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Department of Soil & Crop Sciences
Biorefining Perennial Grasses:

Sustainability via Disruptive Breeding

Russ Jessup
‘Incremental’ vs. ‘Disruptive’

![Image of incremental and disruptive technologies]

- Incremental: Small, steady improvements in existing products or services.
- Disruptive: Revolutionary changes that disrupt existing markets and industries.

Graphs showing performance over time for incremental and disruptive technologies.

- Incumbents nearly always win.
- Entrants nearly always win.

Source: Clayton Christensen, 1997

AgriLIFE RESEARCH
Texas A&M System
‘Value Creation’ vs. ‘Value Capture’

Technology Driven

Consumer Driven

Incremental Innovation Graph

Degree of Value-Add

Degree of Newness

Global population and cereal production

Source: U.N. Food & Agriculture/FAOSTAT database, U.S. Census International Database
‘Establishment’ vs. ‘Innovation’

Complex Established Legacy Sectors (CELS)

• Perennial Grain Crops
• Polyculture Cropping Systems
• BIOREFINERIES
• …
‘Value…$$’ vs. ‘Value Systems’
‘Sustainability’ vs. ‘Achievability’
Biomass?

Primary Production: 2015

Human Appropriation of Net Primary Production

http://www.nasa.gov/images/content/61350main_hanpp2.jpg
World Biomass demand in 2050

<table>
<thead>
<tr>
<th>Category</th>
<th>Forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food / Feed</td>
<td>10 billion ton biomass for 3 billion ton food</td>
</tr>
<tr>
<td>Energy</td>
<td>10 billion ton equivalent to 160 EJ</td>
</tr>
<tr>
<td>Chemical industry</td>
<td>1 billion ton for 0.3 billion top product</td>
</tr>
<tr>
<td>Specialties</td>
<td>1 million ton</td>
</tr>
<tr>
<td>Wood and composites</td>
<td>2 to 3 billion ton</td>
</tr>
</tbody>
</table>

Current production: 170 billion ton biomass of which 6 billion ton is used:
- 1.8 grains
- 2.2 other food (sugar, vegetables, starch, etc.)
- 2 wood
- 0.01 other non-food

4% (2015) → 14% (2050)
Biorefining Perennial Grass Feedstocks
Bioplastics

2,000,000 plastic bottles, used every 5 minutes
Bioplastics

- starch
- sugar (PLAs)
- starch or sugar (PHAs, PHBs, PHHs)
- lignin (cellulose acetate)
- biopolymers...etc.

Bioplastics are not a new idea

Classic film clip of Henry Ford, 1941
whacking an early soy composite bumper

Why didn’t they take off then?
What’s driving their adoption now?
Who is leading?
Specialty Chemical Platforms

- resins
- adhesives
- lubricants
- solvents
- cosmetics
Fiber

- Fiber-crete
- Composites
- Insulation
- Textiles
Silica

- Rice Hull Ash
- Caustic Soda

Caustic Digestion

Black Sodium Silicate

- Electronic Grade Silicates
- Processing

Filtration

- Activated Carbon
- Commercial Grade Silicates
- Micro-Electronic Precipitated Silicas

Purification of water, sweeteners, etc.
Soaps, Paper etc.
CMP Slurries

- Precipitated Silica & Carbon
- Fine-Celled Foam

Processing

Polymer Mixing & Foaming

→ PV
→ Microchips
Protein

Leaf Protein Concentrate (LPC)

Cassava LPC fortification

http://www.leafforlife.org/

Leaf Meal Supplements

<table>
<thead>
<tr>
<th>Grass</th>
<th>Productivity (tons/yr)</th>
<th>Protein content (%)</th>
<th>Animal yield (animals/hectare/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panicum maximum (Guinea grass)</td>
<td>12-40</td>
<td>8-12</td>
<td>1.5-2.5</td>
</tr>
<tr>
<td>Brachiaria radicans (Tanner grass)</td>
<td>20-25</td>
<td>8-12</td>
<td>2-2.5</td>
</tr>
<tr>
<td>Brachiaria humicola</td>
<td>18-25</td>
<td>4-8</td>
<td>1.5-2</td>
</tr>
<tr>
<td>Pennisetum purpureum Schum cv. Mott (Dwarf elephant grass)</td>
<td>40-50</td>
<td>10-15</td>
<td>3-5</td>
</tr>
</tbody>
</table>
Functional Foods

