Sweet sorghum: a suitable alternative energy crop

Dr Serge Braconnier discusses his research into the benefits and extended ethical issues of producing bioethanol from sweet sorghum crops using genetic enhancement

Could you begin by outlining your overall aims and objectives?

Sweet sorghum is a smart crop that does not compromise on food/feed security when cropland is diverted for ethanol production. the overall objective of the project is to develop the production of bioethanol from sweet sorghum in temperate as well as the acid savannas and semi-arid tropics through genetic enhancement. Besides breeding activities, we also have to take into consideration agricultural practices and harvest technologies. Finally, we must study the impacts of the development of ethanol from sweet sorghum at economic, social and environmental levels as well as at different scales: human, village, region and country.

How long does it take to ferment sweet sorghum into a useful quantity of ethanol?

The process to produce ethanol from stalks of sweet sorghum is the same as for sugar cane: the juice is extracted then fermented in big tanks before distillation. Fermentation usually takes around two days depending upon ideal fermentation conditions and strains used.

Will this fuel not be afflicted by the same issues as other biofuels? Have you identified any ethical risks resulting from ethanol production?

Concerning ethical risks, an external expert is involved in the project to survey the risks of the development of sweet sorghum to produce ethanol. Before signing the grant agreement the Commission asked us to identify, ex ante, the different risks. As long as sweet sorghum is used as a multipurpose crop, the risk of the competition food/fuel is less evident than for maize which is the second crop used to produce bioethanol.

What are the projected economic benefits of producing biofuels from sweet sorghum in arid, drought prone environments or regions with poor soil quality?

In temperate areas, sorghum represents a good opportunity for producing cellulosic raw material of good quality. This plant, compared to maize, has great advantages as its requirements of water and fertiliser are low while its potential of improvement through breeding is very high.

In tropical areas, the impact may be huge eg. in the case of Brazil where sweet sorghum has the potential to extend the milling season by up to 100 days in a large-scale distillery. The economics of small-scale distilleries has not yet been adequately studied. It is still at too early a stage to evaluate all the economic parameters of agricultural and industrial production. As SWEETFUEL will provide new varieties adapted to poor soils, we expect that some areas not currently exploited may be planted with sweet sorghum.

In India, data from pilot sites indicates that sweet sorghum cultivation is more profitable than grain sorghum and also other dryland crops like maize/maize pigeonpea intercrops when both grain and stalk are harvested. Sweet sorghum stalks can be crushed at the village level to produce syrup that will be used for ethanol production at the distillery. Syrup production provides employment opportunities to local people. In addition, the bagasse is an excellent source of livestock feed and can be sold to livestock owners for additional income.

Is SWEETFUEL working closely with local farmers to meet the needs of both parties and ensure that the crops and technology utilised in the project are used to their full potential?

SWEETFUEL works with farmers through the national institutions like EMBRAPA in Brazil, ARC-GCI in South Africa, UANL in Mexico and the international centre ICRISAT in India. At the end of the project, a workshop will be organised in each country, and for temperate areas, the meeting will be organised during the European Biomass Conference and Exhibition in 2013 or 2014. The objective of the workshops is to transfer the results of the project (recommendations related to plant material, cultural practices, harvest technologies, public policies etc.) to all of the invited stakeholders.

All the different parts of the plant can be used: grain for food/feed, leaves for feed, stalks for syrup/ethanol, bagasse for feed or co-generation or fertiliser, depending on the choice of technology utilised in the production chain

How does the quality of the ethanol produced compare to other biofuels on the market? What are the projected costs to the consumer?

98 per cent ethanol from sweet sorghum is the same as from sugarcane. It is the industrial process that may make a difference. A litre of ethanol from sweet sorghum would most likely be competitive with ethanol from sugar cane molasses in the semi-arid tropics or maize under temperate environments, due to lower feedstock production cost. The precise projected costs are not yet known as they depend on the country and the process of transformation, but they will be provided at the end of the project.

