Summary Report

of the

“Global Consultation on Pro-Poor Sweet Sorghum Development for Biofuel Production and Introduction to Tropical Sugar Beet”

Organized by IFAD, FAO and ICRISAT

8-9 November 2007

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EXECUTIVE SUMMARY

The Consultation - organized by IFAD, FAO and ICRISAT – brought together Experts, Stakeholders and Staff from development Organizations, Research Institutions, Universities and the Private sector, to discuss “Potential of Sweet Sorghum for bio-ethanol production, with a pro-poor focus”.

A special session on Tropical Sugar Beet (TSB) as a new bio-fuel crop, for tropical and sub-tropical areas, was also presented.

The purpose of the workshop can be summarized as follows:
* What do we know about sweet sorghum as a bioenergy crop?
* What we need to know to promote its potential for needs of poor farmers?
* What are the implications for food security, carbon balance and livelihoods of the poor?

Thematic Area (A):
Overview of Sweet Sorghum (SS)

In general, it was almost unanimously recognized that sweet sorghum has a considerable potential as a pro-poor energy crop, not just as a multi-purpose crop in its own right, but also in comparison with sugarcane. The following characteristics are especially noteworthy:

• Sweet sorghum (SS) is an efficient converter of solar energy, as it requires low inputs and yet, a high carbohydrate producer.
• As a drought-tolerant crop with multiple uses, it is particularly important for farmer in fragile agro-economic conditions.
• It has a concentration of sugar which varies between 12-21%, directly fermentable (i.e. no starch to convert).
• It can be cultivated in temperate, subtropical and tropical climates.
• All components of the plant have economic value - the grain from sweet sorghum can be used as food, the leaves for forage, the stalk can be used (along with the grain) for fuel, the fiber(cellulose) either as mulch or animal feed and, with second generation technologies, even for fuel.
• The bagasse, after sugar extraction, has a higher biological value than the bagasse from sugarcane, when used as forage for animals.
• Its growing period is shorter (3-5 months) than that of sugarcane(10-12 months), and the quantity of water required is 1/3.
• In tropical irrigated areas SS can be harvested twice each year (by ratooning) and its production can be labour-intensive or completely mechanized.

Like most bio-fuel crops, SS has the potential to reduce carbon emissions and its potential to stimulate the domestic and, in particular, the rural economy, was especially noted.

In this respect it was observed that advances in the technologies (and especially development of second-generation technologies within 10-15 years) are expected to lead to big improvements in energy ratios and net carbon
savings, and to reduce the trade-offs between bio-energy crops and food production, which is currently of great concern.

**Thematic area B: Sweet Sorghum Breeding**

There are significant variations in yields between varieties obtained by farmers in China (100 MT/ha biomass) and India (50 MT/ha). The need for increasing the yields and improving bio-mass was stressed and this potential exists. Since SS is at a relatively early stage of its development, continued research was needed to obtain better genetic material and match local agro-economic conditions.

The participants noted that there are many varieties with high stalk and grain yields, high sugar content, and emphasized the need for developing a research agenda to identify cultivars with the following characteristics.

- **Priority 1 traits:** High cane, grain and stalk sugar yields.
- **Priority 2 traits:** Resistance/tolerance to shoot pests, foliar diseases, and abiotic stresses (as above), including phosphorous acquisition efficiency.

The aforementioned results would be achieved through the following activities.

**Activity 1:** Pooling and cataloguing all advanced sweet sorghum cultivars available.

**Activity 2:** Testing advanced varieties and hybrids across tropics, sub-tropics and temperate areas and identifying the most locally adapted cultivars.

**Activity 3:** Breeding for priority 1 traits (cane, grain and stalk sugar yields) by conventional breeding and monitoring them for priority 2 traits in male-sterile and restorer lines.

**Activity 4:** Developing RILs for sugar-related traits, developing maps and identifying suitable stalk sugar-related traits.

**Activity 5:** Improving SS male-sterile lines for various Priority 1 and Priority 2 traits.

**Activity 6:** Developing hybrid seed techniques in various developing Countries, particularly in Africa.

**Thematic Area C: Sweet Sorghum Agronomy**

Speakers noted that since SS is an age-old crop, most farmers have no difficulty in its cultivation and the cultivation practices are simple and readily adoptable. Although it can be cultivated over large areas in rainfed conditions, the use of irrigation was found useful for improving yields. Experiments also showed that potential for SS production can be increased through selection and development of adapted cultivars.

The group recognized that crop husbandry of sweet sorghum should aim at increased productivity with focus on improved feedstock supply duration, to ensure regular supply to the processors. The group also recognized that the research activities related to achieve the above are highly location-specific.

