An ideal biomass crop has.....

- C4 photosynthesis
- Wide Adaptation
- High Yield Potential with regrowth potential
- Water Use Efficiency
- Drought Tolerance
- Pest Resistance
- Good Crop Rotation
- Non competitive with food, feed systems
- Existing Agricultural Infrastructure
- Non-invasive
- Winter Standing
- Excellent Genetic Platform
- Composition
  - Starch, sugar, cellulose available
- Perennial Crop

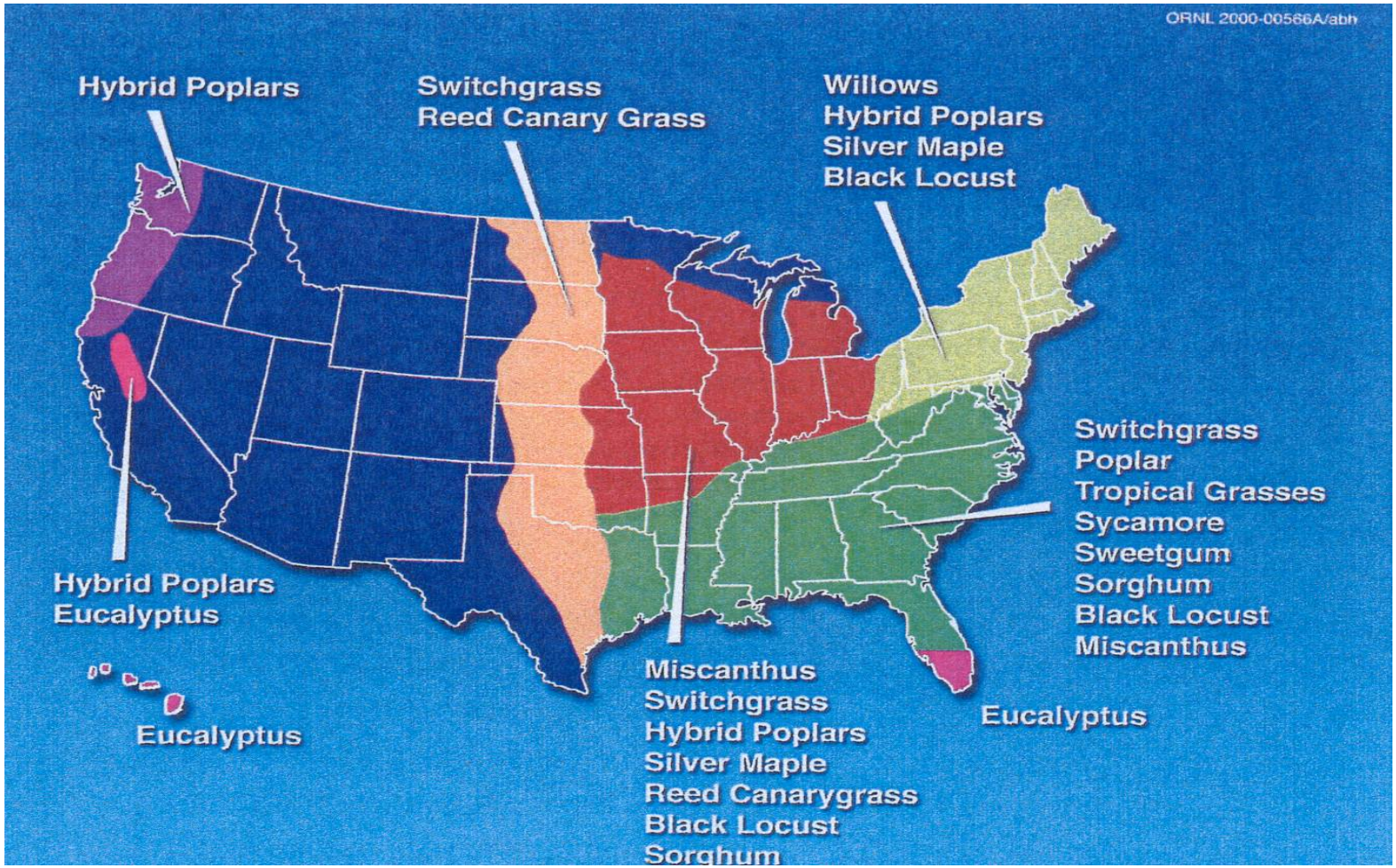
C4 Bioenergy Grasses for the Southern U.S.

Crop	Growth	Propagation	History	Biomass	Notes
Switchgrass	Perennial	Seed	None	Lignocellulose	Problems w/ seed prod. & stand est.
Sugarcane	Perennial	Cutting	Sugar	Sugar, Lignocellulose	cold sus. limits range
Miscanthus	Perennial	Rhizomes	None	Lignocellulose	Propagation limited
Sorghum	Annual	Seed	Grain, Forage	Sugar, Starch Lignocellulose	Drought tolerance

Miscanthus
← Sorghum
Sugarcane →

Switchgrass

Big Country, Many Environments, Multiple Bioenergy Crops (Source: Department of Energy)



Sorghum as a Bioenergy Feedstock

- Wide Adaptation
- High Yield Potential
- Water Use Efficiency and Drought Tolerance
- Existing Agricultural Infrastructure
- Multiple Types for Different Production
  - Sorghum is the only crop to produce sugar, starch and ligno-cellulosic biomass
- Genetic Platform is available
- **Annual Crop**

