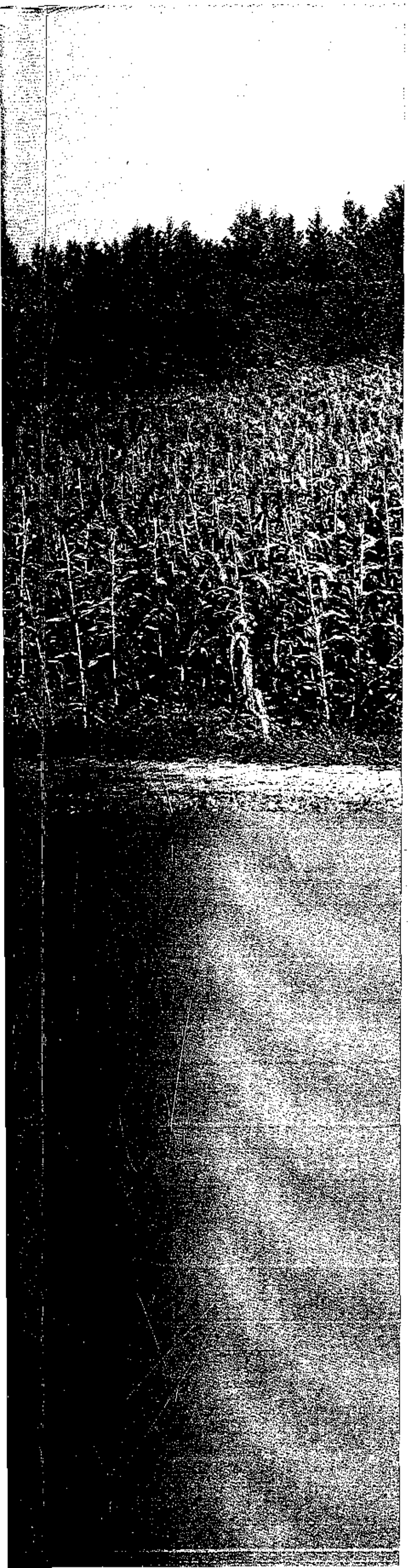

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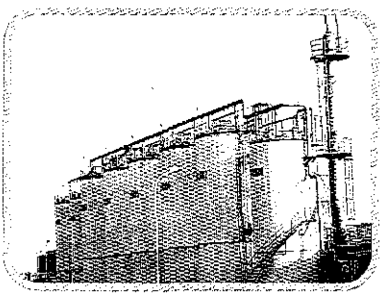
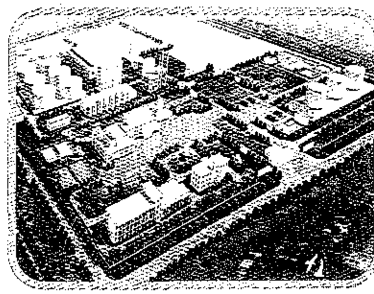
Enhancing Sweet Sorghum Ethanol Value Chain

Editors Ch Ravinder Reddy and Zou Jianqiu



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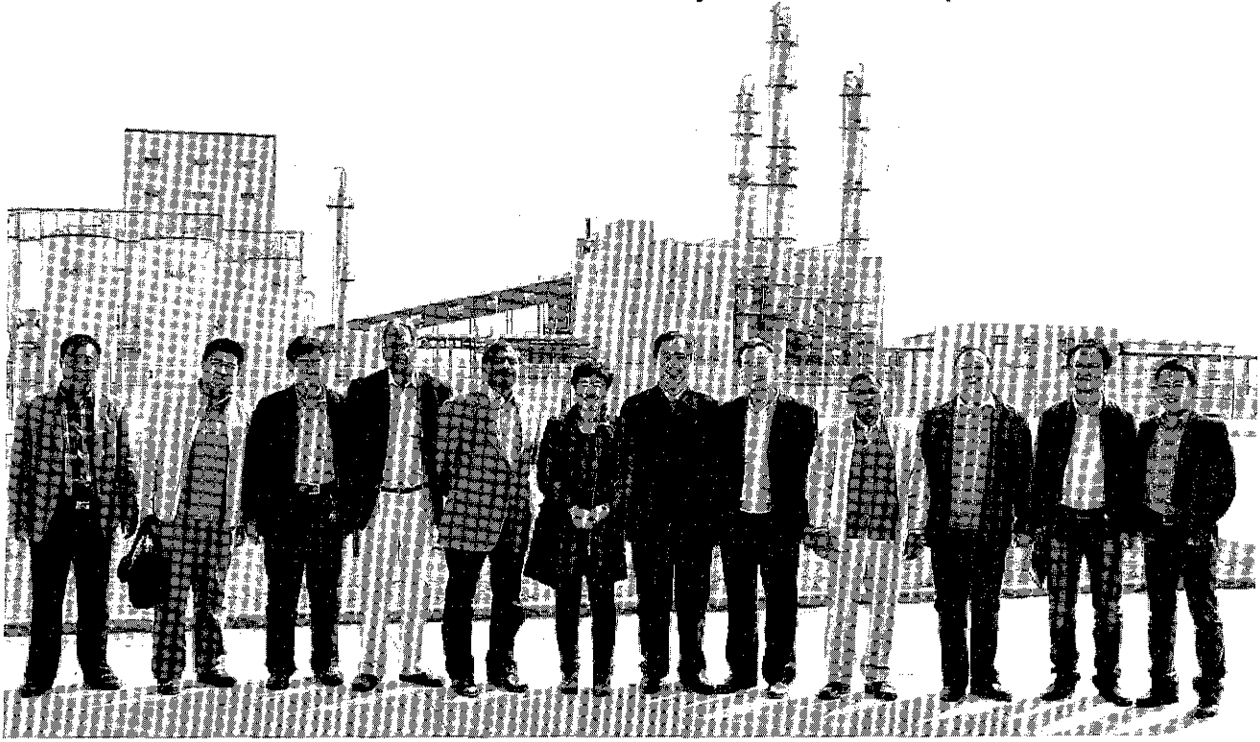

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CONTENTS

Chapter 1: Sweet Sorghum as a Feedstock for Ethanol Production

Belum VS Reddy, Ch Ravinder Reddy and A Ashok Kumar

Biofuels are among renewable energy sources that offer greater hope for future energy requirements. At the same time, biofuels are considered as one of the factors affecting global food prices. However, the certain finality of fossil fuel depletion and the continued environment pollution caused by excessive use of fossil fuels make it imperative to find alternative renewable sources that complement the fossil fuels with limited/little impact on environment.

Sweet sorghum offers an opportunity to increase the incomes of smallholder farmers through the sale of sweet sorghum stalks (stems) to the ethanol distillery while at the same time using the grain as food or feed. Thus sweet sorghum for ethanol production contributes to national energy security and provides additional incomes to farmers, without compromising the food or fodder needs. By providing competitive, remunerative options for cultivation by smallholder farmers in dry land areas, sweet sorghum development can help to ensure that the ongoing "biofuel revolution" aids smallholder farmers for sustainable development, rather than bypassing or marginalizing them.

Distilleries need a reliable stream of quality feedstock at a predictable price and in high volumes; small-scale farmers need a fair and reliable share of the benefits, and technical and credit support. This project envisages assisting small and marginal farmers to benefit from biofuel production chain and reduce the environmental pollution, making the smallholders to be competitive rather than getting marginalized in this new market opportunity. The strategy involves innovative value chain development, organizing farmers into groups, linking them to input and credit suppliers and ultimately linking to ethanol distilleries. Management options to increase the production system efficiency will enhance sweet sorghum's competitive *positioning vis-à-vis other feedstocks such* as *sugarcane* molasses, sugar beet, corn, etc. for ethanol production.

Increased production system efficiency, coupled with value chain models through institutional innovations that engage thousands of poor farmers as feedstock suppliers, would help them profitably market their produce.

As being the case with sugar cane processing plants, ethanol distilleries usually only allow farmers within a 50 km radius of the plant to take part and benefit in the process by directly supplying stalks to the distillery. Farmers located outside this radius are usually excluded from becoming suppliers, because of high transport costs owing to the bulkiness of the stalks. Furthermore the juice recovery from the stalks decreases with increase in time lag between harvesting and crushing. Innovative decentralized crushing units located in the clusters (villages beyond 50 km radius) to be established in the project will test a concept that will ensure participation of remote farmer groups and allow for the crushed cane (bagasse) to remain with the farmers rather than going to the distillery as fuel.

The project aims to establish and demonstrate successful models for up-scaling and out-scaling the sweet sorghum cultivation for ethanol production to increase farmers' incomes and reduce environmental pollution (ethanol being a clean burning fuel, produces negligible amount of CO_2 on burning) without compromising the food or feed or fodder needs of farmers. This paves way for the most efficient whole plant utilization of sorghum; a promising crop for the tropics particularly in the light of the uncertainties that climate change entails such as an increase in temperatures and uncertainties in rainfall that sweet sorghum is capable of tolerating, much better than other feed stocks like sugarcane, maize, sugar beet, etc.

1 Economics of sweet sorghum production

Sweet sorghum is more profitable (23%) to the farmer than the grain sorghum (Table 1). The cultivation costs are same, but the additional costs of leaf stripping for sweet sorghum are accounted in calculation of the net value.

Table 1 Profitability of growing sweet sorghum over grain sorghum.

	Sweet sorghum	Grain sorghum
Grain yield (t/ha)	1.6	2.5
Stalk yield (t/ha)	20 (fresh)	4 (dry)
Grain value (USD/ha season)	234	365
Stalk value (USD/ha season)	293	50
Total value (USD/ha season)	527	415
Leaf stripping (USD/ha season) *	15	—
Net value (USD/ha season)	512	415
Gain from sweet sorghum (USD/ha season) **	97 (23%)	

* Leaf stripping means removal of leaf sheath and leaf blade from the stem. Recent findings from ICRISAT research indicates that leaf stripping in not essential since juice yields are not significantly different with or without leaf stripping, thus saving stripping costs as indicated in the table.

** The distilleries are ready to procure even today the sweet sorghum stalks at Rs 600 per T in India and therefore, the profitability of sweet sorghum to the growers remains the same.

Adopted from Rajasekhar (2007), UAS, Dharwad, Karnataka, India.

2 Comparative advantages of sweet sorghum

Sugarcane molasses is the main raw material for ethanol production in India; sugarcane (molasses and juice), maize and sugar beet in China; and molasses and cassava in Thailand. Sweet sorghum growing period (about 135 days) and water requirement (8 000m^3 for two cropping seasons per year) (Soltani and Almodares 1994) are 4 times lower than those of sugarcane (12 ~ 16 months and 36 000m^3/crop, respectively). Cultivation cost of sweet sorghum is just one fourth of sugarcane owing to less fertilizer and water use, low cost of seed material and propagation through seed. Further, sweet sorghum stalk is better suited for ethanol production because of its higher reducing sugar content compared to other sources. These important traits, along with its suitability for mechanized crop production, seed propagation and comparable ethanol production capacity of [*vis-a-vis* sugarcane molasses and sugarcane (Table 2)] makes sweet sorghum the best alternative source of raw material (which can be used as an alternative rather than a substitute) to ethanol production. The cost of per litre ethanol production from sweet sorghum is cheaper compared to sugarcane molasses at the prevailing prices. Sweet sorghum is more tolerant to drought compared to sugarcane and maize owing to large number of genes related to expensive, cytochrome P450 oxidases as enunciated in the sorghum genome sequence published this year (Paterson et al, 2009).

Table 2 Comparative advantages of sweet sorghum vs. sugarcane/sugarcane molasses for ethanol production.

Crop	Cost of cultivation (USD/ha)	Crop duration (months)	Fertilizer Requirement (N - P - K Kg/ha)	Water requirement (m^3)	Ethanol productivity (liter/ha)	Av. Stalk yield (t/ha)	Per day productivity (Kg/ha)	Cost of ethanol production (USD/lit)
Sweet sorghum	435 over two crops	4	80 - 50 - 40	8 000 over two crops	4 000 year^{-1} over two crops (a)	50	416.67	0.32 (d)
Sugarcane	1 079 crop^{-1}	12 ~ 16	250 to 400 - 125 - 125	36 000 crop^{-1}	6 500 crop^{-1} (b)	75	205.47	
Sugarcane molasses	—	—	—	—	850 year^{-1} (c)	—	—	0.37 (e)

(a) 50t/ha millable stal per cop @ 40L. t^{-1}

(b) 85 ~ 90t/ha millable cane per cop @ 75L. t^{-1}

(c) 3.4t/ha @ 2 50L. t^{-1}

(d) Sweet sorghum stalk @ USD 12.2t^{-1}

(e) Su arcane molasses @ USD 39t^{-1}

The costs of ethanol production primarily involve two variables-cost of production of sweet stalk and cost of processing and the competitiveness of sweet sorghum is unaffected. Ethanol price is competitive vis-a-vis petrol prices in India since reduction in petrol prices is not proportional to fall in global crude oil prices. Ethanol price continues to remain competitive (while crude oil prices declined from USD

140 /barrel to USD 41/barrel-a reduction of 60%) petrol prices in India declined from Rs. 55 to Rs. 45 per litter-only by 20%. (The Economic Times dated 9th February 2009)

3 Thus, the three participating countries' annual demands for fuel ethanol can be met effectively if sweet sorghum is used along with the currently used feed stocks. In addition to the sweet stalks for biofuel production, grain yield of 1.5 to 2.5t/ha per season can be obtained from sweet sorghum crop (this can be used as food or animal feed or even sold for ethanol production). The bagasse from sweet sorghum after the extraction of juice still retains its nutritional value for use as animal feed. Additionally, the pollution level in sweet sorghum-based ethanol production has $1/4^{th}$ of biological oxygen dissolved (BOD), i. e., 19 500mg/liter and lower chemical oxygen dissolved (COD), i. e., 38 640mg/liter compared to molasses-based ethanol production (as per Vasantdada Sugar Industry, India pilot study). Ethanol being a "clean burning fuel" with high octane rating, the existing automobile engines can be operated with petrol blended with ethanol without any need for engine modification up to 26% blending (E26). Thus, sweet sorghum offers good prospects for ethanol production both from the point of economics of production and environmental protection.

4 CO_2 absorption and energy inputs and outputs of sweet sorghum

Due to its high productivity (20 ~ 40 ton dry matter/ha/season) and fast plant cycle (120 ~ 150 days) sweet sorghum has an impressive capacity being a C_4 species to absorb a large amount of CO_2 from the atmosphere during the 4 ~ 5 months growing cycle, with a small amount of CO_2 (~ 4 % of the total absorbed), emitted for the use of conventional energy during its cultivation. During the pre-treatment, conversion and utilization (combustion), further CO_2 emission is produced, but sweet sorghum closed schemes are CO_2 neutral presenting a total CO_2 balance = 0. The details of CO_2 emissions by sweet sorghum are given in Table 3.

Table 3 CO_2 absorption and emissions by sweet sorghum.

CO_2 absorption	CO_2 emission
By the crop ~ 45t CO_2/ha during the growing cycle	~1.5t CO_2/ha (growing cycle) ~8.5t CO_2/ha for conversion into ethanol ~35.0t CO_2/ha for utilization (combustion) ~45 total tons CO_2/ ha

One ha of sweet sorghum plantation can substitute ~11 TOE of net energy without any negative CO_2 emission into the atmosphere. Source: LAMNET and EUBIA, 2001.

5 The energy utilized for cultivation and the energy produced in the form of feedstock is another important factor. The details of energy consumption for the production of the feedstock are given in Table 4.

Table 4 Energy inputs for one ha of sweet sorghum.

Energy inputs	Mcal/ha
Operation of the machines	1 700
Ploughing	305.5
Seedbed preparation	37
Fertilization	15.5
Seeding	50
Weeding	129
Pesticide treatment	16
Irrigation	210
Harvesting	937
Fertilizers and pesticides	1 300
Fertilizers	1 115
Pesticides	185
Seeds, separation and others	250
Transport	1 600
Total input for the crop production	4 850

6 Energy outputs

In case of conversion of sugar into bioethanol and of lignocellulosics into pellets for feed or cogeneration the estimated values are given in Table 5.

Table 5 Energy outputs (in the form feedstock) from sweet sorghum.

	Production (t/ha)	Energy equivalent (Mcal/t)	Energy output (Mcal/ha)
Sugars	8 (from juice)	3 940	31 500
Bagasse, leaves and grain	20	2 150	43 500
Total			74 500

Source: LAMNET & EUBIA 2001.

7 Fertilizer requirements

The blanket fertilizer recommendation for sweet sorghum cultivation is 60 : 40 : 0 N, P_2O_5 and K_2O (kg/ha). However, the fertilizer should be recommended based on the soil test values for both macro and micro nutrients. Intercropping and crop rotation with legume crops helps in maintaining soil fertility and sustain the sweet sorghum production systems.

8 Digestibility studies using sweet sorghum bagasse

Comparison of commercial feed blocks (normal sorghum stover + concentrates, 50 : 50 by weight) with sweet sorghum bagasse feed block (normal sorghum replaced by sweet sorghum bagasse while the concentrates remained the same) showed no significant differences in intake and body weight gain (Table 6).

Table 6 Intake and body weight gain for different feed blocks.

Treatment	Intake (g/kg live weight)	Weight gain (kg/day)
Commercial feed block	3.64	0.975
Bagasse-leaf feed block	3.76	0.871
Sorghum stover (chopped)	1.24	-0.457

Source: Michael Blümmel 2009.

Sweet sorghum improvement at ICRISAT and the performance of ICRISAT-bred lines in different countries-Considerable progress has been made in breeding for improved sweet sorghum lines with higher millable cane and juice yields in India. ICRISAT located at Patancheru in Andhra Pradesh, India, along with the partners (NARS) developed several improved lines of sweet sorghum with high stalk sugar content that are currently being tested in pilot studies for sweet sorghum-based ethanol production in India, the Philippines and Uganda. A few of these cultivars like SSV 84, SSV 74 and CSH 22 SS (NSSH 104) have already been released in India. Some of the varieties/restorer lines developed with soluble solid concentration (^{0}Bx) greater than 19% are ICSR 93034, ICSV 700, ICSV 93046, E 36-1, SPV 422, NTJ 2, Seredo and Entry#64 DTN. Some of the promising female lines with better combining ability for high soluble solid concentration (^{0}Bx) are: ICSA/B 38, ICSB 264, ICSA/B 474, 321, 480, 479, 453, 73, 271 and 487 (Reddy et al. 2007).

Similar research and commercialization of sweet sorghum was done in Thailand and China. The sweet sorghum cultivars Italian, Rio and Cowley are promising in China. The Field Crops Research Institute of Thailand has identified Keller, Rio and Wray as the most promising sweet sorghum cultivars for Thailand situations.

Research at ICRISAT and elsewhere has shown that hybrids produce relatively higher biomass, besides being earlier and less photosensitive compared to the open pollinated varieties under normal as well as water-limited environments. The photoperiod and thermo-insensitivity facilitate sowings at different dates to provide staggered supply of sweet sorghum stalks to distilleries subject to their capacity for ethanol production. Therefore, the development of sweet sorghum hybrids is receiving high priority to produce more biofuel feedstock and grain yield per drop of water and unit of energy invested. Data for ethanol related traits for the selected sweet sorghum hybrids are given Table 7.

Table 7 Performance of selected sweet sorghum hybrids at ICRISAT (on station), Patancheru, India.

Hybrid	Days to 50% flower	Soluble solid concentration (^{0}Bx) (%)	Cane yield (t/ha)	Juice yield (kL/ha)	Sugar yield (t/ha)	Grain yield (t/ha)	Per day ethanol productivity (l/ha) *
ICSA 749 × SSV 74	85	18	57.75	27.15	9.15	3.28	18.48
ICSA 511 × SSV 74	88	17.97	49.25	22.7	7.84	5.79	15.39
ICSA 474 × SSV 74	82	16.33	52.25	25.42	7.57	7.19	17.13
SSV 84 (control)	94	15.65	35.18	16.84	4.98	2.67	10.5
CSH 22 SS (control)	91	15.65	35.17	16.84	4.98	4.12	10.74

* Ethanol productivity estimated at 40 litres per ton of millable cane yield.

Some of the hybrids do well in the rainy season at ICRISAT, Patancheru and others in postrainy season. Therefore it appears that selection of the hybrids is season specific (Table 8). Sorghum is sensitive to photoperiod that means different cultivars required for different growing seasons for the same area. For commercial production of ethanol, a distillery needs feed stock supply on regular basis. This needs different cultivars with high productivity identified for different growing areas and different seasons (Reddy et al. 2007).

Table 8 Selected sweet sorghum hybrids performance in rainy season and postrainy season for soluble solid concentration (^{0}Bx)*, sugar yield[1] in stalks and grain yield.**

Hybrid	Soluble solid concentration (^{0}Bx)		Sugar yield (t/ha)*				Grain yield (t/ha)			
	R**	PR***	R	Rank	PR	Rank	R	Rank	PR	Rank
ICSA675 × SSV74	16.6	10.3	6.3	1	1.1	9	6.7	8	7.1	8
ICSA675 × SPV422	17.3	11.7	6.1	2	0.9	14	6.6	9	6.7	10
ICSA324 × SPV422	16.5	16.1	4.8	13	1.7	2	4.9	17	3.9	20
ICSA474 × E36-1	13.5	14.3	4.8	14	1.7	3	6.3	14	6.2	15
CSH 22 SS (control)	18.5	19.8	5.9	3	1.2	8	4.2	18	7.2	3

Trial entries: 20; *RCBD*; *2 years and 2 seasons testing.*

* Calculated as the product of ^{0}Bx and juice volume (kl/ha).

** R = Rainy season. *** PR = Postrainy season.

Studies at ICRISAT on comparison of sweet sorghum and non-sweet sorghum hybrids between 2005—2007 in the rainy season showed that sweet sorghums produce higher sugar yields (11%) and higher grain yields (5%) than non-sweet sorghum (grain) hybrids, indicating that there is no trade-off of grain versus cane yield in hybrids. On the other hand, there is some trade-off between grain yields and sugar yields in the open-pollinated varieties during the rainy season, but the loss in grain yield is far less than the gain in sugar yield (Table 9). Significant trade-off was noted in the postrainy season for hybrids (Reddy et al. 2008).

Table 9 Tradeoff between sugar yield (t/ha) and grain yield (t/ha) in varieties and hybrids, Patancheru during 2005—2007.

Season	Variety/hybrid	Sugar yield (t/ha)			Grain yield (t/ha)		
		Sweet stalks (SS)	Non-sweet stalks	% gain of SS	Sweet stalks (SS)	Non-sweet stalks	% gain/loss in SS
Rainy season	Varieties	6.0 (6)*	3.9 (11)	54	3.0 (6)	3.3 (11)	−9
	Hybrids	6.2 (5)	5.6 (4)	11	6.2 (5)	5.9 (4)	5
Postrainy season	Varieties	1.7 (11)	0.9 (6)	89	4.6 (11)	4.7 (6)	−2
	Hybrids	1.5 (6)	1.0 (3)	50	6.4 (6)	8.5 (3)	−25

* The numbers in parenthesis refer to the sample size.

There is lot of concern and criticism from different quarter's world over on the use of food grains for ethanol production. Sweet sorghum is a unique food crop that produces both food and sugar rich stalks that facilitate ethanol production without sacrificing the food value of the crop. The sweet sorghum hybrids developed at ICRISAT yield 21% extra sugar and 15% extra grain compared to the grain sorghum hybrids in rainy season. This clearly establishes that there is no trade-off between the food versus fuel, i. e. , no scarifying of one for the other.

ICRISAT's breeding program is actively involved in further research on sweet sorghum hybrids and varieties with higher sugar and grain yields, superior adaptability and pest and disease resistance. This program is carried out under specially funded projects from NAIP (Govt. of India), IFAD and EC. Outcomes from these projects in the next few years will be fed in to the present project which would further improve the crop yields and consequently farmers' income.

The research work carried out by ICRISAT and its partners on sweet sorghum for ethanol value chain supported by the National Innovation Project (NAIP) of Indian Council of Agricultural Research (ICAR) provided some insights in this direction. Under this project, partners with diverse competencies – Directorate of Sorghum Research (DSR), Central Research Institute for Dryland Agriculture (CRIDA), Indian Institute of Chemical Technology (IICT), Indian Livestock Research Institute (ILRI), Sri Venkateswara Veterinary University (SVVU) and Rusni Distilleries, all based in India have worked together as a consortium focusing on development of a sustainable sweet sorghum ethanol value chain through innovative interventions involving an array of options (Belum et al, 2013). The experiences and lessons learned from this work indicated that, while considerable progress has been made in improving the sweet sorghum supply chain for ethanol by a combination of centralized and decentralized supply chain models (Ravinder Reddy et al, 2012), inter alia it requires strong policy support in order to sustain the value chain and enforce the ethanol blending commitments.

From the research work of ICRISAT and its partners, it is evident that improved sweet sorghum hybrids give more income to farmers than grain sorghum hybrids;

different hybrids available to suit different growing seasons and the trade-offs are negligible when hybrids are used. These research findings strongly support the use of sweet sorghum in a big way in India and China for ethanol production.