Suggested research activities by the group, that could have greater impact, are:
• Water and fertilizer (macro- and micronutrients) effects and their interaction on sugar, grain and bagasse yield and quality.
• Effect of day length and temperature and their interaction, on sugar, grain and bagasse yield and quality (and help identify suitable cultivars for season/location).
• Effect of inter-cropping with leguminous crops on the sustainability of the systems.
• Crop rotation experiments to identify the most productive and sustainable cropping systems for different ecosystems.
• Establish research to understand, manage and improve soil organic matter levels, e.g., share of above general biomass that should be retained in-field and new management practices for maintaining some moisture following conservation agriculture practices.
• Understand and manage carbon and energy balances at the field level.
  - Specifically impacts of biochemistry
  - Use of mineral nitrogen fertilizer

**Thematic area D:**
**Sweet Sorghum Post–Harvest Technologies and Processing**
The status and constraints of post-harvest technologies and processing were discussed, both by researchers and private companies technical staff. It was generally observed that, although there was a difference of 50% in processing costs between large and small plants, many companies could now provide machines to process bio-ethanol at a small-scale level, cost-effectively as well. However, experience with some private companies and the findings of Oklahoma State University, showed that post-harvest technologies still pose problems for transportation, crushing and processing of feedstock in a central processing facility, as these can still cause a decline in the quality of the crop and its sugar content yields, and require elaborate logistical arrangements with high capital investment.

In India, one of the processors had problems as the farmers had not staggered production and the processing plant could not handle peak production as the crops matured. Many suffered losses. The company was now thinking of decentralized units to make jaggery that could be processed at a later date. Other possible solutions identified include in-field fermentation which envisages the juice to be pressed, collected, stored, and fermented in the field. While the technology for processing, storing and fermenting the juice had been more or less mastered, the problem of reducing the water content after fermentation to reduce transportation costs still had to be addressed.

**Thematic area E:**
**Sweet Sorghum: Socio-economical Tools for Decision Making and Business Development.**
FAO presented a comprehensive list of tools for decision for developing specific projects, the use of which would ensure that bio-fuels development will be inclusive. The private sector participants noted that many companies had the experience and the technological backing to assist small and middle sized processors in developing bio-fuels production and processing.
Some speakers especially noted that the demand for bio-fuels was high and many investors would be even willing to provide long-term fixed price contracts, with revolving irrevocable letters of credit to ensure that the producers could arrange local level financing to establish both production and processing facilities.

**Special Session on:**
**Tropical Sugar Beet (TSB).**
TSB has been especially bred and tested through experiments in many parts of the world (India, Sudan, Colombia, Kenya, South Africa) both as an alternative crop to sugar cane and as an alternative or a complementary crop to sugar cane crystal production and/or bio-ethanol production. There is considerable global interest in TSB e.g. in India, South Africa, Swaziland, and Colombia.
It has the following characteristics that make it particularly suitable for IFAD and FAO target group.
- It is a short duration crop (5 – 6 months) with quick returns.
- Moderate water requirement, about 30 – 40% of sugar cane. Can be irrigated with brackish water, using drip irrigation, as long as water is moderately saline.
- Fertilizer requirement is also 30 – 40% of sugar cane.
- High sucrose content of 14 –18%.
- Sugar beet can be grown in saline & alkaline soils.
- Easy for harvesting and it continues to grow as long as it is in the soil. It has no peak production period and can be used as complementary feedstock for year-round supply both to the sugar industry and bio-ethanol industry, improving the operating efficiency of both.
- With yields of up 80 MT / ha can be source of high income to farmers.

It is claimed that TSB enhances the yields of the next crop. It is also noted that TSB is harsh on the soils and some additional research work will be required to assess whether it can be used in rotation with sweet sorghum to meet the feedstock needs of processing plants on a year-round basis.
Opening remarks

The Consultation - organized by IFAD, FAO and ICRISAT – brought together experts, stakeholders and staff from development organizations, research Institutions, Universities and the private sector to discuss potential of sweet sorghum for bio-ethanol production with a pro-poor focus.

A special session on Tropical Sugar Beet (TSB) as a new bio-fuel crop, for tropical and sub-tropical areas with saline/alkaline soils, was also presented.

The Consultation was opened by Mr. Kevin Cleaver, Assistant President, IFAD, who noted that in view of the fact that almost 70% of the IFAD projects were in remote areas with poor agro-climatic conditions that offered limited opportunities for increasing the incomes of the poor, selected bio-fuels crops could provide an important source of income and energy to the poor.

Mr. Cleaver noted the following salient points with respect to development of bio-fuels.

- While the recent increase in price of fossil fuels now offers a unique opportunity to provide income to small farmers in these remote areas, their introduction will not be successful unless the many and varied needs of the small farmers for food security, animal feed and cash income are met from their small holdings.

- The issue of food security and reasonable food prices for the poor are important and should be an integral part of the agenda promoting bio-fuels.

- A substantial research agenda is required to address the on-going issues about food prices and focus should be on crops with multiple uses that can provide food security and yet meet some of other needs of the smallholders for animal feed and cash income, as noted in the recently approved IFAD grant.

- The crops selected under this grant cover both crops for bio-diesel (Jatropha and Pongamia) and as well as crops for bio-ethanol production (sweet sorghum and cassava). Sweet sorghum is especially interesting as it produces grain for food, it has a stalk that contains sap for use in bio-ethanol production and the leaves and the stover provide for animal feed.

