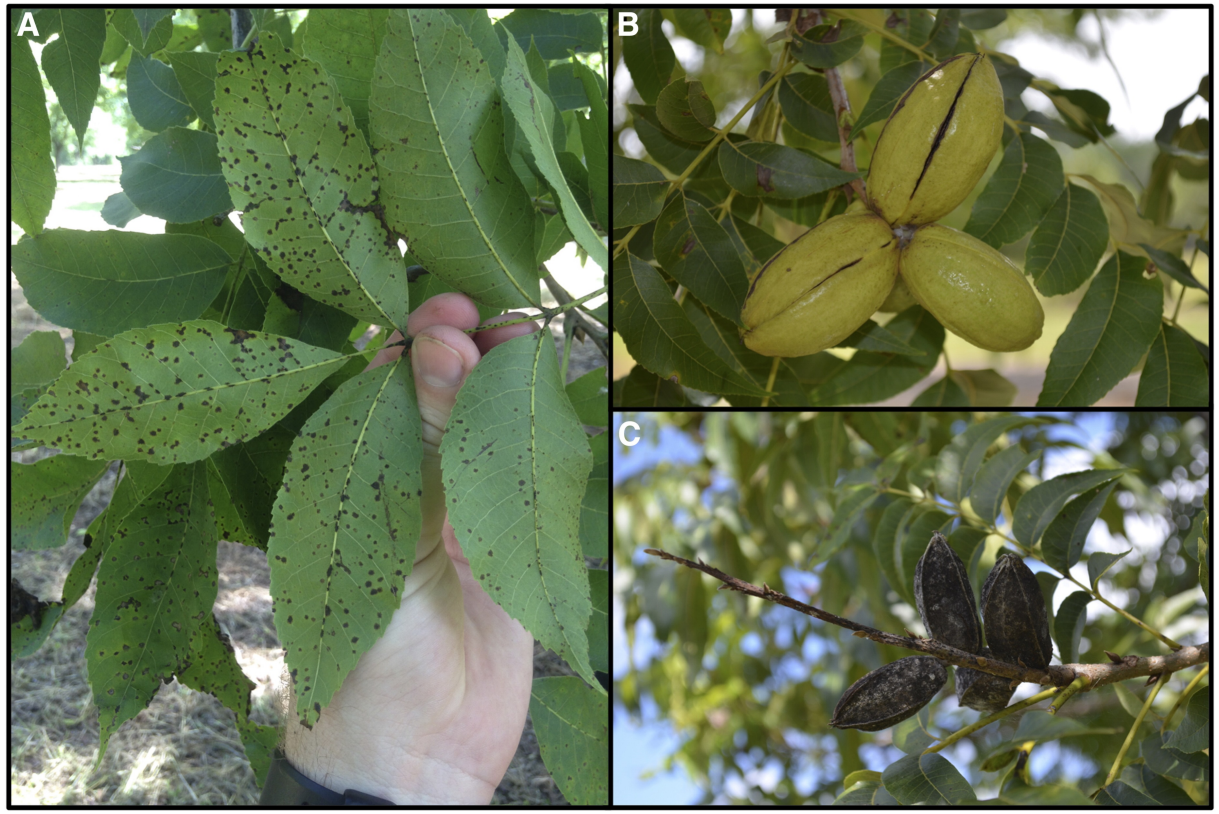
New Approaches to Screening for Scab

Dr. Angelyn Hilton
Plant Geneticist/Pathologist
USDA-ARS Pecan Breeding and Genetics



Fungicide Resistance in *Venturia effusa*, Cause of Pecan Scab: Current Status and Practical Implicatio
J. R. Standish, T. B. Brenneman, C. H. Bock, and K. L. Stevenson
Phytopathology® 2021 111:2, 244-252

Pecan Breeding and Genetics Program

- National pecan breeding program
  - Develop new and improved cultivars for the industry (north to south, east to west)
  - Identify cultivars with superior traits, including disease resistance

- Repository
  - Largest collection of pecans worldwide
  - Protects diversity
  - Allows us to characterize traits in improved cultivars and other varieties/ natives

What is scab and why do we focus on it?

- **Scab is caused by the fungus**, *Venturia effusa*
- **Can cause total yield losses** in susceptible cultivars
- Significant disease issue for central and eastern pecan farmers
- **Fungicide resistance is a major problem**

Increasing severity of disease and reduced kernel filling in pecans (Image: William Reid, Kansas)

