USING COVER CROPS FOR IMPROVING SOIL HEALTH AND NUTRIENT MANAGEMENT

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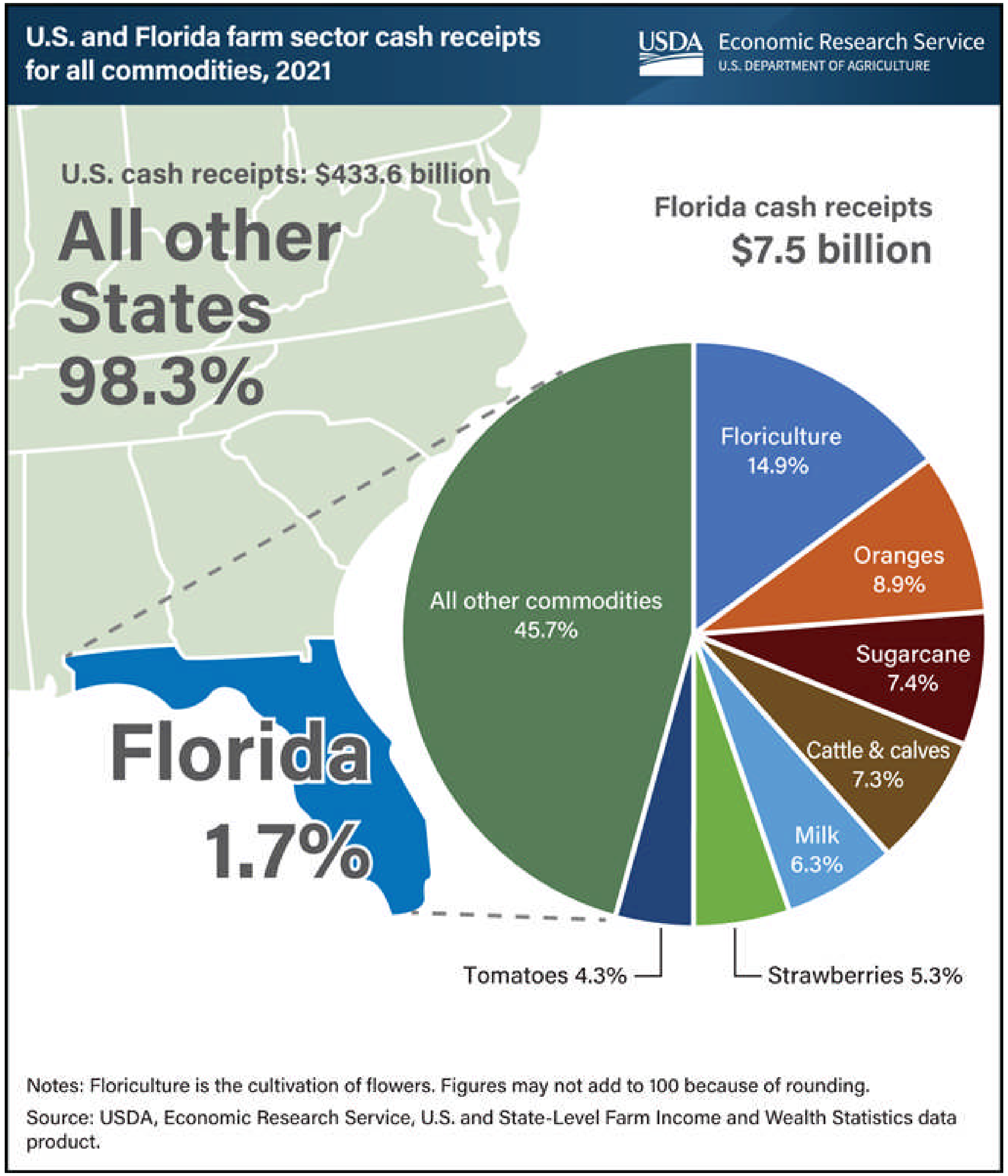


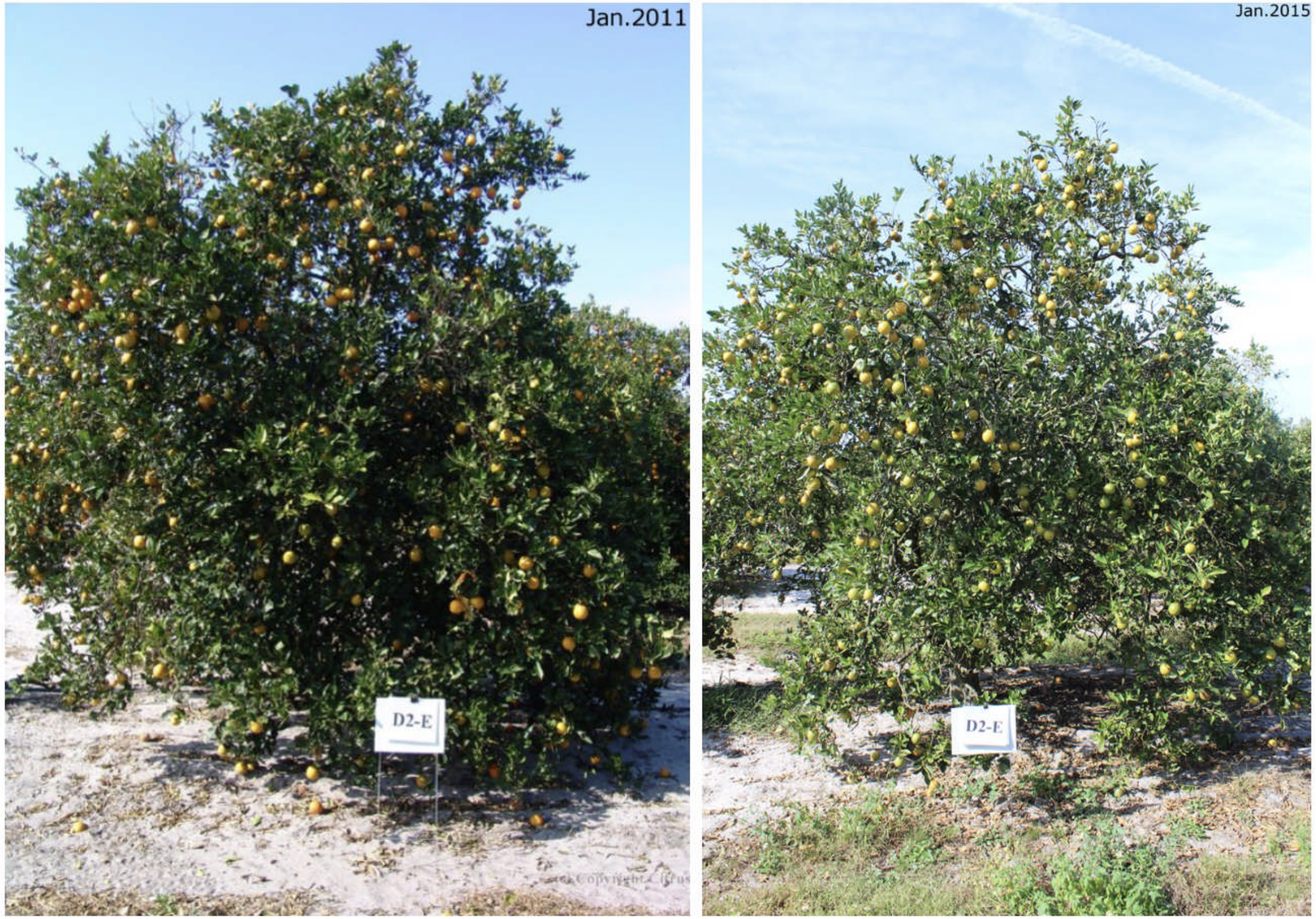
- Citrus production was the second commodity to bring the most cash for Florida in 2021 ($670 million).
- Citrus production in Florida accounted for 42 percent of the total production in the United States in 2021.
- Huanglongbing (HLB) also known as Citrus Greening.
- Candidatus Liberibacter asiaticus (CLas) vector Asian Citrus Psyllid.

Introduction

Infected citrus fruit and leaves (Credit: Bove 2006)

Source: citrusgreening.org.

Introduction



Source: citrusgreening.org. Hamlin Orange tree. Location: DeSoto County, FL.

Four years of HLB progression in the same tree.

- Thinner canopy.
- Lighter leaf and fruit color.
- A higher quantity of green fruit.
- This tree received an extensive foliar nutrition regime.
- It still showed a 40% yield reduction in the four years.

