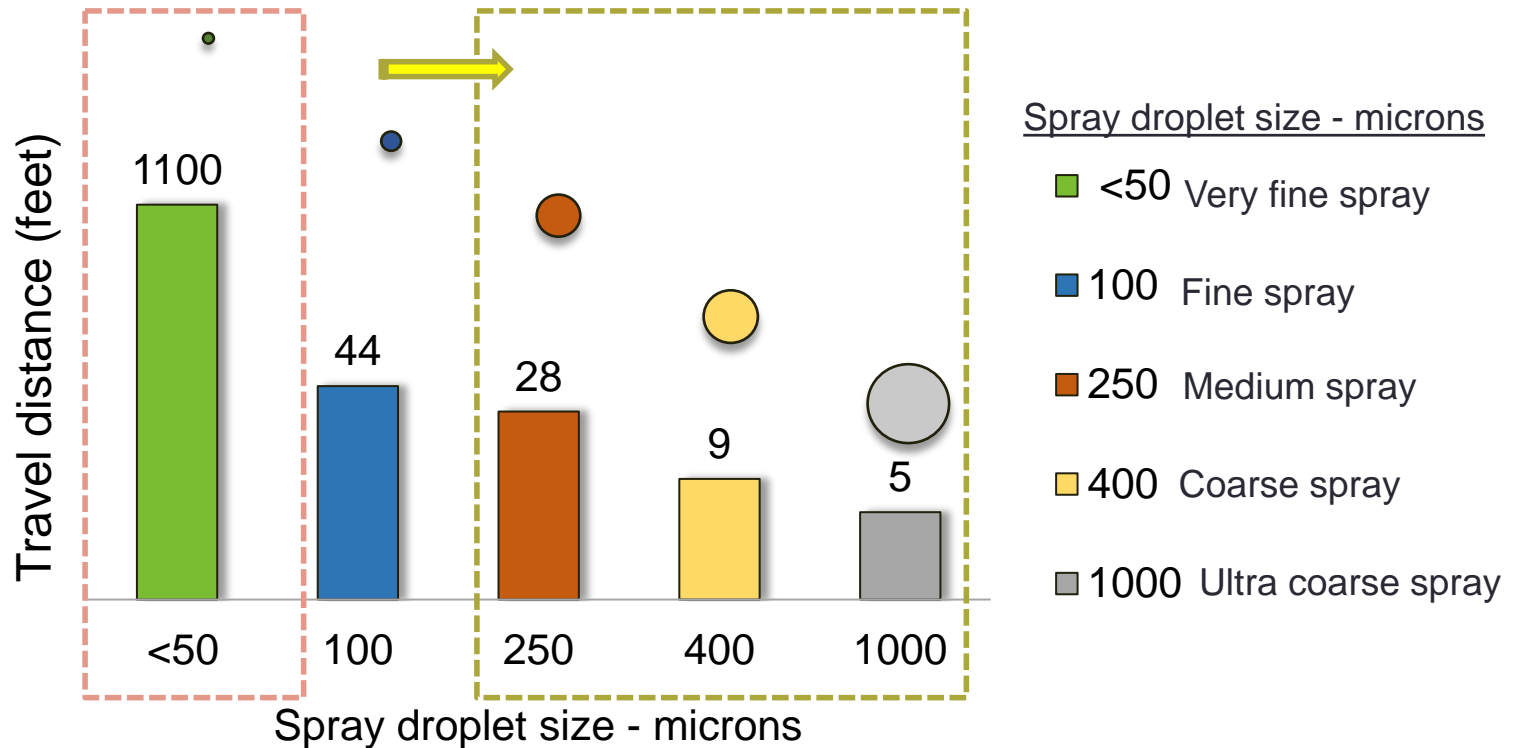
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## Non-chemical alternatives

- Cover cropping

# Lateral travel distance herbicide spray droplets travel

Wind speed : ~3 mph

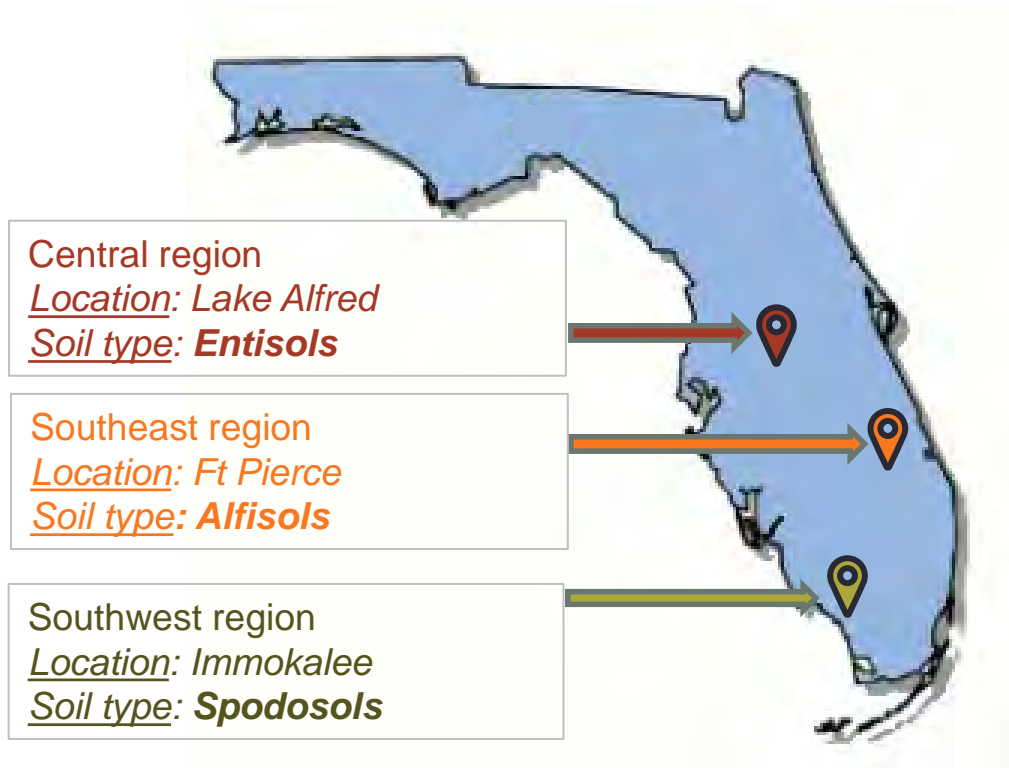


***Smaller spray droplets can travel up to 1000 feet***

**Spray deposition agents reduce the possibility of upward spray drift**



## Glyphosate – Phosphorus interactions in citrus production



# Adsorption/Binding of glyphosate in different citrus soils

High  $K_{ads}$  = High adsorption to soil

Location	$K_{ads}$	$1/n_{ads}$	$R^2$
Southwest	14.28 ( $\pm 0.83$ ) ¶ B	0.41 ( $\pm 0.01$ )	0.98
Southeast	16.56 ( $\pm 0.17$ ) B	0.27 ( $\pm 0.01$ )	0.91
Central	30.88 ( $\pm 0.82$ ) A	0.43 ( $\pm 0.04$ )	0.98

$K_{ads}$  Freundlich adsorption coefficient.

