A Citrus AI App to Diagnose Nutritional Deficiencies, Diseases and Pests in the Field

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Mg


Mn


Zn


Fe

Acknowledgments

- Dr. Arnold Schumann, Professor UF/IFAS CREC, Lake Alfred
  - Email: schumaw@ufl.edu
  - Also credit for this presentation
- Dr. Schumann's Lab, UF/IFAS CREC, Lake Alfred
  - Laura Waldo, Timothy Ebert, William Holmes, Napoleon Mariner, Perse Mungofa, Gary Test

Objectives

- Using citrus leaf symptoms as a tool for diagnosing nutrient deficiencies, diseases and pest damage
- A brief introduction to artificial neural networks and their potential use in agriculture
- Development of a smartphone app for diagnosing citrus leaf symptoms with AI
- Introduction to the Citrus Diagnosis web app
- Using diagnostic information to make management decisions

Diagnostics

- The condition and appearance of citrus leaves can provide useful actionable information about citrus tree health
  - Disease
  - Nutrient
  - Pest
  - Herbicide
  - Salt damage
  - Sunburn

Iron deficiency

Diagnostics

- There are instances where certain symptoms are similar or may vary depending on the cause
- The correct diagnosis of these symptoms many times takes years of field experience
- Ex. nitrogen deficiency, Phytophthora or girdling?

Diagnostics

Varying symptoms that are specific to a diagnosis

Mn

Iron

Canker

Iron

HLB

Greasy Spot

Greasy Spot

Zn & Mn

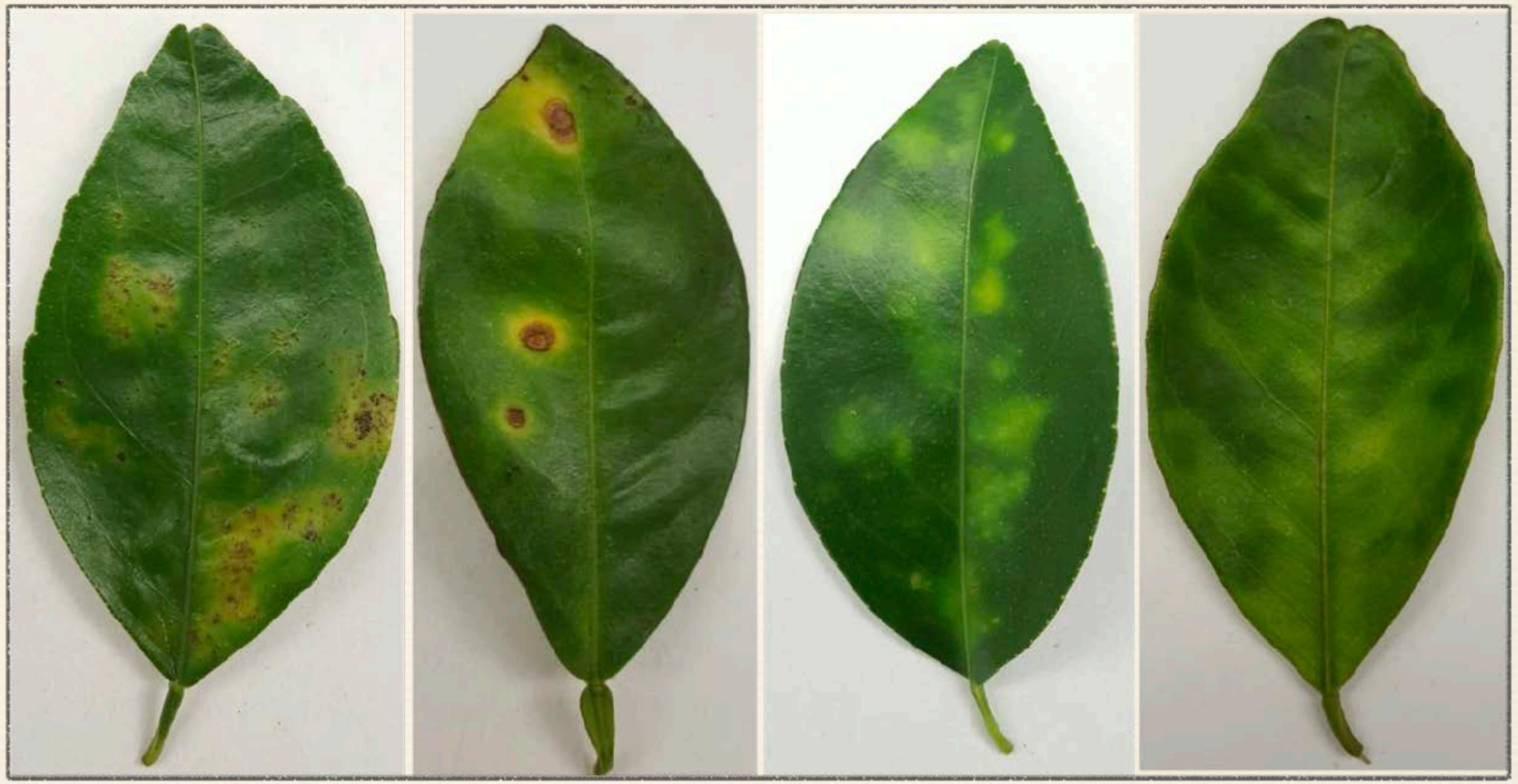
Diagnostics

- The correct identification of nutritional deficiencies critical when associated within an endemic HLB environment
- Key to this is the correct identification of those deficiencies allowing for the application of the appropriate type of fertilizer

Mg Mn Zn Fe

Diagnostics

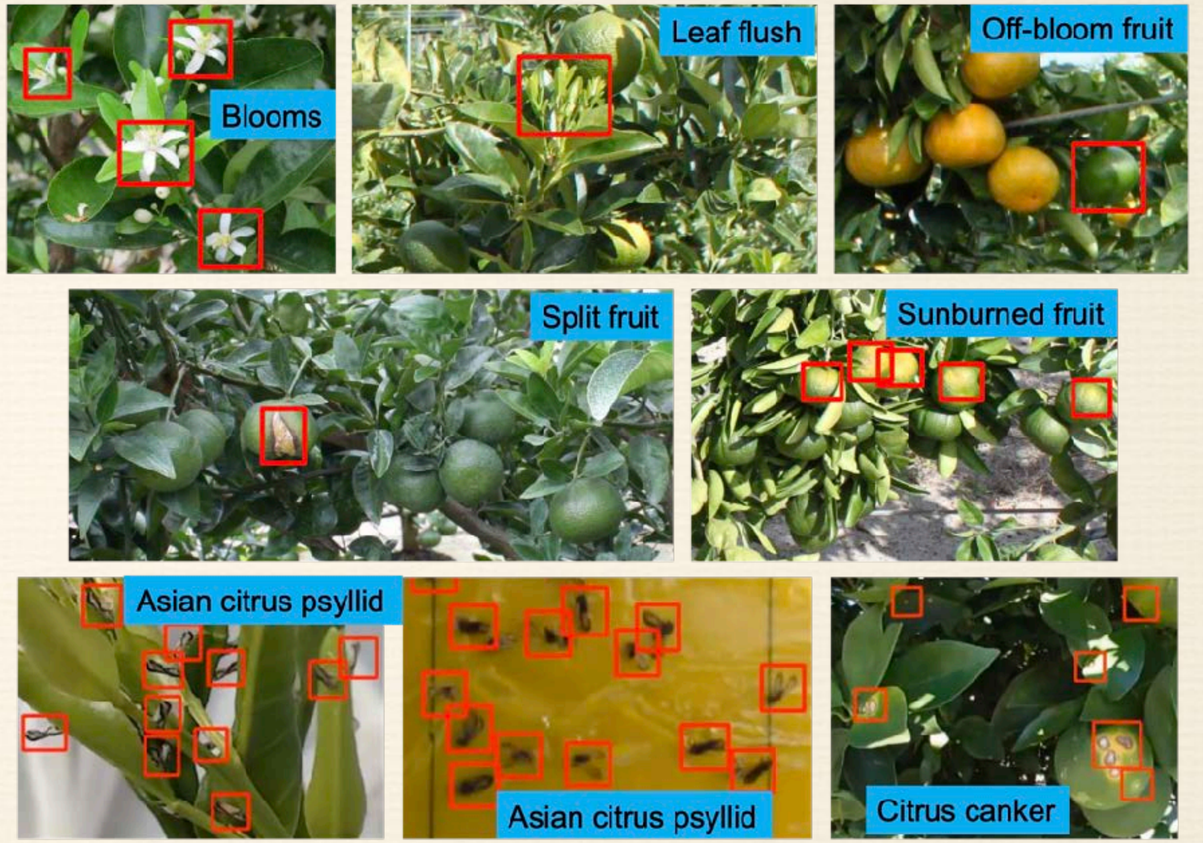
- Disease and pest symptoms on citrus leaves can cause chlorotic patterns that can sometimes be mistaken for nutritional deficiencies



