Incubator (ABI), a component of the Agri-Science Park at ICRISAT. The ABI incubated Rusni Distilleries Pvt. Ltd, which is promoted by a non-resident Indian for sweet sorghum-based ethanol production. ICRISAT facilitated the multiplication of sufficient quantities of seed materials through a private seed company. Additionally it provided consultancies by providing a package of practices for cultivation of sweet sorghum, facilitating the recruitment of field workers, promoting and popularizing sweet sorghum cultivation by farmers.

ICRISAT also facilitated government clearance for ethanol production from the Government of Andhra Pradesh and assisted the company in sourcing equity investment through private partnership and a bank loan.

This project, the first of its kind in the world, will directly benefit 20,000 farm workers. Farmers can earn additional returns of Rs 10,000 (>$200) ha^{-1} from growing this crop.

Further, the ICRISAT-Private Sector Sweet Sorghum Ethanol Research Consortium (SSEC) has been established to tap private sector funds for public research to help poor and smallholder farmers take advantage of widened markets of sweet sorghum. Three distillery units have already joined this consortium. Food conglomerate, San Miguel Corp. (SMC), the Philippines is also showing interest in joining the SSEC as it has declared its extensive diversification efforts even into the energy business.

Benefits for the farmer

Farmers will earn greater incomes from sale of stalks to distilleries that would be over and above income from sale of grain, bagassa and threshed panicles for food and feed.

Timely intervention

The time is right for concerned parties to come together NOW to ensure that sweet sorghum, with all its added advantages, is promoted both as a bioethanol source and more importantly, as a brilliant option for the poor to improve their livelihoods. The work has advanced a bit in Asia, but ICRISAT considers it equally important that it is also extended to Africa.

In the light of climate change (rising temperatures, drought and excess rains), sweet sorghum offers the best options with its resilience to high temperatures, adaptation to drought and ability to withstand water stagnation.

About ICRISAT

ICRISAT
Science with a human face

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a non-profit, non-political organization that does innovative agricultural research and capacity building for sustainable development with a wide array of partners across the globe. ICRISAT's mission is to help empower 644 million poor people to overcome hunger, poverty and a degraded environment in the dry tropics through better agriculture. ICRISAT belongs to the Alliance of Centers of the Consultative Group on International Agricultural Research (CGIAR).

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Sweet Sorghum

A smart multipurpose crop

ICRISAT

INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS
Science with a human face

Introduction

In the wake of steeply-climbing fossil fuel prices, interest in biofuels has grown worldwide.

Until recently the leading biofuel feedstocks were sugarcane and maize. But sugarcane requires a year to grow, and large amounts of irrigation water, and maize also requires a fair amount of water.

Sweet sorghum (*Sorghum bicolor* (L.) Moench) is similar to grain sorghum but with sugar-rich stalks and the ability to use water efficiently. Sweet sorghum has shot into prominence because of its competitiveness as a major feedstock for bioethanol production. Its juice can also be used for the production of jaggery and syrup, and the bagasse (leftover stalks after juice extraction) can be used for cogeneration of power, animal fodder, and as material for organic fertilizer.

Comparative advantages

- Growing period (about 4 months) and water requirement (8000 m^3 over two crops) are 4 times lower than those of sugarcane (12 to 14 months and 36000 m^3 $crop^{-1}$ respectively)
- Greater resilience to limited moisture stress and excess moisture stress
- Propagation through seeds and suitable for mechanized crop production
- The ethanol production process is eco-friendly compared to production from molasses
- Ethanol burning quality is superior with high octane rating and less sulphur than from sugarcane (molasses)
- Shorter gestation period and greater resilience to abiotic stresses
- Cultivation and production costs:

	Sugarcane	Maize	Sweet sorghum
Green stalk yield	75 t/ha	–	35-45 t/ha
Bagasse/stover yield	13.3 t/ha	8 t/ha	4-6 t/ha
Duration	12 months	4.5 months	4 months
Ethanol from grain	Nil	1400 l/ha	760 l/ha
Ethanol from stalk	5600 l/ha	Nil	1400-1800 l/ha
Ethanol from residue	3325 l/ha	1816 l/ha	1000-1300 l/ha (Using steam spurge)
Total ethanol*	8925 l/ha	3216 l/ha	3160-3860 l/ha
Cost of cultivation	US$ 995/ha	US$ 287/ha	US$ 258/ha
Feedstock cost for 1 kiloliter of ethanol	US$ 111.5	US$ 89.2	US$ 81.6
Production cost of Ethanol at distillery	US$ 0.58/l	US$/0.56	US$ 0.46

** Ethanol yields based on currently available technologies; the ethanol yields from second generation (ligno-cellulosic) technologies will be much higher.*

An Indian farmer and his sweet sorghum field.

- Higher biological value and meets food (rich in micronutrients), fodder, and fuel needs.

