Using smartphone artificial intelligence apps for leaf symptom diagnosis

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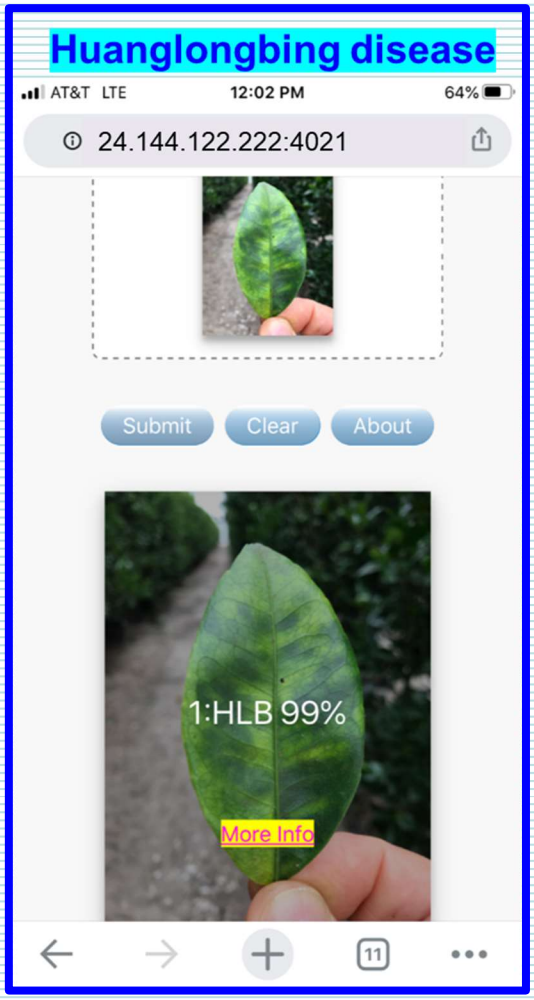
Mg Mn Zn Fe



May 12, 2021 Florida Citrus Show

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OUTLINE

- Using citrus leaf symptoms as a tool for diagnosing nutrient deficiencies, diseases, and pest damage
- Research to develop a smartphone app for diagnosing citrus leaf symptoms with AI
- The Citrus Diagnosis web app
- Other spinoffs from the leaf diagnosis research

The condition and appearance of citrus leaves provides useful information about tree status

- Disease symptoms?
- Nutrient deficiencies?
- Pest damage?
- Herbicide damage?
- Salt damage or drought?
- Sunburn?

= Nitrogen deficiency here

The symptom expression may vary on different leaves and on different varieties; years of experience and training helps

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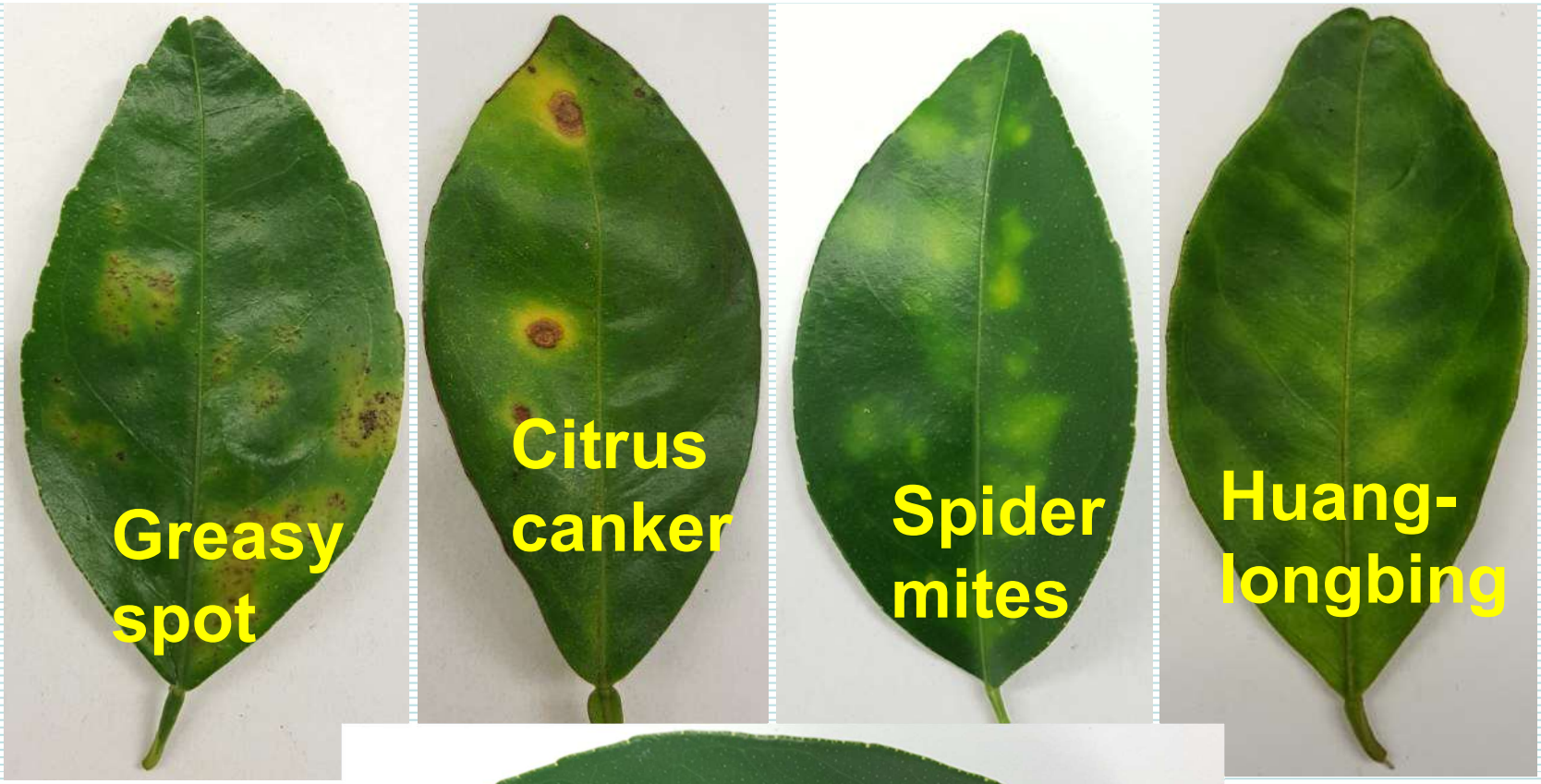
The symptoms of nutrient deficiencies closely associated with HLB disease are particularly important to identify correctly so that appropriate fertilizer can be applied