- Mr. Cleaver also emphasized that because investment in bio-fuel plants is already taking place, time is of the essence as it is important for the poor to take advantage of this emerging opportunity. Partnerships between the poor, the private sector, research Institutions, IFIs and the Governments, are especially important in achieving this objective and the research agenda should address the issues from a broad spectrum of perspectives, with priority to those crops that are ready for adoption.
The Consultation was chaired by Mr. Eric Kueneman (FAO) and co-chaired by Mr. Mark Winslow (ICRISAT) and Mr. Vineet Raswant (IFAD). The Chairmen welcomed the participants, expressed the interest of the organizing Institutions on the subject and on the possible follow up of this new development opportunities for poor rural areas of developing Countries. The purpose of the workshop can be summarized as follows:

* What do we know about sweet sorghum as a bioenergy crop?
* What we need to know to promote its potential for needs of poor farmers?
* What are the implications for food security, carbon balance and livelihoods of the poor?

**Subject matters of the Consultation**

The Consultation was subdivided into 4 thematic sessions:

**Sweet Sorghum: 1) Overview, 2) Breeding, 3) Agronomy, 4) Post-harvest Technologies, Processing and the Private Sector**

and a special session on **Tropical Sugar Beet**.

In the first session (Overview of Sweet Sorghum), 4 contributions were presented, respectively

by Peter Hazell (Imperial College, London) on: “Bioenergy and Agriculture: Opportunities and Challenges”;

by Mark Winslow (ICRISAT) on “Sweet sorghum: ensuring that the poor benefit”;

by K.P.C. Rao (ICRISAT) on “Socio – economic models for integrating the poor into large – scale sweet sorghum feedstock supply chains in dryland India”; 

by Jeff Tshirley (FAO) on “Biofuel production in developing countries: sorghum and greenhouse gas balances”.

Peter Hazell made his presentation first mentioning the several promises of bioenergy, considering: the high cost of oil and the need of cheaper alternatives; the presumed increase of oil demand of at least 50% by 2025; the political instability of several oil producing Countries; the global climate change and the need to reduce fossil carbon emissions; the possible effect in promoting rural economy both in developed and developing Countries; the fact that, unlike oil, most Countries can produce some bioenergy for internal use and, eventually, also for export.

Today, bioenergy accounts for only 14% of total world energy use; 33% in developing Countries (70% in Africa) - mostly burning of biomass -, but only 3-5% in industrial Countries. The use of biofuels for transport is now only high in Brazil (40%), but only 3-5% in US and EU and zero in many Countries. At the present oil price of about 100$/barrel, most oil substitutes are becoming economical: ethanol from sugar cane and sweet sorghum is economic at oil
prices of $30-35/barrel (Brazil); ethanol from maize seed is economic at $55 (US); biodiesel from oilseeds is economic at $80 (EU).

The energy balance (energy used for biofuel production/energy developed by biofuels) is now estimated as follows: ethanol: 1 to 1.2-1.5 for wheat, barley, maize grains; from sugar cane 1 to 8; biodiesel from oil palm 1 to 9, from soybean 1 to 3, from rapeseed 1 to 2.5.

The net carbon savings of biofuels, when blended with gasoline or diesel, can reduce carbon emission by 30%-40% up to 90%, in the case of sugarcane. Future technologies developed to use e.g. cellulose for making biofuels, could strongly decrease the cost of production and promote the use of marginal lands, not usable for food production (like poor forest or semiarid areas). Moreover, new technologies could produce big improvements in energy ratios and net fossil carbon savings in the near future (10-15 years).

Dr. Hazell finally provides several research goals in order to reduce the trade-off between the bio-energy crops and food production: e.g. increasing biomass yield in important crops; focus on food crops generating larger amount of energy-producing by-products; develop and grow biomass in less favored areas, etc. The presentation produces answers to many basic questions.

Mark Winslow introduced a basic question: is biofuel production in antagonism with food production? He expresses the ICRISAT’s belief that BioPower can empower particularly the dryland poor to benefit from the bioenergy revolution. Production of biofuels, if properly used, can improve incomes, food production, environment. How? 1) Using crops that also the poor can grow. 2) Growing crops that produce food, feed and fuel (like sweet sorghum) 3) Increasing productivity, so fuel rides the biofuel wave. 4) promoting pro-poor income-busting feed stocks supply. 5) Growing non-food biofuel crops that grow in wastelands (like castor bean, *Jatropha* etc). 6) Using bio-energy crops which can improve soil and land fertility and protection. Taking particularly into consideration semi-arid Indian areas of Andra Pradesh, data obtained with sweet sorghum gave average farmer’s productions of green stalk of 20 t/ha; of juice of 6 t/ha; of sugar of 1 t/ha and of ethanol of 800 liters (in India now equal to US$ 420).

He concludes that promotion of BioPower presents 3 research priority areas: 1) To increase rural bioenergy self-reliance and income. 2) Alleviate poverty through pro-poor biofuel markets. 3) Bio-energy knowledge sharing leads to sharing the wealth.

International cooperation research and development can achieve this goal.