$1/n_{ads}$  Adsorption isotherm slope

$R^2$  Goodness of fit for Freundlich model.

$\pm$  Standard error

¶ Letters beside the numeric values indicate Tukey's HSD group at  $\alpha=0.05$ .  
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Adsorption relatively high in Lake Alfred soil

# Properties of FL citrus production soils

- Not all sandy soils are identical !

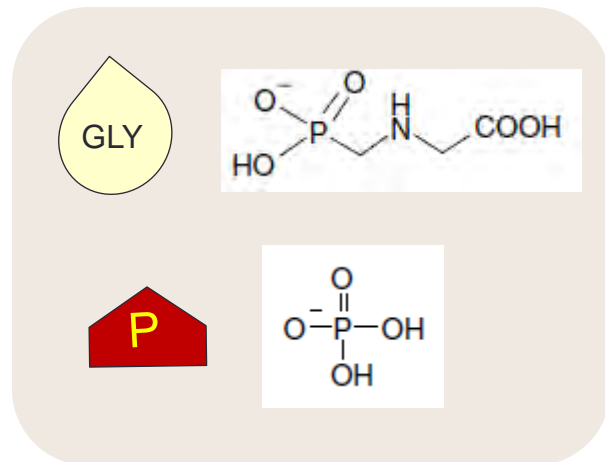
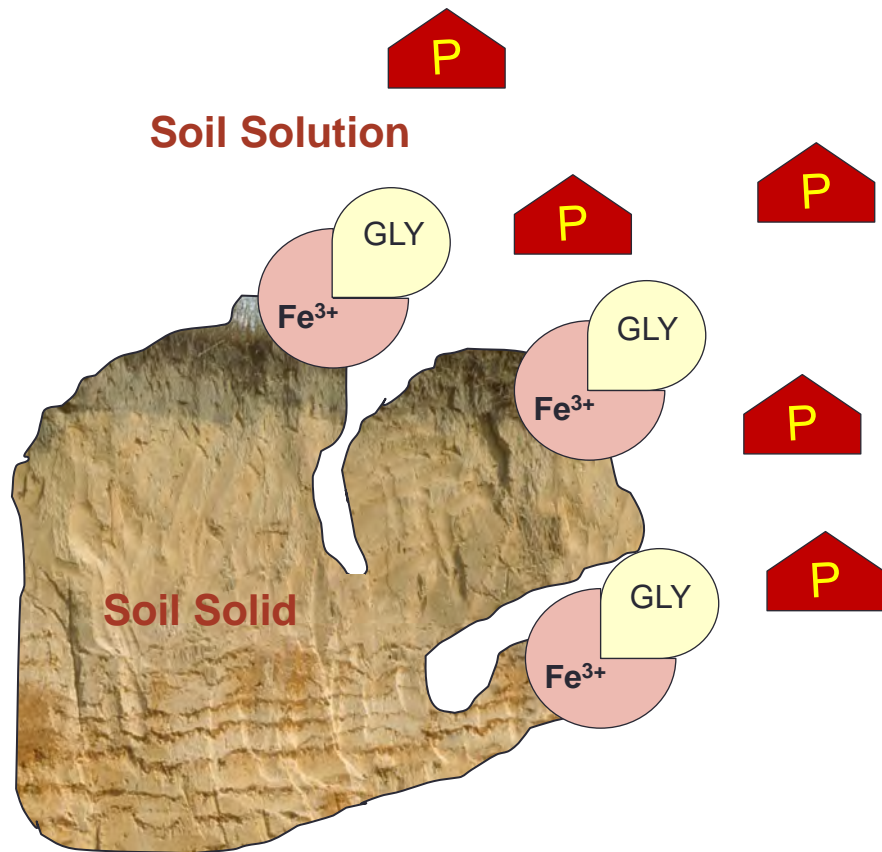
Properties	Southwest Florida (Immokalee)	Southeast Florida (Ft. Pierce)	Central Florida (Lake Alfred)
Soil type	Sandy	Sandy	Sandy
% Silt + Clay	7.2	5.2	10
Phosphorus (lbs./acre)	68	63	260
Soil pH	6.1	6.0	5.9
% Organic matter	0.73	0.44	0.59
Cation exchange capacity (meq/100g)	5	2.8	4

