

# Phenotyping, Physiology, and Crop Production

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# Presentation Outline

- **Highlight of current research projects**
  - SoyFACE
  - University of Illinois Energy Farm
- **Key in-field measurements of interest**
  - Vegetation
  - Microenvironment
- **Genotype to phenotype challenge**

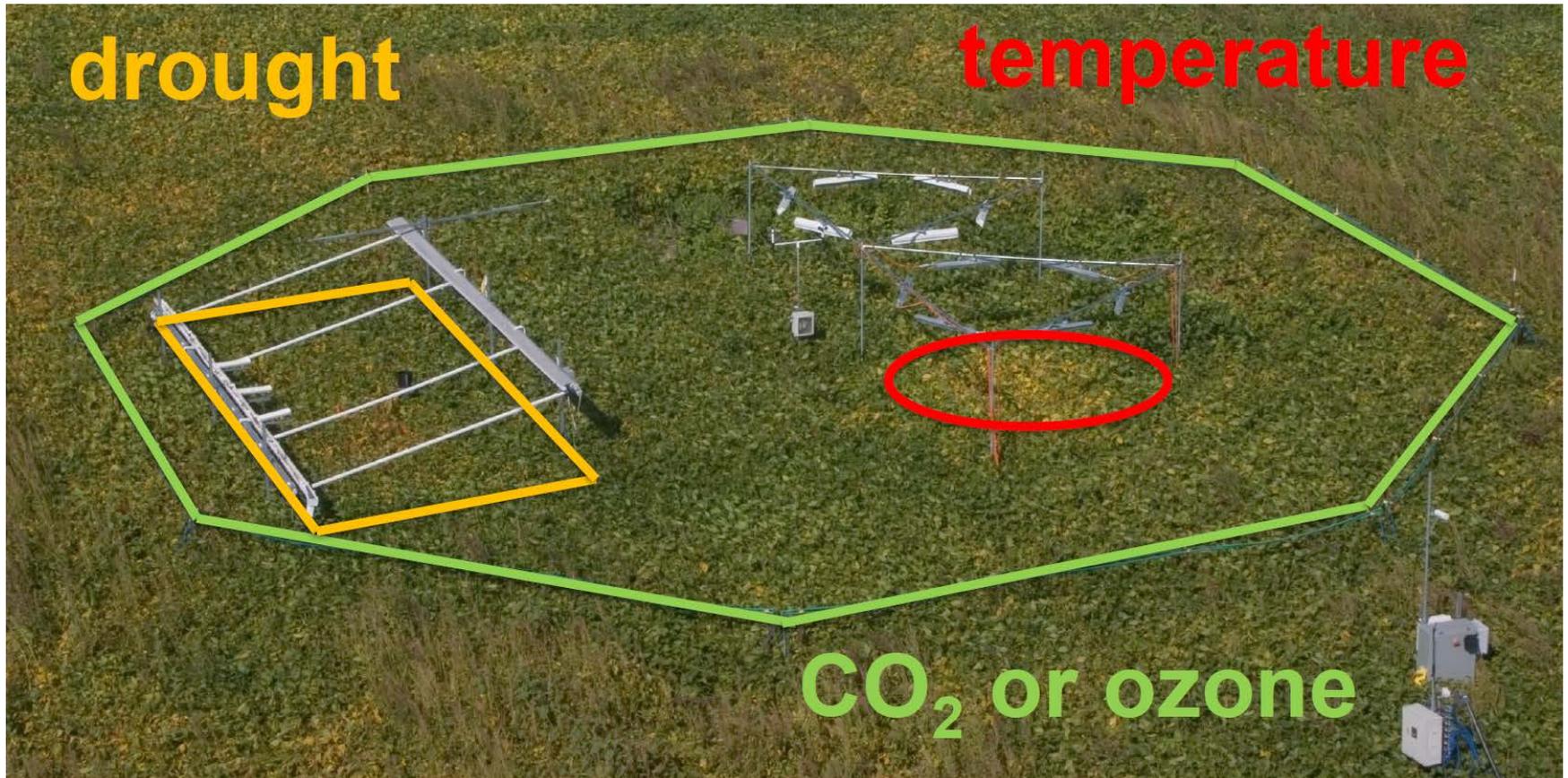
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# SoyFACE Research Facility: Investigating crop responses to global changes



