Energy Sorghums: Types and Production

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Texas A&M University, College Station
# Potential US C4 Bioenergy Grass Feedstocks

<table>
<thead>
<tr>
<th>Crop</th>
<th>Growth</th>
<th>Propagation</th>
<th>History</th>
<th>Biomass</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switchgrass</td>
<td>Perennial</td>
<td>Seed</td>
<td>None</td>
<td>Lignocellulose</td>
<td>Problems w/ seed prod. &amp; stand est.</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>Perennial</td>
<td>Cutting</td>
<td>Sugar</td>
<td>Sugar, Lignocellulose</td>
<td>cold sus. limits range</td>
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<tr>
<td>Miscanthus</td>
<td>Perennial</td>
<td>Rhizomes</td>
<td>None</td>
<td>Lignocellulose</td>
<td>Propagation limited</td>
</tr>
<tr>
<td>Sorghum</td>
<td>Annual</td>
<td>Seed</td>
<td>Grain, Forage</td>
<td>Sugar, Starch Lignocellulose</td>
<td>Drought tolerance</td>
</tr>
</tbody>
</table>

Source: [UIUC](#) | Source: [USDA NRCS](#)
Sorghum as a biomass crop

- 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
Even in a perennial system, an annual is needed......

Source: Mendel Biotech, Inc.
Different Sorghums – Different Uses, Carbohydrate Profiles and Total Yield

- Grain
- Forage
- Sweet
- Energy
Different Sorghums, Different Processes

Grain Sorghum

Sweet Sorghum

Energy Sorghum

Ligno-cellulosic biomass

Starch

Cellulose/Hemicellulose

Sugar

Ethanol

Ligni

Burn

Electricity

Sorghum: only bioenergy crop that produces commercial quantities of ligno-cellulosic, starch and sugar
Sweet Sorghum Production Logistics

- Production Systems
  - use existing infrastructure
- Planting: sorghum based
- Harvest: cane based
- Process: cane based
- Seed of Sweet Sorghums
  - Cultivars
  - Hybrids
    - Forage
    - True Sweet
Brix Values of Forage Sorghum Hybrids – Amarillo
Sugar Yield: Brix and Juice

Sugar Yield = Juice (lbs/acre) * Sugar

Concentration (g/100ml)

<table>
<thead>
<tr>
<th>Ethanol (gallons/acre)</th>
<th>Sugar Content (g/100ml)</th>
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<tbody>
<tr>
<td></td>
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</tr>
<tr>
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<tr>
<td>300.0</td>
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</tbody>
</table>

Commercial Forage Hybrids

Sweet Varieties

r² = 0.01

r² = 0.66

r² = 0.96

AgriLIFE RESEARCH
Texas A&M System
Sweet Sorghum Hybrids

- Varieties
  - Low Seed Yield
  - Difficult to Harvest
- Need Hybrids
- Seed Parent Development
  - High Brix
  - Short Height
  - Med to High Juice Volume
  - Good Seed Production
  - Daylength Insensitive
Sweet Sorghum Yields vary....

- Genotype
- Environment
- Harvest Time
- Biomass (t/acre)
  - 40, (0 to 70) FW
  - 10, (0 to 17.5) DW
- Grain Yield
  - 1, (.5 to 2)
- Fermentable Sugars
  - 15-20% brix
  - 65-75% purity (FS)
  - Mostly sucrose, some glucose and fructose
  - Small amounts of starch
- Sugar Yield (ton/acre)
  - 1.5, (0 to 3)
- Ratoon Crop (%1st crop)
  - 70, (30-125)
Other Issues in Sweet Sorghum

- Sugar is not Stable Post Harvest
- Just-in-Time Harvest
  - Yield
  - Quality
  - Choice of Hybrid
- Crop produces Grain
  - Management of starch in processing
- Year round production is not likely in US
  - Sub Tropical
  - Tropical
- Logical to combine with sugarcane production
Energy Sorghum