Constraints for the use of sweet sorghum-based ethanol technology-Sweet sorghum cultivation for ethanol production is limited primarily because of the following constraints:

- Lack of awareness among the farmers about the cultivation practices of sweet sorghum and its use for ethanol production.
- Many farmers interested to grow sweet sorghum located far away from centralized distillery do not have knowledge of alternative route of producing syrup in their backyard.
- No market access for remote sweet sorghum farmers to take advantage of emerging opportunities.
- Non-availability of seed of sweet sorghum cultivars for commercial cultivation.
- Availability of feedstock on continuous basis.
- Absence of strong linkages among farmers, researchers and industry, and the policy makers.
- Lack of appropriate government policy framework to encourage farmers/industry to play effective role in the sweet sorghum production and marketing (by farmers) and ethanol production and marketing (pricing) by the industry.

ICRISAT along with the National Agricultural Research System (NARS) partners, government line departments, and non-government organisations envisages to establish an holistic and integrated system of sweet sorghum production and its utilization for bioethanol production that not only facilitates to expand livelihood opportunities and increase smallholder farmers' income levels, but also will help to reduce the environment pollution and dependency on the fossil-fuel imports without compromising the food, feed and fodder security.

Overall project objective

The overall objective of the project is to improve the livelihoods of sorghum farmers and their dependants by establishing a sustainable commodity chain among farmers, development workers, non-governmental organisations (NGOs) and distilleries for increased sweet sorghum production and ethanol production. Appropriate interventions are designed to the suit farmer's located near to the distillery (centralized model - 2 000 farmers) and farmers located away from the distillery (decentralized model – 200 farmers). The activities in centralized model (India, Thailand and China) and decentralized model (one unit each for India and Thailand) serves about 2000 smallholder farmers in China and 2 200 farmers in India and Thailand each and additionally create direct-employment for 100 people (in the distillery) and indirect employment for another 20 000 person-days (through sweet sorghum cultivation including the harvesting, leaf stripping and transportation to distillery) in each country.

Specific project objectives

To identify appropriate locations and farmers in India, Thailand and China for sweet sorghum cultivation, and sensitize the farmers, research partners, private seed companies, inputs suppliers, credit agencies and ethanol distilleries for sweet sorghum cultivation and processing into ethanol.

- Develop and establish pilot-scale centralized and decentralized Public-Private Partnership (PPPs) value chain bioethanol enterprise models encompassing sweet sorghum production.
- To build seed production and delivery systems for each region for the selected cultivars.
- Develop and demonstrate methodologies for efficient by-product utilization, i. e., through feedblock making and vermicomposting based on sweet sorghum bagasse.
- Develop mechanism (s) to facilitate guaranteed buy-back at predetermined price of sweet sorghum stalks (centralized model) and syrup (decentralized

model) at the beginning of the season.

- To coordinate implementation of project activities with coalition partners and monitoring of the project activities to ensure effectiveness and projected outputs/deliveries and impact assessment.

Methodologies-For developing the value chain model, innovative strategies will be adopted to address all the issues holistically by harnessing the strengths and synergies of consortium partners. The concerns of all the stakeholders will be addressed to ensure that the value chain becomes stronger and successful. The farmers' participation and collective action is critical in the value chain development.

Organizing the farmers groups, input (seed and fertilizers) supply, technical backstopping, micro-entrepreneurship development in villages, linking farmers to markets, providing for better utilization of by-products, capacity enhancement of stakeholders are the specific innovations aimed in the project.

The following specific innovations form the pillars of the strategy in the value chain development.

- Utilization of sweet sorghum as a feed stock for ethanol production without compromising the food or fodder needs.
- Development of supply chains: A centralized model involving stalk supply to industry and a decentralized model involving localized crushing and syrup supply to industry to benefit more farmers from the biofuel markets.
- Farmer associations for integrated, efficient, dependable production and delivery of high-quality feedstock at competitive cost.
- Backward linkages of distilleries, input dealers and credit agencies with farmers to provide the latest technical information, inputs at lower prices and capital if required.
- Formation of farmers into commodity groups or associations for enhancing their bargaining capacity and market intelligence.
- Contract farming: Guaranteed minimum price, as per contractual agreements between individual farmers or farmer groups, and distilleries help ensure pre-

dictable and reliable returns to the farmers while controlling costs for the processor.

- Capacity-building of farmers and others in the supply chain on production technology; quality issues, value-addition, risk reduction, etc.
- Micro-entrepreneurship development in the villages and employment generation.
- Efficient by-product utilization through feedback making and vermi composting for crop-livestock integration and soil improvement, respectively.

Outputs

- Suitable areas and farmers for sweet sorghum cultivation in target countries identified.
- Various stakeholders in sweet sorghum value chain (production, processing, and marketing) trained.
- A Pilot centralized supply chain model involving linkages between farmers and industry for supply of sweet sorghum stalks for bioethanol production established.
- A Pilot decentralized supply chain model involving localized crushing cum syrup making units supplying sweet sorghum syrup to the industry established and operationalized.
- Learnings from both centralized and decentralized models of bioethanol production from sweet sorghum documented.
- Seed and other inputs supply systems for large scale sweet sorghum cultivation established.
- Feedblolck making from sweet sorghum bagasse demonstrated at DCU (India only).
- Vermicomposting of bagasse and its utilization for sustaining soil fertility demonstrated (India, China and Thailand).
- Two buy back contract farming models each for centralized and decentralized models (formal and informal) identified and tested in practice.
- Market linkage models popularized among the policy makers and other stakeholders and the impacts assessed.
- Project management and monitoring systems put in place.

Chapter 2: Sweet Sorghum Growing Domains in India

P Parthasarathy Rao, Ch Ravinder Reddy and Belum VS Reddy

Sweet sorghum cultivation, as part of the NAIP-ICAR sub-project on the sweet sorghum to ethanol value chain, was pilot tested in Medak district of Andhra Pradesh (Map 3). Preliminary analysis of farm-level data from the project sites indicate that sweet sorghum is a commercially viable crop and is able to compete with other dryland crops such as grain sorghum, sorghum and pigeonpea intercrop, and maize. One of the challenges before and after the completion of the project is up-scaling of sweet sorghum production to larger areas to make it a viable alternative complement as feedstock for ethanol production. In this chapter, we examine potential areas where sweet sorghum cultivation can be taken up in India. This is, of course, subject to the establishment of a distillery in close proximity, maybe 50 ~ 100 km from the farms.

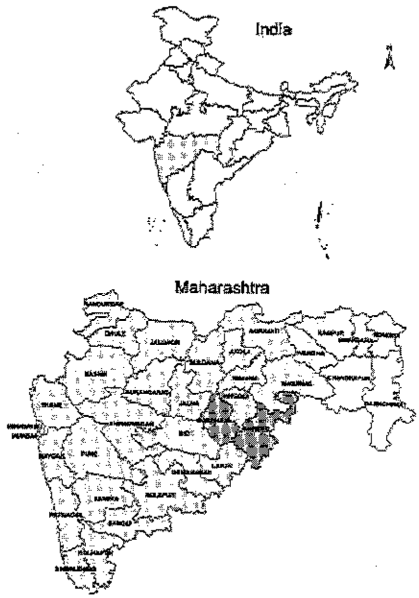
In order to select appropriate sites for up-scaling sweet sorghum cultivation in India, meso-level district data, and expert opinions from crop scientists and extension agents were used. Geographically, the Deccan Plateau and the Eastern Ghats were selected as suitable starting points as these regionsare the main sorghum growing regions in the country and have a large area under rainfed crops. Eleven sub-regions were chosen based on shared common agro-ecological characteristics which would bring about the greatest potential in sweet sorghum cultivation. The coastal sub-regions were not considered as these areas typically have high rainfall and high irrigation potential, and therefore are more suitable for high value crops. The agro-ecological zones were grouped using dominant soil types, climate, length of the growing period, normal rainfall, and soil fertility viz 6.1, 6.2etc. (Table 1 and Map 2). In addition, the percentage of land under rainy season and postrainy season for sorghum were also calculated to identify sub-regions which were already growing sorghum.

Of the eleven agro-ecological sub-regions, five were considered to be potential sweet sorghum growing areas. These are 6. 1, 6. 2, 6. 3, 6. 4 and 7. 2. These sub-regions are mostlysemi-arid environments (moist or dry) with the exception of sub-region 6. 4 which is sub-humid (moist). In addition, these regions had more than 10% of the cropped area under sorghum, either in postrainy season or rainy season with one exception. The exception was sub-region7. 2 which has a very low area under the crop (3% under sorghum in rainy season and 1. 5% under sorghum in post-rainyseason). Even so, this sub-region was selected as there are alreadyother sweet sorghum projects for ethanol existing in this region. There is much variation between the sub-regions based on demographic criteria. With the exception of 6. 4, all the sub-regions are predominantly rural with a population density ranging from 2. 5 to 5. 3 per ha (Table 2). In the sub-regions 6. 1, 6. 2 and 6. 4, the proportion of cultivators is higher whereas in the sub-regions 6. 3 and 7. 4, agricultural labor forms bulk of the rural population. Three out of the five sub-regions show relatively low mechanization. The use of pump sets is also relatively low with diesel pump sets being in the majority. Fertilizer application in the sub-regions is above 125kg/ha but most of the fertilizers are being used on crops like fine cereals, cotton, vegetables and fruit crops. The fertilizer application for sweet sorghum, as required under the improved package of practices, is thus not perceived to be a stumbling block.

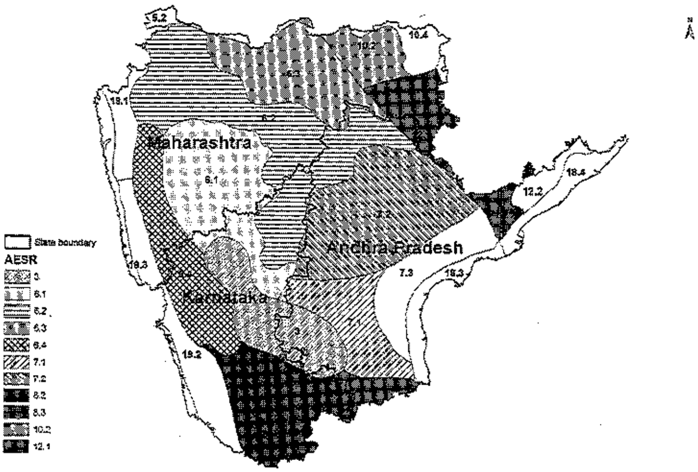
Cropping pattern

Sub-region 6. 2 has the largest net cropped area among the five selected sub-regions (Table 3). The proportion of irrigated land varies widely between the sub-regions, ranging from 8% to 46%. Cropping intensity is relatively high in all the sub-regions. Coarse cereals dominate the cropping pattern of the sub-regions, the only exception being 6. 3 where other rainfed crops such as pulses, oilseeds and cotton form the bulk of crops. Pulses are the second-most important crops planted in the sub-regions.

The agro-ecological sub-regions cover a large geographical area and are very di-



Map 1 Districts currently selected for sweet sorghum-ethanol value chain.



Map 2 Agro-ecological zones for up scaling sweet sorghum.

verse in their characteristics. Hence to target sweet sorghum better, data on each of the districts within an agro-ecological zone was also collected and analyzed. Based on this, eighteen potential districts were selected in the five agro-eco-

Table 1 Agro-ecological characteristics of selected AEZ for up-scaling sweet sorghum.

Note: Rows highlighted in green are the selected sub-regions suitable for up-scaling.

AEZ sub-region	Physiographic	Number of districts	Soil	Climate	Growing season (days)	Normal rainfall (mm)	Soil quality	Soil depth	Soil texture	Rainy season sorghum area ('000 ha)	Postrainy season sorghum area ('000 ha)
3	Deccan Plateau	5	Mixed Red and Black	Arid (tropic)	60 ~ 90	592	Low to Medium; 50 ~ 150mm	Deep	Loamy and clayey	102.03 (5.23)*	209.62 (8.62)
6.1	Deccan Plateau	8	Shallow Black (with medium and deep Black soils as inclusion)	Semi-arid (dry)	90 ~ 120	686	Medium to high; 100 ~ 200mm	Shallow and Medium	Loamy	219.15 (2.58)	2 499.30 (25.53)
6.2	Deccan Plateau	13	Shallow Black (with medium and deep Black soils as inclusion)	Semi-arid (moist)	120 ~ 150	885	Medium to high; 100 ~ 200mm	Shallow and Medium	Loamy; Clayey 15-<35%	569.78 (8.02)	1 325.05 (10.31)
6.3	Deccan Plateau	6	Deep Black (with shallow and medium black soils as inclusion)	Semi-arid (moist)	120 ~ 150	935	Medium to high; 100 ~ 200mm	Shallow	Loamy; Clayey 15-<35%	452.70 (15.94)	46.70 (1.40)
6.4	Deccan Plateau	9	Shallow Black (with medium and deep Black soils as inclusion)	Subhumid (dry)	150 ~ 180	1079	Medium to high; 100 ~ 200mm	Shallow	Loamy; Clayey 15-<35%	164.17 (5.37)	766.54 (9.92)

(续表)

AEZ sub-region	Physiographic	Number of districts	Soil	Climate	Growing season (days)	Normal rainfall (mm)	Soil quality	Soil depth	Soil texture	Rainy season sorghum area (' 000 ha)	Postrainy season sorghum area (' 000 ha)
7.1	Deccan Plateau	2	Mixed Red and Black	Semi-arid (dry)	90 ~ 120	677	Medium 100 ~ 150 mm	Shallow and Medium	Loamy: Clayey 15-<35%	6.01 (1.29)	68.85 (9.40)
7.2	Deccan Plateau	8	Mixed Red and Black	Semi-arid (moist)	120 ~ 150	860	Medium to Very High; 100 ~ 150; >200 mm	Deep	Loamy: Clayey 15-<35%	102.85 (2.91)	64.36 (1.52)
8.2	Deccan Plateau	10	Red Loamy	Semi-arid (moist)	120 ~ 150	954	Low; 50 ~ 100mm	Medium to Deep	Loamy	56.74 (1.77)	15.56 (0.47)
8.3	Eastern Ghats & Tamil Nadu Uplands	1	Red Loamy	Semi-arid (moist)	120 ~ 150	697	Low; 50 ~ 100mm	Deep	Loamy	1.22 (0.23)	0.00 (0.00)
10.2	Deccan Plateau	2	Shallow Black (with medium and deep Black soils as inclusion)	Subhumid (dry)	150 ~ 180	1 193	Medium to High; 100 ~ 200mm	Shallow and Medium	Loamy: Clayey 15-<35%	32.50 (2.99)	3.90 (0.17)
12.1	Eastern Plateau	2	Red and Lateritic	Subhumid (moist)	180 ~ 210	1 524	Low to Medium; 50 ~ 150mm	Deep	Loamy	7.00 (1.18)	19.10 (1.47)

Note: * Figures in parenthesis indicates percent sorghum area to gross cropped area of the sub region

Table 2 Demographic characteristics of the selected agro-ecological zones.

AEZ sub-region	Total population ('000)	% Rural population	Proportion of cultivators (%)	Proportion of agricultural laborers (%)	Rural literacy (%)	Rural population density (number per ha)	Tractors (number per 100 sq km)	Diesel pumpsets (number per 100 sq km)	Electric pumpsets (number per 100 sq km)	Fertilizer consumption (kg/ha)
6.1	24 839	67	24	17	58	2.6	0.6	6.6	0.6	131
6.2	32 191	73	21	19	52	2.9	0.4	6.6	0.6	138
6.3	13 622	73	15	28	64	2.5	0.4	3.8	0.5	125
6.4	35 462	42	24	16	59	3.5	1.6	6.4	0.9	164
7.2	25 874	67	16	23	43	5.3	1.9	27.1	1.2	269

Table 3 Cropping pattern in the selected agro-ecological sub regions.

AEZ sub-region	NCA ('000 ha)	% Irrigated land	Cropping intensity (%)	Fine cereals (% of GCA)	Coarse cereals (% of GCA)	Pulses (% of GCA)	Oilseeds (% of GCA)	Sugarcane (% of GCA)	Cotton (% of GCA)	Others (% of GCA)
6.1	6 386	25	122	10	48	15	14	8	3	2
6.2	7 998	18	128	9	31	24	15	5	15	2
6.3	3 931	8	130	6	14	27	23	1	29	0
6.4	4 206	31	118	14	37	12	15	10	5	7
7.2	3 282	46	119	8	18	14	12	2	16	29

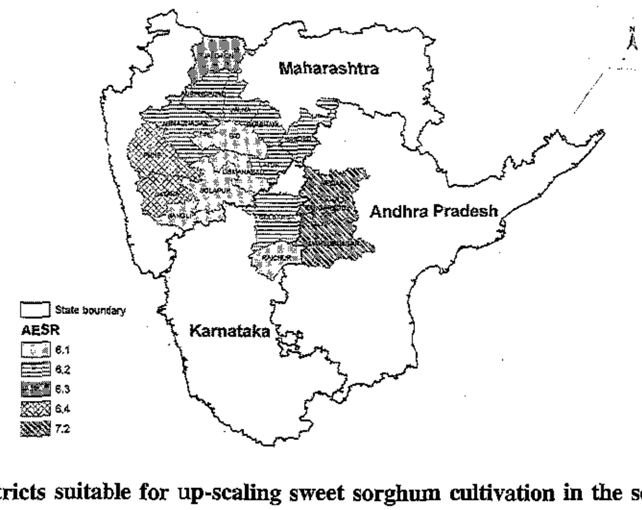
logical zones. The details are given in Table 4. Most of these districts fall in Maharashtra, two in northern Karnataka and three in Andhra Pradesh (Map 3). All the selected districts have over 50 000 ha under sorghum as in 2007 and are potential areas for the first phase of up-scaling sweet sorghum.

Table 4 AEZs and districts within the AEZs for up-scaling sweet sorghum.

Agro-ecological sub-region	District
6.1	Raichur *
6.1, 6.2	Ahmednagar
6.1, 6.4	Pune
6.1	Sangli
6.1	Solapur
6.1	Beed
6.1	Osmanabad
6.2	Gulbarga *
6.2	Aurangabad
6.2	Parbhani
6.2	Nanded
6.2	Jalna
6.2	Latur
6.3	Jalgaon
6.4	Satara
7.2	Medak **
7.2	Mahaboobnagar **
7.2	Rangareddy **

* Karnataka.

** Andhra Pradesh, rest in Maharashtra.



Map 3 Districts suitable for up-scaling sweet sorghum cultivation in the selected AEZs.

Chapter 3. Sweet Sorghum Growing Domains in China

Zou Jianqiu, P Parthasarathy Rao, Lu Feng and Ch Ravinder Reddy

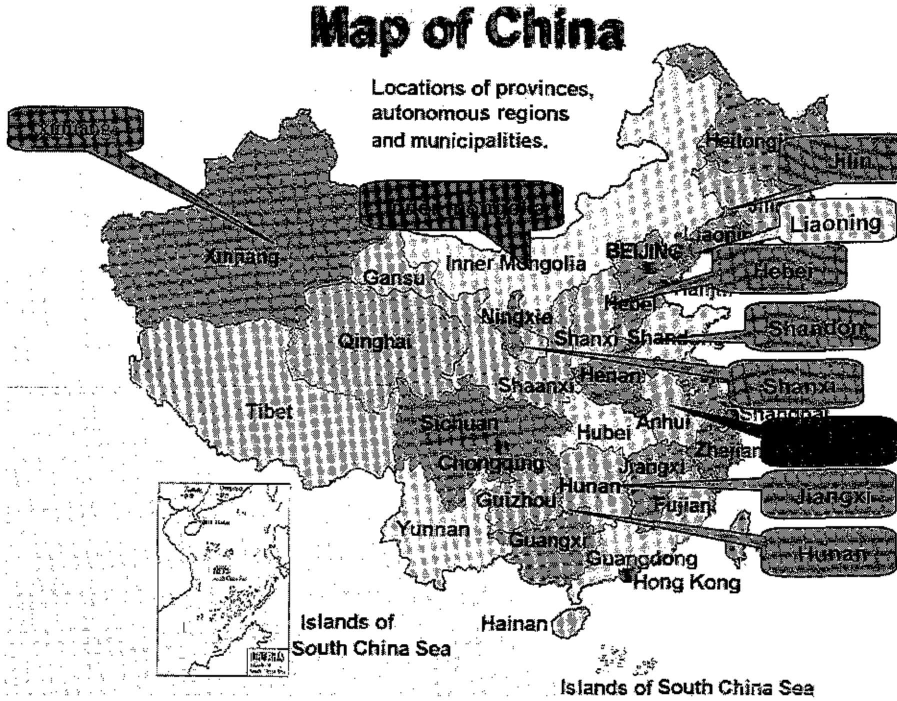
Sweet sorghum growing domains in China *

Cultivation areas	Latitude	Number of districts	Soil	Climate	Growing season (days)	Normal rainfall (mm)	Soil quality	Soil depth	mean annual temperatures	The altitude (m)	The average daily temperature ≥ 10℃ effective accumulative temperature (℃)
Spring sowing precocious area	north latitude 34°30″ ~ 50°15″		mould humus, chestnut soil, black, brown soil,	Arid (tropic)	115 ~ 150	100 ~ 700	low level of ripening, rich organic	Deep	2.5 ~ 7.0℃	70 ~ 3 000	2 000 ~ 3 000
Spring sowing related area	northlatitude 32° ~ 42°30″		Brown soil, brown desert soil	Semi-arid (moist)	160 ~ 250	16.2 ~ 900	Fertility medium, high degree of soil ripening	Medium	8 ~ 14.2	3 ~ 2 000	3 000 ~ 4 000
Spring and summer sowing area	northlatitude 24°15″ ~ 38°15″			Moist (semi-moist)	200 ~ 280	600 ~ 1 300	Fertility low, low degree of soil ripening	Shallow and Medium	14 ~ 17	20 ~ 3 000	4 000 ~ 5 000
South area	northlatitude 18°10″ ~ 31°10″			moist	240 ~ 365	1 000 ~ 2 000		Shallow	16 ~ 22	400 ~ 1 500	5 000 ~ 7 500

* Mark for the green line has-been selected as the sweet sorghum planting advantage area.

Sweet sorghum distribution in China

There are 10 provinces which are potential growing domains of sweet sorghum as marked on the map.



The total release areas of Liaotian series sweet sorghum

As of 2011, the total released acreage of sweet sorghum in Liaoning amounted to 3 000ha on the marginal land and low-yielding land and locatedmostly in Huludao, Fuxin and Chaoyang areas. The above-said grown sweet sorghum hybrids have shown their strong stress with stable high yielding, juicy stalks of high sugar content. The total released acreage of sweet sorghum amounted to 4 000ha in Wuyuan-Inner Mongolia, Dongtai-Jilin, Jiangsu, binzhou-Shandong, Daan-Jiangxi,

Jiangxi and Southeast Asia. Jilin Fuel Ethanol Company, Ltd, is located in Dongtai area, Jiangsu province, where farmers utilize saline-alkaline land near the sea to grow sweet sorghum with Liaotian series as main varieties after release demonstration. Binzhou Guanghua Bio-energy Group is located at Binzhou city, Shandong province; where farmers also grow sweet sorghum on saline-alkali land for developing biofuel ethanol industry. Beijing Sangliang Technology Development Center serves as an agent of Liaotian series sweet sorghum hybrids in Southeast Asia region for biomass energy transformation.

Benefits achieved

The feedback survey results showed that the stem yield reached 75t/ha and the grain yield 4.5t/ha in most planting areas. Sugar Brix varied in different ecological conditions, usually between 15% ~ 22%. Compared with current production levels, the stem yield showed an increase of 8% ~ 10%, grain output an increase of 10% ~ 12%, sugar Brix average increase of 5% ~ 8%.

The accumulated increase in yield of stems amounted to 46 700 ton, and grain yield increase to 4 800 ton, bringing about an economic benefit increase of 2.2 million RMB, which reveals that the promotion of biomass energy industry greatly contributed to the development of local transportation and processing industry with significant social and economic benefits.

Chapter4: Sweet Sorghum Feedstock Supply Chain Models Adopted in India

Ch Ravinder Reddy, G. Basavaraj and Belum VS Reddy and P Parthasarthy Rao

Introduction

Food and energy security are critical for the sustenance of modern civilization. Considering the vagarity in the availability of fossil fuels, their costs and the associated environmental pollution, there has been renewed interest in biofuels globally. Biofuel crops, particularly sweet sorghum, offer dryland farmers an opportunity to increase their income while at the same time protecting the environment without sacrificing food and fodder security. Sweet sorghum is a C4 plant with high photosynthetic efficiency. It produces high biomass (up to 40 ~ 50t/ha) in a short time (four months) under rainfed conditions. It is a SMART crop that produces food, feed and fuel at one go (grain for food, sweet juice for ethanol after fermentation and bagasse for animal feed/compost).