Improved cultivars and scab susceptibility

Resistant

- Kanza
- Lakota
- Elliott
- Avalon

Moderate

- Sumner
- Oconee
- Caddo

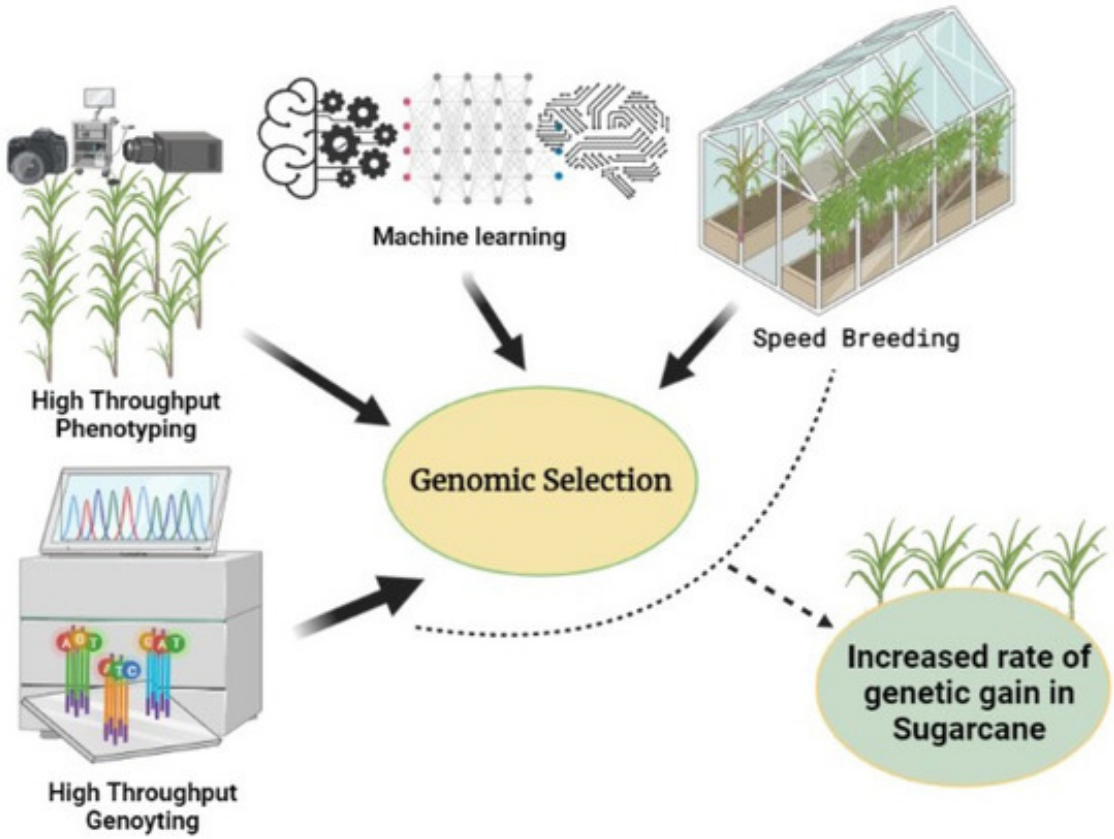
Susceptible

- Pawnee
- Sioux
- Desirable
- Wichita

Breeding for scab resistance

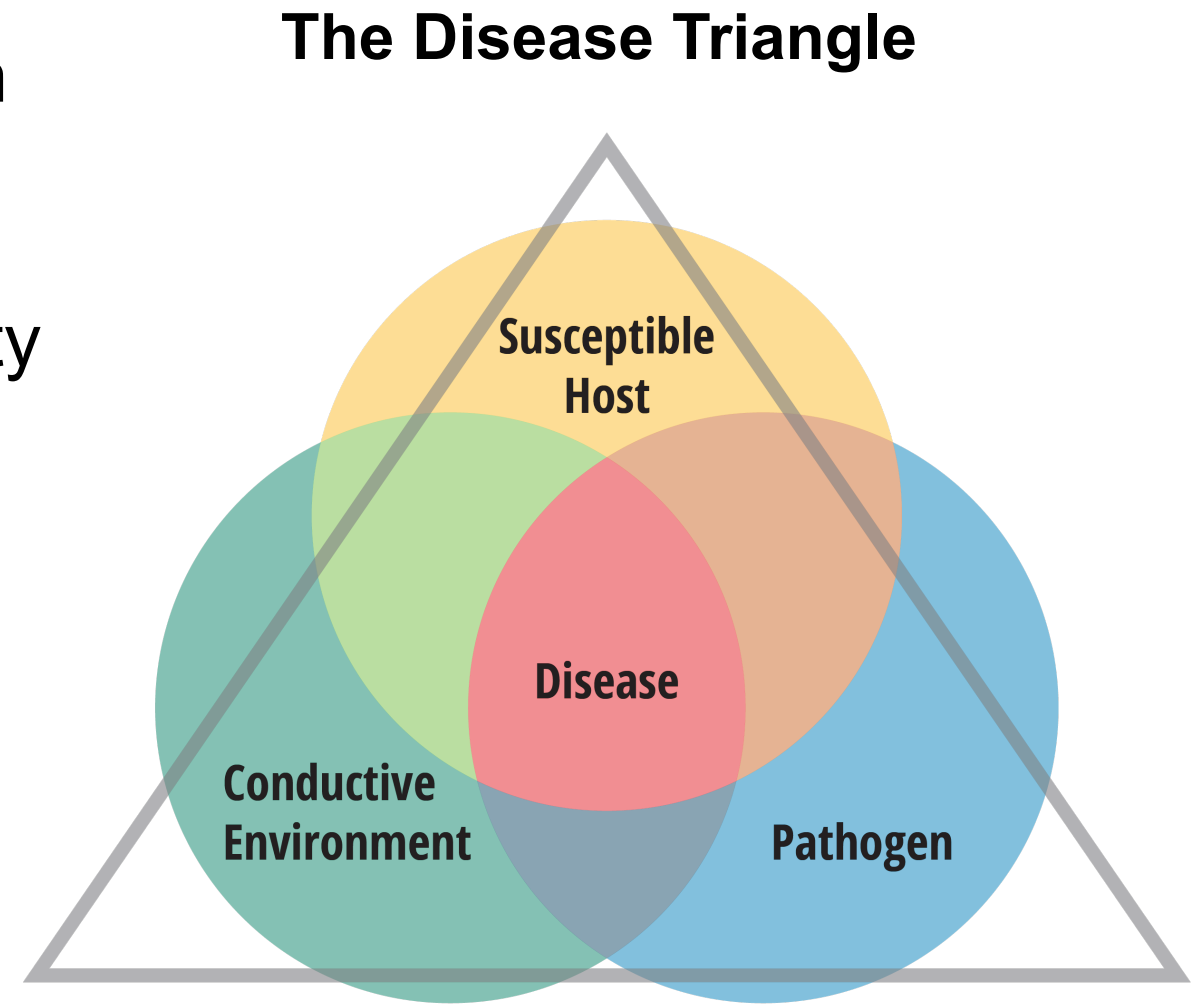
- Traditional breeding
  - Choose two parents with scab resistance
  - Identify progeny using basic screening tools