**Higher Silt + Clay% and Phosphorus in Central FL**



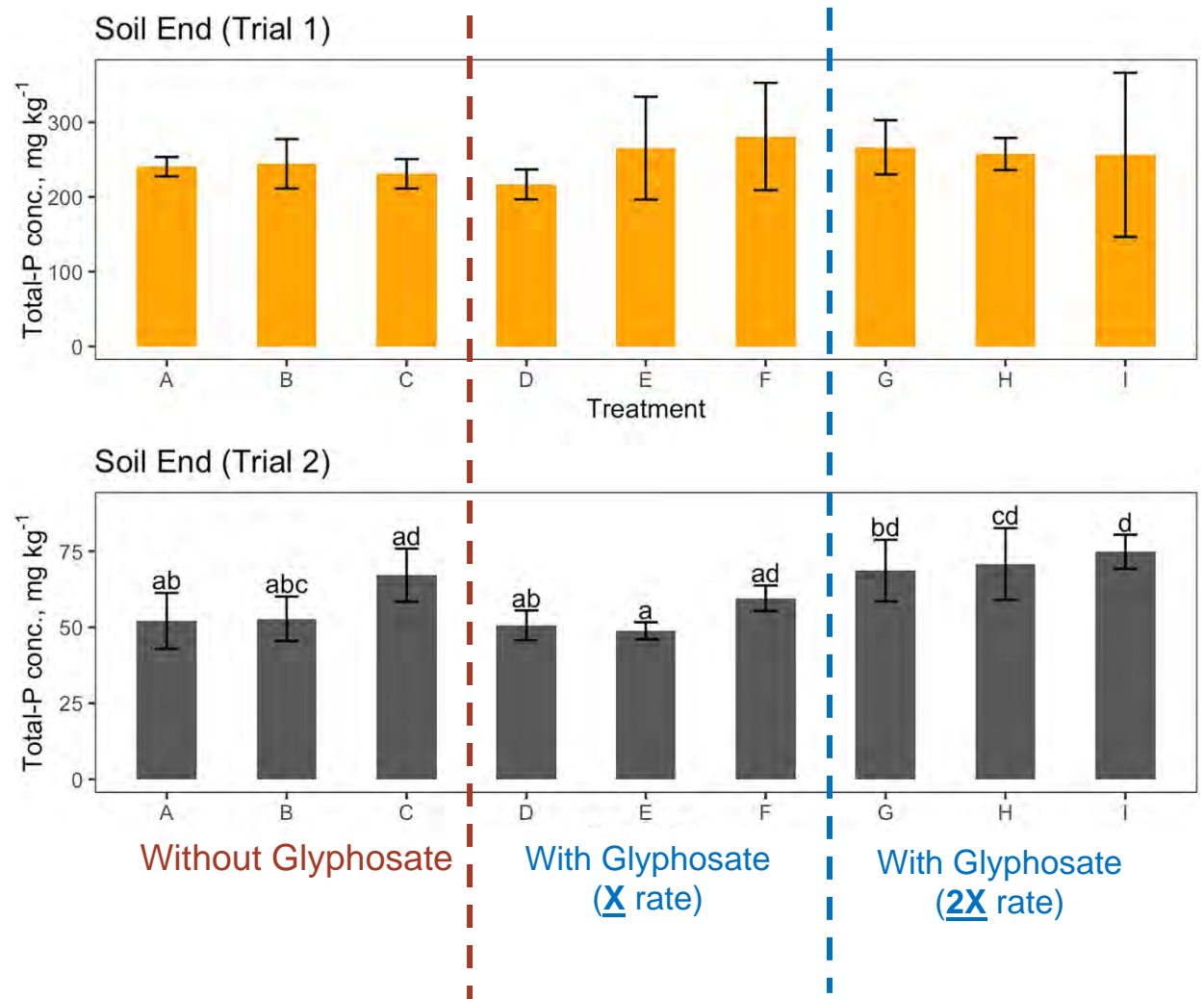


## Glyphosate – Phosphorus interactions in citrus production



# Impacts of glyphosate on citrus nutrition

-- Total-P content in the soil --

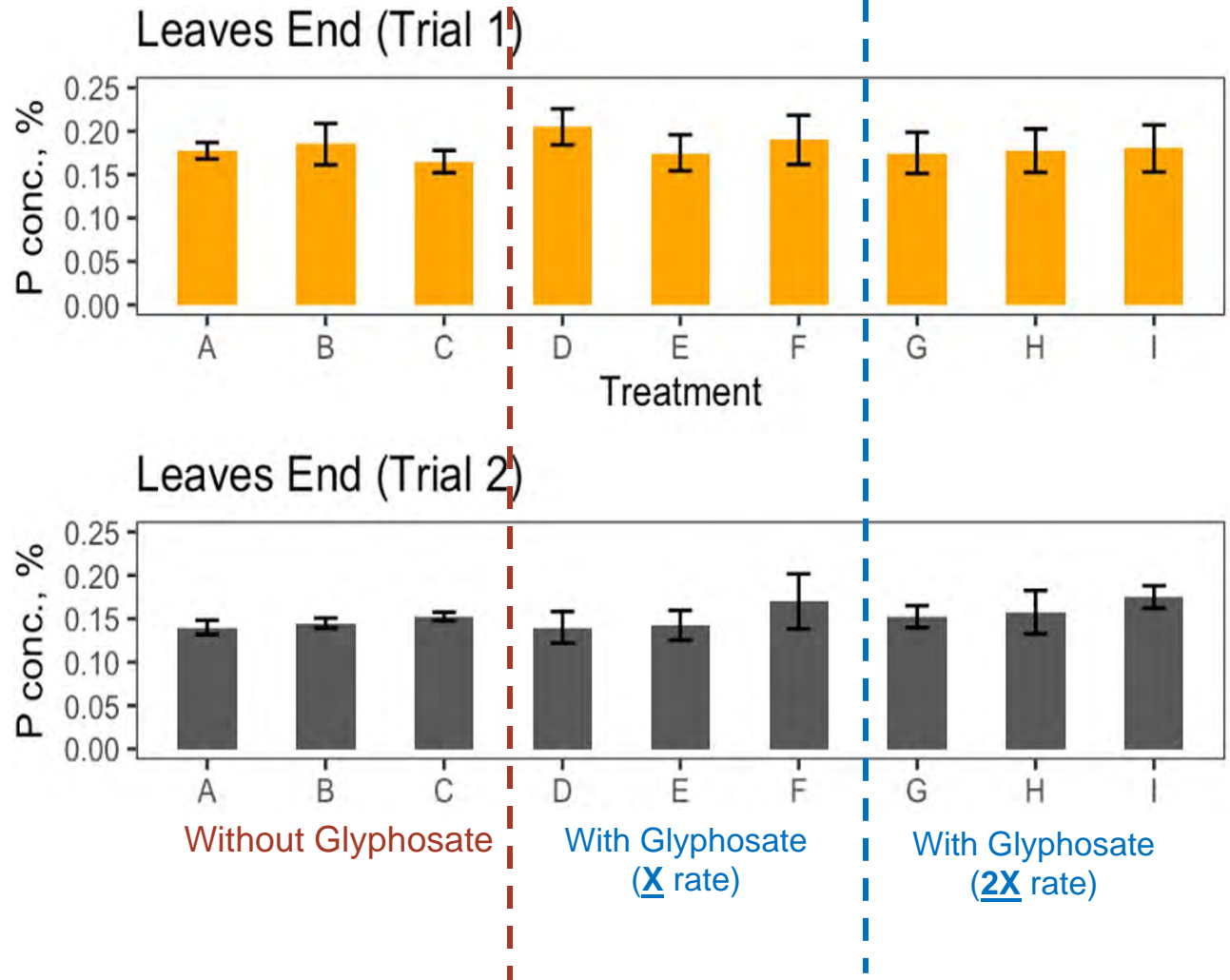




# Impacts of glyphosate on citrus nutrition

No significant effects!