# SoyFACE Research Facility



# T-FACE: Understanding crop responses to rising CO<sub>2</sub> and temperature



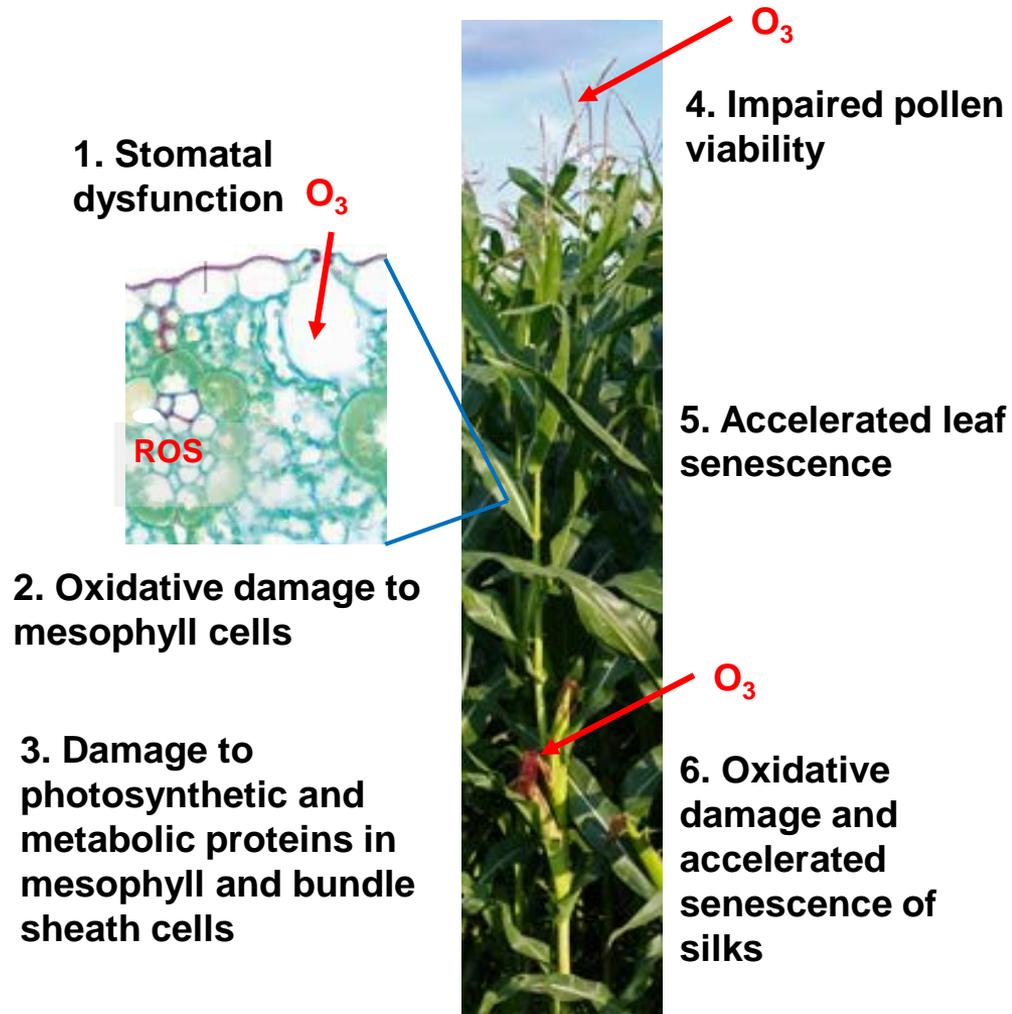
Bernacchi et al.



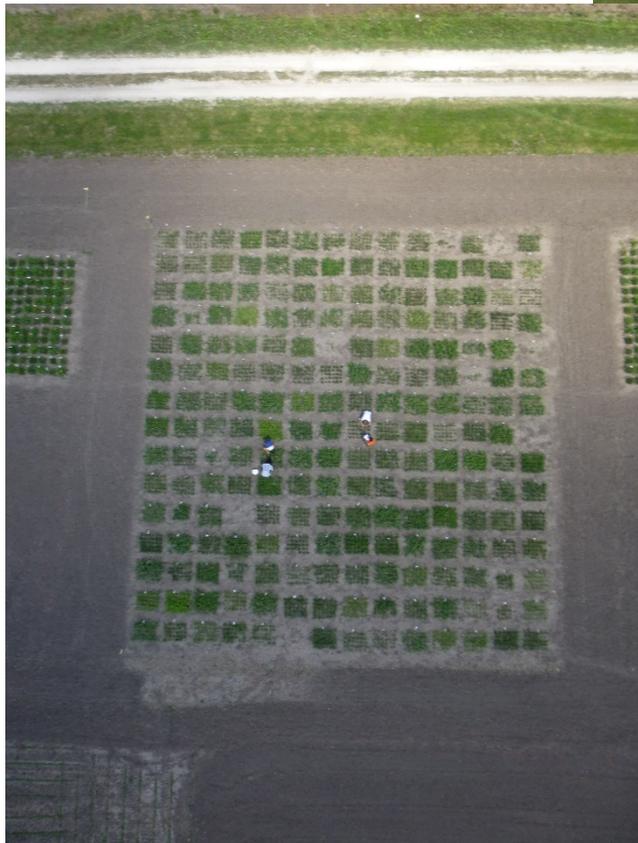
# Genetic and Genomic Approaches to Understand and Improve Maize Responses to Ozone

- Establish high-throughput phenotyping assays to measure  $O_3$  impacts on maize growth, senescence, leaf metabolism and reproductive processes, and identify traits that correlate with yield loss
- Characterize genetic variation in these responses to elevated  $[O_3]$  among 200 inbred and 100 hybrid maize lines in the field

Lisa Ainsworth et al.



# SoyFACE: Setaria



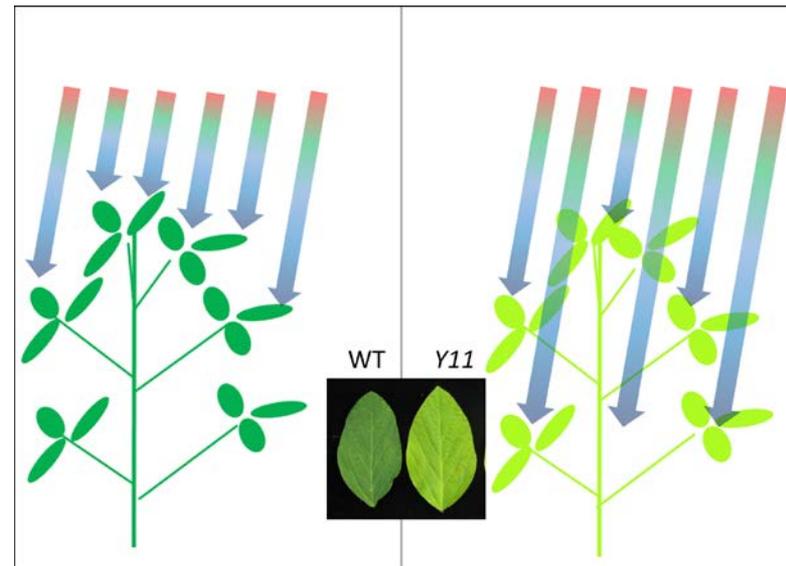
Characterize genetic variation responses to drought and planting density among 200 inbred setaria lines in the field

Andrew Leakey et al.

# SoyFACE: Light Green



Do soybean leaves have too much chlorophyll?