- Genomic selection
  - Focuses on the genetics that contributes to scab resistance
  - **Requires greater accuracy and precision when estimating levels of susceptibility** in parents and progeny



Disease phenotyping

- Phenotyping is the characterization of traits through screening/rating
- Allows us to determine susceptibility
- Methods depend on the type of pathogen
- Requires high disease pressure



Scab screening/rating

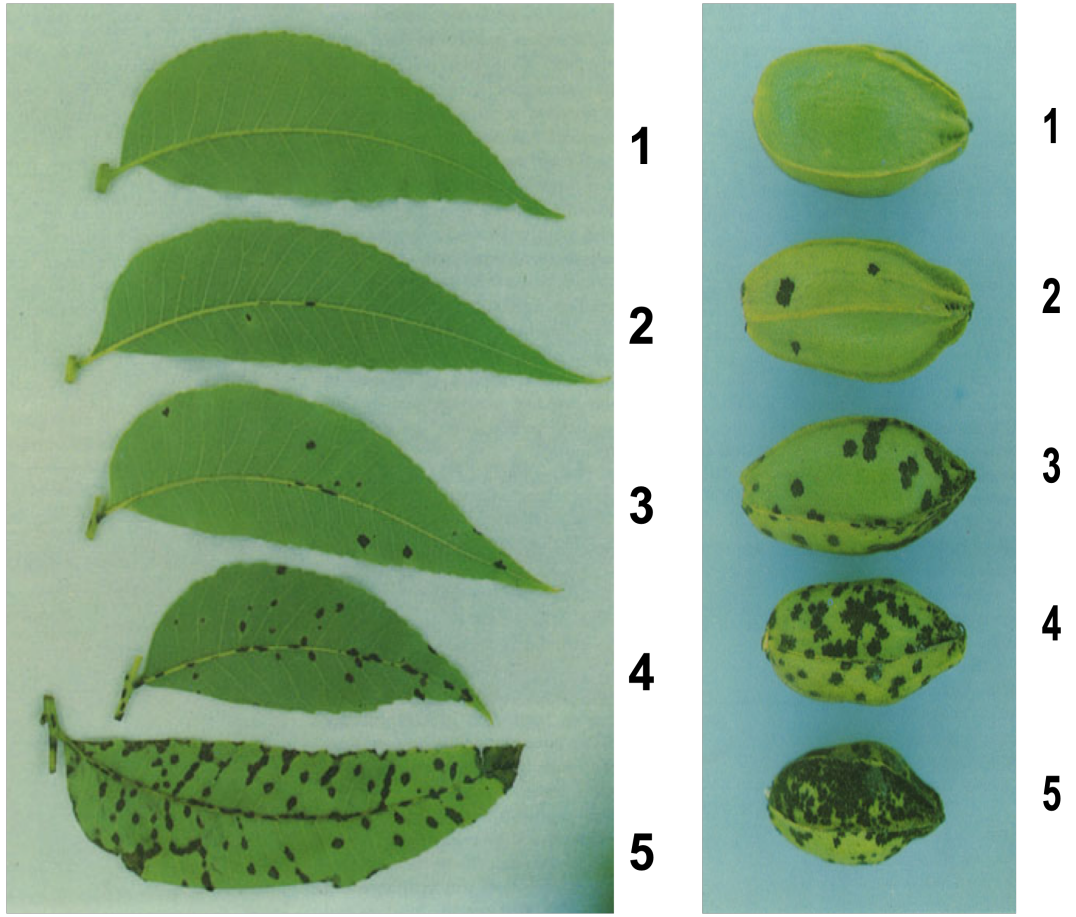
- Identify the worst affected leaf/nut
- Visually estimate the amount of disease present
- Unmanaged orchard for higher disease pressure