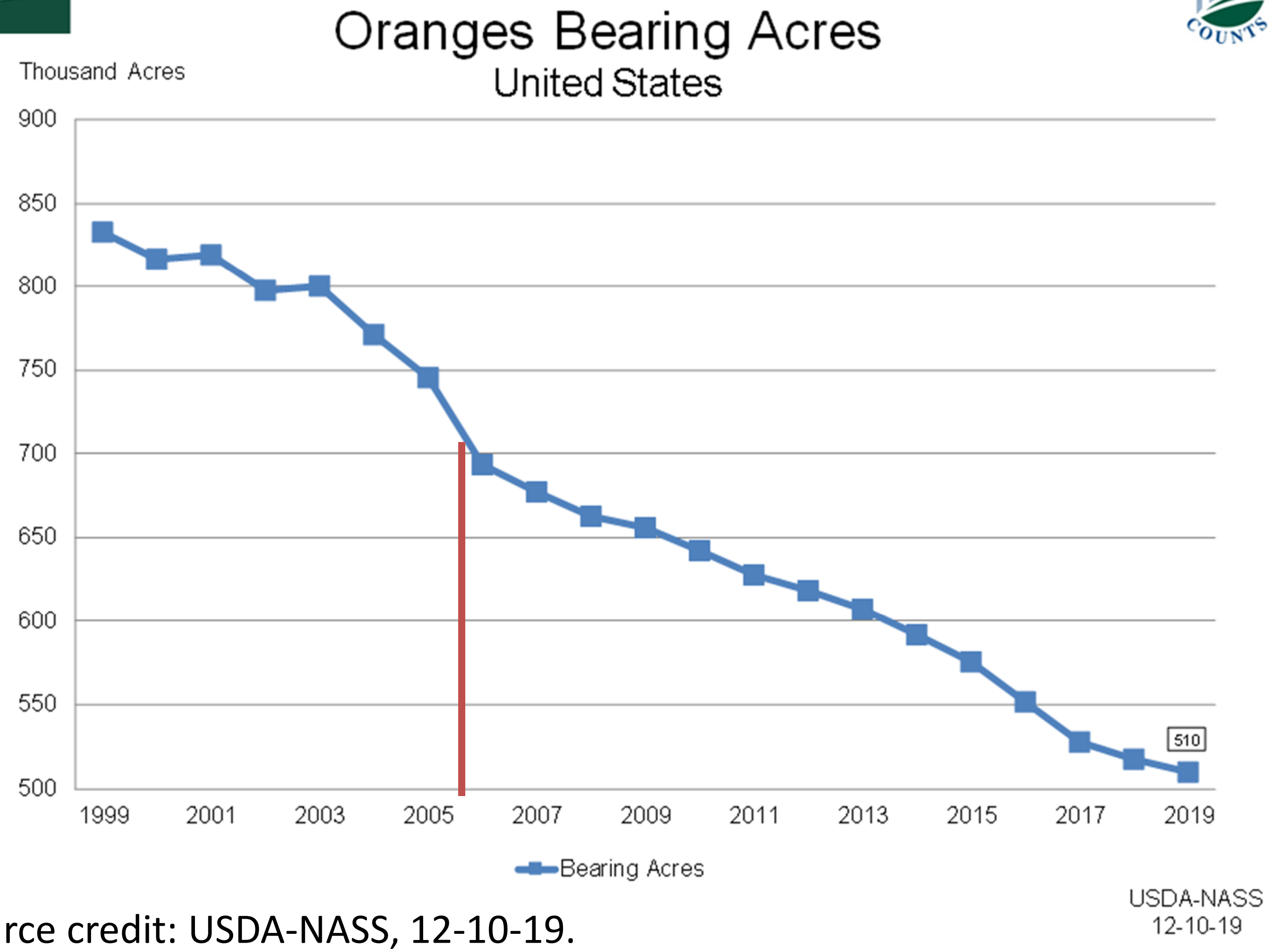
Introduction

Photo credit: Dr. Tripti Vashisth.

Fruit drop

- Fruit drop have been related to water deficit.
- It is vital to keep the trees hydrated during March to June.
- Fruit drop is related to size. Smaller fruit is more prone to drop.
- Preharvest fruit drop is much greater in HLB-infected trees, even with enhanced foliar regimes.

Introduction



Source credit: USDA-NASS, 12-10-19.

- Disease was first detected in FL 2005.
- By 2010 the disease was detected in all producing counties in FL.
- There has been 72% decline in citrus production from 13.5 million tons about 3.2 million tons since 2005 to 2021 (USDA-NASS, 2021).

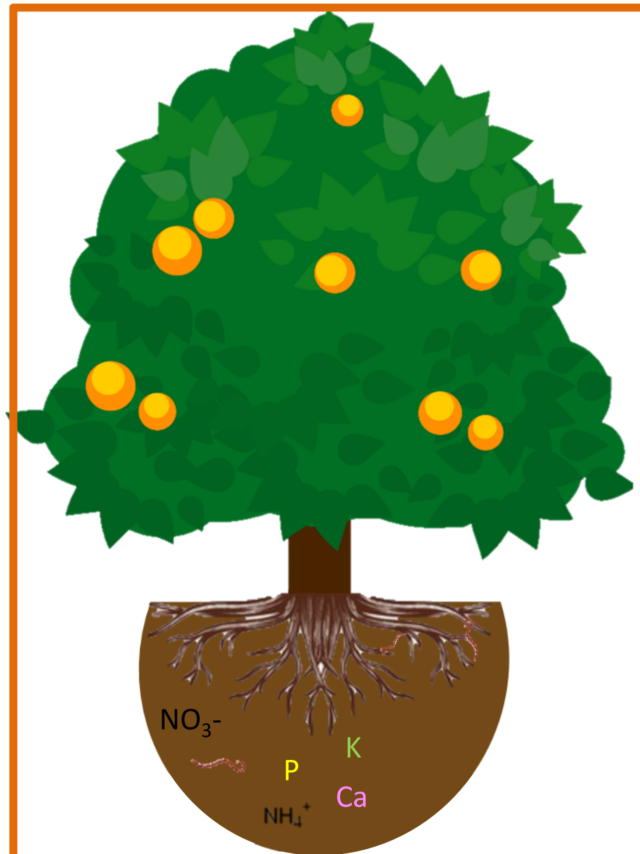
Why this study matters?

Estimate the impact of different cover crop mixes in the soil NH_4^+, NO_3^-, SOM and weed suppression in a commercial citrus grove

More suitable cover crop mixtures for citrus tree production in Florida recommended for growers

Improvement of citrus production

WHY COVER CROPS?



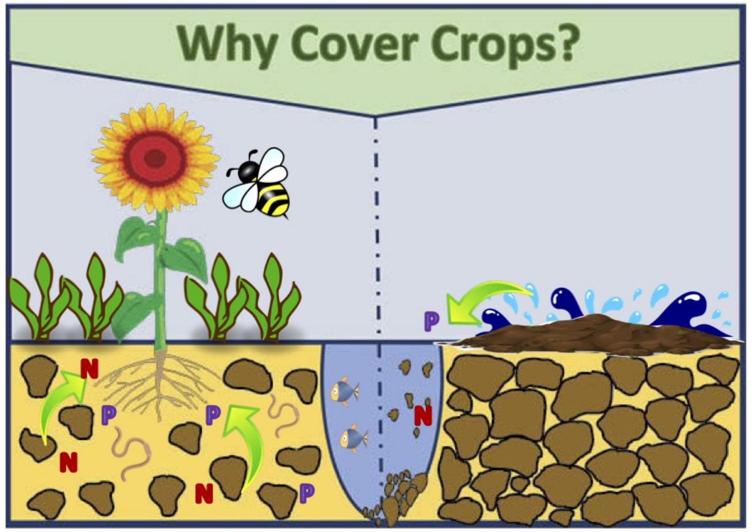
Building Soil Health

Improves biodiversity

Suppress weed growth

Reduce Erosion

Benefits of cover crop mixtures



Credits: University of Wisconsin-Madison

- Nitrogen fixation (Sunn hemp) (CTIC, 2017)
- Allelopathy (Buckwheat) (Falquet et al., 2015)
- Soil penetration (Radish) (Holmes et al., 2017)
- Nutrient sequestration (Grasses) (Kladivko, 2016)

General Objective

Evaluate the effect of cover cropping on weed management, soil quality, and tree health in Florida citrus.

Specific Objectives

I) Measure the effect of cover crops on citrus canopy size, fruit yield and quality.

Hypotheses

I) For the treatments using cover crops, there will be faster tree growth and higher yields than grower standard grove management practices.

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II) Estimate the impact of different cover crop mixes in the soil macronutrients (NH_4^+, NO_3^-, P, K, Mg, and Ca) and organic matter in a commercial orange grove.

Hypotheses

I) For the treatments using cover crops, there will be faster tree growth and higher yields than grower standard grove management practices.

II) The cover mixes would increase available macronutrients and soil organic matter compared with row middles following citrus producers' standard practices.

Specific Objectives

I) Measure the effect of cover crops on citrus canopy size and fruit yield and quality.

II) Estimate the impact of different cover crop mixes in the soil macronutrients (NH_4^+, NO_3^-, P, K, Mg, and Ca) and organic matter in a commercial orange grove.

III) Evaluate nutrient uptake and retention by daikon radish under greenhouse conditions.

Hypotheses

I) For the treatments using cover crops, there will be faster tree growth and higher yields than grower standard grove management practices.

II) The cover mixes would increase available macronutrients and soil organic matter compared with row middles following citrus producers' standard practices.

III) Daikon radish would potentially recover the added soil N and prevent its loss from soil by incorporating more N into its biomass when additional N inputs are incorporated into the soil.

