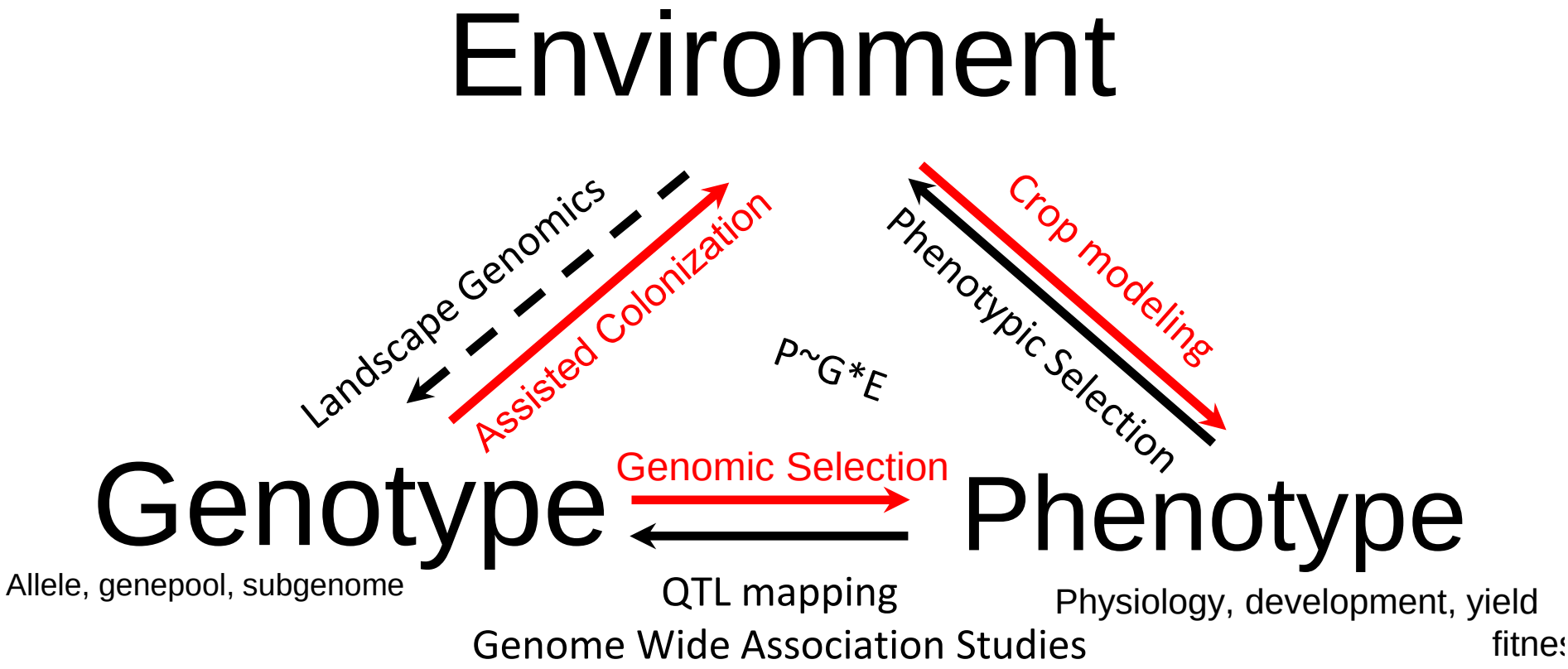
omic Selection for Climate Adaptation in

The Capsule

AusPheno/Controlled Environment 2016

Justin Borevitz

Pre-breeding for Adaptation



Assist Natural Selection – Overcome non random migration && non random mating

Outline

Environmental Control & Phenotyping

- Climate Simulation (Diurnal, Seasonal, Regional)
  - **Research for field plants || breed plants for chamber**
- Optimize cost, resolution and throughput
- Grow Capsule, Container, Facility

Phenomics Analytics

- 2,3,4,5D Point cloud, multispectral (hypercam)
  - Summary, Segmentation & Genetic Classification
- Hyperspectral, thermal, fluorescence

Genomics

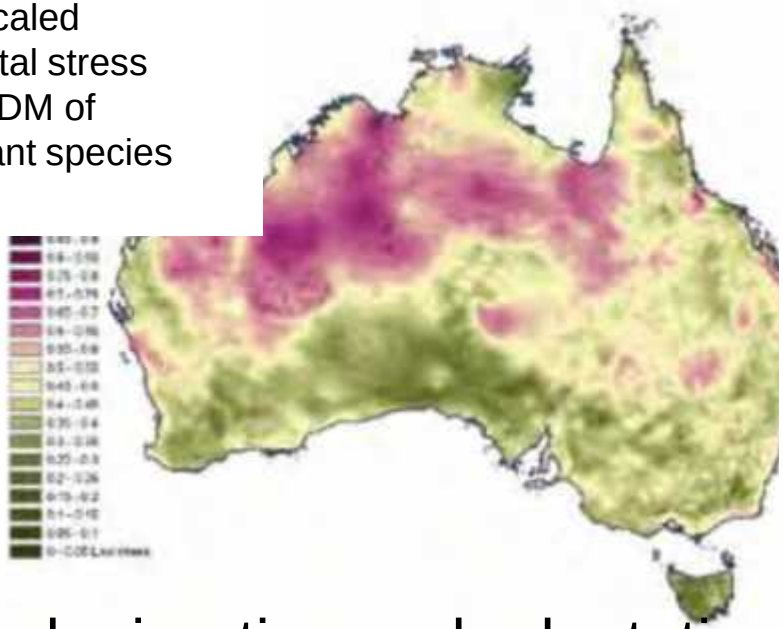
- Mapping Collections (Brachy)
- Association Studies (Brachy, Arabidopsis1001)

Model, Predict, Select, Adapt

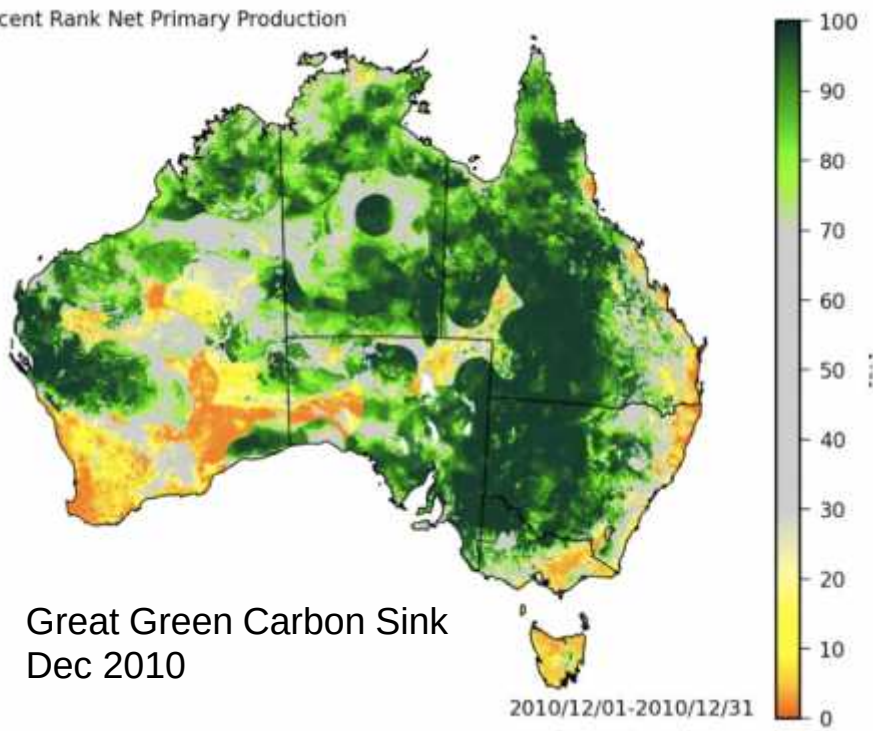
- Crop Models eg PhotoThermal Time & Genetic Models

Climate Change on Vegetation

Biotically scaled environmental stress based on GDM of vascular-plant species



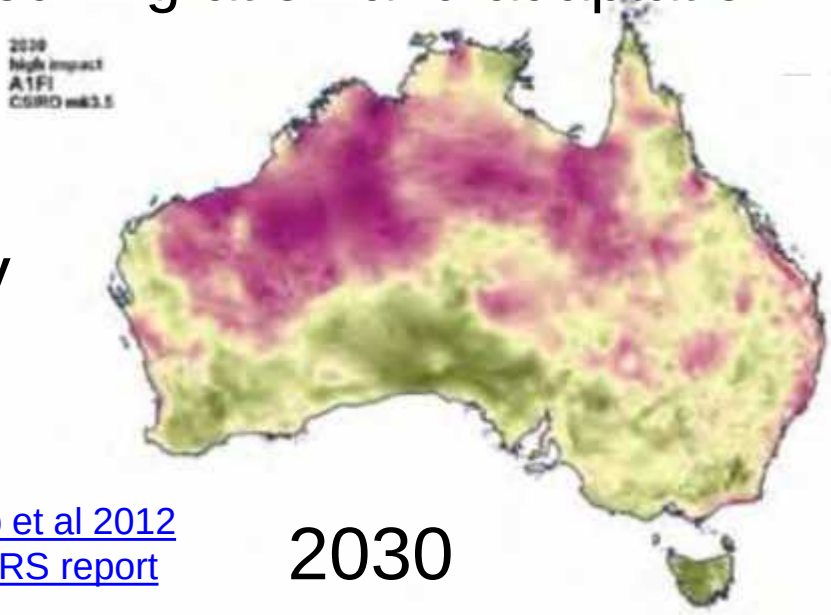
Best case



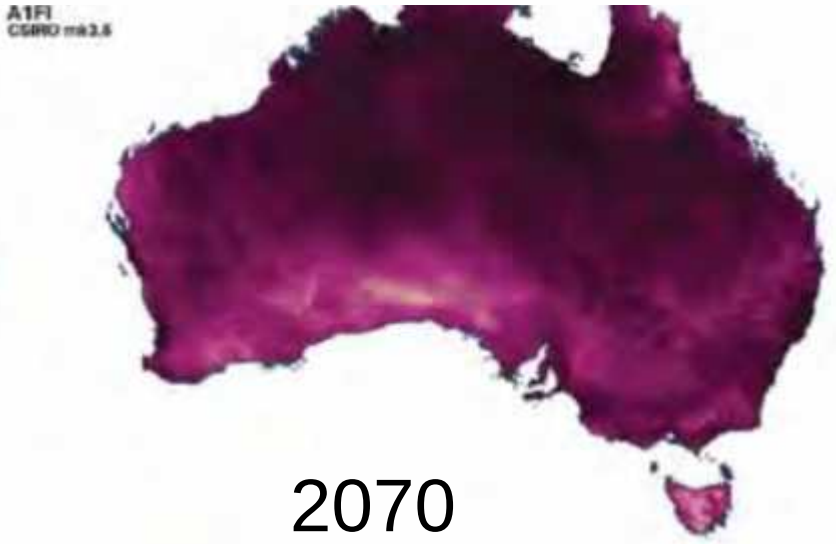
Great Green Carbon Sink
Dec 2010

Assisted migration and adaptation

likely



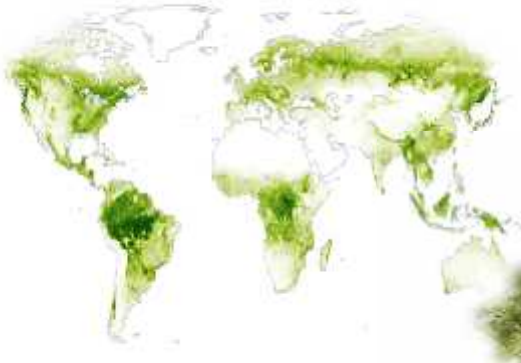
2030



2070

[M Dunlop et al 2012 CSIRO NRS report]

Global Plant Energy System



Provide Food AND Environmental Security

Cultivated lands, Rangelands, Native Vegetation

Borevitzlab
Pogsonlab
Atkinlab
CoE PEB, IWYP, APPF

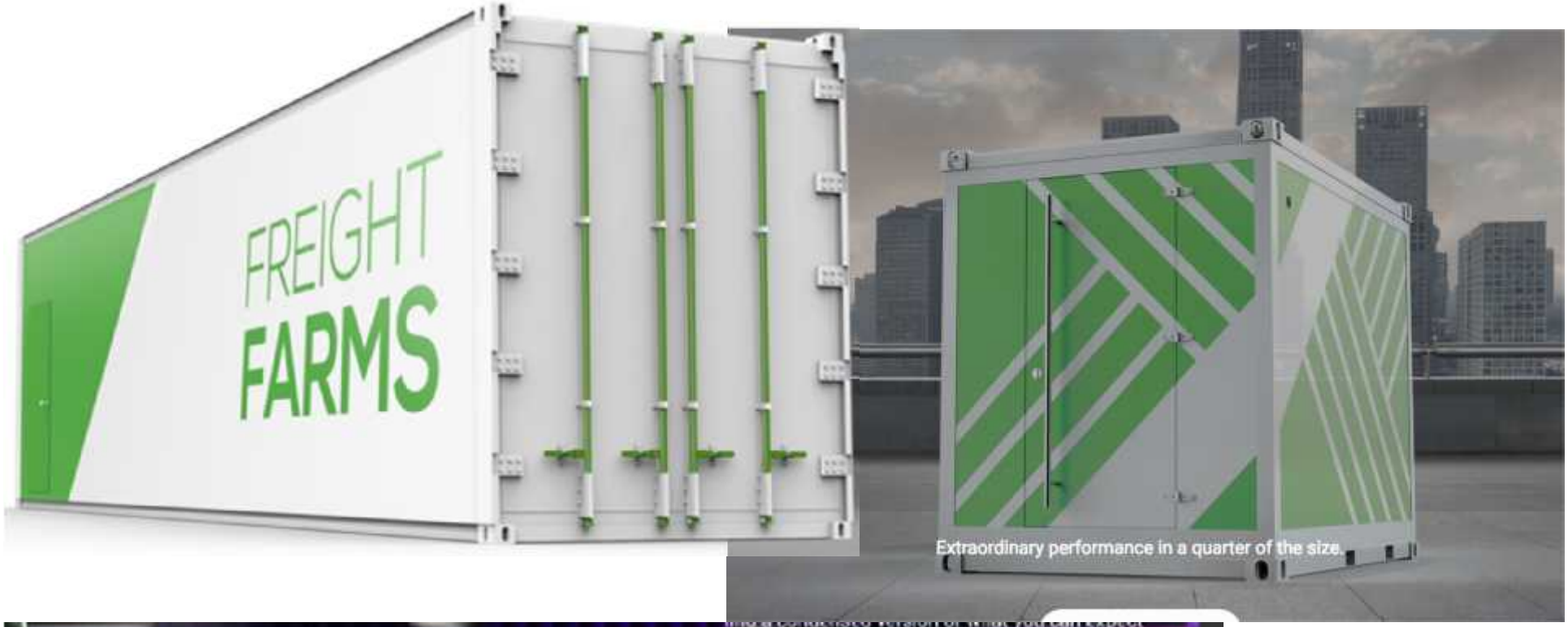
- Threatened by
  - –genetic bottleneck
  - –monocultures
  - –Fragmentation, reduced geneflow
  - –Climate Variability and Change
  - –Depleting Resources (water, nutrients, soil)
- Need another Green Revolution
  - –a transformation in Plant Breeding