Types of rating scales

- Ordinal or nominal scales – separates levels of susceptibility into categories
- Ratio scales are continuous, ranging from 0-100%
  - Estimates percent disease coverage
- Standard Area Diagrams are tools to aid in percent disease coverage estimates

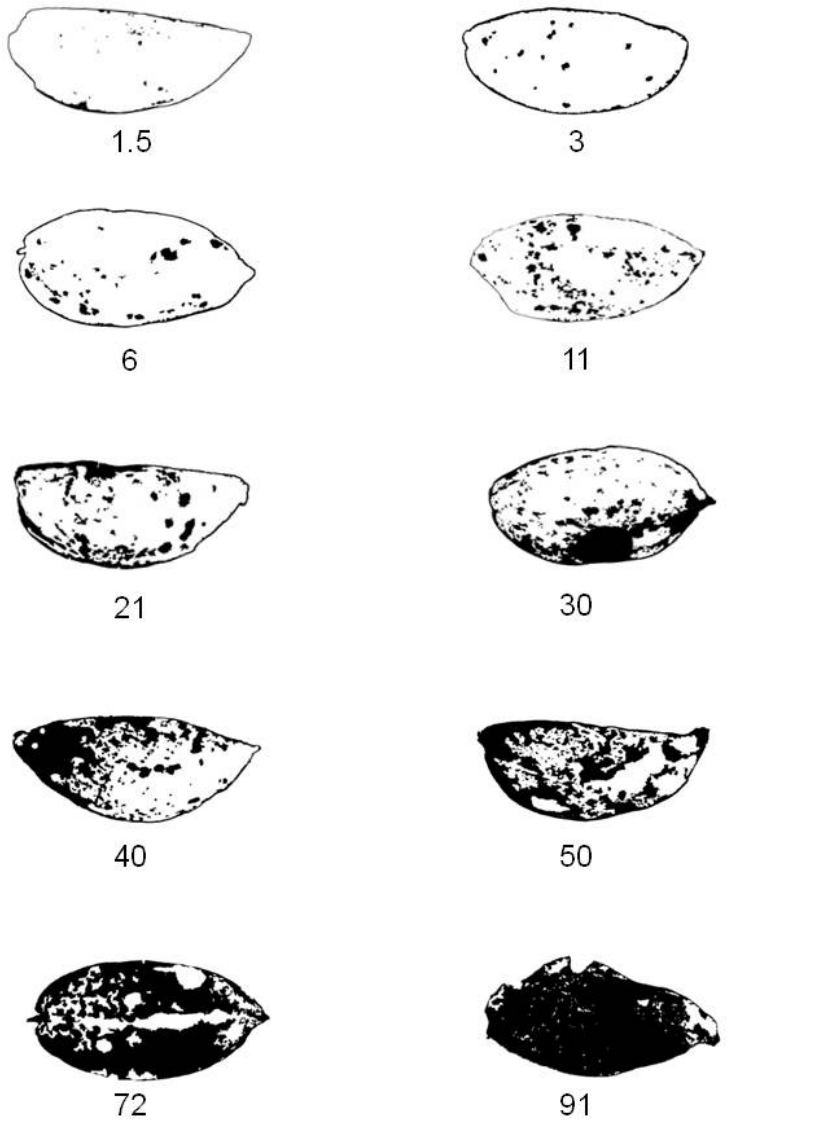
The Hunter-Roberts Scale

- Categorical (ordinal) scale
- Historically used to screen (rate) for scab
- Lacks resolution (low precision) and is often inaccurate
- Limited options for statistical analysis – cannot be used to make genomic predictions



Standard Area Diagram for Nuts

- Developed by Clive Bock and other USDA ARS scientists in Byron, Georgia
- Utilizes a continuous (ratio) scale
- Data can be analyzed over space and time
- Was never fully adopted by the breeding program