Greasy spot | Citrus canker | Spider mites | HLB

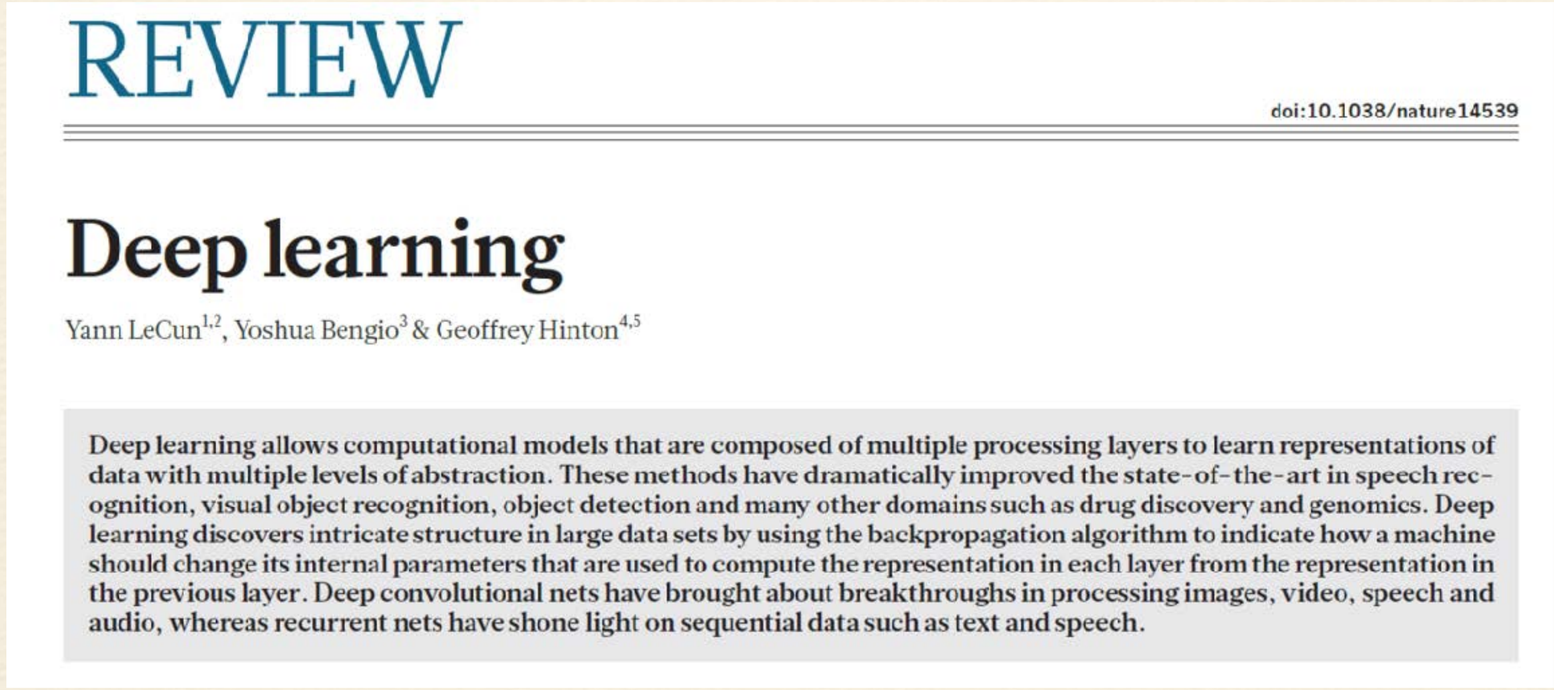
Artificial Neural Networks

Artificial intelligence as deep learning models can help as they are fast and accurate
Objective identification



Artificial Neural Networks (ANN) - Deep Learning

- Deep convolutional - artificial neural networks (2012)
- Excellent accuracy in image recognition
- Technology used for face recognition, image search engines, self-driving cars



REVIEW

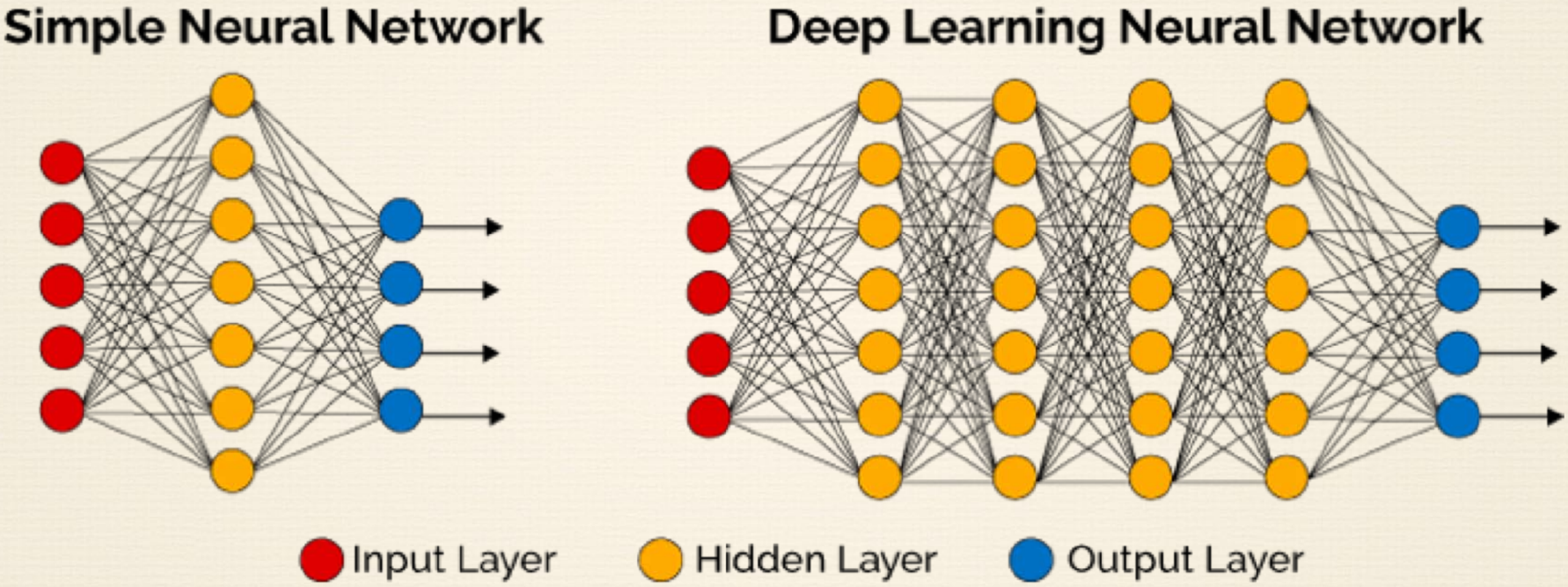
doi:10.1038/nature14539

Deep learning

Yann LeCun[1,2], Yoshua Bengio[3] & Geoffrey Hinton[4,5]