K.P.C. Rao presented a technical, political and socio-economical evaluation of the potential of Sorghum in India, with particular reference to the prospects of Sweet Sorghum (SS) development and utilization also for biofuel production. He stressed the declining area and production of grain sorghum (human food) in India in the last 30 years: from 6.56 million ha in 1970 to 2.43 million ha in 2003 (63% drop). Southern areas were the most affected. This was mainly due to the very low return to cost (about 2.5% on some areas) and to consumers’ preference to other cereals. However sorghum can be re-launched as a commercial crop, to be used as food, feed and for production of sugar and of
ethanol, provided that production and revenue could be increased and the production chain improved, from production to consumer. With the development and utilization of new hybrids, yields could increase as much as 25%-50%. High petrol prices could increase the revenues of ethanol and of the biomass produced by farmers. Credit support to farmers and decentralized crushing units and general improvement in processing technologies and economies of scale could easily bring down the cost of conversion of sorghum stalk into ethanol. Moreover, the dried stalks could have other economical uses. There are several climatic, soil, and social constraints to overcome, but some studies performed in 2007, involving some 800 farmers in Andra Pradesh, have shown that the best yields obtained were in the range of 30-35 tons (of stalk) per ha, while the poorest were as low as to 8-10 tons per ha, with averages of 15 tons per ha. Some farmers harvested also some 400 Kg of grain per ha. Harvesting times were very important: many farmers delayed harvesting and procurement to the processors. The overall results were not positive as to profit for both farmers and processors. Future planning and implementation strategies have to be carefully designed to avoid negative experiences, particularly by farmers. Two procurement models are discussed: decentralized and centralized plants and four socio economical models are presented 1) grower - crushing unit - processor ; 2) grower - self-employed entrepreneur (owning crushing unit) - processor 3) farmers cooperative owning crushing unit with a contractual tie-up with the processor and 4) Village agent organizing production – crushing unit - processor. The 4 socio-economical models were evaluated as to profitability of the several actors involved.

Jeff Tschirley presented an evaluation of the SS potential as producer of ethanol, considering the comparative advantages of this crop as to the food system and to the bioenergy system. However, besides the cost of production and the revenue of ethanol, other factors must be considered: the greenhouse gas benefits, the complementarity to other biofuels crops, the multiple functions in the production system. As to the greenhouse gas benefit, several evaluation methods were analyzed, considering different crops and technologies and greenhouse gas balances were reported for several biofuels and biofuel sources, as estimated by Spitzer, 2006. Moreover data from Fritsche, 2007, were reported as to several factors regarding biofuels of first generation (ethanol, biodiesel and biogas) and of second generation (technologies not yet industrially available) using cellulose and some biomass residues or other crops not yet well known and domesticated (e.g. Jatropha).

As to the potential of sweet sorghum for ethanol production in developing Countries, many questions, as to farmers’ production potential, as to the existence of processing structures adapted to different socio-economical situations, as to the potential for home use and/or for export, including trade conditions, must find still a comprehensive answer.
In the Second session: (Sweet Sorghum Breeding) three contributions were presented, respectively:
by Li Dajue (Institute of Botany, Chinese Acad. of Sciences, Beijing, China) on: “Breeding for multiple use: Sweet sorghum for fuel, feed, food and fiber”
dajueli@hotmail.com
by Robert E. Schaffert (Embrapa, Brazil) on: Sweet sorghum Improvement and production in Brazil”
by Belum VS Reddy (ICRISAT, India) on “Overview of Sweet sorghum Breeding at ICRISAT: Opportunities and Constraints”. b.reddy@cgiar.org

Li Dajue presented recent results of sweet sorghum breeding program conducted in the last 5 years by the research unit working with him. Besides the release of several cultivars, among which cv BJ-248 (sucrose type) represents an important achievement (in Thailand obtained 9.170,9 liters of ethanol/ha), an important result was the discovery, in 2001, in the field, of a male-sterile sweet sorghum plant with high sucrose content in the stem. The plant was cloned by in vitro culture and the line, called GEH-1, when crossed with several SS cultivars produced a yield increase of 40% - 80% more then the cv Keller (used as control). These hybrids were called “Super Hybrids of Sweet Sorghum” (SHSS), producing plants more then 5 meters tall, with large stems, with high sucrose content. GEH-1 plants are becoming, at least partially, male fertile if cultivated under particular photoperiod and temperature conditions; therefore this line A not needs a maintainer B line, with a behavior similar to some male sterile lines of rice, used in China for production of hybrids, when crossed with a restorer R line. Moreover, the research team isolated a mutant line of SS, called GEM-1, showing “absence of tillering” and producing large stems and high Brix values. The character “no tillering” is increasing sugar yields in the stems and provides higher lodging resistance. (Also in sugarcane this character would be useful, but it is unknown in this crop). Correlation studies performed on 5.148 individual plants from many cv and hybrids, regarding: high stalk yields, high grain yield, high sugar (Brix index) content in the stem, showed positive correlations (only small negative correlation (- 0,029 )was found between Brix index and stalk diameter). Besides the possibility, in SS, to select for resistance to drought, to salt and alkali soils, it is possible to select for high biomass and high sugar content also in difficult pedoclimatic conditions. By the Li Dajue team, from 1985 to 2006, the following breeding goals were achieved in new SHSS lines/hybrids: plant height was increased by 42,5%, stalk weight by 65%, biomass yield by 59,4%, Brix in stem juice by 43,8%. The team has now a high germplasm collection of SS lines and selections, among which also is available a very interesting line with stigmas staying alive for 20-30 days (overcoming the problem of synchronization of flowering in hybrid production). Moreover, a technology for storage of SS stalks was patented: it decreases the SS stalk volume by 2/3 and the material can be stored without sugar loss for years.
Prof. Li Dajue concluded stating that SS has a brilliant future for energy, food and feed production in China and in the entire world, also because of his good adaptation to tropical, subtropical and temperate areas.