Need to improve leaf scab ratings

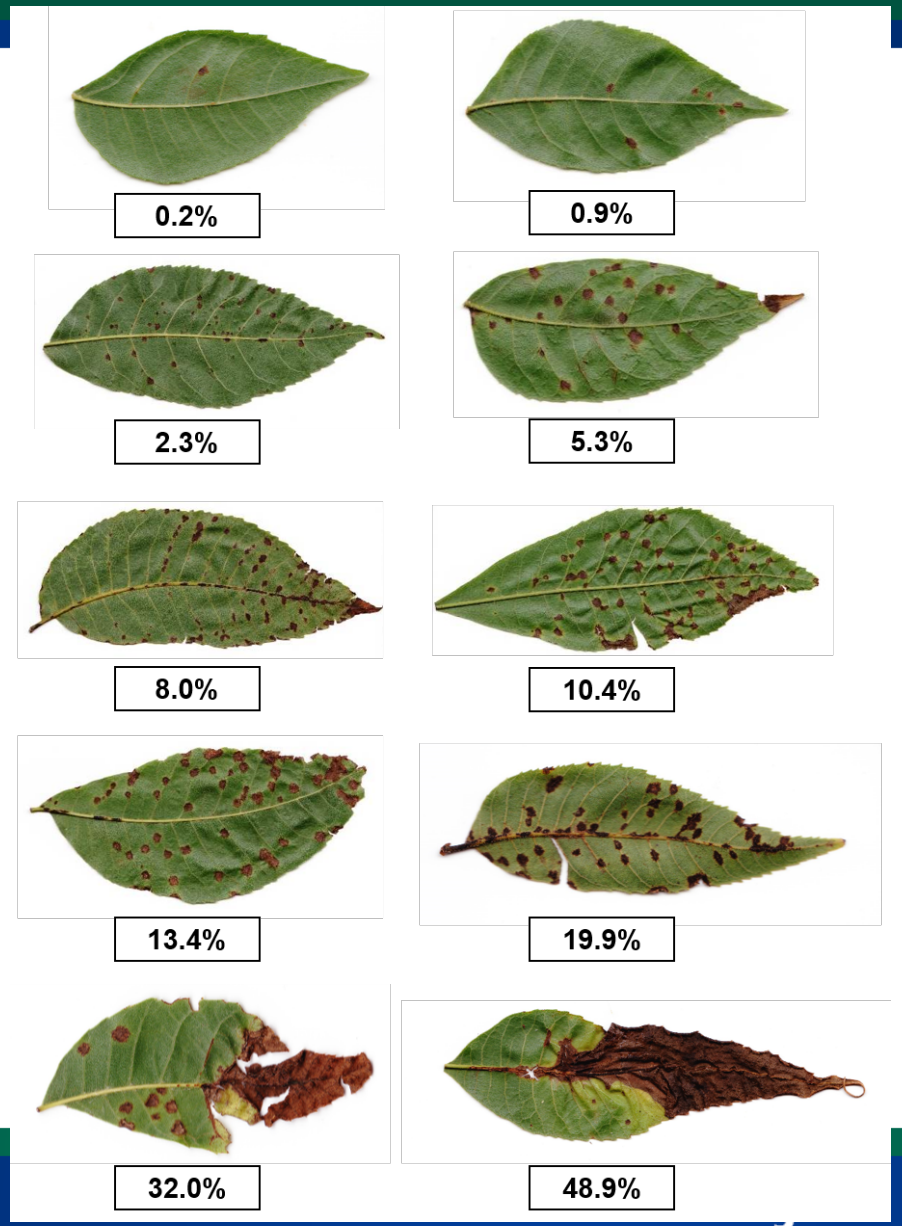
- Leaf scab ratings can be performed on juvenile trees
- Early predictor of tree susceptibility
- Ensures consistent data collection during off-years
- Presence of leaf scab can lead to a higher incidence of nut scab

Creating new standards

- Standardization guarantees uniform methods across all pecan research
- New methods require validation
- Verify that ratings are accurate and reliable
- Must be user-friendly and trainable

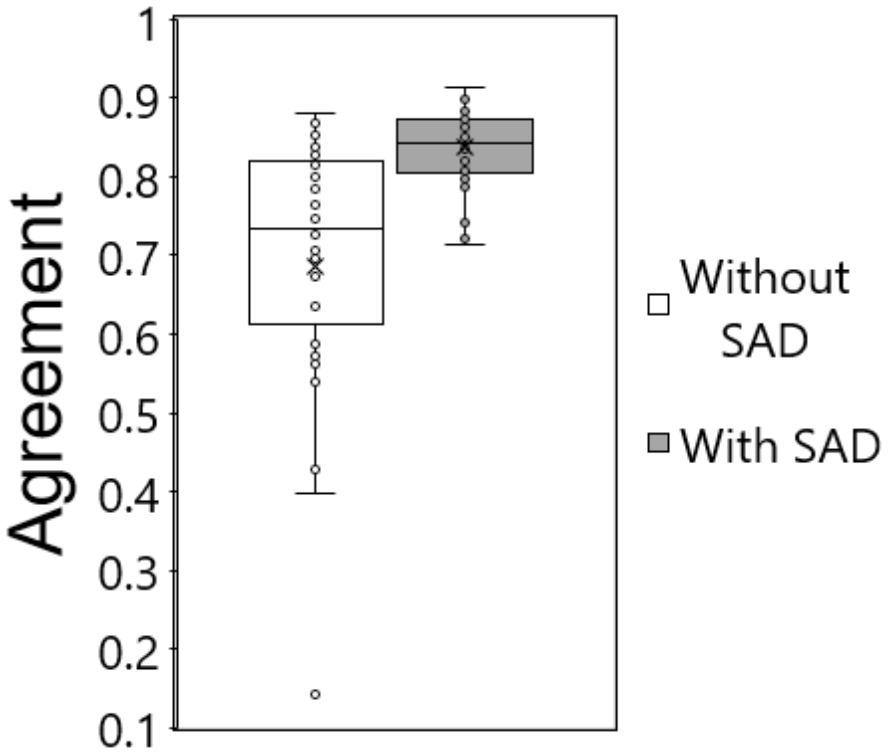
A Standard Area Diagram for pecan leaf scab