Mg **Mn** **Zn** **Fe**

Disease and pest symptoms on leaves may cause chlorotic patterns that can confuse the diagnosis of nutrient deficiency



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University of Florida MS study on machine vision: *P. Mungofa*

HYPOTHESIS

An artificial intelligence machine-vision diagnosis system may outperform the diagnosis by <u>novice</u> <u>and expert human scouts</u>

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PROJECT RESEARCH OBJECTIVES

- Train a deep convolutional artificial neural network (DC-ANN) to recognize nutrient deficiencies, pests and diseases on citrus leaves

- Validate the performance of the trained network to identify symptoms on new unknown leaf samples

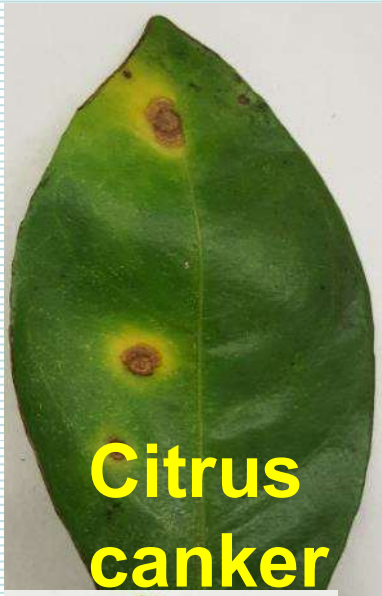
- Compare the model predictions with diagnoses made by nutrient concentration measurements and experts

- Augment the trained DC-ANN with images of leaf symptoms representing other causes: pests, diseases, PGRs

(all the above objectives were part of the MS thesis, Dec 2020)

- Deploy the validated final DC-ANN as a smartphone app

Goal: analyze citrus leaf symptoms with a smartphone



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MATERIALS & METHODS

Neural network training

- Collect digital photos of symptomatic and healthy leaves
- Standard Android smartphone camera, 1 leaf/frame
- ~600 images per class

16 classes of leaf symptoms:

Nutrient deficiencies

- Nitrogen
- Magnesium
- Iron
- Manganese
- Zinc

Pests

- Spider mite damage
- Leaf miner damage
- Thrips damage
- Asian citrus psyllid damage

Other

- Healthy
- Leaf sunburn / salt damage
- Unknown

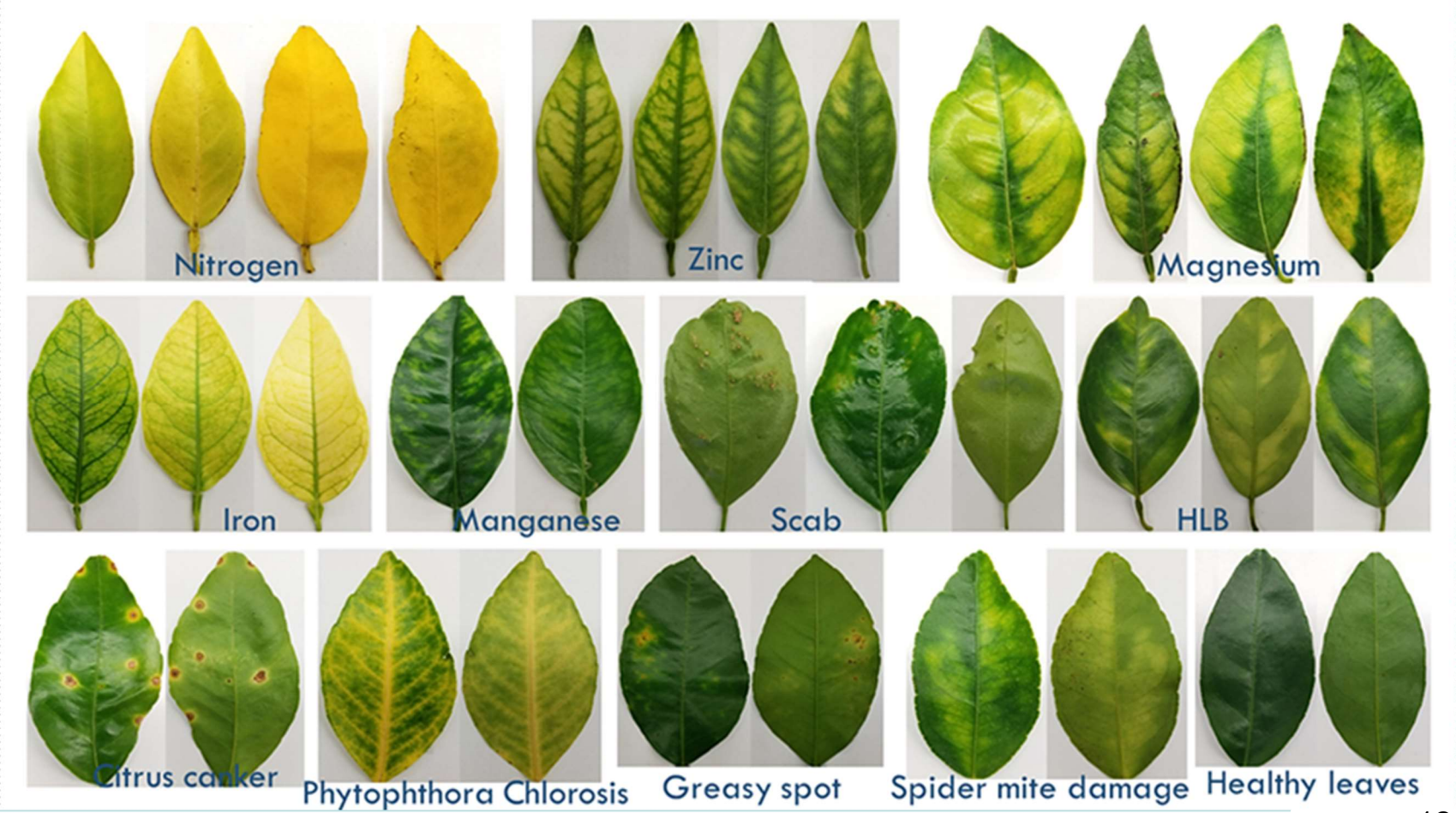
Diseases

- HLB
- Citrus canker
- Greasy spot
- Citrus scab
- Phytophthora

MATERIALS & METHODS

Neural network training: 9,600 leaves, images of both sides

- EfficientNet-B4 network on the Tensorflow framework
- The network was trained until convergence