Bioenergy Sorghum

Sweet Sorghum

- Some Grain Yield
- Juicy Stalk
- Highest concentrations of soluble sugar
- Highly variable for
  - Maturities (photoperiod sensitivity)
  - Types of Sugar
  - Biomass and Sugar Yield

Texas A&M AgriLife Research

Biomass Sorghums

- Strongly PS
  - Do not flower
  - Long Canopy Duration
  - Enhanced Drought Tolerance
  - Higher Yields
- Structural Carbohydrates
  - Minimal Starch
  - Lower Sugar

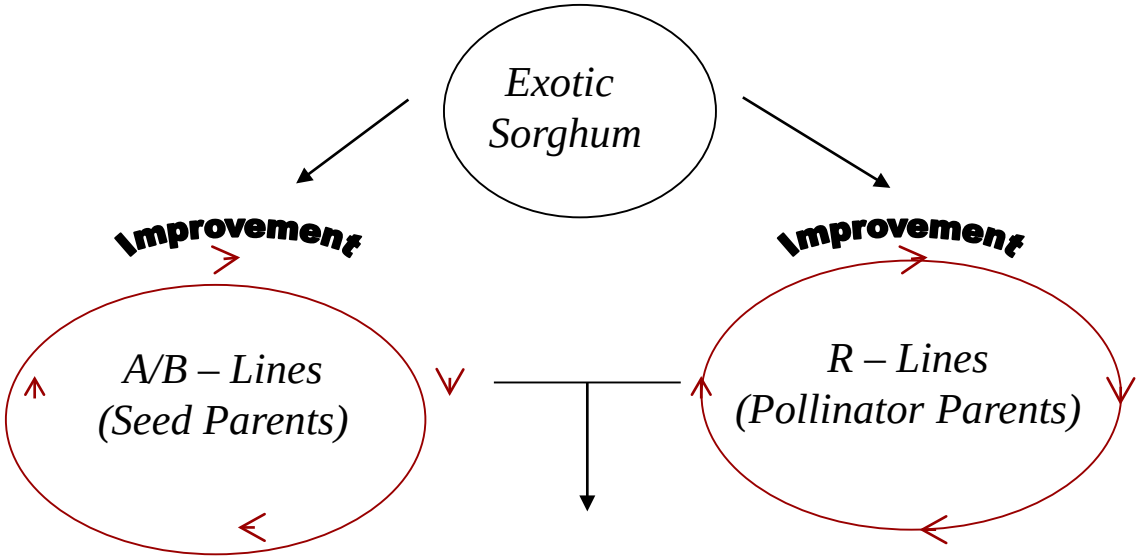
TEXAS A&M AGRILIFE RESEARCH

Sorghum Improvement

- Grown as a Hybrid Crop
  - Seed Parent
  - Pollinator Parent
- Established methodologies applicable to all types of sorghum
- Genetic Diversity is the key
- Effective Phenotyping Critical

Sorghum Diversity

Texas A&M Agrilife Research Breeding



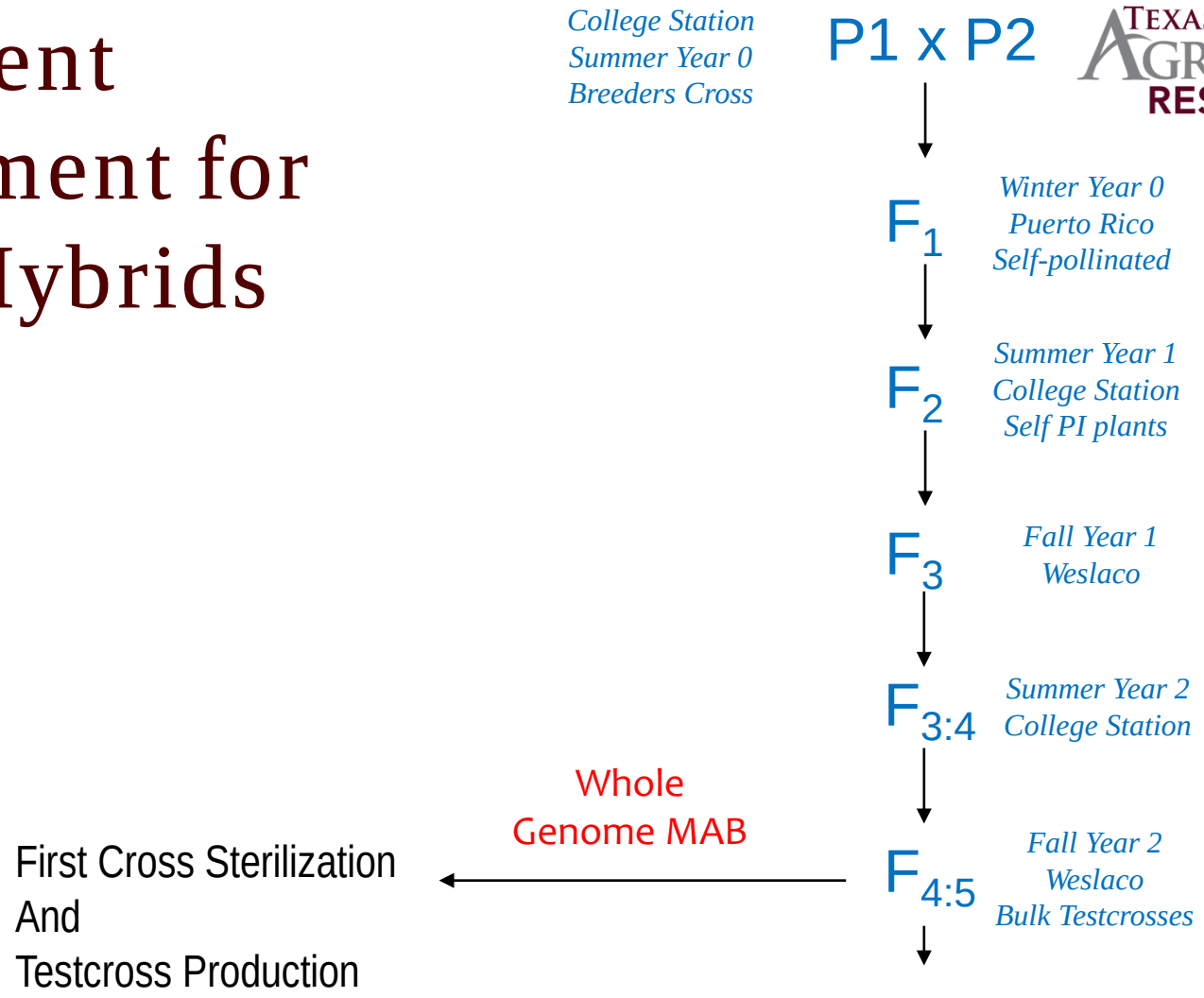
Good Energy Hybrids have 120 % High-Parent Heterosis