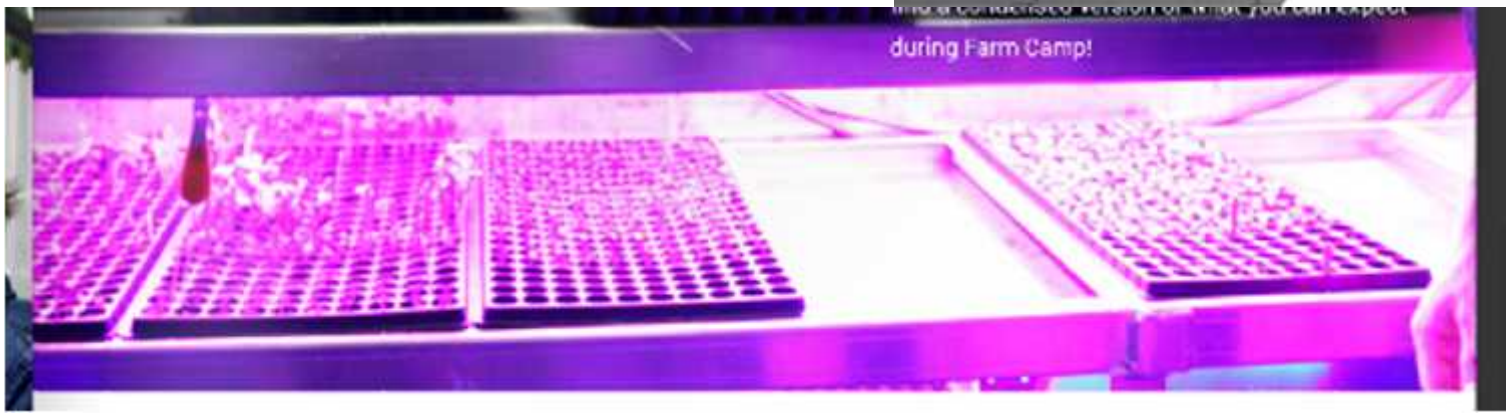
URBAN FARMING future X-PRIZE

Spread (Japan) autofarm lettuce

30,000 heads per day! 4000m2 or ~500 racks

freightfarms.com/





growtainer

http://infinite-harvest.com/

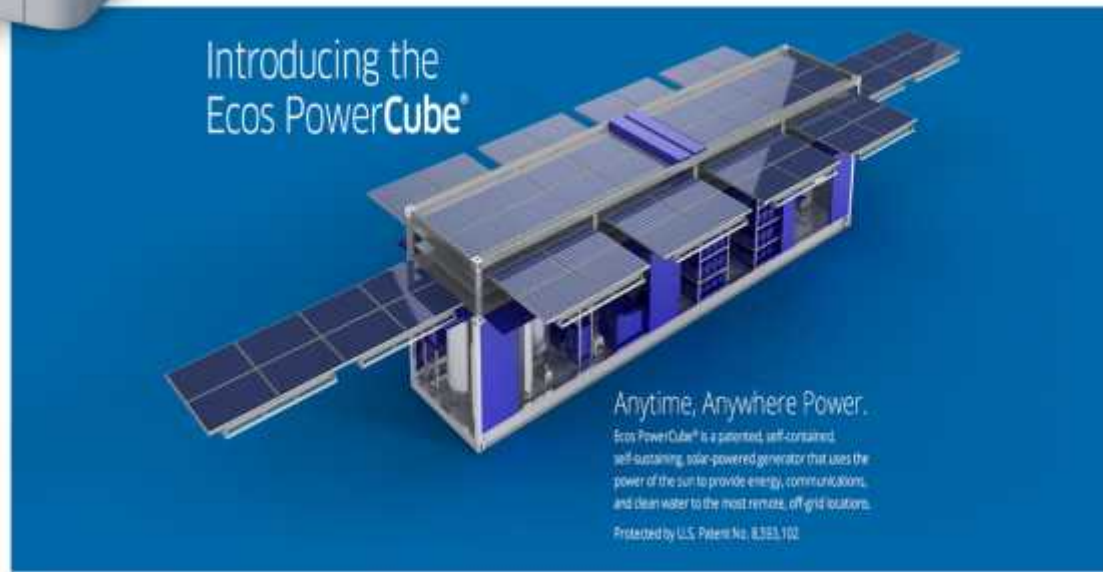
Food Computer (MIT)

Open Agriculture – Share Climate Recipies

ECOS GrowCube

12-16 containers
per facility

Grow a Facility, Modular
And/or Distribute around



Hydrofarm GLC00100

Eli Borevitz – future farmer

Amazon $600

Run climate receipts

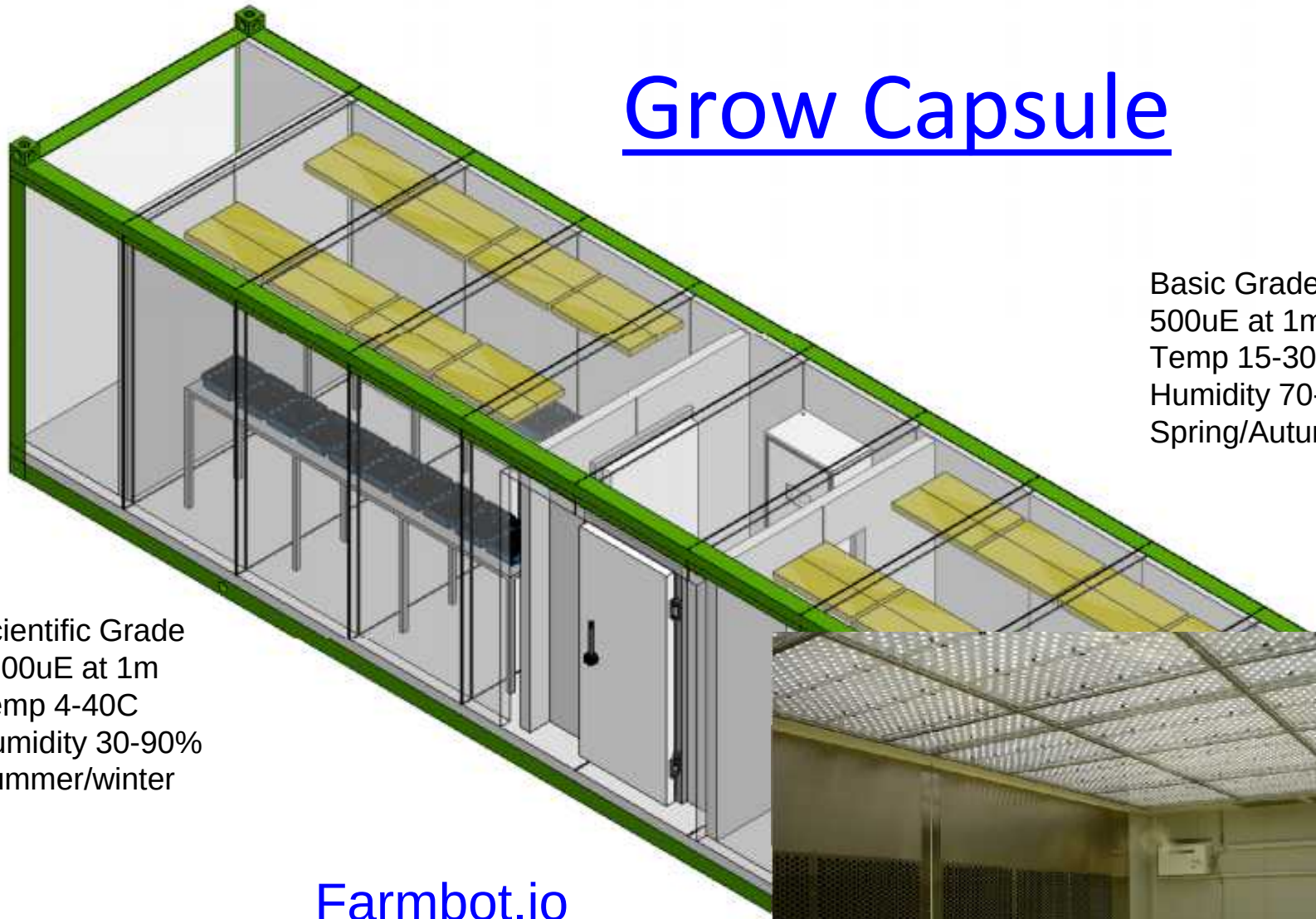
MIT food computer – breed for new environments

Control what you can and monitor for what you can’t

Grow Capsule

PSI

Basic Grade
500uE at 1m
Temp 15-30C
Humidity 70-80%
Spring/Autumn



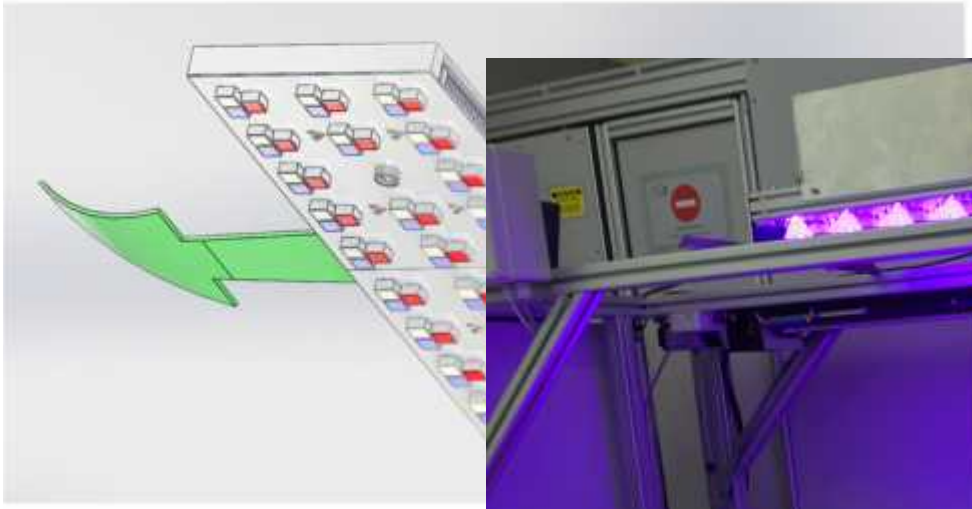
Scientific Grade
1500uE at 1m
Temp 4-40C
Humidity 30-90%
Summer/winter

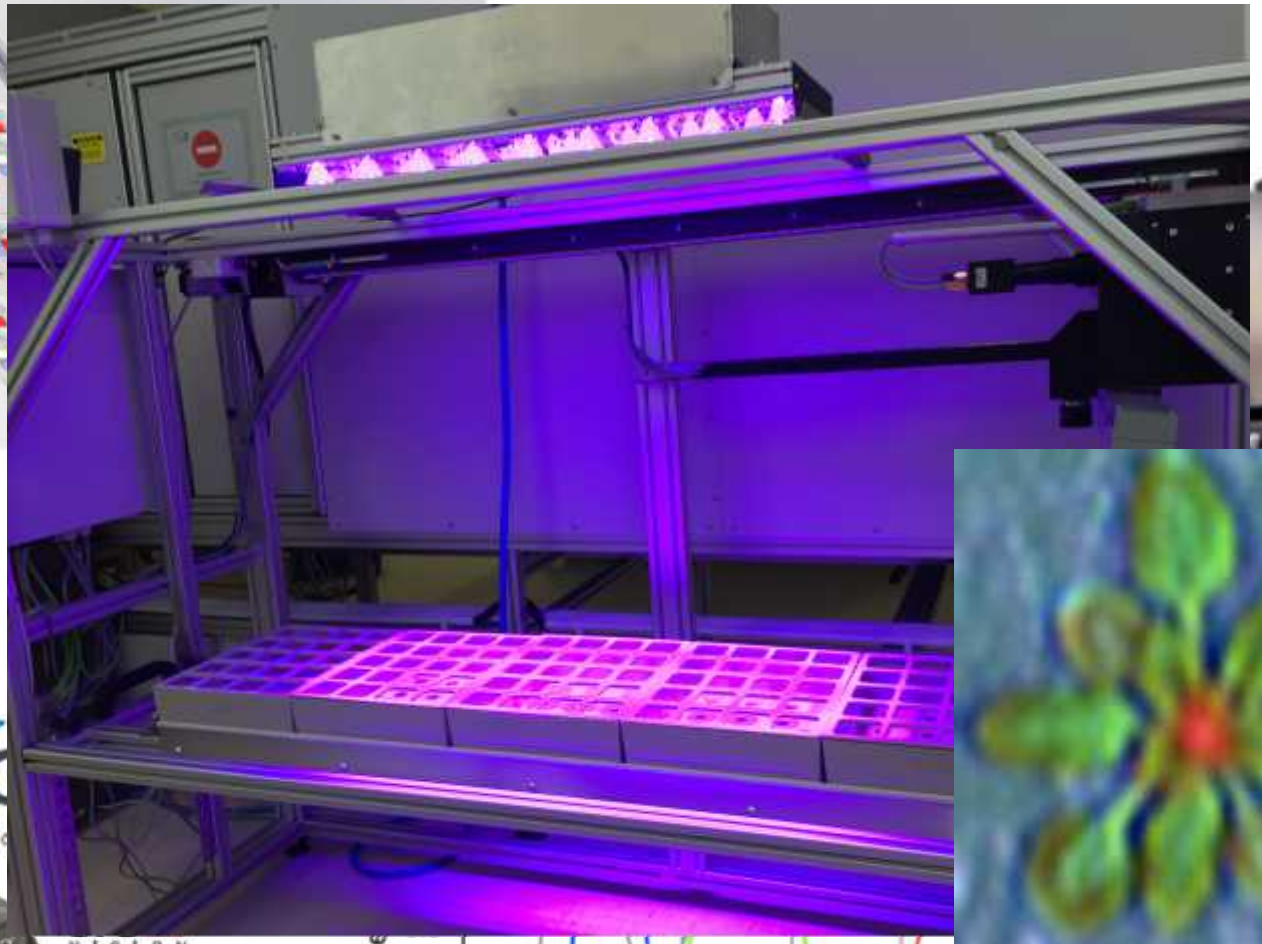
Farmbot.io

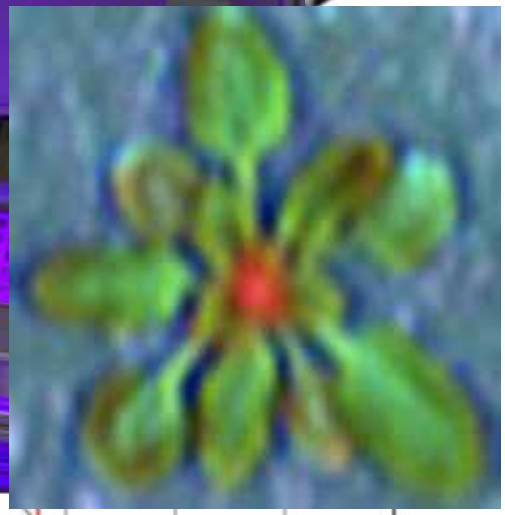
7band LED
Vented light loft
Adjustable shelf height
Solar & battery powered
36-48 trays per room = 960 plants | **Prototype =~$200k**

