SWEETFUEL Regional Stakeholder Workshop

Energy Sorghum –
An Alternative Energy Crop for Industrial Use

26th June 2013, 10:15 – 15:00
Hamburg, Germany

on the occasion of the 22nd European Biomass Conference and Exhibition

Workshop Report

SWEETFUEL is co-funded by the European Commission in the 7th Framework Programme (Project No. FP7-227422) – www.sweetfuel-project.eu

The SWEETFUEL Project

The energy crop sweet sorghum (Sorghum bicolor L. Moench) is raising considerable interest as a source of either fermentable free sugars or lignocellulosic feedstock with the potential to produce fuel, food, feed and a variety of other products. Sweet sorghum is a C4 plant with many potential advantages, including high water, nitrogen and radiation use efficiency, broad agro-ecological adaptation as well as a rich genetic diversity for useful traits. For developing countries sweet sorghum provides opportunities for the simultaneous production of food and bioenergy (e.g. bio-ethanol), contributing to increase access to renewable energy sources without compromising food security. In temperate and usually more industrialised regions (e.g. in Europe) sweet sorghum is seen as promising crop for the production of raw material for 2nd generation bio-ethanol or bio-methan.

The project SWEETFUEL (Sweet Sorghum: An alternative energy crop) is supported by the European Commission in the 7th Framework Programme to exploit the advantages of sorghum as potential energy crop for bio-ethanol production. Thereby, the main objective of SWEETFUEL is to breed for improved varieties and hybrids of sorghum for temperate, tropical semi-arid and tropical acid-soil environments. Breeding aims include, depending on region and ideotype, improved tolerance to cold, drought and acid (Al-toxic) soils as well as high production of stalk sugars, easily digestible biomass and grain.

SWEETFUEL outcomes include new germplasm, improvement of cultural and harvest practices as well as commodity chain concepts adapted to target regions within Europe, Latin America, Asia and Africa.

SWEETFUEL Consortium

The SWEETFUEL partnership is coordinated by the Centre International en Recherche Agronomique pour le Développement (CIRAD) from France and comprises the following 10 partners from research, academia and industry:

- CIRAD (coordinator), France
- ICRISAT - International Crops Research Institute for Semi-Arid Tropics, India
- EMBRAPA Maize and Sorghum, Brazil
- KWS SAAT AG, Germany
- IFEU Institute, Germany
- Universita di Bologna (UNIBO), Italy
- Universita Cattolica del Sacro Cuore (UCSC), Italy
- Agricultural Research Council (ARC) – Grain Crop Institute (GCI), South Africa
- Universidad Autónoma de Nuevo León (UANL), Mexico
- WIP Renewable Energies, Germany

SWEETFUEL Coordination

CIRAD, Centre de coopération internationale en recherche agronomique pour le développement, France

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Workshop Objectives

In this workshop activities and findings of the SWEETFUEL project will be discussed with international stakeholders representing feedstock suppliers, entrepreneurs, NGO's, policymakers, and agricultural research institutions.

Specific emphasis will be placed on the opportunities and challenges of energy sorghum breeding for industrial applications (e.g. biogas and lignocellulosic ethanol production) in Europe.

Workshop Organisation

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Workshop Details

Conference Venue:	*CCH – Congress Center Hamburg, Hamburg, Germany*
	on the occasion of the 22nd European Biomass Conference and Exhibition (EU BC&E) in Hamburg on 23-26 June 2014
Conference Language:	*English*
Project website:	*www.sweetfuel-project.eu*

Workshop Report

The SWEETFUEL Regional Stakeholder Workshop in Hamburg was opened by **Rainer Janssen** from WIP Renewable Energies, Germany. Mr. Janssen highlighted the excellent cooperation among all SWEETFUEL project partners during the past five years and underlined the importance to continue breeding efforts on energy sorghum despite the current lack of political support for energy crops in Europe. Due to the long time span required for breeding of improved energy crop varieties, continuity of research and development is urgently needed to meet potential future demands within a global bio-based economy.

Serge Braconnier, SWEETFUEL coordinator from CIRAD, France provided an overview on main activities and results of the SWEETFUEL project. With respect to ***new sorghum lines or hybrids for temperate zones***, project partners have developed new male lines for hybrid biomass sorghum, new female A/B early lines for hybrid biomass sorghum, and new female A/B lines with low lignin content.