Robert Schaffert presented the Brazilian breeding activities on sweet sorghum. In the late 1970’s Brazil initiated a bio-energy program (Pro-Alcohol) to meet Brazil’s fuel needs. Besides large distilleries using sugarcane, micro-(100L/hr) and mini-(100L/hr) distilleries were strongly promoted and EMBRAPA’s sweet sorghum program was developed to provide raw material for these small distilleries, mainly established for small farmers. Pilot projects were successfully developed in mid-1980’s.

The advantages of using SS vs. sugarcane were: SS can be harvested 3-4 months after seeding; the production can be completely mechanized; it can be established from seed; the grain produced can have several uses; the bagasse has higher biological value than the bagasse from sugarcane; SS is more water use efficient.

Several breeding priorities were established: high biomass and sugar yield; large panicles if grain is used; non-tillering types, etc. Specific yield and quality goals were: at least 40 t/ha of biomass, minimum sugar content 12.5%; minimum alcohol yield 40 L/t of biomass. New SS cvs were obtained: BR 506 and BR 507, providing higher ethanol yield than Brandes and Wray.

However, the program was then mainly shifted to the production of sugar from sugarcane, while the breeding of sweet sorghum was mainly oriented for forage production.

Recently the SS program for biofuel production was again promoted, aiming to the evaluation of about 50 sorghum cvs and of breeding of hybrids, identifying lines A, B and R, resistant to biotic and abiotic stresses (particularly to aluminum toxicity), with no tillering stems, with high sugar and cellulose (brown midrib leaves) content, adapted to short day, using also modern transgenic technologies. New research activities are now promoted in Brazil.

Belum Reddy introduced ICRISAT’s BioPower strategy: it could present an opportunity of benefit for dryland farmers, ensuring both food and energy security, increasing smallholders income and sustaining environment, focusing on the increasing of biomass, of juice and of grain yields. The SS ethanol production is now cost effective (increase of oil cost !), has high water use efficiency, is seed propagated, the hybrids production technology is available and it has a high positive energy balance (1:8, as sugarcane).

In India, the cost of production of 1 liter of ethanol of sorghum, including irrigation, is 20% cheaper than the production of 1 liter from sugarcane.

ICRISAT’s strategy goals are: 1) improvement of SS cvs, hybrid parents and hybrids, adding bmr (brown midrib) character for the increase of cellulose content and decrease of lignin (useful for both forage and energy use); 2) improvement of management practices by Public – Private – People Partnership.

By screening of high number of A, B and R lines present in the germplasm, coming from many areas and testing of about 500 hybrids, several hybrids
showing, in rainy season, sugar yield above 5 t/ha were obtained. In optimal conditions, some hybrids reached 9 t/ha of sugar. The several yield components were also carefully investigated. The presentation provided also information of production in other tropical Countries, the relative cost of production of ethanol in comparison with sugarcane and maize, the potential of production in different tropical soils etc. ICRISAT can be a good source of important germplasm for the utilization of SS as biofuel source, in many Countries of the world.

In the Third session: (Sweet Sorghum Agronomy) five contributions were presented, respectively:

by Belum V.S. Reddy (Icrisat, India) on “Hybrid Sweet Sorghum production systems overview”. b.reddy@cgiar.org
by Jeremy Woods (Imperial College, UK) on “Sweet sorghum agronomy for optimization of farmers’ returns”. jeremy.woods@imperial.ac.uk
by Li Hongju (Beijing Green Energy Institute, China) on “Sweet sorghum production systems and agronomy” hongyuli630@hotmail.com
by Kevin Gallagher (FAO, Roma, Italy) “Approaches for the development and dissemination of improved pro-poor technologies” kevin.gallagher@fao.org
by Luigi Pari (CRA, Italy) “Sweet sorghum mechanization”. luigi.pari@entecra.it