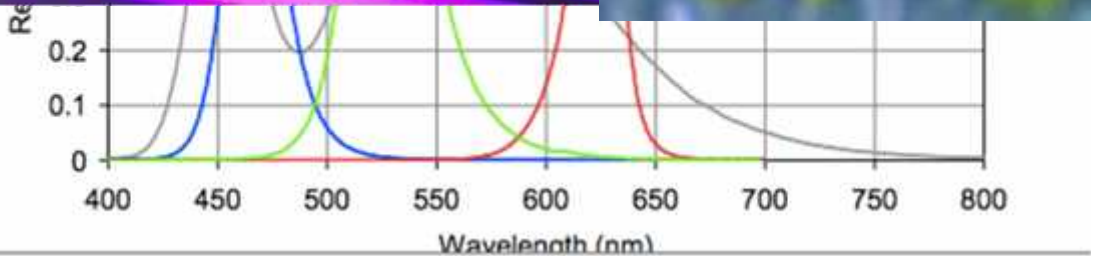
Face Plate

LED ENGIN - RGBW
40W 12 LED < 1cm^2



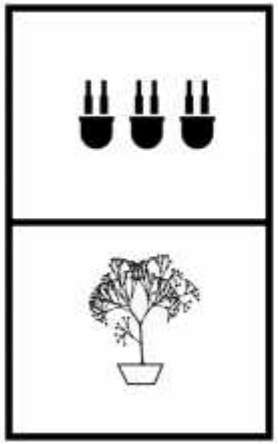




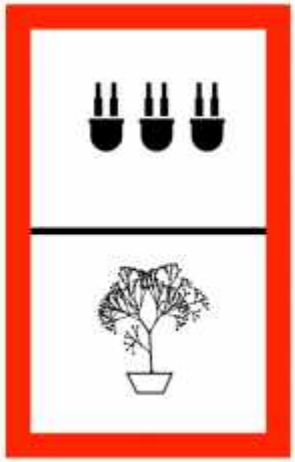


Innovations

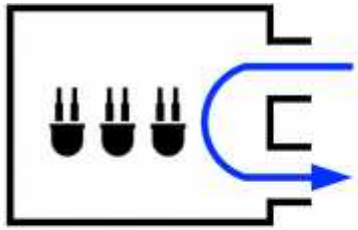
Efficient LED lighting



Isolated lighting

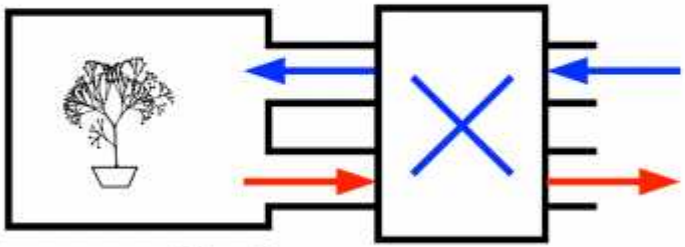


Airtight and super insulated



Outside air cooling

Dessicant wheel dehumidifier



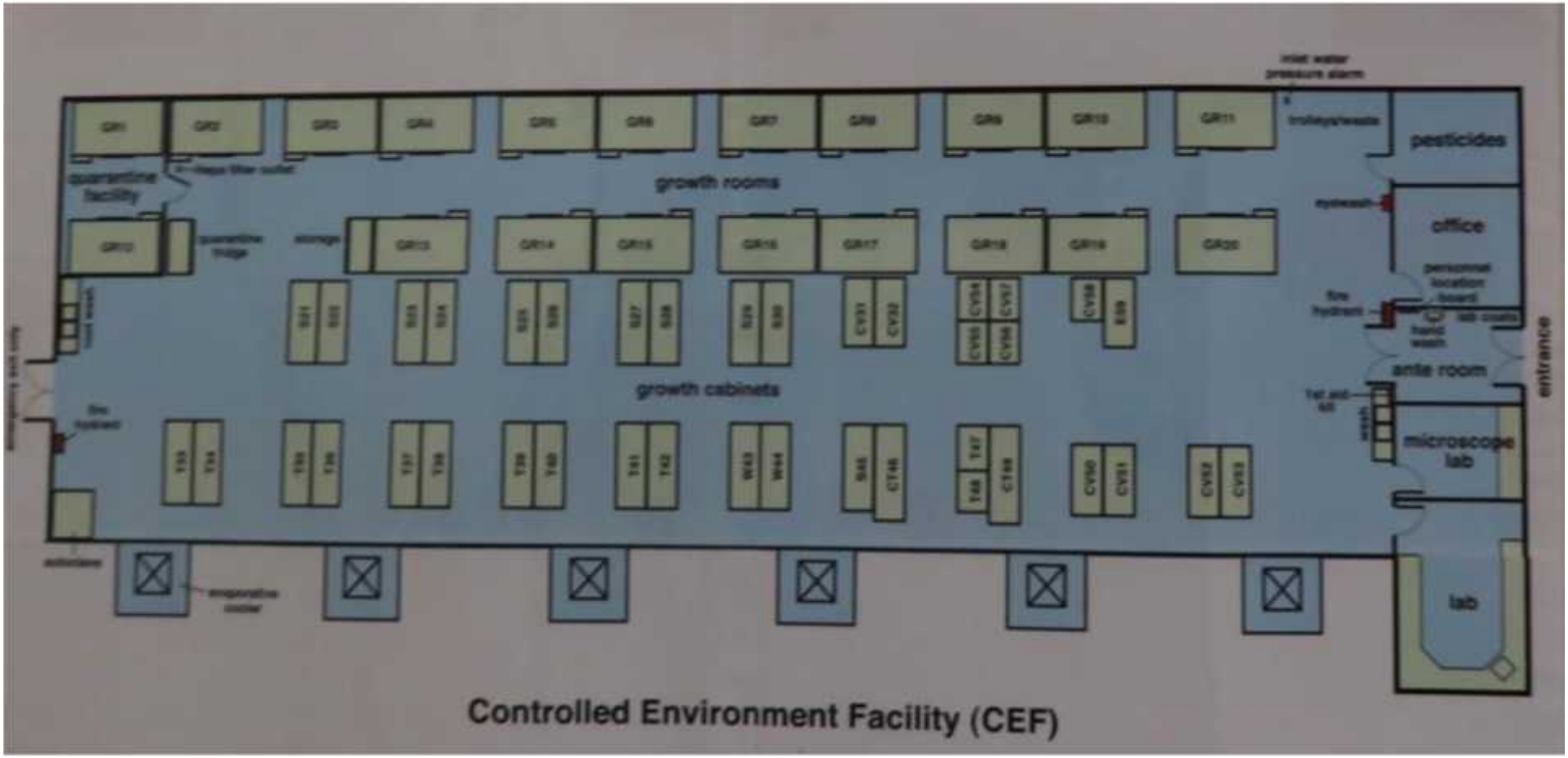
Heat recovery ventilation

Independent Controls

Heat pump water chiller

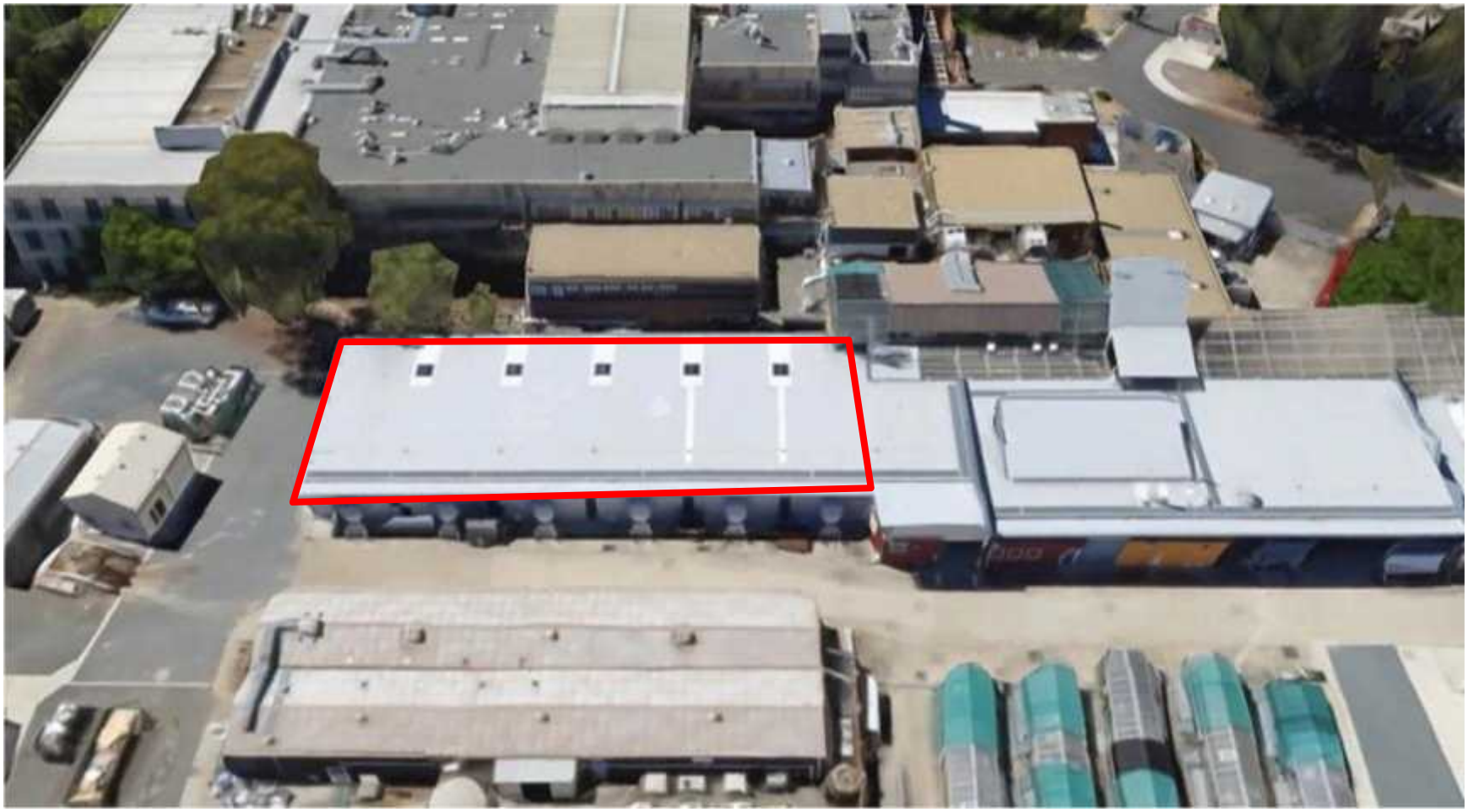
Harley Truong, H3space.com.au

Current CEF ~30 chambers & 20 rooms

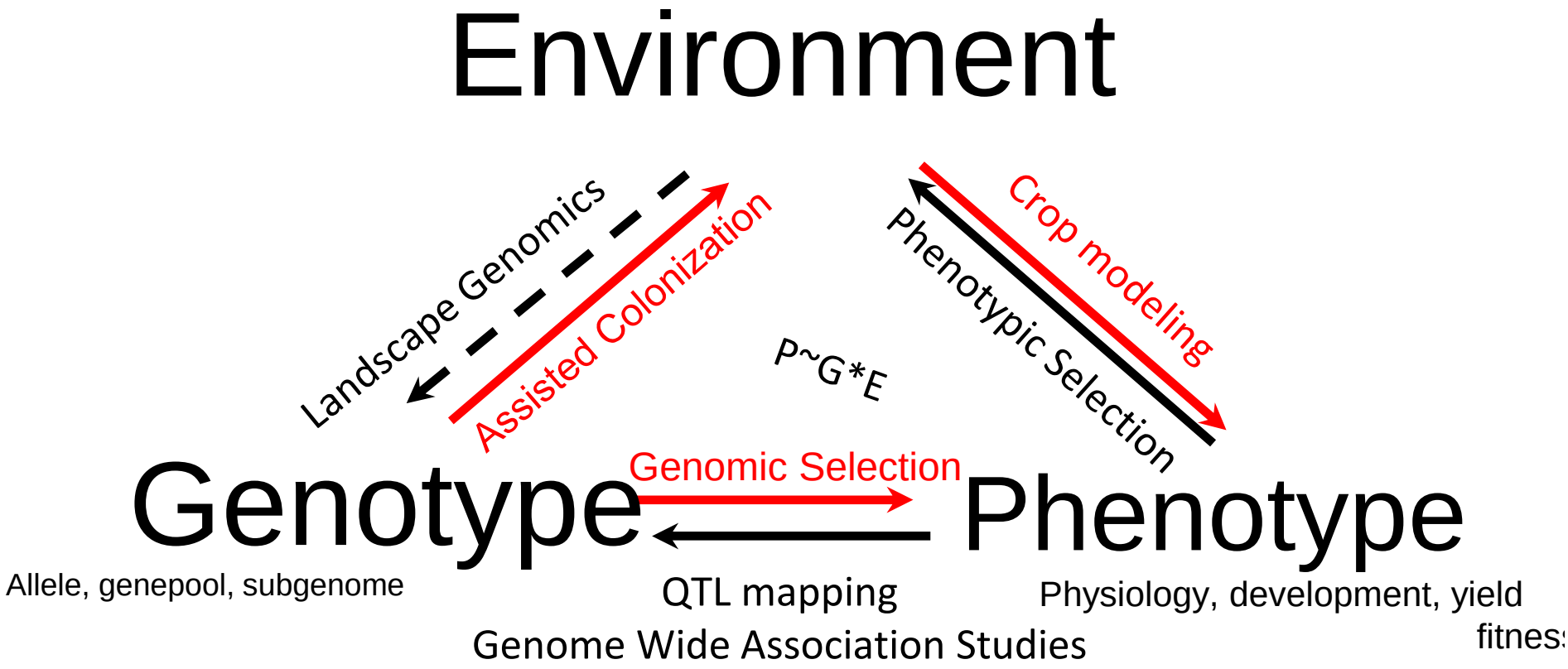


$30-50k/month utilities

Current Controlled Environment Facility (CEF) 1990's



Pre-breeding for Adaptation

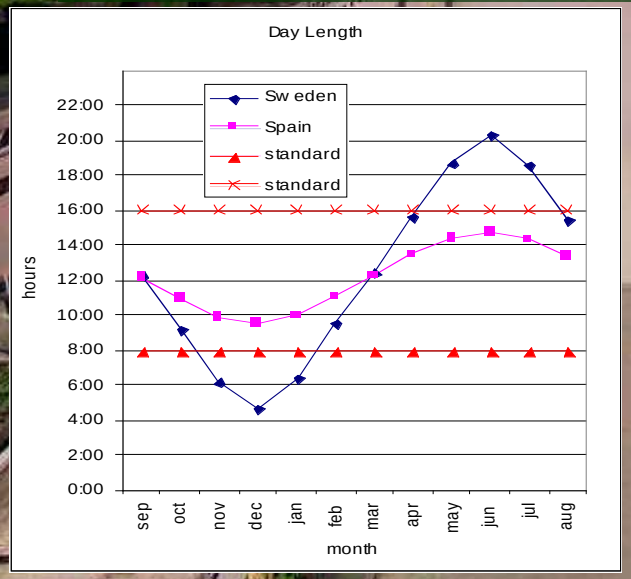


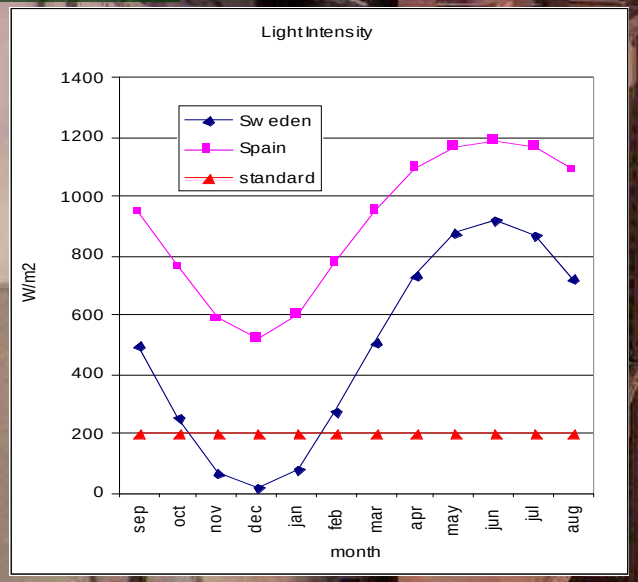
Assist Natural Selection – Overcome non random migration && non random mating