Deep learning allows computational models that are composed of multiple processing layers to learn representations of data with multiple levels of abstraction. These methods have dramatically improved the state-of-the-art in speech recognition, visual object recognition, object detection and many other domains such as drug discovery and genomics. Deep learning discovers intricate structure in large data sets by using the backpropagation algorithm to indicate how a machine should change its internal parameters that are used to compute the representation in each layer from the representation in the previous layer. Deep convolutional nets have brought about breakthroughs in processing images, video, speech and audio, whereas recurrent nets have shone light on sequential data such as text and speech.

ANN- Deep Learning



https://becominghuman.ai/deep-learning-made-easy-with-deep-cognition-403fbe445351

ANN - Automated objective detection

Hypothesis - An AI machine-vision diagnosis system may outperform the diagnosis **by novice and expert human scouts**

UF Master of Science study on machine vision: P. Mungofa

Smartphone App Development

- Project Research Objectives
  - To 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 and unknown leaf samples
  - Compare the model predictions with diagnosis made by nutrient concentration measurements and human experts
  - Augment the DC-ANN with images of leaf symptoms representing other causes: pests, diseases, plant growth regulators (unknown class)
  - Deploy the validated final DC-ANN as a smartphone app

Smartphone App - Analyze Citrus Leaf Symptoms with a Smartphone

Citrus canker

Spider mites

HLB

Fe

Zn

Smartphone App - Materials and Methods

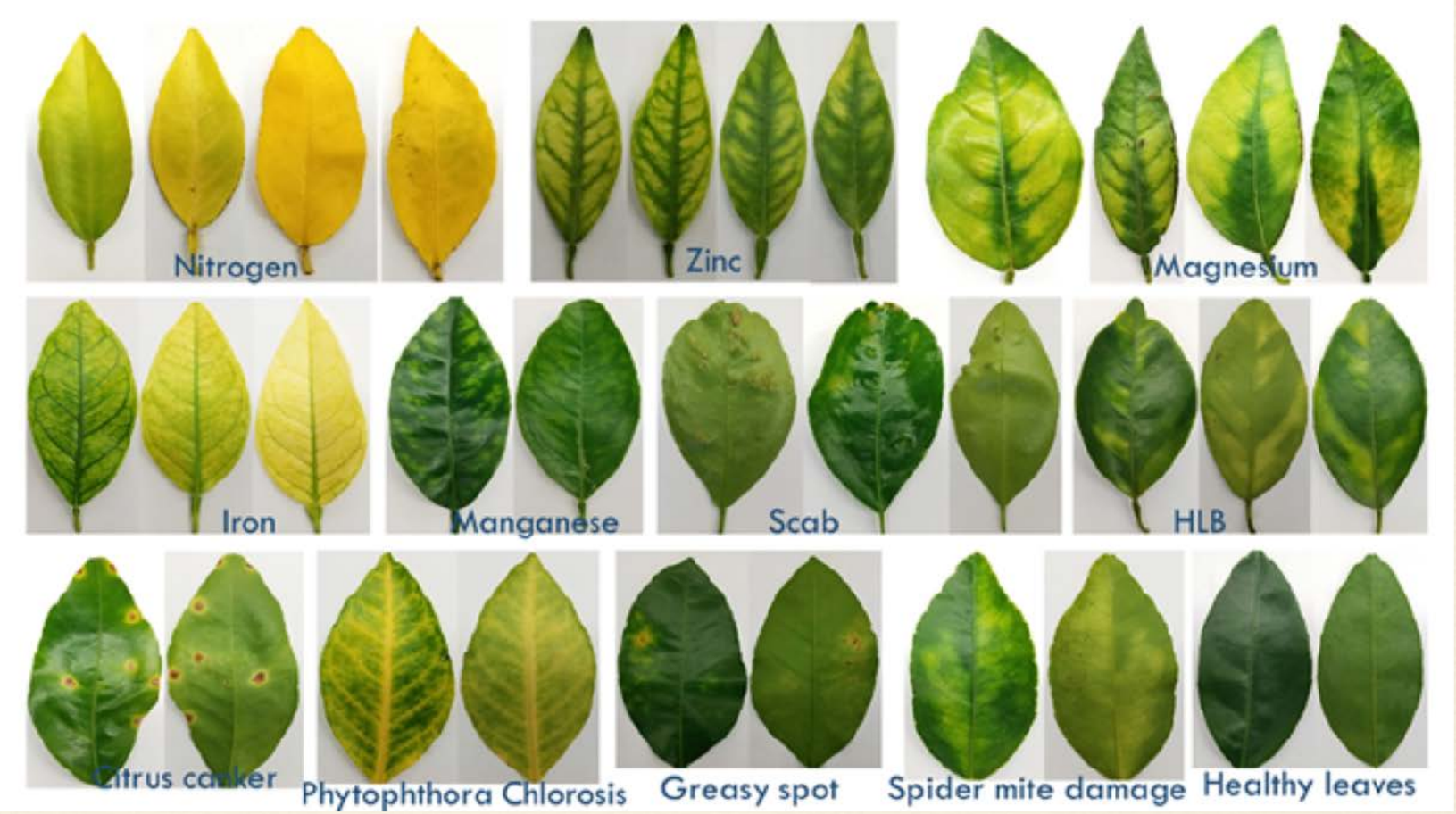
- Neural network training
  - Collect digital photos of symptomatic and healthy leaves
  - Standard android smartphone camera, 1 leaf per frame
  - Approximately 600 images per class

Smartphone App - Materials and Methods

- 16 Classes of leaf symptoms
  - Nutrient deficiencies
    - Nitrogen
    - Magnesium
    - Iron
    - Manganese
    - Zinc
  - Pests
    - Spider mites damage
    - Leafminer damage
    - Thrips damage
    - Asian citrus psyllid damage
  - Diseases
    - HLB
    - Citrus canker
    - Greasy spot
    - Citrus scab
    - Phytophthora
  - Other
    - Healthy
    - Unknown

Smartphone App - Materials and Methods

- Neural network training,
- Trained until convergence,
- 9600 leaves both sides



Smartphone App - Materials and Methods

- Validation for each symptom class was done
- 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, laboratory determination of nutrient concentrations was done by commercial lab
- Validation accuracy was scored by percentage correct diagnosis according to expert assessment of the leaves, as well as the agreement with nutrient concentrations.