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MATERIALS & METHODS

Neural network validation

- Validation: for each symptom class, 3 replications of 20 images
- Photos for testing the model were separately obtained from independently sampled leaves
- The trained model was used to predict with the test images
- After photographing the leaves, each replicate was pooled, dried for 48h at 70^{o}C, ground, and nutrient concentrations analyzed at a commercial laboratory
- Validation accuracy was scored by percentage correct diagnosis according to expert assessment of the leaves, as well as the agreement with nutrient concentrations

Selected RESULTS

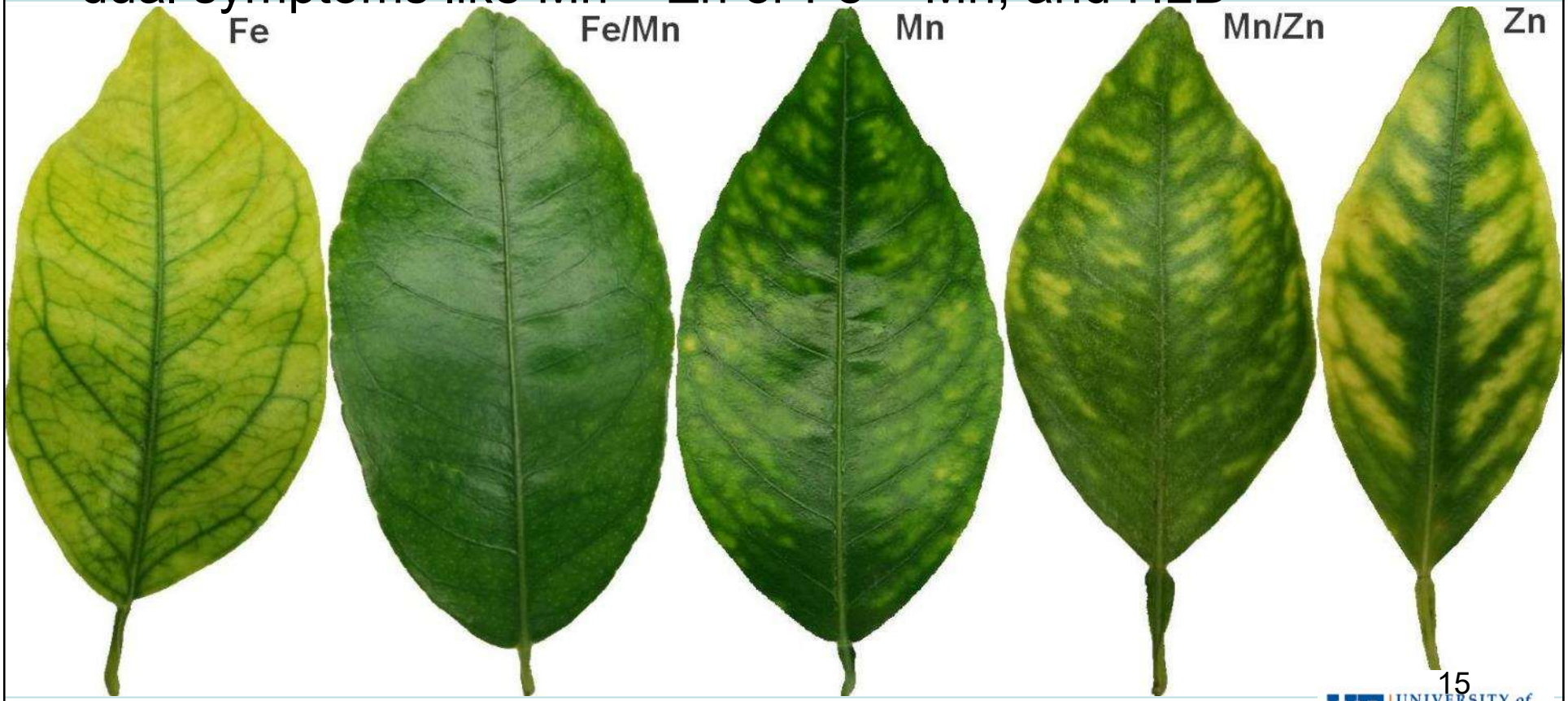
Leaf Symptom	Accuracy (%)	Nutrient conc. (mg/kg)	Deficiency threshold (mg/kg)
Healthy	100	all optimal	-
Scab	100	ND	-
Greasy spot	100	ND	-
Canker	100	ND	-
Magnesium	100	300 ± 0.0	2,000
Mites	100	ND	-
Iron	100	19 ± 1.7	35
Phytophthora	100	ND	-
HLB	100	ND	-
Manganese	99.0	8 ± 1.7	18
Zinc	99.2	4 ± 0.2	18

Average accuracy (16 classes): 99.7%

DISCUSSION

Nutrient deficiencies:

- The trained EfficientNet-B4 was able to detect all nutrient deficiencies on single leaves with 99-100% accuracy
- The model was able to distinguish between subtle differences in chlorosis expression between different symptoms, including dual symptoms like Mn + Zn or Fe + Mn, and HLB