Prebiotics

COS: Cello-oligosaccharides

XOS: Xylo-oligosaccharides
Vitamins

- plant derived ‘whole-food’ vitamins
- feed ‘leaf meal’ supplements

---

Dietary survey of Sri Lankan pre-school children and the potential role of leaf concentrate supplementation

Table 3. Potential contribution of a leaf concentrate (LC) supplement* in ameliorating nutrient deficits

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Observed mean intake (% of RDA)</th>
<th>Deficit in mean intake (% of RDA)</th>
<th>Contribution provided by LC (% of RDA)</th>
<th>Deficit not by LC (% of deficits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>78 (16)</td>
<td>22</td>
<td>negligible</td>
<td>-</td>
</tr>
<tr>
<td>Protein</td>
<td>130 (33)</td>
<td>-</td>
<td>8</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>51 (47)</td>
<td>49</td>
<td>95</td>
<td>95</td>
</tr>
<tr>
<td>Ascorbic acid</td>
<td>138 (107)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Thiamin</td>
<td>99 (25)</td>
<td>1</td>
<td>12</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>90 (60)</td>
<td>10</td>
<td>25</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Niacin</td>
<td>72 (22)</td>
<td>28</td>
<td>16</td>
<td>57</td>
</tr>
<tr>
<td>Iron</td>
<td>150 (80)</td>
<td>-</td>
<td>82</td>
<td>-</td>
</tr>
<tr>
<td>Zinc</td>
<td>20 (7)</td>
<td>80</td>
<td>44</td>
<td>55</td>
</tr>
<tr>
<td>Calcium</td>
<td>105 (60)</td>
<td>-</td>
<td>negligible</td>
<td>-</td>
</tr>
<tr>
<td>Folic acid</td>
<td>159 (68)</td>
<td>-</td>
<td>158</td>
<td>-</td>
</tr>
</tbody>
</table>

* Based on a supplement per child of 19 g of moist leaf concentrate made from 333 g of leaf. Cox et al. 1993
Fertilizer
Phytoremediation → Phytomining

Volatilization

Transpiration

Mercury, selenium, TCE & PCE, + metabolites

Rhizospheric Metabolism

Metals, organics, & radionuclides

Inorganics

Heavy metals, radionuclides TCE/PCE metabolites

Organics

TCE PCE

Soil & sediment stabilization

Nickel

Gold

‘Nanoparticle’ Portable Fuel Cells
Carbon: Sequestration

80 ppm atm CO₂ = 167 Gt Carbon
Hold your breath?

**Soil Sequestration (10+ Yrs)**
- Soil Density = 1.2
- 12” soil = 3,658 T/Ha
- 1% SOM = 36.58 T/Ha
- SOM (58% C) = 21.21T C/Ha
- 5.1 B Ha cropland globally
- 1.56% SOM/Ha = 80 ppm atm C

**Rhizomatous Crops (1 Yr.)**
- Perennial S. Spp.
  - 60-70% biomass belowground
  - 18” soil = 26.7 dT rhizomes per Ha
  - Rhz (45% C) = 12 T C/Ha
‘Fossil’ Biofuels vs. ‘Renewable’ Biofuels
World primary energy consumption grew by 1.4% in 2008, below the 10-year average. It was the weakest year since 2001. Oil remains the world’s dominant fuel, though it has steadily lost market share to coal and natural gas in recent years. Oil’s share of the world total has fallen from 38.7% to 34.8% over the past decade. Oil consumption...
U.S. Renewable Energy Utilization

**Figure 2: Summary of biomass resource consumption**

- **Forest products industry**
  - Wood residues: 44
  - Pulping liquors: 52
  - Urban wood and food & other process residues: 35
  - Fuelwood (residential/commercial & electric utilities): 35
  - Biofuels: 18
  - Bioproducts: 6

<table>
<thead>
<tr>
<th>Biomass Consumption</th>
<th>Million dry tons/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>190</td>
</tr>
</tbody>
</table>

- Forestlands and agricultural lands contribute 190 million dry tons of biomass - 3% of America’s current energy consumption.