Sweet sorghum: a smart fuel solution

In the quest for the perfect sustainable fuel, **SWEETFUEL** focuses not only on understanding the mechanisms which underpin the production of bioethanol from sweet sorghum, but also on producing new varieties adapted to different environments and evaluating the broader impact this use of the crop may have

THE INCREASING COST of fossil fuels as a result of growing demand on limited stocks has encouraged the development of sustainable fuels as a now economically viable option. Research has progressed to discover and develop increasingly cheaper and more efficient forms of sustainable energy including recent studies into the production of bioethanol from crops. As a result of such developments, arable land is increasingly being taken over for energy crops. This fact, combined with climate change, the constant fight against scarcity of water and an ever growing population increasing the demand for food and energy, has begun to threaten agricultural systems, particularly those in the tropics and subtropics. The need for alternative sources of fuel poses the question of how development of the energy crop sector may be turned from a threat into an opportunity for a community to invest in the quality of their land resources, intensify their cropping systems and, most importantly, buy food as the traditional subsistence systems no longer provide enough to meet demand.

In order to find the solution to this problem, the SWEETFUEL project was launched in 2009 with funding from the European Commission's Seventh Framework Programme (FP7). The project looks specifically at the development of sweet sorghum as an alternative energy crop – using novel molecular tools within breeding programmes – and the wider economic, environmental and social impacts of doing so.

A CROP OF MANY QUALITIES

Sweet sorghum is a multipurpose crop, simultaneously providing food, feed and fuel. It is a C4 cereal, one of the most efficient plants to convert light into carbohydrates through photosynthesis and can be grown on 80 per cent of the world's agricultural land. Its requirements in terms of water and nutrients are far lower than main energy crops, and compared to such crops, maize and sugarcane, sweet sorghum has great advantages: it can grow in marginal soils, it has the capacity to produce grains for human or animal consumption and it accumulates sugars in its stalk that can be used for ethanol production. In addition, the bagasse (fibrous residue) resulting from juice extraction can be used as feedstock, fertiliser or burned for cogeneration. Through the process of the project, scientists will improve sweet sorghum through genetic enhancement to produce new genotypes that are more tolerant of cold temperatures for temperate area, drought, soil acidity, aluminium toxicity as well as phosphorus deficiency for semi-arid tropics, thus allowing extension of that crop on larger area. Within the project, scientists have developed SAMARA, a new model to simulate plant production. This model will help to identify the potential zones suitable for sweet sorghum growth.

RECOGNISING REGIONAL REQUIREMENTS

The widespread and varied application of the project is vital to its success, as Dr Serge Braconnier, coordinator of the project, states: "It is important to make a distinction between temperate areas and semi-arid regions because the ideotype of sweet sorghum is not the same for both environments". In temperate regions, Braconnier anticipates the installation of a two-stage process of production in order to extract the ethanol from ligno-cellulosic material. For this, breeders target a sorghum that produces the maximum biomass and has low lignin content for facilitating the first step of the process: the digestion of cellulosic fibres to produce sugars. The plant for the second stage of ethanol extraction will be on a much larger scale and the whole system will be centralised. As Braconnier explains, "even if big plants producing second generation alcohol are not yet operational at industrial level, we guess it will be the case in the future and we anticipate this".

For tropical semi-arid regions, scientists target a dual-purpose sorghum (a sweet sorghum) that is able to produce grains for the food chain and to accumulate sugars in stalk that will be used for ethanol production.