Belum Reddy presented SS characteristics in relation to the different possible utilizations, SS pedoclimatic adaptation, global (and particularly Indian) diffusion and production statistics, specific seed technologies for production of selected lines, cvs and hybrids. Then agronomic practices were treated in depth: land preparation, seed rate and spacing, sowing, fertilization, intercultivation and pesticide application( with particular reference to shoot fly, stem borer, most important diseases), irrigation, weed management, harvesting. Then the technologies of processing: preparation of cane, farmer’s and industrial extraction of juice. This presentation could be a very useful summary for extension operators. He concludes that SS can be cultivated in rainfed and irrigated conditions, in tropical, subtropical and temperate areas, can easily be propagated by seed, using both pure lines and hybrids and farmers can easily cultivate this crop

Jeremy Woods first reported on a series of trials performed in 4 pedoclimatic regions of Zambia using 9 cvs of SS. Variation in different areas were found as to stem diameter, population density, Brix values at milk-dough stages and at maturity of grains. Highest values of sugar content were obtained with cv Wray, Keller, GE 2, GE 3 and TS1. Highest yields were obtained in best soils with irrigation and fertilizers and with 2 crops (by ratooning) per season. In the second part an analysis was reported on potential areas that could be devoted to SS for biofuel production in 4 Countries of Southern Africa (Malawi,255.000ha; Mozambique,3.469.000ha; Tanzania,174.000ha, Zambia 1.485.000 ha). The conclusions of the analysis was that SS is a highly efficient and durable crop( high radiation, nutrient, water, carbon/GHG uses); it is a
very versatile crop (large variability in earliness), for several uses (grain, sugar, forage, biomass), but it is still in a very early stage of development, particularly as to the utilization of genetic variation and to adaptation to specific pedoclimatic conditions.

With the right approach and careful implementation SS could play a major role in the development of new, multi-purpose, pro-poor markets.

Li Hongju noted the long history of sweet sorghum in China: the syrup cultivar ’China amber’ was exported to France in 1853 and then in USA, where, in 1880, the total yield of syrup reached the peak of 114 million litres.

He showed the feed use for birds and other domestic animals as well as for production of wine and pure ethanol.

As to agronomy, he presented the temperature requirements for all growth stages and showed maps for early and late cultivar growing areas in China.

He also provided data on variability regarding photoperiod response and growth. As to cultural practices, he recommended the pruning of tillers and the practice of ‘earthing up’ the seedlings in order to prevent lodging and increase nutrient absorption. He added that the income output from sweet sorghum can be up to 10-20 times higher than that from wheat or maize.

Kevin Gallagher provided a general road map for moving from individual farmers, selling in local markets, towards commercial groups in non-local markets - and at points in-between. This was general and not specific to SS.

He emphasized the role of Farmers’ Field Schools and Action research in disseminating crop information with particular regard to IPM.

Luigi Pari presented the recommendations, coming from a 5 years SS development programme, financed by EU from 1993 to 1997, covering SS production, processing and utilization as biofuel.

The programme concluded that there is a need: of new breeding programmes; of optimization and economic evaluation of agronomic specific techniques; of the development of adapted harvesters (emphasizing that for sugar production leaves and panicles should possibly be removed from stalks before or at harvesting); of the fermentation process (being centralized or decentralized).

He then presented the introduction and adaptation of the sugarcane harvester Claas cc 1400, for harvesting SS in Italy. He noted the non-adaptable large dimensions of this harvester and discussed the advantages and disadvantages of 3 smaller prototypes developed by Italian firms for smaller farms’s utilization.

He recommended entire stalk (as opposed to chopped) harvesting.

Also the importance of pelletization of ligno-cellulosic residues was considered.

Note: Dr Palaniswamy () mentioned the development in India of a hand-held mechanical harvester that costs only US$ 400/unit.
In the Forth Session: (Post-harvest technologies, Processing and the Private sector) three contributions were presented, respectively:

by Danielle Bellmer (Oklahoma State University, USA) “In field fermentation issues”
by Anil Mandke (Praj Industries, India) “Innovative technologies in fermentation, distillation and wastewater treatment”
by A.R. Palaniswami(Rusni Distilleries, India)”Processing facilities development for small farmers integration, including small-scale requirements” rusnibiofuels@gmail.com

Danielle Bellmer stated that now the USA are importing over 60% of petroleum needs and are present 117 operational Ethanol production facilities (57 are under construction). In this contest it is considered that SS has great potential as an energy crop since could be cultivated in temperate and tropical areas, has low irrigation needs, it has stems with 12%-21% of sugars directly fermentable.
The traditional division of tasks considers that farmers are only involved in biomass production and processing industrial plants are centralized.
A new perspective is represented by a potential “in field processing” in which juice extraction is done by machine in the field and the fermentation is performed in the farm, while the central facility is only performing alcohol dehydration.
This new technology is involving harvesters which are also mechanically extracting the juice and the utilization of any type of vessels, in the farm, in which the juice is fermented (like in the traditional wine production in Europe) and then stored in plastic or metal vessels, taking care of sterilization requirements. The SS “wine” is then transferred to central facilities for dehydration, eventually after a first step of dewatering done in the farm.
Prototypes of self-propelled “harvesters/ juice extractors” are being developed by the University of Oklahoma scientists, while appropriate technologies for SS juice fermentation are analyzed.
Comparison was made between the two basic extraction technologies: roller press and screw press( the second was more efficient) and evaluations were made on juice yield as affected by time of harvest(the earlier the higher) and on the effect of stalk diameter on juice yield (the larger the best).
Still critical process questions remain: 1) best technology for in-field single pass pressing; 2) determination of extent of dewatering to be completed on-farm and best technology.3) sterilization requirements.
It is obvious that the presentation is basically valid for the US farming conditions.