Smartphone App - Discussion

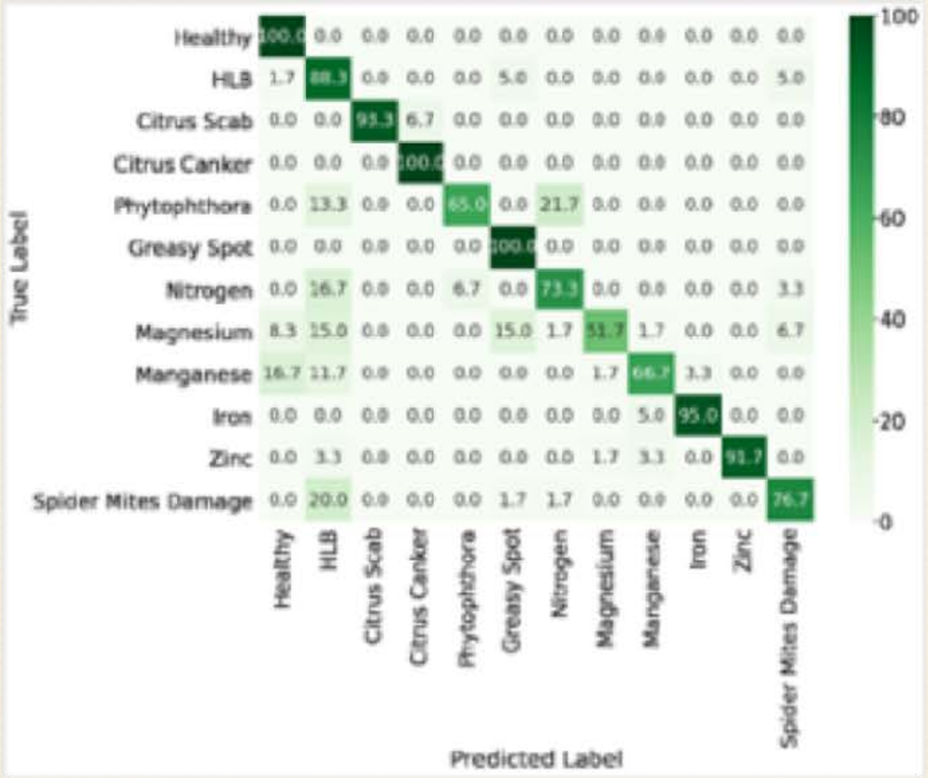
- Average accuracy of the 16 classes was 99.7%
- The trained network was able to detect all nutrient deficiencies on single leaves with 99 to 100% accuracy
- Able to distinguish between subtle differences in chlorosis expression between different symptoms, including dual symptoms like Mn+Zn or Fe+Mn and HLB

Smartphone App - Discussion

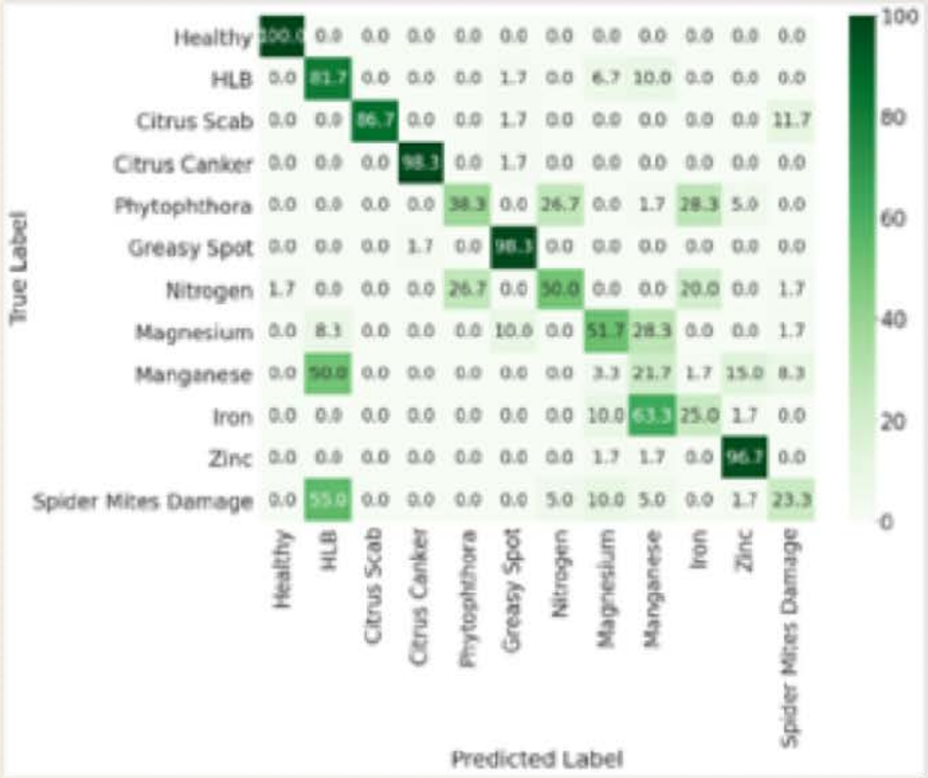
- There are leaf surface differences in pest and disease detection
  - Symptom lesions of canker, greasy spot, are strongly developed on the lower leaf surface
    - Prediction accuracies were significantly higher for greasy spot on the lower vs the upper leaf surface
    - Differences we NS for canker since lesions penetrate the entire leaf surface

Smartphone App - Discussion

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



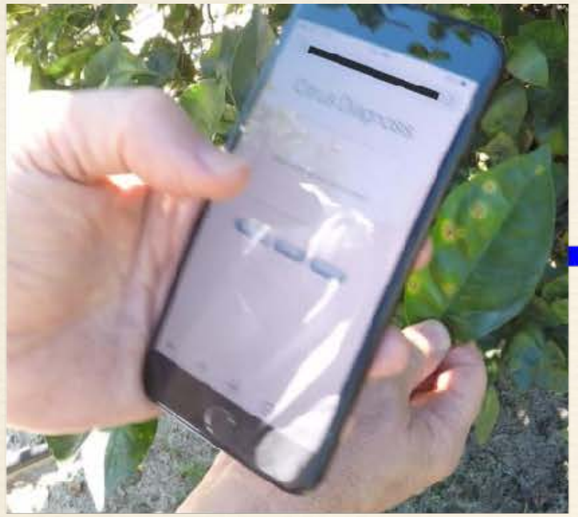
Confusion Matrix – Experts responses



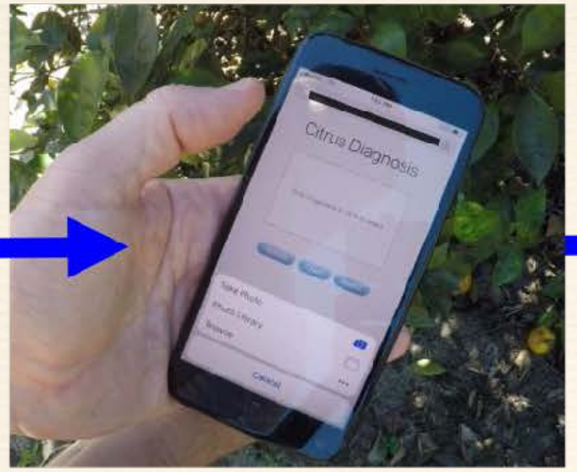
Confusion Matrix – Novices responses

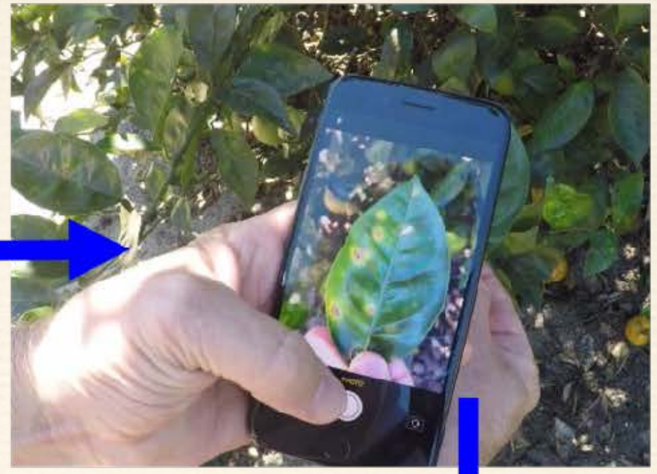
- Credit: P. Mungofa, University of Florida MS thesis, October 2020