For semi-arid tropics, new sorghum lines or hybrids include four sweet sorghum varieties available at commercial level in Brazil (i.e. BRS 506, BRS 508, BRS 509 and BRS 511), new hybrids adapted to different cropping seasons in India (i.e. ICSV 93046, ICSV 25311 + ICSV 25308 adapted to terminal stress and ICSV 25300 adapted to mid-cycle stress), five dossiers submitted to record new sweet material in the national catalogue in Mexico, as well as five sweet cultivars available in South Africa.

For each scientific SWEETFUEL result ***Exploitation Flyers*** have been elaborated and a ***Handbook "Energy Sorghum - an alternative energy crop"*** was published in June 2014. These publications are available at the project website www.sweetfuel-project.eu.

In conclusion, Mr. Braconnier stated that (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 biomass production and transformation processes, as well as the specific location of the production system.

Magdalena Chobotova from KWS Mais GmbH, Germany presented an industry perspective on the breeding of energy sorghum for temperate climates. Based on incentives provided by the German Renewable Energy Sources Act (EEG, Novelle 2004), breeding of energy sorghum in KWS started in 2007. Main breeding targets include a potential yield comparable to energy maize (also on sandy soils), high biomass yield (high dry matter yield: 25 - 30 t/ha at 600 mm rain per year, dry matter content at harvest: 28%), stability, fast young development (increase of cold tolerance, fast and homogenous germination power), as well as disease resistance.

Mrs. Chobotova provided an overview of KWS breeding locations in Germany and Italy as well as results from the breeding programme for the years 2007-2011 showing improved dry matter yield and dry matter content at harvest. However, the target values have not been achieved yet and improvements are still required with respect to lodging tolerance and early vigour (cold tolerance).

The following five important steps for successful biomass sorghum growing have been identified by KWS:

- ***(1) Location choice***: warm soils, light soils (sandy soils are better than clay and heavy soils), no areas with high grass pressure, soil analysis necessary (pH value, nutrition in soil).
- ***(2) Seed bed preparation***: very precise seed bed preparation, soil preparation after rye, direct sowing after rye not recommended, soil pressure after sowing necessary.
- ***(3) Sowing***: right choice of machinery, temperature of soil (min 12°C in 10 cm depth), sowing depth of 3-5 cm, max. 150 kg of nitrogen fertiliser per ha (lodging risk at higher fertiliser rate), row distance of 22-45 cm.
- ***(4) Weed control***: correct herbicide (mixture) selection and timing
- ***(5) Optimal harvest time***: panicles are open, kernels on panicles are developing, maturity of kernels between milk and waxy stadium.

Guido Reinhardt from IFEU, Germany presented results from the environmental assessment performed in the framework of the SWEETFUEL project. The full "Report on Environmental Assessment" is available at the project website www.sweetfuel-project.eu. For the assessment the following energy sorghum scenarios were investigated:

- ***(1)*** Biomass Sorghum: ***Biogas*** (Cultivation of biomass sorghum on idle land, biogas or biomethane production, temperate climate zones)
- ***(2)*** Sweet Sorghum: ***Cane fallow*** (Intercropping between two sugar cane cycles instead of peanuts/soy, subtropical to tropical climate)
- ***(3)*** Sweet Sorghum: ***Grain – food*** (Replacement of grain sorghum cultivation, semi-arid climate)
- ***(4)*** Sweet Sorghum: ***Syrup*** (Replacement of e.g. cotton cultivation, decentralised syrup production, centralised ethanol production, subtropical to tropical climate)

The Life Cycle Assessment (LCA) for all energy sorghum scenarios shows environmental advantages as well as environmental burdens, following the same pattern observed for other biofuels. Energy sorghum LCA displays a remarkable bandwidth of results depending on specific conditions, and thus a large potential for optimisation was identified. With respect to GHG balances of the "Biogas" scenario the following results were obtained:

- The higher the biomass yields the more greenhouse gases can be saved. Breeding efforts should focus on optimised crop cultivars. Cultivation methods should aim at highest yields possible.
- Digestate storage tanks should be covered and sealed gas-tight.
- The digestate should be incorporated into the soil as fast as possible.
- If biogas is further refined into biomethane, the use of biomethane in a combined heat and power unit should be favoured over a use as natural gas substitute or fuel.
- Direct combustion in CHP units is favourable compared to the "Biogas" scenario, whereas the production of second generation biofuels is less attractive.