ICRISAT's BioPower strategy

Bio-energy today is mostly derived from agriculture. Without conscious pro-poor action, influencing government policies and technologies, the poor may become poorer. ICRISAT and partners contribute to **pro-poor BioPower** development.

- BioPower empowers the dryland poor to benefit from emerging bioenergy opportunities
- Ensures both food and energy security
- Focuses on biomass, juice and grain
- Greater smallholder incomes and sustaining environments.

ICRISAT's R&D strategy

1. Development of
   a. Improved sweet sorghum varieties, hybrid parents and hybrids
   b. Improved brown midrib (bmr) varieties, hybrid parents and hybrids
   c. Improved crop management practices and Public-Private-People Partnerships

Milestones

- Research on the development of sweet sorghum cultivars was initiated in 1980 and two landrace lines, IS 6872 and IS 6896 with high stalk sugar content and biomass were identified.
- Later, several sweet sorghum lines were identified among Nigerian and Zimbabwean lines, and among advanced breeding progenies.
- Sweet sorghum research discontinued in the early 1990s due to changed focus driven by donors' perceptions and needs of national agricultural research systems (NARS).
- Research was renewed in 2002 to meet the increased demand for ethanol, driven by government policies to blend ethanol.
- Research on hybrid parents is given a high priority at ICRISAT

Managing Director, Rusni Distilleries, AR Palaniswamy describes the ethanol production to Dr Dar.

- Promising hybrid seed parents, ICSB 264, ICSB 293, ICSB 321, ICSB 401, ICSB 405, ICSB 472, ICSB 474, ICSB 722 and ICSB 729 have been identified.
- Promising varieties/restorer lines, NTJ 2, SPV 422, Seredo, ICSR 93034, S 35, ICSV 700, ICSV 93046, ICSV 25263, SP 4487-3, SP 4484-1, SP 4484-3, SP 4482-1, SP 4482-2 and SP 4481-1 have been identified/developed.

Hybrids

- Photoperiod and thermo-insensitiveness is essential to facilitate plantings at different dates. This will ensure year-round supply of sweet sorghum stalks for ethanol production. Hybrids are relatively more photoperiod- and thermo-insensitive besides being earlier than pure-line varieties; so their planting and harvesting schedules are easy, facilitating regular supply of feed stock
- A sweet sorghum hybrid, CSH 23 (NSSH 104), developed by the National Research Center for Sorghum (NRCS), Hyderabad, India using ICSA 38, an ICRISAT-bred male-sterile line and SSV 84 (sweet sorghum variety bred and released by the Indian national program in 1992/93) was released for commercial cultivation in 2005.
- Hybrids are superior to varieties for grain, juice and sugar yields by 30 to 50%. Some of the promising hybrids are: ICSSH 3, 19, 22, 23, and ICSSH 28.

Trade-off between food and fuel

- Rainy-season sweet sorghum hybrids gave higher sugar yield (20% = 0.8 t ha^{-1}) and higher grain yield (16% = 0.9 t ha^{-1}) compared to non-sweet stalk-grain sorghum hybrids.
- Rainy-season sweet sorghum varieties gave only 18% (0.8 t ha^{-1}) less in grain yield while the gain in sugar yield is 42% (1.7 t ha^{-1}).
- In hybrids, varieties, R-lines and B-lines, trade off for sugar yield at flowering and maturity is negligible and grain is an added advantage if cut at maturity.
- ICRISAT focuses on hybrids to fulfill both food and fuel needs.

Second-generation ethanol from sorghum

- Ethanol can also be produced from lingo-cellulose biomass feed stocks such as cereal crop residues (stover)
- Cereal stover, including that of sorghum, contains lignin, cellulose and hemicellulose
- Sorghum stover with bmr (which contains significantly lower lignin content by up to 50%) takes less energy for conversion into ethanol
- Total ethanol yield from sweet sorghum when cellulose technology is applied (19400 l ha^{-1}) is higher than bmr sorghum (15760 l ha^{-1}), European grass (16650 l ha^{-1}) and Switch grass (17100 l ha^{-1}),
- ICRISAT is developing high biomass brown midrib sorghums.

Measures for extended feedstock supply

- Planting cultivars with differential maturities
- Extension of plantings and or seasons
- Planting over different locations (with higher rainfall variability avoiding planting same period)
- Decentralized crushing units (converting juice in to syrup/jaggery)
- Widening of window for harvesting stalk.

Technology sharing and commercialization

Improved cultivars and crop production technologies are shared with NARS. Seed samples have been supplied to the Philippines, Thailand, Kenya, Ethiopia, Malawi, Egypt, Japan, Colombia, Mexico, Uruguay and Azherbaijan.

Sweet sorghum for bioethanol production was incubated by ICRISAT through its Agribusiness

Director General Dr Dar and Mr Homi R Khusrokhan, Managing Director, TATA Chemicals Ltd., shake hands after signing the MoA on joining the Sweet Sorghum Ethanol Research Consortium.