Public Research

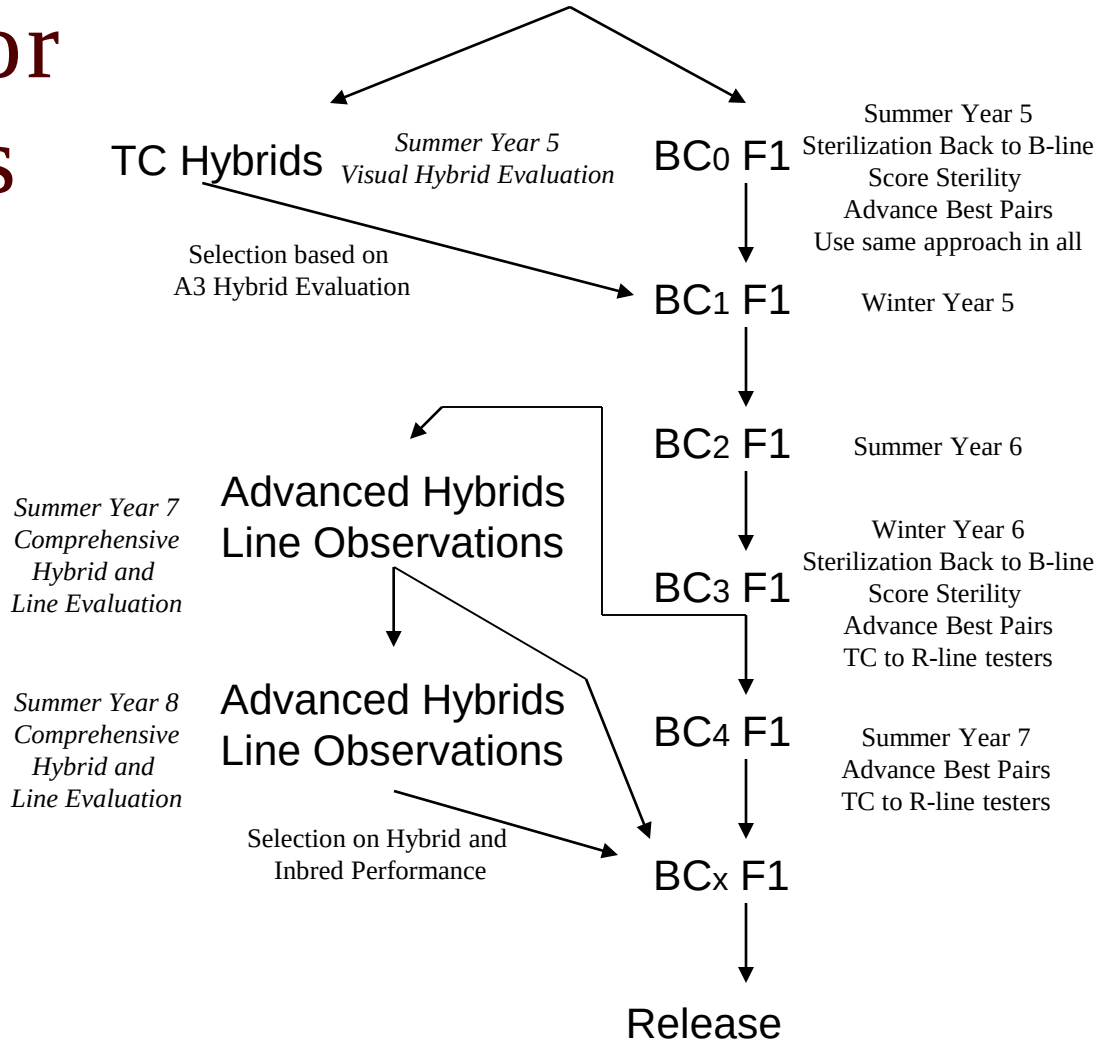
Private Industry

- Pedigree, Backcrossing, Population
- Winter nurseries – RGV, MX, PR
- Private Comp. Cooperative Testing
- Products: Germplasm and Parental Lines