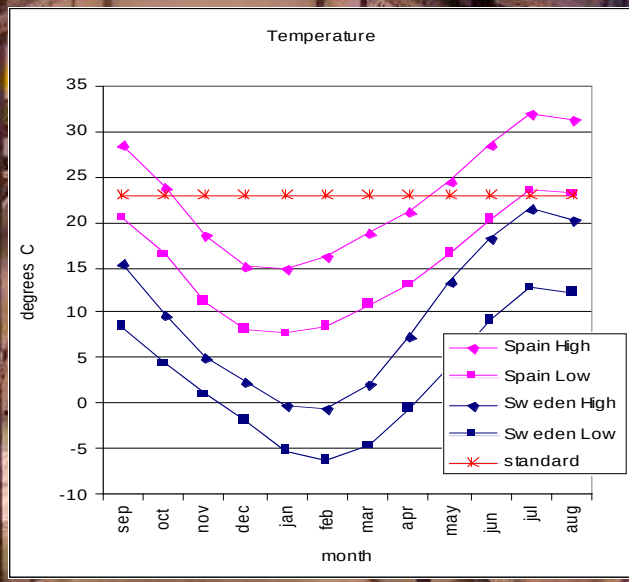
Seasons in the Growth Chamber

- Cycle Day length
- Cycle Light Intensity
- Cycle Light Colors
- Cycle Temperature
- Cycle Humidity

Henry Imberti
Percival



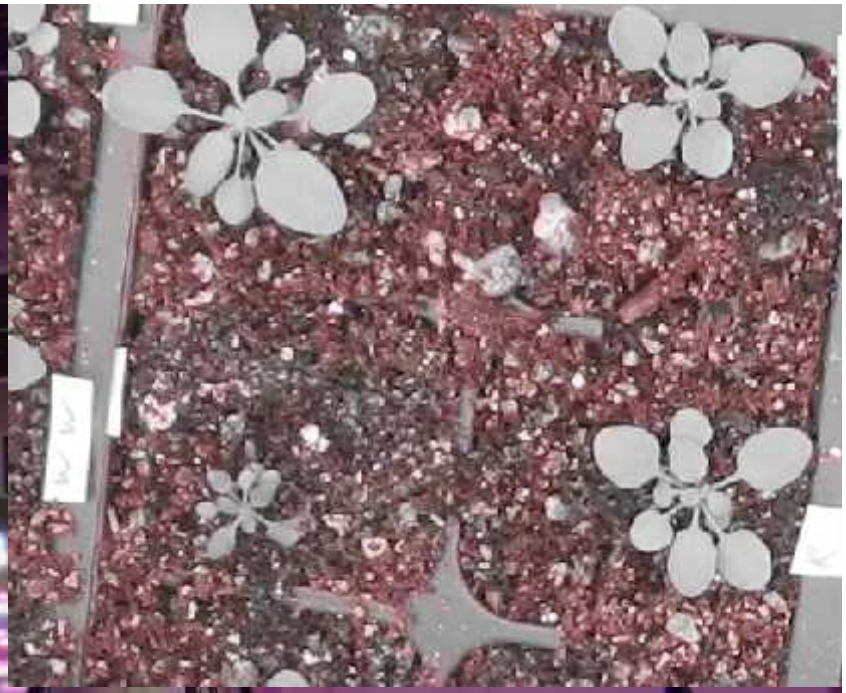


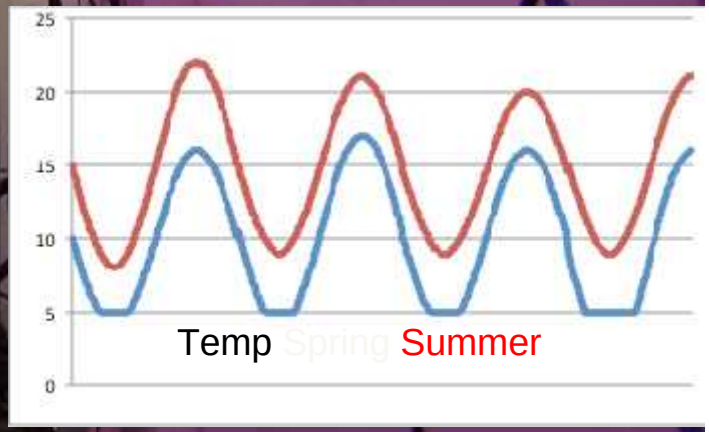


Sweden

Spain

Spectral Pheno Climatron
local climate w/o weather

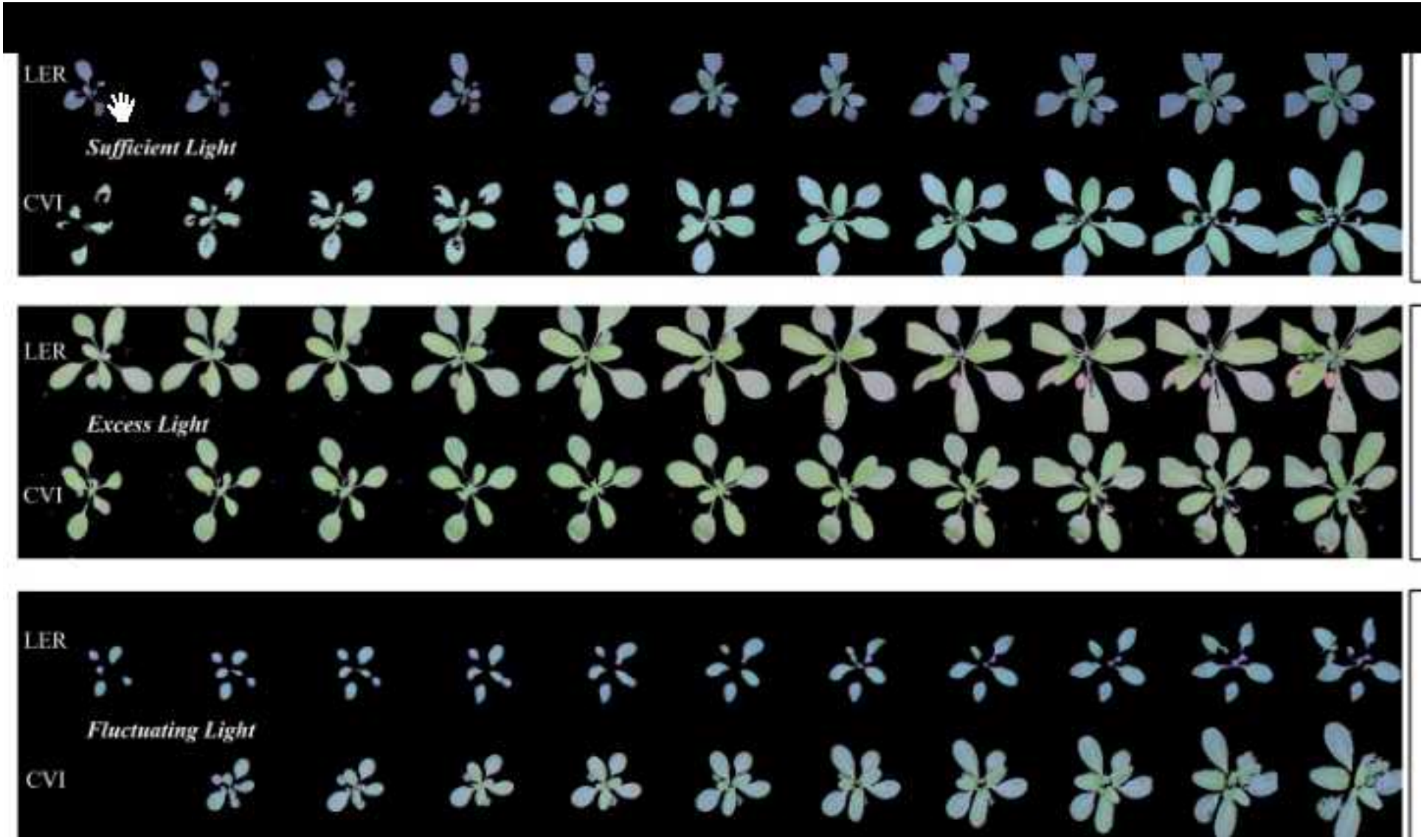




Kevin Murray

2013/03/09 - 08:32:00

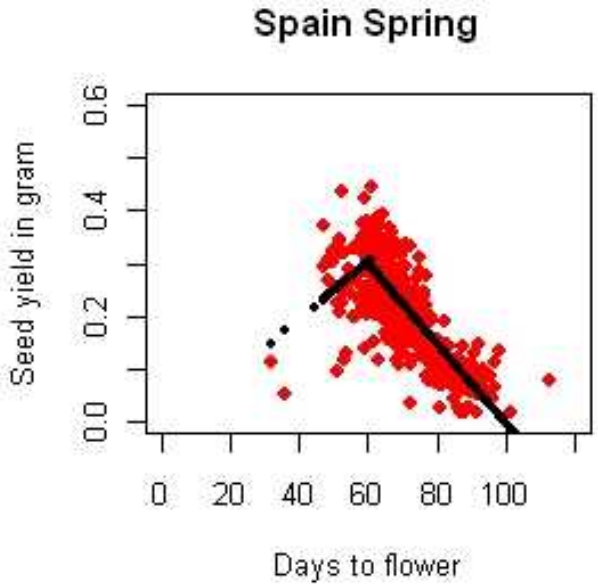
Dynamic Light: Clouds | Forest

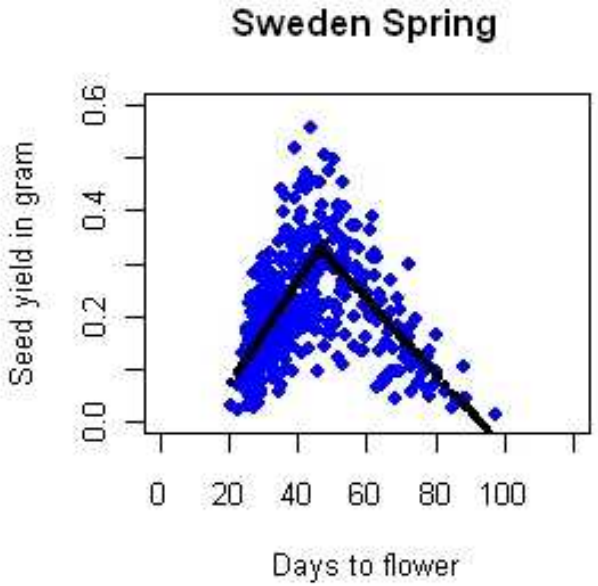


Kevin Murray

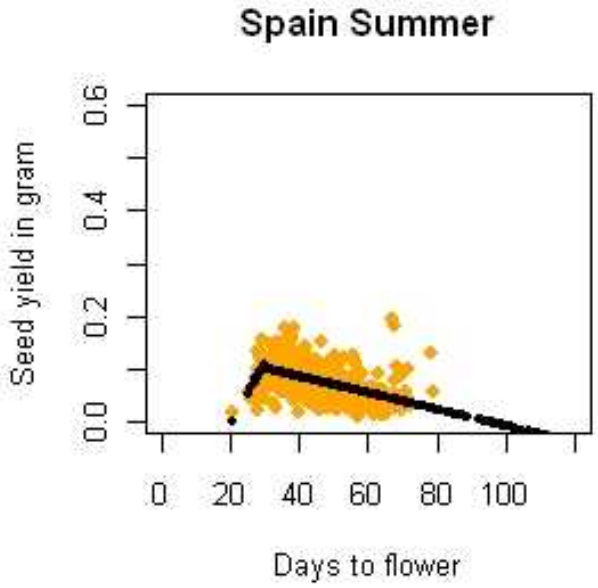
Adjust R/FR ratio to simulate density

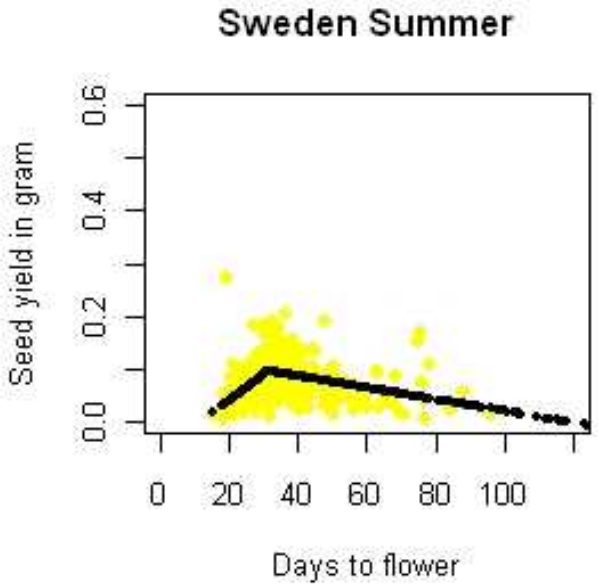
Correlation between Flowering Time and Seed Yield





Black lines showed segmented regression with optimal breaking points.