Source: EIA, 2004a & b
Biofuels: Biopower

- **Solid**
  - biopower

- **Liquid**
  - ethanol
  - butanol
  - biodiesel

- **Gas**
  - Biogas/syngas
Biofuels:

- **Solid**
  - biopower

- **Liquid**
  - ethanol
  - butanol
  - biodiesel

- **Gas**
  - Biogas/syngas
Biofuels: Butanol

• Solid
  • biopower

• Liquid
  • ethanol
  • butanol
  • biodiesel

• Gas
  • Biogas/syngas

Butanol fermentation

• Butanol \( (\text{CH}_3(\text{CH}_2)_3\text{OH}) \) has higher heating value per gallon (energy content) than ethanol and is less hygroscopic
• Acetone-Butanol-Ethanol fermentation pathway
• Clostridium beijerinckii, \( C. \ acetobutylicum \)
• Gas stripping

DuPont - BP Biofuels Partnership
Biobutanol Development & Launch

[Diagram showing the process from biomass to biobutanol]
Biofuels: Biodiesel

- **Solid**
  - biopower

- **Liquid**
  - ethanol
  - butanol
  - biodiesel

- **Gas**
  - Biogas/syngas

Pretreatment

‘Lipid Accumulating’ Microbes

Biodiesel (FAME, FAEE)

- Transesterification
  - Reaction between lipid and alcohol using alkaline catalyst
    - Fatty acid methylester (FAME) - oil + methanol/NaOH or KOH
    - Fatty acid ethylester (FAEE) - oil + ethanol/KOH or NaOH
  - Reduced viscosity, improved atomization
  - Improved emissions (uncertainties regarding NOx)
  - Lower toxicity
Biofuels: Syngas

- **Solid**
  - biopower

- **Liquid**
  - ethanol
  - butanol
  - biodiesel

- **Gas**
  - Biogas/syngas

**Anaerobic Digestion**

- CH$_4$ + CO$_2$ biogas
- Digesters, landfills
- Electricity
- Heat
- Biogas upgrading
  - Pipeline quality
  - CNG
  - URE
  - Gas-To-Liquids (GTL)
- Other chemical synthesis

Onsite and Grid Power, Fuels, Chemicals

Syngas

- Direct use
- Fischer-Tropsch
- Isomerisation
- Oxo synthesis
- Water-gas shift
- Methanation
- Alkali-doped
- Ethanol synthesis
- Methanol synthesis

Air-Tight Digester Vessel

First Phase: Liquefaction

Second Phase: Gasification

Complex Organic Material (Manure)

Simple Organics (Volatile Acids)

Acid-Forming Bacteria

Methane-Forming Bacteria

8 - 20 Days, Temperature dependent
‘Bioenergy Belt’:
Tropical vs. Temperate Feedstocks

Average Precipitation
United States of America

- Miscanthum: Switchgrass, Giant Reed
- Sorghum: Pennisetum, Saccharum

Modeling performed by Christopher Daly using the PRISM model, based on 1961-1990 normals from NOAA Cooperative stations and NRCs SN landscape survey sites. Sponsored by USDA ARS Water and Climate Center, Portland, Oregon.

Oregon Climate Service: George Taylor, State Climatologist (541) 737-5705

AgriLIFE RESEARCH
Texas A&M System
‘Bioenergy Belt’
Perennial Grasses

Biomass Production
10 - 30 dt/ac/yr

Carbon Sequestration
3 – 4 dt/ac/yr

Low Inputs
(Resource Use Efficiency)

Alternative Uses
(Biorefineries)
Sustainability VS. Invasiveness

- **Soil**: GHGs, Carbon Sequestration, Erosion

- **Water**: Quality, WUE, Phytoremediation

- **Biodiversity**: Wildlife Habitat
Land VS. Water Resources

Grasslands

~80 million acres (TX)
>300 million acres (US)
>50 million acres of ‘landscapes’ (US)
Sterile, Seeded, High Biomass Feedstocks

Triploid Sterility (Seedless Crops)

Grapes
Watermelon
Banana
(Apples)
Improved PMN (Seeded)

Pearl Millet  
2n=2x

X

Napiergrass  
2n=4x

PMN

Seeded-Yet-Sterile (3x) hybrid

***Hybrid Seed Production: 1700 lbs/ac

Yield: 17+ dt/ac  
(10+ dt/ac in Yr. 1)
Improved PMN (Seeded)

Field PMN seed production feasibility trial (Weslaco)