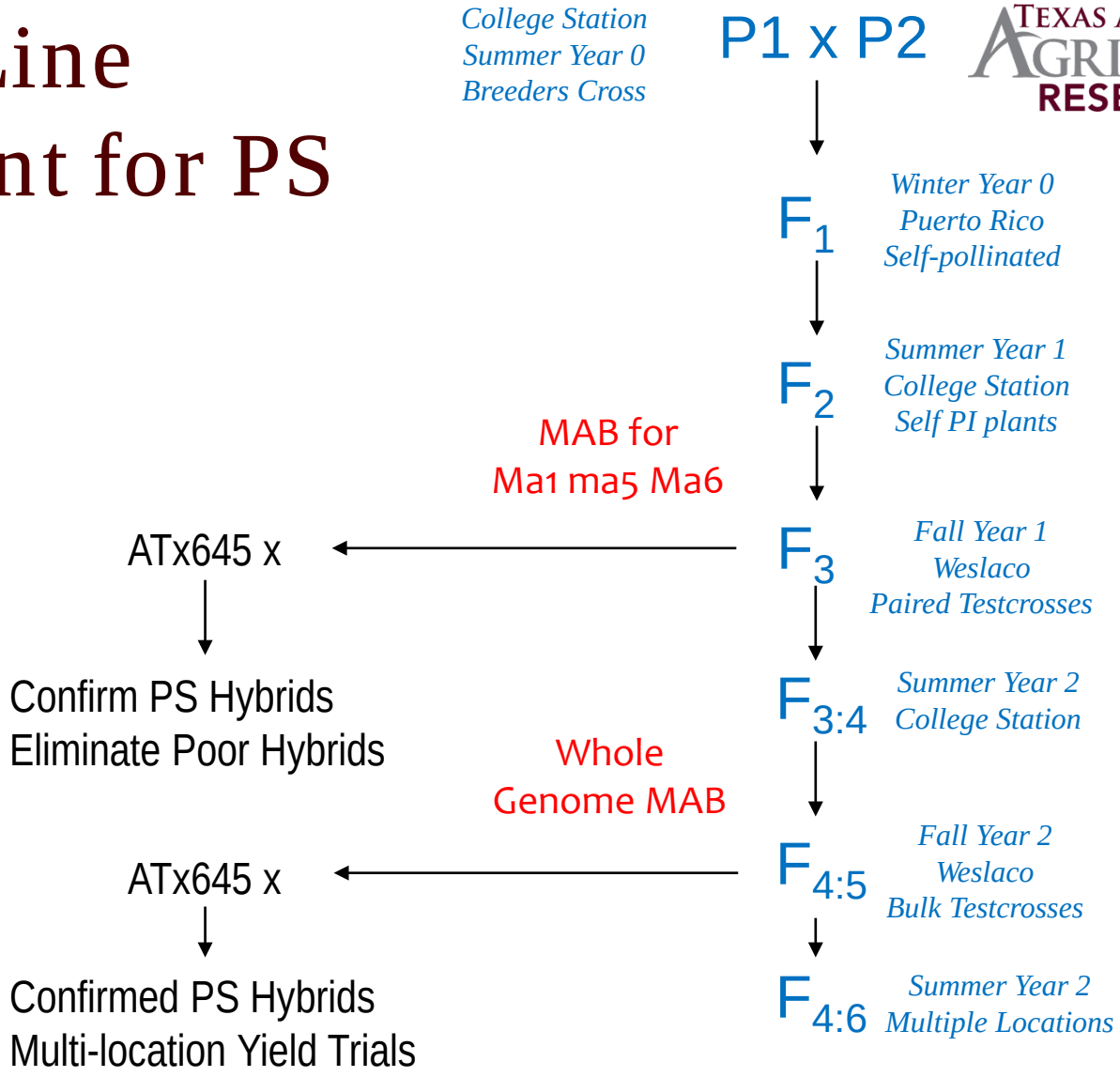
Seed Parent Development for Energy Hybrids