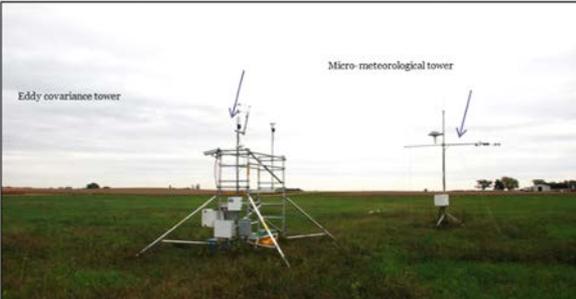


Don Ort et al.

# University of Illinois Energy Farm

## Eddy covariance

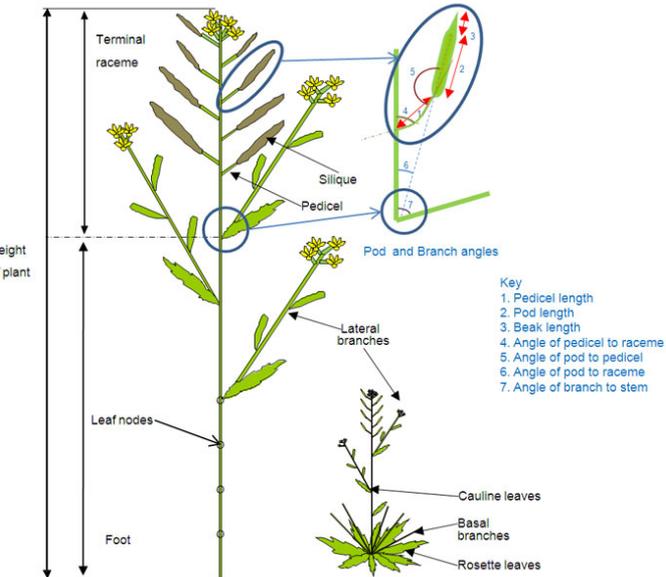
Measures the surface atmosphere gas and energy fluxes from the covariance between the wind speed and gas concentration



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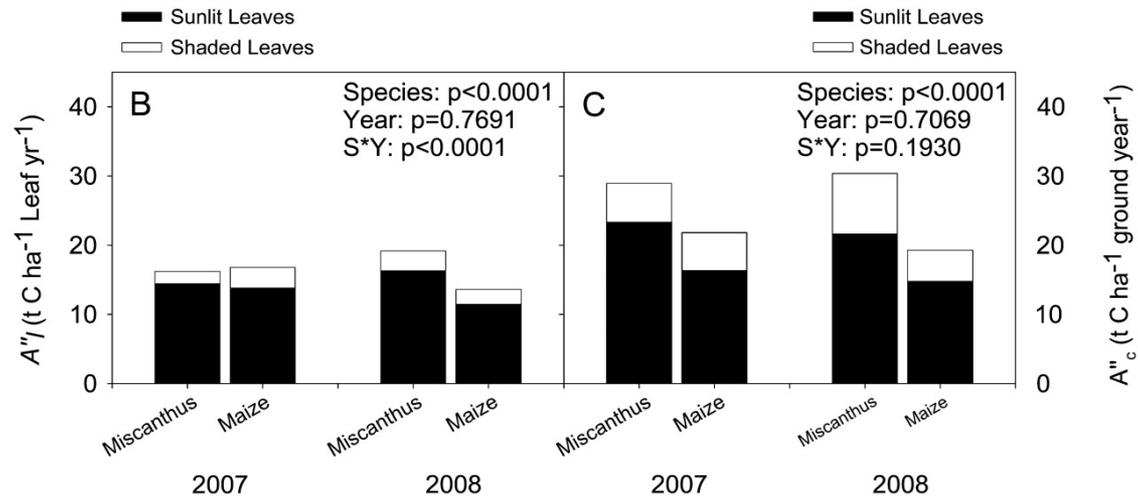
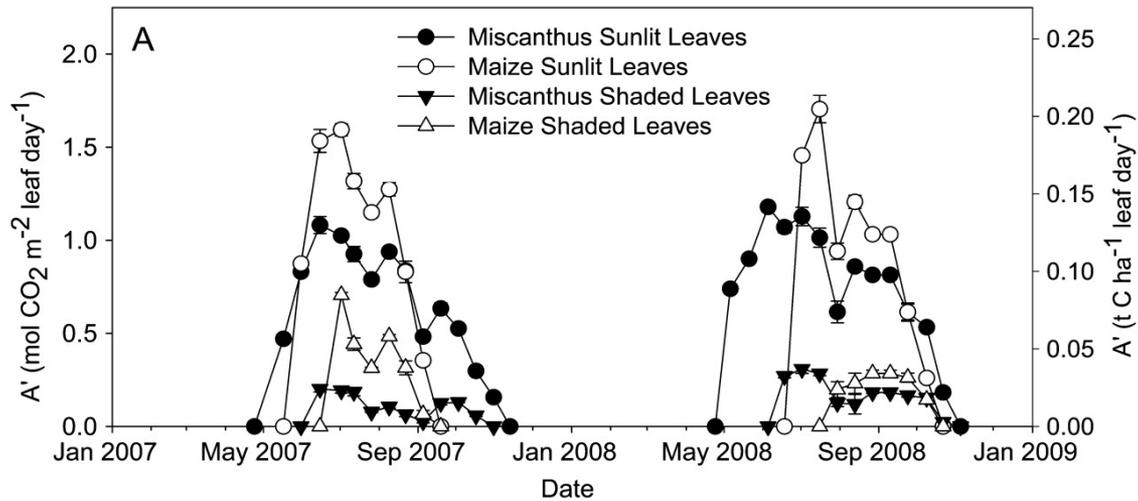
# Phenotypes of Interest