-- P content in the leaves --



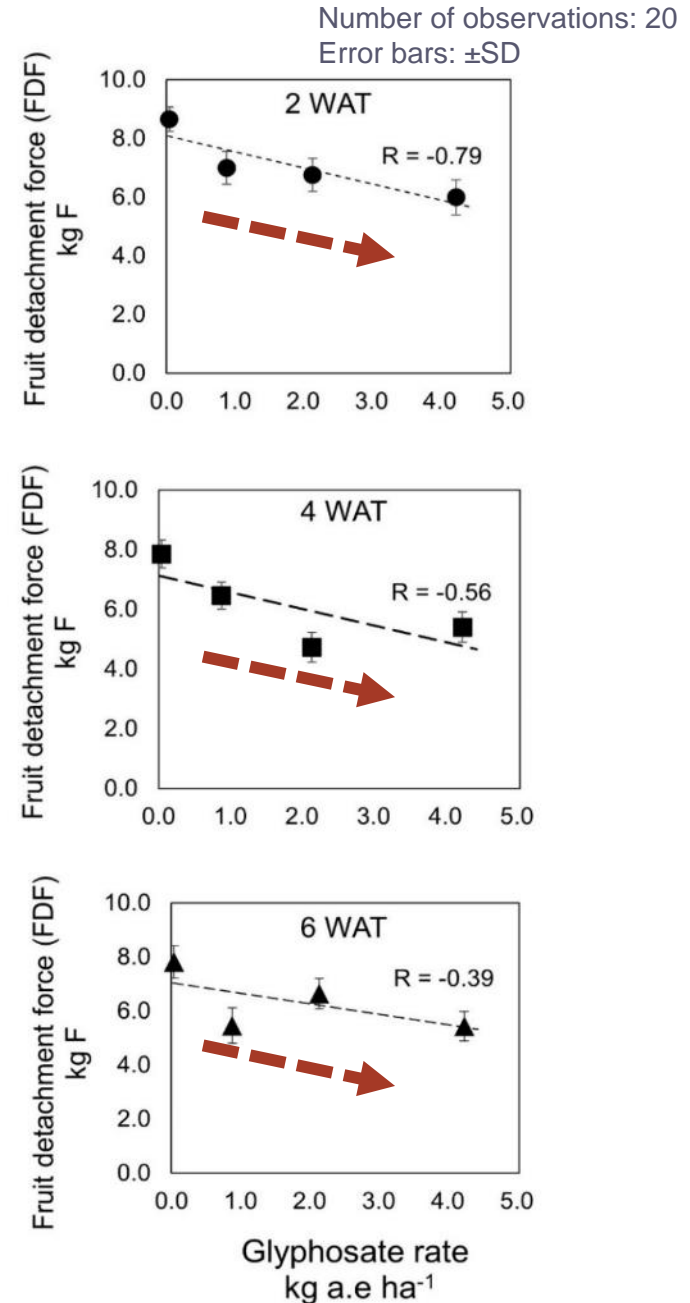
# Crop-safety of glyphosate – in Florida Citrus

Image Credits: Citrus Industry magazine

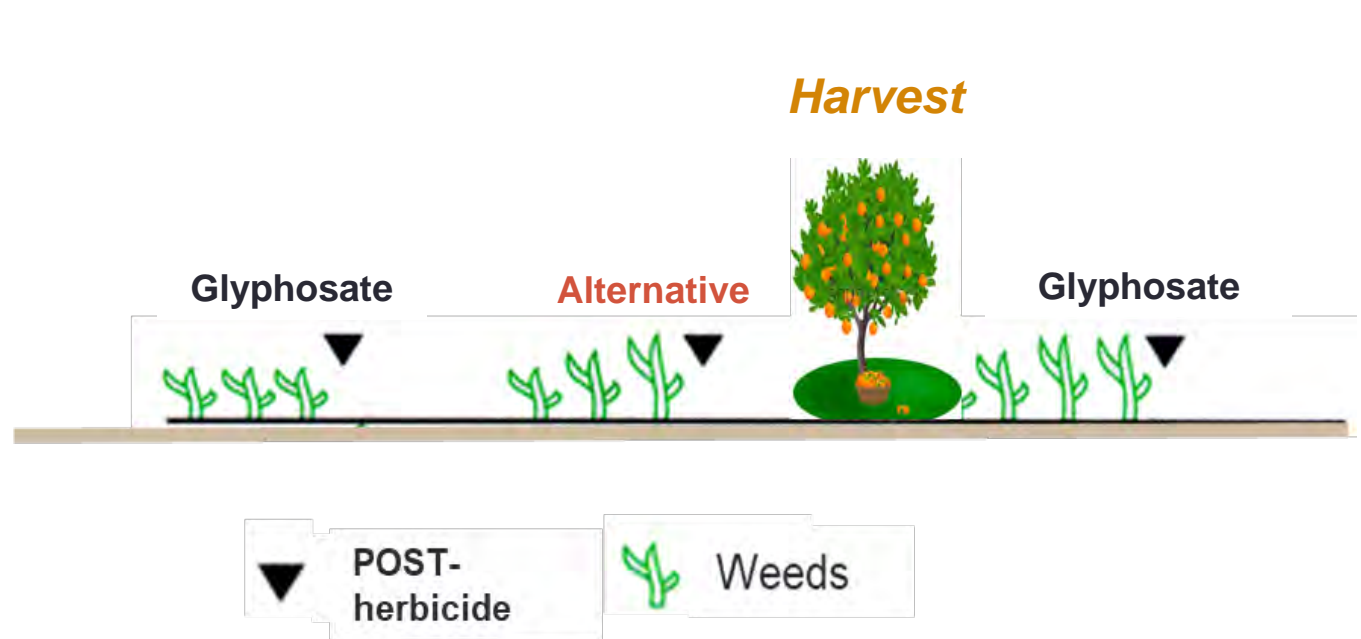


Avoiding glyphosate sprays close to harvesting timeline in 'Valencia citrus' may be beneficial in improving the yield safety

