Sorghum’s resurgence – A unique crop opportunity
Houston, 2013
Sorghum receiving ‘mainstream’ media attention

The New York Times
Wells Dry, Fertile Plains Turn to Dust
May 19, 2013

npr
Heat, Drought Draw Farmers Back To Sorghum, The 'Camel Of Crops'
October 31, 2013

Bill Gates @BillGates 2 May 12
In my first trip to #Ethiopia, I learned about sorghum, a staple crop for many of the world’s poorest. Gallery: b-gat.es/IGOEub

Chromatin
Factors driving sorghum adoption

Water Scarcity ➔ Western US
Marginal Land ➔ Western US
Population Growth ➔ Shanghai
Income Growth ➔ Shanghai

Food / Livestock Feed
Energy

100 – 130 million global acres and increasing
Sorghum’s biology is adapted to tolerate drought

<table>
<thead>
<tr>
<th>Drought Tolerance</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>50% more stomata per in² of leaf than corn</td>
<td></td>
</tr>
<tr>
<td>Stomata are smaller</td>
<td></td>
</tr>
<tr>
<td>Smaller leaf:root ratio than other crops</td>
<td></td>
</tr>
<tr>
<td>Extensive root system</td>
<td></td>
</tr>
<tr>
<td>Stay-Green Traits</td>
<td></td>
</tr>
<tr>
<td><strong>Perfect flowers</strong></td>
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</table>

<table>
<thead>
<tr>
<th>Drought Avoidance</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy wax layer (bloom) on leaves/stems</td>
<td></td>
</tr>
<tr>
<td>Slow/hasten maturity under stress</td>
<td></td>
</tr>
<tr>
<td>Motor cells at leaf midrib to facilitate leaf curling under stress</td>
<td></td>
</tr>
</tbody>
</table>
Grower decisions

Texas 2012

Texas 2013

Water conserving, stress tolerant, fast growing crops have a strong advantage
Multi-year studies in Kansas & Nebraska

- Yield comparisons, $n = 202$:
  - Corn and sorghum hybrid tests at same location, KS, NE
  - Cropping-system or rotations studies with both crops in same year in same rotation

- Production Costs and Returns:
  - 2012 Corn and Sorghum Cost-Return budgets, KSU, UNL
  - Localized costs and market prices used for each location
<table>
<thead>
<tr>
<th>Category</th>
<th>SC Kansas Rainfed</th>
<th></th>
<th>NE Kansas Rainfed</th>
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<tbody>
<tr>
<td></td>
<td>Corn</td>
<td>Sorghum</td>
<td>Corn</td>
<td>Sorghum</td>
</tr>
<tr>
<td>Yield (bu/acre)</td>
<td>110</td>
<td>110</td>
<td>160</td>
<td>130</td>
</tr>
<tr>
<td>Price per bu</td>
<td>5.68</td>
<td>5.58</td>
<td>5.68</td>
<td>5.58</td>
</tr>
<tr>
<td>Gov’t Payment</td>
<td>16.58</td>
<td>16.58</td>
<td>14.68</td>
<td>14.68</td>
</tr>
<tr>
<td>Total Revenue</td>
<td>641.38</td>
<td>630.39</td>
<td>923.49</td>
<td>740.09</td>
</tr>
<tr>
<td>Seed</td>
<td>66.47</td>
<td>12.58</td>
<td>87.48</td>
<td>16.01</td>
</tr>
<tr>
<td>Herbicides</td>
<td>28.16</td>
<td>18.48</td>
<td>30.00</td>
<td>30.58</td>
</tr>
<tr>
<td>Insect/Fungicides</td>
<td>1.00</td>
<td>0.00</td>
<td>26.55</td>
<td>0.00</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>85.00</td>
<td>94.20</td>
<td>110.56</td>
<td>72.80</td>
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<tr>
<td>Consult/Dry/Ins.</td>
<td>0.00</td>
<td>0.00</td>
<td>17.29</td>
<td>11.70</td>
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<tr>
<td>Machinery</td>
<td>116.76</td>
<td>114.02</td>
<td>98.86</td>
<td>87.02</td>
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<tr>
<td>Land Rent</td>
<td>74.40</td>
<td>74.40</td>
<td>136.80</td>
<td>136.80</td>
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<tr>
<td>Total</td>
<td>391.54</td>
<td>332.31</td>
<td>527.46</td>
<td>372.99</td>
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<tr>
<td>Return over Costs</td>
<td>249.84</td>
<td>298.07</td>
<td>396.03</td>
<td>367.10</td>
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</table>
Sorghum mitigates grower risk

**Tipping point affected by:**
- Water availability
- Crop yields
- Input costs
- Crop revenue

**Graph:**
- Sorghum Economic Advantage
- Sorghum Yield Advantage

**Axes:**
- Corn Yield, bu/a
- Grain Sorghum Yield, bu/a
US Opportunities for Sorghum

10-year average corn yields

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
International water limitations

Per capita water availability

Sorghum growth range

- 12,000 - 625,000
- 7,000 - 12,000
- 5,000 - 7,000
- 4,000 - 5,000
- 0 - 4,000
- No data
Water as a resource

Water export via agriculture

Agriculture accounts for > 90% of fresh water consumption.