Smartphone App - Application

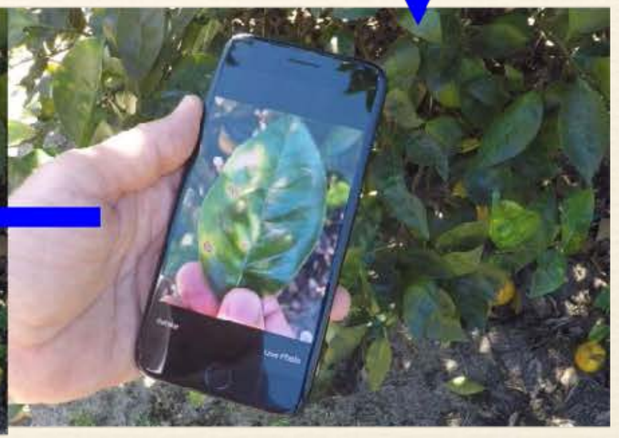


1. Pick a leaf



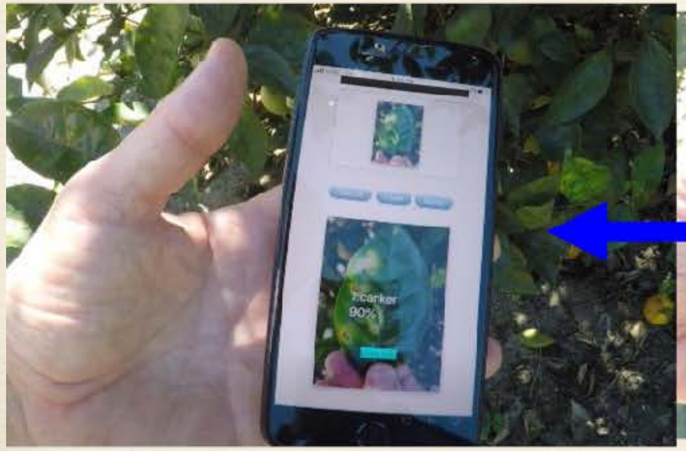


2-3. Take a photo



4. Use photo

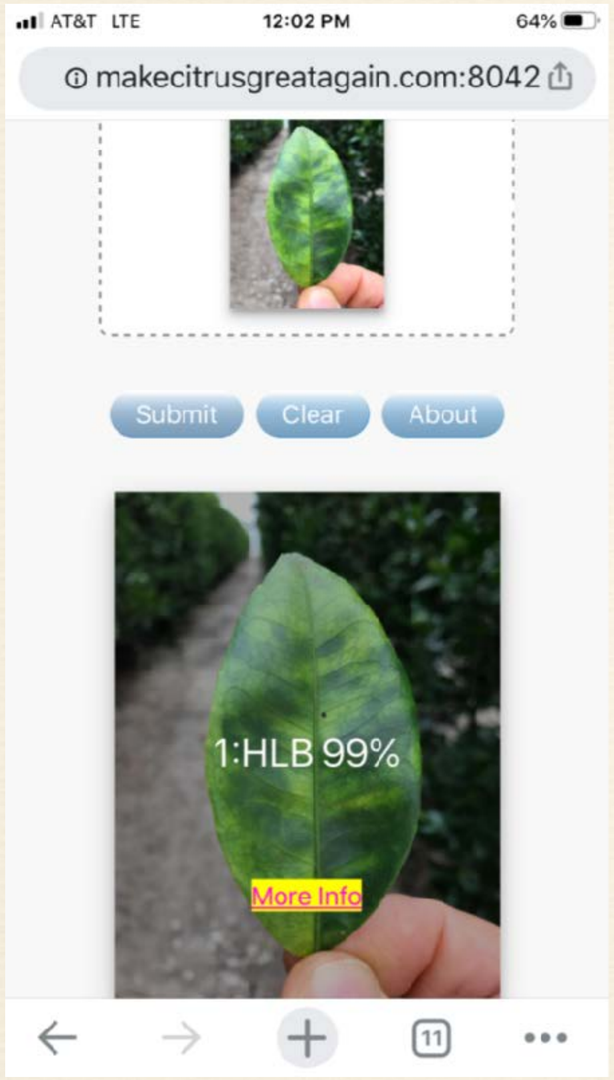