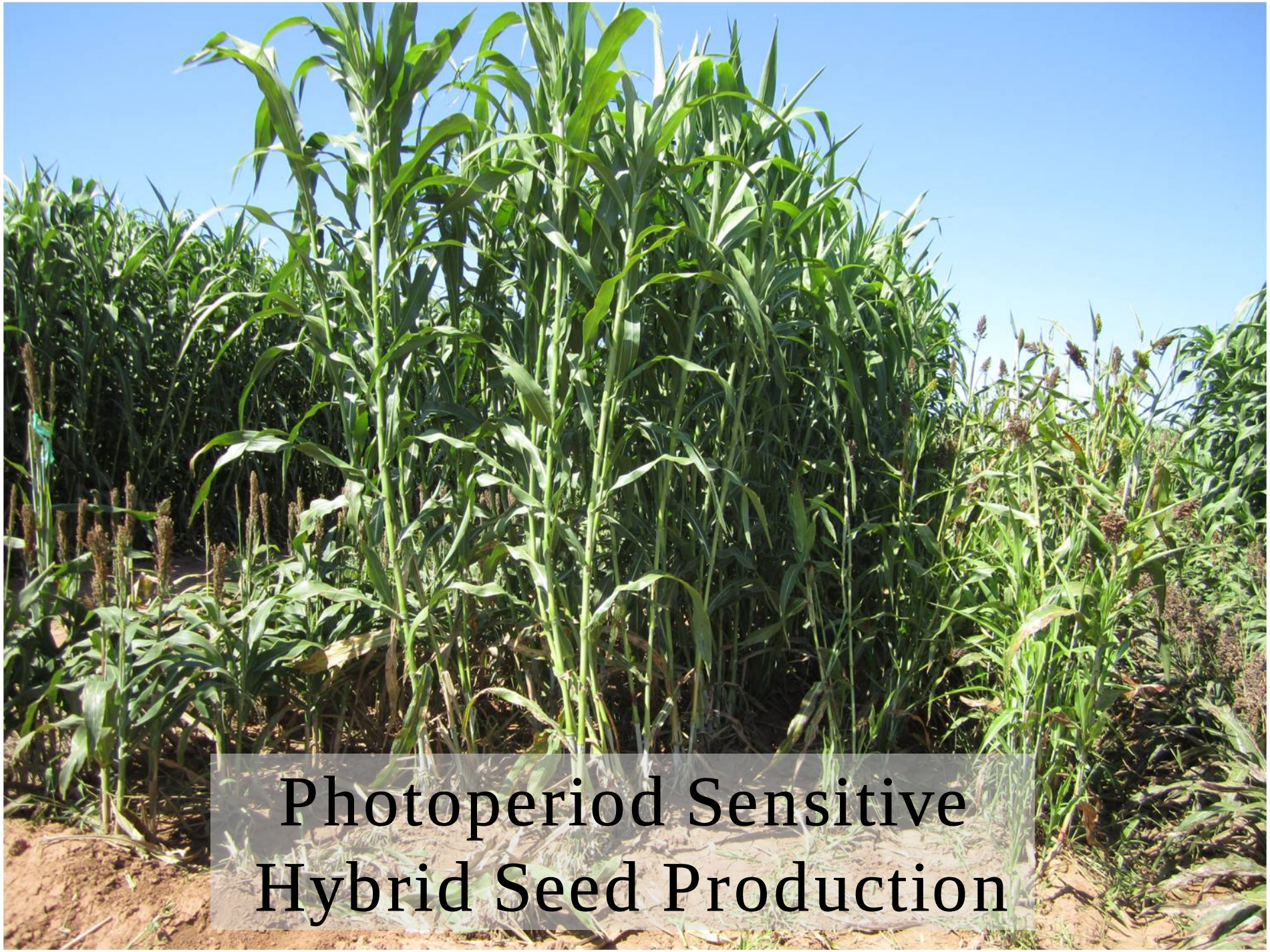


Seed Parent Development for Energy Hybrids



Pollinator Line Development for PS Hybrids




Photoperiod Sensitive
Hybrid Seed Production

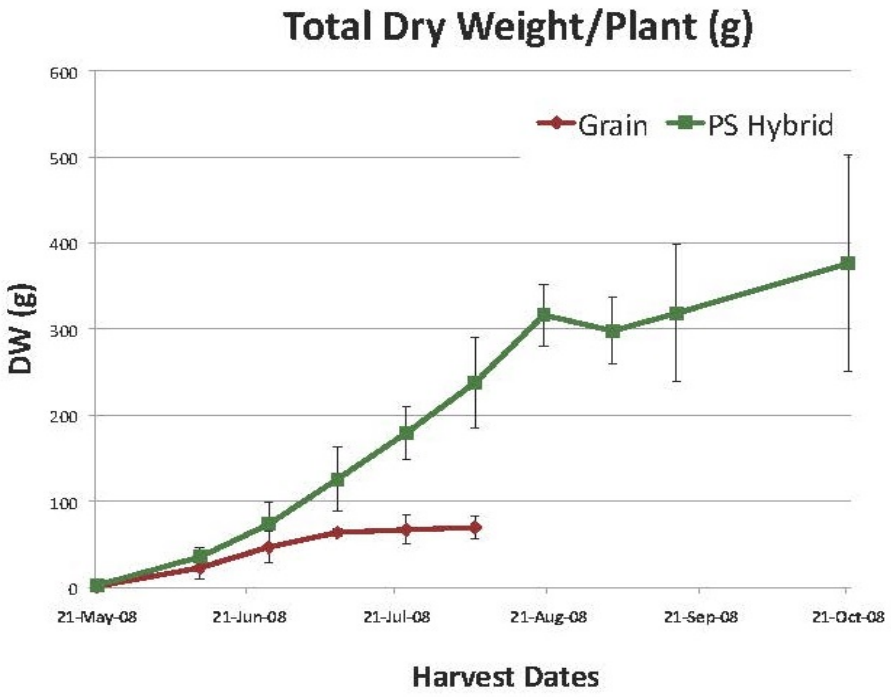
Energy Sorghum Breeding

- Seed Parents
  - Short Stature
  - Acceptable seed yield
  - High Sugar
- Pollinator Parent
  - Complementary Height
  - Complementary Maturity
  - Juicy, Sugar
  - Combining Ability

- Either (or both)
  - Disease Resistance
  - Drought Tolerance
  - Lodging resistance
  - Composition
  - Heterosis