DISCUSSION

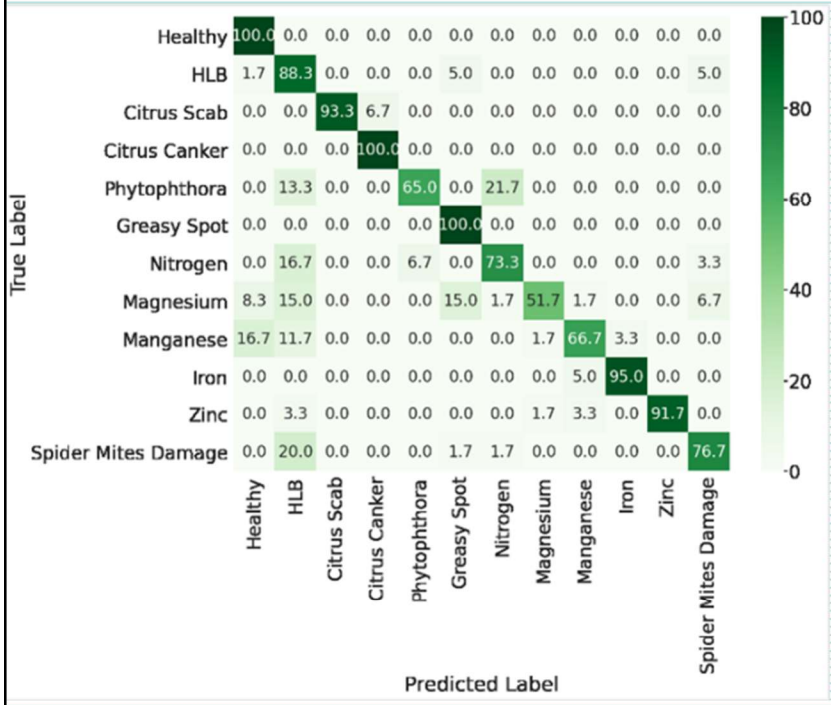
Leaf surface differences for pest and disease detection:

Symptom lesions of canker, greasy spot, are strongly developed on the abaxial leaf surfaces.

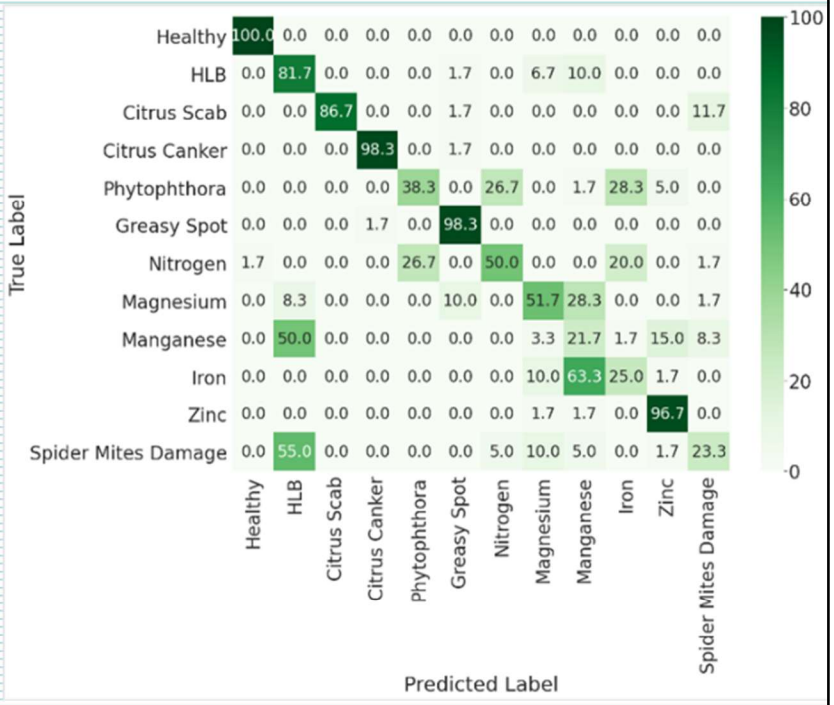
- Prediction accuracies were significantly higher for greasy spot on abaxial vs adaxial surfaces
- Differences were NS for canker since lesions penetrate the entire leaf lamina

DISCUSSION

- Trained AI image classification models are more accurate than novice or expert humans at diagnosing leaf symptoms



Confusion Matrix – Experts responses



Confusion Matrix – Novices responses

Credit: P. Mungofa, University of Florida MS thesis, October 2020

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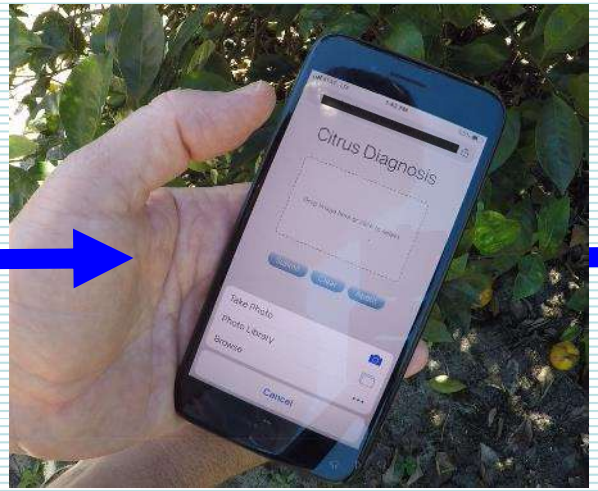
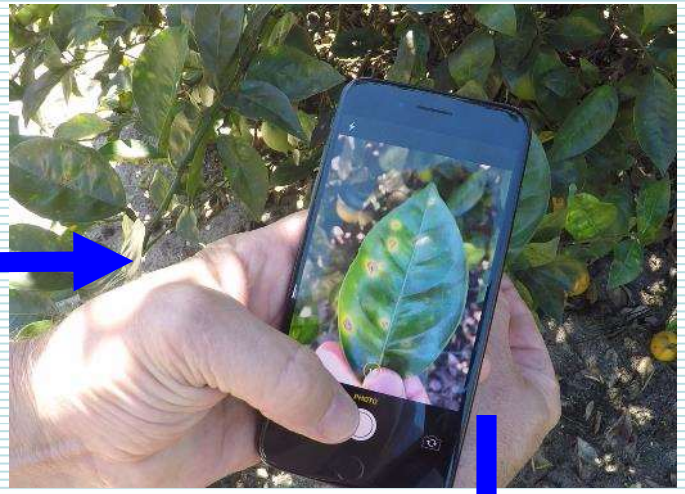
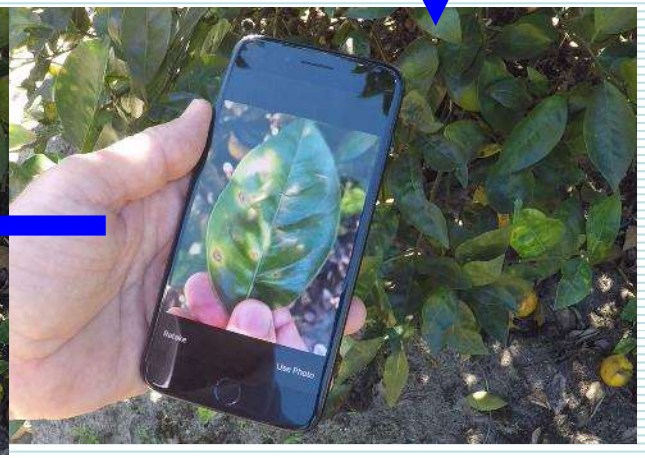
Leaf diagnosing with a smartphone web app:

1. Pick a leaf

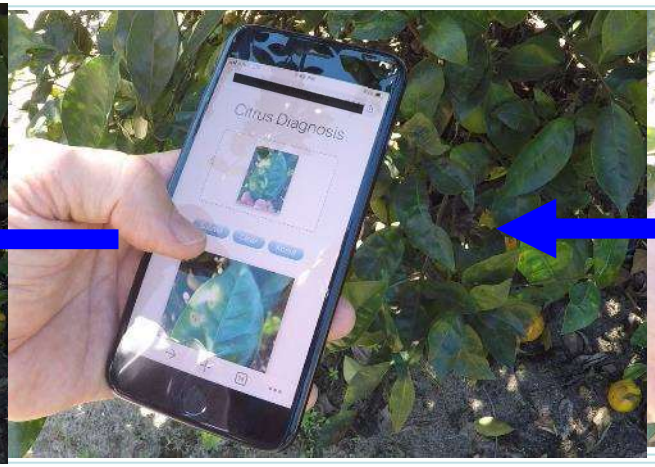




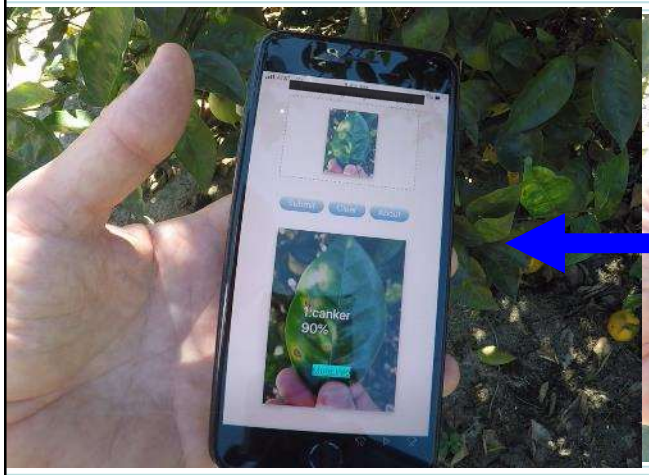
2-3. Take a photo



4. Use photo



5. Submit photo



6. Show result

http://www.makecitrusgreatagain.com/SmartphoneApp.htm

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SYNTHETIC DATA GENERATION:
Background replacement for ~20,000 images to improve performance of the app in varied situations (background images from COCO and own collection)

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SYNTHETIC DATA GENERATION:

Original image
(white paper background)

Remove or
Replace
background with UNET
semantic segmentation

Crop the leaf
with Yolo

Good results BUT
requires background removal
preprocessing in the app

Good results and a simpler,
more reliable app

Train images with EfficientNet-B7

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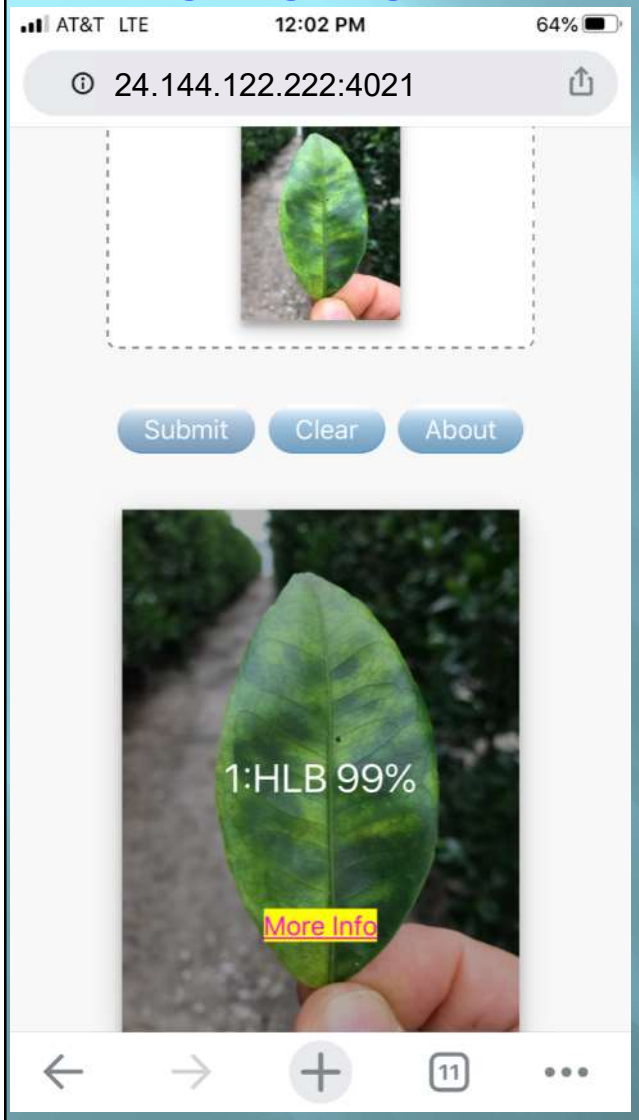
SYNTHETIC DATA: background removal