Further to the distinction between temperate and semi-arid regions, the project recognises other specifics that may affect the research and/or results and the process in such cases has been adapted accordingly. In the acid savannas of Brazil, the large sugarcane distilleries are interested in producing sweet sorghum to extend the harvest, or industrial, period for an additional 30 to 100 days. Infrastructures for this have now been put in place. In India both systems may be found: a centralised system with a big plant and many farmers providing their harvest to the plant, and some small crushing units that are able to extract juice from sorghum stalks and concentrate it through boiling to produce syrup since production of alcohol by farmers is forbidden in India. In South Africa, one company started to produce ethanol that is transformed into gel used in a specific stove for cooking, as farmers are not allowed to commercialise alcohol. In Mexico there is no big plant as yet, but there are projects underway which, it is hoped, will be completed soon.

CONNECTING AND COLLABORATING

As seen, the potential for producing bioethanol from sweet sorghum may be influenced by a variety of factors which has encouraged SWEETFUEL to become a widespread project incorporating 10 partners. These partners hail from Europe, Mexico, Brazil, India and South Africa and are overseen and coordinated by CIRAD (Centre de cooperation international en recherché agronomique pour le développement). The partners include national public and private organisations chosen for their expertise in specific areas and/or to test the project across a wide variety of environments. For example, KWS SAATAG, a German private seed company, will focus on the adaptation to low temperature in temperate regions, while UANL, a university from Mexico, will evaluate the material in Mexican environments as well as provide germplasm for the research.

Due to the parties currently involved, the project will look to encourage further collaboration once the project ends. For example, CIRAD and EMBRAPA, the national research institution from Brazil, are likely to combine in the area of genomics and lignin generation research whilst EMBRAPA will inevitably join together with ICRISAT (International Crop Research Institute for the Semi-Arid Tropics) based in India, in the study of germplasm and cultivar development.

Developing productive cultivars with tolerance to different biotic and abiotic stresses is a big challenge. Ultimately, Braconnier is optimistic about the project's continuation after the first phase: "The small steps made under the SWEETFUEL project will pave the way for further improvement in understanding different mechanisms of sugar accumulation within the plant, plant and environment interaction, as well as the sweet sorghum value chain through its life cycle compared to alternatives".

INTELLIGENCE

SWEETFUEL

SWEET SORGHUM: AN ALTERNATIVE ENERGY CROP

OBJECTIVES

SWEETFUEL aims to develop sweet sorghum genotypes that would provide maximal quantities of high-quality substrate for the production of bio-ethanol, for temperate, tropical semi- arid and tropical acid-soil environments.

FUNDING

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PARTNERS

Centre international en recherche agronomique pour le développement (CIRAD), France • **International Crops Research Institute for Semi Arid tropics (ICRISAT)**, India • **Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA)**, Brazil • **KWS SAAT AG**, Germany • **Institut fuer Energie und Umweltforschung Heidelberg GMBH (IFEU)**, Germany • **Alma mater Studiorun-Universita di Bologna (UNIBO)**, Italy • **Universita Cattolica del Sacro Cuore (UCSC)**, Italy • **Agricultural Research Council (ARC-GCI)**, South Africa • **Universidad Autónoma de Nuevo León (UANL)**, Mexico • **Wirtschaft und Infrastruktur GMBH & Co Planungs KG (WIP)**, Germany

CONTACT

Dr Serge Braconnier
Project Coordinator

CIRAD
Unit Research 'Agro Ecological Adaptation and Varietal Innovation' (AIVA)
TA A104/1 Avenue Agropolis
34398 Montpellier Cedex, France

T +33 467 61 7539
F +33 467 61 5742
E serge.braconnier@cirad.fr

http://www.sweetfuel-project.eu/

SERGE BRACONNIER is an ecophysiologist at CIRAD. From 1998 to 2005, he was Scientific Responsible of Centre d'étude régional pour l'amélioration de l'adapation à la sécheresse (CERAAS) working on improvement of plant adaptation to drought, and coordinator of the INCO project Groundnut – Aflatoxin. Since 2005 he has worked for CIRAD coordinating the FP7 project SWEETFUEL, as well as the ANR project 'S3F for Haïti', both aiming to develop sweet sorghum for producing a renewable energy.