Source: Gairhe et al. 2022 HortScience



Do rotate POST-emergent herbicides



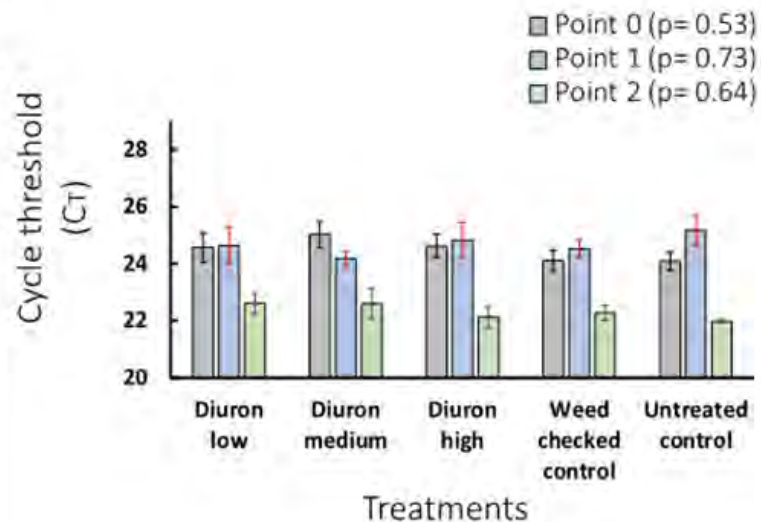
- **Cautious glyphosate application close to fruit-maturity timeline**

# Tested pre-emergence herbicide programs did not significantly affect HLB disease severity

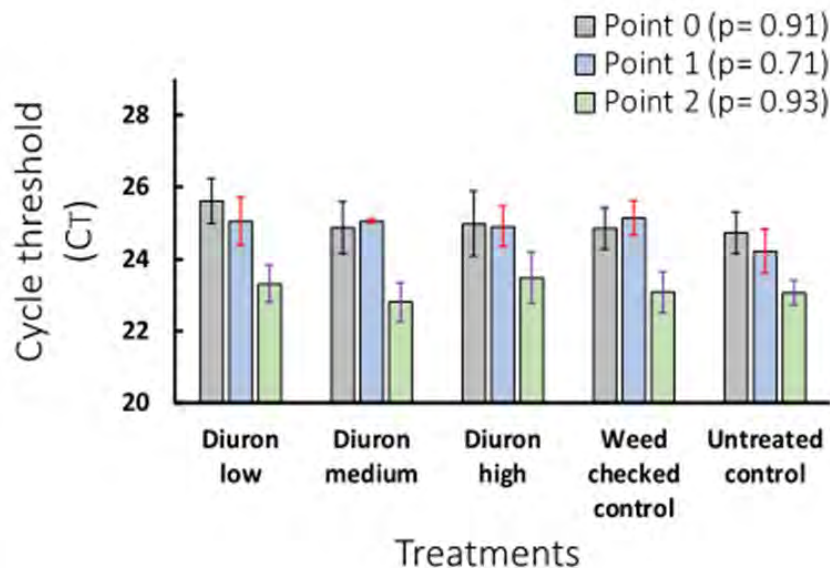
## Hamlin orange



- No significant differences between the HLB severity



## Valencia orange



*Similar trend for Indaziflam observed !*

# Tested pre-emergence herbicide programs did not significantly affect the roots

- Observation period of ~3-months

Hamlin orange

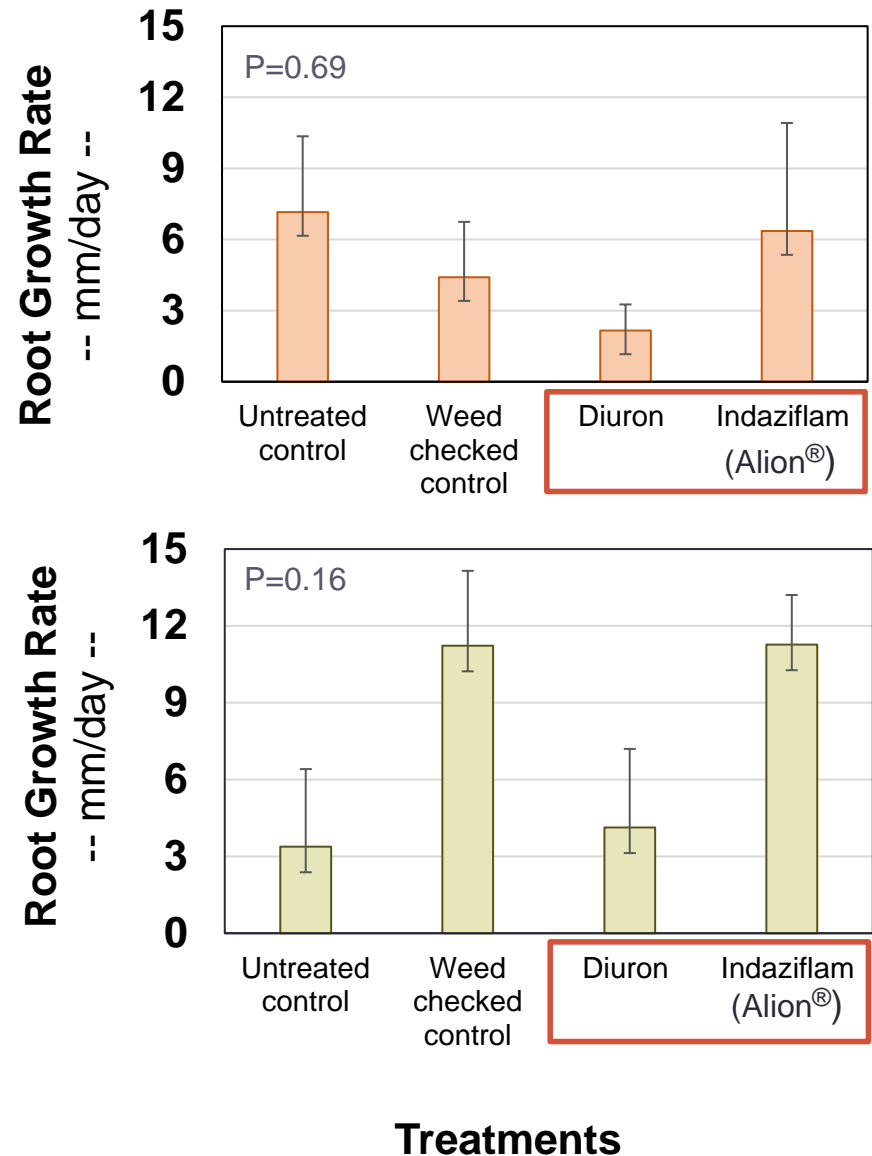


- No significant differences between the treatment means

Valencia orange



Number of reps: 4  
Error bars:  $\pm$ SD  
Tukey's HSD ( $\alpha$  0.05)