- Sampled 300 leaves with scab symptoms
- Used a software called ImageJ to **determine the true percent disease coverage**
- Developed a new Standard Area Diagram with color images to better represent the disease
- 37 raters from Georgia, Texas, and New Mexico rated 80 leaves with and without the standard area diagram



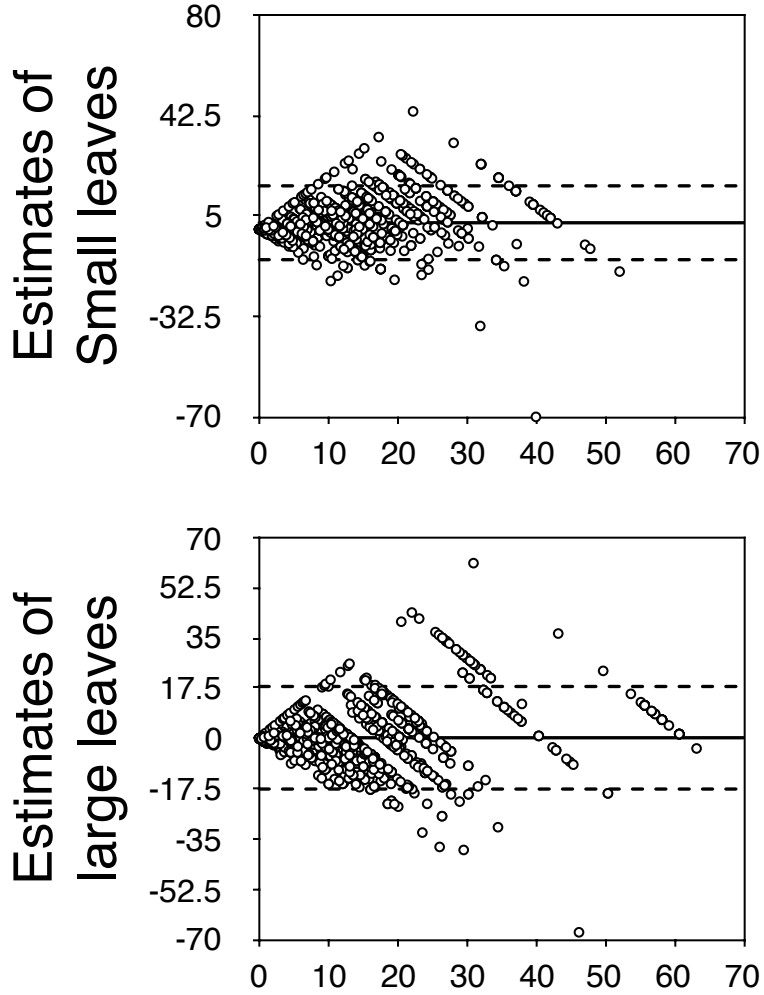
Validation of the Standard Area Diagram

- Agreement is a combination of accuracy and precision, measures how close ratings are to the true values
  - 1 = 100% agreement
- **15% improvement in the agreement of visual ratings with the true percent disease coverage**
- Ratings were **significantly more reliable** when the Standard Area Diagram was used