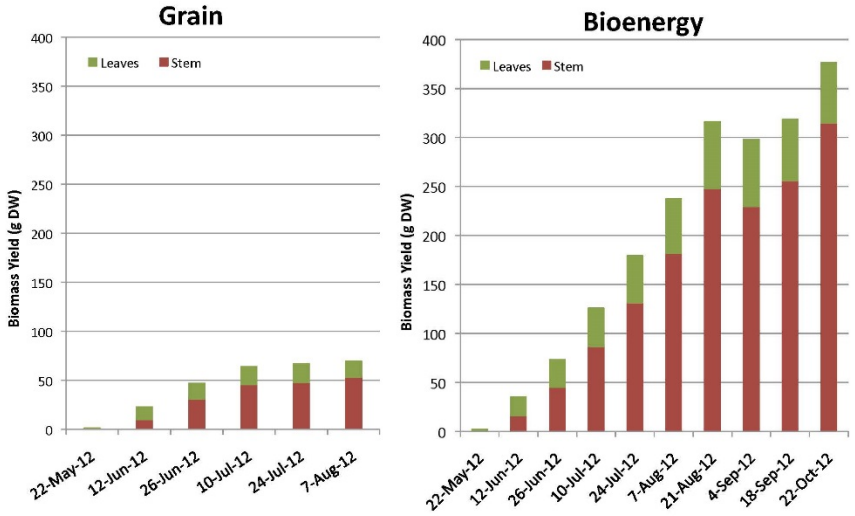
Traits

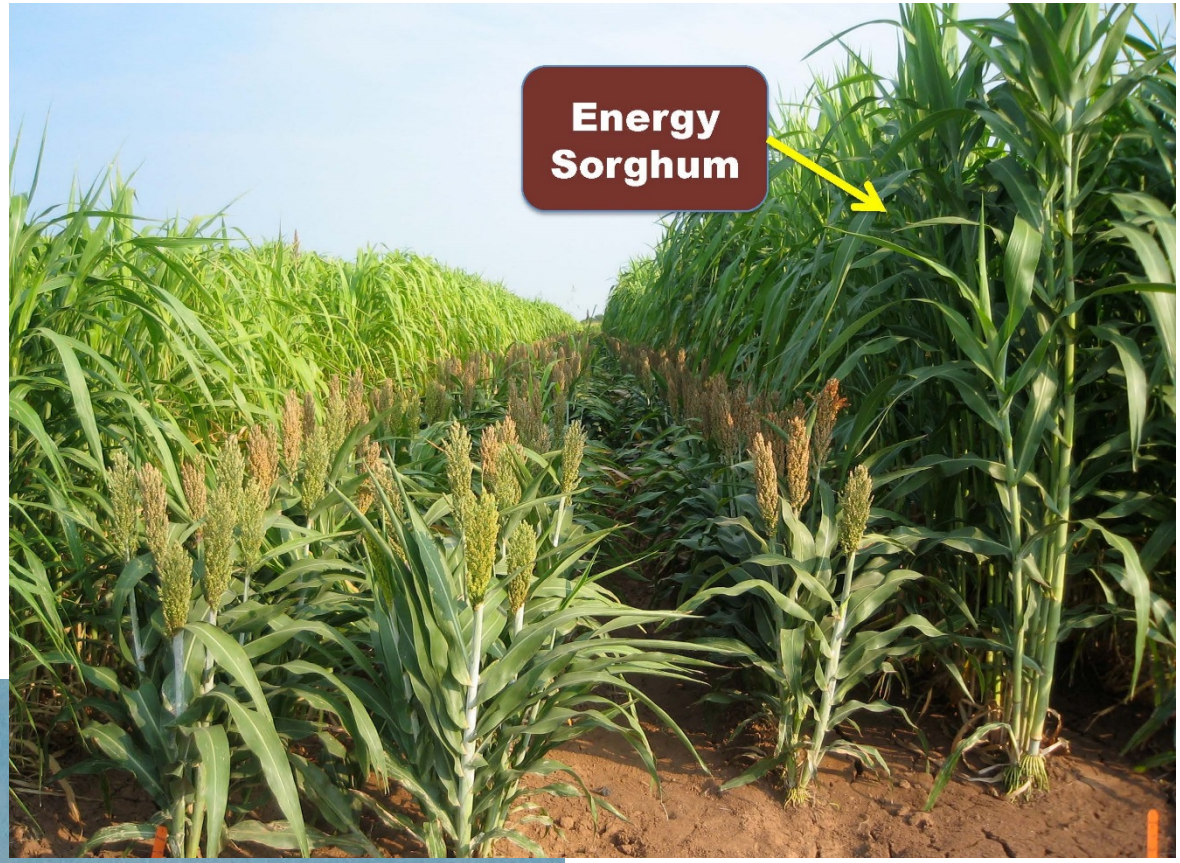
- Biomass Yield
  - Growth and Development
  - Economic Portion of Crop
- Composition
  - Non-structural Carbohydrates
  - Structural Carbohydrates
  - Protein
  - Ash
  - Lipids
- Input Use Efficiency
  - Water
  - Nutrient
- Abiotic Stress Tolerance
  - Drought
  - Nutrient
  - Lodging
- Biotic Stress Tolerance
  - Disease resistance
  - Pest Resistance
  - Lodging
- Evaluation
  - How
  - When