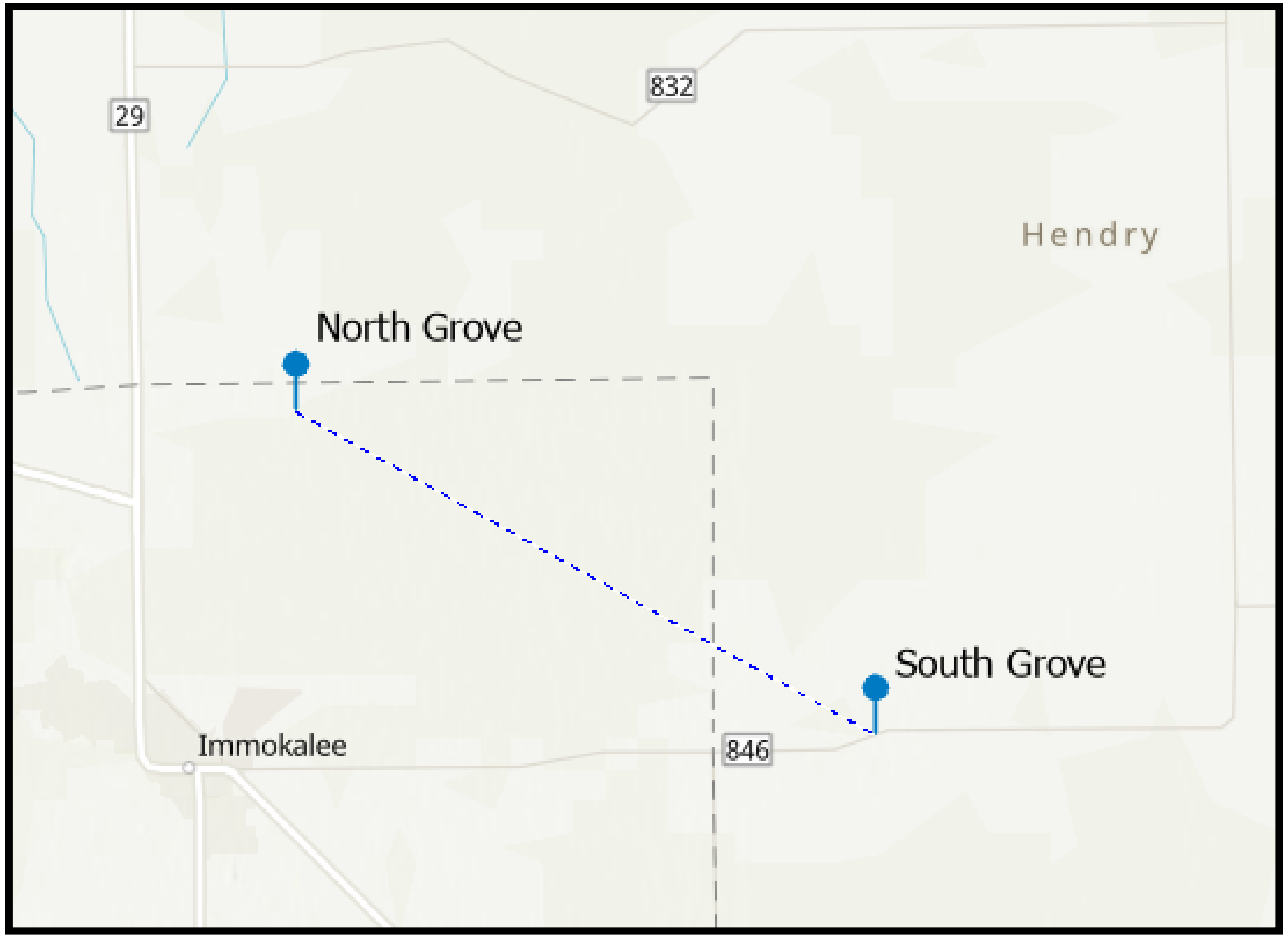
MATERIALS AND METHODS

& RESULTS

Study Site

- Two commercial groves in Southwest Florida
- Valencia on *Swingle citrumelo* rootstock
- Tree density: 145 trees/acre
- Irrigation type: microsprinkler
- Visual symptoms of HLB

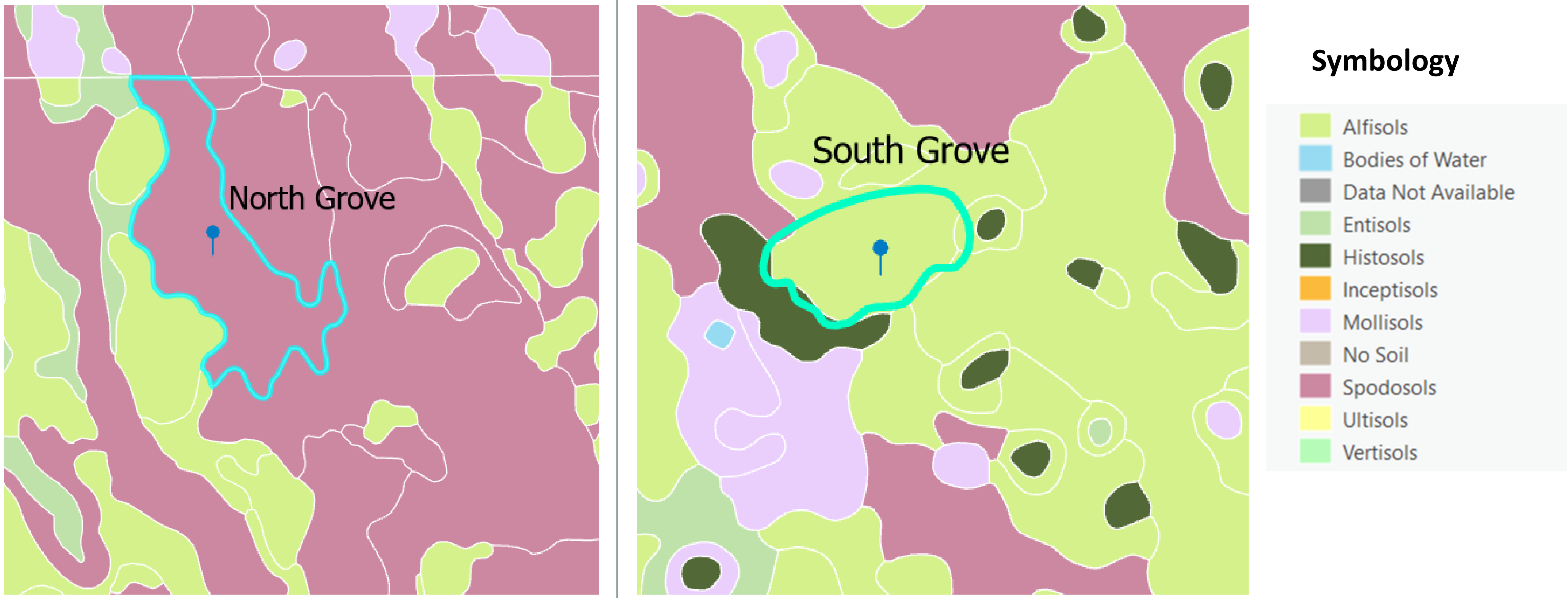
Study Site



Source: NASA, Esri. Software: ArcGIS Pro version 3.0.1

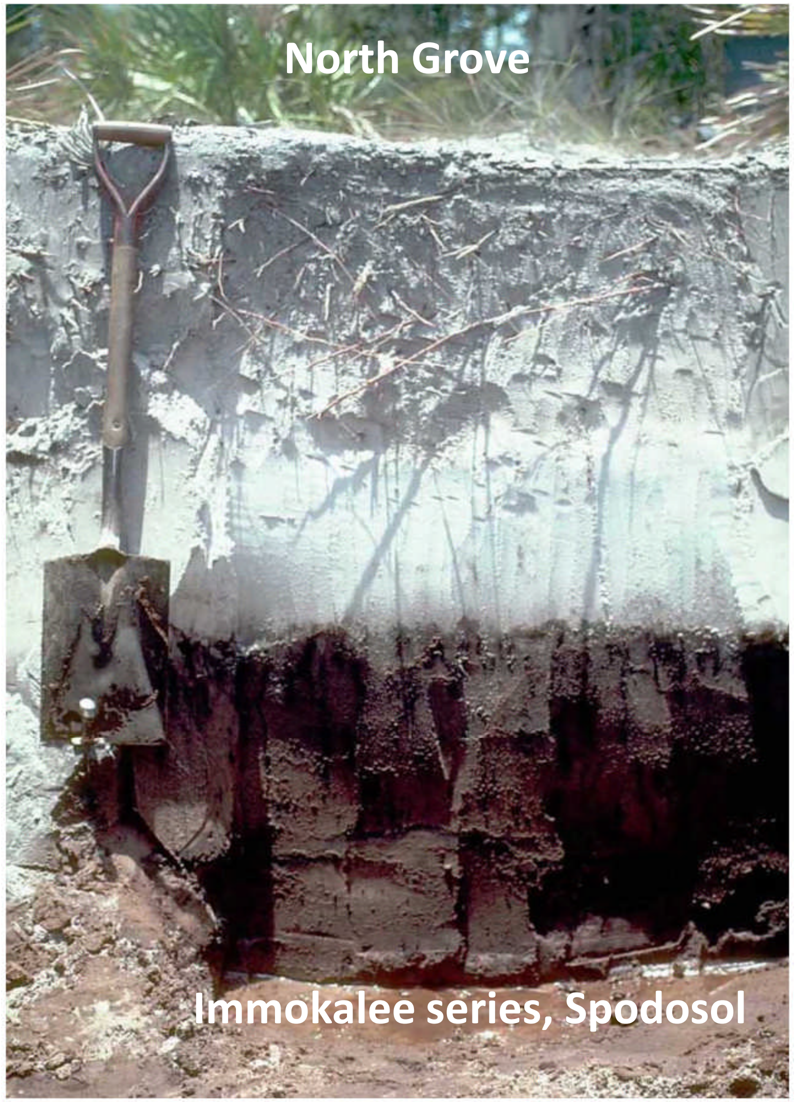
- Straight distance between the two groves 20 miles.

Study Site- Soil Type



Source: USDA NRCS, Esri. Software: ArcGIS Pro version 3.0.1

Study Site- Series and Soil Order



Soil Property	North Grove	South Grove
OM (%)	3.24	1.18
pH	7.6	7.33
CEC (cmol kg^{-1})	12.5	4.4

Source: Obreza and Collins, 2008.

Study Site- Evaporative Stress Index (ESI)-Drought Condition

Source: NASA, Earth_data, Esri. Software: ArcGIS Pro version 3.0.1

Symbology

Drought Monitor Class

- Abnormally Dry
- Drought - Moderate
- Drought - Severe
- Drought - Extreme
- Drought - Exceptional

- North Grove-Moderate Drought, ESI -1.
- South Grove-Severe Drought, ESI -2.