<table>
<thead>
<tr>
<th>Pearl Millet ID</th>
<th>Seeding Date</th>
<th>Flowering Date</th>
<th>Napiergrass ID</th>
<th>Flowering Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEGL 09TX04</td>
<td>8/19/2013</td>
<td>11/10/2013</td>
<td>Merkeron</td>
<td>11/5/2013</td>
</tr>
<tr>
<td>PEGL 508273</td>
<td>9/2/2013</td>
<td>11/6/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEGL 09TX04</td>
<td>8/26/2013</td>
<td>11/22/2013</td>
<td>PEPU09FL03</td>
<td>11/20/2013</td>
</tr>
<tr>
<td>PEGL 508273</td>
<td>9/10/2013</td>
<td>11/21/2013</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Floral nicking—seeded pearl millet & vegetative napiergrass
Improved PMN (Seeded)

PMN herbicide phytotoxicity trials

- Hardened plants (greenhouse: completed)
- Seedlings (greenhouse: completed)
- Seed (growth chamber: completed)
- Seed (field: 2014)

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>(% safety: survival and leaf chlorophyll)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prowl, Atrazine, Permit, Plateau, Aim</td>
<td>91-100</td>
</tr>
<tr>
<td>Guardsman, Warrant</td>
<td>81-90</td>
</tr>
<tr>
<td>Metribuzin</td>
<td>61-80</td>
</tr>
<tr>
<td>Direx</td>
<td>21-60</td>
</tr>
<tr>
<td>Huskie, Dual</td>
<td>0-20</td>
</tr>
</tbody>
</table>

- Concep (fluxofenim) ‘protectant’ lethality
Improved PMN (Seeded)

• 3 locations
• 1 harvest (Dec.)
• 17.1 dta

Release: ‘Commercial Variety’ or ‘Selected Plant Materials’
PMN: Resource Use Efficiency

- College Station: Beeville
- NUE, WUE
- PMN, Sorghum, (Switchgrass)
- 2 harvests (July, Nov.)
Improved PMN (Seeded)

- PMN Seed Pelleting

PMN ‘multiple-seed pellet’
A, dehulled PMN seed
B, bulked PMN pellets
C, representative PMN pellets
D, deconstructed PMN pellets and isolated seed
Improved KG (Seeded)

Napiergrass
2n=4x

X

Pearl Millet
2n=2x

Kinggrass

Seeded-Yet-Sterile (3x) hybrid

***Hybrid Seed Production: Undetermined

Yield: 20+ dt/ac

+20% vs. Napiergrass
+10% vs. PMN
Napiergrass Sterility System

- Novel hybridizations

**KG:** Objs. 2.1 & 2.2
(Merkeron x PEGL09TX04, PI508273)
(seeded KG, pop. dev.)

**P. spp. hybrids:** Objs. 2.1 & 2.3
(PEPU09TX01 x *P. spp.*)

- Male-sterile population

(PEPU09TX01 x Merkeron)
80 novel F₁ MS accessions

  - Selfed-seed capacity (completed)
  - Pollen fertility (in progress)
  - Genetic mapping (in progress)

- Improved biomass male-sterile selections (2014)

  - Improved Kinggrass hybrids
Improved KG (Seeded)

• Hybrid KG Seed Production

KG

- KG12TX08

• Seed pelleting / coating

Male-Sterile Napiergrass

Pearl Millet
Molecular Tool Development

Spp. specific (hybrid verification):

- *P. orientale*
- *P. flaccidum*
- *P. purpureum* (PMN)
- *P. glaucum* (Kinggrass)

AJPS (2013)

Confirmation of Pearl Millet-Napiergrass Hybrids Using EST-Derived Simple Sequence Repeat (SSR) Markers

Charlie D. Dowling¹, Byron L. Burson¹, Jamie L. Foster², Lee Tarpile³, Russell W. Jessup¹