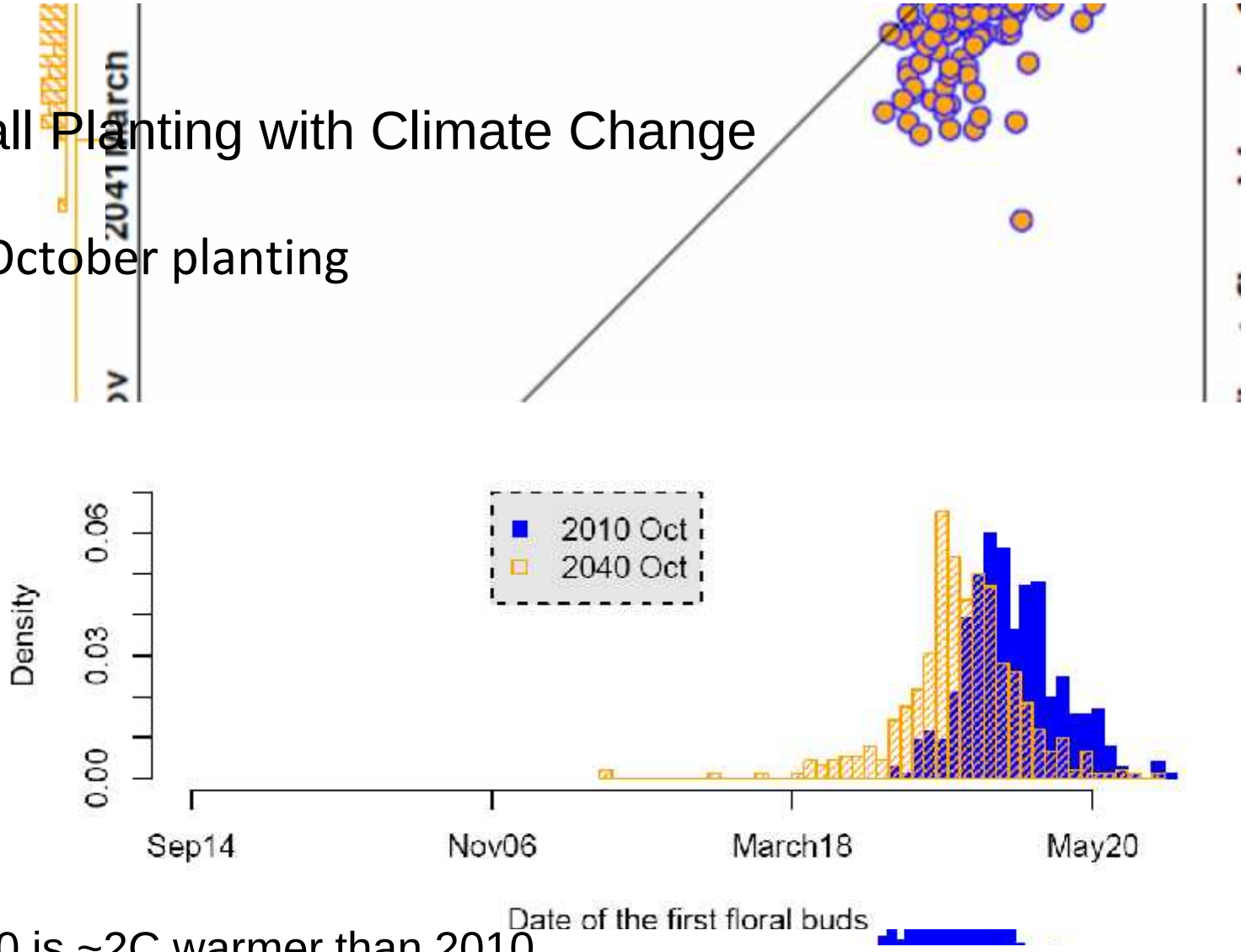


Yan Li

Flowering Time and Fitness

Fall Planting with Climate Change

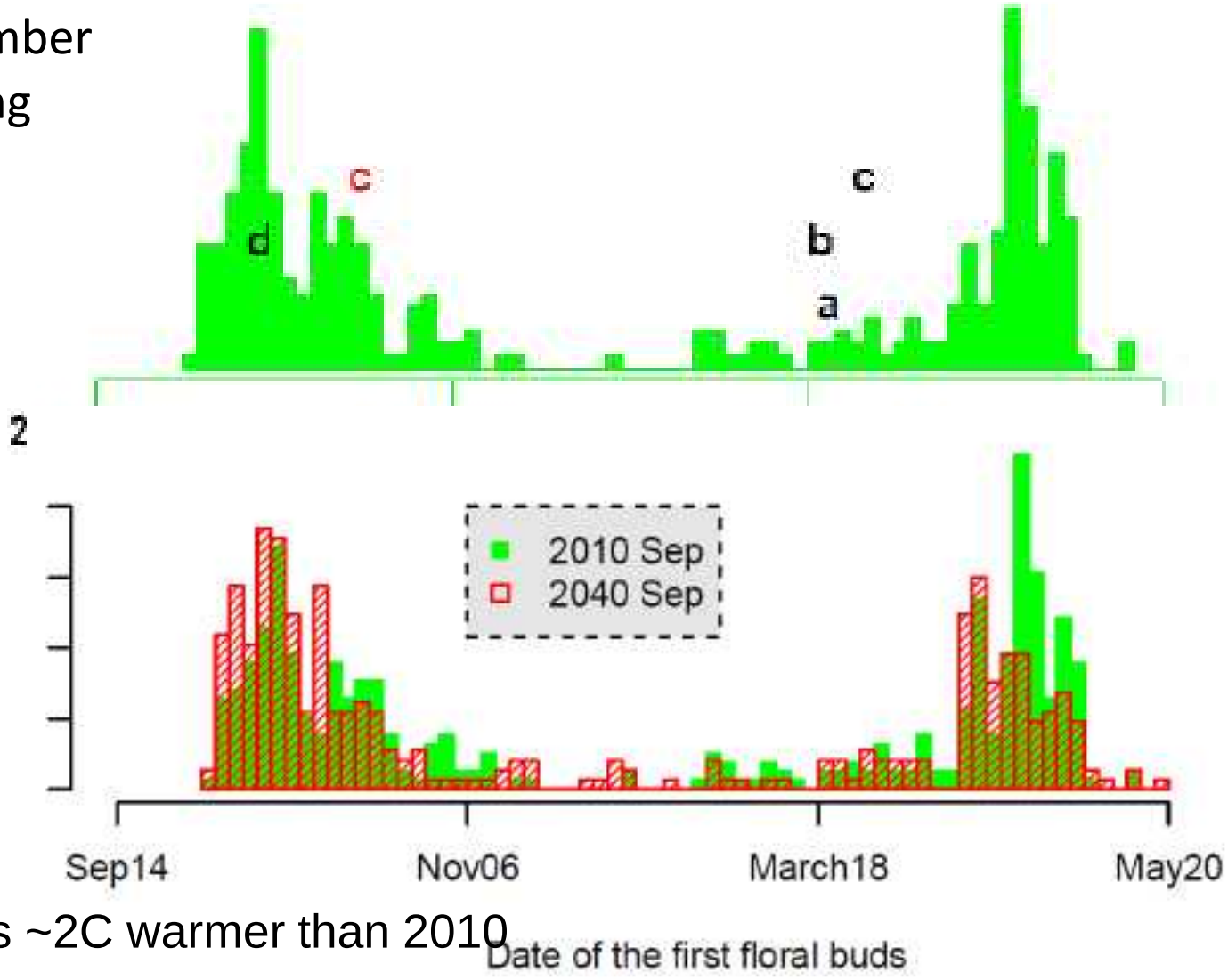
October planting



2040 is ~2C warmer than 2010

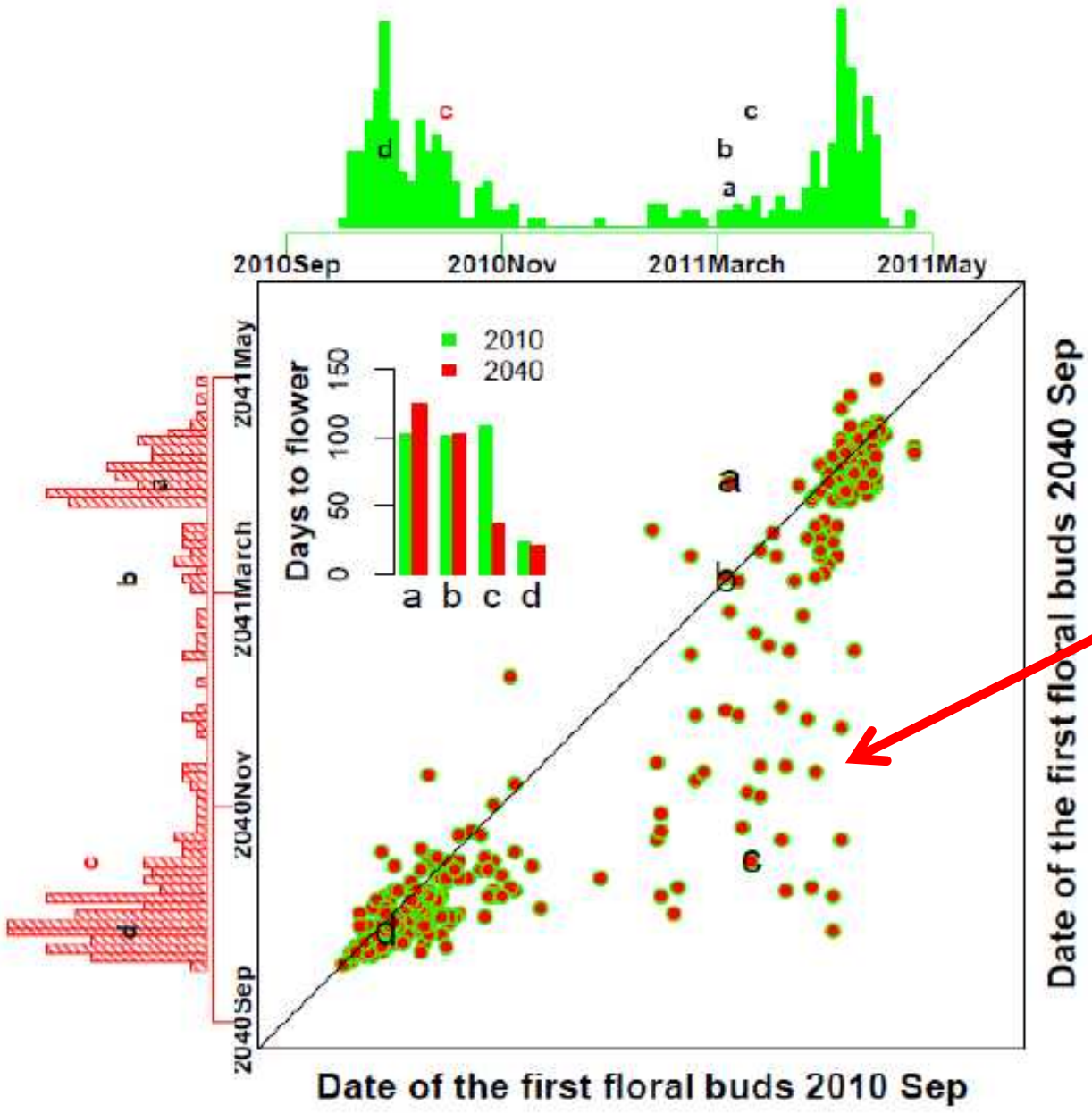
Fall Planting with Climate Change

September Planting



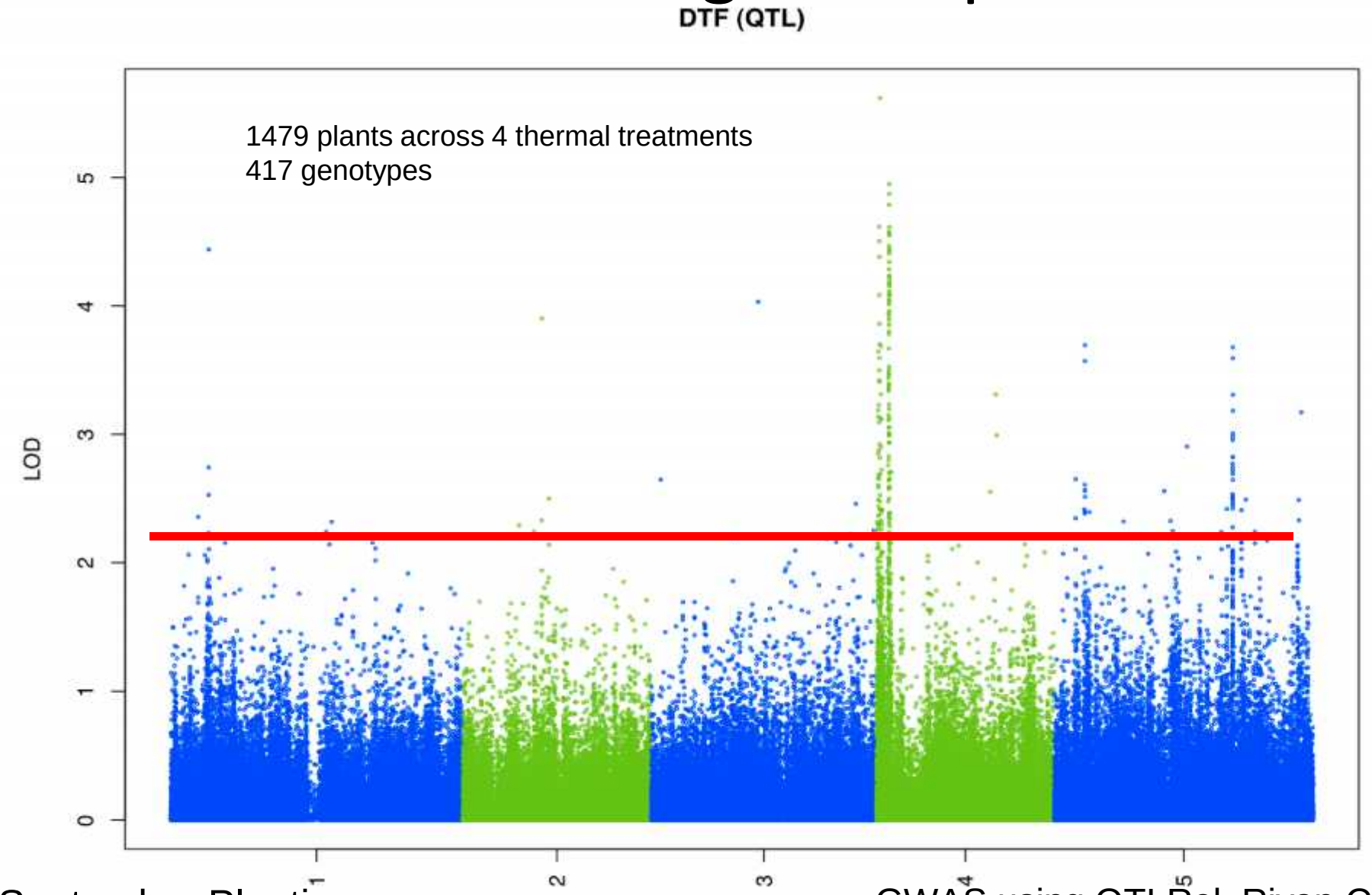
2040 is ~2C warmer than 2010

Early Fall Planting 2010 vs 2040



GWAS on temperature sensitivity

GWAS Flowering * Temperature



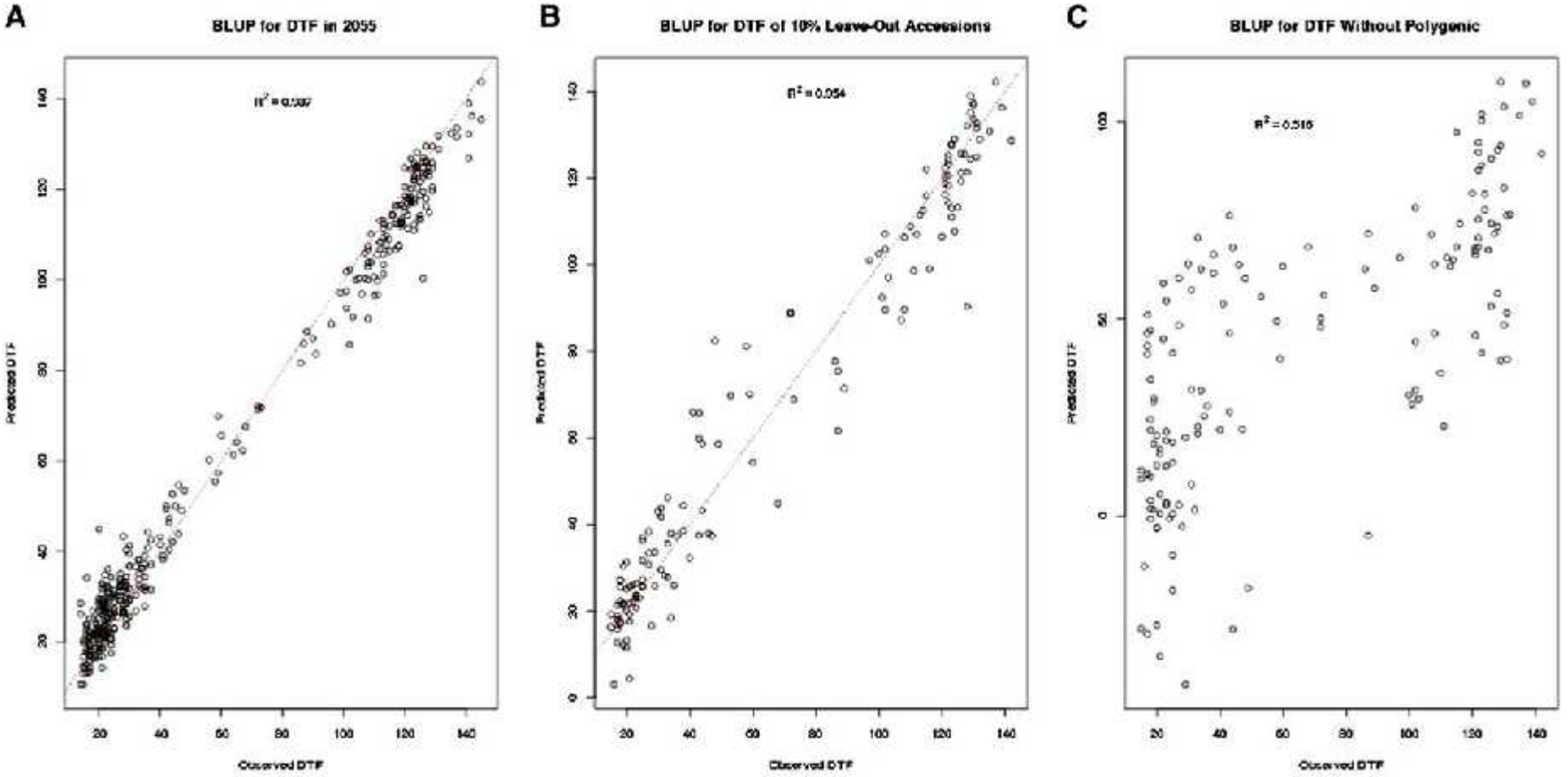
September Planting

GWAS using QTLRel, Riyan Cheng

5 FFT loci, 4 apriori loci, 5 GxE thermal sensitive flowering loci

Riyan Cheng

Prediction of Future Flowering

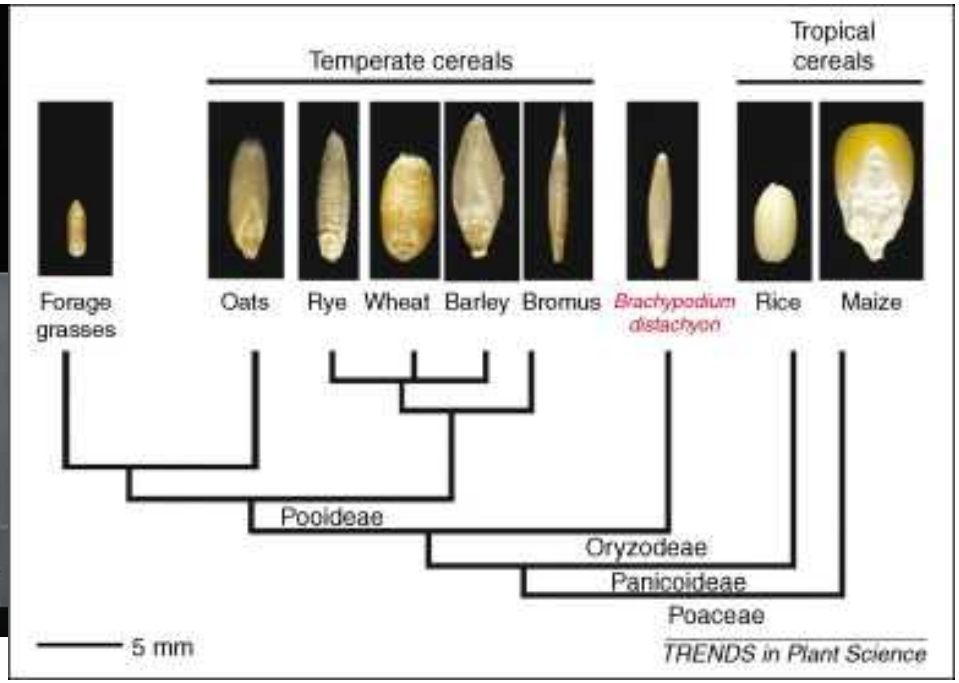


Predicted phenotype
Major QTL effects + polygeneic

Predicted phenotype
Major QTL effects alone