Anil Mandke compared sugarcane and sweet sorghum annual ethanol ( 6,000 L/ha versus 6600) and bagasse (21 MT/ha versus 29) production in tropical India, considering the respective crop cycles(10-12 months versus 3-5 ); stalk yield/cycle/ha (70-90 to 60/70); number of cycles/year (1 to 2); annual stalk yield MT/ha(80 to 110); sugar content by wt. on stalk (13-15% to 11-13%) considering also that, normally, sugarcane has higher sucrose content in the
juice than SS. The sugars extraction technology is very similar in both crops. He then reported bagasse and juice production data and energy balances from a typical industrial plant of 500 KLPD. More details were given as to juice extraction, fermentation and distillation technologies, considering also effluent reduction, water conservation, energy integration and multi-fed stock (sugarcane, SS, sugar beet) options.

**Palaniswami A. R.** is pursuing a vision: “Enhancing Energy Security by Empowering the Farming Society” and a mission: “To improve well being of farmers and rural communities and contribute to environmental safeguard by industrialization of ethanol from sweet sorghum”. The Firm Rusni Distilleries has been a pioneer in producing SS ethanol globally, mainly for its use as fuel.

In collaboration with ICRISAT, have promoted projects for rural SS production and developed appropriated technologies for production of biofuel considering environmental sustainability and energy saving. Organization details, as to number (more than 3,000) of small (average 2 ha) farms involved were given, for a plant working some 105 days per season, using more than 800 tons of stalks per day, were given. SS has higher fermentation efficiency than sugarcane (85-88%) in addition to higher crushing efficiency (85%). It requires low energy (1/4) and less (1/2) machinery cost. It produces less effluents (2-3 L/1L of ethanol), compared to grains (18L/1L of ethanol).

With support of the Government and ICRISAT farmers were given information and means (selected seeds), small crushing machines and fermentation devices particularly for production areas far from the distillery, in order to transport only fermented liquids. Farmers were supported by contracts, with a tripartite agreement involving Farmers, Rural Banks and a Company providing seeds and technical assistance.

The basic future goals are: promotion of cooperative farming and decentralization of syrup manufacture; direct utilization or selling of crushing residues (biomass) for animal feeding; establishing of an ideal Public-Private-People partnership.

**In the Fifth Session: (Socio-economic tools for decision-makers and business development)** three contributions were presented, respectively:

by **Jennifer Nyberg** (FAO, Rome) “Socio-economic tools for decision makers. Case study: Tanzania”;
by **M.G.M. da Silva** (GreenEneSys, Brazil) “Opportunities for the private sector to assist the poor in bio-fuel development”; marcus.silva@greenesys.com
by **Arrigo della Gherardesca** (Milano, Italy) “Fuel for development: Producing biofuels at the bottom of the pyramid”. arrigo.dg@tin.it

**Jennifer Nyberg** reported data on the poor in the world: 854 million, mainly in 45 Countries, distributed in 27 Countries in Africa South of Sahara, 11 mainly in Southern Asia and 7 mainly in Central America.
She indicates food security indicators and solution opportunities and relations between prices, biofuels and food security. Present increase of commodity prices is positive for producers, but negative for poor consumers. Moreover, there is a clear linkage between fossil fuel prices and food crops feedstocks, with an evident price increase in major biofuel feedstock market (sugar, starch, and oilcrops). In addition there is a relationship between environment, bioenergy and climate change on food security and weather shocks.

Policy factors are also influencing food security and bioenergy relationship, in function of the competition for resources and inputs to agriculture. Other important factors are peace, political stability and good governance, but also development assistance needs better targeting.

The "Bioenergy and Food Security " Project in Tanzania was developed considering 4 basic criteria, agreed among project’s partners: 1) Analysis of energy sector and bioenergy options 2) Analysis of food security dimensions 3) General Country characteristics and 4) Institutional and governance issues. The project is based on the cooperation between: farmers, private sector investors, Government officials, external assistance.

Several key indicators were considered: total population: 36,3 million, with 44% undernourished; the rural population reaching 75,8%; the agricultural share of Country income reaching 44,5%; GPD per capita of 330 US$ per year, with 85% of self-sufficiency in basic cereals (mainly maize) and 10% of import dependence.

The present energy supply mix available is represented by 90% of biomass (mainly wood), petrol and electricity 9%. Low levels of technologies and of electrification are available. Bioenergy feedstocks considered in the project were: for bioethanol: sugarcane, sweet sorghum, cassava, sisal; for biodiesel: oil palm, Jatropha, sunflower.

Several constraints have been analyzed: legislative, land tenure, infrastructural, difficult access to credit, gender considerations, potential conflicts over access and control of natural resources.