5. Submit photo

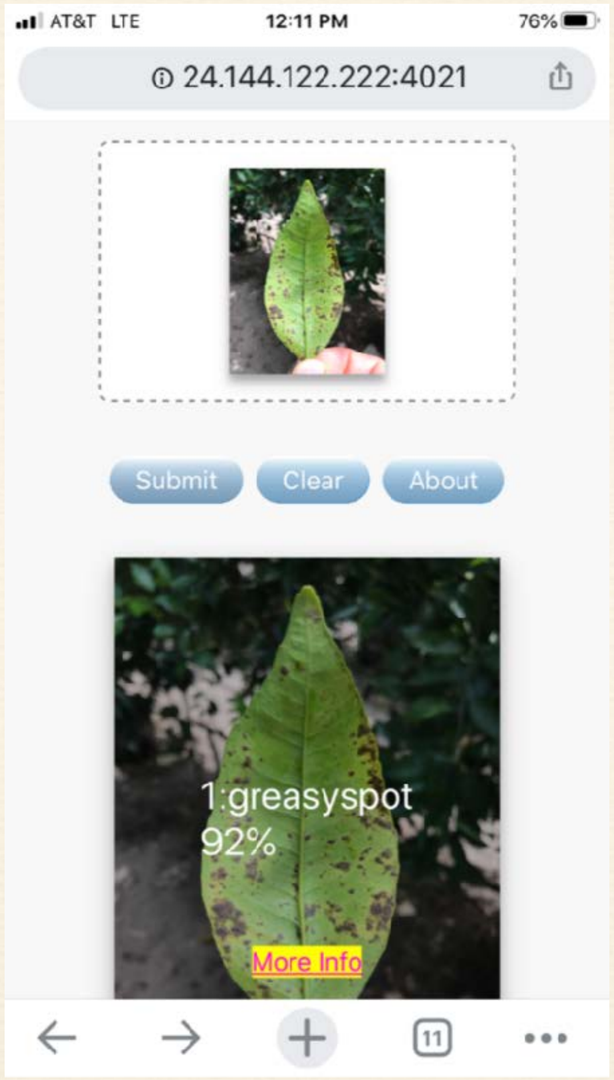


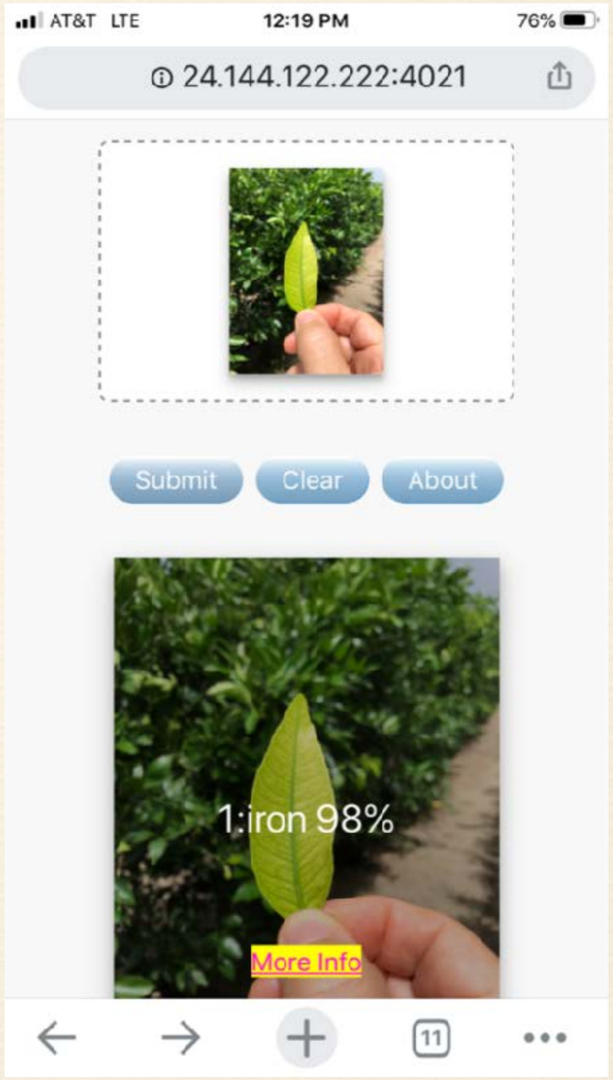
6. Show result

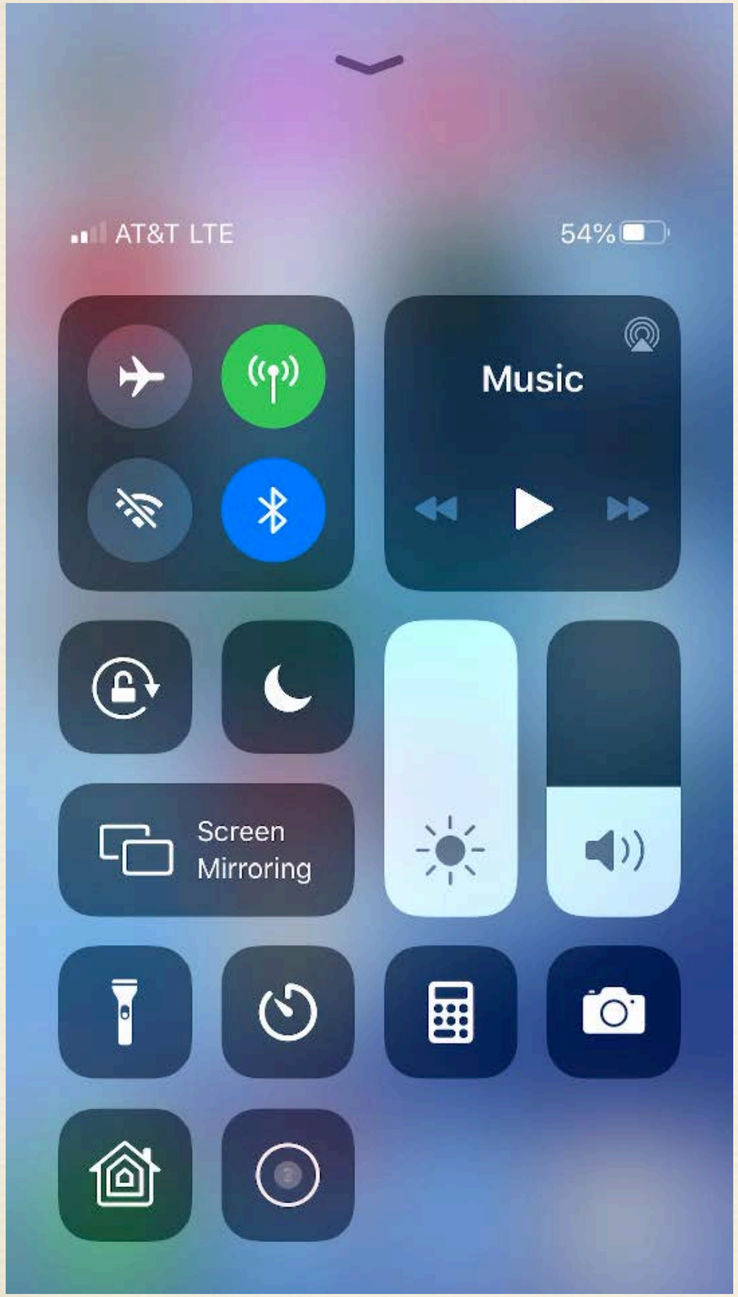
http://www.makecitrusgreatagain.com/SmartphoneApp.htm

