Sorghum: An established crop for sustainable, global production
• Focused on sorghum
• Market-leading hybrid seed
• Grain, forage and sweet
Tremendous Investment in Sorghum R&D

- Largest sorghum breeding program in U.S.
- Testing and launching new hybrids faster than the industry norm
- New products out performing industry leaders

Pipeline initiated in 2009. Expect many new products in the next 2-3 years.
Molecular Breeding and Genetics

• First tenants in the new Texas Tech Business Park
  – Scientists working on molecular breeding/marker assisted breeding, plant transformations and ARPA-E project.
  – Focus is on sorghum traits that:
    • Enhance Yield
      – Protection against biotic and abiotic factors that reduce yield
    • Improving quality
      – Digestibility of grain, forage and biomass

  – Farnesene-producing sweet sorghum
Water uses:

- Agriculture: 70%
- Energy + Industrial: 19%
- Municipal: 11%

Water Consumption in Agriculture (acre feet)

<table>
<thead>
<tr>
<th>Year</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>2.2 B</td>
</tr>
<tr>
<td>2050</td>
<td>2.4 B</td>
</tr>
</tbody>
</table>

FAO
Climate models predict severe droughts

A. Dai, Wiley Interdisciplinary Reviews: Climate Change, Vol 2, pp 45-65, Jan 2011
Water is a limiting resource globally

Water export via agriculture
International Opportunities for Sorghum

Per capita water availability
### Sorghum Drought Mechanisms

#### Drought Tolerance
- 50% more stomata per in² of leaf than corn
- Stomata are smaller
- Smaller leaf:root ratio than other crops
- Extensive root system
- Stay-Green Traits
- Perfect flowers*

#### Drought Avoidance
- Heavy wax layer (bloom) on leaves/stems
- Slow/hasten maturity under stress
- Motor cells at leaf midrib to facilitate leaf curling under stress
Sugars and Feedstocks from Sorghum

• Grain Sorghum
  – Starch from grain
  – Lignocellulose from crop residue

• Dedicated Energy Sorghum
  – Lignocellulosic from biomass
  – Free sugars in some hybrids

• Sweet Sorghum
  – Free sugars in juice
  – Lignocellulosic from bagasse
Tipping Points for Yield and Economics

- Where is the yield tipping point?
- How do economics affect the tipping point?
- World vs U.S. cropping systems
  - How are we going to feed the world in the face of declining water supplies?
  - Chromatin is using this approach to target markets and product development

### NC Kansas Rainfed

<table>
<thead>
<tr>
<th>Category</th>
<th>Corn</th>
<th>Sorghum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (bu/acre)</td>
<td>130</td>
<td>120</td>
</tr>
<tr>
<td>Price per bu</td>
<td>3.83</td>
<td>4.58</td>
</tr>
<tr>
<td>Total Revenue</td>
<td>497.90</td>
<td>549.60</td>
</tr>
<tr>
<td>Seed</td>
<td>93.60</td>
<td>18.90</td>
</tr>
<tr>
<td>Pesticides</td>
<td>50.01</td>
<td>49.30</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>119.67</td>
<td>104.03</td>
</tr>
<tr>
<td>Machinery &amp; Other</td>
<td>278.94</td>
<td>268.47</td>
</tr>
<tr>
<td>Total</td>
<td>542.22</td>
<td>440.69</td>
</tr>
<tr>
<td>Return over Costs</td>
<td>(44.32)</td>
<td>108.90</td>
</tr>
</tbody>
</table>

Corn yield to equal sorghum returns = 170 bu/acre
Sorghum Mitigates Grower Risk on Marginal Land

- Sorghum Economic Advantage
- Sorghum Yield Advantage

Tipping point affected by:
- Water availability
- Crop yields
- Input costs
- Crop revenue
US water limitations are driving a shift to sorghum

Sorghum’s Economic Advantages

Sorghum provides an economic advantage for growers at corn yields less than 140 - 100 bushels / acre.

US Sorghum acres have increased by 40% over the past 2 years.
For energy crops or crop residue, growers are the key decision makers.
Typically have an opportunity once per year to make a crop plan.
Key factors:
- Feasibility (Land / Water / Climate)
- Market demand
- Costs of production
- Risk
Chromatin’s Sorghum Ethanol Programs

• In 2012, EPA determined grain sorghum ethanol can be “Advanced Biofuel”
  – Less water use and lower inputs = more favorable greenhouse gas profile than corn

• Improved economics for ethanol plants

• Yield and quality similar / more favorable than corn
  – 2.8 gallons of ethanol per bushel
  – Higher protein DDGs
  – 4% oil
  – Higher sugar content in stover
New products: Increased biomass digestibility

**Enzymatic digestibility**
(% of Dry Matter)

<table>
<thead>
<tr>
<th>Biogas production</th>
<th>(NL CH4 / kg Tot. Solids)</th>
<th>% Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure</td>
<td>134</td>
<td>--</td>
</tr>
<tr>
<td>Manure + Sorghum biomass</td>
<td>175</td>
<td>30%</td>
</tr>
<tr>
<td>Chromatin Hybrid 1</td>
<td>194</td>
<td>45%</td>
</tr>
<tr>
<td>Chromatin Hybrid 2</td>
<td>210</td>
<td>57%</td>
</tr>
</tbody>
</table>

Markets
- Feed
- Biogas
- Cellulosic Fuel
Sorghum & Renewable Energy

• Source of sugar, starch, cellulose for fuel, chemicals, power
• Grain ethanol qualified as Advanced Biofuel
• 4 month growing cycle
• Farmer adoption
  • Infrastructure present
  • Annual crop
  • Market flexibility
• At commercial scale today
• Chromatin is READY!