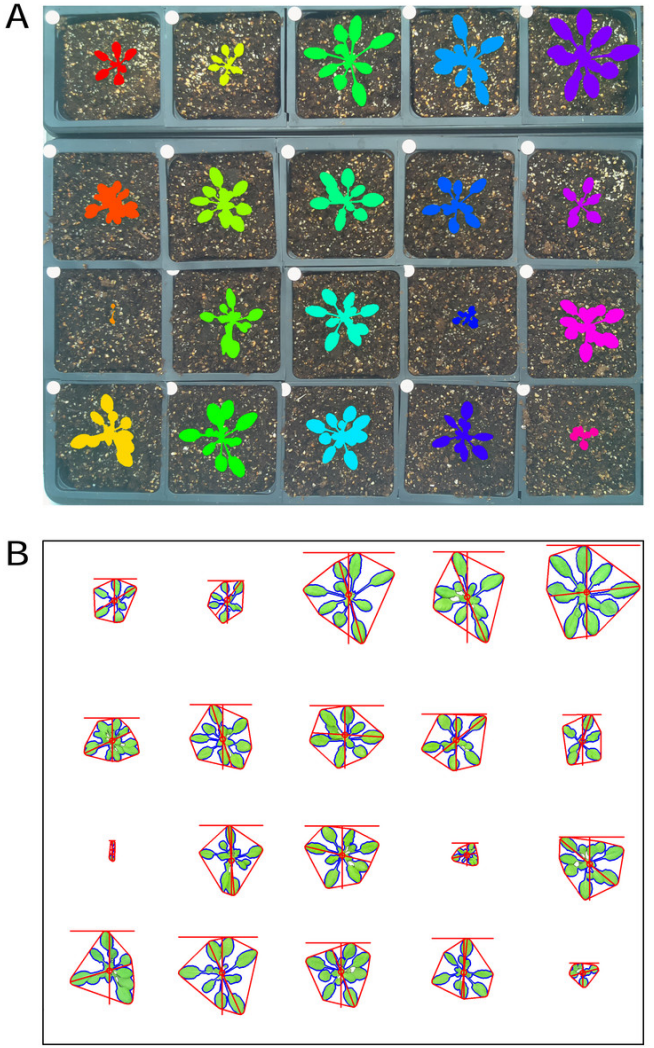
Problems with visual observations

- Bias between raters
- Environment can impact rater fatigue
- Influence of leaf size, lesion number, etc. can lead to overestimation and underestimation
- Dependent on how our brain processes information

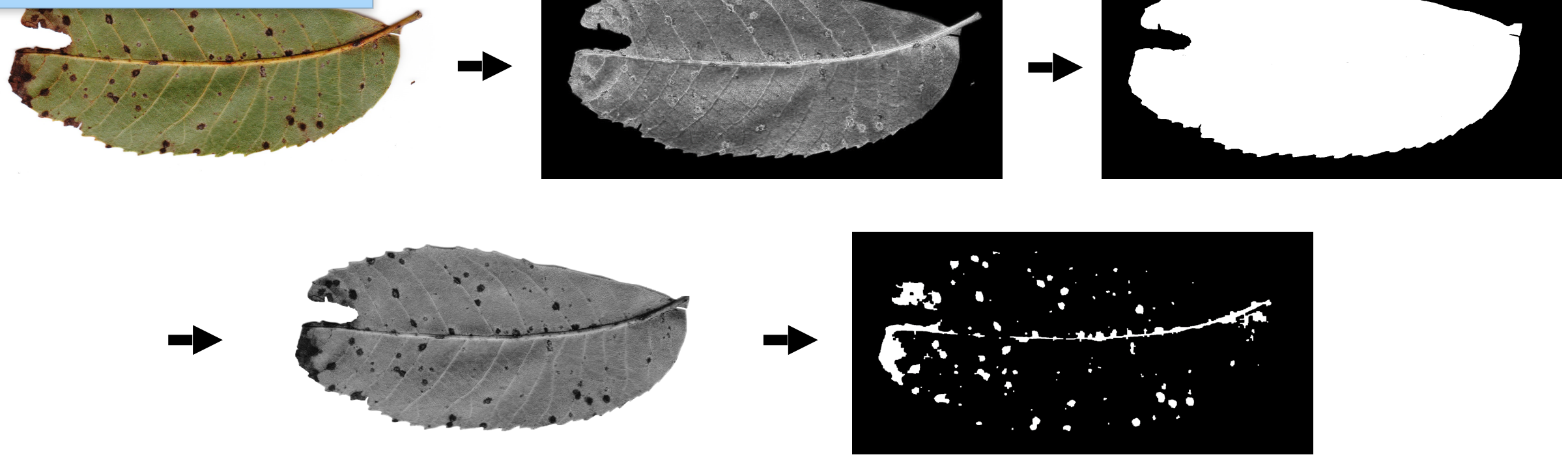


High-throughput image analysis

- Building software from the ground up
- Mitigates the human-problem
- Captures data that can't be done with the naked eye
- Allows us to process more samples – get more data!
- Cannot completely replace visual observations