Olson et al., BioFPR, 2012

Biomass Partitioning X Time




Energy
Sorghum


1DWARF
2 DWARF
3DWARF
4 DWARF

Traits

- Biomass Yield
  - Growth and Development
  - Economic Portion of Crop
- Composition
  - Non-structural Carbohydrates
  - Structural Carbohydrates
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  - Ash
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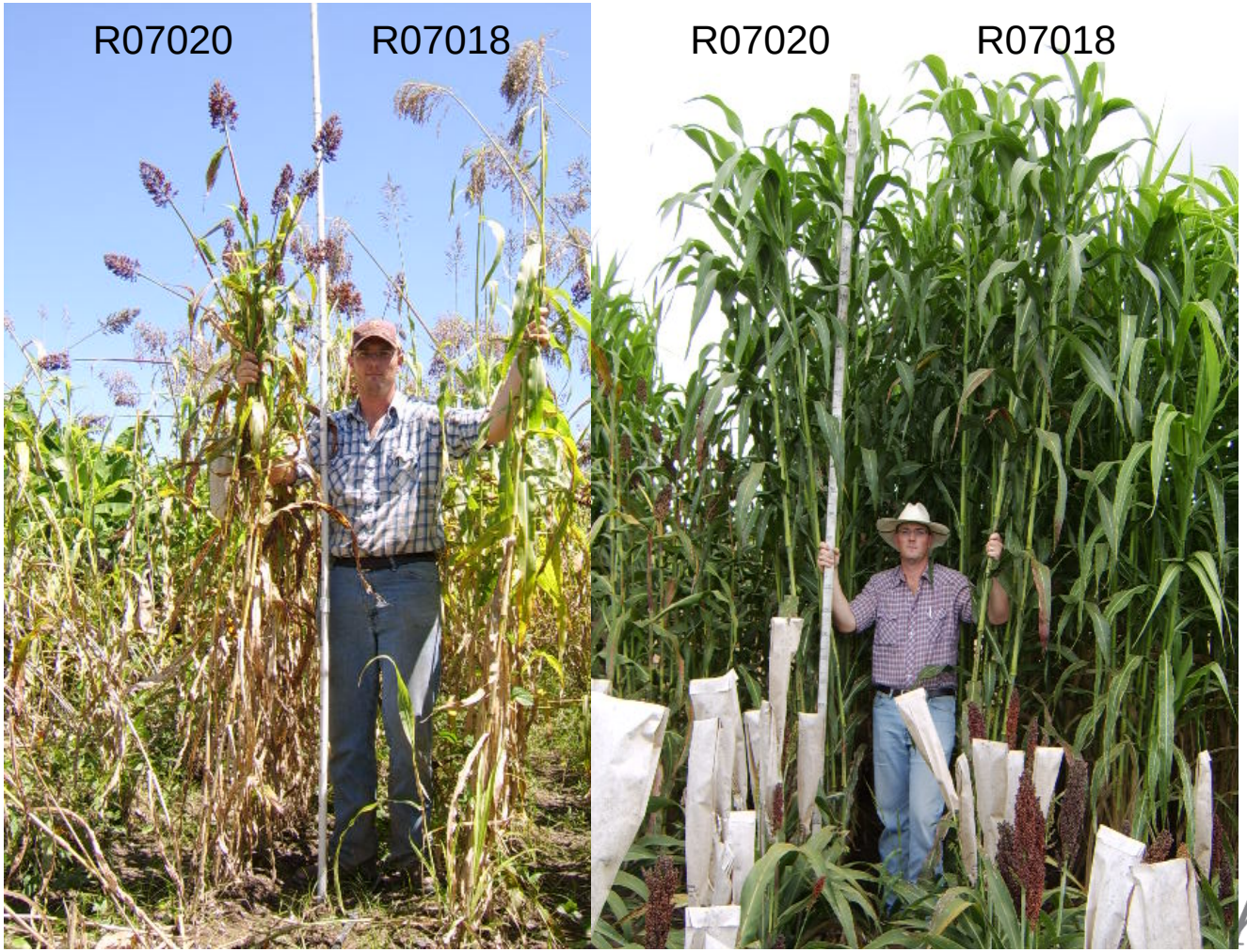
- Biotic Stress Tolerance
  - Disease resistance
  - Pest Resistance
  - Lodging
- Evaluation
  - How
  - When