Rafael Parrella from EMBRAPA Maize and Sorghum, Brazil reported on ethanol production from sweet sorghum in Brazil. For industrial application in the sugarcane sector sweet sorghum is being proposed to be planted at the beginning of the rainy season in areas of sugarcane renovation (see Figure 1) to increase the period of operation of large distilleries in Brazil by up to 100 days (initially 15 - 60 days).

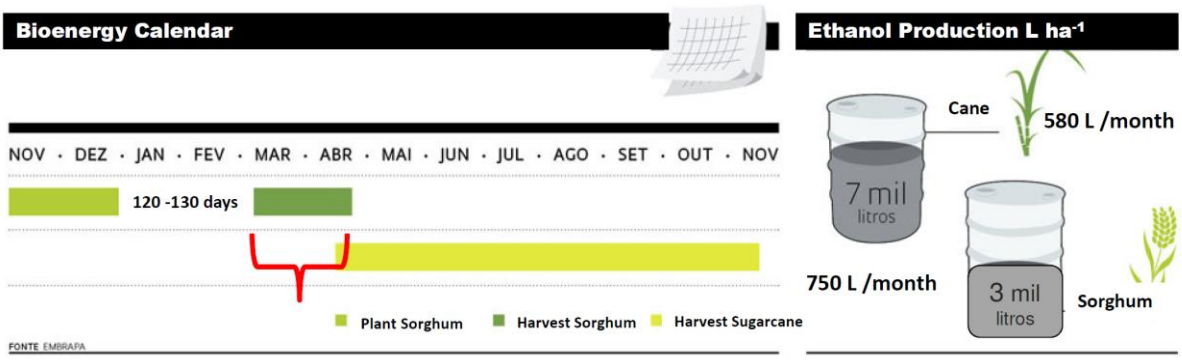

Figure 1: Industrial application of sweet sorghum in the sugarcane sector

The following minimum economic thresholds for industrial application of sweet sorghum in the sugarcane sector are estimated:

- Biomass production (t/ha): >60 (value achieved 2013/2014: >50)
- Total sugar (% juice): >14 (2013/2014: >12.5)
- Ethanol production (l/t): >70 (2013/2014: >60)
- Ethanol production (l/ha): >4200 (2013/2014: >3000)
- Period of Industrial Utilisation (PIU) (days): >30 (2013/2014: >30)

In the past years EMBRAPA has released several improved sweet sorghum varieties (BRS 506, 508, 509 and 511) with the following production system recommendations:

- Best row spacing: 0.5 or 0.7 m
- Best plant density: 120,000 to 140,000 plants per ha
- Nitrogen: 120 kg per ha (40 kg at planting and 80 kg at 4 leaf stage)
- Insect control when necessary

In order to facilitate industrial application, however, further improvements on sweet sorghum hybrids are necessary especially with respect to an increased Period of Industrial Utilisation (PIU). The main challenge thereby is to develop sweet sorghum A and B lines that are juicy, sweet and produce hybrids with small panicles. For applications in Brazil the “ideal” sweet sorghum idiotype has a small panicle (less lodging, less competition with sugar accumulation, and reduced harvesting and processing complications) and no tillering (better control of stem population, larger stem diameter, better juice quality).

Recently, there is also growing demand in Brazil for biomass sorghum for the production of process steam and electricity in industrial CHP applications. New biomass sorghum hybrids have been developed by EMBRAPA including the new hybrid CMSXS7015 validated in early 2014.

The **panel discussion on "Sweet Sorghum Valorisation in Semi-arid Tropics – Food and Fuel Production"** was moderated by Serge Braconnier from CIRAD, France and included the following panellists:

- Srinivas Rao, ICRISAT, India
- Francisco Zavala-Garcia, Universidad Autónoma de Nuevo León, Mexico
- Wikus Snijman, Agricultural Research Council, South Africa
- S.Z. Li, Tsinghua University, China

Srinivas Rao from ICRISAT, India presented results from two sweet sorghum demonstration activities in Hupari and Shirol, both in the sugar bowl area of Maharashtra (located between Hyderabad and Mumbai). Economic calculations showed significant potential retuns on investment for distilleries as well as farmers involved in the sweet sorghum demonstration trials.

Francisco Zavala-Garcia from the Universidad Autónoma de Nuevo León, Mexico highlighted the need for combined grain and ethanol production in Mexico as the country is dependent on grain imports. Recent legislation mandates blending of ethanol in gasoline in three major cities whereas the production of ethanol from grain is forbidden in Mexico. Thus, opportunities for sweet sorghum as dual purpose crop may arise, even though the current price level for ethanol set by the national petrol company PEMEX is too low to stimulate investment.