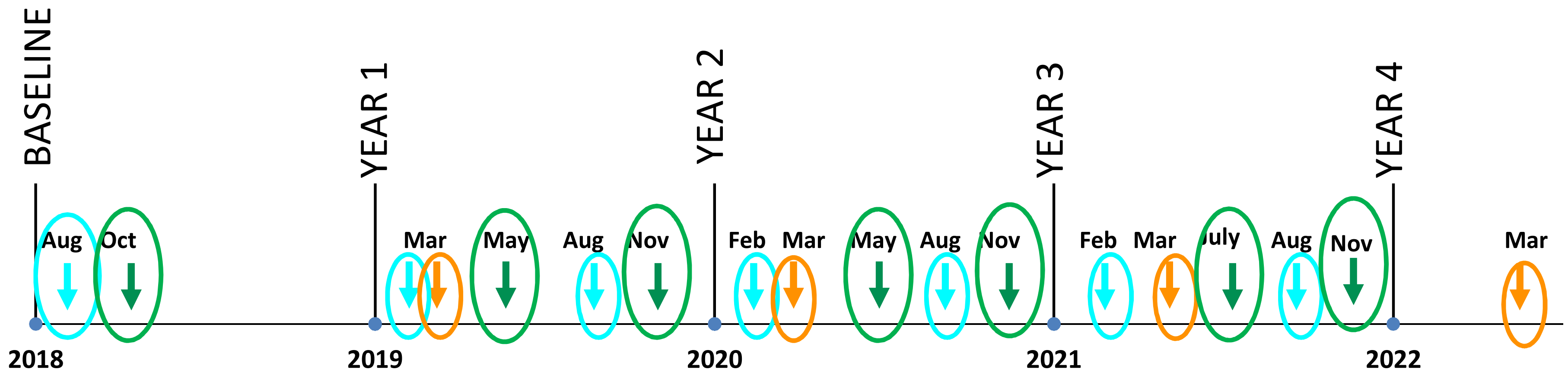
Treatments

Treatment	Description	Cover Crop Planting	
		Summer	Winter/Spring
LEGUME	Cover Crop Mix # 1	Sunn hemp (*Crotalaria juncea* L.) Cowpea (*Vigna unguiculata* L.) White clover (*Trifolium repens L.*) Brown top millet (*Urochloa ramosa (L.) T. Q. Nguyen)* Buckwheat (*Fagopyrum esculentum* Moench) Dove millet (*Panicum miliaceum* L.)	Sunn hemp (*Crotalaria juncea* L.) Cow pea (*Vigna unguiculata* L.) Daikon radish (*Raphanus sativus* L.) Oats (*Avena sativa L.*) Wrens Abruzzi cereal rye (*Secale cereale L.*)
NO-LEGUME	Cover Crop Mix #2	Brown top millet (*Urochloa ramose (L.) T. Q. Nguyen)* Buckwheat (*Fagopyrum esculentum* Moench) Dove millet (*Panicum miliaceum* L.)	Daikon radish (*Raphanus sativus var*. L.) Oats (*Avena sativa L.*) Wrens Abruzzi cereal rye (*Secale cereale L.*)
CONTROL	No-Treatment Control/Grower Standard	N/A	N/A

Treatments

Photo: Rachel Berner, research site.

Study Timeline



Symbology

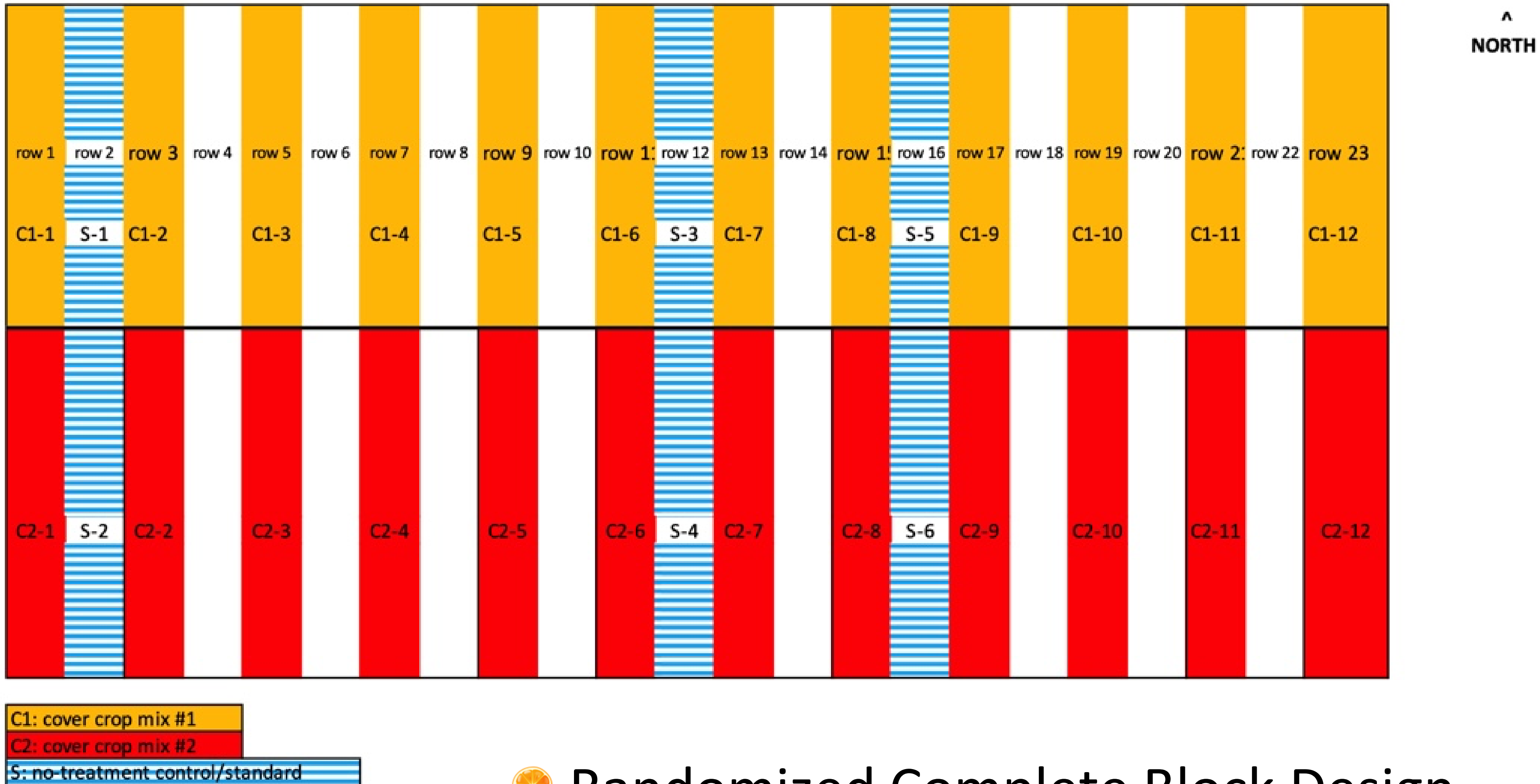
Cover-crop planting

Sample collection

Harvest

Baseline measurements	***Year 1, 2, 3 sample collection***	***Year 1, 2, 3 and 4 harvest***
Tree growth Soil and leaf nutrient concentrations Percentage weed coverage	Tree growth Percentage weed coverage Weed biomass Soil and leaf nutrient concentrations	Juice quality Fruit quality

Experimental Design



- Randomized Complete Block Design
- 12 reps/treatment

Data Analysis I

- Not all response variables are normally distributed.
  - Continuous quantitative variables, e.g., yield follow a normal distribution.
  - Discrete counts, e.g., fruit number follow a Poisson or negative binomial distribution.
  - Continuous proportions, e.g., weed percentage follow a beta distribution.

- Taking repeated observations over time on the same plot → repeated measures.
  - Residuals do not follow assumptions for simple ANOVA.
  - R-side modeling to account for non independence.

→ Generalized linear mixed model methodology
  - PROC GLIMMIX (SAS/STAT 15.4)

Data Analysis II

➔ Type I error rate $\alpha = 0.05$.

- Comparing treatment means
  - Factorial treatment design-Cover Crop, location, time.
    - Emphasis on interactions e.g., cover crop by location.
    - Simple effect comparisons, e.g., cover crops within location.
    - No adjustment for multiplicity.

Milliken, GA, Johnson, DE. 2009. Analysis of messy data volume 1: designed experiments (Vol. 1). CRC Press.
Saville, DJ. 2015. Multiple comparison procedures—Cutting the Gordian knot. Agron J. 107:730-35.

Objective 1

Measure the effect of cover crops on citrus canopy size, fruit yield and quality.

Hypothesis 1

For the treatments using cover crops, there will be faster tree growth and higher yields than grower standard grove management practices.

Data Collection-Tree Growth

Trunk Diameter

Tree height

Canopy size

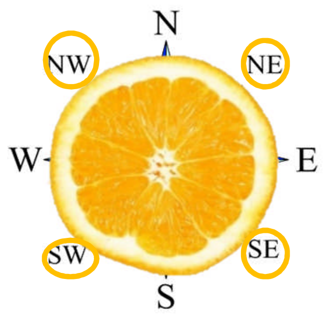
- Tree growth measurements every 6 months (Feb and Aug)
  - Trunk Diameter
  - Tree Height
  - Stem Circumference
- Canopy volume-calculated as: [(diameter parallel to row x diameter perpendicular to row) x height]/4 (Obreza & Rouse, 1993)

Data Collection-Yield

- Once a year
- Ten fruits per rep
- Fruit size
- Diameter size-
  vertical and horizontal
- Fruit quality:
  - Percent juice
  - Brix
  - Acid
  - Brix/acid ratio
  - External color
  - Juice color
  - Nutrient content