Pipeline Development



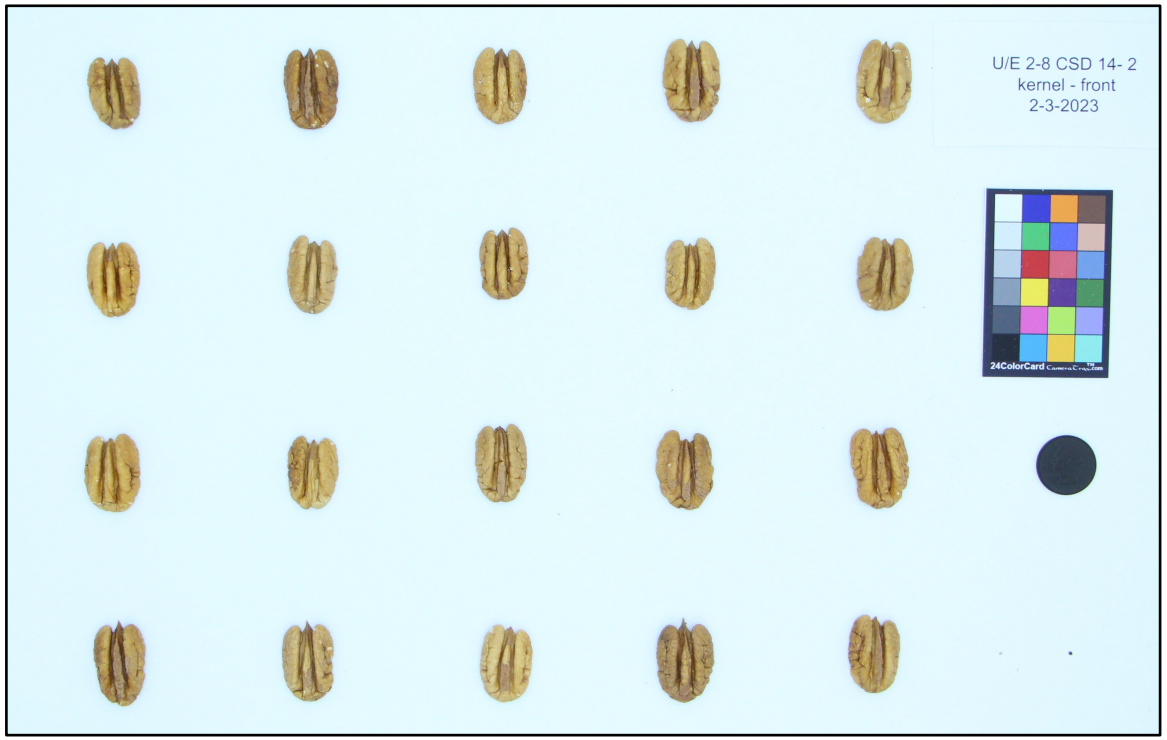
= 12.3% disease coverage

What's next?

- Use machine learning to more accurately detect and quantify scab
- Apply similar techniques to other disease/pest issues
  - Leaf scorch, die-back, downy spot, anthracnose, black pecan aphid
- Develop AI tools to diagnose diseases
  - Make available to producers

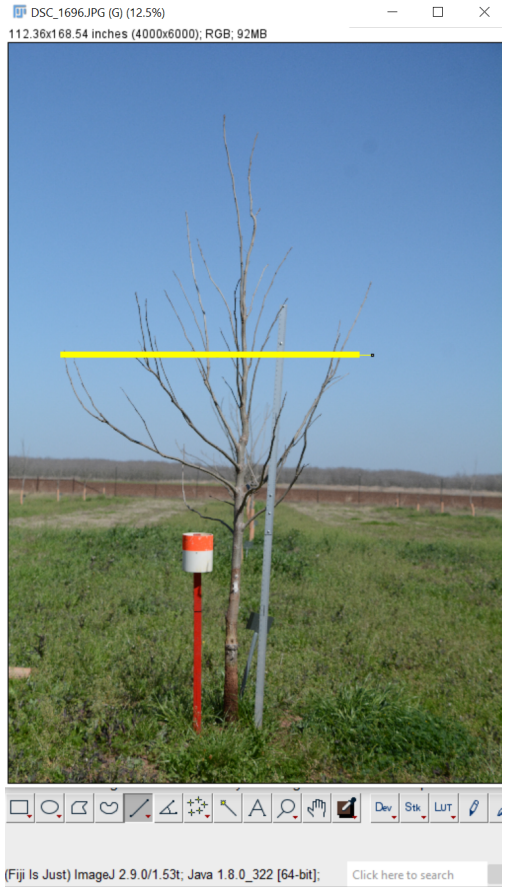
Image analysis of other traits

- Leaf area
  - Important for determining photosynthetic capacity
- Nut shape and size; shell thickness
  - Specific to cultivar
- Kernel size, fill, color, texture, groove widths
  - Measures of quality
- Tree form
  - Branch angles, growth rate



Tree Form Example

Step 1: Set scale

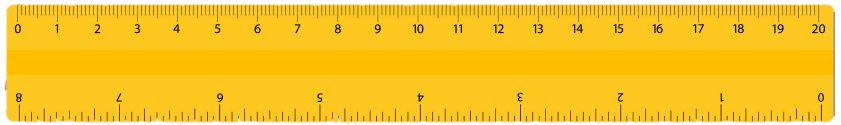


Step 2: Canopy width

Step 3: Plant height

Step 4: Trunk diameter (2ft above ground)

Tree Height Validation



Physical Height
$R^2 = 0.9436$

$R^2 = 0.8976$
$R^2 = 0.9181$

$R^2 = 0.9287$
$R^2 = 0.9457$

Tree Height

ImageJ
$R^2 = 0.9954$

$R^2 = 0.9099$
$R^2 = 0.9288$

Laser Hypsometer
$R^2 = 0.941$

Trunk Diameter Validation

Calipers

$R^2 = 0.8255$

$R^2 = 0.9089$

Trunk Diameter

ImageJ

$R^2 = 0.8907$

Diameter Tape

USDA Agricultural Research Service
U.S. DEPARTMENT OF AGRICULTURE

Acknowledgements

National Pecan Federation

Pecan Breeding and Management of the National Collection of Carya Genetic Resources
Project # 3091-21000-046-000-D

Trees For The Future
SCRI Grant #2022-51181-38332

Coordinated Development of Genetic Tools for Pecan
SCRI Grant #2016-51181-25408


Pecan Breeding and Genetics
Agricultural Research Service
U.S. Department of Agriculture
10200 FM 50
Somerville, Texas 77879

Questions?