Wikus Snijman from the Agricultural Research Council, South Africa reported on the rather low interest in sweet sorghum in South Africa during the past years. This, however, may change due to the mandatory blending (5% biodiesel, 2-10% bioethanol) adopted in 2013 which will be effected from October 2015. Even though the currently identified feedstock for ethanol production is sugarcane and sugar beet, opportunities may exist for sweet sorghum due to the South African focus on rural development and areas under-used for existing agriculture.

Shi-Zhong Li from Tsinghua University, China presented an innovative technology for the production of ethanol from sweet sorghum, namely the Advanced Solid State Fermentation (ASSF) which has already been successfully demonstrated in China. Advantages of the ASSF technology include a reduced fermentation time, lower water consumption and waste water levels, reduced energy consumption as well as overall lower investment costs. Recently, Mr. Li is engaged in establishing a cooperation for the implementation of sweet sorghum based ethanol production in South Africa. By using 1.5 million ha of potentially available arable land (9% of the total) in South Africa to grow sweet sorghum, 10 million tons of ethanol, 4.5 million tons of sorghum grain, and 20 billion kWh of electricity (sold to the national grid) may be produced, leading to the creation of 100,000 jobs in the ethanol industry sector and 500,000 jobs in the agriculture sector.

Walter Zegada-Lizarazu from University of Bologna, Italy reported findings on the agronomy of energy sorghum in temperate climates. With respect to sowing, a well cultivated seed bed is needed and sowing depths of 2.5 to 3.5 cm are recommended. Maize planters can be used for energy sorghum and no-tillage sowing is possible. Furthermore, early spring sowing is not recommended due to low cold tolerance and reduced growth rates and late spring sowing is not recommended due to the reduced effective growing season. With respect to nutrient management, energy sorghum shows low fertilization requirements (~ 40% < maize), lower N uptake, and more N uptake at later growth stages. Excessive N fertilization can reduce biomass yields, juice quality, and ethanol yields. Several harvesters are being tested worldwide, but harvesting machinery for energy sorghum still needs to be improved. The fast decay of the harvested material constitutes a major problem for energy sorghum production systems.

In the field of agronomy the current main bottlenecks are limited availability of certified commercial seeds, the need for improved genotypes for different environments, soil conditions, and available agro-techniques, as well as the lack of appropriate harvest and post-harvest logistic systems.

Karen Zeise from the Bavarian Technology and Support Centre (TFZ), Germany presented recent developments on biomass sorghum for biogas in Germany. Stimulated by the favourable feed-in tariffs for biogas units established in the Renewable Energy Sources Act (EEG), Germany is currently dominating the primary energy production from biogas in Europe with more than 7500 biogas plants in operation in 2014. The increase of cultivation area under silage maize in Germany lead to problems with respect to public perception ("maize encroachment") as well as impacts on occurrence of pests and diseases, soil structure and organic matter content.

The diversification of crops, the cultivation of alternative crops, as well as mixed cropping, intercropping and catch cropping systems are promoted in order to reduce energy maize cultivation. Mrs. Zeise presented results from energy sorghum field experiments performed at TFZ including an analysis of the methane yield of different sorghum varieties. Further developments are still required with respect to lodging resistance and early maturing cultivars. Thereby, extensive instead of intensive cultivation systems should be targeted and strategies for fertilizer use, soil preparation, sowing and designing crop rotation shall focus on benefitting from the higher nutrient and water efficiency of sorghum as well as its suitability for catch cropping.

The **plenary discussion on "Industrial Use of Energy Sorghum in Europe**" was moderated by Dominik Rutz from WIP Renewable Energies, Germany and included the following panellists:

- Magdalena Chobotova, KWS SAAT AG, Germany
- Karen Zeise, Bavarian Technology and Support Centre (TFZ), Germany

The following topics were highlighted:

- The revised feed-in tariff structure within the German Renewable Energy Sources Act (EEG), coming into effect on 1 August 2014, cancels the bonus for biogas production from energy crops and thus negatively affects industry interest in energy sorghum.
- Due to the EEG revision the biogas sector in Germany is expected to "freeze" in its current state (i.e. few new plants will be built). The limit of maximum 60% maize use in biogas plants may provide opportunities for energy sorghum.
- Potential new markets for energy sorghum may arise in South-East Europe and France.
- Opportunities may also exist for the production and pelleting of biomass sorghum in South Africa. Sorghum pellets are well suited for use in combustion units due to their low chlorine and sulphur levels.
- Further research and demonstration is needed on the breeding of improved biomass sorghum hybrids, especially with respect to lodging tolerance and early vigour (cold tolerance).
- In the coming years, continuity of research and development will need to be facilitated by the private sector as well as by research institutions despite the currently unfavourable framework conditions.