Data Collection-Tissue Samples

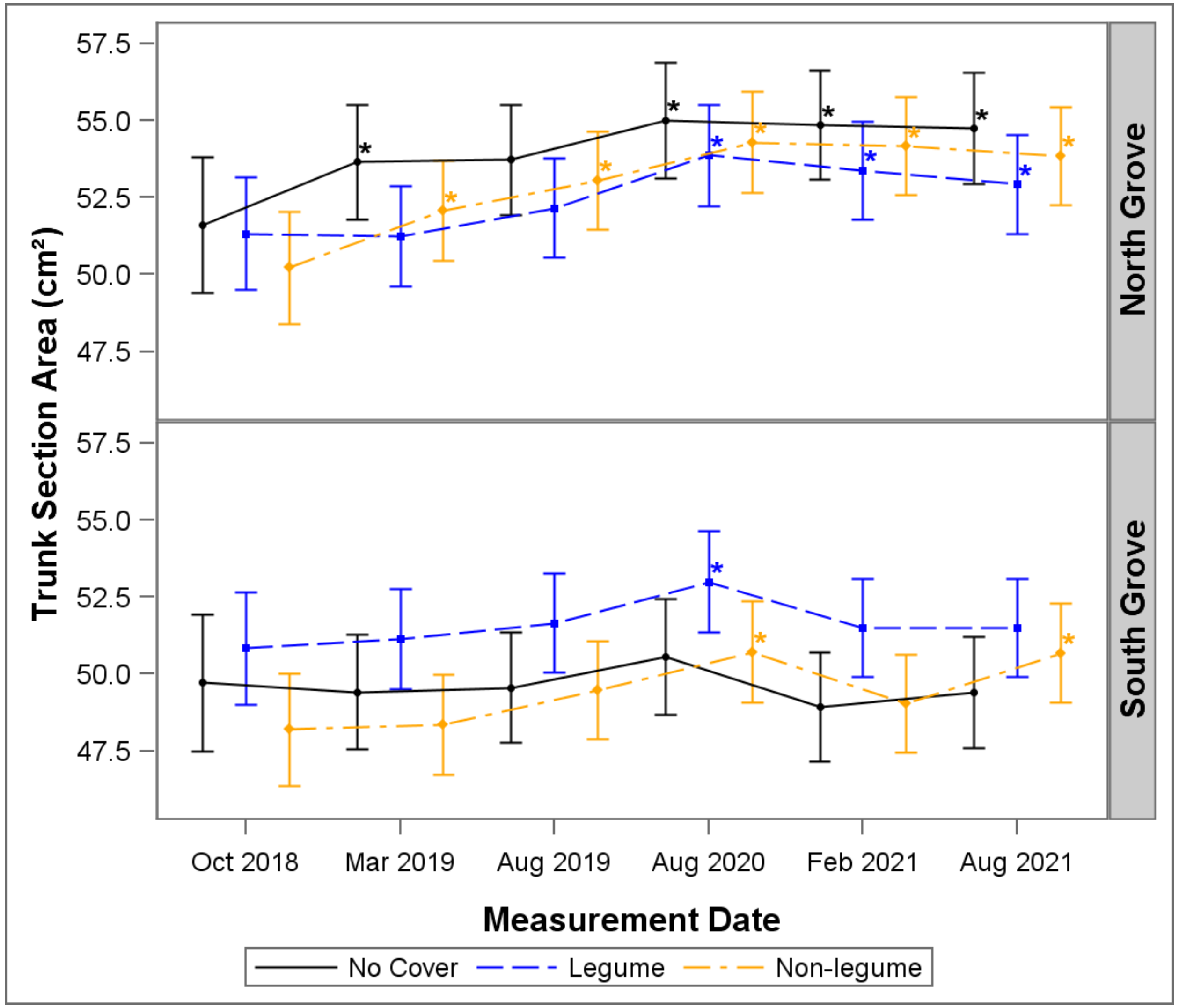

Photo: North Grove.



- Once a year– (Aug)
- 4 to 6 mature leaves per quadrant
- Leaf dry ash digestion
- C:N ratio by combustion

RESULTS

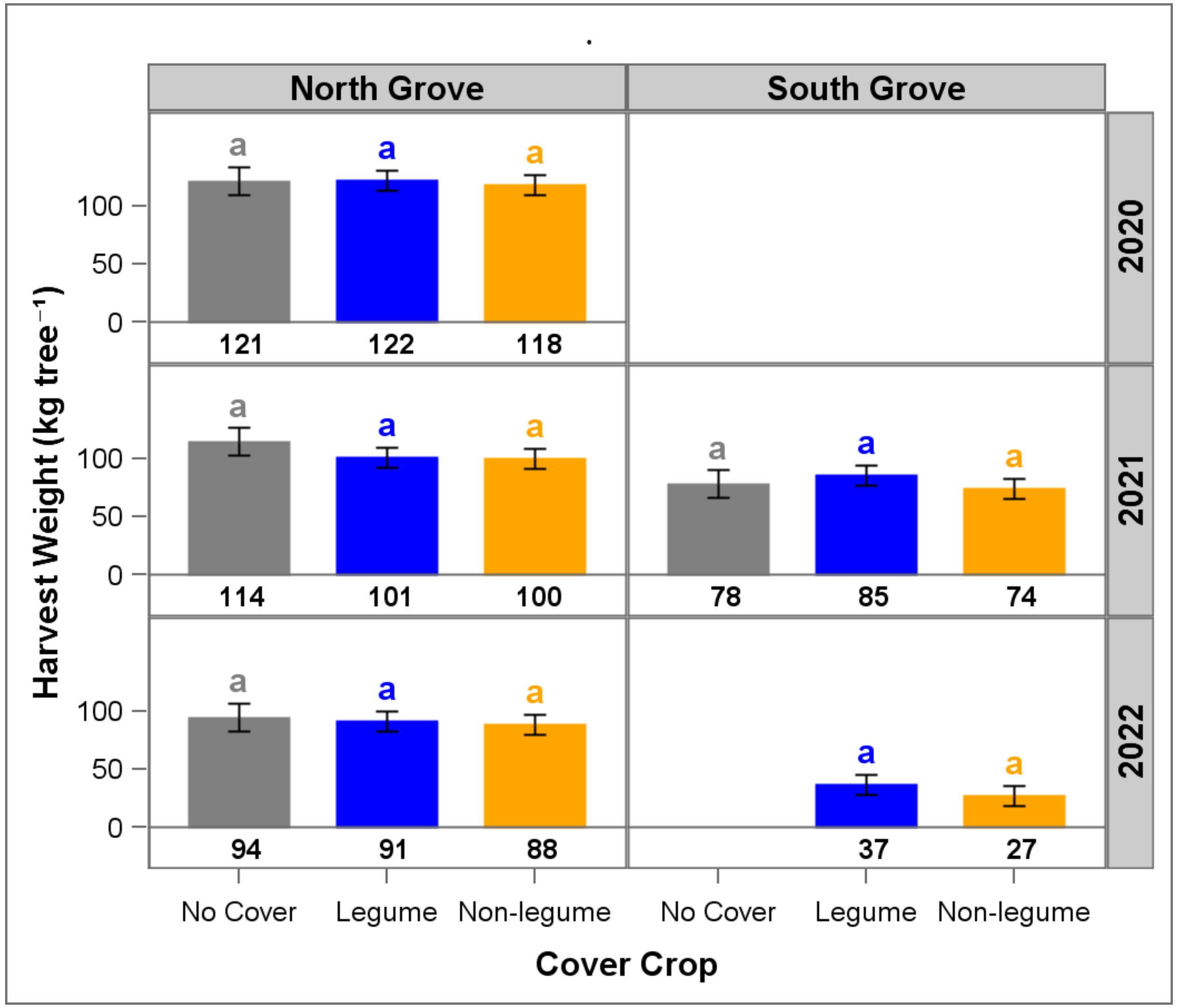
Trunk Cross-Section Area



- Temporal significant changes in trunk section area (cm^2) in North Grove for all the treatments, compared with its baseline measurement.
- Temporal significant changes were only observed in the LG and NL treatments in South Grove.