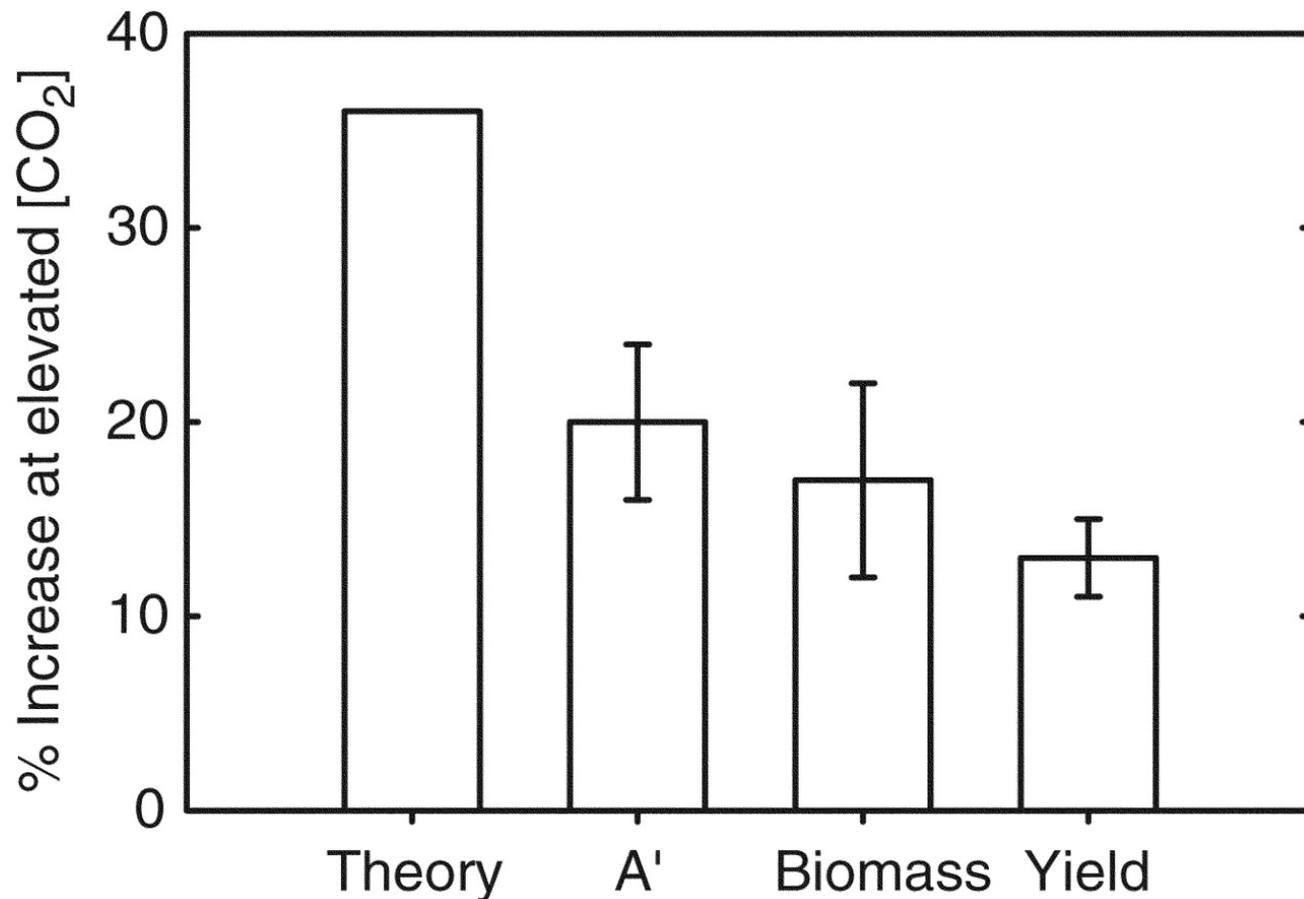
# Biomass Harvest



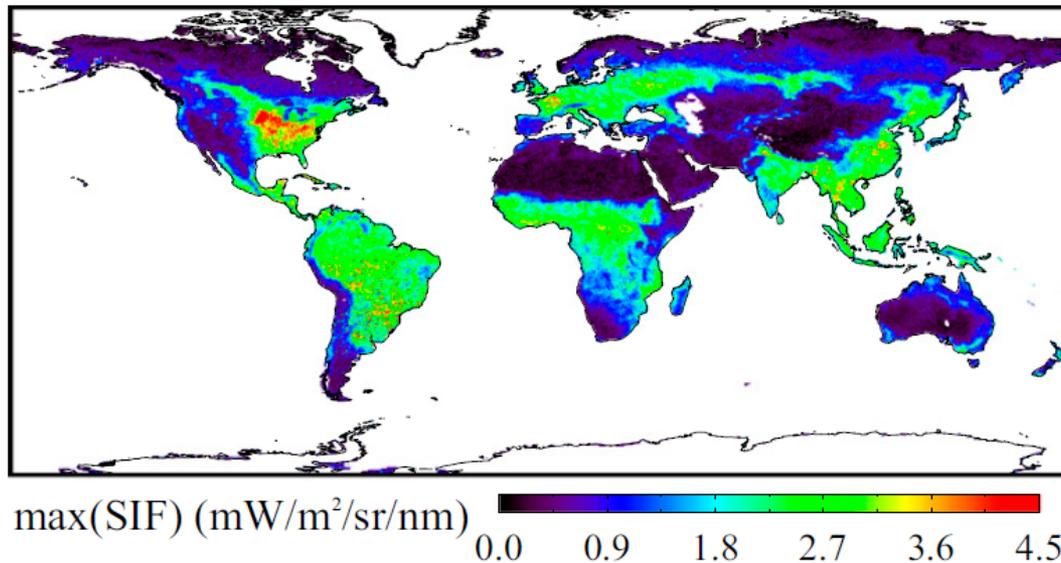
# Photosynthetic Measurements



# Scalability among biomass pools

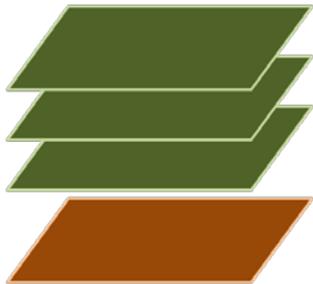
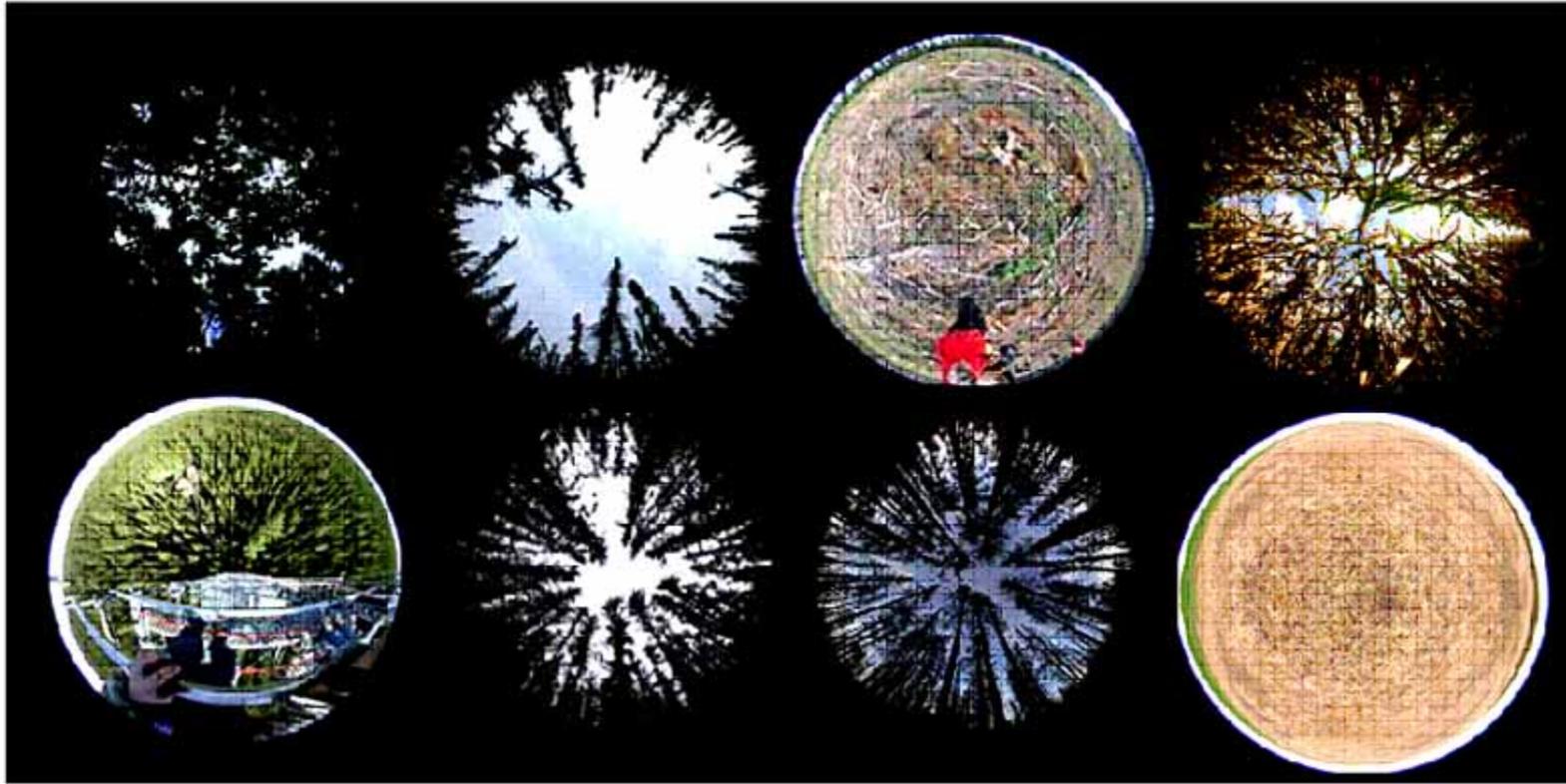


# Remote Sensing



**Fig. 1.** Global map of maximum monthly sun-induced chlorophyll fluorescence (SIF) per  $0.5^\circ$  grid box for 2009. SIF retrievals are performed in a spectral window centered at 740 nm (see *Materials and Methods* and *SI Appendix, SIF Retrievals*). This map illustrates the outstanding SIF signal detected at the US CB, which shows the highest SIF return of all terrestrial ecosystems. The maximum SIF over the largest part of the US CB region is detected in July.