SYNTHETIC DATA: background removal

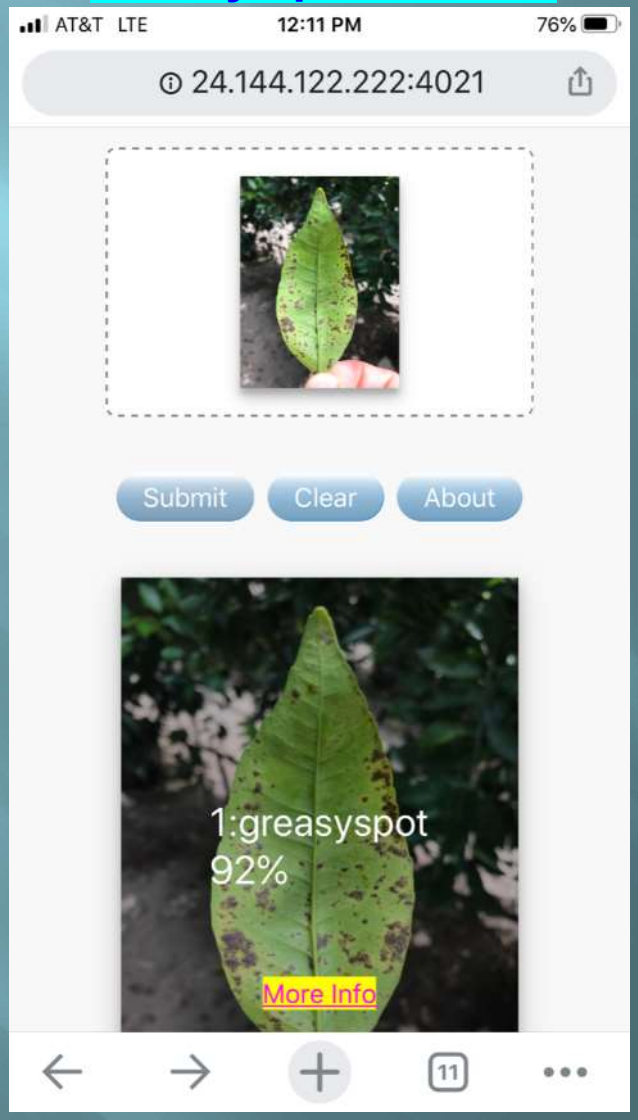
SYNTHETIC DATA: background removal

Smartphone web app:

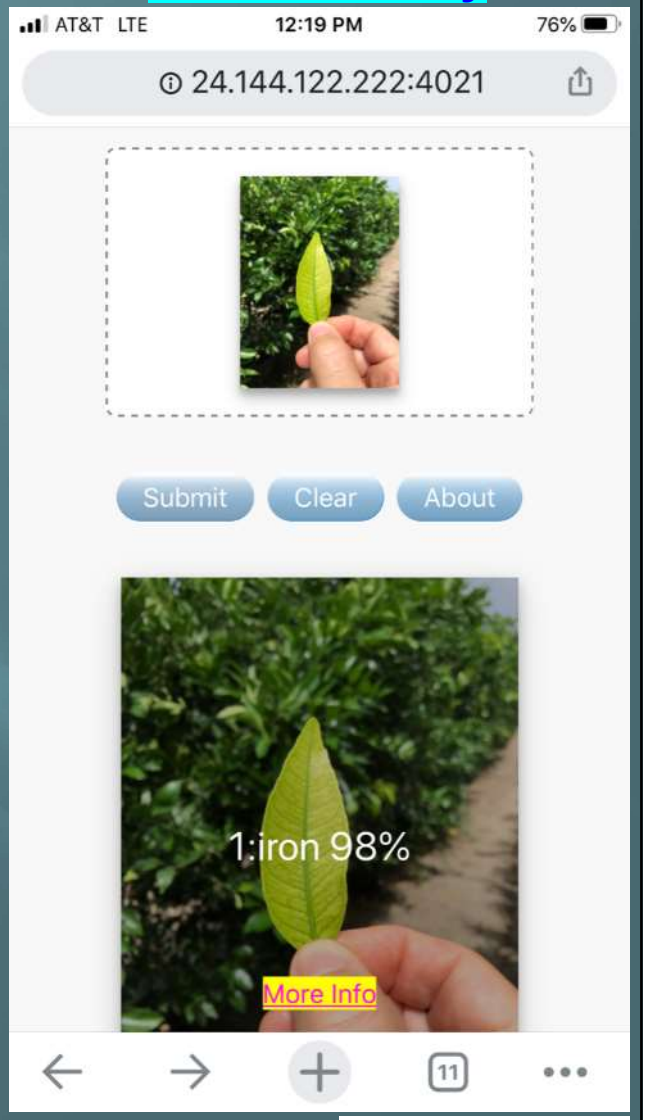
Huanglongbing disease



Greasy spot disease



Iron deficiency



Smartphone web app registration:

http://www.makecitrusgreatagain.com/SmartphoneApp.htm

5:19

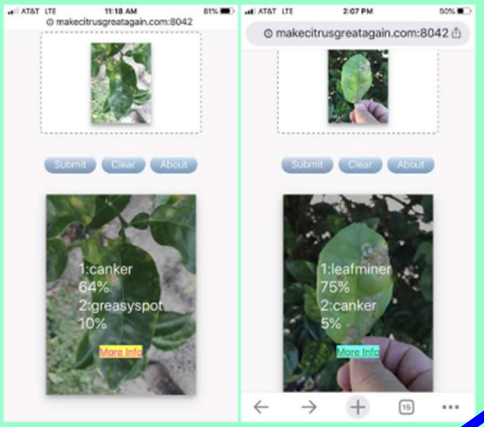
usgreatagain.com

***** Citrus Diagnosis *****
smartphone web app

This app uses artificial intelligence to diagnose leaf symptoms of nutrient deficiencies, diseases and pests on citrus trees.