- **Photoperiod Sensitive:**
  - Reproductive growth when daylengths < 12"15" (or lower)

- **Benefits:**
  - Long Canopy Duration
  - Enhanced Drought Tolerance
  - Higher Biomass Accumulation
Biomass Yield Potential
Amarillo, Texas (2003-2005)

Tons/Acre (65% Moisture)

- Haygrazers (10): 22.3
- Photoperiod Sensitive (8): 33.3
- BMRs (23): 21.9
- Non-BMRs (32): 25.1
- Corn (3): 24.8

Source: B. Bean, T. C.
Water Use Efficiency
Amarillo, Texas (2003-2005)

Source: B. Bean, TCE
Energy Sorghum Growth Curves

Total Dry Weight/Plant (g)

Grain vs. PC Hybrid

Harvest Dates
Energy Sorghum Logistics

• Lignocellulosic Biomass
• Multiple Types to minimize storage and extend season
  – Multi-cut
  – Single-cut
• Planting
  – Traditional Sorghum
• Harvest
  – Multiple Approaches
• Rainfed Production
• Storage and Processing
• Season Long Harvest
• Large Scale Testing
• New Hybrid Scale Up
Energy Sorghum Observations

- Forage/Energy Sorghum PS Hybrids:
  - 8-10 dry T/acre
  - Animal palatability required
  - Multiple Harvest Crop

- Energy Sorghum:
  - Exp. Hybrids produce 8-14 dT/acre
  - Not selected for animal palatability
  - Single Harvest Crop

- Testing is Expanding this year....
## Composition Variation

**Table 3. Descriptive statistics on the predicted bioenergy constituents for sweet and biomass studies**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>SWHE(^\dagger) ((N^\dagger = 489))</th>
<th></th>
<th>PSEX ((N = 237))</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Range</td>
<td>Mean (stdev)</td>
<td># in top 5%</td>
<td>Range</td>
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<tr>
<td>Glucan</td>
<td>20.1 - 40.8</td>
<td>28.1 (4.2)</td>
<td>36</td>
<td>21.8 - 34.0</td>
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<tr>
<td>Xylan</td>
<td>7.7 - 18.3</td>
<td>13.7 (1.5)</td>
<td>0</td>
<td>15.3 - 21.0</td>
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<tr>
<td>Lignin</td>
<td>8.9 - 15.8</td>
<td>12.1 (1.3)</td>
<td>0</td>
<td>12.9 - 20.1</td>
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<tr>
<td>Solubles</td>
<td>21 - 43.2</td>
<td>31.5 (5.0)</td>
<td>36</td>
<td>16.8 - 37.7</td>
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</tbody>
</table>

SWHE, sweet heterosis study from College Station and Weslaco for 2007 and 2008; PSEX, photoperiod-sensitive selections from College Station for 2008

\(^\dagger\)Number of samples predicted
Critical Research Needs

- Plant nutrition: specifically N
  - one ton of sorghum DM requires 20 lb N
- Genotype x Environment
- Harvesting technology
- Basic agronomics
- Water Management
  - Irrigated
  - Rainfed
- Cropping system sustainability
Agronomy / Crop Production

- Seeding and harvest time:
  Goal: providing a continuous supply of feedstock
- Growth and quality curves over time
- Effect of planting date
- Effect of stockpiling feedstock in the field
- One harvest or two harvests?
- Continuous harvesting between mid-June and mid-November?
## Stagger Planting in Sweet Sorghum

<table>
<thead>
<tr>
<th>Plant Date</th>
<th>Predicted Harvest</th>
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<tbody>
<tr>
<td>April</td>
<td>June</td>
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<tr>
<td>May</td>
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<table>
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<th>Della</th>
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</table>
Sorghum

- Energy Types will be available
- Annual Energy Crops will be needed
- Forage Sorghum Production Guidelines need modification for Energy Production
  - Fertilization
  - Harvest
  - Crop Rotations