Plant Omics Journal (2014)
# Kinggrass: PMN

<table>
<thead>
<tr>
<th></th>
<th>Kinggrass: PMN</th>
<th>Switchgrass</th>
<th>Energy Cane</th>
<th>Miscanthus x giganteus</th>
<th>Miscanthus sinensis</th>
<th>Sorghum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sterile F₁ Hybrid Seed</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Yr. 1 Harvest</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Yield &gt; 10 dt/ac/yr (single harvest)</td>
<td>✓</td>
<td>✔</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✔</td>
</tr>
<tr>
<td>Perennial</td>
<td>✓</td>
<td>✔</td>
<td>✔</td>
<td>✓</td>
<td>✓</td>
<td>✔</td>
</tr>
<tr>
<td>Marginal Land Adaptation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✔</td>
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<tr>
<td>Soil C-Sequestration</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✔</td>
</tr>
<tr>
<td>Low Establishment Costs (seeded)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>Low Production Costs</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✔</td>
</tr>
<tr>
<td>Polyculture</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✔</td>
</tr>
<tr>
<td>Winter Standability</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✔</td>
</tr>
<tr>
<td>Non-invasive (seed)</td>
<td>✓</td>
<td>✔</td>
<td>✓</td>
<td>✓</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>Non-invasive (vegetative)</td>
<td>❓</td>
<td>❓</td>
<td>❓</td>
<td>❓</td>
<td>❓</td>
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<tr>
<td>Apomixis Introgression Potential</td>
<td>✓</td>
<td>✓</td>
<td>❓</td>
<td>❓</td>
<td>❓</td>
<td>✔</td>
</tr>
</tbody>
</table>
Improved Pearl Millet

- Very late flowering (Oct. - Nov.), prolific tillering pearl millet
**cms Biofuel Pearl Millet**

![Image of Pearl Millet plants]

**Marker-Assisted Introgression**

- **Pearl Millet (cms lines)**
- **Pearl Millet (Prolific Tillering)**

- **1100 F₁:** 2 selections (70+% recurrent parent introgression) selected
- **BC₁:** 430 plants evaluated (85+% recurrent parent introgression)
- **BC₂:** 160 plants: ongoing evaluations
- **Biofuel A:B-pair pearl millet selection and seed increase (2015)**

**Release:** ‘Breeding Line’ or ‘Inbred Line’
Improved Napiergrass

Forage (Mott) → Biofuel (Merkeron)
Improved Napiergrass

- Diverse, late flowering napiergrass collection
- Advanced hybrids (>1400)
Improved Napiergrass

- Inbreds
  - $S_1$ (>900; 2011)
  - $S_2$ (>800; 2014)
  - $S_3$ (2015...)
Improved Napiergrass

<table>
<thead>
<tr>
<th></th>
<th>Yield (dt/ha)</th>
<th>Moisture Content (%)</th>
<th>Plant Height (cm)</th>
<th>Tiller # per Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beaumont, TX</td>
<td>17.7</td>
<td>48</td>
<td>290</td>
<td>30</td>
</tr>
<tr>
<td>Beeville, TX</td>
<td>16.8</td>
<td>56</td>
<td>318</td>
<td>31</td>
</tr>
<tr>
<td>College Station, TX</td>
<td>19.8</td>
<td>47</td>
<td>305</td>
<td>33</td>
</tr>
<tr>
<td>AVERAGE</td>
<td>18.1</td>
<td>51</td>
<td>305</td>
<td>31</td>
</tr>
</tbody>
</table>

Release: ‘Commercial Variety’ or ‘Selected Plant Materials’
Napiergrass: Legume Intercrops

***Legume N-contribution without biomass penalty

NaCa = Napier grass + Calopoc, NaNe = Napier grass + Neonotonia, Nap = Napier grass, NaSi = Napier grass + Siratro, NaCe = Napier grass + Centrosema, NaCli = Napier grass + Clitoria
Napiergrass: Legume Intercrops

Intercropping Trials

- College Station: Beeville
- Cowpea (Red Ripper, etc.)
- Butterfly Pea
- Lablab (Rio Verde)
- Wild Bean (Rio Rojo)
- Scarlet Runner Bean
- Spurred Butterfly Pea
- Milkpea
- American Wisteria
- Groundnut (potatobean; Apios)

***NO climbing legume spp. with TX adaptation & PMN:Napiergrass compatibility identified***
Cold-Tolerant *P* *spp.* Hybrids

(Napiergrass X Pennisetum *spp.*)

• Cold tolerance

*P.* *orientale,* *P.* *flaccidum,* *P.* *alopecuroides* (zone 5)

PMN, Kinggrass, *P.* *purpureum* (zone 8)
Cold-Tolerant *P* spp. Hybrids

- 2011-12
- 2 viable progeny
- Interspecific hybrid confirmed w/ parental spp. specific EST-SSRs
- Seedling lethality
Cold-Tolerant *P* spp. Hybrids