Please view the short video instructions before registering to use the app.
(Note that registration and activation is necessary in order to use the app)

*** STEP1: Click HERE FIRST to view the registration instructions**



Other instructional video clips:	
Introduction	In-field demonstration
How to take photos for the best results	Quick demo of the app

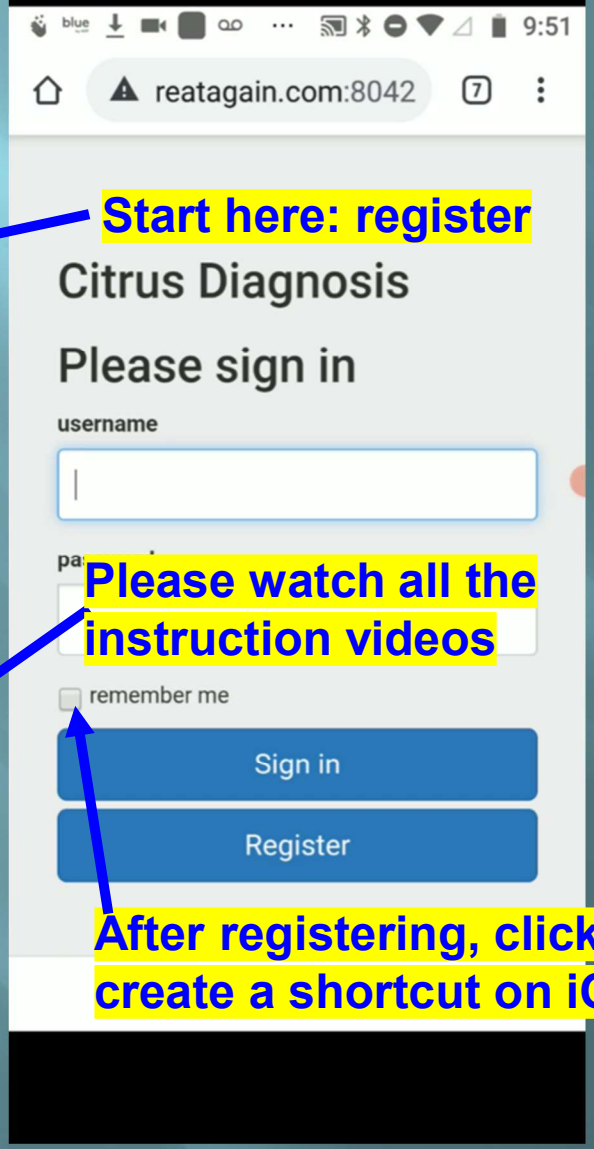
Click here for the Citrus Diagnosis web app

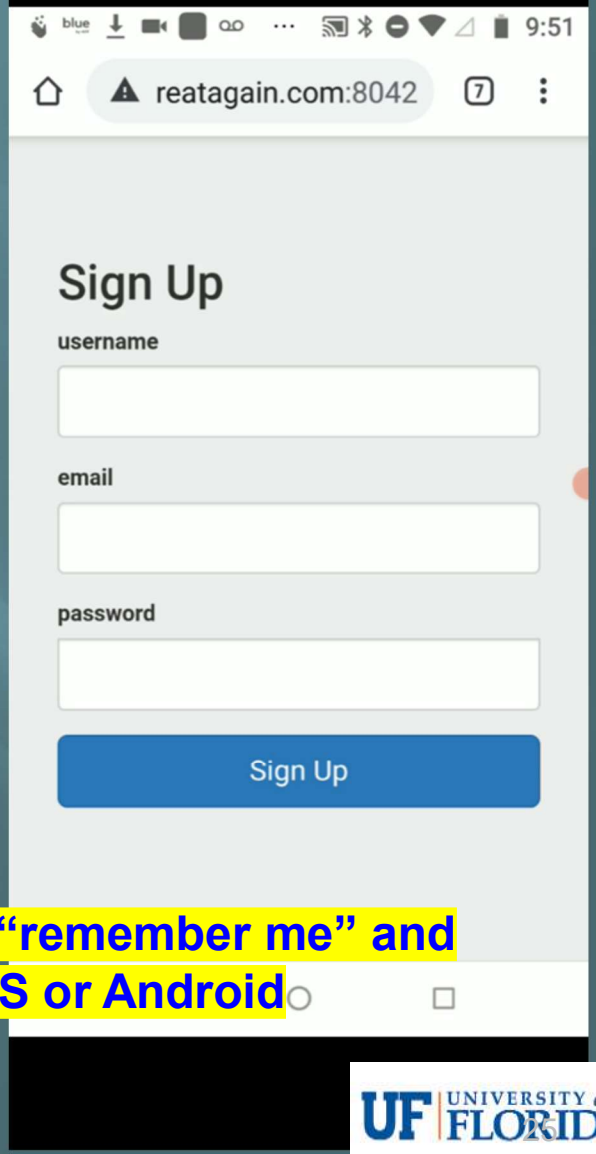
Return to the smartphone app project page