RESULTS

Harvest



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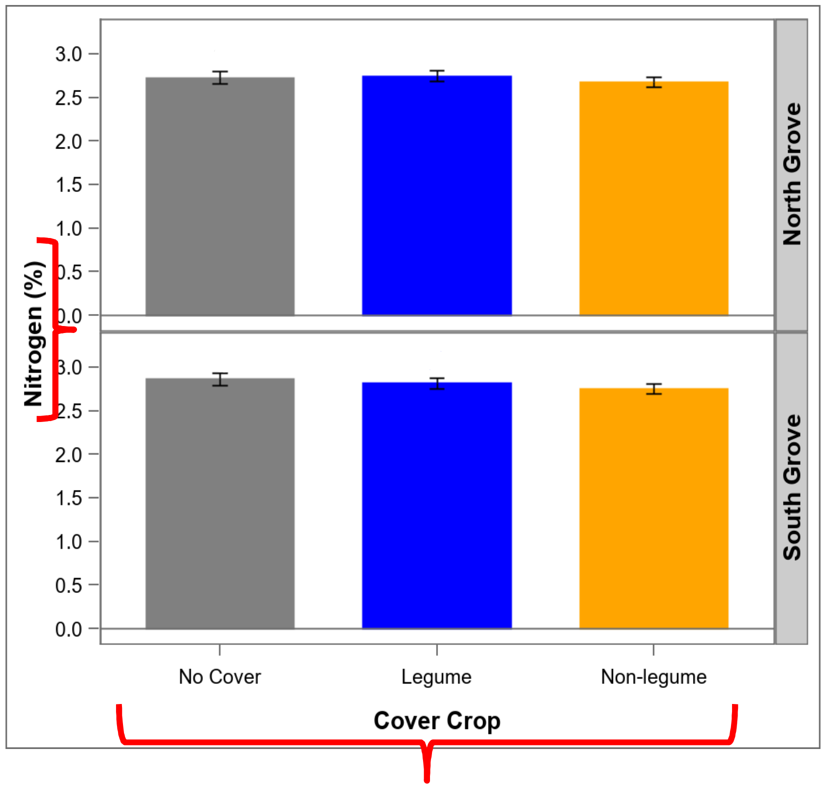
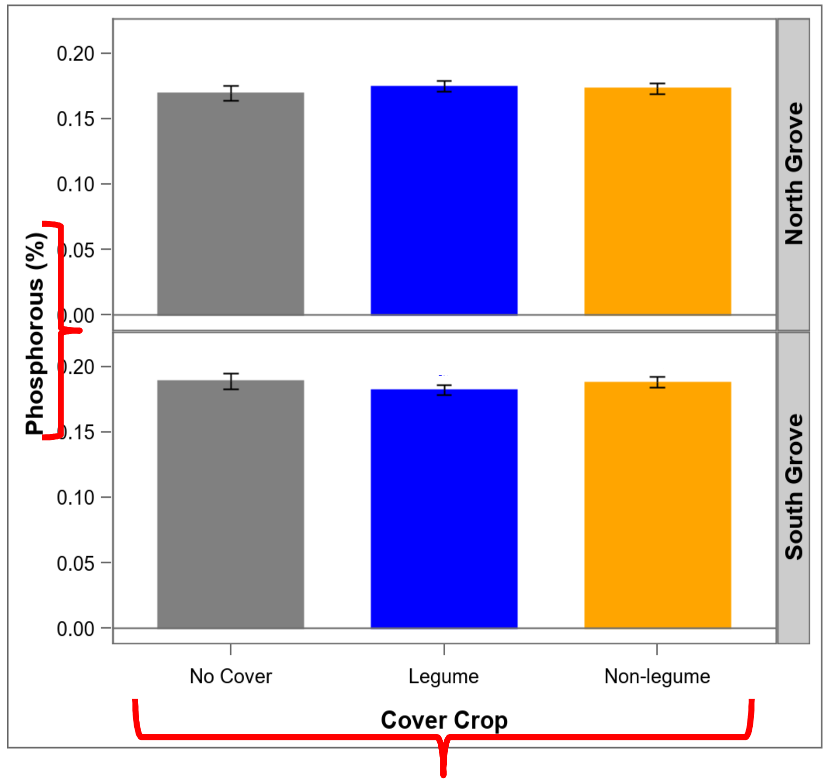
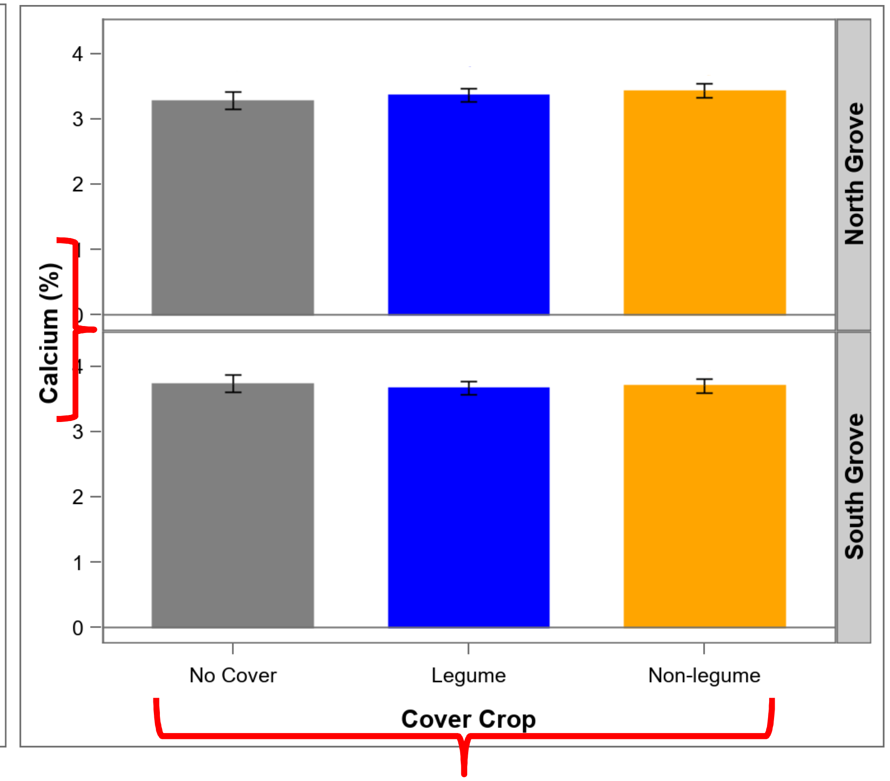
RESULTS

Leaf Macronutrient Concentration







Summary Objective 1

Cover cropping with legume (LG) and non-legume (NL) species did not have a significant effect on citrus yield, vegetative growth, leaf nutrient concentrations or fruit quality. However, we did not observe a decline in vegetative growth parameters compared to baseline measurements (Gattullo et al., 2020) .

This could be because this study was carried out on mature HLB-affected citrus trees (>25-years-old), and at this age, the trees may typically require more time to respond to any effect caused by cover cropping.

Thus, more long-term studies should be conducted to quantify the effect of CC on HLB-affected mature trees . It is also recommended to conduct studies on young citrus to evaluate the impact of CC at that age.

Objective 2

Estimate the impact of different cover crop mixes in the soil macronutrients (NH_4^+, NO_3^-, P, K, Mg, and Ca) and organic matter in a commercial orange grove.

Hypothesis

The cover mixes would increase available macronutrients and soil organic matter compared with row middles following citrus producers' standard practices.

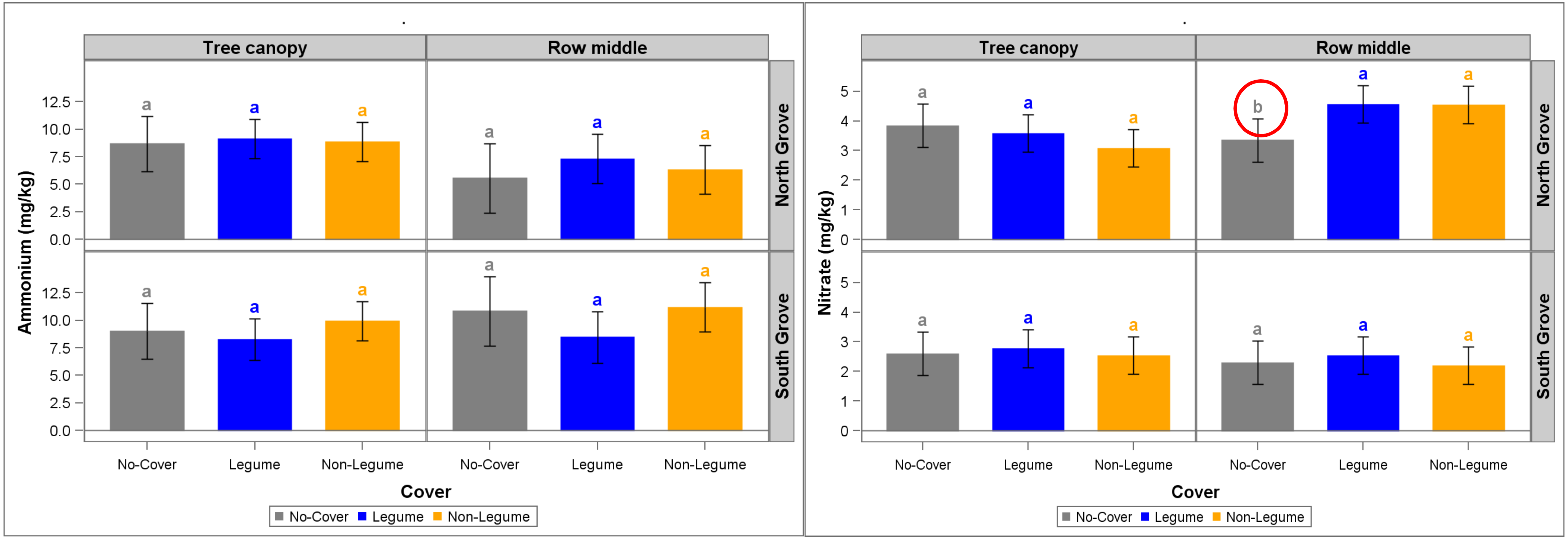
Data Collection- Soil Nutrients Analysis

- Once a year (Aug)
- Ten randomly selected trees/rep
- Location one: row middle
- Location two: 30 cm from the trunk under the canopy
- Both of them at a depth of 0-30 cm (top)
- Total of two samples per rep

