Sweet Sorghum: a good opportunity for producing energy?

Serge Braconnier & SWEETFUEL Consortium

AAIC 2014, 13-19 September, Athens
• FP7 project co-funded by the European Commission
• Total budget = 5 M € for a EC contribution of 3 M
• 5 years duration + 6 months (01/2010 – 06/2014)
• 10 partners from 7 countries and 3 continents:
  - France: CIRAD
  - Germany: KWS – IFEU – WIP
  - Italy: UniBO – UCSC
  - Brazil: EMBRAPA
  - India: ICRISAT
  - Mexico: UANL
  - South Africa: ARC-GCI

• objective: development of ethanol production from sorghum in temperate and semi-arid tropical zones through genetic enhancement and improvement of cultural and harvest practices
• 91 deliverables
• site web: www.sweetfuel-project.eu
# Breeding objectives

<table>
<thead>
<tr>
<th>WP1</th>
<th>Uses</th>
<th>Ideotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>2G ethanol or biogas</td>
<td><strong>Biomass sorghum</strong> with high biomass (height &gt;3m) good tolerance to low temperature photosensitivity adapted to late flowering good quality of biomass (low lignin content to increase digestibility) good tolerance to lodging good tolerance to water deficit</td>
<td><strong>Grain production is not essential</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WP2</th>
<th>Uses</th>
<th>Ideotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>1G ethanol + grain &amp; fodder</td>
<td>Sweet sorghum with high biomass production (20-30 t DM ha(^{-1})) grain production from 1.5 to 3 t ha(^{-1}) high soluble sugar in stalks, Brix° of 15 to 20 with 80% saccharose juicy stalks high value of the bagasse as fodder (high digestibility = (bmr) trait) adapted to cropping seasons in India good tolerance to drought</td>
<td><strong>Grain production is essential</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WP3</th>
<th>Uses</th>
<th>Ideotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>1G ethanol + cogeneration</td>
<td>Sweet sorghum with high biomass production (40-50 t DM ha(^{-1})) high soluble sugar in stalks, Brix° of 15 to 20 with 80% saccharose juicy stalks high energetic value of the bagasse for cogeneration (high lignin) adaptation to marginal soils (acidity, aluminum toxicity, (P) deficiency) adaptation of crop cycles (good complementarity with sugarcane)</td>
<td><strong>Grain production is not desirable</strong></td>
</tr>
</tbody>
</table>
### Importance of the cropping cycles

2 options for biomass sorghum in Europe:

- **summer cropping**
  - One yield per year

- **double cropping systems**
  - 2 yields per year
  - Opportunity to combine food and fuel productions

#### Cropping Calendar

<table>
<thead>
<tr>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Summer crop</strong></td>
<td>Biomass sorghum</td>
<td>30 to 40 t/ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Double cropping system</strong></td>
<td>Winter crop</td>
<td>Biomass sorghum</td>
<td>Winter crop</td>
<td>20 to 25 t/ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Harvest, storage and transformation

- Harvest with same equipment as for maize
- Storage and transformation the same as maize
- Small biogas units are usually « multifeedstock »
For 2G ethanol production, it is difficult to give information

Sorghum biomass was not experimented at Crescentino (Italy)

This should be done in 2015 by the pilote plant at Pomacle (France)
Results from SWEETFUEL: new pre-breeding material

New male lines for hybrid biomass sorghum
New female A/B early lines for hybrid biomass sorghum
New female A/B lines with low lignin content
(New sweet sorghum hybrids > current checks)

Our new hybrids produce a good biomass in term of quality (mainly the percentage of dry matter), but have a problem in yield stability and require further breeding

Biomass from sorghum is suitable for biogas production 2G ethanol production direct combustion

Its benefits and problems throughout the whole life cycle are qualitatively similar to those of existing biogas production from cultivated crops such as maize. Yet, concrete implementation and agricultural practice can make a big difference especially with respect to environmental impacts.
The good complimentarity between sugarcane and sweet sorghum

The sugarcane sector is today the major niche for sweet sorghum development in Brazil because this does not require any additional investment in new equipment (harvest & transf. Same as sugarcane) and any extension of current exploited lands (20% of sugarcane area available each year).