ICRISAT is working on sweet sorghum improvement and has incubated the sweet sorghum ethanol production technology with Rusni Distilleries through its Agri-Business Incubator. The sweet sorghum ethanol distillery established by Rusni Distilleries Pvt. Limited took advantage of this value chain model. The chain of project activities involved in producing sweet sorghum-based bioethanol encompasses capacity building of stakeholders in sweet sorghum crop production, stalks harvesting, and transportation; forward linkages with private sector (distillery) for crushing and processing of the juice for ethanol production and decentralized stalks crushing and syrup making at village and supplying syrup to various end-users. A consortium of partners including ICRISAT, National Agricultural Research Services

(NARS), private sector, NGOs, farmers associations actively contributed in developing this value chain.

An assured supply of raw materials is critical for the success of any industry. Sweet sorghum being a season-bound crop, its stalks are available for crushing only for a limited period (3 ~4 months) during different seasons of the year. To ensure a viable ethanol industry, assured and continuous supply of raw material is essential for at least 8 ~9 months of the year. Therefore, to extend the period of raw material availability, ICRISAT is working on both centralized (farmers supplying stalks directly to distilleries) and decentralized (farmers supplying stalks to the village level crushing units) models for the benefit of farmers and industry. A combination of the two models, centralized and decentralized, helps in stalk supply chain management.

Value chain models

1 Centralized model

While centralized distilleries crush the stalks in bulk quantities and produce ethanol, the decentralized units crush the stalks at the village level and convert the sweet juice into syrup. The centralized model requires high volumes of stalk and the costs of transportation therefore are high (Fig. 1).

1.1 Rational

In the centralized model, a typical 40 kilolitres per day (KLPD) ethanol distillery requires feedstock from 8 000 ha of crop area per year spread over two seasons - 3 500 ha in the rainy season (rainfed) and 4 500 ha in the postrainy season (irrigated). As farmers supply stalks directly to the distillery, it requires mobilization of farmers in villages within 50 km radius of a distillery so that the time for and cost of transportation of stalks is kept at minimum.

However, the centralized model has some limitations:

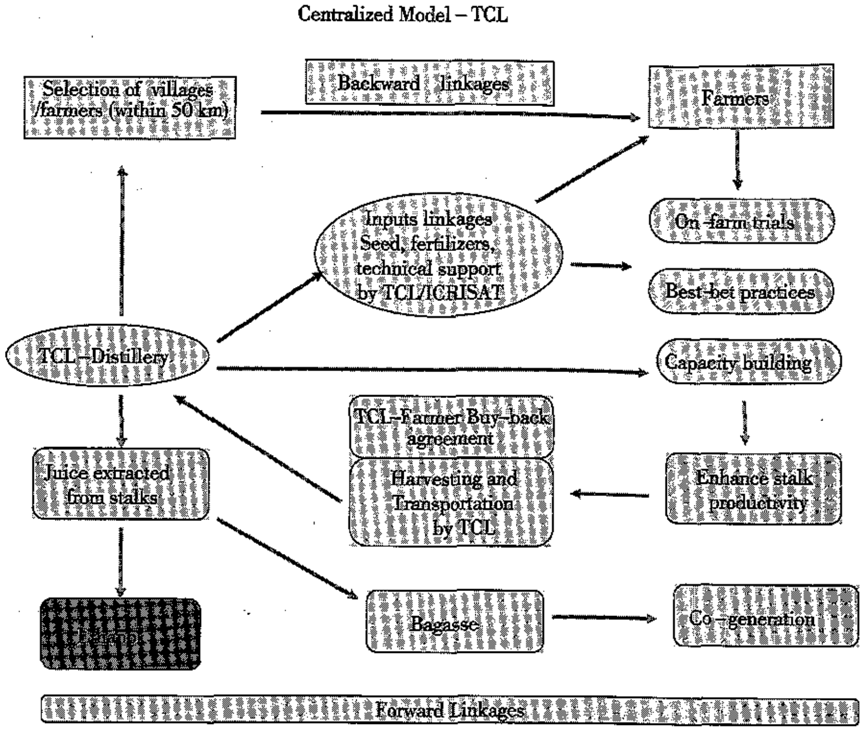


Fig. 1 Centralized model: linking farmers to distillery.

- Farmers located more than 50 km from the distillery will be burdened by high transportation costs owing to the bulk of stalks.
- Delay in crushing stalks beyond 24 hours of harvest causes a 6% reduction in juice yield.
- Delay in transportation of stalks to distilleries by 24 hr after harvest leads to reduction in stalk weight up to 20%, depending on climatic conditions causing a financial loss to the grower.
- Finding 4500 ha with irrigation facilities within the stipulated radius during the postrainy season is a daunting task in SAT areas. Organizing such a large number of farmers to undertake sweet sorghum cultivation is also difficult.
- Growing other crops like soybean, maize, rice and wheat may be more economical than sweet sorghum under irrigated conditions.

The decentralized model overcomes some of these difficulties.

1.2 Institutional arrangement for linking farmers to biofuel industry

Under the centralized model, a cluster of villages within a radius of radius of 50 km from the distillery are targeted to grow the crop and transport sweet sorghum stalks to the distillery within 24 hours of harvesting to prevent losses in juice recovery and quality. Typically, agro-processors have to run the processing unit to full capacity, otherwise it will not be economical for them. The processing unit needs continuous supply of quality raw material round the year. Companies cannot produce required amount of raw material by themselves, as land is a constraint for them. Companies are therefore entering into contractual agreements with the small farmers to overcome the land constraint. Contract farming has been adopted as form of commercial agricultural production since many years and both the companies and farmers benefit from it.

Production activities must be seen as part of the whole supply chain to ensure sustainable income growth of farmers. "Linking farmers to markets" will develop long-term business relationships among farmers and different stakeholders as it includes backward and forward linkages for sustainable livelihoods through value addition and harnessing Public-Private-People Partnerships (PPPP). This type of linkage model is beneficial for all stakeholders who are involved in it either directly or indirectly. Stalks buyers (distillery) provide all inputs (seeds, fertilizers, pesticides and weedicide) on credit basis as well as technical guidance to farmers to enhance productivity, during harvesting and in supplying stalks to the distillery. The ICRISAT - Rusni partnership provides improved crop production technology and technical backstopping to the partners and farmers on various activities in ethanol value chain. The model developed was used for scheduling of feedstock growing and supply to the industry during different crop seasons (based on multi-location on-farm evaluation for identifying suitable sweet sorghum cultivars and agronomic manipulation to increase the harvest window). The farmers were linked with distillery through a signed buy-back agreement for smooth supply of inputs to farmers and stalks to distillery. Inputs are supplied to farmers on credit basis and cost of inputs were recovered from the cost of stalks supplied to distillery.

Farmers' associations were formed and strengthened to develop negotiation skills so that they can have edge over buyers in dealing with contract agreement. Mutual trust is key factor for successful business relations among the parties involved in linkages and linkage activities have to concentrate on developing trust. The private sector needs to play a key role in fostering linkages with the farming community, but the government can improve efficiency of linkages by providing required infrastructural facilities and policy framework.

1.3 Issues In the centralized model

- Fixing stalk procuring price by the distillery
- Timely harvesting and transportation of stalks to distillery
- Quality of stalk based on sugar content (Brix %)
- Staggered planting for continuous stalks supply
- Availability of cultivars of varying maturity period (early- < 90 days; medium- 90 to 120 days; late > 120 days) for widening harvesting window
- Availability of cultivars for postrainy season cultivation
- Stability of fermentable sugars in juice and syrup

2 Decentralized Model

2.1 Rationale

The purpose of setting up decentralized crushing units (DCU) at the village level is to crush sweet sorghum stalks, extract and boil the juice to produce syrup. It aids the supply chain management particularly by reducing the volume of feedstock that would otherwise have to be supplied to centralized crushing units and increasing the period of feedstock (supply of syrup) availability to industry to make sweet sorghum ethanol a commercial reality. The by-product, bagasse (crushed stalk) is left in the village to be used as animal feed or as organic matter to enrich the soil. This paves the way for a more efficient whole-plant utilization of sweet sorghum. Also the DCU serves as a model for farmer-centric, farmer-driven rural industry for improving the livelihoods of small-scale sorghum farmers (Fig. 2).

2.2 Farmer linkages

Under the decentralized model, villages located at more than 50 km distance from the distilleries (TCL-Nanded) will be served by decentralized crushing units

Decentralized crushing unitmodel

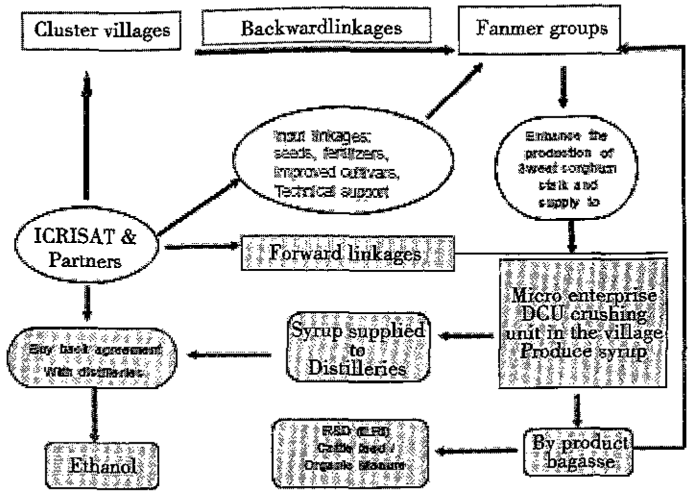


Fig. 2 Decentralized model: Linking farmers to DCU.

(DCU) managed by farmers group/micro-entrepreneurs for extracting the juice and syrup production from sweet sorghum stalks in the village itself.

The model strengthens the farmers through capacity building and linking farmers to input supply agencies including credit/financial institutions and output markets. Initially the project supplies all inputs to participating farmers at the right time and facilitates the signing of a stalks buy-back agreement with pre-agreed stalk procurement price and recovery of all input cost from the farmers after crop harvest and supply of stalks to the DCU. The model also envisaged to link the DCU with the distillery with buy-back agreement for supply of syrup on a pre-agreed price.

2.3 Issues with DCUs

a. High initial investment for the establishment of DCU.

b. Assurance by distillery only for small quantities of syrup procurement from DCU.

c. Criteria for price fixation for syrup for industry and payment schedule.

d. Basis for payment to farmers (stalk weight, syrup (Brix %) or any other).

e. Procedure for giving back bagasse to farmers or use of bagasse by the DCU.

2.4 Establishment of Decentralized crushing unit

2.4.1 Selection of villages and site for DCU

An exhaustive survey needs to be conducted in project area to select appropriate villages for growing sweet sorghum and to establish decentralized crushing units (DCU) for syrup production.

In the CFC-FAO project on 'Enhanced Livelihood Opportunities of Smallholders in Asia: Linking Smallholder Sweet Sorghum Farmers with the Bioethanol Industry' the villages were selected on the basis of ① their accessibility; ② natural resources (soil, water, topography, etc); ③ social harmony; ④ dryland cropping systems; ⑤ sources of irrigation; ⑥ farmers' response to the idea, and their willingness to participate in the project activities; and ⑦ the feasibility of growing sweet sorghum and finding a suitable site for setting up a DCU. Scientists from ICRISAT and MAU and farmers from Sanpuri Farmers Association, a nongovernmental organization, (NGO) teamed up and surveyed areas to select the villages and to identify an appropriate site for establishing the DCU. After the reconnaissance survey in different areas of Parbhani district in Maharashtra state of India, In-depth discussions were held with the village administration, i. e., the village sarpanch, secretary, village leaders and lead farmers in the cluster villages to obtain basic information on cropped area, crops grown, irrigated area, types of soil, yields of different crops, markets, political affiliations and the possibility of securing panchyath land (community land) to set up the DCU.

After analyzing (biophysical characterization) the merits and demerits of the different clusters, it was found that Nankheda cluster in Parbhani district was suitable for large-scale sweet sorghum cultivation and for establishing the pilot DCU. Subsequently, five villages were identified (Table 1) in this cluster within a 10 km radius from Nankheda, the nucleus village.

Table 1 Total number of villages and households in Nankheda cluster.

S. No	Village name	Number of households
1	Nankheda	236
2	Kadagaon	157

（续表）

S. No	Village name	Number of households
3	Sanpuri	136
4	Sultanpur	234
5	Jalalpur	214
	Total	977

As there was no panchayat land available in the village, on our request a couple of farmers offered their land on lease for establishing DCU. Of three sites inspected in the village, an easily accessible tract of land with a power line, water facility and a blacktopped approach road was chosen. The owner of the site agreed to lease 0.4 ha of land for a 20 year period free of cost. A lease agreement was signed and registered between the land owner and Marathwada Agricultural University (MAU) in the presence of the village administration and farmers association (FA) to avoid problems of change in the mind set of donor.

2.4.2 Design and layout of the site

ICRISAT and partners jointly designed the DCU layout plan to position plant and machinery for easy and convenient operations of weighing, crushing and chaff cutting (the bagasse). The site is close to the Nankheda village located alongside a main road that connects the cluster village and to the Parbhani district headquarters. It has water facility and a power connection. Based on the dimensions of the site, the layout of roads, location of the crusher and other machinery was planned (Fig. 2).

2.4.3 Plant and machinery

In order to procure reliable and efficient machinery for the decentralized crushing unit, enquiries were made with local jaggery making farmers and industry personnel. The following equipment and machinery procured for the DCU establishment:

- Crusher
- Weigh bridge
- Generator
- Chulhas (stoves)
- Juice boiling pans

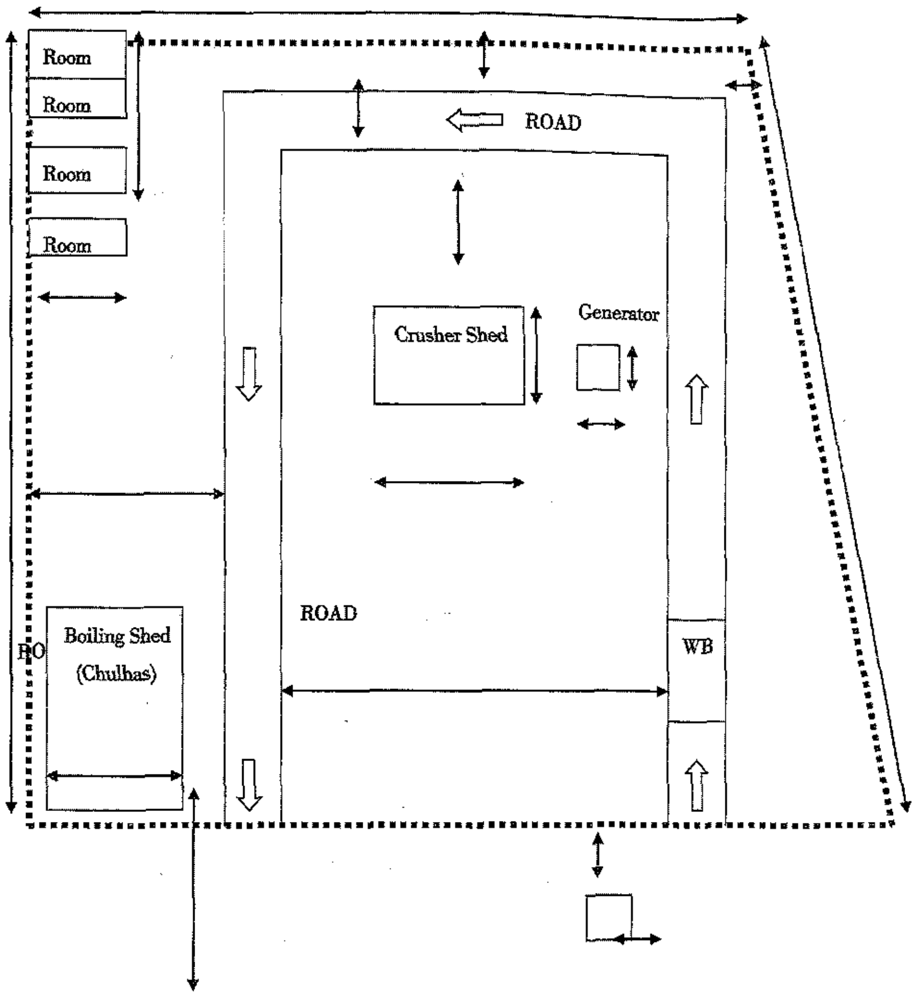


Fig. 3 Layout of the decentralized crushing unit at Nankheda village, Parbhani.

- Juice boiling accessories (stirrer, dragger, sieves and scum storing drum)
- Electric motors and pumps
- Supply pipelines
- Juice storage tank
- Steel baskets
- Motors
- Chaff cutter

- Juice filter press

(1) Crusher: The crusher is an important component of the DCU. It is required to crush the sweet sorghum stalks to extract the juice. In this project, a popular sugarcane crusher model with three rollers, 2 t per hour crushing capacity was chosen after consultations with local dealers, jaggery making farmers and a couple of crusher manufacturers. To improve the crushing efficiency a private sector engineering company assistance was sorted to modify the rollers of the crusher to suit sweet sorghum stalks and increase juice extraction. The crushing efficiencyis calculated by the quantum of juice extracted from a ton of stalks, which varies with the genotype, season of crushing and time laps between harvesting and crushing. The modified crusher efficiency was 350 liters per ton of stalk compared to sugarcane crusher was around 260 lit. per ton. Crusher being critical in DCU should have less maintenance cost and fewer mechanical problems. Its spare parts and repairing facilities are easily available. The specifications of the crusher are presented in Annexure 2.

The crusher at DCU-Nankheda, Maharashtra has a capacity of 2 t per hour. It can be operated with a 25 HP electrical motor connected with a pulley and V-belts. During crushing, the juice flows through a preliminary juice collection and filtration pit beside the juice outlet channel. From this outlet, the filtered juice flows into a juice collecting drum (900 lit. capacity) placed beneath the soil surface for convenience. The juice collected in the drum is pumped by a motor into boiling pans through an industrial hosepipe.

(2) Weigh bridge: Farmers bring their stalks in tractor, bullock carts and sometimes on truck. It is important to weigh the stalks coming to DCU for crushing as the payments to farmers will be made based on the quantity of fresh stalks they supply to DCU. In this project, we installed a surface mounted weigh bridge with a capacity to weigh up to 50 tons stalk load. If a weigh bridge facility is available within the village limits or nearby DCU, such an investment can be avoided. The weight of the stalks are recorder with a computer attached to weigh bridge and issue stalk weight slips with farmer name and other details of farmer.

(3) Generator: Three-phase (industrial) power supply is required to run the crusher. That makes it convenient and cheaper. As there was no industrial power line close to Nankheda village, and there is frequent power shutdown in rural areas. Hence, power supply to the DCU was arranged by installing a captive 40 KVA generator. DCU operations were seasonal and operated 30 ~ 40 days/year in the rainy season.

(4) Chulas: These are earthen stoves for boiling the juice. They are made of bricks and cemented with pressed mud. Each chulha measures 6.6 ft in diameter, and embedded 3.0 ft. depth beneath the soil surface. An exhaust outlet of 10 ft. height was erected 7.0 ft. from the chulhas, also made of bricks and pressed mud. Each chulha has a 9.0 ft long air passage channel below the soil surface connecting chulla and exhaust tower. The bagasse feeding opening is 1.6 ft length located in the rim of the chula.

(5) Boiling pans: The standard sugarcane juice boiling pans were adopted. They are made of 18 gauge thick galvanized mild steel sheets, with a diameter of 7.0 ft. and a depth/height of 1 ft 6 inches. Each pan can hold 700? 750 liters of juice per cycle. The boiling pan has to be put aside for cooling of syrup before filling syrup into plastic cans for storage. We need to have one additional set of boiling pans for convenience of continuous operations.

(6) Juice boiling accessories: Several small tools are needed for syrup production. Metallic sieves are required to remove unwanted contaminants floating on the surface of the boiling juice and to remove the froth or scum which rises to the surface during boiling. Wooden draggers are needed to scrape the bottom of the pan and to stir the juice frequently. A scum storing drum is used to collect the scum removed during boiling. All these accessories are custom made locally.

(7) Motors, juice collection tank, steel baskets and pipeline: Motors are required to lift and pump juice from the juice collection tank to the boiling pan with a hose pipe. The juice collection tank is placed near the crusher (in a pit) connected with an outlet pipeline from the crusher delivery channel. Steel baskets (3

ft × 3 ft) are used to shift the bagasse from the crushing site to the drying yard.

(8) Juice filter press: The juice produced by crushing the stalks were passed through the filter press to remove concomitant contaminants (soil, leaf bits, stalk bits etc.) mixed with the juice during crushing operation. By filtering the juice before boiling the juice in the pans for making syrup is found to be of good quality, free of burnt smell, light brown in color and the process of syrup production is faster (takes less boiling time).

2.4.4 Other facilities

(1) Water: Fresh water is required for cleaning the crusher, boiling pans and other tools every day. A reliable water facility and a motor to pump this water is a prime requirement. For this project, we used the water from the lease farmer's bore well.

(2) Technician: Trained local technicians must be engaged for maintenance of the plant and machinery and troubleshooting. We made arrangements with local technicians to render their services as and when required.

(3) Sheds: It is important to protect the chulhas and crusher from the rain and sun. Also, erecting a shed with tin or asbestos sheet roofing will enhance labor efficiency. (Annexure 1.)

2.4.5 Command Area Development

The sweet sorghum command area needs to be developed to meet the raw material requirement of the DCU. In the present project, as there was a limited area available under irrigation, therefore, major emphasis was placed on sweet sorghum cultivation in the rainy season. In order to enable local farmers cultivating sweet sorghum, the required seed, fertilizers and herbicide were supplied on credit basis. The costs of these inputs were recovered while making payments for the stalks supplied by farmers to DCU for crushing. Appropriate capacity building activities like awareness camps, exposure visits, on-farm and on-station training programs on crop production, integrated pest, disease and nutrient management practices, field trials and demonstrations in the cluster villages were undertaken to enhance productivity.

Under the present project, the services of an NGO, Sanpuri farmers association were utilized to complement the project team particularly on identification of participating farmers, supply of seeds and other inputs, in staggering the planting and ensuring that the farmers adhered to the recommended package of practices (thinning, weeding, topdressing, etc.) for production enhancement and developing harvesting schedules for the supply of sweet sorghum stalks to the DCU.

2.4.6 Crushing and Syrup Production

(1) Procurement of raw materials

This is critical to the success of the model as it involves winning the confidence of farmers through timely harvest, stalk procurement and prompt payment. Under the ICRISAT-CFC project the services of Sanpuri Farmers association were used to link the farmers to the DCU. This involved community mobilization for various activities of the project including scheduling the harvesting process to facilitate steady supply of stalks for crushing at the DCU and payments for stalks were made on pre-agreed price (buy-back agreement) per ton of stalk.

(2) Crushing: Sweet sorghum stalks should be crushed on the same day of harvesting (Fig. 4). Any delay in crushing results in low juice recovery and eventually low syrup yield. The DCU established at Nankheda village, Parbhani Tq. has the capacity to crush 2 tons per hour can crush stalk from a 25-30 ha area during the rainy season (Kharif) in 30 days of operation working one shift of 8 hours per day. Usually crushing operation starting time depends upon sowing date and generally crop is harvested at physiological maturity (110 days after sowing). The juice yield depends on cultivar, time of harvest (age of crop), duration between harvest time and crushing, and temperature.

(3) Syrup making: The syrup making process involves collection of juice from the crushing point and boiling it to evaporate the water and concentrate the sugars in the juice. The juice from the crushing point is pumped to the boiling pans for making syrup with limestone, superphosphate, and okra (ladies finger) fruit powder are added to the constant boiling and stirring. Chemicals like calcium (Garika Soda), castor oil, boiling juice in different concentrations to avoid froth formation and for coagulation of unwanted materials float on the surface of the boiling juice.

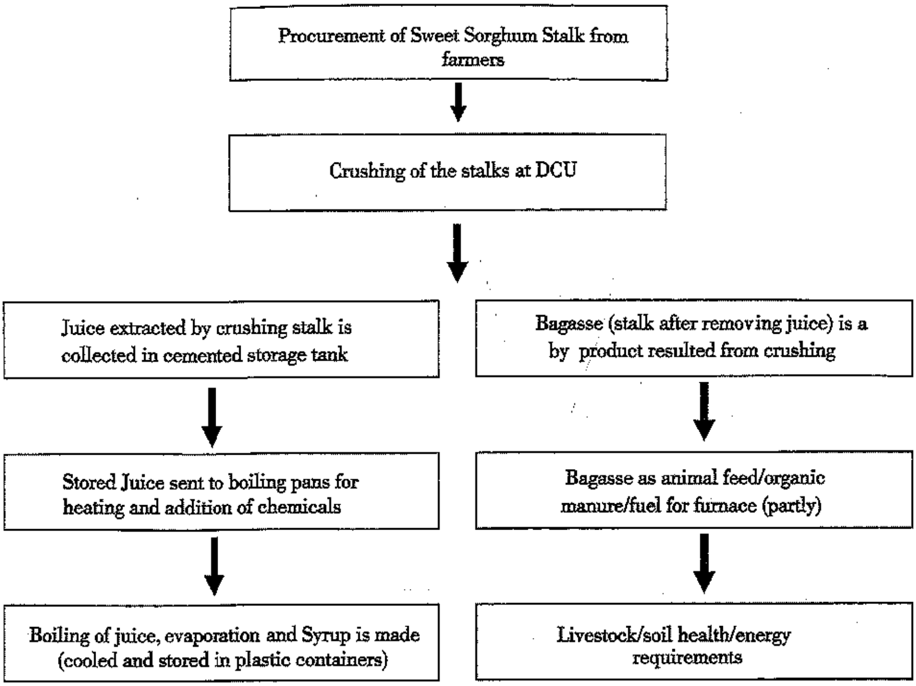


Fig. 4

The juice in the pan is constantly stirred during boiling, some undesirable contents coagulate float on the surface (skimmings) are removed frequently. The skimmings are generally rich in protein and starch as well as some sugar and can be used in preparing animal feed. As the syrup density increases, the boiling temperature increased gradually. The boiling pans are removed from the burners (chulas) when the temperatures reaches 226 ~ 230°F (108°C to 110°C) or when the syrup attains a density of 70° Brix tested with a syrup hydrometer or sugar refractometer. The final syrup is allowed to cool to 140 ~ 160°F and stored in plastic containers at room temperature.