# Leaf Area Index



LAI = 3



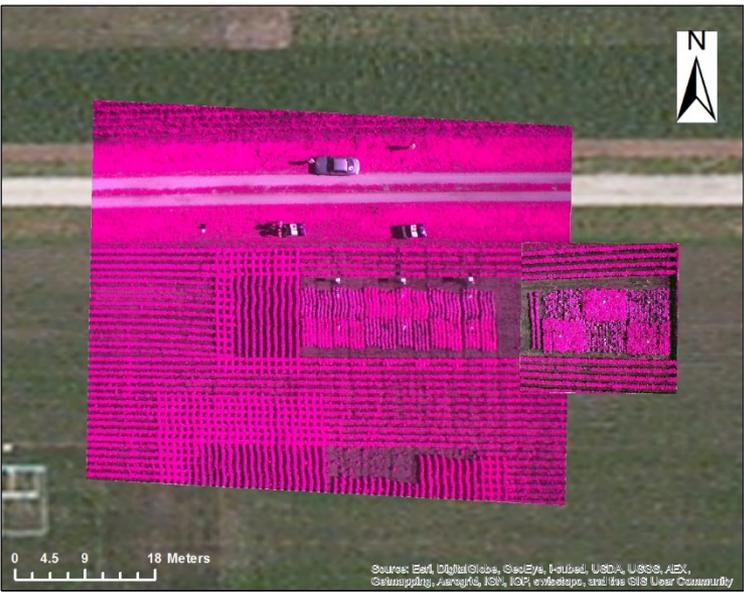
LAI = 1

# Remote Sensing

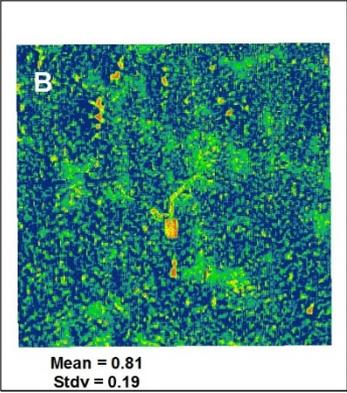
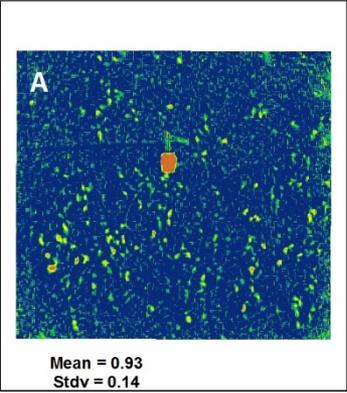
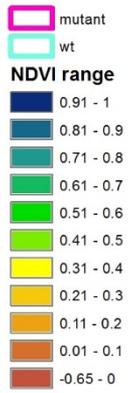
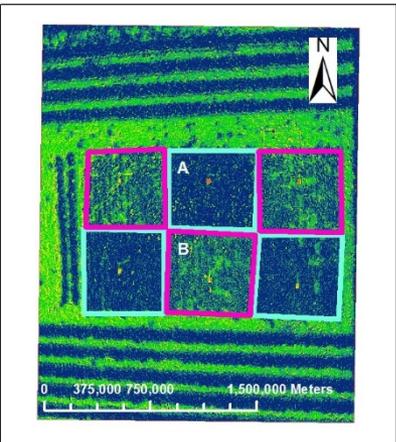
## Green light experiment at SoyFACE, Champaign, IL



Aerial photo source: Bernacchi's Laboratory  
Map: World Imagery, Basemap, ArcGIS



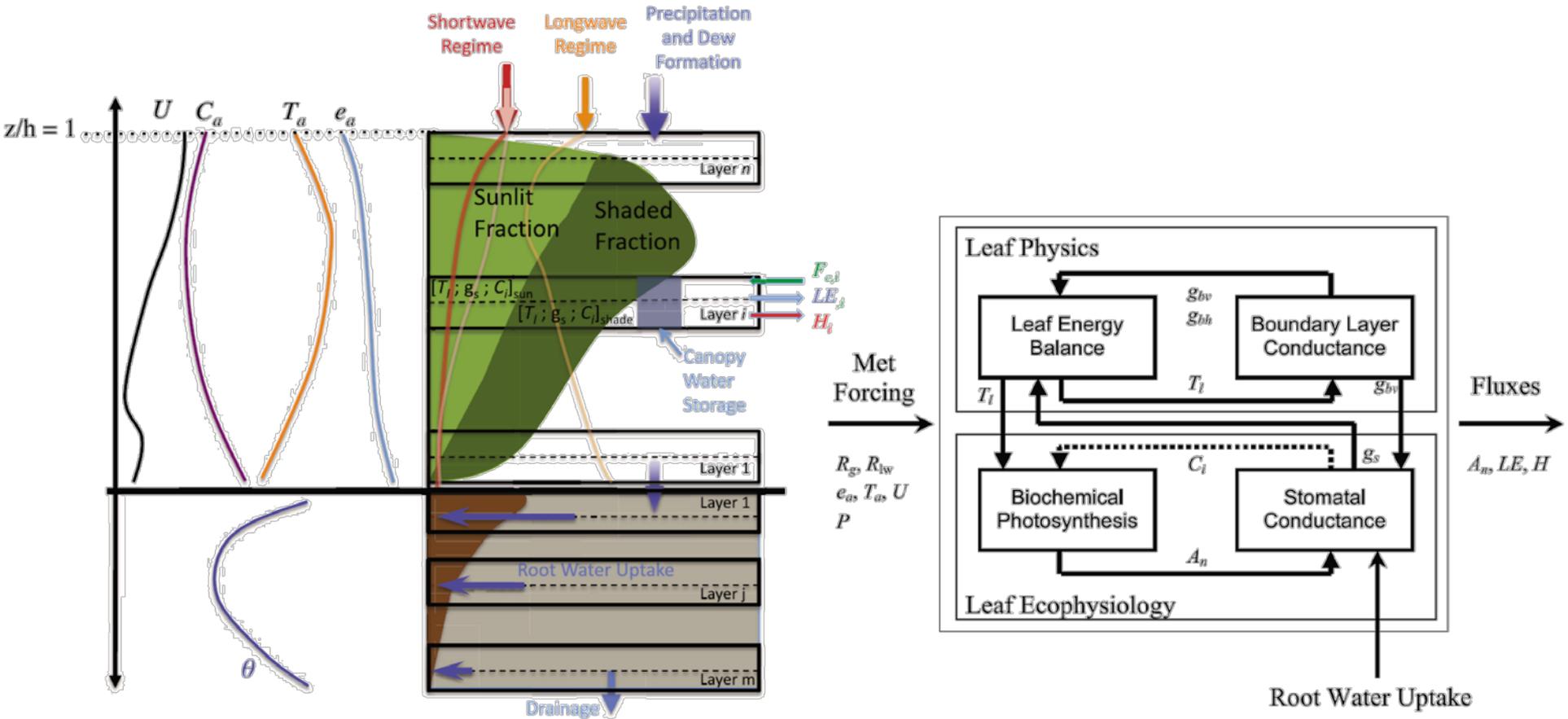
## NDVI for soybean at the green light experiment, Champaign, IL