<table>
<thead>
<tr>
<th>Manufactured Item</th>
<th>Water needed (L)</th>
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</thead>
<tbody>
<tr>
<td>1 glass milk</td>
<td>200</td>
</tr>
<tr>
<td>Blue jeans</td>
<td>11,600</td>
</tr>
<tr>
<td>1 MWhr (coal)</td>
<td>200,000</td>
</tr>
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</table>

Hoekstra A Y, Mekonnen M M PNAS 2012;109:3232-3237
A perfect storm

Sorghum

- Water limitations
- Population growth & protein demand
- Gluten-free, non-GMO
- Energy
Chromatin’s Sorghum Platform

Germplasm / Product Pipeline

Seed Production

Conditioning / Processing

Sales and Distribution

Harvest & Delivery
Chromatin Operations

- 150 employees
- Chicago headquarters; operations centered in Texas; Entities in Mexico & Brazil
- 100% Sorghum Focused
Chromatin’s Global Market Reach – 6 million acres

Product Sales
- Direct
- Network

Product introduction
- 2011
- 2012
- 2013
- 2014
Chromatin’s Sorghum Product Pipeline

• Team
  – 4 full time breeders focused on Grain, Forage and Sweet Sorghum

• Pipeline
  – 35 commercial products
  – 15,000 breeding lines from 7 commercial and 9 pre-commercial sources
  – 600 new breeding populations annually
  – 5000 to 6000 test crosses evaluated annually
  – 8 breeding nurseries, 365 day program
  – 42 test sites and 26,000 test plots dedicated to breeding
  – >90 international commercial test sites
  – 59 new products in pilot production in 2014; many with potential to become market leaders
Sorghum and Tannin Content

- Commercial grain sorghum hybrids sold for planting in the U.S. RARELY contain tannins.
- Tannin containing hybrids exist.
  - Sold into Central and South American markets
  - Grown in the U.S. under identity preserve contracts for non-traditional uses.
- Numerous studies have confirmed the lower feed efficiency of tannins in poultry. Tannins have been reported to reduce starch and protein utilization.
- Only sorghum with a pigmented testa (Type II & III) sorghums contain condensed tannins.
- All sorghums contain phenolic acids and flavonoids.
Sorghum and Tannins

Which has tannins?

![Variation in appearance of sorghum tannins.](source)

Source: Myths about Tannin sorghums, L.W. Rooney

Fig. 3. Variation in appearance of sorghum tannins. (Adapted from Rooney and Miller 1982).

- No Pigmented Testa
- Pigmented Testa
- No Pigmented Testa
New Products – Grain Sorghum

Chromatin Pipeline Products

Maturing pipeline leading to new product launches

<table>
<thead>
<tr>
<th>Year</th>
<th>Count</th>
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<tbody>
<tr>
<td>2012</td>
<td>1</td>
</tr>
<tr>
<td>2013</td>
<td>3</td>
</tr>
<tr>
<td>2014</td>
<td>11</td>
</tr>
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</table>
Types of Forage Sorghum

• Forage Sorghum Hybrid
  – Coarse stem
  – Photoperiod and photoperiod insensitive
  – High yields

• Sudan x Sudan Hybrid
  – High quality
  – Fine stems
  – Multi-cut

• Sorghum x Sudan Hybrid
  – Hybrid between Sudan grass and sorghum
  – More uniform and larger planting seed
Forage Sorghum-conventional height

- Photoperiod sensitive and photoperiod insensitive
- Brown mid-rib
- Coarse stem
- Excellent standability
- High digestibility
- High energy
- High grain:stover—photoperiod insensitive
Brachytic Forage Sorghum

- Shorter than traditional forage sorghums
- Less susceptible to lodging
- Tonnage similar to traditional forage sorghum
- Polygenic trait
Sudan x sudan hybrids and Sorghum x Sudan hybrids

- Photoperiod sensitive and photoperiod insensitive
- Brown mid-rib
- Fast regrowth
- Fine stem
- High digestibility
- Uniform seed size
Photoperiod sensitivity (PPS)

- Inhibits floral initiation until certain photoperiod times are met
- Increases harvest window while delaying sacrificing quality
Sorghum and bioenergy

- Recent designation as an Advanced Biofuel feedstock in December 2012 (Grain Ethanol)
- Sorghum will also be able to participate in the growth of cellulosic ethanol
- Sweet sorghum is being targeted for use as ethanol feedstock in Brazil
- Ready to participate in emerging opportunities
  - Biopower (electrical power generation)
  - Biogas (electrical and thermal energy)
  - Biofuels (liquid transportation fuels)
  - Chemicals (value-added building blocks)
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
Chromatin’s Biotechnology and Next-generation Fuels

- Chromatin’s unique gene-stacking capability has allowed us to add several genes to sorghum.

- Designing *Farnesene*-sorghum: High value fuel and combustion products.

- Supported by a $5.8 M award from the ARPA-E program at the DOE.
  - Target fuel production costs ~ $1.60 / gal
  - 11,000 BTU / lb biomass
Sweet Sorghum

- Bred for high sugar yields
- Bagasse (material after juicing process) makes excellent fuel or cellulose feedstock
- Is limited to Southern environments (in U.S.) to have long enough harvest season to be economical.
Sorghum Advantages

Established annual crop, fast growing, and sustainable

– Infrastructure, agronomics and supply chain in place for rapid scale up

– Multiple market channels; feed, food and renewable energy

– Produces starch, sugar, and cellulose

– From seed to harvest in 4 months
Multi-Billion $ Market Growth Potential for Sorghum Seed

- Water scarcity driving shift from corn
- Increasing global demand for protein creating demand for animal feed
- Hybrid seed replacing low productivity varieties
- Grain ethanol from sorghum as “Advanced Biofuel”
- Sweet sorghum in Brazil extending mill productivity
- Reduction of US cotton subsidies
- Biomass sorghum anticipated to enter renewable power, chemicals, and fuels markets
- Engineered sorghum will create higher value feed and fuel
- Growing demand for gluten-free
Sorghum: Customized by Chromatin, Renewable by Nature™