The finished syrup is strained with a mesh to remove any crushed plant materials or other inert foreign materials were analyzed for chemical contents (Annexure 3). The syrup is stored in wide mouthed clean, air-tight plastic containers at room temperature. The shelf life of the syrup at 70° Brix stored at room temperature was around 24 months without any significant deterioration of sugars. Detailed syrup making process given in Box 1.

BOX 1 Syrup production process

A. Extraction of juice

The ear heads are harvested at physiological maturity, followed by stalks which are transported to DCU for crushing and extraction of juice. The percentage of juice extracted depends on the time lag between harvesting and crushing. A 24-hr to 48-hr delay in crushing will result in reduction of juice output by 20% ~30% depending on relative humidity and temperature as well as the crusher type. Generally sugar cane crushers yield 260 L. t^{-1} of stalk. A modified crusher developed for crushing sweet sorghum stalk yields 350 ~425 L. t^{-1} stalk. In large scale crushing the average juice production was 300 L. t^{-1} stalk.

B. Filtration of juice

a) The juice extracted from the crusher is strained through a wire screen to remove big particles of crushed material

b) The juice is again filtered using fine wire mesh before allowing it into juice collection tank to remove all the solid particles present in the juice.

c) After crushing the juice has to be boiled immediately to stop the fermentation process to restore the conversion of fermentable sugars.

d) The juice extraction and pumping juice into pans is a simultaneous process to stop fermentation.

C. Boiling of juice

The extracted juice is transferred to boiling pans that have the capacity to hold 700 l. The following precautions are taken at this stage.

a) Steady evaporation is the most important process of making syrup.

b) Evaporation should be done with uniform heating for obtaining good quality syrup.

c) Slow heating is required to prevent syrup from burning.

d) Initially coagulation starts when juice temperature increases.

e) As the temperature increases during boiling the juice scum is formed on the surface of the juice which is removed.

f) Syrup quality improves with continuous removal of coagulated materials from the surface of the boiling liquid in the pan.

D. Clarificants (chemicals) for removal of impurities and as preservatives

Quantities of chemicals used for boiling one pan of juice (700 l):

a) Super phosphate (single) 2kg.

b) Lime (sodium carbonate) 1kg.

The chemicals, which remove dirt from the juice, are mixed with the liquid before boiling.

c) Hibiscus (ladies finger powder) -10g added after filling the juice in the pan

d) Caustic Soda (Sodium hydroxide) -50g to be added during boiling.

e) Castor oil - 100g (causes froth on the boiling juice, which collects all the dirt, which is later decanted)

f) Sodium hydrosulphite - 50g (added last at 70% Brix. Chemical is added to the syrup just before removing the syrup from the pan, and stirred well. This also restores the color of the syrup.

E. Evaporation process

a) The density of juice increases (Brix%) as the boiling temperature rises.

b) When the temperature of the juice reaches 105 ~ 107℃, the Brix of the syrup should be 65% ~ 70%.

c) The Brix and temperature of the boiling juice must be monitored at regular intervals.

F. Cooling of syrup

a) Syrup should be cooled immediately to avoid burning.

b) Syrup should be brought down to 85 ~ 80℃ within 10 ~ 15 mins to avoid burnt taste and smell.

G. Syrup yield

a) Syrup yield: 50 ~ 55kg t^{-1} (15% ~ 18% of juice v/w) at 70% ~ 80% Brix.

b) Syrup yield depends on initial Brix% of juice and final Brix% of syrup.

c) The color of the syrup varies with the genotype and season of growth.

H. Syrup storage

a) The syrup can be stored up to two years without any deterioration of sugars at room temperature (Annex. 1 and 2)

b) Syrup should be stored in air tight containers, leaving some gap on top of the container.

c) The syrup can be stored in plastic cans or in polythene coated bags at room temperature.

I. Points to remember

a) Delay in harvesting of stalks, after more than 130 days will reduce the juice content in the stalks.

b) Brix of the stalks should be more than 15% for producing good quality syrup.

c) Filtration of juice must be done to remove stalk particles before boiling.

d) Effective removal of coagulated material and scum during juice boiling is very important for good quality syrup.

e) The syrup should not be heated above 105 ~ 107℃.

f) The syrup should be rapidly cooled within 10 ~ 15 mins.

(4) Training stakeholders in DCU operation

Under the ICRISAT-CFC project, the DCU was established to crush stalk for rainy seasons for a period of 30 ~ 40 days in a year. Initially the crushing unit and its operations were carried out by the farmers' group under the direct supervision and management of project scientists. All operators, daily-wage laborers and project staff were trained in handling the operations of the DCU before starting crushing. Utmost care should be taken while the DCU is in operation particularly handling the crushers and chulhas. Training programs conducted to enhance capacities of farmers' group like farmers' association, local community-based organization (CBOs) partner institutions staff and NGOs, to operate and manage the DCU. The training programs include hands-on-training in overall maintenance and repairs, trouble shooting, stalk supply chain management and assessing quality parameters like juice and bagasse output and accounts and book keeping in effective management of the DCU operations. The farmers' group will be linked to the ethanol or other related industries with formal buy-back agreements for purchase of the syrup produced by the DCU.

Summary

To summarize, availability of feedstock for longer periods in a year (more than 6 months) is a critical factor limiting the expansion and suitability of the sweet sorghum ethanol industry. The decentralized model enables supply of feedstock to the distillery over a longer period of time in a year through syrup route. The DCU in general will serve as an extended arm of the distillery and operate as a stand-alone self-sustaining unit. At present, all the syrup produced at DCU, will be supplied to TCL distilleries Ltd, Nanded for ethanol production.

Each decentralized unit provides employment to 20 ~ 30 people during the crushing season. The major beneficiaries of the DCU are likely to be small and marginal farmers who form the core of the target group as they get ready inputs, guidance and an assured market for their produce. Women's participation is high in all DCU operations, thereby aiding women empowerment. The success and overall economic viability of DCU depends on its operational efficiency and market linkages with distilleries and other industries to obtain a better price per unit of syrup. Once the model is found to be viable and sustainable, efforts will have to be made to up-and out scale the unit. This paves the way for micro entrepreneurship development in villages that increases the income and employments options and reduces migration to urban areas. Establishment of DCU with essential plant and machinery, the cost can be at minimum if a farmer establish with his own investment and involving his own family labor as given in Annexure 1.

Annexure 1: Cost of Establishment of DCU

Essential equipment for establishing a village level Decentralized Crushing Unit given below:

Plant and machinery*

S. No.	Particulars	Cost ** (Rs '00000)
a)	Sweet sorghum crusher (2 t/hr): Motor for crusher 20HP, V Belts, gear oil	4.5
b)	Syrup boiling pans - 2 m dia. and accessories (like stirrers, dragger, sieve, scum storage drum, etc) Capacity	0.36
c)	Generator: 40 KVA capacity with Ashok Leyland engine coupled with alternator mounted on a common base frame with control panel fuel tank, battery and leads and accessories	4.62
d)	Pumps and motors 1 HP, for pumping water process like cleaning the tanks, crushers and pans: 1 no.	0.04
g	Rubber/PVC hose pipe 1" dia 200 m length,	0.16
h	Syrup storage plastic drums industrial use (50 kg capacity)	0.30

(续表)

S. No.	Particulars	Cost ** (Rs '00000)
a)	Crusher shed with local available materials (palm tree leaves/ bamboo thatched sheets/ paddy straw covering)	0.2
b)	Chulas shed with local materials (palm tree leaves/bamboo thatched sheets/ paddy straw covering)	0.2
b)	Foundation for generator placement	0.10
f)	One utility room construction with asbestos sheet:	0.4
g)	Construction of 2 ft height basement for crusher placement 6 x 3 ft with iron channels, nuts and bolts fitting	0.19
h)	Construction of 3 no. chulhas for boiling juice	0.49
a)	Electrical wiring, switches, control panel etc,	0.10
	Total amount (INR)	11.66

* Works and equipment prices quoted by local agents/dealers in Maharashtra state of India.

** Minimum Cost of DCU establishment (if a farmer want to establish with his own investment).

Chapter 5: Value Chain Models Implementation in India: Lessons Learned

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1 Background

We begin with a very brief introduction / background of the Project CFC/FAO/ 41) before presenting lessons learnedfrom the implementation of theproject in India. The project on "Enhanced Livelihood Opportunities of Smallholders in Asia: Linking Smallholder Sweet Sorghum Farmers with the Bioethanol Industry" (CFC/ FIGG/41) was funded by the Common Fund for Commodities (CFC) and Food and Agriculture Organization (FAO) -Intergovernmental Group on Grains (FIGG) as technical Supervisory Body.

The project was initially designed forimplementation in India, China and Thailand. The project was launched on 3 ~ 4 March 2010, at ICRISAT, Patancheru, India, and all the partners from respective countries attended the launching-cum-workplans meeting at ICRISAT. Tata Chemicals Ltd. (TCL), a private sector partner in India from the industry, is a distillery to convert sweet sorghum stalk into ethanol. The partners from Thailand also participated in the workplans, but subsequently withdrew from the project since they felt that they may not be able to execute the project for reasons of their own.

Project implementation was initiated in India and China as per the work plan. In Year 2, the private sector partner, TCLclosed its operations in India. The CFC-FAO team conducteda midterm review of the project progress in India (from 7^{t} to 8

December, 2011) and China (during their visit to China from 24 ~ 27 April, 2012). The team concluded that project objectives couldnot bemet in India due to closure of TCL, an important partner (centralized operations linking farmers to the distillery and producing ethanol both from sweet sorghum stalk and sweet sorghum syrup) in the ethanol value chain. Hence, CFC asked the project executing agency (PEA), ICRISAT to stop the project activities in India. In China, the midterm review team concluded that project activities were implemented satisfactorily and the progresswas in the right direction. Hence, CFC asked ICRISAT to proceed with the project work in China.

Considering the above changes, CFC-FAO felt it was important to develop a detailed report on lessons learned from the project activitiesconducted initially in India. The project team analysed the issues involved and the lessons learnedwhich are summarised under the twomodels/systems, ① Centralized operations, and ② Decentralized operations that were operationalized in the project implementation.

2 Project implementation

2.1 TCL activities

Tata Chemicals Ltd. (TCL) became a partner with ICRISAT by signing with the Hybrid Parent Research Consortium (HPRC) in 2008. The HPRC is an initiative of ICRISAT that was formed with the basic objective of increasing accessibility to better hybrids to poor farmers through effective public-private partnerships.

TCL established a distillery in 2007 near Nanded in Maharashtra state of India. TCL commissioned the sweet sorghum ethanol distillery during 2008 with a capacity to crush 900t of stalk and produce 30 kilo liters of ethanol per day (KLPD). It hadalso started sowing of sweet sorghum in an area of 1 480 ha in 80 villages around TCL within a radius of 120 km in 2008 (Table 1).

Table 1 Sweet sorghum area, productionand yield under TCL from 2008—2010.

Particulars	2008	2009	2010
Area sown (ha)	1 480	1 220	479
Actual area under crop (ha)	565	987	453
Yield t/ha	11.8	15.0	20.0
Harvested area (ha)	12 (1%)	200 (16.4%)	370 (77.2%)
Quantity of stalk crushed (t)	181	3 008	7 681
Stalks Purchase price (Rs/t)	500 ($11)	675 ($15)	1 000 ($22)
Harvesting and transportation cost (Rs/t)	613	668	476
Cultivars grown	Sugar Grace (98%), Urja, SSV84	Urja, RSSV84, JK Recova, Sugar Grace	JK Recova, Sugar Grace, CSH22 SS, ICSV 93046, RSSV9

The location of the factory was decided based on incentives and facilities offered by the government of Maharashtra for establishing the industry in Nanded district. The distillery itself was set up on the outskirts of Nanded, the district headquarters. Selection of villages and farmers for cultivation of sweet sorghum was based on willingness of farmers to cultivate this crop. The villages within 120 km in and around the distillery were selected by default and inputs were distributed to the farmers who volunteered to grow sweet sorghum in these villages. Thus, there were no particular criteria followed in the initial stages (2008—2009) for selection of villages and farmers.

The cropping pattern around Nanded was mainly sorghum, soybean and cotton, which are the major rainfed crops grown on the black soils. Sweet sorghum is targeted to replace grain sorghum, which is grown for fodder and food grain under low input regimes. Soybean and cotton have replaced major sorghum growing areas in the region, and as a result, sorghum is pushed to marginal soils whichare not suitable for cotton and soybean. The company assumed that sweet sorghum is like grain sorghum, and farmers in the region were well versed with sorghum cultivation and therefore they wouldn't need any further technology for cultivation and crop management practices. They had not partnered with research institutes, NGOs, or KVKs for technical and social adoption of sweet sorghum that could help in crop diversification. As a result, TCL did not give due importance to hiring people with experience in sweet sorghum research and cultivation, but placed more emphasis on those qualifiedin business management. The farmers cultivated sweet sorghum crop based on their experience with grain sorghum, and hence realized low yields of stalk and without grain and fodder. For this reason, they found it uneconomical to cultivate sweet sorghum, compared to other crops like soybean and cotton.

In the second year of their operations, i. e. 2009, the area planted with sweet sorghum by TCL farmers was reduced to 1 220 ha within a radius of80 km. In 2010, the area planted with sweet sorghum was further reduced to 479 ha and it was planted withina 50 km radius.

TCL initiated interaction with the sweet sorghum group ofICRISAT by virtue of their partnership in another project in 2009, and became partners under the CFC project in 2010. Since then, their staff wasexposed to some areas of sweet sorghum crop cultivation and management practices. Specifically, they wereexposed to and trained in ① sweet sorghum cultivation and corrective measures required in controlling pests and diseases, ② production of pure seed, ③ selection of fields, ④ selecting farmers for cultivation, and ⑤ conducting on-farm trials with improved cultivars.

With the increased know-how, TCL could increase the average stalk yieldfrom 11 t per ha in 2008 to 15 t per ha in 2009 and to 20 t per ha in 2010. Also, TCL could harvest only a small area and crush a small quantity of stalks received at the distillery in 2008 and 2009, and could crush most of the feedstock received during 2010. The lowstalk procurement and crushing in 2008 and 2009 wasdue to various technical constraints and in-house problems as mentioned below:

(1) Seed distributed to farmers irrespective of village location and farmer status.
(2) Low stalk yield because of poor knowledge about sweet sorghum crop management practices

(3) Farmers could not harvest the crop and transport to distillery on time because it was not economical for them to do so

(4) Poor awareness about the sweet sorghum and its processing, harvesting and timely transportation

(5) TCL staff were not fully trained and equipped to handle such a large area of plantation and found it difficult to monitor the crop performance in farmers' fields in faraway scattered places

(6) Managerial and field staff thought erroneously that sweet sorghum cultivation was like grain sorghum, assuming that farmerswere aware of cultivation for several generations, and hence decisionsabout cultivation were left to the farmers.

(7) Managerial and field staff hadlimited knowledge about the sweet sorghum crop production and protection practices since their background was business management and engineering. Frequent change of managerial staff affected project implementation activity on acontinuous basis.

(8) Poor and weak partnershiplinkages with public sector units like agricultural universities, national and state research institutions, NGOs and CBOs for transfer of technologyand who have knowledgeof the local area and have social contacts, has reflectednegatively on the adoption of improved crop production technologies by the farmers.

(9) Weak network of input supply system delayed the supply of seeds and fertilizers to farmers, whichresulted in delayed sowings, and further allowing thecrop to succumb to shoot-flyinfestation

(10) Technical problems related to stalk crushing machine in the distillery delayed crushing operations leading to drying of feedstock, which led to low ethanol yields.

(11) Distillery could not find sufficient labor for harvesting, loading and transportation of stalks, which led to significant reduction in the quantities of feedstock reaching the distillery.

Building anunderstanding and developing confidence of TCL in establishing partnershipunder the CFC project involved considerable efforts and time by ICRISAT. These efforts include:

(1) Carrying out three designer workshops, which helped to understand the needs of TCL and the roles that ICRISAT can play in meeting some of their needs.
(2) Participation of ICRISAT staff in the meetings with different stakeholders as well as one on one meeting with senior officials of TCL.
(3) Informal meetings by Project coordinator with TCL staff at Nanded. All these finally helped in TCL to enter into a formal MOU with ICRISAT. This and the formal MOU ICRISAT had with Marathwada Agricultural University (MAU) Parbhani, Maharashtra state, helped to bring in TCL into the project fold through MAU.

In the year 2010, TCL reduced the sweet sorghum sowing area to 479 ha and the radius of planting wasalso reduced to 50 km from the distillery due to the difficulties experienced in harvesting, transportation and labor availability in the previous years. Also, the guidance received from ICRISAT, after becoming a member of HPRC, ICRISAT and establishing close interaction with partners (MAU and ICRISAT) of the CFC - ICRISAT project (CFC/FAO/41) helped them to plan the project activities.

Thus, TCL made changes in the centralized model in consultation with ICRISAT to overcome constraints experienced in the years 2008 and 2009. These helped to address the farmers concerns and enhance technical backstopping, thushelping to realize higher production and productivity.

2.2 Lessons learned under the centralized system

2.2.1 The model

The CFC project design is based on a consortium partnership approach involving various stakeholders in project implementation with concrete workplans and roles and responsibilities assigned to each partner.

The centralized model in India was designed and implemented for scheduling of feedstock supply to the distillery during the rainy season of 2010, covering an area of 479 ha under sweet sorghum withinaradius of 50 km from the distillery. The project farmers were linked to TCL with a buy-back agreement for supply of stalks on a pre-agreed price and with technical backstopping to enhance productivity. It was also agreed that farmers will be supplied with inputs like seed, fertilizers and pesticides on a credit basis, and be capacitated with improved crop production technologies; later the costs of inputs would be deducted from the payments for stalks supplied by the farmers.

2. 2. 2 Site selection

The TCL distillery is located in Nanded district (30 Km from Nanded city) where black soils are predominant. The cropping pattern was shifting from sorghum to commercial crops like soybean and cotton, and in some villages they also started growing wheat. Sorghum was pushed to marginal soils and farmers grew sorghum only to meet household food and livestock fodder requirements. The irrigation sources were meager and power shortageswere high. Hence, there was little or no scope for postrainy season sweet sorghum crop production in the area. To look at an optionof two crop seasons for sweet sorghum, the geographical location of TCL was at a disadvantage with respect to the local cropping patternand natural resource endowments. Also, the farmer holdings around the distillery were small and in uneven topography and the fields were full of small rocks. These posed problems for using harvesting machinery.

ICRISAT and TCL jointly selected 10 villages in two clusters, which have good fields, to implement project activities and to demonstrate improved crop production technologies to the sweet sorghum farmers. Surveys on the costs of cultivating sweet sorghum and competing crops were carried out by ICRISAT's social scientists in selected project villages to assess the comparative advantage of sweet sorghum cultivation.

2. 2. 3 Stalk supply chain management

To overcome the stalk supply chain management constraints that were experienced in the years 2008 and 2009 (stated above), joint discussions were held with the ICRISAT team which led to the following changes in the model made by TCL to address farmer concerns and technical backstopping to enhance production and productivity.

(1) The earlier input supply model (company supplying inputs directly tothe farmer, which led to delay in supply) was modified by introducing a*spoke and hub* model, ie, identified input supply agents in the villages who were already dealing with inputs to take over supply of inputs under the project, and farmers were linked to input supply agents for timely supply of inputs. This model has been successfully implemented.

(2) Enhanced capacity building activities and awareness programs by ICRISAT and MAU on sweet sorghum crop for ethanol production were conducted in each village to improve knowledge on crop production technology for TCL staff and sweet sorghum farmers.

(3) TCL and ICRISAT jointly developed and adopted new strategy for enhancing productivity in the centralized area (Figure 1). The critical components in the new strategy were selection of farmers and fields with soybean as previous crop and limiting holdings to more than one ha area.

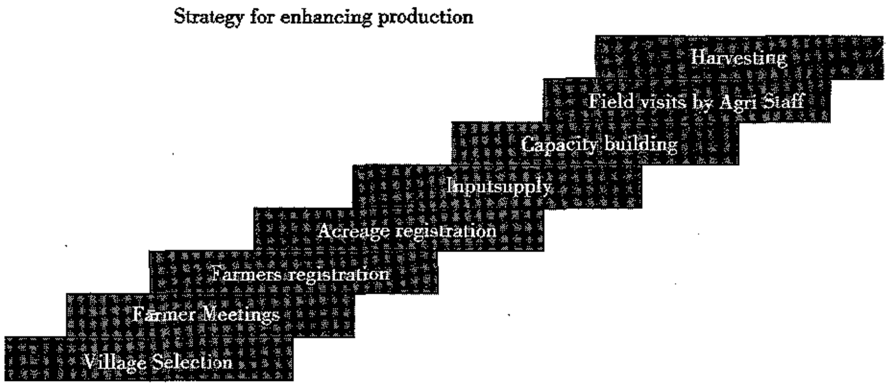

Fig. 1 TCL New strategy for increasing productivity in the project villages.

(4) Sowing of varying maturity group cultivars supplied by private sector seed companies and ICRISAT to increase the harvesting window. This has prolonged the

harvesting period significantly over previous years. Besides increasing the harvest window, stalk yields too have improved from 11.85t/ha in 2008, 15t/ha in 2009 to 20t/ha in 2010 due to the replacement of private sector cultivars with improved cultivars supplied by ICRISAT (covering 40% of the area). There were instances when the recorded stalk yield was up to 35t/ha in farmers' fields, thus demonstrating the potentiality of the cultivars. Thus, if farmers can improve the practices of cultivation, they can harvest nearly 30 ~ 35t/ha even with the cultivars presently supplied to them.

However, there were some problems encountered by TCL and ICRISAT in adopting the cultivars supplied by the private sector seed companies. One cultivar sown in 40% of the total area showed a lowering of the Brix% (stalk sugar content) at flowering and seed setting. Another cultivar showed segregation--plants differing in height and flowering. These abnormalities may be due to non-adaptability of cultivars to target areas and genetic mixtures. The abnormalities of cultivars in the field have a drastic effect on crop productivity as well as ethanol production.

(5) Centralized harvesting and transportation of stalks by TCL from the project villages (instead of farmer groups as per the revised agreement with the farmers) has escalated the procurement cost of TCL by 40%. The other problem was mobilization of labor for harvesting, loading and transportation of stalks from farmer fields to distillery, which got delayed due to non-availability of sufficient labor.

2.2.4 Capacity strengthening

ICRISAT and MAU jointlydeveloped the capacities of farmers and TCL field staff in crop production practices, following the approach of Training of Trainers (TOTs). The courses were organized at all levels to create para-professionals to provide backstopping training to the beneficiaries on continuous basis. For the beneficiaries, the training methods comprised on-station classes both at MAU, private organizations and ICRISAT, and visits to farmer's participatory on-farm demonstrations (best-bet practices). Also, field days were conducted, where interactions between farmers and scientists helped to build confidence in farmers.

This holistic training process was innovative and ensured acceptance and buy-in of the program, not only by direct beneficiaries, but also by relevant government officials, NGOs and the private sector working closely with the project.

The capacity building yielded several obvious positive results, and these included:

(1) The holistic capacity building and training process, which included all stakeholders, provided beneficiaries with a clear information flow map about sweet sorghum in general and specific production practices depending on the soil and pest conditions. With this training, the farmers were able to implement crop production practices in a stepwise manner.

(2) The process used also helped the program to receive support and buy-in from private, public, people and government sectors involved.

(3) The involvement of beneficiaries in the training (i. e., ofpara-professionals) means that the program can be easily replicated and sustained because the beneficiaries develop a sense of ownership that will help to carry the program even after completion of the project. This apart, follow-up training programs with new knowledge is important to help enhance the capabilities and skills of the para-professionals and in turn the farmers.

(4) The training programs helped the farmers (and the para-professionals) to understand the importance of the cultivars andthe production practices for enhanced productivity. It also helped them to understand the importance of choosing cultivars with different maturity groups to help widen the feedstock supply. This helped to realize the enhanced stalk productivity (the average stalks yield has increased from 11 ~ 20t/ha).