One additional option for sorghum in Brazil: production of biomass suitable for cogeneration or 2G ethanol.
Harvest and transformation in Brazil
Harvest and transformation in Brazil
Results from SWEETFUEL: new sorghum lines or hybrids

• **In Brazil**, 4 sweet sorghum varieties are available at commercial level BRS 506, BRS 508, BRS 509 et BRS 511
  + one biomass sorghum (for cogeneration)

• **In India**, new hybrids adapted to different cropping seasons are available ICSV 93046, ICSV 25311 + ICSV 25308 adapted to a terminal stress and ICSV 25300 adapted to mid-cycle stress

• **In Mexico**, 8 dossiers were submitted to record new material in the national catalogue

• **In South Africa**, one OPV + 5 sweet cultivars are available
  + material for further breeding programmes (RILs…)

AAIC 2014, 13-19 September, Athens
**EXPLOITABLE FOREGROUND**

**New Sweet Sorghum Cultivar – BRS 508**

**Explanation and Purpose**

BRS 508 is a variety developed by Embrapa Maize and Sorghum to meet the growing demand for complementary feedstock as an alternative to sugarcane for ethanol production. This cultivar has high yield potential of stems (average 50-70 t ha⁻¹) and high levels of fermentable sugars in the juice (total sugar 18-20 g L⁻¹ at the maturity peak), 2.0 t ha⁻¹ grain yield, and resistance to lodging and to major pathogens. Average maturity cycle for the production of ethanol is about 115-125 days after sowing, and with a period of industrial utilization (PUI) of more than 30 days.

**Exploitation Strategy**

Sweet sorghum can be grown in all areas currently recommended for sugarcane production in Brazil. Sorghum can provide quality feedstock during the period between the months of February and April, before the beginning of sugarcane harvest for ethanol production, extending the total harvest period of distilleries for two additional months.

**IPR Measures**

The results of this project from Embrapa are freely available and the breeding materials developed and released herein are available for licensing by the private sector for seed production and commercialization. SWEETFUEL partners have had and continue to have access to both experimental and released cultivars with appropriate Material Transfer Agreements.

**Further Research**

This and other varieties (R-lines) will continue to be evaluated in an evaluation network, as male parents of sweet sorghum hybrids as new sweet sorghum female lines (A and B lines) become available. Adaptation to other regions can be assessed through multi location and multi seasonal trials.

**Impact of Exploitation**

Research is currently underway to produce sweet sorghum during the period of sugarcane renovation (20% total area recommended annually) during the months of November to May to provide an alternative feedstock to anticipate sugarcane harvest and distillery operation by up to 60 or more days before the beginning of sugarcane harvest in April and May, increasing ethanol output and reducing ethanol production and operational costs.
Energy Sorghum
An alternative energy crop
A Handbook
• Impact assessment / definition of the different scenarios

- for each scenarios and their options, an impact assessment was done at economic, social and environmental level, as well as a SWOT analysis, which results in various recommendations (see deliverables D6.2, D6.3, D6.4, D6.5 and D6.6)

AAIC 2014, 13-19 September, Athens
Results of SWEETFUEL

Fig. 4-1 Contributions of individual result (light brown bar) scenario for the enviro based on typical cultivation

Fig. 4-6 Breakup of operational costs for selected sweet sorghum scenarios, typical case

- Agriculture: diesel
- Agriculture: field emissions
- Agriculture: remainder
- Conversion: material input
- Grain sorghum cultivation
- Leaves
- Credits: grains
- Credits: calcium carbonate
- Energy supply
- Fossil equiv. production
- Net result

- Agriculture: fertiliser
- Agriculture: reference system
- Transports
- Conversion: grains
- Surplus bagasse
- Credits: vinasse
- Credits: fusel oil
- Credits: excess power
- Use phase
- Fossil equiv. usage

Grain to food Scenario
- Feedstock cost
- Processing cost
- Labor costs
- Interest
- Rent
- Other pay on wc
- Other costs

Coffee Fallow Stalk to Ethanol Scenario
- Feedstock cost
- Processing cost
- Labor costs
- Interest
- Rent
- Other pay on wc
- Other costs

Syrup to Ethanol Scenario
- Feedstock cost
- Processing cost
- Labor costs
- Interest
- Rent
- Other pay on wc
- Other costs
Conclusion / Recommendations

• Specific recommendations for sweet sorghum

  Improve harvesters with a focus on harvesting both co-products (grains and leaves)

  Where grain is not demanded for food purpose, use both grain use and stalks to produce ethanol

  Converting juice to syrup at village level is neither economical nor environmentally beneficial (but positive impact at social level)

• Specific recommendations for biomass sorghum

  When producing biogas, combining production and utilization of power and heat should be preferred over power production only

  Direct combustion of biomass sorghum for heat and power production is the environmentally most beneficial use option
(sweet or biomass) sorghum is an efficient crop for producing energy (biogas, biomethane, bioethanol, heat), but...

Due to its seasonality, it must be combined with another crop

Its efficiency, its impacts on environment (LCA, GHG balance, energy balance), depend on the biomass production and transformation processes, as well as the location of the production system.
Sorghum biomass has a promising future
Sweet sorghum: a multiple purpose crop
Thank you for your attention

Contacts:
serge.braconnier@cirad.fr
(Web site: www.sweetfuel-project.eu)