Soil inorganic N – 2M KCl

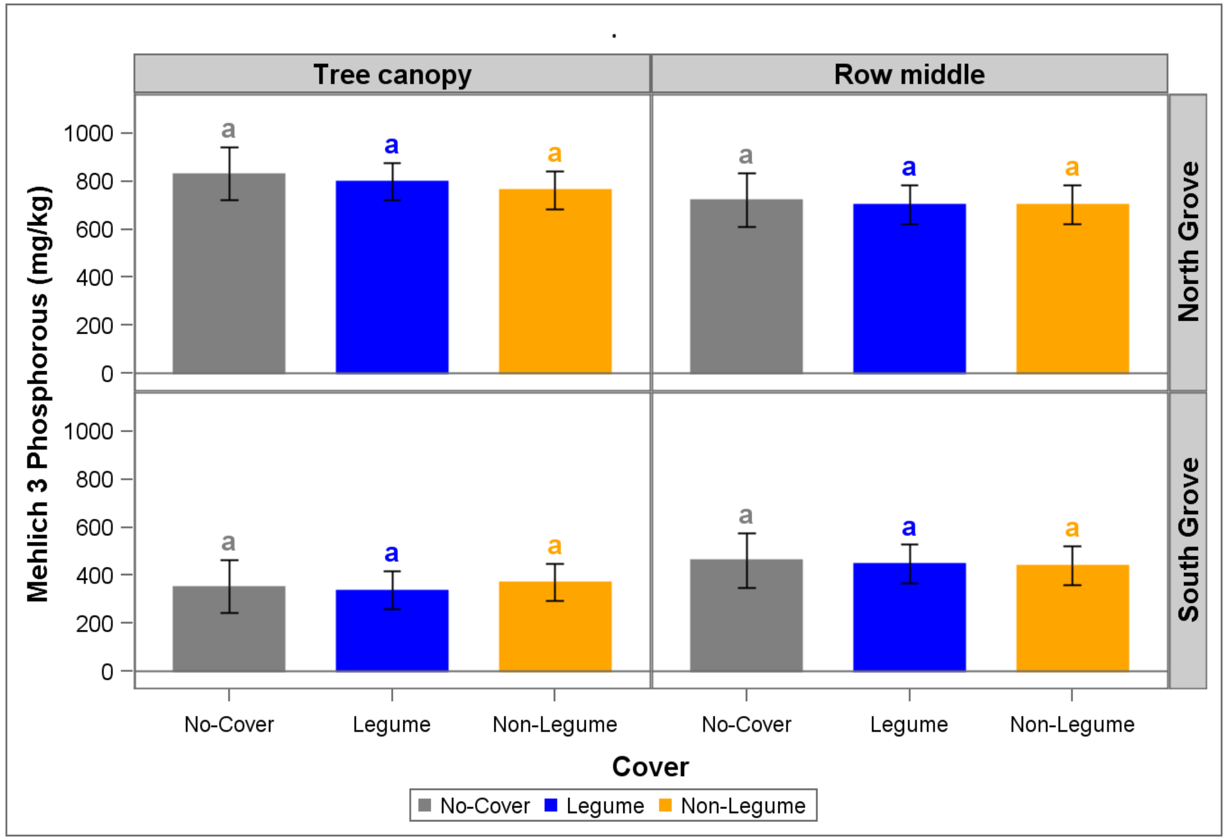
Soil macro and micronutrients-Mehlich 3

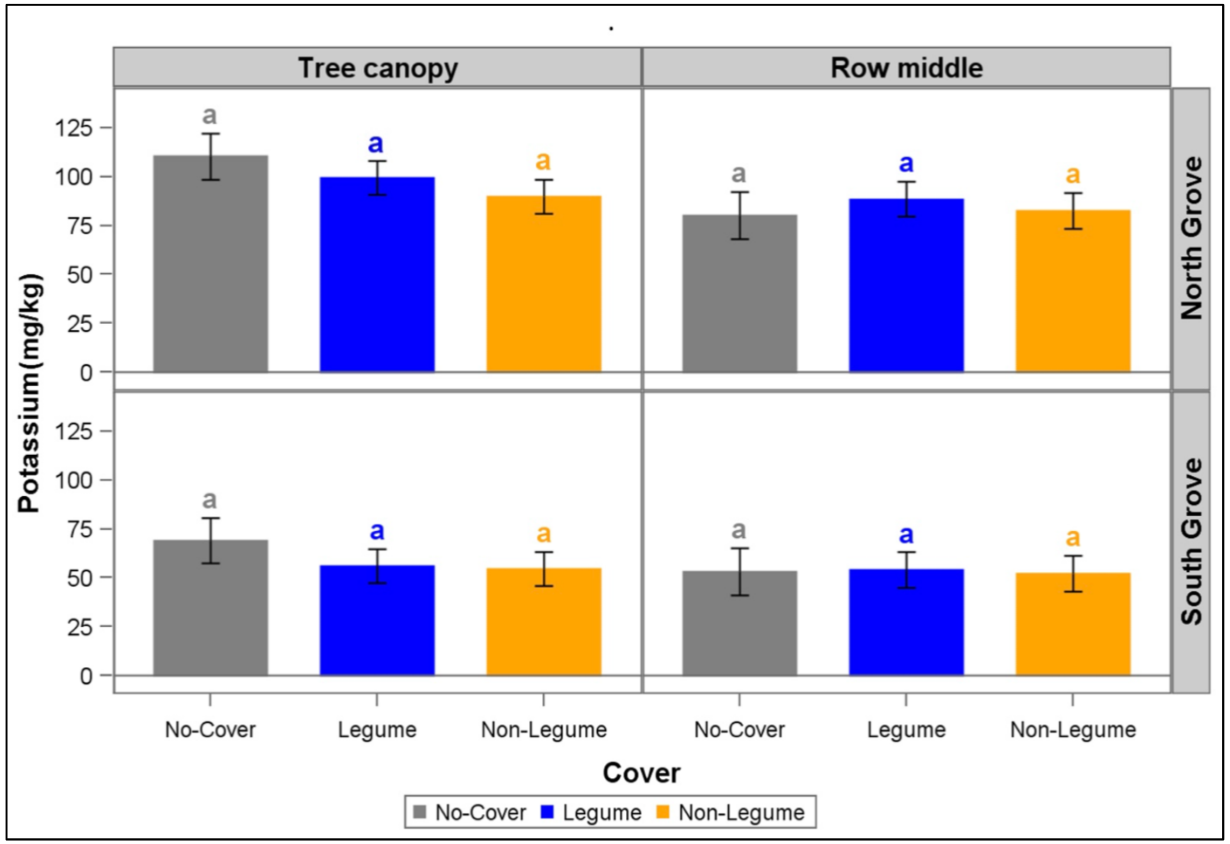
Soil Ammonium and Nitrate



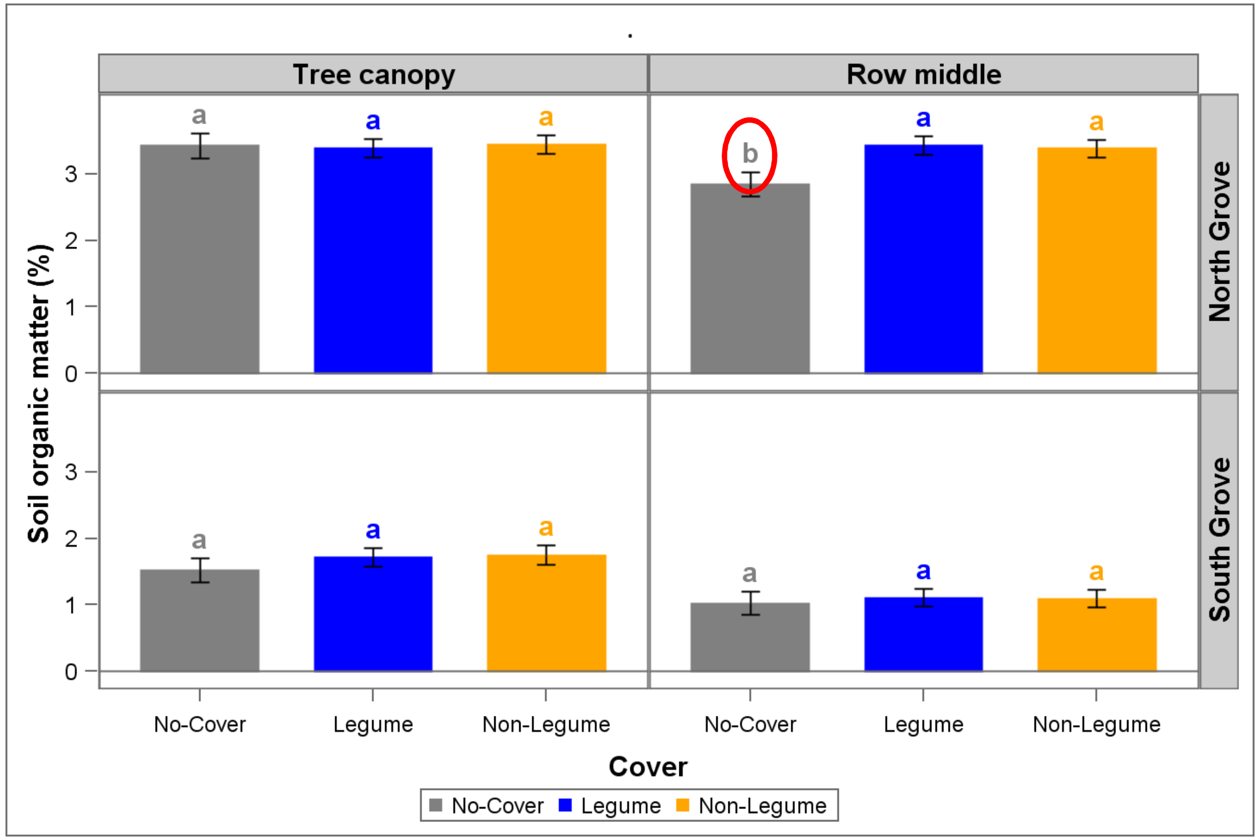
Brewer et al. 2024. Journal of Plant Nutrition

Soil Phosphorus and Potassium





Soil Organic Matter



Summary Objective 2

- CC in the citrus row middles improved soil in the aspects of NO_3^--N availability and soil organic matter (SOM) only.

- Both cover crop mixes (LG+NL and NL) increased NO_3^--N and SOM in the row middles of the orchards after seven consecutive cover crop plantings.

- The NO_3^--N and SOM increase were only observed in one of the groves, while the other grove was characterized by lower cover crop germination and establishment, and this could be due to abiotic and biotic differences in the ecosystems (O'Connell et al., 2015; Oliveira et al., 2016).

Take Home Message of Objective 1, & 2

- As a winter cover crop, Daikon radish was noticeably successful.
- Sunnhemp had a good establishment all year around.
- Both cover crop mixes were able to provide successful weed suppression.
- Both cover crop mixes increased OM and NO_3^--N in the row middles.
- It takes time. Cover cropping takes time. On average, it takes the producers three years to break even. Yield increases on crops such as corn (3%) and soybean (5%) have observed after five years of cover cropping (SARE, 2019).
- Cover crops needs to be seen as an investment rather than a cost. It is no one-size-fits-all as observed with the two citrus groves in this study.

Objective 3

Evaluate nutrient uptake by daikon radish in two Florida sandy soils under greenhouse conditions.

Hypothesis

Daikon radish would potentially recover the added soil N and prevent its loss from soil by incorporating more N into its biomass when additional N inputs are incorporated into the soil.