2.2.5 Seed system

Seed is an important component in the supply chain of sweet sorghum production. Supply of quality seed in required quantities and at the right time is an important factor for higher productivity; So TCL had agreement with private and public sector companies for supply of seed of various cultivars. But the cultivars selected and quantity of seed procured was never discussed with ICRISAT. One of the cultivars, sown on 40% of the total area under sweet sorghum cultivation, had low Brix% (sugar content) at flowering stage, and other cultivars supplied to farmers were not genetically pure and showed segregation (as indicated as above). Crushing the stalks of cultivars with low sugar content and low stalk yields due to genetic impurity resulted in an economic loss to the distillery.

Though ICRISAT had supplied seeds of the promising cultivars to TCL for trials of stalk Brix%, and grain and stalk yield evaluation. But the trials were not conducted properly. Also, the research data was not recorded systematically for analysis because of non-levelled fields and untrained field staff. As a result, TCL lost the opportunity of selecting new cultivars with high productivity and adaptability to the target location.

TCL did not show interest in developing an in-house seed system and its own R&D wing. With the result, though ICRISAT trained the rice breeder employed by TCL, the breeder seed (in large quantities) of cultivars (with different maturity) that were selected based on ICRISAT's on-station trial data could not be utilized by TCL. Instead, TCL relied heavily on the seeds of private sector cultivars which were not tested for its adaptability and yield in project area resulting in economic losses as described above.

Sowing was delayed due to delay in procurement of seed from the private sector and its delivery to farmers during 2008—2009, which thus resulted in shoot fly attack. This could have been avoided if TCL had trained staff members in crop production and its agronomy.

Based on the lessons learned, and in consultation with ICRISAT, TCL adopted the spoke and hub model of input supply in 2010 for timely distribution of seeds (which were treated with chemicals prior to sowings to avoid shoot fly incidence).

2. 2. 6 Post-harvesttransportation and pricing

The cost of transporting stalks alone accounted for 22% of the cost of stalk procurement from farms located far away from the distillery. Hence, it was found uneconomical to procure stalk and transport them to the distillery for crushing.

Transportation of stalks from interior places to the distillery, especially during rainy season, was difficult due to non-motorable roads. The delay in transportation resulted in drying up of stalks leading to economic losses to the distillery.

Arranging laborfor harvesting and scheduling harvests in the fieldswhich were scattered was found to be a herculean task. Efforts to mechanize harvesting with imported machinery was found unsuitable for local conditions (small size holdings with <0.3 ha and with uneven topography).

2. 2. 7 Economics of processing and policy regulation

The opportunity cost of land was very high for the selected locations to cultivate sweet sorghum. Hence, the farmers were paid Rs 1000 t^{-1} of sweet sorghum based on the competing uses of land (cotton and soybean cultivation). The cost of raw material including the cost of harvesting and transportation of sweet sorghum for ethanol processing was Rs 1 400 t^{-1} (USD28 at 2010 conversion rate of USD1 = Rs 50). Further an expenditure of Rs 300 ~ 400 was incurred by the distillery as processing cost. With extraction of ethanol at 55 $l\ t^{-1}$ of stalk, the returns realized by the distillery will be Rs 1485 (USD 29) at the current sale price of Rs 27 l^{-1} (USD 0. 54) (price fixed by the Government). Hence, for the industry to break even, the price of ethanol should be increased to Rs 32 l^{-1} (USD 0. 64).

2. 2. 8 Research and development

Lack of research and development facility at TCL created paucity in the information on adaptability of available genotypes andselection of improved new cultivars with varying maturity periods that would not only help toincreasethe harvesting window but would also be suitable to the geographical area. Dependency on private sector seed companies hascaused huge loss of time and economic resources to the company. This apart, growing their genotypes on large areas without supportive research data has added to their woes.

3 Lessons learned under decentralized system

The purpose of the Decentralized Crushing Unit (DCU) at the village level was to aid in supply chain management by reducing the volume of feedstock that would otherwise have to be transported to a centralized crushing unit. It was also meant to supply the feedstock in the form of syrup as and when the distillery has spare capacity, thereby increasing the period of feedstock (supply of syrup) availability to the distillery.

This type of supply chain management was non-existent before the project operations started. Hence, with the establishment of the DCU, the sweet sorghum stalks were crushed immediately after harvest and juice extracted and boiled immediately (as the shelf-life of juice is very short) to produce syrup. Thesyrup (with Brix % in the range of 70% ~ 80%), can be stored for two years without any deterioration of fermentable sugars, and can be processed to produce ethanol at the distillery.

The DCU establishment also helped in:

- Inclusion of farmers located far away from the distillery
- Easy mobilization of farmers as it was restricted to a few villages
- Avoiding economic loss to the grower and the processor.
- Increased employment opportunities, as crushing of sweet sorghum immediately after harvest coincides with the lean season of agriculture (under rainfed conditions). The crushing of sweet sorghum during the lean period provides farmers with additional employment opportunities. On an average, annually about 40 person days of employment per household was generated during the project period. The monetary value of the additional employment generated was about Rs 6 400 (USD 128) per household annually (the wage rate prevailing during 2012 was Rs 160 per day (USD 3.2).

3.1 Site selection

With the joint efforts of ICRISAT, MAU and an NGO, one cluster comprising of fourvillages was selected for growing sweet sorghum and establishment of a DCU. Prior to selection, a database on the socio-economic profile of the selected *Taluka*was developed, which served as a basis for site selection. Additionally, reconnaissance surveyswere conducted with the key office bearers (village sarpanch, secretary, village leaders and lead farmers) to obtain basic information on cropped area, crops grown, irrigated area, types of soil, yields of different crops, markets and political affiliations.

Selection of a suitable decentralized area (Nankheda cluster) for implementing project activities close to the partner organization (MAU) helped the project in effective monitoring and implementation of the project activities through frequent visits. This also helped in reducing travel time and cost of travel.

3.2 Capacity building

Crop production and syrup making technologies were transferred to farmers through various training programsconducted by ICRISAT scientists jointly with MAU. Initially, the crushing unit and its operations were carried out by the farmers' group under the direct supervision and management of project scientists. All operators, daily-wage laborers and project staff were trained in the syrup making process, which involved collection of juice from the crushing point and boiling it to concentrate the sugars in the juice. The training programs also includedimproved production technologies, hands-on-training on maintenance and repair of machinery, trouble shooting, stalk supply chain management and assessing quantity and quality parameters of juice and bagasse, and accounts and book keeping for effective management of the DCU operations.

The stalk and grain yields were low during Year 1 because farmers were new to the sweet sorghum crop and did not adopt recommended crop management practices (as they were under the impression that sweet sorghum is like grain sorghum).

Thenew component (seed-cum-fertilizer drill for sowing) introduced in the model adopted in Year 2 improved timelysowings and application of the recommended dose of fertilizer, which resulted inenhanced productivity of stalks over conventional sowings by 23%. The participation of farmers' association (FA) in implementation of project activities through identification of participating farmers, supplying of seeds and other inputs, adopting staggered plantings and ensuring that farmers adhere to the recommended package of practices (thinning, weeding, top dressing, etc.), resulted in enhanced production. Sowings were taken up by usinga tractor mounted seed-cum-fertilizer drill to improve agronomic practices and timely sowings. The FA also helped in developing harvesting schedules for the supply of sweet sorghum stalks to the DCU.

The farmers' association crushed the stalk and produced syrup (although in small quantities) in Year 2, and were able to manage DCU operations independently.

3.3 Seed System

The seed requirement of the DCU area was very limited because of small area of operation. Initially, ICRISAT supplied inputs (seed and fertilizers) 15 days prior to the sowing date. The responsibility of selection of the farmers and seed distribution was given to partners (MAU and FA). Demonstrations were conducted in the villages to facilitate farmer participatory selection of cultivars.

Supply agencies of sweet sorghum seed were reluctant to supply small quantities of seedof improved sweet sorghum cultivars to DCU farmers, which was a setback to the farmers. To ensure availability of good quality seed of improved cultivars at the right time and at an affordable price to the farmers in the project, ICRISAT initiated a community seed systemin the cluster village through FA. The members of FA and self-help groups (SHGs) were trained in seed production and storage techniques to meet their seed requirements. Breeder seed was supplied by ICRISAT to FA for seed multiplication in the cluster villages, and FAselected SHGs having assured irrigation facilities to take up seed multiplication in the villages. TCL has a gentleman's agreement with the FA for supply of selected variety seed to the centralized area.

The seed production method adopted by SHGs under technical guidance and supervision of MAU hadproduced 10 tons of ICSV 93046 variety seed in the summer season of 2011, and wassold to the farmers in 23 villages which were around the cluster in Parbhani districtat Rs 50kg^{-1}. The agriculture news bulletin, AGRO ONE, of Maharashtra state disseminated the CFC project story on seed production and seed availability with the FA, and this made a good impact on the marketing of sweet sorghum seed produced by SHGs.

The alternative use of sweet sorghum for fodder purposes has gained great popularity, and there is a high demand for sweet sorghum seed in the Parbhani district. As the news spread to other areas of the state, the demand for sweet sorghum seed has been on the increase.

3.4 Processing of sweet sorghum to syrup

In the first year of the project (2010), most of the efforts were toestablish the DCU and FA and to make the DCU operational. Hence, only a small number of farmers were contracted to grow sweet sorghum. The DCU was commissioned and small quantities of stalks were crushed to produce syrup.

- Total stalks crushed = 40t
- The juice extraction = 31%
- The syrup recovery = 23% (60 ~ 65 Brix%)
- Total syrup produced = 2 820kg

It can be seen that there is a scope to increase juice extraction from 35% to 50% byeffective adjustments in the crushers. Secondly, the syrup recovery can be increased from the present level of 13% of juice to nearly 20% ~ 24% by exploring and deployingimproved technologies.

In the second year of the project (2011), 100 small-scale farmers grew sweet sorghum on 40hectares in the cluster villages. Due to the prevailing drought in the DCU location, there was an increase in the demand for fodder. So, most of the farmers could not supply the stalks to the DCU as per the buy-back agreement. Farmers who cultivated sweet sorghum sold their stalks directly to fodder agents and realized a 40% higher price than the price offered under the DCU buy-back agreement. Also, farmers were saved from the burden of harvesting, as the fodder agents themselves harvested the crop and transported the stalks.

Due to thereasons mentionedabove, there was not enough sweet sorghum for crushing to produce syrup in the second year, and hence the data on crushing could not be gathered. As a result, the economic feasibility analysis of crushing sweet sorghum to produce syrup under DCU operations could not be carried out.

The syrup produced under the DCU was to aid in supply chain management and for continuous supply of feedstock to the distillery. TCL could not procure the syrup from the DCU as the quantity of syrup produced by the DCU was too little to be fed into large fermentation chambers. Obviously, it was technically not feasible. Hence, this calls for a specially designed study to understand technical and economic feasibility of using small quantities of syrup in a large scale distillery (30 KLPD) for ethanol production.

Under DCU operations, bagasse (remains of stalk after crushing and extraction of juice from sweet sorghum stalks), which comprises of 50% ~60% (wet basis)) is a potential feed source for livestock. The bagasse produced under DCU was chopped and fed to milch animals, whichhelps toincrease the milk production. The research findings of sweet sorghum bagasse as a potential feed for milch animals was made available to the farmers in the form of flyers and posters (in local language) to educate them on the importance of bagasse and sweet sorghum as an alternate source of feed for livestock.

In the subsequent years/seasons of the project (2011 summer and 2012 seasons) farmers started growing sweet sorghum instead of grain sorghum as fodder sorghum on small areas (<0. 2 ha) to feed their livestock (particularly milch animals).

3.5 Conclusion

The public-private consortium approach in implementing a value chain of an innovative sweet sorghum based bioethanol production in a project mode has many dimensions. Fundamentally, the social (livelihoods of small-scale farmers) and the economic aspects (benefits to farmers and distillery) of the value chain, especially with private sectorpartnership, is an essential factor to gauge the success of this consortium approach. The private sector is usually neither transparent in its deeds and interactions nor does it shares the strategies nor future plans with public sector organizations. Private sector not only looks outfor success in the commodity production process, which is newto them, but also at the cost and political and policy implications for continuation of its business. Hence PEA had a difficult time. It took considerable time and effort, at different levels, to not only gains the confidence of TCL but alsoto develop a friendly relationship to bring it into partnership mode to execute the CFC project.

The basic requirements toestablish an agro-based industry (TCL) and linkages for the supply of raw material faced some constraints and problems in the centralized area. Selection of location (Nanded, Maharashtra) for the establishment of sweet sorghum distillery by TCL was not a proper choice in terms of theagro-ecological conditions and prevailing cropping systems of that location.

Human resources development related to sweet sorghum (production practices and seed systems) and supply chain management were ignored by TCL. This badly affected not only the sweet sorghum productivity and supply chain but also TCL's communication abilities with experts on the science of sweet sorghum.

Lack of technical staff and inability to reach and communicate science contributed to the failure of TCL in forging effective collaboration with research organizations, specifically with MAU and ICRISAT. TCL's failure was also in scoping the knowledge on sweet sorghum and seed systems, in leveraging the technical backstopping on supply chain management and for capacity building activities from MAU, ICRISAT, KVK and NGOs.

Rectifying the teething problems with crushing machinery at TCL distillery took considerable time, which also played a crucial role in delayed stalk crushing, and subsequent drying up of stalks.

TCL was established, under license, specifically for feedstock ofsweet sorghum and not on multiple feed stock use bases. This was another setback to theviability of the distillery. The overall crushing period was only 35 days in 2010 with sweet sorghum as feedstock andthe distillery was idle for the next 11 months. Moreover, there is very little scope for growing a second crop (postrainy season) in the command area, as there are no facilities for irrigation.

TCL did not pay attention to the use of syrup produced in the DCU nor to the adoption of the DCU model. They ignored the very mechanism established to supply the syrup for use as feedstock in complementary with sweet sorghum stalks to run the distillery all year round. Also, the DCUcould not scale up syrup production owing to serious drought, because of which there was high demand for sweet sorghum stalk as fodder. As TCL closed its operations, there was not enough time for the DCU to move ahead with scaling up its operations.

If innovative technologies such as this have to be successful, it is essential that governmentpolicy should not only support and favour sweet sorghum cultivation and ethanol production but incentivesneed to be given to the industry and farmers. Also, government support in allowing the industry to use multiple feedstocks will go a long way in sustaining the industry.

Chapter 6: Sweet Sorghum Feedstock Supply Chain Models Adopted in China: Lessons Learned

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Introduction

Sugarcane, cassava, sweet sorghum and sweet beet are viable feedstocks for non-grain fuel ethanol production in China. Increasing the planting area for sugarcane and sweet beet is restricted by climate and regional conditions. Therefore, cassava and sweet sorghum are the most suitable materials for ethanol production in China. Additional advantage of sweet sorghum is that, it can be planted in most of the regions in China, including saline and alkaline soils. Of the 100 million hectares of drought-prone and saline boundary lands in China, at least 5% of them are suitable for planting sweet sorghum. Sweet sorghum planted in these lands can yield about 4.5t/ha of grain and 60 ~ 90 tons fresh stalk per hectare. Sorghum-based ethanol is presently being commercialized; although testing is still on to bring the technology and efficiency on par with competing raw materials. Ethanol production of sweet sorghum versus sugarcane remains competitive, as the biomass yield of sweet sorghum is pretty high and labor cost is relatively low.

Project background

The CFC project was implemented by sorghum research institute (SRI), LAAS, Shenyang, PR China and other co-partner institutions involved in the project include ZTE energy company Ltd. Inner Mongolia, farmers groups / organizations, NGOs, private seed companies, regional agricultural research stations, with ICR-

ISAT acting as project executing agency (PEA) coordinating the project activities. The details of the main partner institutes involved are:

(1) The Sorghum Research Institute (SRI) per se took care of the overall project implementation in China. Dr Zou Jianqiu, The Director, Sorghum Research Institute (SRI), Liaoning Academy of Agricultural Sciences, Shenyang, was the country coordinator.

(2) The private sector distillery, the ZTE Energy Company Limited (hereinafter referred to as ZTE or the company), was basically involved in research and development (R and D) of solar PV technology and project contracting, R and D of biomass energy, energy management contract, palm cultivation and oil processing trade, international agricultural investment and development, import and export of patents and technologies, capital operation and management as well as other related fields. ZTE is the largest provider of telecom equipment among the listed companies in China, with a registered capital of RMB 1.29 billion.

As indicated under the Chinese government policy of promoting non-food grain feedstocks for bioethanol production, the company established a bio-energy industry using sweet sorghum stalks as feedstocks for producing bioethanol. The distillery is located in Bayannao'er, Wuyuan County, Inner Mongolia, PR China, with a capacity to produce 30 000 l of ethanol per day (30 KLPD) by crushing 1 200 t of stalks per day.

Sweet sorghum ethanol value chain

Sweet sorghum is a fascinating crop by virtue of its rapid growth, high biomass production potentiality, and adaptability to a range of conditions, high water use efficiency and its multipurpose use. Though scientists have been working on sweet sorghum for several years, its potentiality as biofuel feedstock is of recent development. Considering the energy requirements of a rapidly growing economy like India and China and its ethanol blending commitments, sweet sorghum as an alternative feedstock for bioethanol production is a perfect choice.

Sugarcane, cassava, sweet sorghum and sweet beet are viable feedstocks for non-grain fuel ethanol production in China. However, increasing the planting area for sugarcane and sweet beet is restricted by climate and regional conditions. Sweet sorghum is unique, since it is adapted to a wide range of agro-ecological conditions from tropical to temperate climates, from low input to intensive agriculture, making it suitable for cultivation in many parts of China (as also the world). It requires less water for cultivation than sugarcane. Also, with the use of sweet sorghum stalk for ethanol production, there is no food-fuel tradeoff associated with its use unlike corn and other grains. Therefore, sweet sorghum is the most suitable material for ethanol production and can be planted in at least 5% of the 100 million hectares of drought-prone and saline boundary lands in China. Sweet sorghum planted in these lands can yield 60 ~ 90 tons of fresh stalks per hectare and can produce grain up to 4. 5t/ha.

The company needs to source its raw material from cultivation of 6 000 ha area each year (assuming an average of 50t/ha stalk yield) to supply enough feedstock for continuous production (a minimum of 180 days of distillery operation). To get the required amount of feedstock, centralized models linking the company to sweet sorghum farmers in clusters of villages within a 50 km radius from the company were implemented through judicious utilization of company resources and field operations. The centralized model, it was hoped, would ensure continuous supply of feedstock to the distillery leading to a win-win situation for both the farmers and the company. The success of the linkage ultimately depended on the strategic research carried out under the project for higher stalk yield and sugar content in the stalks of sweet sorghum, which decide the profitability of the ethanol value chain. Besides technology, success depends on efficient value chains that enable cost effective and timely procurement and continuous supply of stalk to distillery.

Stalk supply chain models

Value chain models can be structured in a variety of ways depending on the crop, the objectives and resources of the company and experiences of farmers. Based on the crop diversification and experience of the company, it had floated two models to enable the smooth supply of sweet sorghum stalk to the distillery for crushing and ethanol production. Model 1 is where the company leased the land from farmers and grew sweet sorghum. Model 2 is a contract farming model where the farmers grew sweet sorghum and supplied to the company based on a formal contractual agreement signed between company and farmers. The company increasingly depended on the contract farming model for procuring the feedstock for ethanol production.

Model 1: Company Leased Land

Sweet sorghum was a new crop to the area and the main objective of the model was to popularize the crop, gain experience in sweet sorghum production practices, and to develop awareness about the new crop among farmers and to ascertain adaptability, yields and economics of sweet sorghum production.

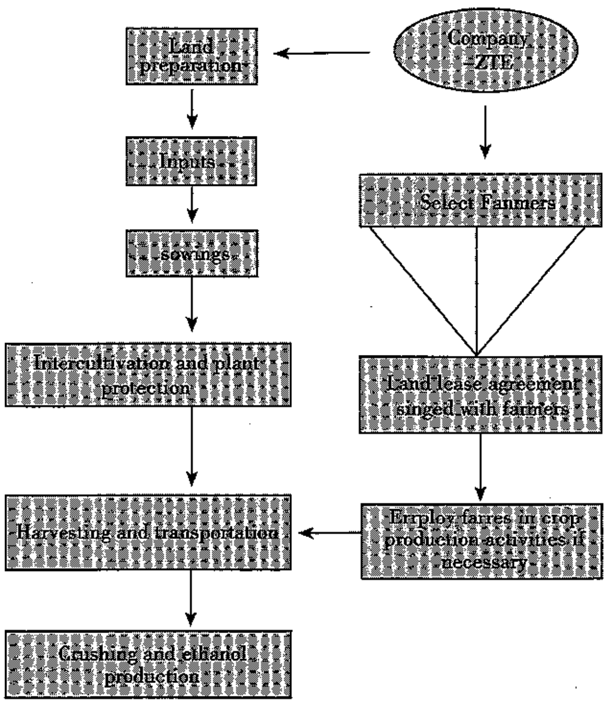

Fig. 1 Sketch of company leased land model 1.

The company interacted with the farmers directly to lease their lands for cultivation of sweet sorghum crop and signed the lease agreement for 1 ~ 5 years with payment of lease amount on a yearly basis (land lease agreement is not available). To achieve the objective of the model, the company took over all the activities of crop production, commencing from land preparation, sowing to harvesting and transportation of stalks to the distillery, all of which was carried out by its own staff members. Depending on the labor availability, farmers (land owners) were employed for crop production activities, but it was not an obligation on the part of the company to create employment to the farmers who had leased their land to the company. The company deployed machinery for increasing efficiency and to reduce delays in sowing, harvesting and transportation of stalks (for reducing losses in juice production and for continuous and timely supply) to the distillery for crushing.

The company had leased and cultivated 30 000 Mu (2 000 ha) from farmers of Bayannao'er, Wuyuan County, Inner Mongolia, in the first year (2010) by signing a land lease agreement with farmers on payment of lease amount of RMB 550 per mu per year for a term of 1 to 5 years. In year 2 (2011), the company reduced cultivation in the leased area to 10 000 Mu (666 ha) because it had achieved some of its objectives such as demonstration of sweet sorghum cultivation, and adoption of cultivars in target areas. Also, the company realized that it is less cost effective to produce the crop on its own compared to the contract farming model where the crop is produced by the farmers. Based on the economics of production, the company had planned to withdraw model 1 gradually and increase the area under contract farming, model 2.

Observations on Model 1

Advantages to the company

The crop was new to the area; the company could learn while implementing the model

Standardized protocols of crop production and management

Learning grounds for company field staff and management

Testing new crop adaptation, cultivars, production technologies and new machinery

Assured *application of all inputs on time*

Ease of assessing the economics of crop production components and other costs for harvesting and transportation of stalks to the distillery

Creating awareness about the new crop and disseminating crop production technologies among the farmers through training and on-farm demonstrations

Production was more reliable than open market purchase and there was assured supply of quantity and quality stalks to the distillery

Disadvantages to the company

Leasing large areas of land was a constraint and managing crop production was a herculean task

Needed to employ large contingency of staff members which increased both overheads of the company and management problems

The staff members of the company may have been corrupt, particularly in the allocation of inputs and employment of labor for crop management

Large amounts of initial investment

Inability of staff members to harness the labor efficiency increased cost of operations

Advantages and disadvantages to the farmers

Assured income from land as leased amount

Can be employed in other work and gain additional income

Low risk on lease agreement with the company

Farmer reduced to a laborer on his own farm

Cannot benefit from higher yields due to adoption of superior technology

Model 2: Contract Farming

This model was implemented for scheduling uninterrupted feed stock supply to the distillery during the crop season. Under this model, clusters of villages within a radius of 50 km from the distillery were targeted. The aim was to transport the raw materials (stalks) to the distillery within 24 hours of harvesting to prevent loss in juice recovery and quality. The company appointed 'middlemen' (local village leaders, agents or farmers) who acted as intermediaries between the company and the growers for facilitating selection of farmers, providing seed, timely harvesting, loading and transportation of stalks to the distillery, and to make payments to the farmers (Figure 4). The middlemen also liaised with the company technical staff and farmers to provide training on crop production practices and schedule stalk supply to the distillery. The company entered into buy-back agreements with the farmers for purchase of stalks at a pre-agreed price. The company staff and the extension agency of the local agricultural department worked in co-ordination to maximize the production of stalks and grain, and to increase the harvest window, and strengthen the technical capabilities of the farmers at the cost of the company.

The ZTE contract farming model, measured in terms of new options for farmers, increase in productivity and the introduction of modern technology, was a success in year 1 (2010). The company focused on selecting region specific desired cultivars through research, and popularized these through extension services. The research and development center of the company undertook multi-location on-farm evaluation of genotypes for identifying suitable sweet sorghum cultivars and genetic and agronomic manipulation to increase the harvest window. It was thus successful in bringing about a big change in the county farmers' production system and towards its objective of ensuring supply of quality produce to its distillery at the right time in required quantities.

