Sorghum: A Commercially Viable Biomass Crop

Customized by Chromatin, Renewable by Nature

BIO/ Pac Rim Summit: October 11, 2012

Chromatin, Inc.
Chromatin’s unique value proposition....
Market position & capabilities

- **Seed products**: Hybrid grain & forage sorghum planting seed with a 45+ year commercial history, brand recognition

- **Production capacity**: 30 million pounds of hybrid seed annually

- **Supply chain**: Export to 20+ countries; products on 3+ million acres per year

- **Relationships**: 300+ growers, dealers, distributors, agents

- **Breeding**: Harnessing natural diversity through molecular breeding

- **Synthetic biology**: Technology to reshape seed quality traits and feedstock composition

SORGHUM PARTNERS, LLC
a Chromatin company
## Why sorghum as a biomass crop?

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Water Use</th>
<th>Environmental Impact</th>
<th>Energy Use</th>
<th>Climate Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>High yield on marginal land</td>
<td>85% &lt; sugarcane 50% &lt; corn</td>
<td>Herbicide and pesticide use 40-80% &lt; corn</td>
<td>Much less than corn — Less irrigation; fewer chemical inputs</td>
<td>Naturally heat and drought tolerant</td>
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### Low barriers to adoption

- Globally cultivated crop
- Established infrastructure
- Agronomics well-understood
- 3-in-1: starch/sugar/cellulose
- Durable markets
Chromatin’s sorghum breeding pipeline

• Proprietary collection includes 90-95% of global sorghum diversity

• Targets: Increased starch, sugar, cellulose and lignin with improved total yield

• Key traits identified with molecular markers

• Test sites and strip trials span the entire United States and several countries throughout South America, Europe and Asia/Pacific

• 60,000 new hybrids made each year
Drought resistance is a high value target

- 2012: One of ten driest years recorded for KS, NE, IA, MO, and IL and top 20 for surrounding states.
- 2011: One of five driest years recorded for TX and OK and in the top 20 for surrounding states.
- Estimated > $100MM has been spent to develop drought tolerant corn; however, reports suggest less than 10% improvement over other corn.
- Monsanto’s drought tolerant trait: expect $250-500 M revenue and impact on 45-55 million U.S. acres.
- Pioneer projects that their drought tolerant corn products are suited for 30% to 70% of their acres.
- Sorghum is already drought tolerant. This crop can be marketed to compete with corn in water stressed areas.
2 years of drought has impacted growers

- Droughts of 2011 and 2012 have renewed interest in grain sorghum
- 2012 corn forecast at ~120 bu./acre; ~155 bu./acre most years
- Grain sorghum provides a better return for growers when corn yields <100 bu./acre and sorghum is priced at 87% of corn
- When grain sorghum prices ~ corn prices, it is a better choice when corn yields < 140 bu./acre
### Sorghum water use efficiency

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</thead>
<tbody>
<tr>
<td>Sorghum</td>
<td>138.9</td>
<td>8.0</td>
<td>118.0</td>
<td>5.5</td>
<td>77.4</td>
<td>5.6</td>
<td>111.4</td>
<td>6.4</td>
</tr>
<tr>
<td>Corn</td>
<td>127.2</td>
<td>5.8</td>
<td>101.2</td>
<td>4.3</td>
<td>97.5</td>
<td>6.7</td>
<td>108.6</td>
<td>5.6</td>
</tr>
<tr>
<td>Soybeans</td>
<td>61.3</td>
<td>2.9</td>
<td>44.0</td>
<td>2.0</td>
<td>33.4</td>
<td>2.4</td>
<td>46.2</td>
<td>2.4</td>
</tr>
</tbody>
</table>

**Grain Water Use Efficiency**

![Graph showing grain water use efficiency](image1)

**Biomass Water Use Efficiency**

![Graph showing biomass water use efficiency](image2)

University of Nebraska data
Starch and sugar products available today

Grain Sorghum

Up to 20% higher yields in starch fermentation processes

Forage / Sweet Sorghum

Achievable with breeding

Meets biopower specs

Easily digestible sweet varieties rich in C5 / C6
High-energy sorghum pipeline...

Chromatin sorghum

Today:
7900 BTU / lb
> $1000 / acre advantage
If 20 M acres, $20 B

Pipeline:
8500 BTU / lb (breeding)
>9000 (synthetic biology)
$10B (on 20 M acres)

Target technologies → markets:
• Gasification
• Hydrothermal carbonization
• Pyrolysis
U. S. test plots and strip trials...
Chromatin’s Gene Stacking Technology

Traditional Gene Delivery

Gene A
Plant with gene A

Gene B
Plant with gene B

Mini-Chromosome Technology

A B C D E F G H I J K L

Plants

Gene Array

Gene Array

Delivered Genes

Host Chromosome

Plant Cell

Linear

Circular
Making Mini-C Containing Plants

- Immature embryos
- Gene Gun
- Regenerating embryo
- Callus growth on selective media
- Callus expressing marker protein (DsRed)
- T0 Plants expressing marker protein (DsRed)
Chromatin technology

Synthetic biology adds gene stacks to crops

Mini-chromosome

High energy & high sugar sorghum

Energy

- Extractable fuel
- Increased BTU

Sugar

- Increase sugar content
- Improve sugar extraction / degradation

Licensed for use in specific crops:

Corn, soybean, cotton, canola, sugarcane

“And by the end of the decade, I see mini-chromosome technology as the primary trait transfer technology used in corn,” – Roger Kemble, Syngenta Biotechnology (Farm Industry News, 3/9/11).
• Chromatin-led project selected for $5.8 million DOE funding

• Engineering the terpenoid metabolic pathway in sorghum to produce farnesene

• Sorghum mini-chromosome to deliver up to 12 genes to sweet sorghum

• Final production costs ~ $1.60 / gal

• 11,000 BTU feedstock
Products for the emerging biomass market

**Forage Sorghum**
- 10 commercial products
- Leading position in US hybrid seed market

**Grain Sorghum**
- 17 commercial products
- Rapid expansion into growth markets

**Sweet Sorghum**
- Enabling commercial and scalable production for large emerging global markets
Vertical integration in sorghum feedstock

Gene Stacking

Proprietary Seeds

Seed Production & Distribution

Biomass Production

Customers & Strategic Partners

Gene Stacking: Mini-chromosomes

Proprietary Seeds: Sorghum Partners, LLC

Seed Production & Distribution: 30 M lbs of seed, 3* M acres

Biomass Production: High Energy, High Sugar

Customers & Strategic Partners: Chemical Fuel Power

Licenses:
- Bayer CropScience
- Dow AgroSciences
- Syngenta Biotechnology
- Monsanto

Seed Sales:
- Starch-based fuel
- Animal feed

Partners:
- Growers
- Logistics providers
- Pellets Milling
- Juice production

Proprietary Feedstock Products

$
Investors and operations

Chicago

Champaign-Urbana

Texas

**Investors**
- Leading venture capital firms
- Leading strategic investors
Customized by Chromatin, Renewable by Nature

- Commercial-stage and scalable technology & products today
- Creating value via sales of grain, forage and sweet sorghum planting seed
- Creating value by designing customized biomass feedstock