All presentations held at the SWEETFUEL Regional Stakeholder Workshop in Hamburg are available at the project website www.sweetfuel-project.eu.

Annex 1 – Workshop Agenda

Thursday, 26 June 2014

09:45 *Registration*

10:15 **Welcome to the Workshop**

RAINER JANSSEN, WIP RENEWABLE ENERGIES, GERMANY

10:20 **SWEETFUEL Activities and Results**

SERGE BRACONNIER, CIRAD, FRANCE

10:40 **Breeding of Energy Sorghum for Temperate Climates – Industry Perspective**

MAGDALENA CHOBOTOVA, KWS SAAT AG, GERMANY

11:00 **Environmental Assessment of Energy Sorghum**

GUIDO REINHARDT AND CHRISTINE CORNELIUS, IFEU, GERMANY

11:20 **Ethanol Production from Sweet Sorghum in Brazil – Industrial Application in the Sugar Cane Sector**

RAFAEL PARRELLA, EMBRAPA MAIZE AND SORGHUM, BRAZIL

11:50 **Panel Discussion on Sweet Sorghum Valorisation in Semi-arid Tropics – Food and Fuel Production**

MODERATION:

SERGE BRACONNIER, CIRAD, FRANCE

PANNELISTS:

SRINIVAS RAO, ICRISAT, INDIA
FRANCISCO ZAVALA-GARCIA, UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN, MEXICO
WIKUS SNIJMAN, AGRICULTURAL RESEARCH COUNCIL, SOUTH AFRICA
S.Z. LI, TSINGHUA UNIVERSITY, CHINA

12:30 *Lunch Break*

13:20 **Agronomy of Energy Sorghum in Temperate Climates**

WALTER ZEGADA-LIZARAZU AND ANDREA MONTI, UNIVERSITY OF BOLOGNA, ITALY

13:40 **Sorghum for Biogas in Germany**

KAREN ZEISE, BAVARIAN TECHNOLOGY AND SUPPORT CENTRE (TFZ), GERMANY

14:00 **Discussion with the audience: Industrial Use of Energy Sorghum in Europe**

MODERATION:

DOMINIK RUTZ, WIP RENEWABLE ENERGIES, GERMANY

PANNELISTS:

MAGDALENA CHOBOTOVA, KWS SAAT AG, GERMANY
KAREN ZEISE, BAVARIAN TECHNOLOGY AND SUPPORT CENTRE (TFZ), GERMANY

14:50 **Summary**

RAINER JANSSEN, WIP RENEWABLE ENERGIES, GERMANY

15:00 *End of the workshop*

Annex 2 – Workshop Participants

22 nd EUROPEAN BIOMASS CONFERENCE & EXHIBITION

SWEETFUEL Workshop

Date 26 June 2014

	Name	Organisation	Signature
	Ramiro Jansen	WIP	
	Francisco Zavala-Garcia	UANL Mexico	
	Karin Zeise	TFZ Germany	
	Serge BRAConnier	CIRAD	
	Daniel Ruß	WIP	
	Rafael A.C Parella	Embrapa	
	Nádia Parella	UFSJ	
	MAGDALENA CHOBOTOVÁ	KWS MAIS Gmbh	
	Wikus Snijman	ARC-GCI	
	Linda Reinhardt	FEE G	
	ANDREA RONTI	UNIBO	
	Nils Rettenmaier	IFEU	
	Walter Zegada	UNIBO	
	Paulo Hermann	Embrapa Labex	
	Bruna Moraes	CTBE/CNPEM	
	Shi Shiyu	Tsinghua Uni.	
	Srinivas	ICRISAT	
	Mauricio Cocchi	ETA	
	Teresinha Gonzalez	CICYTEX SPAIN	
	Marisol Berti	North Dakota State Univ, USA	
	STEFANO AMADEI	UCSC	
	Claudia Tramón	U. of Concepcion CHILE	

ROCIO DIAZ-CHAVEZ IMPERIAL COLLEGE