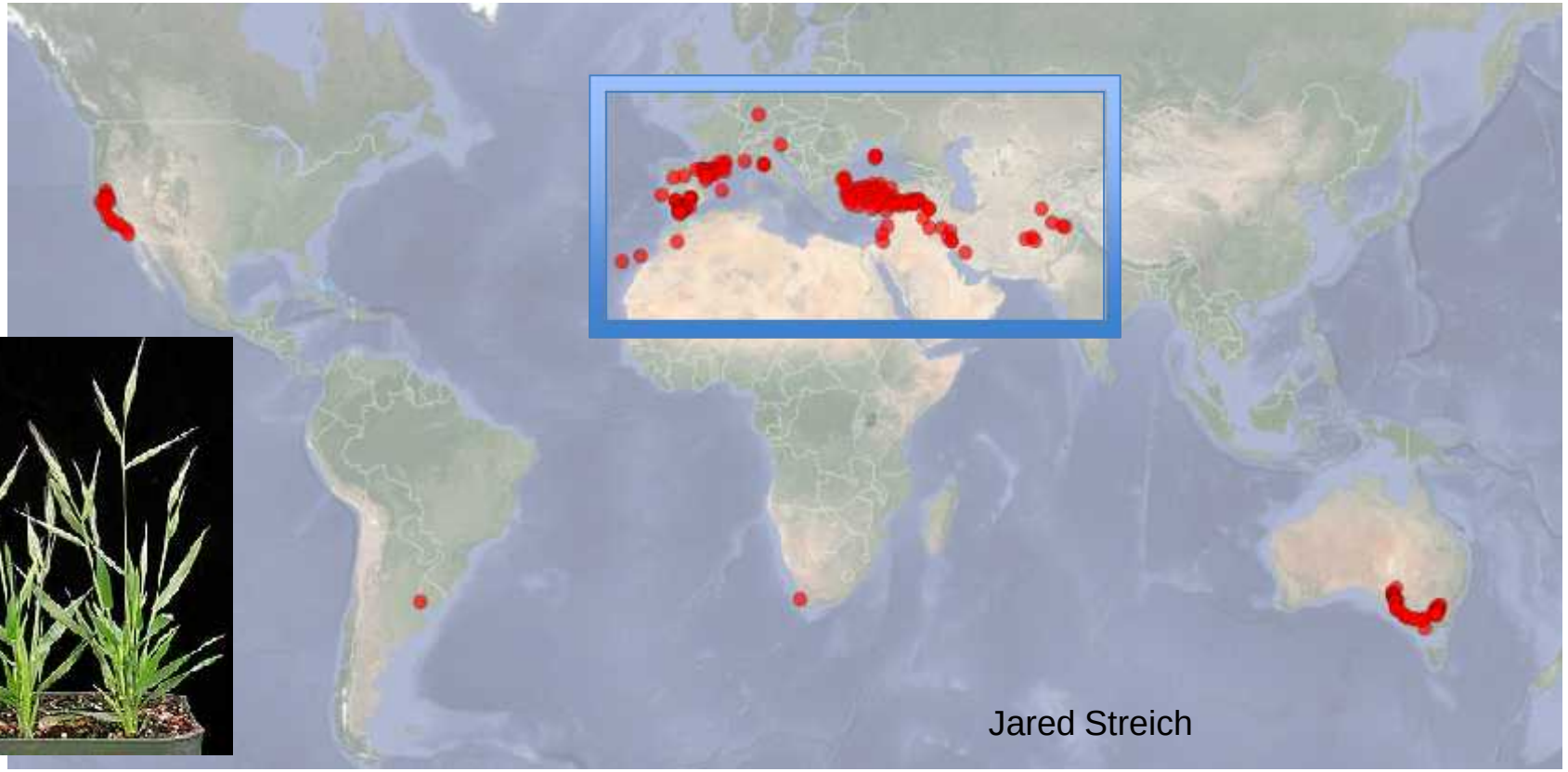
Brachypodium ssp

- Small grass
- 2 diploid species
- 1 tetraploid species
- Broad geographic
- Ecological range

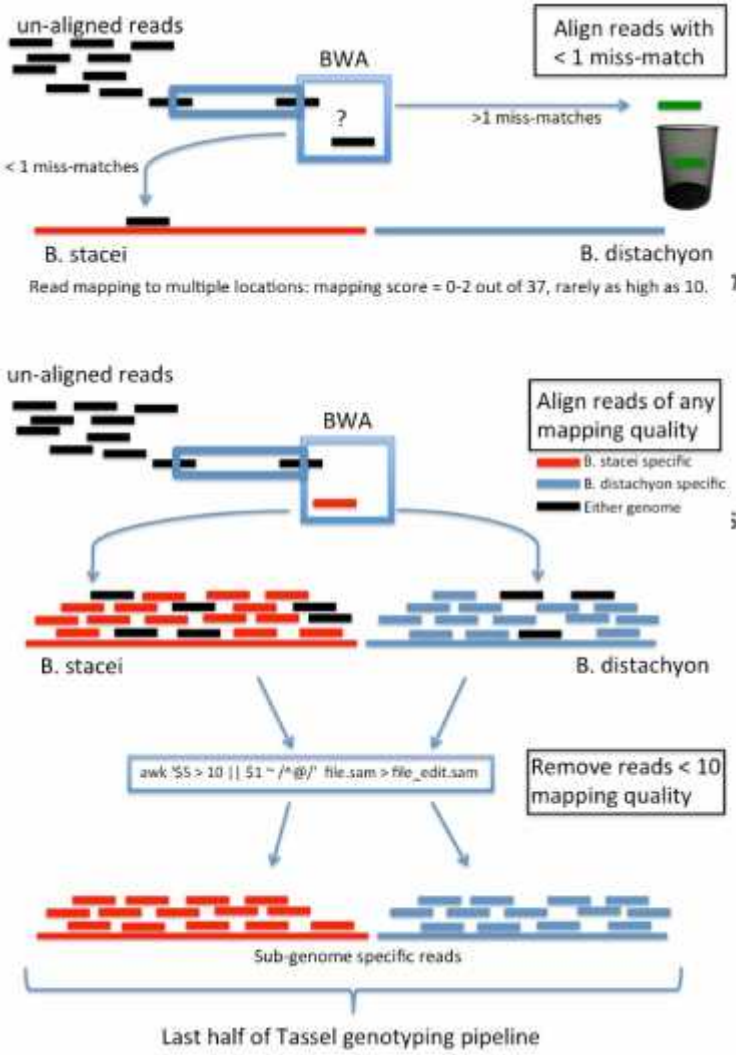


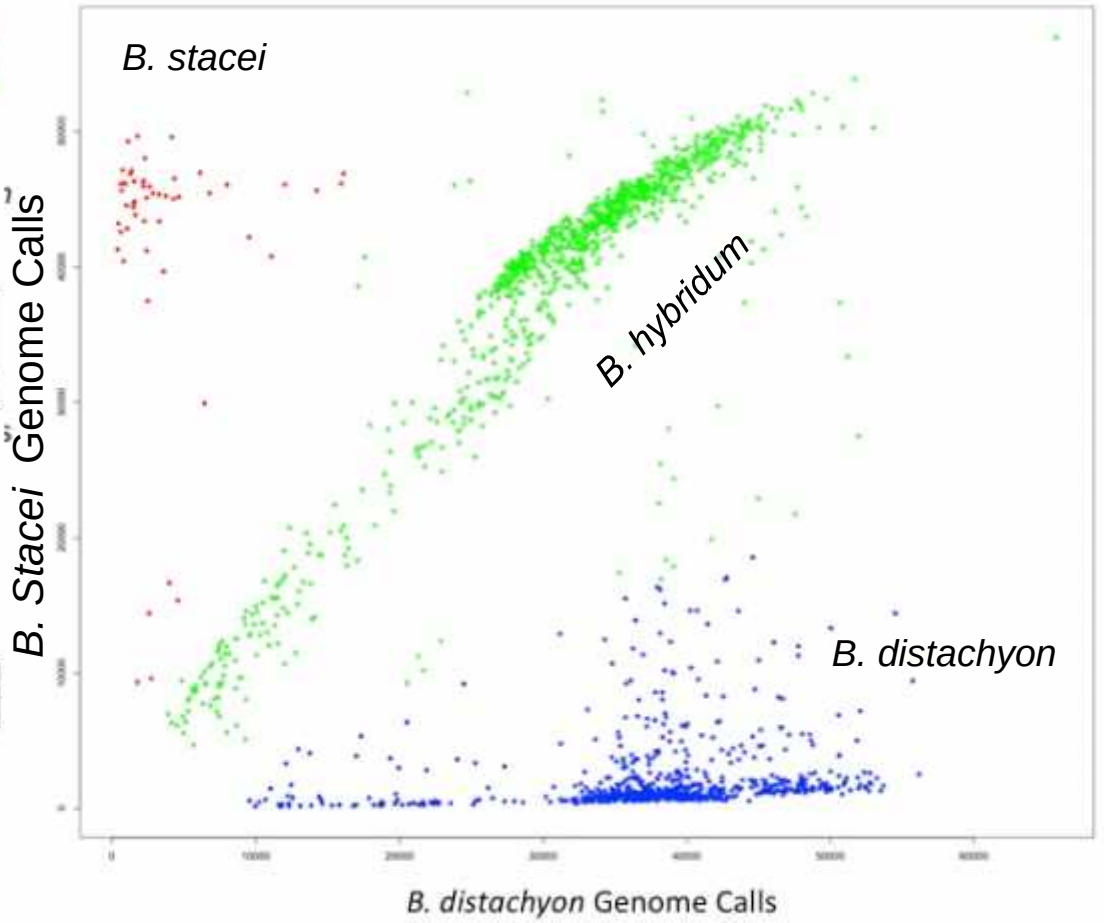
Germplasm: 2,722 Accessions, 817 locations

≈ 350 USDA Public Global Accessions: Dave Garvin and John Vogel
≈ 120 Private Collection: Spanish lines, Luis Mur
≈ 130 Spanish Private: Accessions, Pilar Catalan
≈ 120 Private Collection: US accessions, Shuangshuang Liu via Kent Bradford
≈ 950 Borevitz Lab: 240 EU accessions, ≈ 660 Australian accessions, 48 North America acc.
≈ 400 Armenia, Israel, Lebanon, Greece, Private Collections, Ezrati Lab
≈ 120 Private Collection: Turkey, Budak Lab
≈ 50 Private Collection: Italy, Greece, Georgia, Armenia, Spain, Hazen Lab