Start here: register

Please watch all the instruction videos

After registering, click "remember me" and create a shortcut on iOS or Android





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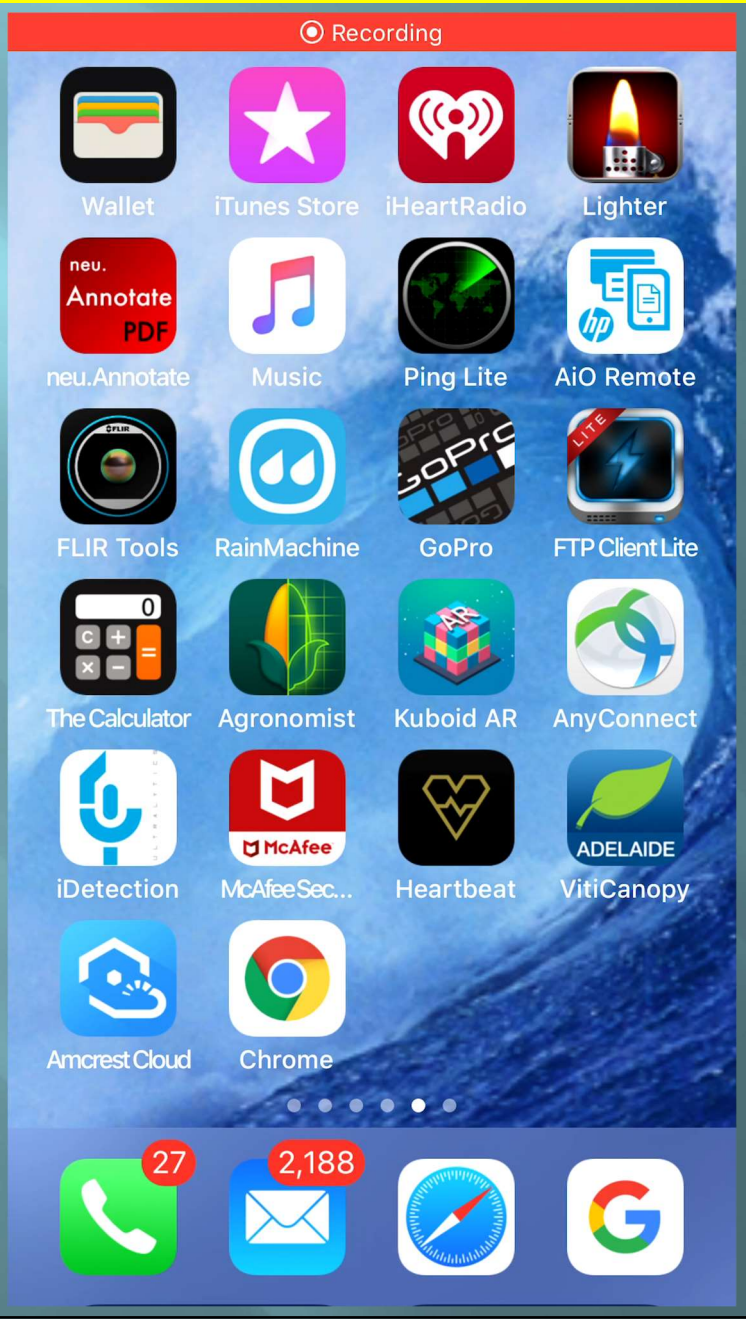
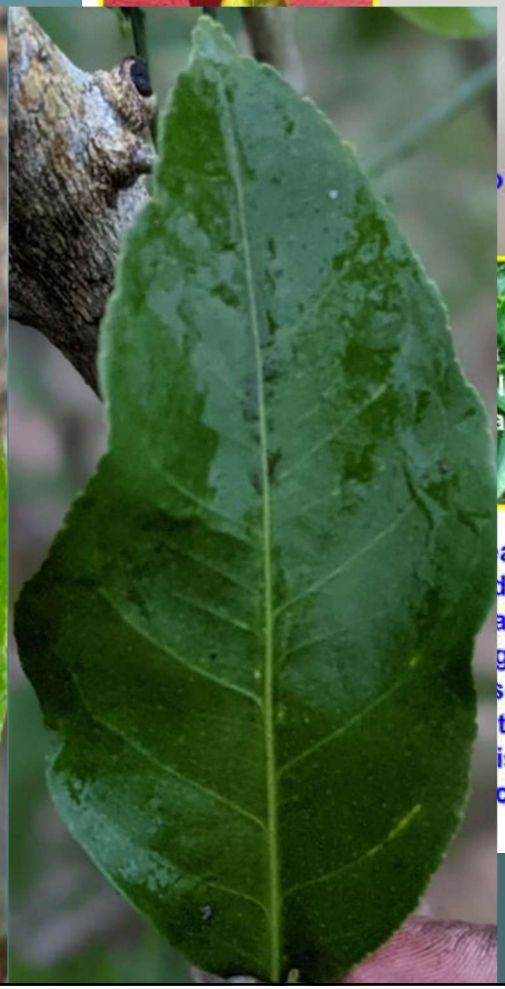
Smartphone web app: video clip



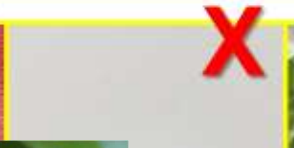
Smartphone web app:

How to take a photo for the smartphone app:

- ✓ Handheld leaves work well, e
  the petiole or cradled in the
- ✓ A well-focused leaf with an u
  works well as shown here;
- ✓ Use vertical orientation, peti
  of the photo frame with the le



How NOT to take a photo for the smartphone app:



small

Too large, leaf apex truncated

ltiple
aves

Too small, bright background, leaf has low illumination, horizontal

aves, not clusters
ds produce unpredictable results
ations in photos
ge leaf image in the photo
sed images
trong lighting
ise blurred images
covered by sooty mold, dust

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Smartphone web app:

- **Other spinoffs from the leaf diagnosis research**
  - Understanding what the trained AI model is looking at when it diagnoses the different symptoms
  - Making sense of unexpected results: can the AI model "teach the teacher"?
  - How can we use this information to improve our own visual diagnostic skills?
  - Propose an on-line leaf diagnosis training course using our library of 20,000+ high quality leaf images
  - Can easily add more diagnostic classes (melanose, sooty mold, potassium…)

Can the AI model teach us new skills?

Can you tell what these three leaf symptoms are? (hint: The leaf on the right displays a combination of the symptoms on the other two leaves)

N: Veinal chlorosis and yellow midrib

Fe: Interveinal chlorosis and green midrib

N+Fe: Interveinal chlorosis and yellow midrib

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Smartphone web app:

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Smartphone web app:

CONCLUSIONS: smartphone apps

- An ANN model was successfully trained to identify healthy or symptomatic citrus leaves: nutrient deficiencies, pests, diseases
- Independent validation accuracy was 99 to 100% (mean 99.7%) and agreed with expert diagnoses and chemical analyses
- Additional leaves for new symptoms are being collected and will be added to the app once the model is retrained
- The trained networks are being deployed to smartphones for in-field diagnosis of citrus leaf symptoms (extension agents, growers, home-owners) –

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