The company targeted an area of 3000 ha in year 2 in Bayannao'er, Wuyuan County, Inner Mongolia within a radius of 50 km from the distillery. The company appointed 30 middlemen to select farmers and entered into a stalk buy-back agreement with selected farmers to purchase the stalks at RMB 285 t^{-1} ($45) of green stalk (Annexure 1). The price of stalks depended on the mode of transportation (by the farmer or company) and distance from the distillery (details given in Annexure 2). The company also extended technical support, input supply linkages and monitored crop to maximize the production. Local middlemen appointed by the company acted as intermediaries between the company and the farmers, facilitating seed supply, technical backstopping, machinery for sowing and harvesting, and timely delivery (harvesting and transportation) of stalks to the distillery. Details of the specific components of the model are given below (Figures 2, 3 and 4).

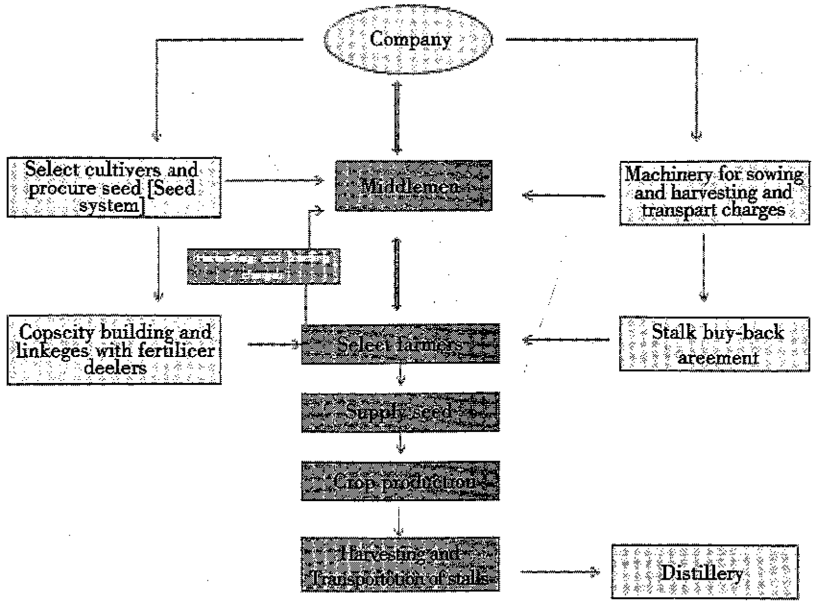

Fig. 2 Sketch of contract farming model 2.

Provision of inputs and extension services

The contractual agreement included considerable production support to farmers by the company in addition to basic inputs such as seed, free training and extension services. These services were provided by the company to ensure required stalk yields and quality (high brix %).

All the crop production practices (starting from land preparation, sowing, inter-cultural operations, and pest and disease management) had to be carried out by the farmers at their own cost, including the purchase of seed from the middlemen. Support services such as supply of sowing and harvesting machines were given to the middlemen free of cost by the company to serve the farmers. Middlemen leased the machinery to the farmers and arranged for harvesting, loading and transportation of stalks at appropriate time and charged then RMB 10 per ton of stalk and the company paid the middlemen RMB 1.3 per ton/km towards stalk transportation. Farmers were linked to appropriate input dealers for procurement of quality fertilizers and pesticides for which the farmers had to pay. (Figure 2).

Harvesting and transportation

The company appointed middlemen selected from the project area. There were around 30 middlemen appointed by the company with each middleman taking care of 5 ~ 6 villages. The middleman was either a village head (appointed by the government) or a local village leader. The company offered machinery for sowing and harvesting to the middlemen free of cost who in turn provided services to the farmers and charged them small amounts. The middlemen charged the farmer RMB 10 per ton of stalk harvesting and loading, and the company paid RMB 1.3 per km to middlemen for transporting stalks to the distillery (Figure 4). The harvesting schedule was prepared based on date of sowings and maturity period of cultivars.

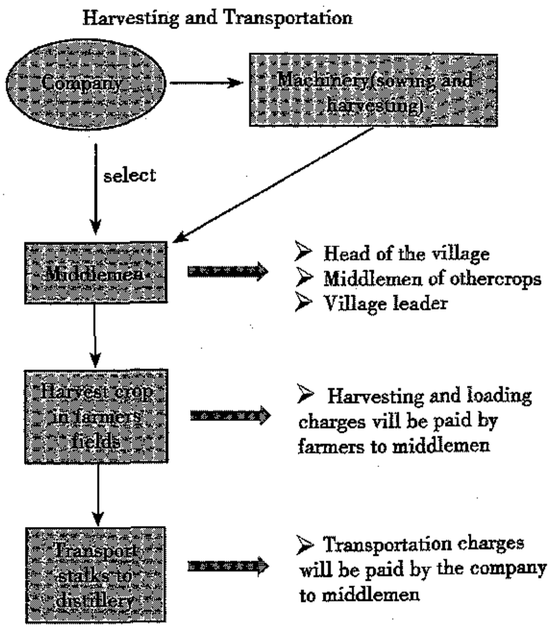

Fig. 4 Sketch of harvesting and transporting stalks to distillery.

Crop production

Sweet sorghum is a warm-season crop that matures early under high temperatures and short days. It tolerates drought and high-temperature stress better than many crops. The soils of Inner Mongolia are light sandy loams having a PH range of 8 ~ 9, predominantly alkaline-saline soils and crops are grown under canal irrigation from yellow river. Air temperatures suitable for sorghum growth vary between 15 ~ 37℃. Sorghum, being a C4 tropical grass, adapted to latitudes ranging from 40°N to 40°S of equator.

Different cultivars developed by SRI, China (Liaotian 1, 3, 5, 7 and 9) were tested, prior to releasing them for large scale cultivation, on research station and on farmers fields in Inner Mongolia for their adaptability and stalk yield and sugar yield. Crop is generally sown in the month of March last week or April first week; it takes 130 ~ 140 days for its maturity. Stalk yield ranged from 60 ~ 80t/ha and grain yield from 2.7 ~ 4.9t/ha; sugar content ranged from 18 ~ 20 Brix%.

Details of the sweet sorghum grown under contract farming models and the stalk yields achieved by the farmers by growing different cultivars, seed supplied by private and public sector seed companies during the project period are given in Table 1.

Table 1 Details of cultivars grown, crop area, yields of stalks and ethanol from 2010—2013.

Particulars	Year							
	2010		2011		2012		2013	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Area sown (in ha)	1 333	333	1 333	667	1 340	1 433	1 180	620
Yield t/ha	52	70	57	75	61	75	68	66
Quantity of stalk crushed	69 000	23 000	76 000	50 000	80 000	110 000	80 000	41 000
Stalk procurement price	NA *	265 Yuan /t	NA	295 Yuan /t	NA	305 Yuan/t	NA	340 Yuan/t

(续表)

Particulars	Year							
	2010		2011		2012		2013	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Cultivars grown	Chuntain no 1, and 2; sugar grace, Liaotian no 1.	Chuntain no 1, and 2; sugar grace, Liaotian no 1.	Liaotian no 1 and 3; chuntain no 2; sugar grace	Liaotian no 1 and 3; Chuntain no 2; sugar grace	Liaotian no 1 and 3; sugar grace	Liaotian no 1 and 3; sugar grace	Liaotian no 1; sugar grace	Liaotian no 1; sugar grace
Total ethanol produced (in t)	3 000	1 000	3 300	2 200	4 000	5 500	4 000	2 000

* NA: Not applicable

Guaranteed price and market

The company and farmer groups negotiated the price per ton of stalk and entered into an agreement, and settled on a pre-agreed price and assured procurement of stalks with a penalty clause on failure to procure stalks and without imposing farmers' quota system.

Mitigating risk and environment issues

To reduce the risk of crop failure, the company established an R&D center prior to introduction of sweet sorghum, which is a new crop to the region. Testing of new cultivars and their adaptation and yields were ascertained prior to entering into contract agreements with farmers who took up sowing on a large scale. Such risks are more likely when the agribusiness ventures into crop diversification.

Physical and social environments usually receive little attention from either agribusinesses or the government. Environmental issues can vary from country to country but also from county to county. ZTE took all environmental and social aspects into account before launching sweet sorghum as a feedstock crop for ethanol production. Sweet sorghum replaced crops like sunflower and maize in some areas. Moreover, sweet sorghum is a dual purpose crop where the grain is harvested for food, feed and alcohol production and the stalks are used for ethanol production. Hence, there is no tradeoff for food and fuel. There is no deforestation as the crop is grown on plain lands and hencethere is no soil erosion. There is no depletion of water resources because of the new crop as the target area is irrigated by yellow river for all the crops in the project villages. Sweet sorghum also adapts very well to saline soils and hence there is no soil degradation. There is no scope for multi-cropping system in Inner Mongolia as the region has only 4-5 months of frost-free period in a year during which only a single crop can be grown. The farmers are well aware of crop rotation practices, soil health and ecology.

Observations on Model 2

Advantages to the farmer

Provision of high yielding cultivar seed and crop production services

Opportunity to learn new technologies and skills

Guaranteed and fixed pricing structure

Assured market

Disadvantages to the farmer

Farmers were not given a choice in selecting the seed variety; they had to sow the seed provided by the middlemen of the company.

Farmers were totally dependent on the company for sale of the produce since there were no alternative markets.

The farmers had the risk of crop failure.

Advantages to the company

In China, large tracts of land are not available for commercial development and the company cannot buy land. In such cases, using land owned by smallholder farmers and involving in contract farming is a cost-effective way of procuring raw material. Sufficient land is also not available for leasing since farmers own small pieces of land. Hence, the company is moving from production on leased land (model 1) to purchasing stalks produced under contract farming by smallholder farmers, whose production is more cost effective.

Sweet sorghum is a new crop in these areas. Because of the nature of the commodity and also because of non-existence of alternative market for sale of the crop, it was assumed that the farmers would not fail to supply agreed quantities. And the risk of farmers dis-honoring the agreement was also remote.

Farmers were linked to input dealers for supply of quality fertilizers and pesticides and middlemen supplied seed for which farmers made the payment. Farmers were capacitated and were trained free of cost on crop production practices and also extension services for enhancing productivity.

The company was not involved in the supply of credit and inputs to the farmers. Hence, the risk of diversion of inputs to other commercial crops and sale of inputs to other farmers was ruled out.

Achievements

(1) ZTE has procured license from the government of China for the production of ethanol on commercial scale. Under this license, the company is allowed to test the ethanol produced by blending it with petrol in automobiles. This two year mandatory requirement ended in June 2014 upon completion of 2 years of testing. Now that testing of the blended ethanol in automobiles is completed successfully, ZTE will approach the Government for permission for commercial marketing of ethanol. Thus, ZTE will soon start commercial marketing of ethanol produced by using sweet sorghum.

(2) Capacity building of 1 063 farmers growing sweet sorghum in ICM (Integrated Crop management) practices including IPM (Integrated Pest Management) and INM (Integrated Nutrient Management) has enhanced stalk productivity of sweet sorghum by 30% ie., from 52 t/ha in 2010 to 68 t/ha in 2014. The net income of farmers growing sweet sorghum was higher than the farmers who were growing corn and sunflower in Inner Mongolia.

Farmers are now confidently cultivating sweet sorghum, a new crop to this area, due to capacity building and technical support of (new improved cultivars and integrated crop management) ICRISAT and SRI. In addition, the farmers get additional technical support from the staff of ZTE, local govt. and agriculture department who were also given training by ICRISAT and SRI. Crop production protocols have been standardized on-farm by conducting demonstrations on farmers' fields for achieving higher stalk and grain yields on saline/alkaline soils of Inner Mongolia.

(3) Improved sweet sorghum cultivars supplied by private and public sector seed companies were tested at Regional Research Station, Inner Mongolia and also on the farm (farmers' fields) for assessing yield of stalk and sugars by SRI and ZTE prior to its release to the farmers. Thus, the farmers were assured of high stalk yielding cultivars and ZTE was benefited by high sugar yield for ethanol production. Different cultivars developed by SRI, (Liaotian 1, 3, 5, 7 and 9) were tested on research station and in farmers' fields in Inner Mongolia for their adoptability and stalk and sugar yield, prior to releasing them for large scale cultivation.

ICRISAT and SRI facilitated implementation of value chain of seed for supply of improved cultivar seed through formal sector on regular basis. Supply of seeds of improved cultivars has given excellent boost for increasing production and productivity of sweet sorghum stalks in Inner Mongolia.

(4) With backstop support of the CFC project, ZTE tested two stalk supply models in Inner Mongolia. Model 1 (company leased land) had good initial impact on the selection of cultivars, adaptability of sweet sorghum to the location, and demonstration of new crop to the farmers, researchers, government agricultural department officials and financial institutions in the area. Model 1 is a good platform for introduction of new crop, and in awareness development and building capacity of farmers to take up new crop cultivation and it is also a learning ground for company staff and other stakeholders on crop diversification in Inner Mongolia.

Implementation of model 2 (contract farming) on large scale has capacitated more number of farmers on sweet sorghum crop production and management practices, enhancing their knowledge of contract farming, and price negotiation. The company had increased stalk procurement price from 265 Yuans (41 USD) per t in 2010 to 340 Yuans (53 USD) per ton in 2013.

(5) Sweet sorghum is a new crop in Inner Mongolia and was successfully grown and popularized by implementing different contract farming models. Linkages between farmers and company were fostered through implementation of models and buy-back of stalks was assured through agreements. Farmers are willing to grow sweet sorghum by devoting a part of their land for its cultivation, because of company support and assured market.

Company is helping in mechanization of sweet sorghum cultivation by providing machinery for sowing, harvesting and loading and also providing transportation. This helped in timely completion of operations and supply of stalks to the company. The mechanization also reduced drudgery of farmer's labor in crop production and post-harvest operations.

(6) Sweet sorghum is replacing crops such as sunflower and maize in Bayannao er, Wuyuan County, Inner Mongolia where lands are predominantly saline sandy soils and are not generally suitable for the cultivation of high value crops. Thus, sweet sorghum is a suitable crop as biofuel feedstock without any trade-off for food and fuel.

Scope of sweet sorghum biofuel industry in China

(1) Availability of high genetic variability of sweet sorghum lines (as energy crop) with partner organization (SRI) provides good breeding opportunities in order to develop new improved cultivars suitable for ethanol production.

(2) Genetics of crop are relatively well known. Genetic diversity is extensive and maintained by SRI.

(3) Regional sorghum research station established by partner organization (SRI)

is helpful in testing cultivars suitable for Inner Mongolia saline soils and climate.

(4) Sweet sorghum is a C_4 plant with high photosynthetic efficiency and can produce high biomass in short time. It is characterized by high water, radiation and nutrient use efficiency in comparison with other energy crops (e. g. maize, sugar cane)

(5) Full mechanization of cultivation is possible, thus allowing for industrialized value chains.

(6) Commercial proven technologies for crop production and stalks processing for ethanol production are available.

(7) The Government of China has an ambitious target for ethanol blending program in the foreseeable future. Government policies in China are favourable for promoting production of ethanol from non-food crops that can be grown in marginal environments

(8) Discussions on food-fuel conflicts create opportunities for dual purpose crops such as stalk and grains. This may also improve public acceptance for production of ethanol from sweet sorghum.

(9) By-products of ZTE like bagasse as a source of alternative fodder and feed to livestock, and vinasse (the liquid remaining after separation of ethanol) can be used as fertilizer and methane gas production. Hence, there is scope for exploring new products and markets.

(10) Increase in national security of energy supply: Potential for substituting petroleum products within the existing available infrastructure and motor vehicle technology

(11) Reduction of environmental impacts: Ethanol from sweet sorghum is an important option for reducing greenhouse gas emissions and mitigating climate change

(12) Creates new demand for agricultural products enabling diversification and promotes socio-economic activity especially in rural areas

Annexure I

Contract farming agreement for purchase of sweet sorghum stalks from farmers

Contract Numbers:

Name of stalk purchasing company (hereinafter referred to as Party A): Inner Mongolia Hefeng--xingyuan Agricultural Science and Technology Co., LTD

Address: Wuyuan Industrial Park, Inner Mongolia

AND

Farmer name (hereinafter referred to as Party B):

Address:

Telephone: ID card number:

In order to clarify the rights and obligations of both parties relationship, regulating the behavior of parties, protecting the legitimate rights and interests of both sides, according to the Contract Law of the People's Republic of China and under the principles of fairness, free will, Party A and B agree on the terms as following:

Article I: Sweet sorghum varieties, planting area, sowing and stalk quality

1. The sweet sorghum varieties and planting area were decided by both the parties.

Sweet sorghum varieties: ························planting area:

2. Sowing

Party B must be sure to do the sowing in good time as required by party A.

3. Stalk quality

(1) The Party B should harvest the sweet sorghum ear head and stalks should be free from roots.

(2) Impurities should be less than 5% (weight percentage); otherwise the stalk needs to be cleaned again by Party B until the stalk meets the above requirement.

(3) The stalk with ear should have impurities less than 5% (less than 5 per 100 stalks), otherwise the stalk needs to cleaned again by Party B until the stalk meets the above requirement.

(4) If the stalk has rotted or is damaged badly due to any reason, they will be rejected by Party A.

(5) A minimum of 60% stalks should be longer than 2.5 meters in length, otherwise they will be rejected by Party A.

(6) If the impurities are more than 15%, they will be rejected by Party A.

Article II: The purchase price

1. Within 25 km of the company, sweet sorghum stalks should be transported to

the company by Party B. The prices of stalks is 295 Yuan per ton, Party B will receive a subsidy of Rmb 29 per ton, so the settlement price is 324 Yuan per ton. When the distance between village and company is 25 to 50 km, if the stalks are transported to company by Party B, the stalk prices will be 295 Yuan per ton, and Party B will receive a subsidy of RMB 1.2 per ton km. If the stalks are transported to company by Party A, the stalk prices will be 293 Yuan per ton.

Article III: Trading time, place and transporting method

1. Between 20 August 2012 and 20 September 2012, Party A shall keep Party B informed about trading time.

2. Time of harvest and transport methods: The time of harvest is decided by Party A. Party A shall give 7 days' notice to Party B.

Article IV: The settlement

After Party B has sold sweet sorghum stalks to Party A according to the contract agreement, Party A should pay all the money to Party B within 30 working days.

Article V: The rights and obligations of both the parties

1. The rights and obligations of Party A

1) Party A should purchase sweet sorghum stalks, provided by Party B, according to the contract.

2) Party A should provide the high yielding cultivar seed and impart training on cultivation techniques to Party B. Party B should purchase seed from middlemen by paying 50 Yuan per kg of seed, and no credit facility is available. Party A shall provide equipment for sowing and harvesting to Party B, but all charges for sowing and harvesting has to be borne by Party B.

2. The rights and obligations of Party B

(1) Party B should provide sweet sorghum stalks to Party A according to the contract.

(2) When Party B is signing the contract, he/she should show original ID (provided by the Chinese government) and provide a photocopy of the ID to Party A.

Article VI: Liability for breach

1. If Party B willfully not sell sweet sorghum stalks to Party A or sell the sweet sorghum stalks to others, should pay 500 Yuan per Mu to Party A, based on the planted area in the contract.

2. If sweet sorghum stalks don't reach quality standards, they will be rejected by

Party A, at the same time, party B should pay 500 Yuan per Mu to Party A, based on the planted area in the contract.

3. If Party A fails to purchase the sweet sorghum stalks of Party B, Party A should give Party B economic compensation of ten percentage price higher than the agreed price of contract of sweet sorghum stalks.

4. The party in breach shall bear the liability.

5. This agreement don't matter of exert, both parties′consultation solve

Article VII: Force majeure clause

In the event of any such causes arising, the party affected shall give prompt notice to the other party of the cause.

Article VIII: The way dispute resolution

If the execution of the contract between the two sides in any dispute, negotiation or mediation fails, it shall be decided according to Wu Yuan city people's court

Article IX: The effective date of the contract

The contract will be valid from the date of signing this agreement to finishing the settlement.

Article X: Remarks

This contract is made in duplicate (originals) and both the parties of Party A and Party B will have one copy of original agreement. The contract agreement will come into effect after signing and stamping by both the parties.

Party A: (chapter) party B (signature):

The authorized representative (signature)

Signing date: Signing date:

Chapter 7: Seed Systemsfor Supply of Improved Cultivar Seeds of Sweet Sorghum in India and China

Ch Ravinder Reddy, Zou Jianqiu and Lu Feng

Preamble

A part of the Common Fund for Commodities (CFC) project activity was to develop seed systems (community seed program) for multiplication of farmer-selected sweet sorghum cultivar seedsand toimprove their availability to the farmers at the right time and ataffordable cost for the benefit of the farmers in the project. There are not many seed companies producing seed of improved sweet sorghum cultivars, suitable for different climatic zones. And wherever they exist, they are reluctant to supply small quantities of seed to the farmers. To counter this lacuna, an informal seed system termed as "community seed program" was developed and implemented. This program is meant to address the issue of supplyof seeds of farmer selected varieties inthe decentralized area in India on a sustainable basis even after the completion of the project.

Under the formal seed system, large quantities of seed areprocured from different seed companies (formal sector). TCL in India procures seed through the formal sector as it requires large quantities which it supplies to the farmers. In China, "community seed program" is not yet introduced and hence ZTE in China procures seed through the formal sector ie., from different seed companies.

1 Seed system in India

1.1 General Issues

The response of the farmers to development initiatives vary from one place to another. Some of the factors that motivate them to become seed growers include good harvest and an increase in the income from the sale of seed. A poor harvest in the first season discourages them to become seed growers. Some farmers do become self-reliant within fewseasons. It is noticed that it takes a minimum of five years to develop a sustainable community seed program.

The first year of the project focused on awareness and capacity building activities, such as technical training in seed production and making the farmers understand the seedproduction process and its storage, and also to develop business skills. Some of the important activities during the second year included orientation visits of the farmers to research stations and gene banks (for seed sources) and the State Seed Certification Agencies (SSCAs) and farmers' cooperative society. These visits helped the farmers to acquaint with seed production and certification procedures. The visitsto the various information dissemination centersand the discussions with their staff onthe relevant topics were exercisesfor confidence building, and for creating awareness on investments and expenditure for meeting quality parameters for the seed. In addition, it was beneficial for the seed producers (farmers) to visit seed companies, non-government organizations (NGOs), Krishi VignanaKendras (KVKs) and other service providers, who could be give them contacts for outlets and lead them to potential markets.

1.2 The model

A basic model of the "community seed program" or "integrated seed system" was-developed involving the consortium partners. Generally, models developed for a specific area/village/region and crop may not yield the same results elsewhere because of several variables. For instance, the willingness of the stakeholders, the crop and cropping system and varieties grown, climatic conditions, socioeconomic, political and perhaps biotic factors act as factors for differences in the yield.

The following steps were decided upon in order to develop community seed systems - Village Seed Bank (VSB) for selected sweet sorghum varieties and their distribution to the farmers in the project:

Integrated Seed System Model

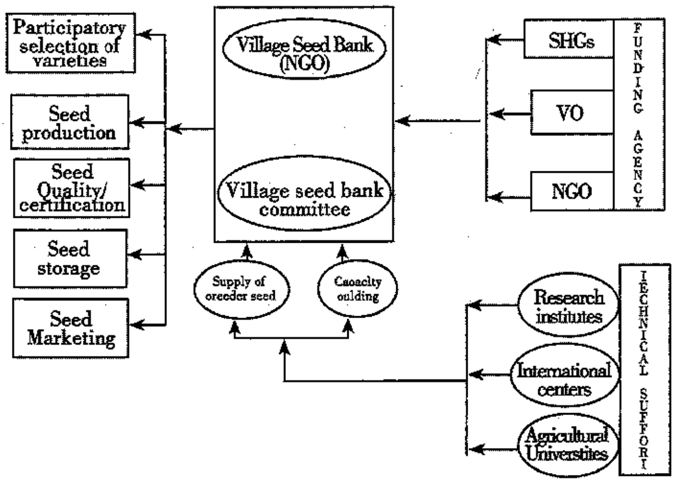

Fig. 1 Integrated seed system model tested in India.

1.2.1 Reconnaissance survey

After identifying the areas of operation, the non-governmental organization (NGO) or project implementing agency (PIA) needs to carry out reconnaissance surveys for seed needs assessment (SNA). This involves a series of participatory dialogues to engage the community in the diagnosis of problems related to seed, and to secure the community's commitment to develop and act on the solutions. Also, the SNA has to identify knowledge gaps that can be corrected during the training programs. It should assist communities in developing an action plan on what needs to be done, while remembering that the role of the NGO is only to facilitate this process.

1.2.2 Participatory selection of varieties

It is for the communities to identify the crop varieties to be multiplied. There is a tendency for the farmers to select improved hybrid varieties even if it is at the expense of important varieties. Facilitators should check this tendency. Farmers should be encouraged to select a good mix of crop types (crop diversity). Locally adapted varieties would be ideal in the first year. This tends to increase the chances of success since the farmers already have adequate experience to grow them. The NGO should be proactive in promoting farmers' participation in the selection of varieties for a particular area/region/village.