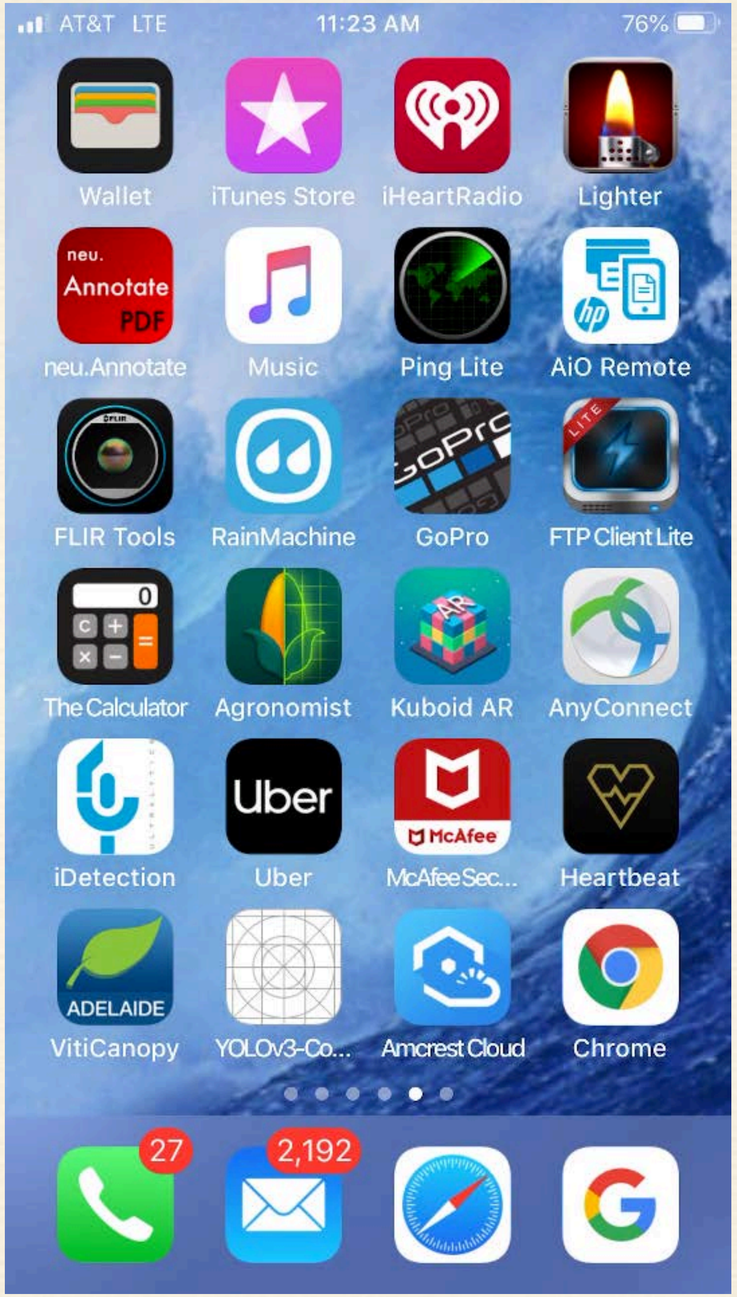
Smartphone App - Application








AT&T LTE
54%
Music
Screen Mirroring


AT&T LTE
11:23 AM
76%
Wallet
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Ping Lite
AiO Remote
FLIR Tools
RainMachine
GoPro
FTP Client Lite
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Agronomist
Kuboid AR
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27
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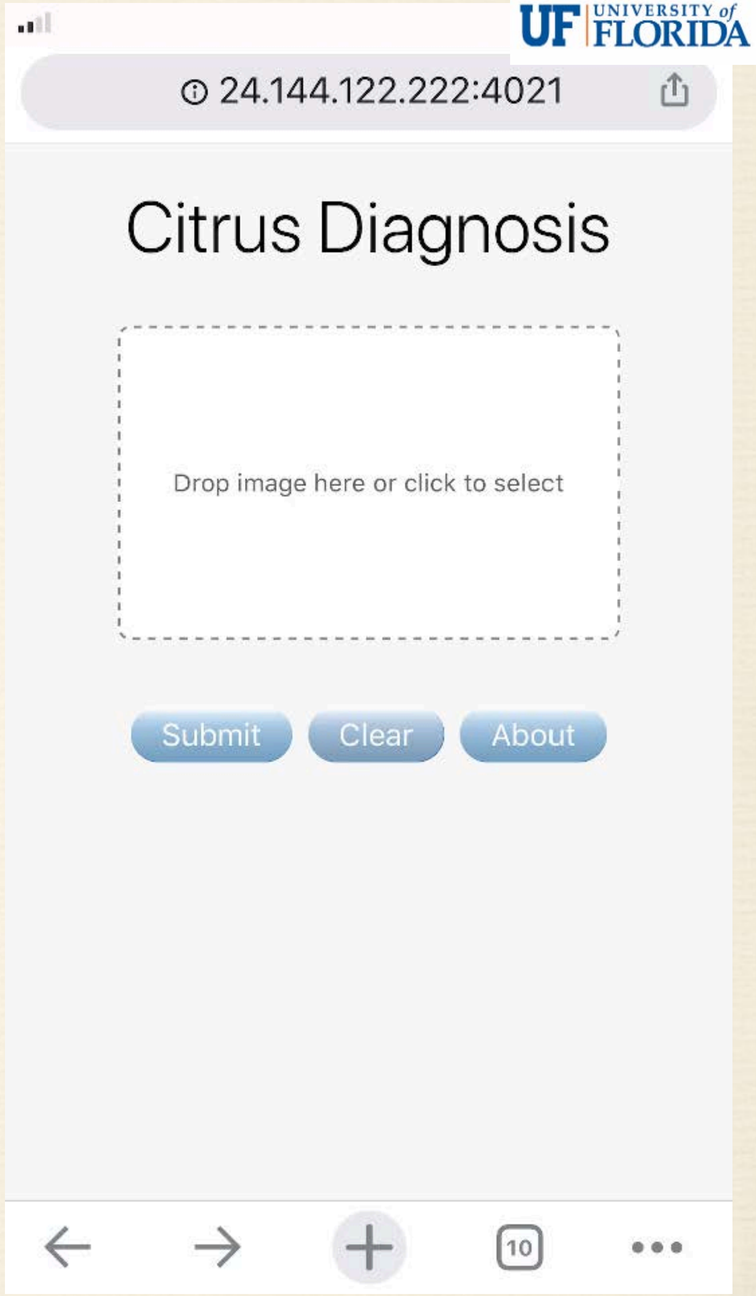
UF UNIVERSITY of FLORIDA
24.144.122.222:4021
Citrus Diagnosis
Drop image here or click to select
Submit
Clear
About

Smartphone App - Application

It is only as good as the data entered, so present good quality data

Smartphone 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 i.e. can the AI model "teach the teacher"
  - How can we use this information to improve our own visual diagnostic skills
  - Propose an online leaf diagnosis training course using our library of 20,000+ high quality images
  - Easily add more diagnostic classes (melanose, sooty mold, potassium etc.)

Teaching New Skills

Nitrogen: Veinal chlorosis and yellow midrib

Fe: Interveinal chlorosis and green midrib

N+Fe: Interveinal chlorosis and yellow midrib

Conclusions

- An ANN model was successfully trained to identify healthy or symptomatic citrus leaves: nutrient deficiencies, pests and diseases
- Independent validation accuracy was 99 to 100% (mean 99.7%) and agreed with expert diagnosis and chemical analyses
- Additional leaves for new symptoms are being collected and 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-owner/growers)

Acknowledgements

- Joseph Redmon, Ali Farhadi. 2018. YOLOv3: An Incremental Improvement. University of Washington (http://github.com/pjreddie)
- The CREC lab team, UF/IFAS Lake Alfred: Laura Waldo, Timothy Ebert, William Holmes, Napoleon Marnier, Purse Mungofa, Gary Test
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Contact: Dr. Arnold Schumann @ schumaw@ufl.edu