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## Non-chemical alternatives

- Cover cropping
-

“Weeds in the row-middles are a major source of weed infestation into the tree rows”



## Use of cover crops in citrus production

### Cover crops

- Plants primarily grown for enriching the soil, and for other benefits
- Non-cash crops
- Emerging practice in citrus production in FL

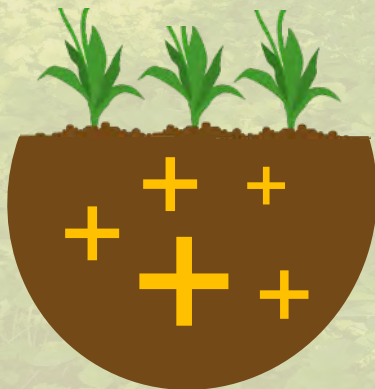


Cove crop mix planted in citrus row middles



# BENEFITS OF COVER CROPS

Build soil health  
& quality



Retain soil from  
erosion



Suppress weed  
growth



Improves bio-  
diversity



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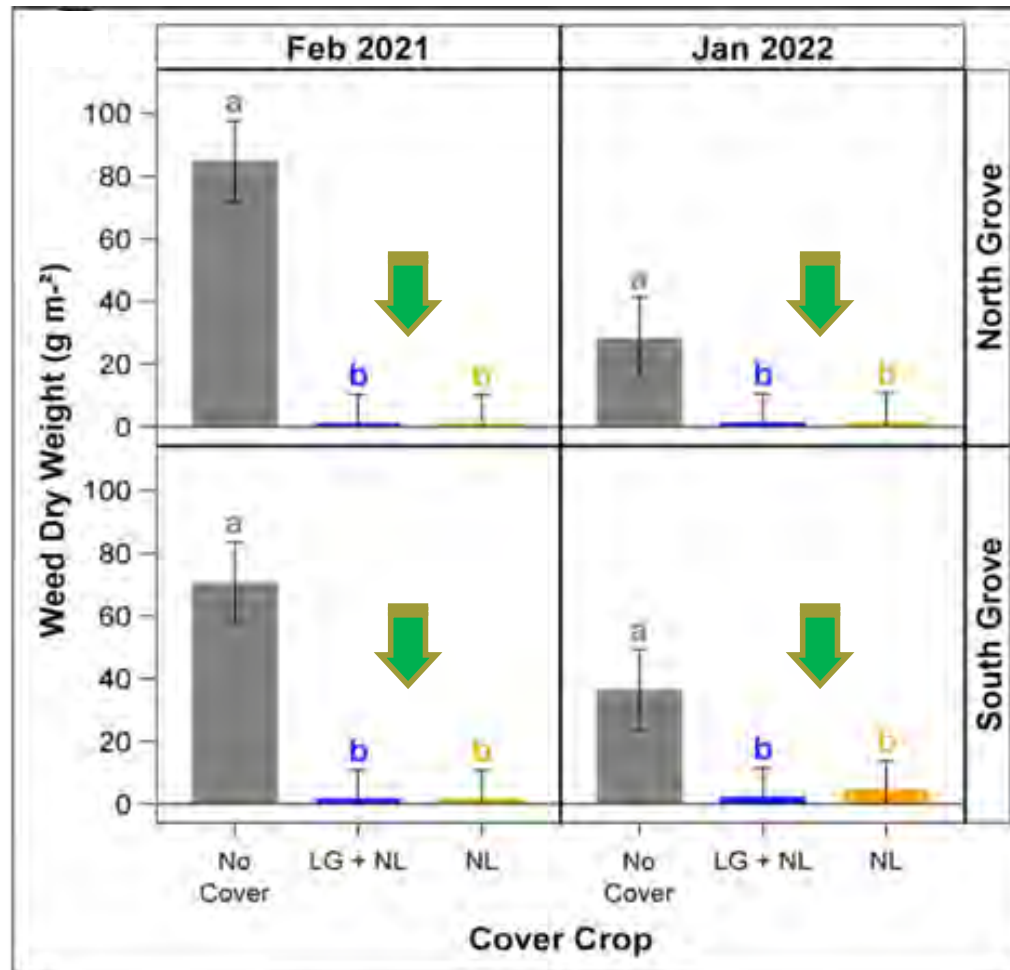
Suppress weed  
growth



Improves bio-  
diversity



# Weed suppression consistently observed in multi-year multi-location studies



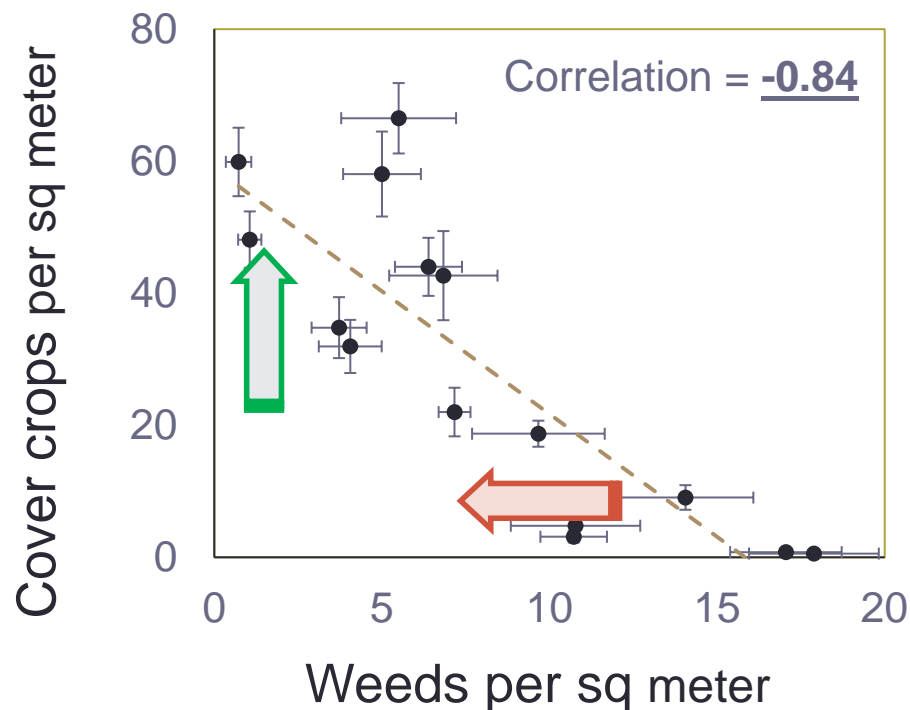
LG+ NL =Legume +  
Non-legume

NL = Non-legume

- Based on observations from a two-year in two locations
- Error bars represent the standard error of the mean
- Mean separation by LSD ( $P < 0.05$ )