1.2.3 Selection of seed growers

Once the varieties selected for multiplication are identified through farmers' participatory selection, the community (VSB) can select individuals who will be the seed growers. Since the seeds are known to be conserved and multiplied mostly by women, it is appropriate and advantageous that seed production of such crops be taken up by them. To help the farmers to select their local seed growers carefully, the NGOs need to help in developing the criteria to facilitate theprocess for selecting seed growers. Some suggested criteria adopted in the intervention are:

- He/she should be a resident of the village and a member of an SHG group,
- Should be a farmer with land holding,
- Should be willing to attend training programs without fail,
- He/she should be friendly in nature and approachable to others,
- Should be inclined to put in sincere efforts in the project,
- Must be willing to work in a team,
- Must be experienced in growing one or more of the crops intended for multiplication
- Must be honest and willing to repay seed loans.

Having such a set of criteria reduces bias and helps farmers to choose the seed growers appropriately.

1.2.4 Capacity building

Identification of seedgrowers is followed by technical training. The seed growers are trained in basic seed production techniques including seed regulations and seed certification methods, seed health management and seed storage management. Training is enhanced by an educational tour to ICRISAT and similar programs wherelearning happens through farmer-to-scientist interactions. Farmers must also be trained in business skills, basic group dynamics and leadership.

As is the case with all farmers' training programs, the trainer was required to be conversant with the principles of adult learning and facilitation skills. SHGs were included in all the training programs. Training was conducted by competent technical officers who fully understood the basic seed production standards and the Seeds Act. For such innovative projects, consortium approach has yielded good results.

The members of the village seed bank were trained in quality aspects of seed production and certification. Initially, farmers did not offer the seed production plots to the seed certification agency. They took time in doing so. For getting quality seed certificate, the office bearers of VSB monitor the seed plots along with the institution/partner organization staff.

1.2.5 Procurement of basic seed and distribution

The NGO or farmers need to secure basic seed (foundation seed) for their seed production activities. As it can be difficult to secure basic seed, ICRISAT and DSR have been identified as basic seed sources. Wherever poor weather affects the growing season, it is imperative to arrange seed for the following season. It is advisable to give subcontract to the breeders who are recognized by the government or research organizations to produce basic seed in specific quantities. Linkages have been developed between farmers' associations and public sector institutions (ICRISAT/DSR) to ensure timely supply of basic seed for sweet sorghum.

In the absence of basic seed, a seed grower can plant certified seed, but this can be done only for one season. Thereafter, farmers must secure basic seed for production of quality seed which ensures long-term benefits.

1.2.6 Formation of seed growers' association

Some of the seed growers prefer to work on individualbasis. But in seed growing, forming an association has the following advantages:

- Registration is cheaper for a group than for individuals. SHGs can take up this activity right away without any registration,
- It is cost-effective to work as a team when procuring basic seed and selling seed: there is the benefit of bulk buying and selling,
- Group contributions can pay for activities such as crop inspections, seed sampling and testing,
- During the early years of seed growing the team is important in providing mutual support, encouragement and a collective voice,
- Forthe farmers to work effectively as a group, the Needs Assessment process determines whether they need to be trained in group dynamics, leadership, record keeping, conflict management or business skills, and
- The seed growers' association is required, in the long term, to mobilize funds to sustain their activities of not only growing the seed but producing quality seed.

1.2.7 Seed Marketing

The success of a community seed bank or village seed bank project lies in the ability of the seed growers to sell their produce. Some farmers have used field days, weekly village markets, and contacts within localcommunity or through community based organizations for advertising. Others have used the platforms of public meetings or other ceremonies in the village to sell the seed. Seed growers should be innovative in adopting ideas that are workable within their rural setup. However, they should be careful not to set the price of their seed beyond the local farmers' reach.

Wherever possible, the project partners should help in linking farmers to credit institutions for short term crop loans. Seed storage is a big issue in the villages; a proper storage facility will encourage farmers to store the seed for at least 6-8 months after which they will be able to sell the seed. A revolving fund facility in the project is highly helpful in establishing a community seed system. This enables community-based organizations to obtain initial investments to not only buy inputs like breeders' seed, chemicals, fertilizers, gunny bags for packing seed and other seed storage materials but also meet the marketing requirements. The repayment of funds is ensured after the sale of seedwhich will then generate new loans for resource-poor farmers. Some farmers lend seed to other farmers which is to be repaid later in the form of either grain, or labor or lending of livestock for field operations.

Strengthening of farmers' knowledge and capacities to produce quality seed to meet their own requirements in the DCU areasof the project villages is a success story. The seed production method adopted by SHGs under technical guidance and supervision of the Marathwada Agricultural University (MAU) has produced 10 tons of ICSV 93046 variety seed, which wasthen distributed to farmers in 23 villages around the cluster in Parbhani district asTata chemicals Ltd. (TCL) was closed. The agriculture news bulletin, AGRO ONE of Maharashtra state, disseminated the success story of CFC project whichmade a good impact on marketing of the seed produced by SHGs. Alternative uses of sweet sorghum for fodder and grain purposes has become extremely popular. There is a great demand for seed in Parbhani district and this demand is spreading to other areas of Maharashtra state.

2 Advantages

- Availability of seed of improved varieties in sufficient quantities within the village at a low price
- Assured and timely supply of seed material to farmers
- Decentralized seed production
- Improved seed delivery to resource-poor farmers
- Reduced dependency on external sources for seed and effective curbs on spurious seed trade
- Good opportunity for SHGs to invest and develop a village seed enterprise

- Encourages village-level trade and improves village economy
- Social responsibility of seed production and delivery system
- A step towards sustainable crop production
- Introduction of diseases carried through seed (seed-borne pathogens) produced and imported from other agro-eco regions can be avoided
- Scope for the farmer-participatory varietal selection and feedback to the scientific community on the performance of cultivars
- Availability of true-to-type varieties and healthy seed within the reach of farmers at affordable price
- The probability of sustainability is high asthe farmers are involved from the beginning inthe establishment of community seed programleading to seed production, storage and marketing through investment of their own and sharing the benefits

3 Constraints

- Unwillingness of farmers to adopt quality seed production practices
- Additional investment for inputs in seed production
- Poor buy-back assurance to farmers from FA/SHGs/NGOs
- Lack of proper seed storage facilities and management at village level
- Unsure availability of funds with FA/SHGs/NGOs for seed procurement, packing, storage and transportation
- Fixing of minimum support price for seed procurement
- Un-assured technical support for seed production and its monitoring
- Lack of willingness to take up the responsibility of quality control aspects and monitoring of seed production activity
- Availability, access and procurement of breeder seed from research institutes for seed production at regular intervals

4 Conclusion

Many development projects have used community level seed production as the starting point for commercial seed development. The results have been disappointing with little commercial sustainability. Reasons for the lack of success are twofold – a) lack of attention to transaction costs (making contracts for source seed, ensuring quality control and obtaining information), and b) lack of experience and resources for marketing. To be successful, community-level seed projects need more appropriate goals such as testing new varieties, disseminating information, developing farmers' experimentation capacities, and forming better links between farmers and researchers.

The farmers' association in the project area and SHGs who were trained in seed production methods have produced 10 t of ICSV 93046, a sweet sorghum variety, and sold seed to the farmers in the project at the rate of Rs $50kg^{-1}$. With this experience of benefiting from seed production, farmers are enthusiastic to take an initiative and develop this into a small-scale seed enterprise.

Farmers, as seed producers, can be quite efficient and some seem to have the potentiality to expand this business as a specialized, small-scale seed enterprise. To make this effective, seed trade associations, government agribusiness promotion programs, and especially theNGOs, SHGs, and Krishi VignanaKendras (KVKs) have a vital role in promoting and improving production, marketing and distribution systems. The key to the success in developing and strengthening informal seed systems would be by improving farmer's and seed producer's access to information on products, seed price and market options.

The approach involves farmers' participation in the program directly, where the farmers are empowered to produce quality seeds and manage a seed bank in the DCU area which would make the seed available on time. The model 'community seed system' can be promoted so that the resource poor farmers can avail quality seeds of sweet sorghum at the right time and at affordable prices. This system will help to reduce the dependence of the farmers on external seed sources and encourage village level seed trade, and so also improve the village economy. To sustain seed production activity and to have long term benefits, the breeder seed supply linkages need to be developed with public sector research institutions. At present, for hybrid seed supply, the farmers are linked to private seed companies.

5 Seedsystem in China

In China, the company (ZTE) provides seeds of high yielding cultivars to the selected farmers (Figure 2) on payment basis. The company also established a research and development center for studying and testing the cultivars' adaptability, yield and resistance to pests and diseases in the target locations. This was done prior to the distribution of the seed to be grown on a large scale. Cultivars, from different private and public sector organizations, were procured and tested in the company's R and D center which was approved by the Government of China (SRI, LAAS is the approving authority) LAAS, a public sector seed company supplied seed (Table 1) of different cultivars which performed well in saline-alkaline soils of inner Mongolia eco-system. Thus the selected high yielding cultivar seeds would be purchased in large quantities from the respective organizations and distributed to farmers through middlemen. The farmers have to buy the seed from middlemen @ RMB 50 per kg.

Table 1 Seed procured by ZTE during the project period.

Year	Seed sources	Seeds supplied by LAAS (kg)	Planting area (Ha)
2010	◆ Liangfeng Seed Company of LAAS	FGBC: 2000 ZTE: 10000	FGBC: 140 ZTE: 1666
2011	◆ Liangfeng Seed Company of LAAS	FGBC: 1500 ZTE: 20000	FGBC: 50 ZTE: 2000
2012	◆ Liangfeng Seed Company of LAAS	FGBC: 380 ZTE: 17500	FGBC: 26 ZTE: 2770
2013	◆ Liangfeng Seed Company of LAAS	FGBC: 300 ZTE: 11000	FGBC: 20 ZTE: 1800
Total		FGBC: 4480 ZTE: 58500	FGBC: 236 ZTE: 8236

6 Technical support

The company has built up the confidence among the farmers about the new crop and cultivation technologies, more so, on the impact of the yields on the net re-

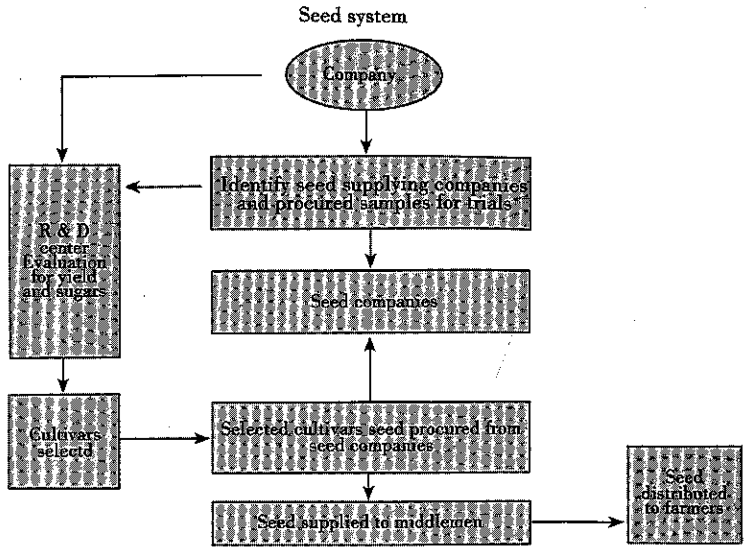

Fig. 2 Sketch of formal seed systemmodel adopted by the company (ZTE) in China.

turns as compared to other crops traditionally grown in that area. It has evolved all the stages correctly, right from the stage of selecting cultivars of sweet sorghum (based on yields and sugar content) to developing a package of practices for the farmers. It has ensured successful transfer of sweet sorghum cultivation technology from the field trials to the commercial levels and to closely monitor the performance of the crop on the farmers' fields.

Capacity building activities were designed and implemented jointly by SRI and ICRISAT (CFC project) and ZTE technical staff to train the farmers in new crop technologies and create more awareness about the sweet sorghum crop. New crop production techniques are often necessary to increase productivity. The company introduced mechanization of crop production, harvesting, loading and transportation activities to augment the smooth and timely supply of feedstock for crushing.

The R and D activities on cultivar selection, introduction of new cultivars, testing various genetic materials supplied by ICRISAT and other research stations from

China are evaluated under the supervision of SRI scientists in collaboration with ZTE staff.

Thus, the ZTE success is due to its strategic partnership with local bodies like farmers groups, the Agricultural University, Government Agricultural Department, other agricultural research institutes such as SRI and Liaoning academy of agriculture sciences (LAAS) and international institute like ICRISAT for technology transfer. Right from the beginning, ZTE knew that changing the mindset and winning the confidence of farmers to adopt a new crop would not be an easy task for outsiders. The company's unique partnership with various partners in private and public sector agencies fuelled its growth in Inner Mongolia.

Chapter 8: Policy Options for Promotion of Alternate Feedstocks for Ethanol Production in Semi-Arid Tropics of India with Special Reference to Sweet Sorghum

G. Basavaraj, P Parthasarathy Rao, Ch Ravinder Reddy,
A Ashok Kumar and B V S Reddy,

Background

Energy consumption is one of the major indicators of the country's economic progress and its usage increases with economic growth and development. India ranks sixth in terms of energy demand accounting for 3. 6% of the total global energy demand (Prasad et al. 2007) and this is expected to increase by 4. 8% per annum in the next few years (Gonsalves 2006). India's energy demand is primarily met through nonrenewable energy sources such as coal, natural gas and oil that will continue to play a dominant role in the country's energy scenario in the next few decades. However, being short in domestic production, India mainly depends on crude oil imports that account for about 81% of the oil consumption in the country (Ministry of Petroleum and Natural Gas, 2009) and the imports are slated to increase further with the growth in the economy. The highest demand for energy comes from industry, followed by the transportation sector that consumes about 16. 9% (36. 5 m of oil equivalent) of the total energy (217 million t) in 2005—2006 (TERI 2007). Within the transportation sector, consumption of motor spirit (gasoline) grew by 6. 64%, from 7. 01 million t in 2001—2002 to 11. 26 million t in 2008—2009 and that of high speed diesel (HSD) by 4. 1%, from 36. 55 million t to 51. 67 million t, respectively (GOI 2009). Amid the growing demand for crude, the prices of crude too are increasing and fluctuating putting a strain on the foreign exchange reserve of the country (import bill of $75.6 billion in 2009—2010). Further, increased emissions from usage of fossil fuels is leading to environmental pollution which is a major cause of concern. Hence, in lieu of the growing concerns of energy security (due to high dependency on fossil fuels) and environmental pollution, securing long-term supply of energy sources that are renewable and non-polluting has been the major thrust of many governments all over the globe including the government of India.

Among several alternative renewable energy sources (wind, solar, hydro), energy derived from plant biomass is found to be promising and a sustainable energy source that contributes to reduction in greenhouse gas emissions (Subramanian et al. 2005). Bioenergy derived from plant based biofuels are also found to provide wide range of social and economic benefits (Gonsalves 2006, Rajgopal 2008). Hence, to promote biofuels as an alternative energy source, the Government of India in December 2009 announced a comprehensive National Policy on Biofuels formulated by the Ministry of New and Renewable Energy (MNRE), calling for blending atleast 20% of biofuels with diesel (biodiesel) and petrol (bioethanol) by 2017. The policies are designed to facilitate and bring about optimal development and utilization of indigenous biomass feedstocks for biofuel production.

However, experience has shown that the Government's initiatives have not been translated into results on the production and commercialization fronts to meet the country's energy demand through biofuels due to ineffective policy implementation.

This paper highlights the challenges affecting biofuel production particularly that of bioethanol and discusses how to bring about the long-term sustainability and commercialization of bio-ethanol production in the country. The paper then explores and discusses the viability of using alternative feedstock such as sweet sorghum grown on dry lands for sustainable bio-ethanol production and policy options for its promotion

Challenges towards sustainable bio-ethanol production

In January 2003, Government of India launched the Ethanol Blended Petrol Program (EBPP) in nine States and four Union Territories promoting the use of ethanol for blending with gasoline and the use of biodiesel derived from non-edible oils for blending with diesel (5% blending). Due to ethanol shortage during 2004-05, the blending mandate was made optional in October 2004, and resumed in October 2006 in 20 States and 7 Union Territories in the second phase of EBPP. These ad-hoc policy changes continued until December 2009, when the Government of India came out with a comprehensive National Policy on Biofuels formulated by the Ministry of New and Renewable Energy (MNRE).

Currently, the entire bio-ethanol requirement for blending mandates has to come from molasses, a byproduct of sugarcane. The availability of molasses depends on cane and sugar production that are cyclical in nature. Lower molasses availability will put pressure on molasses prices which in-turn affects ethanol production from molasses. Molasses prices in the last decade have fluctuated substantially and have ranged between Rs 1 000 ~5 000 per ton (Shinoj et al. 2011).

Additionally, ethanol produced has many other alternative uses such as potable alcohol, and in chemical and pharmaceutical industries. During a normal year, cane converted into sugar generates enough molasses to produce alcohol that can meet the needs of both the potable and chemical sectors. The Government of India has assigned the responsibility of procurement, storage, distribution and marketing of biofuels to Oil Marketing Companies (OMC). Even during a normal year of cane production, OMC's are unable to procure the required quantity for blending as the current administered price of ethanol is Rs 27 a litre while the market price for ethanol is on the higher side. There is assured demand from beverage and pharmaceutical industries under the current tendering system for ethanol. Further, blending of ethanol obtained at Rs 27 a liter would prove uneconomical as the cost of petrol sans taxes during 2011 was around Rs 23 a liter (Shinoj et al. 2011). Import of ethanol for fuel usage is currently restricted through policy and even if made free, would cost the exchequer very dearly, as the international markets for ethanol are already very tight due to demand from other biofuel-consuming countries.

Given the scenario of the growing demand for alcohol from the potable and chemical sector (growing at 3% ~ 4% per annum) and the highest available alcohol from molasses pegged at 2.3 billion liters, there will be a shortage of alcohol for blending that will grow between now and 2020—2021 even if we assume a moderate blending target of 10% (Table 1).

A study by Shinoj et al. (2011) finds that as per the 10% blending target set by the government, the demand for fuel ethanol is projected to be 2.16 million t and total demand (ethanol + alcohol) will be as high as 3.76 million t by 2016—2017. If molasses alone has to meet the entire requirement of 3.76 million tons of ethanol, an area covering approximately 10.5 million ha with 736.5 million tons of sugarcane has to be cultivated (around 20% ~ 23% in excess of what is required to meet the corresponding sugar demand). This would be a doubling of both area and production to achieve 10% blending. Presently, the country lacks both technology and infrastructure required to implement this. Further, it is not possible to increase the area under sugarcane beyond a certain limit given that sugarcane is highly water intensive with a requirement of 20 000 ~ 30 000 m^3 per ha per crop. Increasing the area under sugarcane will be at the cost of diverting land from other staple food crops.

Table 1 Availability and utilization of ethanol in India.

Year	Highest available alcohol from molasses (billion liters)	Ethanol utilization (billion liters)		alance	Ethanol required for Blending (billion liters)	Deficit/ Surplus
		Potable	Industry		@ 10%	
2010—11	2.3	0.86	0.82	0.62	1.53	-0.96
2011—12	2.3	0.89	0.84	0.57	1.64	-1.14
2012—13	2.3	0.91	0.87	0.52	1.70	-1.32
2013—14	2.3	0.94	0.90	0.46	2.02	-1.53
2014—15	2.3	0.97	0.94	0.39	2.13	-1.76
2015—16	2.3	1.00	0.97	0.33	2.23	-1.99

(续表)

Year	Highest available alcohol from molasses (billion liters)	Ethanol utilization (billion liters)		alance	Ethanol *required* for Blending (billion liters)	Deficit/ Surplus
		Potable	Industry		@ 10%	
2016—17	2.3	1.03	1.00	0.27	2.34	-2.24
2017—18	2.3	1.06	1.04	0.2	2.46	-2.51
2018—19	2.3	1.09	1.07	0.14	2.58	-2.78
2019—20	2.3	1.12	1.11	0.07	2.71	-3.09
2020—21	2.3	1.16	1.15	-0.01	2.85	-3.42

Source: Planning Commission (2003) estimates on highest available alcohol from molasses.

Policy distortion affecting bio-ethanol production

The biofuel policy mentions that a level playing field is necessary for accelerated development and utilization of biofuels vis-a vis direct and indirect subsidies to fossil fuels and distortions in energy pricing (GOI, 2009). Policy also mentions that issue of fuel vs. food security is not relevant in the Indian context justifying bioethanol production from molasses, a by-product of sugarcane, and biodiesel from cultivation of shrubs and trees bearing non-edible oil seeds on waste, degraded forest land and non-forest lands. However, to augment the availability of ethanol and reduce the excess supply of sugar, the policy permits the sugar industry to directly produce ethanol from sugarcane juice. The policy implies further concessions to sugarcane growers and processors who are already benefiting from the input subsidy. Sugarcane has the advantage of existing massive infrastructure and favorable government policy support since earlier years. This has led to policymakers tailoring policies favoring ethanol production from sugarcane and molasses. Thus, the policy is sugarcane centric. We have shown that this route is not sustainable since molasses alone will not be able to meet the blending targets. Second, the diversion of sugarcane juice for direct ethanol production would be at the cost of reduction in sugar production and thus has implications on food security. Also, allowing direct conversion of sugarcane juice to ethanol is neither economically nor environmentally sustainable, given the fact that sugarcane is a water intensive crop. Thus, the policy emphasis on sugarcane is counterintuitive to the policy recommendation of using degraded, less fertile land and non-food feedstock for biofuel production. The sugarcane centric policy would thus have a detrimental effect on resource allocation in the agriculture sector. The vision and goals of the policy is to bring about accelerated development and promotion of the cultivation, production and use of biofuels while contributing to energy security, climate change mitigation, apart from creating new employment opportunities and leading to environmentally sustainable development. While the concerns of climate change have adverse impacts on agriculture crops, this would only exacerbate the situation if cultivation of water intensive crops are promoted.

Hence, to meet the targeted blending requirements alternative feedstocks will have to play a more important role to fill the current and future gap between demand and supply of bioethanol. Sweet sorghum is one such alternative feedstock that has been pilot tested in recent years for cultivation under rain-fed conditions for ethanol production. Though the policy document mentions feedstocks like sweet sorghum, sugar beet, etc, for ethanol production, these crops have neither been given due prominence in the policy nor has a clear roadmap been specified for their commercialization and utilization.

Competitiveness of sweet sorghum

The economic competitiveness of sweet sorghum was worked out from on-farm data collected from a pilot project carried out by ICRISAT funded under the National Agriculture Innovation Project (NAIP), Indian Council of Agricultural Research (ICAR), Government of India (GOI). The analysis conducted by the authors from the cultivation data collected over the past three years (2008—2009 to 2010—2011) across locations of Andhra Pradesh has shown that sweet sorghum is competitive with dryland crops such as sorghum and maize. The benefit cost ratio (BCR) for sweet sorghum was 1.55 while it was 1.30 and 1.37 respectively for maize-pigeon pea intercrop and sorghum-pigeon pea intercrop in 2008 (Table 2). Though BCR obtained were less than one for sweet sorghum during 2009 and 2010 due to poor rainfall years, sweet sorghum performed better than the competing crops.

Table 2 Benefit cost ratio of sweet sorghum cultivation with competing crops in Ibrahimbad, Andhra Pradesh

rop Name	Benefit-Cost Ratio		
	2008	2009	2010
Sweet Sorghum	1. 55	0. 96	0. 81
Maize-Pigeon pea	1. 30	NA	0. 97
Sorghum-Pigeon pea	1. 37	0. 97	0. 59

Economic viability assessment without accounting for capital costs of investment was carried out to understand the relative economics of ethanol production from 4 different feedstocks (sugarcane molasses, sugarcane, sweet sorghum and grains) in India. The assessment shows that sweet sorghum is economically the next best alternative to molasses for ethanol production (Table 3), when the feedstock is priced at Rs 800 per of stalk with an average recovery rate of 4. 5 % alcohol per ton of stalk at the prevailing ethanol price.

As can be seen from the table, feedstock and ethanol pricing have a bearing on the viability of ethanol production from all available feedstocks. Economic viability assessment was also carried out by the authors taking into consideration the various economic and financial costs in establishment of the distillery. The results of the assessment show that the profitability of ethanol production is highly sensitive to ethanol price, feedstock price and recovery rate. Sensitivity analysis performed to derive the values of the key parameters of profitability shows that for sweet sorghum when the feedstock is priced at Rs1500 per ton of stalk with the recovery rate at 4. 9% alcohol the price of ethanol has to be increased to Rs 36 per liter from the existing administered price of Rs 27 per liter to make the distillery viable.

Based on the recovery rate an analysis was performed by the authors to assess the land requirement for sweet sorghum cultivation by 2020 if it is commercially exploited as an alternate source of ethanol production. It is expected that a crop like sweet sorghum would only bridge a small gap in ethanol requirement supply from the existing feedstock i. e. , molasses. The estimates show that to meet 30% of the ethanol requirement at 10% blending by 2020 (3.47 billion liters①), the area required under sweet sorghum would be about 1.16 million hectare (mh). This is under the assumption of sweet sorghum stalk yields of 20 t/ha and 4.5% recovery rate. This would be a small proportion of the total area under sorghum cultivation in the growing regions in the country.