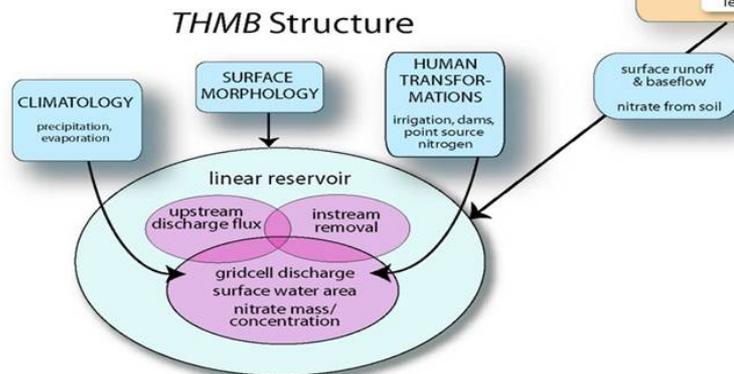
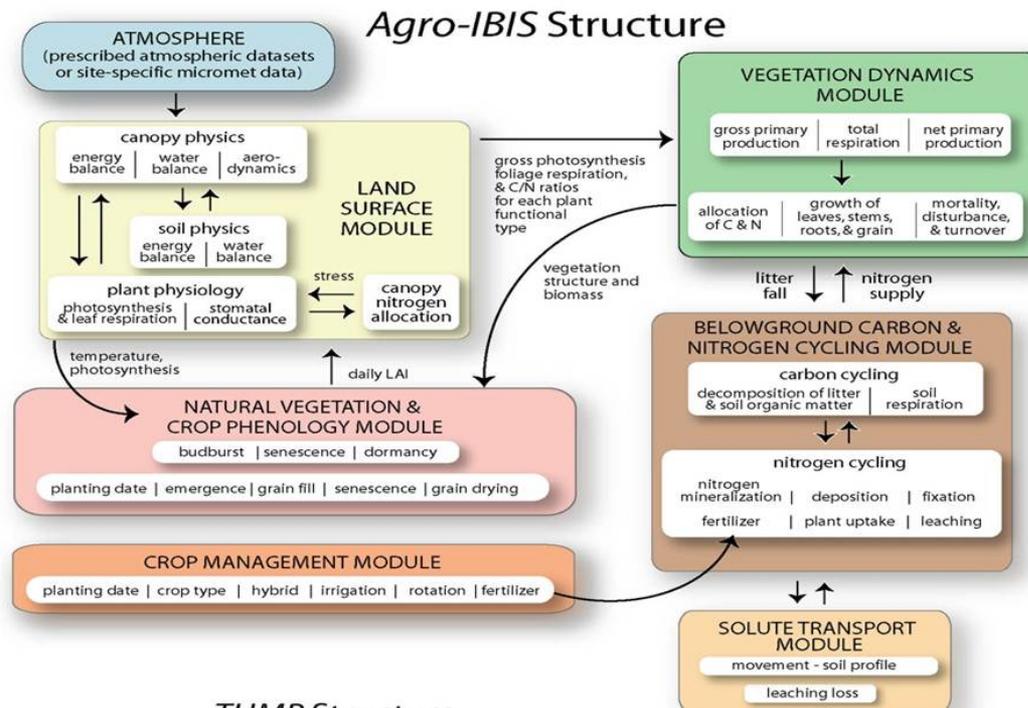
# There is more than just biomass...

- Height
- Leaf Number
- Anthesis Date
- Silking Date
- Anthesis to Silking Interval
- Tassel sterility
- Leaf reflectance
- Leaf senescence
- Leaf antioxidant capacity
- Silk antioxidant capacity
- Leaf isotope ratios
- SLA
- Leaf & ear diseases
- Yield
- $V_{c,max}$
- $J_{max}$
- Respiration rates
- Stomatal conductance
- Temperature profiles
- Light profiles
- Radiation profiles
- Temperature profiles
- CO<sub>2</sub> concentration profiles
- Leaf orientation
- Chlorophyll concentration
- Transpiration rates
- BVOC emissions
- Herbivory
- Etc...

# Modeling: Plant to Canopy



# Modeling: Canopy to Ecosystem

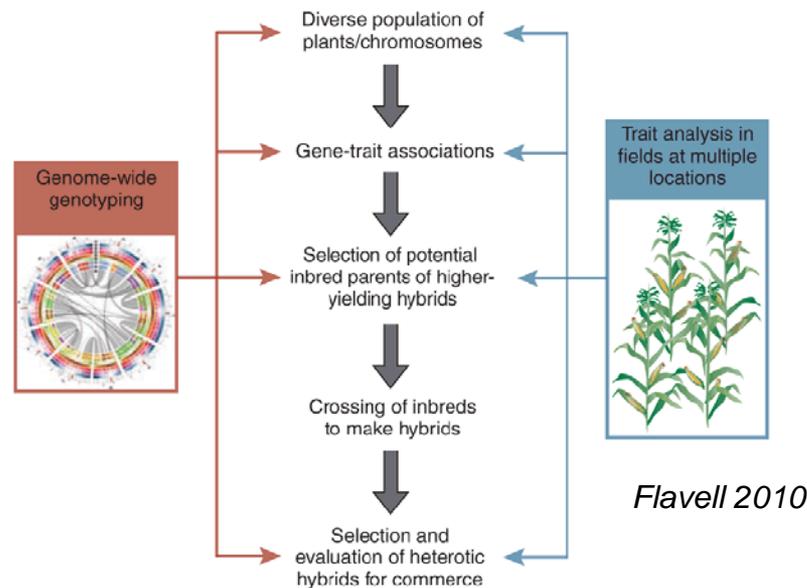


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# Crop Adaptation & High-Throughput Field Phenotyping