- Pollen fertility
- Pollen tube assays
  - Successful entry into micropyle
Cold-Tolerant *P. spp.* Hybrids

- **Embryo Rescue**
  - *A. in-vitro* culture of pollinated (intact & stump), dissected ovaries of male-sterile napiergrass
  - 4590 ovary dissections and culture completed.
  - ‘Stump’ pollinations attempted.
  - Unsuccessful to date.
Cold-Tolerant *P. purpureum*

2012-13+

- Contingency (Increased Rhizomatousness)

- 28 Rhz selections in TAMU-Commerce trial

- N. TX overwintering accessions identified
Cold-Tolerant *P. purpureum*

- Elite cold-tolerant  x  cold-tolerant *P. purpureum*

Six 2012-2013 zone 8a trial overwintering selections
  - Commerce, TX

Two 2013-2014 zone 7b trials established
  - Vernon, TX
  - Alma, AR

***2013 Winter Severity***

- Derived from 28 initial College Station, TX cold-tolerant selections.
Cold-Tolerant *P. purpureum*

- Elite cold-tolerant x cold-tolerant *P. purpureum*

Vernon, TX (Sep. 2014)
Cold-Tolerant *P. purpureum*

Characterization of Candidate Overwintering Genes in Forage: Biofuel Napiergrass (*Pennisetum purpureum* Schumach.)
PMN Biorefineries

- Biofuels (biopower, ethanol, butanol, diesel,…)
- Silica (7+ %)
- Protein (15+ %)
- Fiber
- Bioplastics
- Functional Foods (COSs/XOSs)
Disruptive Ideotypes
Non-flowering

*S. halepense* × *S. bicolor*

- Putative ‘No Head Mutant’ (nhd1)
  - *S. bicolor*
Perennial (Seeded) Sorghum

- Novel *S. bicolor* x *S. propinquum*
- 4.5 m plant height
- Winter standability (<10% lodging 1/31)
- Photoperiodic (Operational Sterility)
- Fertile, Diploid Hybrids
- Temperate-adapted ‘Perenniality’
‘Seeded’ St. Augustinegrass

**Strategy**
- Seed Production
  - Fertile plant materials (diploid; $2n=2x=18$)
  - Selection (seed yield; germination)
  - Synchronous flowering time

- Seed Processing
  - Non-hulled seed (rachis fragments)
  - Hullled seed (seed priming; direct seeding)

- Uniformity
  - 1 cycle of self-hybridization
  - Selection (phenotypic uniformity)
    - Internode length/ color
    - Leaf width/ length
    - Flowering time
    - DNA markers (genetic uniformity)

- Vigor
  - Seedling vigor
  - Stress tolerance
    - Drought
    - Cold
    - Salinity

**Precedence...previous attempts**
- Seed fertility/ production
- Seed processing (embedded rachis)
- Non-uniformity (genetic heterogeneity)
- Low vigor (inbreeding depression)

 abaixo
- 2 Synthetic Hybrids
- 2014-2015 Polycross
- 2015 Seeded Hybrid Eval.
‘Stay-Green’ Bermudagrass

- Rain-out drought trials

- 48 selections
  - Overton: M. Rouquette (23)
  - 2011 Drought ecotypes (21)
  - Mutants (2)
  - Checks (2; Tifton 85, Tifway 419)

- 2013 (90 day; 1 m root zone)
  - 36 surviving genotypes

- 2014 (60 day; 10 cm root zone)
  - 3 surviving genotypes
Mutant Centipedegrass

- Chemical: Physical mutagenesis
- Dominant (M₀) mutants identified
- Putative ‘Knotted-1’ (Kn1)
  - Maize
Ornamentals

*Miscanthus sinensis*

X

‘Strictus’   ‘Cabaret’

Novel Variegated Turfgrass (Synergistic Mutagenesis)
DECENTralized Web Courses

SCSC 302
https://recturf.tonidoid.com/app/webshare/share/RECTURF/index.html

SCSC 689
https://ipps.tonidoid.com/app/webshare/share/IPPS/index.html
Feedback

It’s tough to make predictions…

…especially about the future!

Bahh, Bahh, GREEN sheep!
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