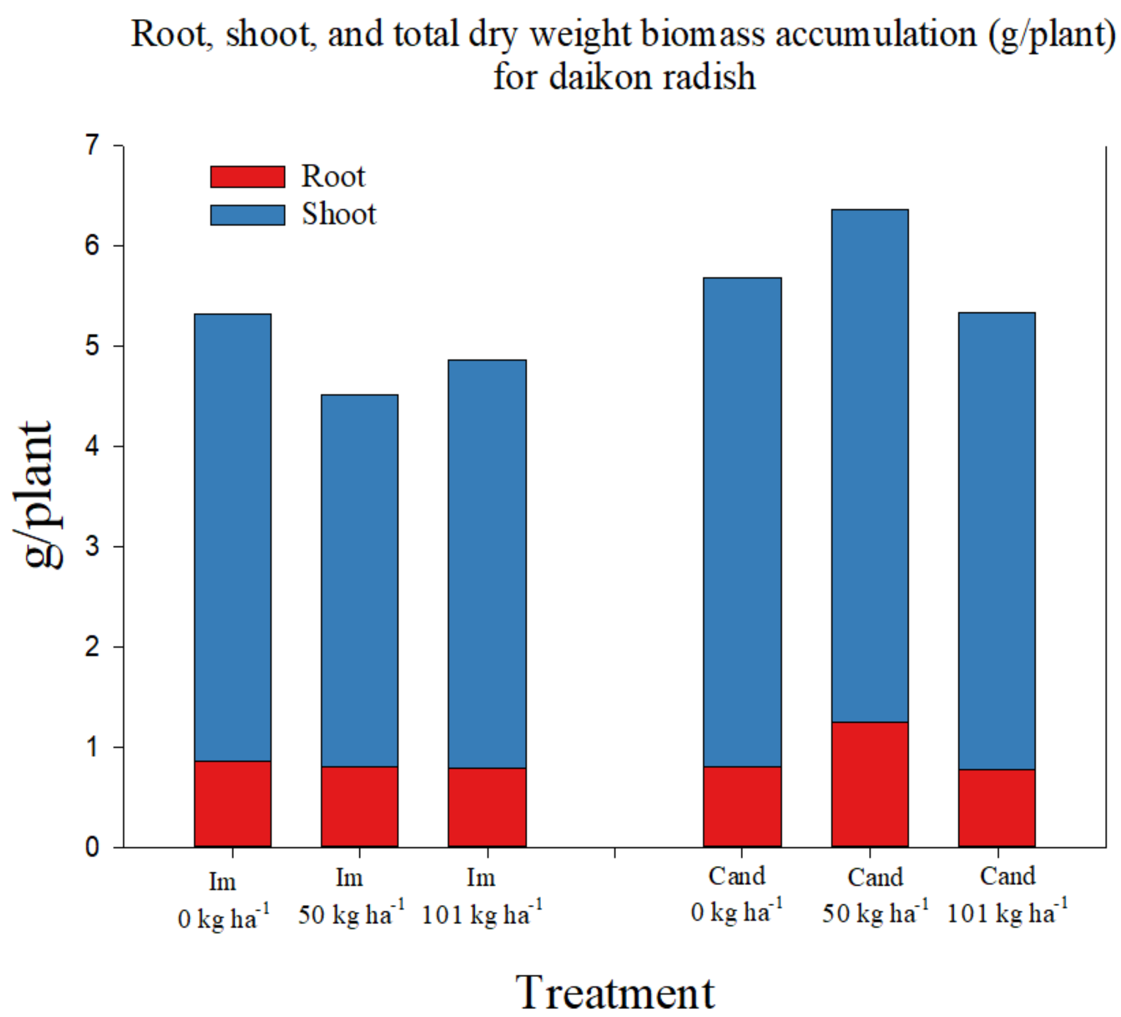
Experimental Design

Block 1				Block 2				Block 3				Block 4			
90	0	90	0	90	90	0	0	90	0	90	45	45	0	90	90
Yes	Yes	No	No	No	No	Yes	No	Yes	No	Yes	Yes	No	No	No	No
Lake Alfred	Lake Alfred	Immokalee	Immokalee	Lake Alfred	Immokalee	Lake Alfred	Lake Alfred	Immokalee	Immokalee	Lake Alfred	Lake Alfred	Immokalee	Immokalee	Immokalee	Lake Alfred
103	**106**	**109**	**112**	**203**	**206**	**209**	**212**	**303**	**306**	**309**	**312**	**403**	**406**	**409**	**412**
45	90	90	45	90	0	0	45	45	0	90	0	45	0	45	90
No	Yes	No	No	Yes	Yes	No	No	Yes	Yes	No	Yes	No	Yes	Yes	Yes
Lake Alfred	Immokalee	Lake Alfred	Immokalee	Immokalee	Immokalee	Immokalee	Immokalee	Immokalee	Immokalee	Lake Alfred	Lake Alfred	Lake Alfred	Immokalee	Lake Alfred	Lake Alfred
102	**105**	**108**	**111**	**202**	**205**	**208**	**211**	**302**	**305**	**308**	**311**	**402**	**405**	**408**	**411**
0	45	45	0	45	45	90	45	0	45	90	45	0	0	45	90
No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	No	No	Yes	No	Yes	Yes
Lake Alfred	Immokalee	Lake Alfred	Immokalee	Immokalee	Lake Alfred	Lake Alfred	Lake Alfred	Lake Alfred	Immokalee	Immokalee	Lake Alfred	Lake Alfred	Lake Alfred	Immokalee	Immokalee
101	**104**	**107**	**110**	**201**	**204**	**207**	**210**	**301**	**304**	**307**	**310**	**401**	**404**	**407**	**410**

- Randomized complete block design.
- Two-by-three full factorial with three N fertilizer rates (0, 50, and 101 kg N ha^{-1} as urea).

Data Collection

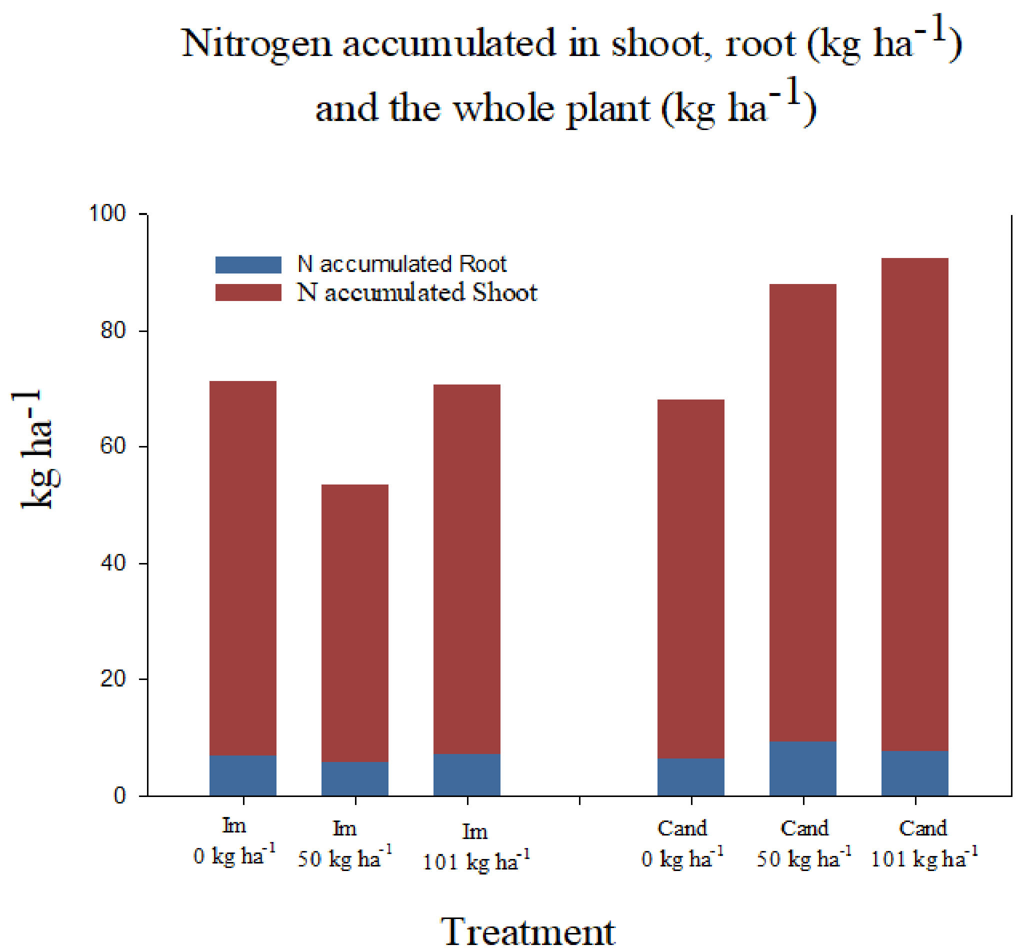
- Baseline soil.
- Biomass samples were taken six weeks after planting (43 days).
  - Roots.
  - Shoots.
- Dry weight.
- N% content (roots and shoots).
- Soil samples.



Brewer et al. 2023. Agro. Geosci. Envi.

RESULTS

RESULTS



Brewer et al. 2023.
Agro. Geosci. Envi.

Summary Objective 4

- Increasing the amount of N fertilizer applied to daikon radish plants did not increase biomass production or more N accumulated in the shoots and roots of the plants. Daikon radish plants could produce a similar amount of biomass with no N applied. The plants in the control replications (0 kg N ha^{-1}) were able to scavenge and uptake the residual N (baseline inorganic N) present in both Florida sandy soils and produce similar biomass as the plants receiving 50 and 101 kg N ha^{-1} (Greub and Roberts, 2020).

- More extended studies should be conducted considering nitrogen (N) leaching, daikon radish decomposition, and N addition of dead plants to the agricultural system.

- New studies should measure root length, number of leaves, and the area where the roots were growing and measure N in that area.

ACKNOWLEDGMENTS

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