2 Diploid 1 Allotetraploid species





Jared Streich

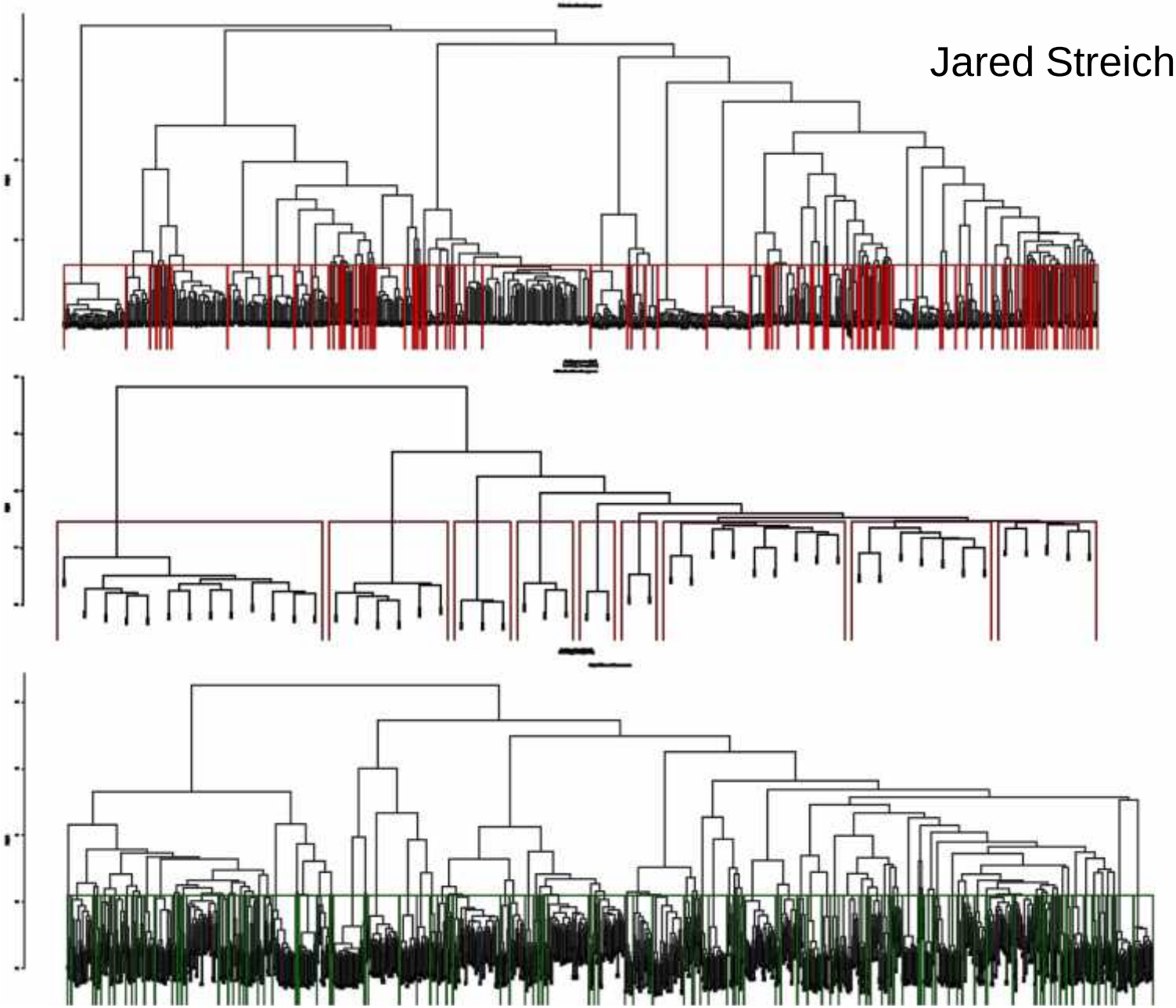
Summary - Species Diversity Sets

Jared Streich

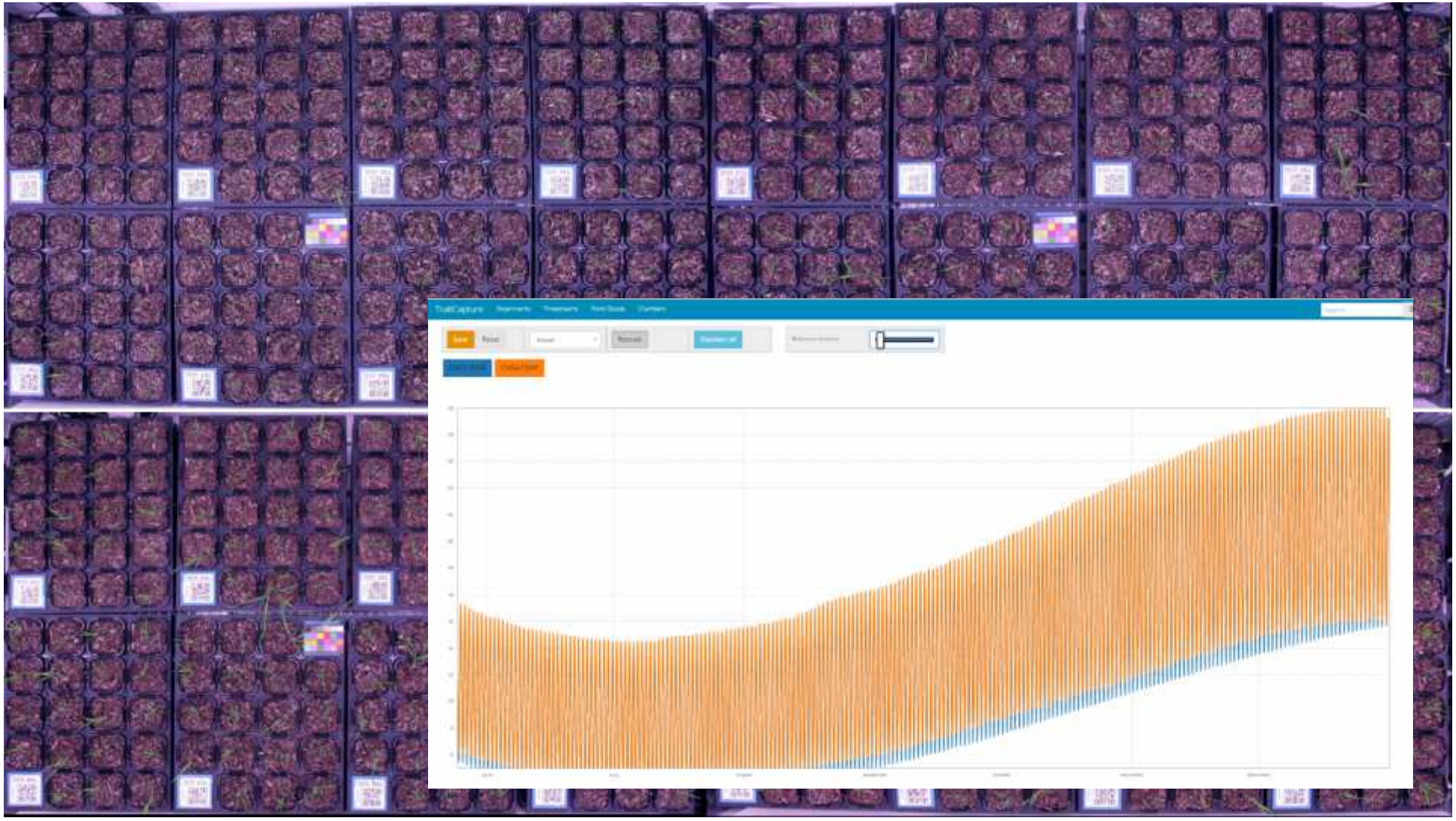
B. distachyon
n = 505
130 genotypes
33,201 SNPs

B. stacei
n = 51
10 genotypes
21,058 SNPs

B. hybridum
n = 1,015
80 genotypes
37,774 variants



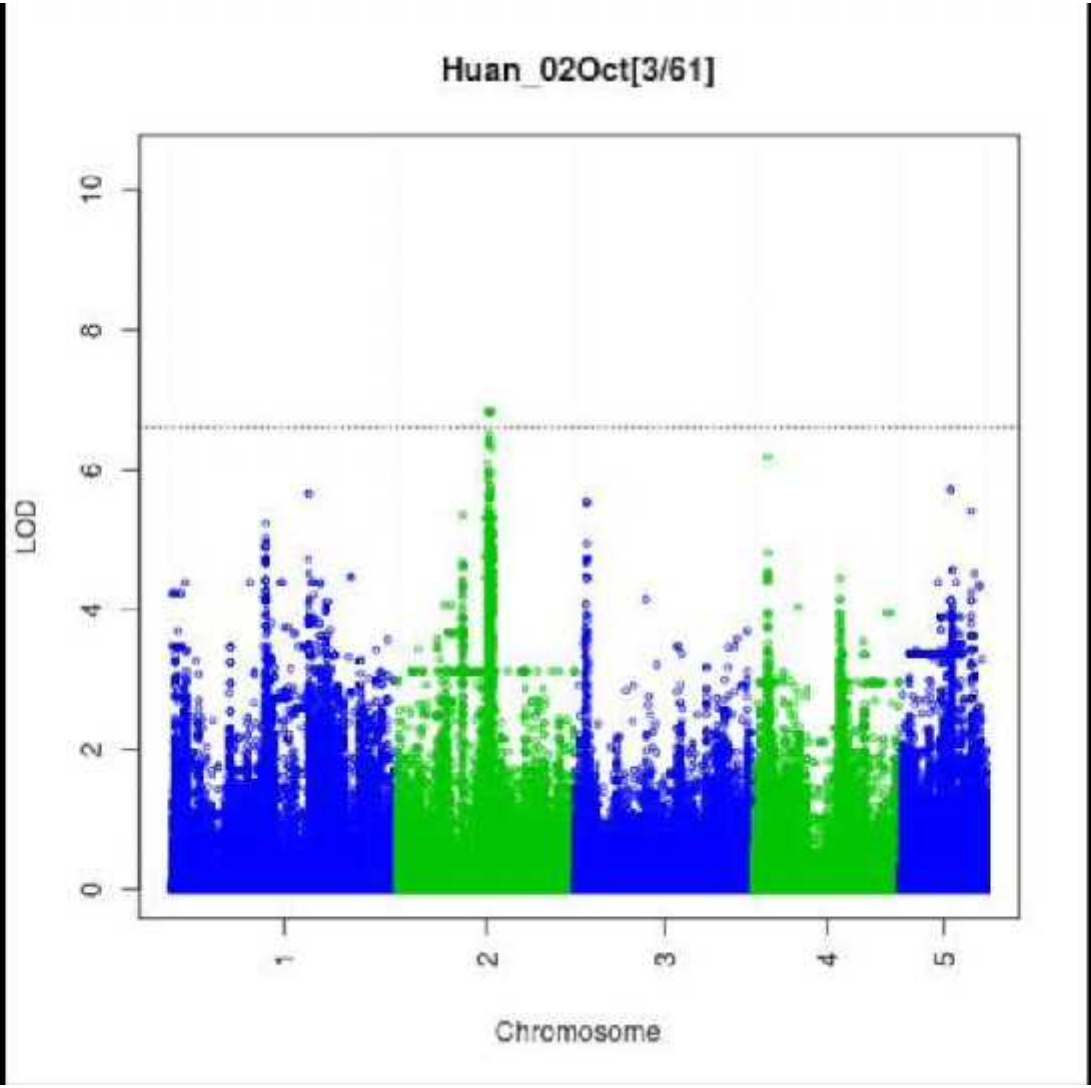
Brachypodium Wagawaga (2015 vs 2050)