Phenotyping – old fashioned ways……

QTL Analysis of PS Sorghum

Puerto Rico

College Station



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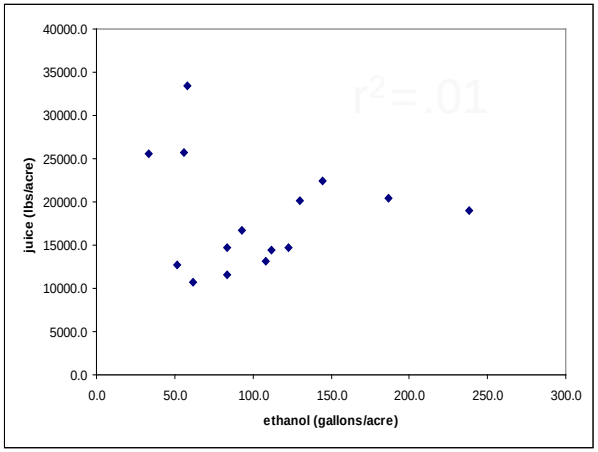
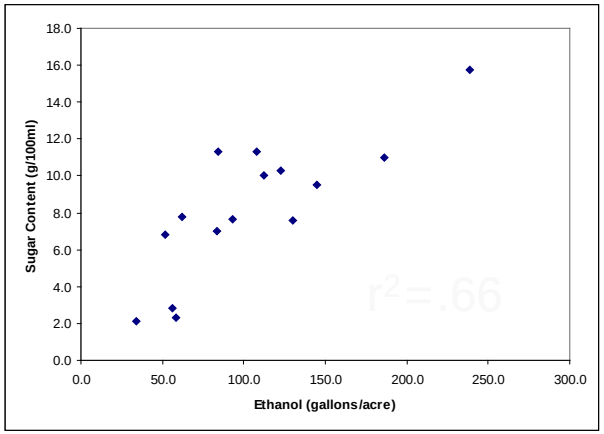
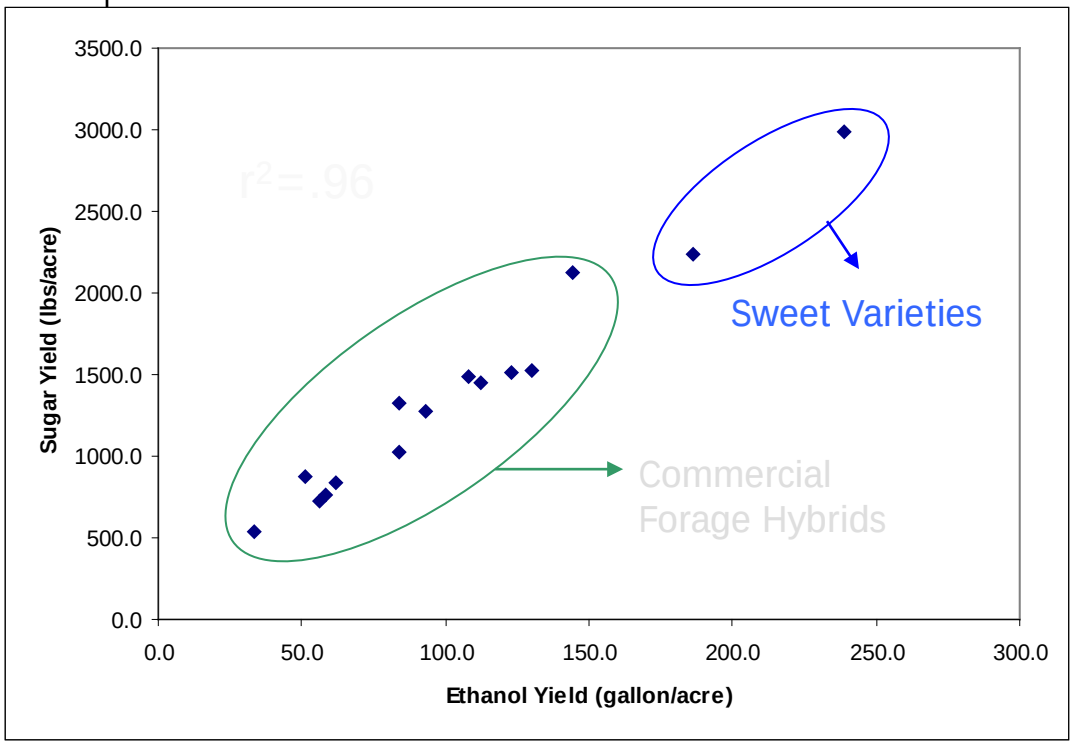
Sugar and Ethanol Production





Sugar Yield = Juice (lbs/acre) * Sugar Concentration (g/100ml)



Composition Range (NIR estimates)

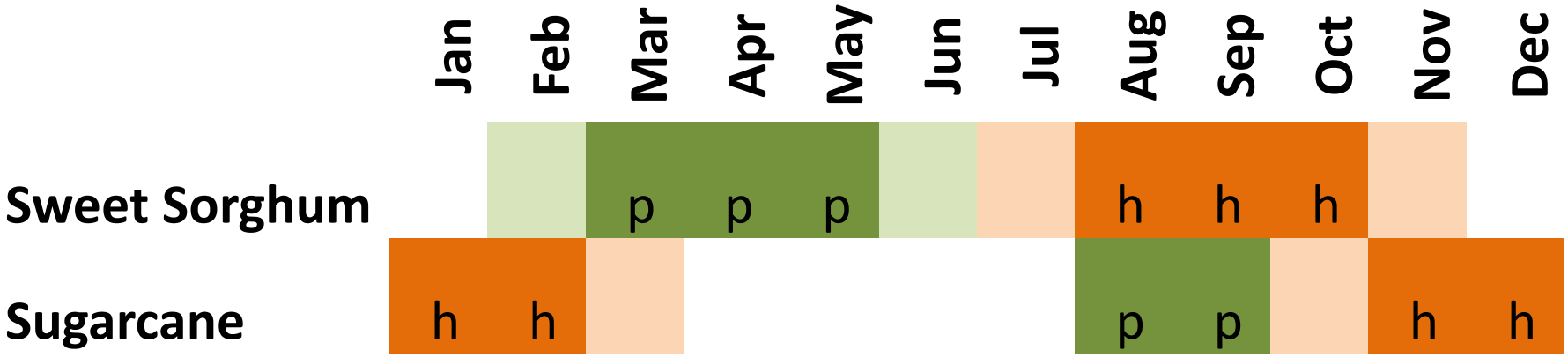
	Dietary Lignin	Dietary Cellulose	Dietary Hemicellulose
Total	9.5 - 20.6	14.7 - 43.4	13.8 – 25
Breeding	13.7 - 20.6	26.1 - 37.1	18.7 - 24.6
Forage PI	9.5 - 17.4	18.8 - 43.4	15.8 – 25
Forage PS	13.9 - 15.9	31 - 32.7	19.9 - 20.9
Grain	14.4 - 17.8	31.9 - 33.2	18.2 - 18.7
Sweet Sorghum	10.8 - 11.6	24.4 - 32.8	15.6 - 21.3

- Significant variation for composition
  - 2X range lignin composition
  - 2.5X range in cellulose
  - 1.5X range in hemicellulose
- Most Variation in breeding germplasm

Growth and Development
Harvest Season Duration

May Planting	April Planting

Complementary Crops: U.S. Gulf Coast



- Combined harvest results in a seven month harvest window.
- Different maturity sorghums and sugarcane are critical