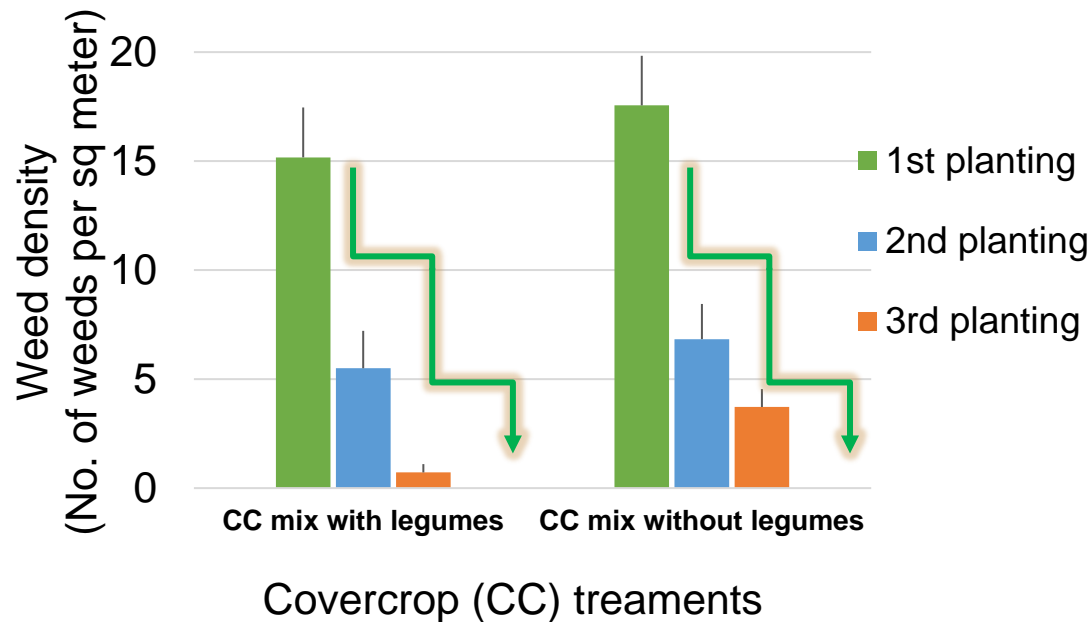
Higher the cover crop density, better the weed suppression in row middles

**Weed density and cover crop density were negatively correlated** in treated row-middles



- Based on the average of observations from a two-year study in two locations
- Error bars represent standard error of mean

## Cover copping may also contribute to longer term weed management in row-middles



- *Due to potential reduction in the 'weed seed addition' to the soil*
- *Weed seed bank depletion*

# Use of cover crops as a weed control strategy in citrus

## Non-cover cropped area

Guinea grass

Black Nightshade

Geranium



## Cover-cropped area

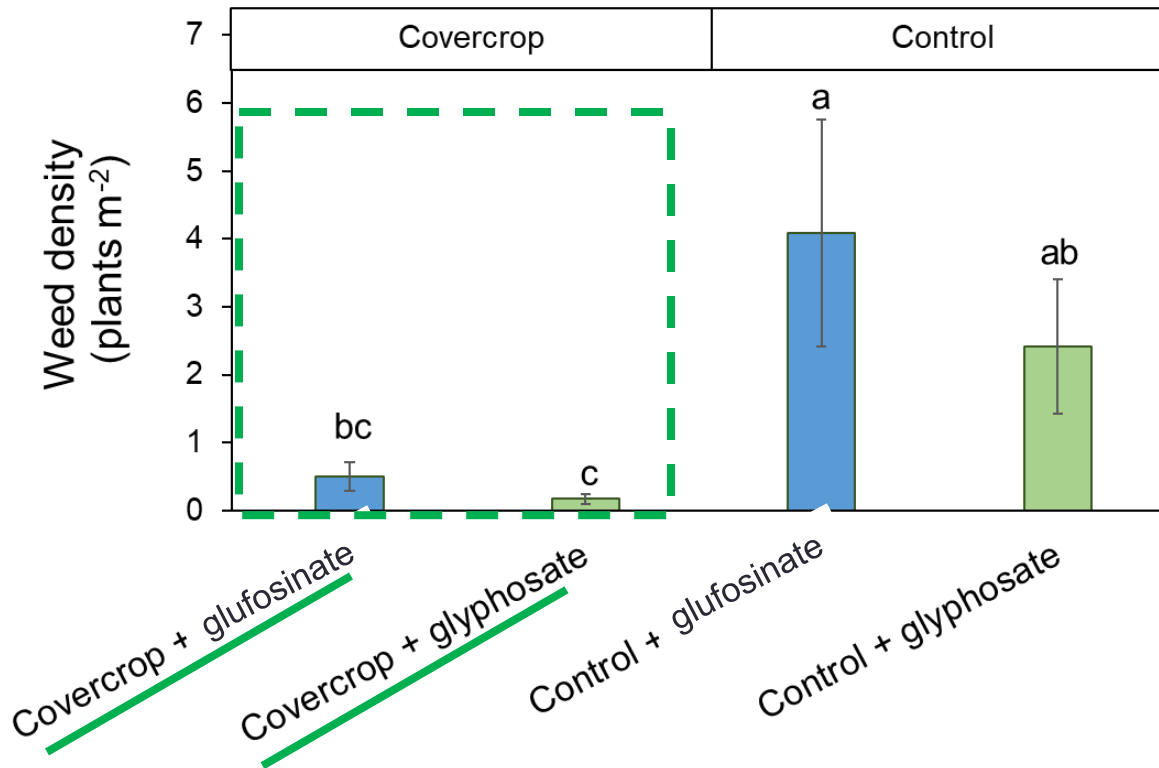
Daikon Radish (Cover Crop)



Planting cover crops in the row-middles effectively reduced grass infestation in the **tree rows**

## Weed control in tree rows

Data shown from Guinea grass (*Megathyrus maximus*)



Guinea grass growing in citrus tree rows



## Summary

### Effective herbicide use

- *POST sprays (optimizing outcomes)*
- *PRE herbicides for preventing germination from the soil seed bank*
- *Tank mixing PREs*
- *Soil binding agents for PRE*
- *Managing herbicide tolerance issues*

### Tree-safe herbicide use

- *Herbicide application best practices*
- *Impact of glyphosate on tree nutrition*
- *Avoid glyphosate sprays near harvest*

### Cover-cropping in citrus

- *Row middle vegetation management*
- *Be patient!*



## Citrus weed control – *How is it different?*

The focus of a citrus weed management program is the ***tree***, not the weeds!