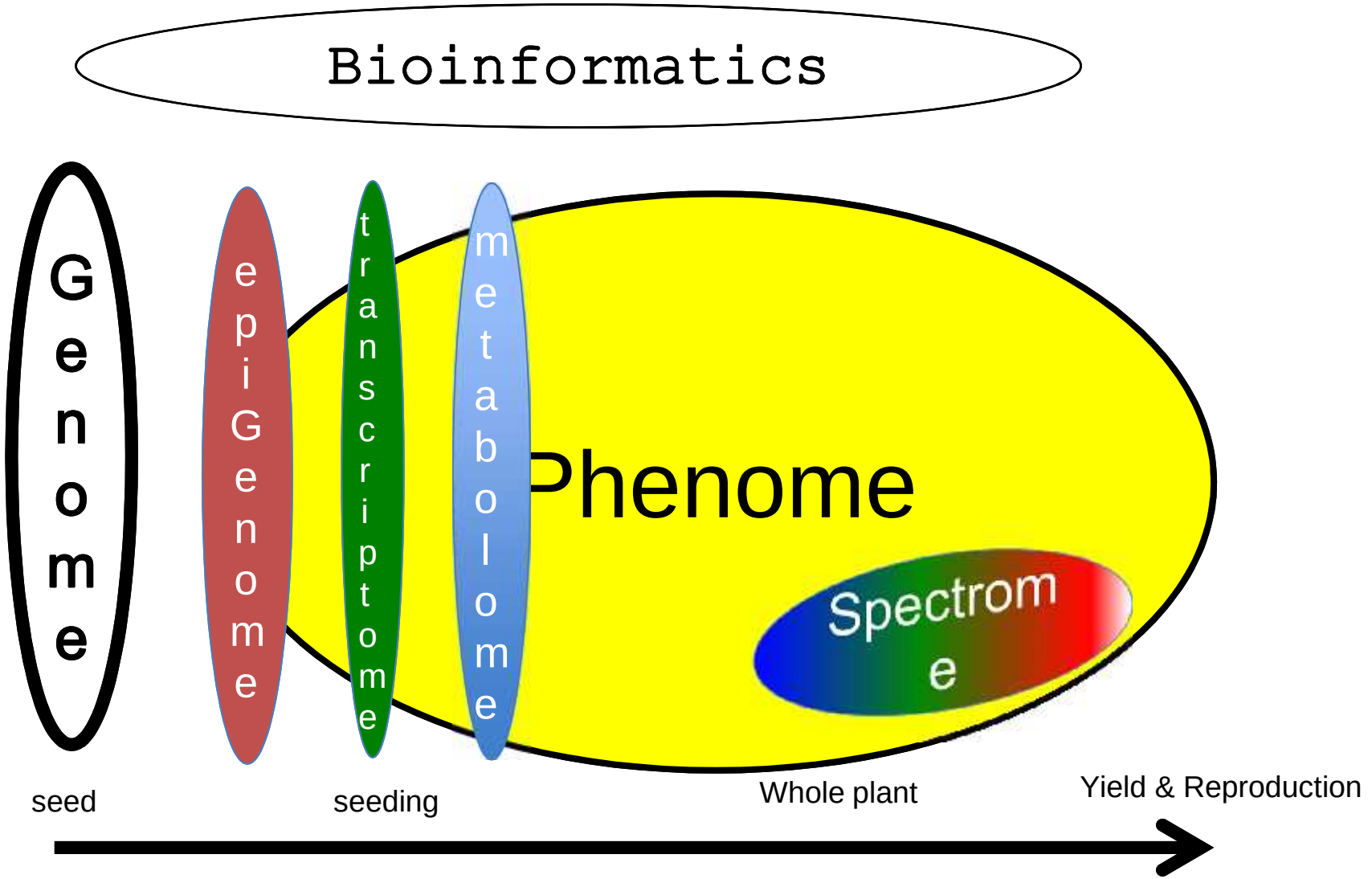
Brachy GWAS developmental time

Pip Wilson
Manual
Measurements

Training for
Machine Learning
Image analysis



Systems genetics



Technology

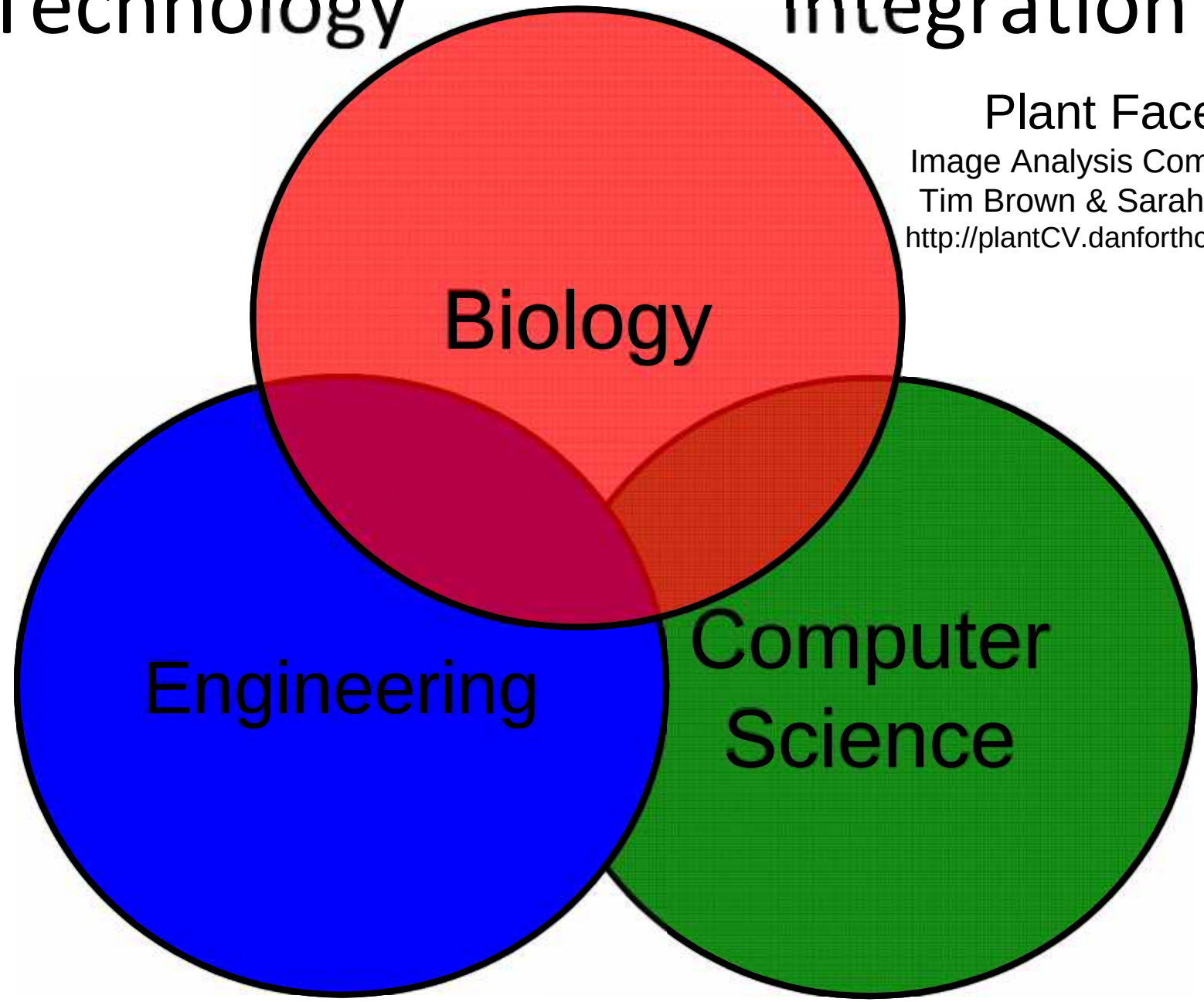
Integration

Plant Faces

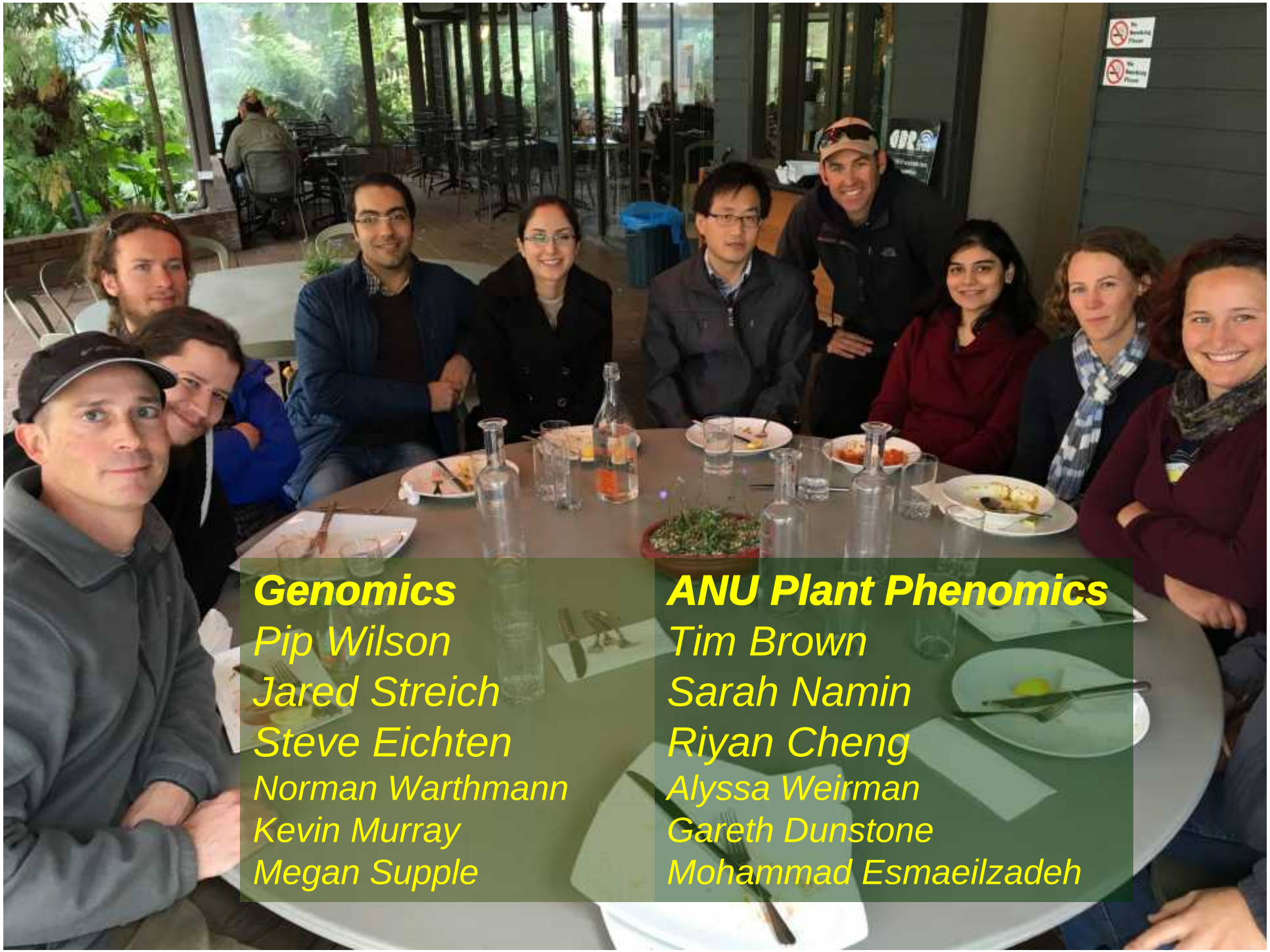
Image Analysis Competition

Tim Brown & Sarah Namin

http://plantCV.danforthcenter.org

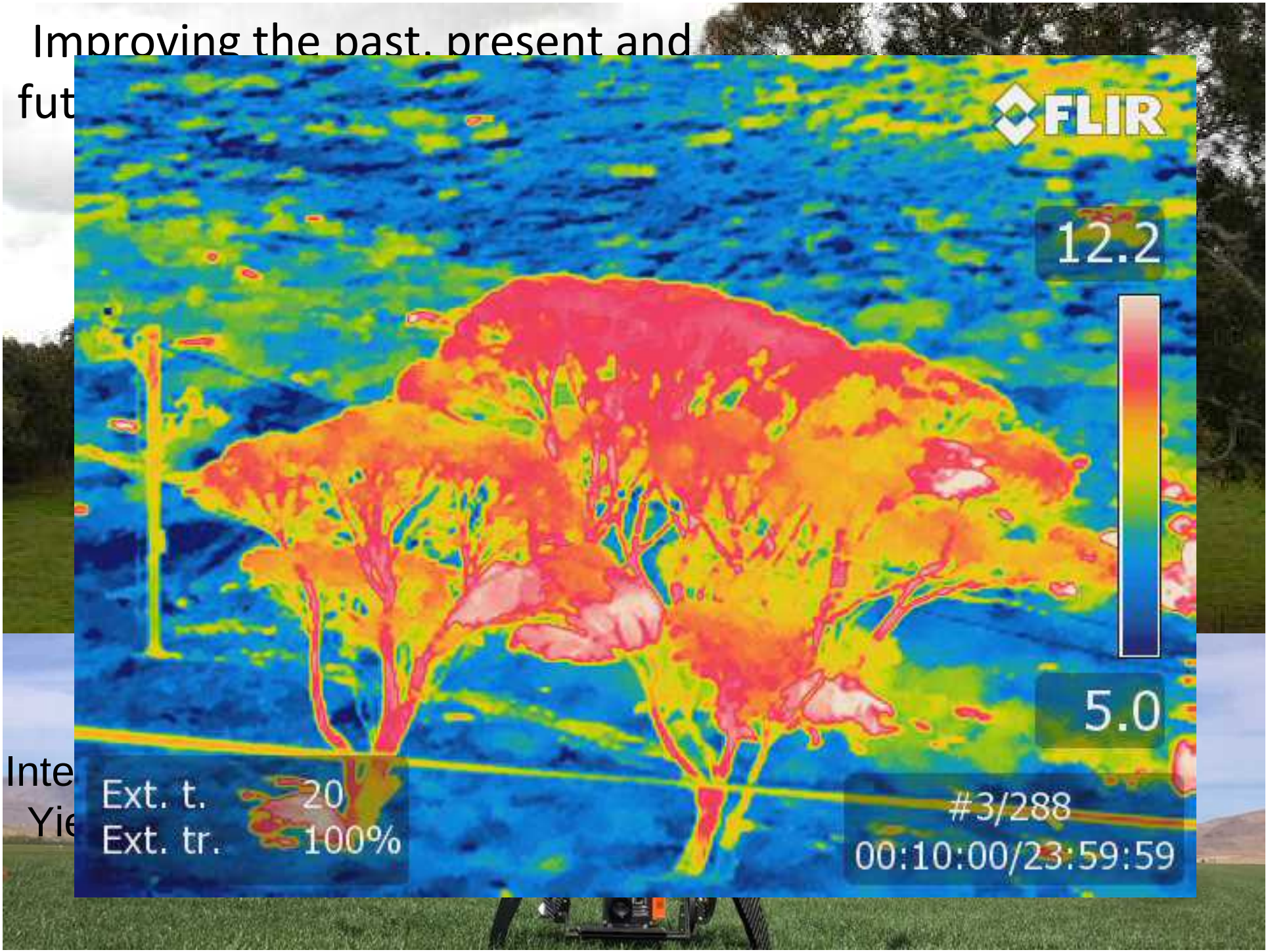


Unite Primary Industries
Mining and Agriculture
Landscape
Reconnection
+ geo-engineering
Genomics
Pip Wilson
Jared Streich
Steve Eichten
Norman Warthmann
Kevin Murray
Megan Supple
ANU Plant Phenomics
Tim Brown
Sarah Namin
Riyan Cheng
Alyssa Weirman
Gareth Dunstone
Mohammad Esmaeilzadeh
Nick Brasher
Prue Kell
Sue Lyons
Steve Dempsey
borevitzlab.anu.edu.au


Genomics
Pip Wilson
Jared Streich
Steve Eichten
Norman Warthmann
Kevin Murray
Megan Supple
ANU Plant Phenomics
Tim Brown
Sarah Namin
Riyan Cheng
Alyssa Weirman
Gareth Dunstone
Mohammad Esmaeilzadeh

Improving the past, present and

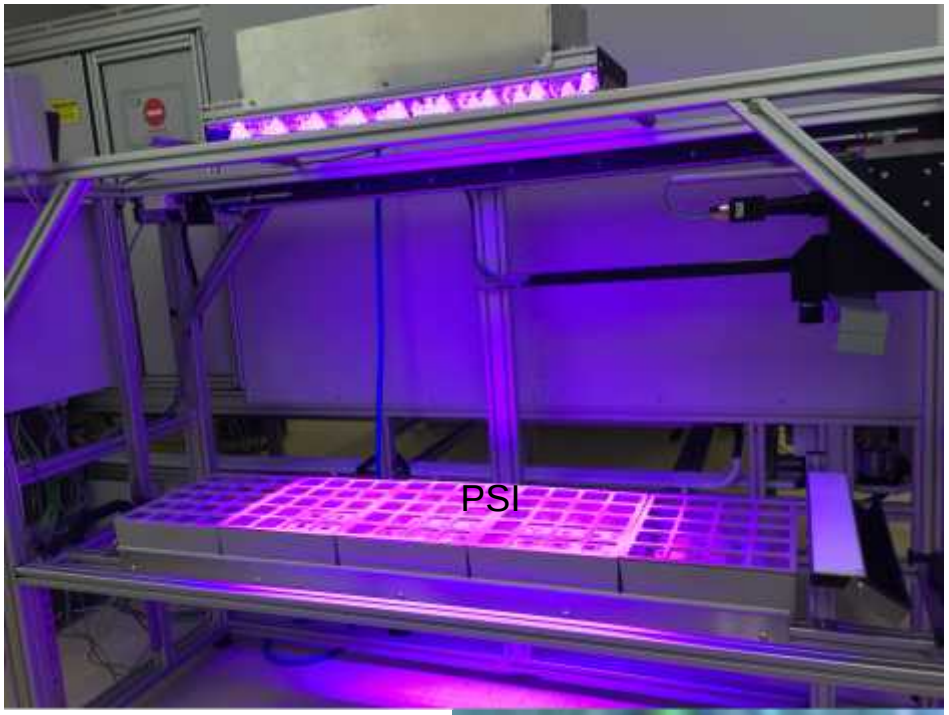
fut



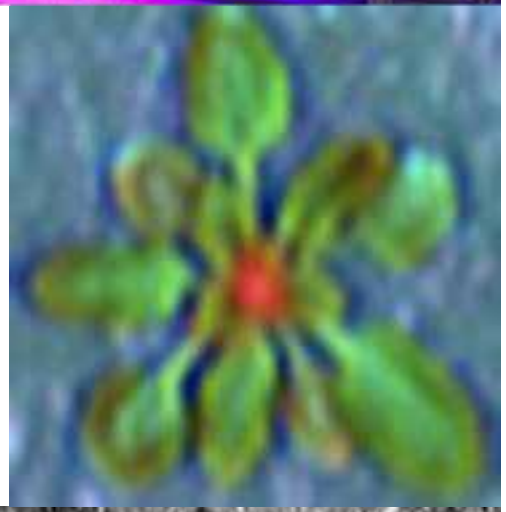
Inte

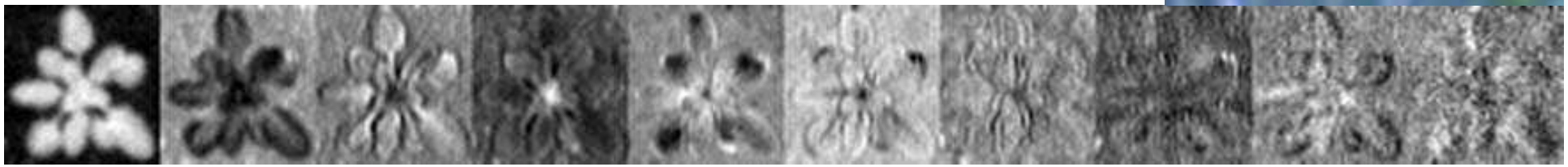
Yie

Spectranomics



- What is this?
  - –Spectra is the 5th dimension.
  - –Chemical spectral fingerprinting
  - –Physiology based spectral index
    - Evans, Furbank, **Alexander Ivakov**
- What do you do with this information?
  - –Crop & Genetic Models ->Predictions
    - Yield (biomass, grain)
    - Water and Nutrient Use Efficiency
    - Life Support Services





Prediction and Selection

- Population structure and kinship - random
  - Depends on sample and trait
- SNPs - fixed
  - 10s of large effect (1% var explained) = 10%
  - 100s medium (0.1%) = ~10%
  - 1000s small (0.01%) = ~10%
- Experimental Scale
  - 1000s sample @ $10s = >$10k
  - 100s samples @ $100s

B. distachyon

- Significant amount of Biodiversity in both the Iberian Peninsula and Turkey

- Australia has two *B. distachyon* diploids, one East Med. One West. Med. One originating in Turkey BdTR13_ genotype, the other being a Pyrenees ABR like line.