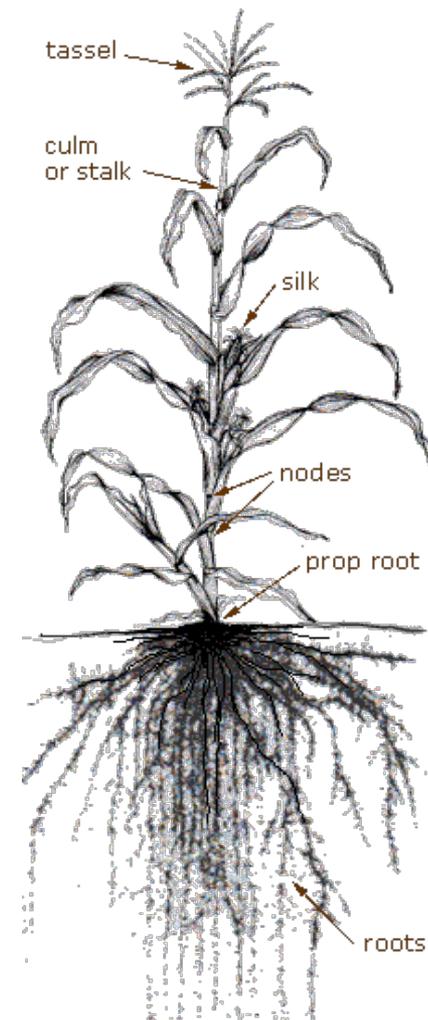
- Solving the genotype-to-phenotype challenge is necessary to develop crops with greater resource use efficiency and stress tolerance.



- With recent advances in sampling (e.g. corn chipper) and sequencing of genotypic data, phenotyping is now the bottleneck.

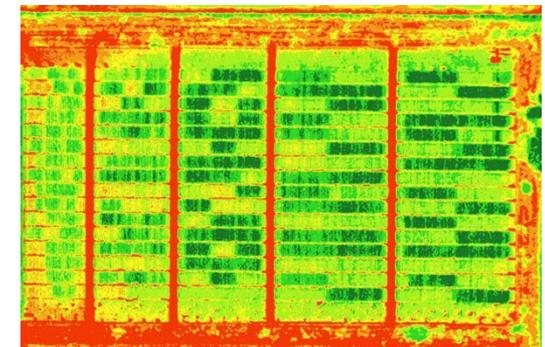
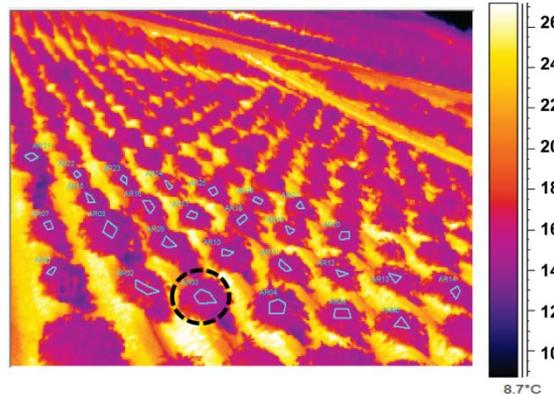
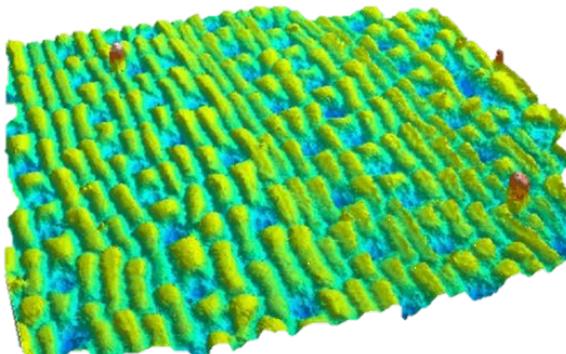
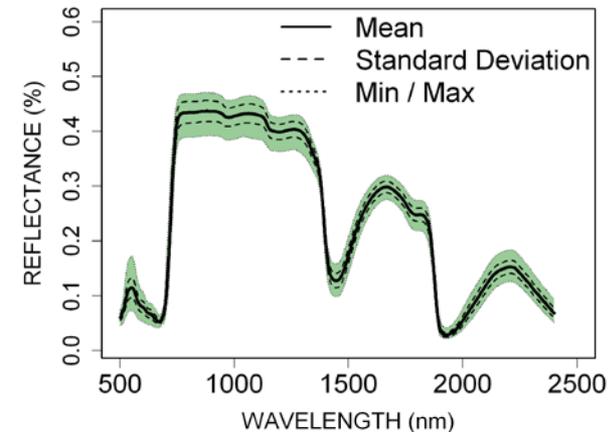
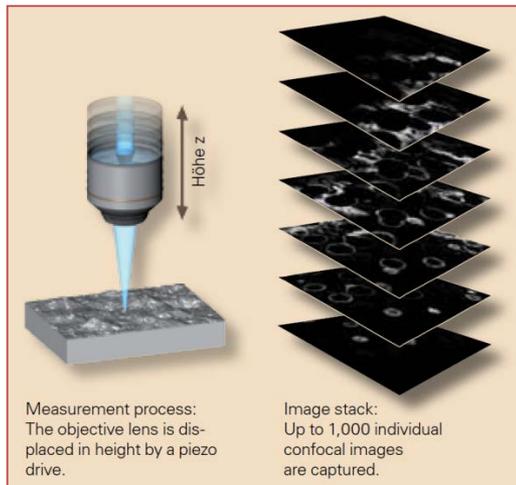
# Challenges of scale

- Stress tolerance, resource use efficiency and productivity are complex phenotypes to assess and engineer.
- They involve crop developmental stages
- They depend on multiple component traits in different tissues
- They interact with variation in the crop growing environment
- *Therefore*, high throughput phenotyping is needed across significant scales of space, time and biological organization



# Phenotypic data acquisition

- Imaging and hyperspectral technologies are allowing rapid phenotyping across time and space, with real-world relevance to traits of interest.



# Summary

- Significant challenges exist toward understanding crop responses to their environment
- Critical, but routine, measurements are substantial time sinks, are prone to measurement error
- High throughput phenotyping is an active area of study, with rich potential for interdisciplinary research across the biological, computing and engineering sciences.
- Research should focus on each of the major phases of phenotyping:
  - Data acquisition
  - Data analysis
  - Data interpretation