### ***Critical weed free period for citrus***

In Florida citrus most critical impact of the weed competition occurs roughly during bloom periods to early fruit set

## Acknowledgements



Biwek Gairhe



Nirmal Timilsina

## My lab group



*From Left: Nirmal Timilsina, Robert Riefer, Ruby Tiwari, Shea Teems, Ramdas Kanissery, Diderot Saintilma  
Inset: Mahesh Bashyal, Miurel Brewer  
Not in picture: Rebecca McGill*

# Thank you...

## Acknowledgements

- Collaborators
- Growers
- Cooperators



United States Department of Agriculture  
National Institute of Food and Agriculture

# Quick Reference Guide to Postemergence Herbicides for Citrus Weed Control

Products recommended in the Florida Citrus Production Guide and their effects on weed management.

HS1410

R. Kanissery, C. E. McAvoy, J. D. Burrow, S. H. Futch, B. A. Sellers, and S. S. Teems

Herbicide <sup>a</sup>	MOA <sup>b</sup>	REI <sup>c</sup> Hours	PHI <sup>d</sup> Day(s)	Weeds Controlled		Comments	Suggested Rate per Acre		
				Grasses	Broadleaf				
Nonselective Systemic Herbicides	Glyphosate -Endermax	G (7)	Varies	1	X	X	Avoid contact with citrus fruit, foliage, and green bark. Rainfall within 1-4 hours after application may reduce effectiveness.	Annual weeds: 0.75-1.5 lb A.i. <sup>e</sup> Perennial weeds: 1.5-3.75 lb A.i. See product label for annual maximum rate.	
	Glyphosate -Chemical mixing	G (7)	Varies	1	X	X	Do NOT use within 1 week before or after treatment.	Biologics: 0.125 lb A.i. followed by 2nd application 45 days later Biomecigox: 0.125-0.27 lb A.i.	
	Glyphosate -Strong	G (7)	Varies	1	X	X	Use sprayer to ensure full coverage and difficult weeds.	50%-100% solution -cargill sprayer 100%-100% solution -pound sprayer	
	Glyphosate -Sulfonamide	G (7)	Varies	1	X	X	Avoid contact with citrus fruit, foliage, and green bark.	7%-7% solution	
	Glyphosate plus 2,4-D Lindamoxif	G, D (7)	Varies	1	X	X	Apply with 2,4-D and lowest rate of glyphosate possible on green citrus trees. Do not use trees.	See recommended rates in HS-402208.	
Nonselective Contact Herbicides	Carfentrazone-ethyl Am EC	(14)					Avoid contact with green tissue or fruit. Finished spray volume of at least 20 GPA required.	Max application rate/year Max 2.0 fl oz/yr 73 fl oz	Min. time btwn. appl. 14 days
	Glufosinate-ammonium Rely 230	(10)	12	14	X	X	Warm temperatures, high humidity, and bright sunlight improve performance. Avoid contact or spray drift with green bark, stems, or foliage. Spot treatment: 1.7 fl oz per gallon of water. Apply to undesirable vegetation/foliage until wet but prior to rainfall.	48-82 fl oz 246 fl oz (4.5 lb a.i.)	3 at max rate 14 days
	Paraquat Gramaxone SL 2.0	D (22)	24	—	X	X	Addition of surfactant or crop oil concentrate is essential for maximum contact activity. Avoid contact with citrus fruit, foliage, and green bark. For new labeling requirement, applicators must complete mandatory training program and be certified applicators of restricted-use pesticides.	2.5-6.0 pt 20 pt	5

<https://edis.ifas.ufl.edu/pdf/HS/HS141000.pdf>

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# 2023-2024 Quick Reference Guide to Preemergence/Residual Herbicides for Citrus Weed Control<sup>1</sup>

HS1438

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Products recommended in the Florida Citrus Production Guide and their effects on weed management.

This table lists registered pesticides that should be integrated with other pest management methods. Contact your local UF/IFAS Extension office for additional information (<https://sfl.ifas.ufl.edu/find-your-local-office/>).

Herbicide <sup>a</sup>	MOA <sup>b</sup>	REI <sup>c</sup> Hours	PHI <sup>d</sup> Day(s)	Weeds Controlled				Comments	Suggested Rate Per Acre
				Annual Grasses	Perennial Grasses	Annual Broadleaf	Perennial Broadleaf		
Indaziflam <sup>®</sup> Alion	L (29)	12	7	X		X		Do not apply Alion within 30 days prior to planting or within 30 days after planting citrus trees.	5-6.5 oz.
Bromacil Hyvar X 80 WP	C1 (5)	12	—	X	X	X		Do not use on deep-sandy, ridge soil types.	Trees 4 years and older: 2-4 lb. Trees 1-3 years old: 2-3 lb.
Bromacil & Diuron Krovar 1 DF	C1, C2 (5, 5)	12	—	X	X	X		Do not use on deep-sandy, ridge soil types.	Trees 3 years and older: 4-6 lb. Trees 1-3 years old: 2-4 lb.
Diuron Diuron 80DF	C2 (5)	12	—	X		X		Foliage contacted by diuron may develop a bleached or bronzed appearance.	2-4 lb.
Diuron Direx/Diuron 4L	C2 (5)	12	—	X		X		Trees 4 years and older: 80 days between sequential applications. Trees less than 4 years: 60 days between sequential applications.	1.6-3.2 qt.
Diuron Karmex 80DF	C2 (5)	12	—	X		X		Trees 4 years and older: 80 days between sequential applications. Trees less than 4 years: 60 days between sequential applications.	2-4 lb.
Norflurazon Solicam 80DF	F1 (12)	12	30	X	X	X		For best results apply prior to weed emergence.	2.5-5 lb.
Metolachlor	F3	12	30	X	X	X		Avoid contact with citrus fruit, foliage, and green bark.	3.5-5.0 lb/acre (see label for details)