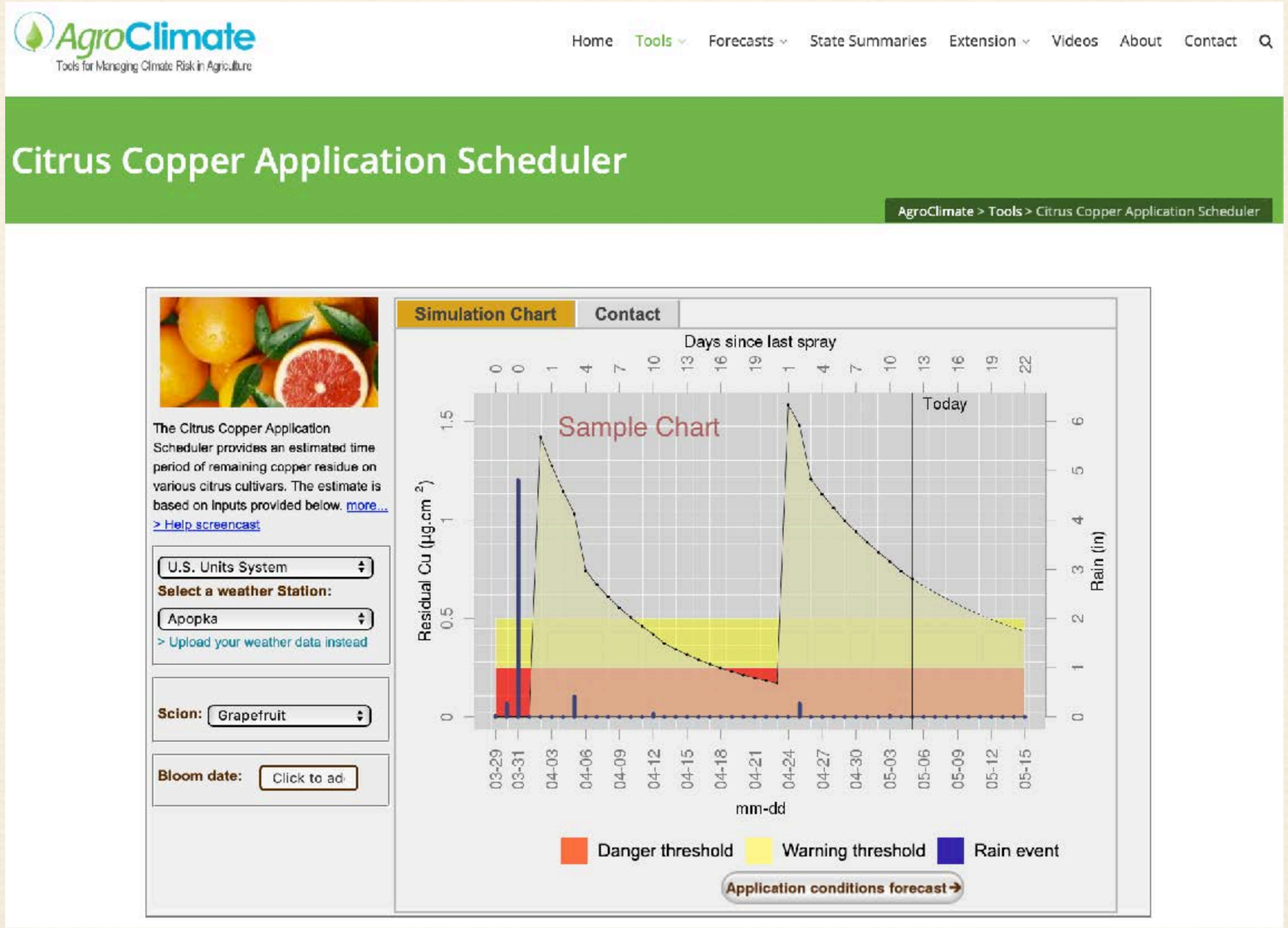
Citrus Copper Application Scheduler

http://agroclimate.org/tools/citrus-copper-application-scheduler/

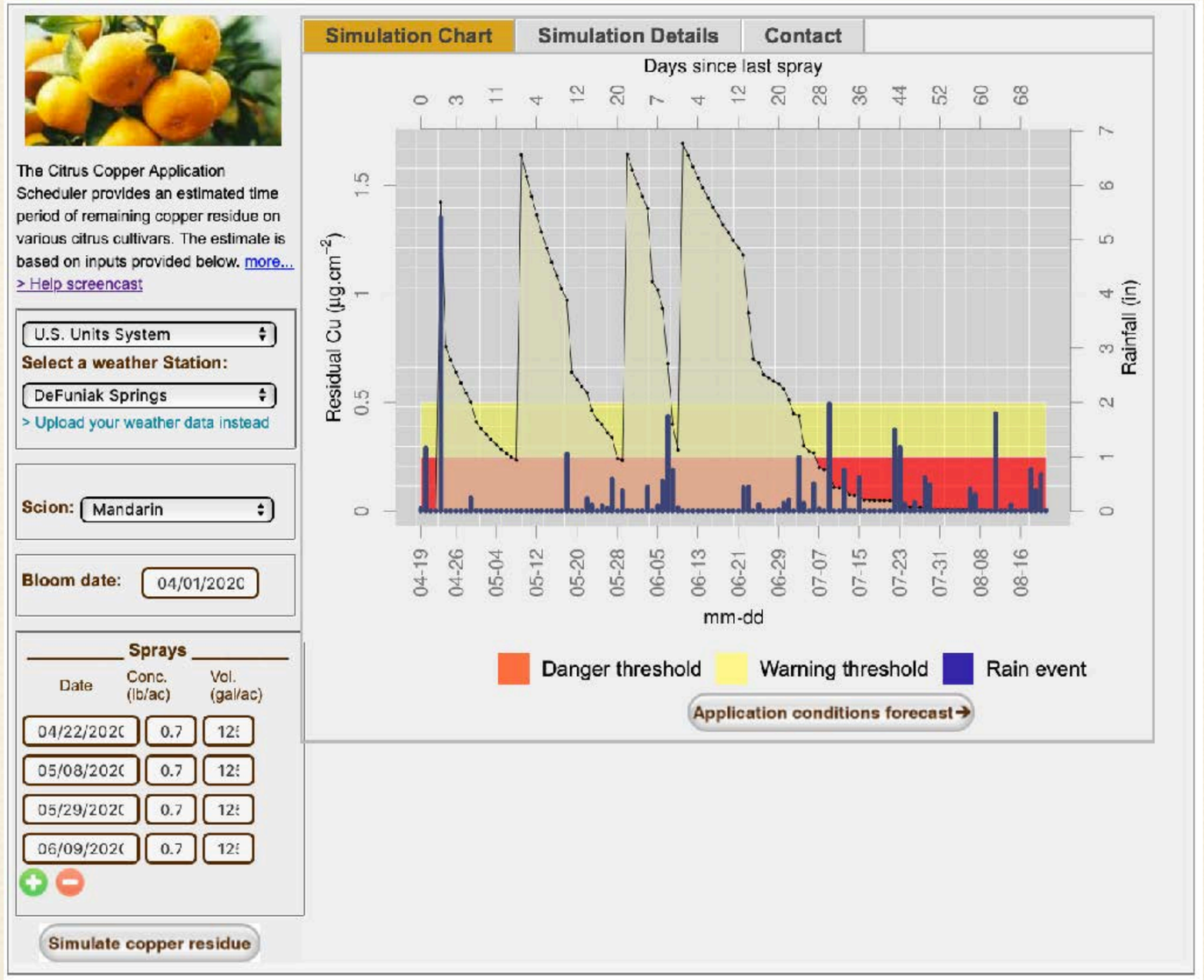
Copper Fungicide/Bactericide

- Copper is recommended for a number of fruit fungal pathogens in Florida citrus
  - Citrus scab (*Elsinoe fawcetti*)
  - Melanose (*Diaporthe citri*)
  - Greasy spot (*Mycosphaerella citri*)
  - Citrus canker (*Xanthomonas citri*)
  - Alternaria (*Alternaria alternata*)

Copper Scheduler



Copper Scheduler



Copper Scheduler

The Citrus Copper Application Scheduler provides an estimated time period of remaining copper residue on various citrus cultivars. The estimate is based on inputs provided below. more...
> Help screencast

U.S. Units System

Select a weather Station:

DeFuniak Springs

> Upload your weather data instead

Scion: Mandarin

Bloom date: 04/01/2020

Sprays

Date	Conc. (lb/ac)	Vol. (gal/ac)
04/22/2020	0.7	125
05/08/2020	0.7	125
05/29/2020	0.7	125
06/09/2020	0.7	125

Simulate copper residue

Simulation Chart | Simulation Details | Contact

date	bloom (days)	residue (ug/cm*cm)	rain (inches)	spray vol(gal/ac)	spray conc(lb/ac)
04-19	18	0	0.05	0	0
04-20	19	0	1.16	0	0
04-21	20	0	0	0	0
04-22	21	0	0	125	0.75
04-23	22	1.42	5.41	0	0
04-24	23	0.76	0	0	0
04-25	24	0.69	0	0	0
04-26	25	0.64	0	0	0
04-27	26	0.59	0	0	0
04-28	27	0.54	0	0	0
04-29	28	0.5	0.24	0	0
04-30	29	0.41	0.01	0	0
05-01	30	0.38	0	0	0
05-02	31	0.35	0	0	0
05-03	32	0.33	0	0	0
05-04	33	0.31	0	0	0

Export details to CSV