M.G.M da Silva stated that the present fossil liquid fuel production is a strictly centralized industry, demanding very high investments for oil field exploration and extraction, for oil transport, for building and operation of refineries and distribution network. Only very few societies can afford the costs. Brazil went bankrupt in the 1970’s due to its growing fuel bill (85% of its needs were imported). Other big Countries have similar problem (e.g. India now imports 75% of its petroleum needs). In many developed and developing Countries the oil bill drain more then doubled in a few years. The development of local biofuel production is opening a new chapter in history, challenging the model of centralized liquid fuel production (see Brazil situation). Production, processing and distribution costs of biofuels are much cheaper, the money used for production remains in the Country not going outside, it produces labour, it decreases the fossil CO2 in the atmosphere, the technologies to be used are available, also for small production, biofuel can be used locally to provide energy for improving also food production.
GreEneSys is a private firm established to help small/medium scale production of biofuels in emerging countries to reduce energy dependency in a sustainable manner. It particularly support mid-size manufacturers of equipment to produce and utilize biofuels in strategic planning, selling and funding, creating a network to implement adapted solutions. The GreEneSys has technical and financial partners in Brazil, Mexico, India, Japan, USA and provides expertise in sugarcane, castor bean, Jatropha, and in the engineering, finance and project management involved in biofuel production.

Arrigo della Gherardesca noted that, in many Countries, if petrol price stays at US$ 80-100 per barrel, biofuels are competitive without subsidies; now some 200 Countries can produce biofuels for their uses and even for export, since the market is highly demanding. In order to provide benefit also to small farmers, an appropriate financial support should be organized. However, specifically for biofuels, all sorts of financing could be available: venture capital, private equity funds, bank loans, export credit, development loans, international organizations (IFAD, FAO, UNIDO), Cooperation funds, NGO etc. Particularly micro-Credit private organizations could be envisaged to help small farmers (possibly also organizing cooperatives) with small loans, for buying the necessary inputs (costs of seeds, fertilizers, irrigation, harvest, transport of the product, renting of processing machines etc.) and establishing with contracts the price of the production and the appropriate time for credit return. Similar support can be provided to the local industrial partner, in order to provide the processing plants. Finally the credit organization could find the internal and external buyers of the biofuels, establishing medium and long term contracts. In this way the entire supply chain “from field to the wheels” could be organized. Obviously, different crops could have different agreements, also in function of the time needed from planting to harvesting (e.g. Jatropha would need longer time for credit return, since it will start production some 2-3 years from planting; in this respect SS could have advantage since the production cycle is normally of 4-5 months).

Special Session on Tropical Sugar Beet (TSB)

The contribution was presented by

Dilip Gokhale Mediterranean Beet (*Beta maritima* L.) was developed as sugar crop to provide sugar to continental European Countries, during Napoleon time, because the British navy was blocking sugar import from the America’s sugarcane industry.

It was considered a typical “temperate climate” crop, not adapted to short day and to pedoclimatic conditions of the tropics.

After 11 years of research, Syngenta was able to develop varieties of sugar beet adapted to tropical growing conditions and producing the same quantity of sugar per hectare as sugarcane, in half of the time (6 months) and with 1/3 of water supply. This was achieved by genetical and agronomical adaptation research. The tropical sugar beet (TSB) produces high yield (from 50 to 130
ton/ha, with 16-18 % of sucrose), is tolerant to high temperatures, to drought (deep root system), to saline and alkaline soils, can easily rotate with other tropical crops and the industrial processing to get sugar is available since long time; processing plants have been also produced locally in India. Successful crops were obtained first in India, Colombia, South African Republic and then in Sudan, California, tropical Australia, China and Brazil. Tropical areas now have at least 3 sugar producing crops: sugarcane, sweet sorghum and TSB, from which bioethanol can be produced. However, TSB is not generating biomass that can also be used for producing energy for processing, like sugarcane or sweet sorghum.

Concluding Remarks

They were given by Shantanu Mathur, OIC, PT, who thanked the speakers and noted the need for an action research programme that should address the concerns/constraints raised by the participants to ensure that all actors in the value chain, from production to processing and marketing, benefit from the research programme. Mr. Mathur also noted that whatever developments that took place should also ensure that the needs of the small farmers and poor rural women were fully met.

Notes

All Consultation participants are welcome to visit EcoPort’s sweet sorghum website at http://ecoport.org/ep?Plant=1982. Click on ‘Full record’ to get the plant’s description and ecological features etc. and on category ‘Crop plant’ for production, breeding etc. The (on left) camera icon will show 66 pictures and the drawing icon 32 diagrams. This site needs up-dating and should a participant wish to contribute then send the contribution in text format to jeremey.woods@imperial.ac.uk with a copy to peter@griffe.org.

Under a FAO Chinese Technical Cooperation Project “A training manual for sweet sorghum” was produced by Li Guiyin, Gu Weibin, Alastair Hicks and Keith R. Chapman and the EcoPort version was revised by Peter Griffe. Participants may wish to visit the site at http://ecoport.org/ep?SearchType=earticleView&earticleId=172