Table 3 Relative economics of ethanol production from different feedstocks in India.

Parameter	Sweet sorghum	Sugarcane molasses	Sugarcane juice	Grains (Pearl millet & broken rice)
Cost of raw material (Rs/t)	700 *	3 000 ~ 5 000 **	1 200 ***	8 000[3]
Cost of processing (Rs/t)	384	1 890	490	2 800
Total cost of ethanol production (Rs/t)	1 084	4 890 ~ 6 890	1 690	10 800
Output of ethanol (l)	45	270	70	400
Value of ethanol (Rs/t)	1 215	7 290	1 890	10 800
Net Returns (Rs/t)	131	2 400 ~ 400	200	0
Cost of feedstock (Rs/l)	15.56	11.11 ~ 18.51	17.14	20.0
Cost of ethanol (Rs/l)	24.08	18.11 ~ 25.51	24.14	27
Profit from ethanol (Rs/l)	2.91	8.88 ~ 1.48	2.85	0

Note: The information on the parameters is collected from Rusni distilleries for sweet sorghum, Nizam Deccan Sugars Pvt. Ltd. for molasses and AGRO Bio-tech, Ajitgarh, Rajasthan for grains.

The value of by-products is not considered in the analysis.

* Even when the feedstock is priced at Rs. 800, it becomes profitable to produce ethanol from sweet sorghum without accounting for capital costs.

** The molasses prices have ranged between Rs. 3 000 and 5 000 /t during the last few years and hence the profitability of molasses ethanol production is highly sensitive to fluctuating molasses prices.

*** The data on all the other feedstocks cost is for the year 2009. The prices of feedstock (sugarcane and grains) have increased in the recent years.

Policies for promotion of alternate feedstocks

In the current market context, policy support for the production of a biofuel crop primarily depends on mutual co-existence of producers and processors to promote alternate feedstocks. For growers, it's the relative profitability of bioethanol crops

① Authors calculation.

vis-a - vis competing crops and assured buy-back at pre-determined prices are the important factors determining allocation of land for these crops. For industry, the raw material's conversion efficiency, its continuous supply for at least 5 ~ 6 months in a year, the economics of establishing multi-feedstock production units and the purchase price of ethanol by oil companies are critical factors. For growers and industries producing ethanol from alternative feedstock, policy support should be in the form of:

- Provision of assistance to farmers cultivating sweet sorghum justifying the support on the arguments of augmenting bioethanol production under rainfed conditions which meets the both food and fodder requirements of farmers

- A one-time capital assistance for industries crushing alternate feedstocks for ethanol production or assistance in the form of "infant industry sops" for bioethanol industry for setting up of machinery for bioethanol production

- Compensating industry for the difference in economic cost of ethanol production from alternate feedstock's and the minimum purchase price until industry achieves technological and efficiency breakthrough

- Permission to crush sweet sorghum by integrating with sugar industry during lean periods of sugarcane crushing

- Licensing and permissions to be made easy for establishment and operationalization of multi-feedstock units that can operate for longer periods in a year to augment the ethanol production using different feedstocks

- Increasing the administered price of bioethanol produced from alternate feedstocks

Conclusions

The concerns of economic viability and sustainability of ethanol production indirectly from molasses and directly from sugarcane juice necessitates the need for promotion of alternate feed stocks like sweet sorghum. The apprehension of diversion of land for cultivation of biofuel crops does not exist in case of sweet sorghum which can be cultivated under rainfed conditions and does not compromise on food security.

About 57% of the cultivable area in SAT India is under rainfed conditions. Crop choices are limited for resource poor farmers under harsh environments of semi-arid regions. Dryland crops like sorghum and millet thrive under such harsh conditions. Hence, cultivation of sweet sorghum in marginal and rainfed areas of SAT regions provides opportunity for small holder farmers to enhance their incomes through cultivation of biofuel crops. Promotion of sweet sorghum through favorable polices related to production, processing and marketing and more importantly pricing will pave the way for bioenergy revolution in India through agriculture intensification in dryland areas.

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Chapter 9: Policies Promoting Biofuel Production and Blending in China

P. Parthasarathy Rao, Zou jianqui, Ravinder Reddy and Lu Feng

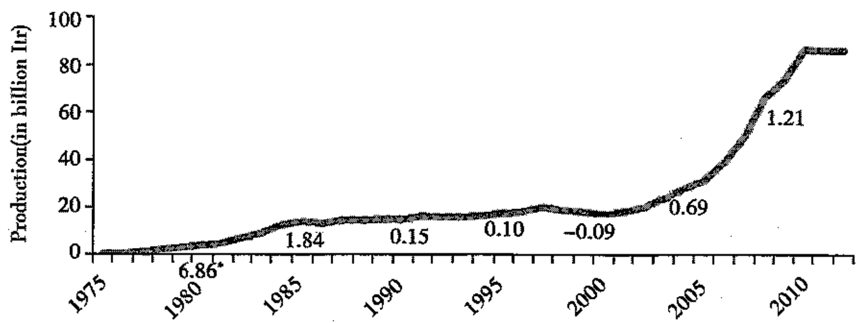
Introduction

By 2035, global energy consumption is projected to grow by 41% and consumption of liquid fuels is expected to rise by 20%-almost 15 million more barrels per day. With the world's population projected to reach 8. 3 billion by then, an additional 1. 3 billion people will need energy. To meet this demand, a diverse energy mix is needed. This is where biofuels can help; by 2035 the demand for the share of biofuels for transport is expected to grow from 2. 5% to 4% (by energy) (BP Outlook 2030, published in Jan 2013).

Why biofuels

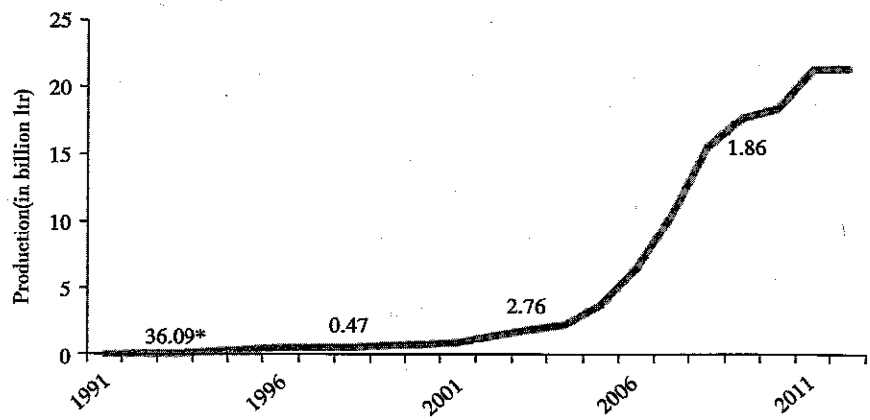
- To increase national security of energy supply
- Biofuels have the potential of substituting petroleum products (blending) within the existing available infrastructure and motor vehicle technology
- Reduction of environmental impacts: ethanol and biodiesel are important options for reducing greenhouse gas emissions and mitigating climate change
- Creates new demand for agricultural products enabling diversification
- Promotes economic activity especially in the rural areas

In view of this, production of biofuels globally has been increasing during the last 15 ~ 20 years. The pace of growth has picked up since the year 2000 due to rising crude oil prices and also due to concerns for greenhouse gas emissions. Among the biofuels, ethanol production was 80 billion liters while bio diesel production was around 22 billion liters (Figure 1 and 2). However, only 5 countries (including EU) accounted for 92% of the ethanol production globally. USA was, by far, the most important producer of ethanol accounting for 61% of global production followed by Brazil with a production of 25% and China which produces 2.5% (Figure 3). A number of other countries (Australia, India, Mexico, Newzeland etc) accounted for a small share with production growing from a small base. For biodiesel too, EU accounted for the bulk of the production, and within EU, Germany is the maincountry.



*annual growth rate(five year interval)

Fig. 1 Trends in world fuel ethanol production.



*annual growth rate(five year interval)

Fig. 2 Trends in world biodiesel production.

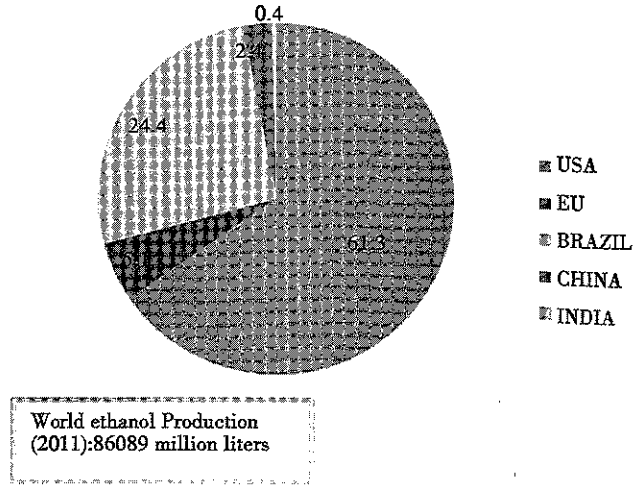


Fig. 3 Contribution of major fuel ethanol producing countries in the world Ethanol production.

To promote the use of ethanol blending, ethanol producing countries have mandated blending targets, both short term and long term targets (Table 1). Brazil had the highest blending target of 20% in 2013. Most other countries have the target of 10% ~15% by 2020.

Table 1 Fuel ethanol production and mandatory blending requirement across selected countries.

Country	Feedstock	Fuel ethanol Production (billion liters-2012)	Fuel ethanol Blending mandates (as on 2013)	Fuel ethanol Blending Target (Year)
United States	Corn	50.3	10%	20% (2015)
Brazil	sugarcane	20.7	20%	—
European Union	Wheat, Corn Barley, sugar beet	4.6	5.75%	10% (2020)
China	Corn, wheat, cassava	2.5	10%	15% (2020)
India	Sugarcane Molasses	0.3	5%	10% (2017)

China: Energy Situation

China, the most populous country with a fast growing economy, is the second largest energy consumer in the world after the U. S and is projected to move to be the largest consumer by 2014 (U. S. Energy Information Administration (EIA)). However, the oil resources in China are not enough to face this rapid growth. China's energy needs are met mostly through coal and other fossil energy, which are non-renewable in nature. It's total oil and liquids production has risen by about 54% over the past two decades. However, even with this production, China has never been able to meet its skyrocketing domestic demand. 40 percent of the oil requirements of China rely on imports, and this is a major concern for the government which it wants to bring down over time (Figure 4).

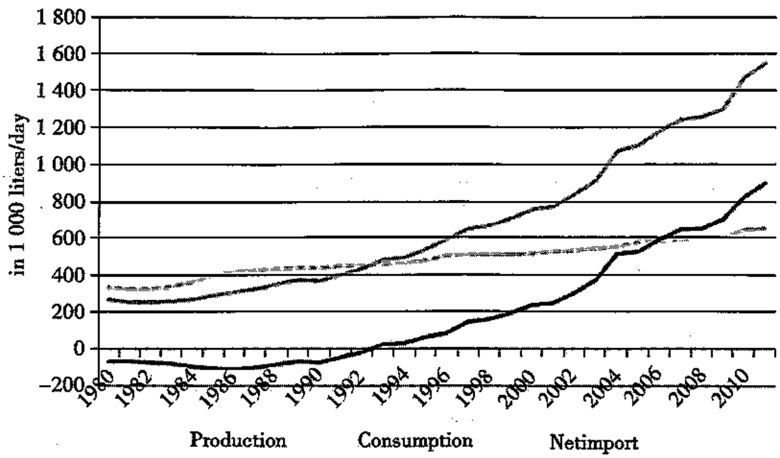


Fig. 4 China's Oil Production, Consumption and net import, 1980—2011.

Emphasis on Renewable energy in China

The Chinese government is implementing multiple policies to promote renewable energy. From 2008 to January 2012, China held the top position in clean energy investment. The Renewable Energy Law passed in 2005 explicitly states in its first chapter that the development and the usage of renewable energy is a prioritized area in energy development. The Twelfth Five-Year Plan, the current plan, also places great emphasis on green energy. Detailed policies and programs include the Golden Sun program, which provides financial subsidies, technology support and market incentives to facilitate the development of the solar power industry and there aresuggestions on Promoting Wind Electricity Industry which offers preferential policies for wind power development. Besides promoting policies, China has enacted a number of policies to standardize renewable energy products, to prevent environmental damage, and to regulate the price of green energy. These policies include, but are not limited to Renewable Energy Law, the Safety Regulations of Hydropower Dams and the National Standard of Solar Water Heaters.

China disseminated the Medium and Long-Term Development Plan for Renewable Energy in 2007, which included sub-targets of 2010 and 2020, and broken down into various renewable energy technologies.

Table 2 Renewable energy targets in the medium and long-term planning.

Target	Unit	2010 Target	2020 Target
Percentage of renewable in energy consumption	%	10	15
	Sub-targets		
Hydro power installation capacity	Million kilowatts	190	300
Biomass power installation capacity	Million kilowatts	5.5	30
Biomass briquette consumption	Million tons	1	50
Biogas for heat in rural areas	billion m	15	30
Non-grain fuel ethanol consumption	Million tons	2	10
Biodiesel consumption	Million tons	0.2	2
Wind power installation capacity	Million kilowatts	5	30
Solar PV power installation capacity	Million kilowatts	0.3	1.8
Solar water heater installation capacity	Million m	150	300

Source: Martinot and Junfeng, 2010)

The Medium and Long-term Development Plan for Renewable Energy states that by 2010, China will aim to raise the share of renewable energy in total primary energy consumption to 10 per cent and 15 per cent by 2020 (NDRC, 2007).

Biofuels in China

Two biofuels to be used for transport viz., ethanol and biodiesel are produced and used in varying degrees in China. Ethanol is mainly produced from grain, especially from maize and in addition recentlyfrom non-grain feed stalks (non-grain sugar and starch energy crops, involving cassava, sweet sorghum and sweet potato). Biodiesel is mainly produced from waste cooking oil and fat residues. In 2001 a 10 per cent ethanol blend with gasoline (E10) was used in ten provinces in China as part of a mandatory consumption program. With domestic demand for transport fuels skyrocketing, all ethanol and biodiesel produced in China is consumed domestically. However, with the increased use of mixed gasoline, it is estimated that crude oil import will be reduced by 10 million tons. This is very important for national economy and stability. Biofuels are therefore, proving to be an essential part of easing China's dependency on energy imports and securing its growth. Figure 5 shows the fuel ethanol production and areas with E10 consumption at the end of 2005. The use of E-10 gasoline in China by the end of 2010 is expected to be used in all provinces except for Tibet, Qinghai, Gansu, Ningxia, and Shanxi provinces/autonomous regions.

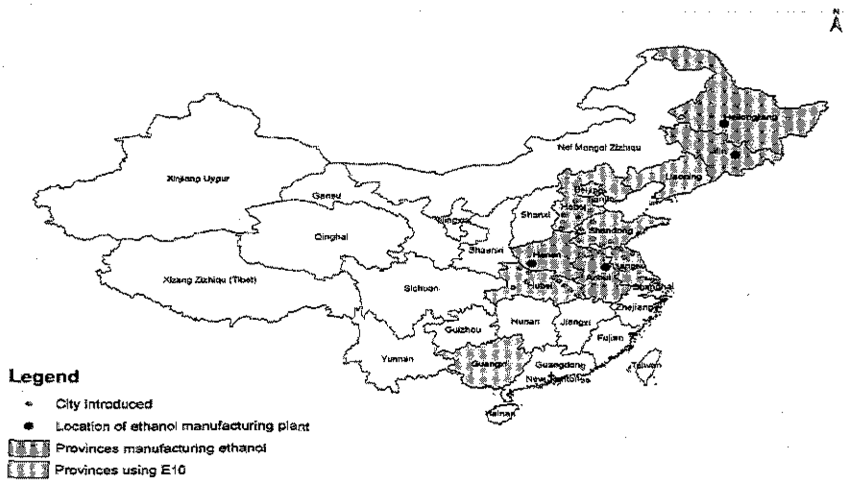


Fig. 5 China Ethanol Producers and Areas with E10 Consumption, 2005.

With a rapidly growing economy, particularly the transport sector, China is in need of expanding its renewable energy use. Along with the energy security issue, the other relevant policy issues like the rural-development and pollution problems have recently directed Chinese government to enthusiastically promote the biofuels. Until 2006, grain was the main feed stock for ethanol production. Shi, et al.

(2010) projected that to meet the target of 15% non-fossil energy by 2020, set by the State Council, about 11 million tons of ethanol and 2 million tons of biodiesel will be required. The fuel ethanol production in 2010 was only 1. 86 million tons with only 0. 37 million tons using non-grain feedstock.

Bioethanol production in 2014 is 2 700 million liters or 2. 18 million tons. Of this, 64 percent of fuel ethanol production was sourced from corn, 30 percent from wheat and 6 percent from cassava (In 2012). Biodiesel production is 966 million liters or 0. 85 million tons (Figure 6).

The initial motivation to produce fuel ethanol was to utilize the aged-grain, but the inventory of aged-grain consumed declined rapidly and has been close to zero in 2006. As of 2010, there were only five fuel ethanol plants with a production value of 1. 86 million tons in China (4. 81% and 8. 41% of fuel ethanol productions in U. S. and Brazil by volume including a 200 000 tons fuel ethanol project using cassava as feedstock.

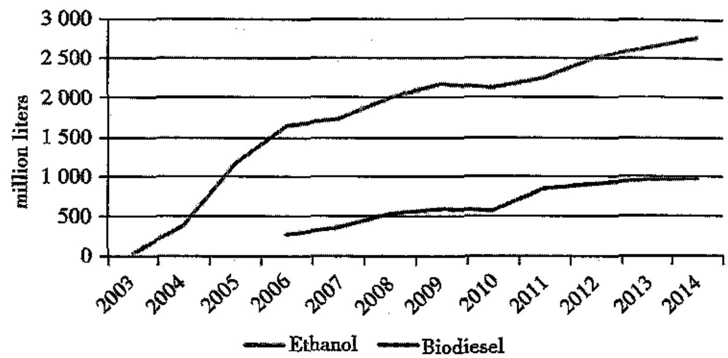


Fig. 6 Fuel ethanol and biodiesel production in China (million liters).

Biofuel Policy in China

China has been an enthusiastic supporter and promoter of biofuels in the recent decade. The factors which precipitated this policy is not only because of their focus on achieving high economic growth but to provide alternative market for grain and improve income and employment opportunities in China's impoverished rural areas and also given the fact that there has been a rise in the oil imports. The Chinese government extends its support to the biofuels for transportthrough subsidies, and other support for biofuel production, distribution and consumption.

Since 1980s, China has been supporting liquid biofuel development through investment in R&D of biofuel. However, until 2000 there was no specific government policy. In 2001, China enacted standards on "Denatured Fuel Ethanol "and "Bioethanol Gasoline for Automobiles" . As a part of this policy, China established national compulsory standards for the production of E10 (gasoline mixed with 10% ethanol).

A trial ethanol production plant with 200 000 tons capacity was established in 2001, the Tianguan Ethanol Plant, in Henan province. This led to the NDRC launching a pilot scheme promoting the use of E10 in three cities in Henan: Zhangzhou, Luoyang and Nanyang. The policy aim of the pilot program was alleviation of fuel shortages, improved urban air quality and promotion of agricultural development.

In 2004, China expanded the pilot testing program of bioethanol gasoline for automobiles to seven provinces (Jilin, Hubei, Hebei, Anhui, Shandong, Jiangsu and Liaoning) and 27 cities. Another four provinces were selected to participate in the second phase of testing. Under the pilot program, all thefuel ethanol produced must be sold to either CNPC or Sinopec. Virtually all petrol stations in China are owned by either Sinopec or CNPC

The ethanol programme which was launched by China in 2002 has steadily expanded over time, with the provision of support shifting from direct subsidies to tax breaks and low-interest loans.

China provided a total of RMB 780 million (US $ 115 million, roughly US $ 0.40 a liter) in biofuel subsidies in 2006. This included support for ethanol in the form of direct output-linked subsidies paid to the five licensed producers, as well as tax exemptions and low-interest loans for capital investment. Further support is provided through mandatory consumption of ethanol-blended fuel in ten provinces (a ten per cent blend with gasoline, E10). No official subsidies are currently available for biodiesel

Ethanol and biodiesel industries are also likely to benefit from the subsidies given to feedstock production and from the soft-loans given to research and development. Total support for ethanol and biodiesel is expected to reach approximately RMB 8 billion (US $ 1.2 billion) by 2020, according to official estimates. This does not include support to feedstock such as the RMB 3000 (US $ 437) per hectare per year available to the farmers from 2007 to grow feedstock on marginal lands.

Policies on ethanol produced from grain

In 2006, in China, maize constituted around 90 per cent of the feedstock for the production of fuelethanol and with stale grain reserves exhausted, ethanol producers had begun to use fresh maize.

Since 2008, China made ethanol use mandatory in six provinces (Heilongjiang, Jilin, Liaoning, Henan, Anhui and Guangxi) and 27 cities in Hubei, Hebei, Shandong and Jiangsu.

Table 3 Subsidy for grain based ethanol

Year	(in U.S. $ / Metric Ton of ethanol)
2005	270
2006	239
2007	202
2008	253
2009	241
2010	215
2011	203
2012	79

In 2008, the average subsidy for fuel ethanol production set by the central government reached \$253/ton, while it was approximately \$202/ton in 2007 and \$239/ton in 2006. The rise in the subsidy amount is primarily due to high grain prices in 2008. However, since 2008, China's food/feed price inflation has forced the government to tighten its control on the grain processing sector (including ethanol) with the result that there is lower financial support for grain-based ethanol production. In 2012, the subsidy for grain based ethanol had come down to as low as \$79/ton. Further, government subsidies were cut for fuel ethanol production to all the five designated plants and 10 mandated provinces.

Escalation of food prices since 2007 has triggered a series of policy shifts in the industrial use of grain for bioethanol. To reduce industrial grain consumption, the government denied approval of newprojects involving grain-based processing (including fuel ethanol plants) in 2007 and 2008. The government halted the construction of new maize-based ethanol plants and made policies to encourage the production of biofuels from non-grain feedstocks grown on marginal lands. Since then, only two new ethanol plants have been approved, a cassava based ethanol plant in Guangxi, which became operational in late 2007, and a 300 000-tonne capacity sweet potato-based plant in Hebei, which became operational in 2008.

It also prohibited the existing four approved ethanol plants from expanding their

capacity without NDRC approval. China's Ministry of Finance announced that by 2015, the government will also remove its support on the Value Added Tax (VAT) rebate and impose a five percent consumption tax for grain-based ethanol production.

Policies on ethanol from non-grain feedstock

With increasing concern of the government about the effect on grain security by using maize as the predominant ethanol feedstock, China's ethanol policy was adjusted to favour non-grain feedstocks, in particular sweet potato, cassava and sweet sorghum, grown on non-arable "marginal" lands.

Development Program for Renewable Energy 2006—2007 states that "Biofuel must not compete with grain over land, it must not compete with food that consumers demand, it must not compete with feed for livestock and it must not inflict harm on the environment". The Ministry of Agriculture, Agricultural Biofuel Industry Plan, released in July 2007, outlines the government's aim to develop new crop base for biofuel production by 2010, including sweet sorghum and cassava.

In 2006 'Renewable Energy Law of China' promoted the development and utilization of renewable energies, including liquid biofuels. It established a Renewable Energy Fund (Article 24) specifically to assist "biofuel technology research and development, standards development and demonstration projects and support biofuel investigation and assessment of raw materials, resources and information dissemination and relatedmanufacturing equipment."

The Regulation of the Renewable Energy Fund nominates the development of bioethanol and biodiesel as key priorities, and specifies the types of biofuel-related activities that should be supported. These include science and technology research, demonstration projects and manufacture of equipment locally for biofuel development.

China identified advanced biofuels as an emerging and strategic industry and made commitmentsto further development in the 12^{th} five year plan (2011—2015). The government set a target of 4 million tons for fuel ethanol production by the end of 2015 under the medium and long term development plans. However, given the inadequate supplies of non-grain feed stocks and slow progress in creating advanced technology, experts are pessimistic about reaching this target

Under the Catalogue of Renewable Energy Industry Guidance, preferential loans can be provided to biofuels projects that use non-grain feedstock. In addition, the Ministry of Finance provided subsidies to demonstration projects producing ethanol from cellulose, sorghum or cassava or making biodiesel from forest products. The Ministry of Agriculture Agricultural Biofuel Industry Plan, released in July 2007, outlines the government's aims to develop new crop bases for biofuel production by

2010, including sweet sorghum and cassava.

In December 2007, the Ministry of Finance issued policies promoting the use of non-food sources for biofuels. Subsidies were given to the projects producing ethanol from cellulose, sweet sorghum and cassava or for making biodiesel from forest products.

In 2011, the National Energy Administration (NEA) established a biofuel research center for non-grain feed stocks at China Agricultural University. This Center has two research priorities: ① to standardize procedures on collection, transportation and storage of non-grain feed stocks; and ② to standardize marginal land for non-grain feedstock production. The Govt. has approved one cassava ethanol plant which is located in Guangxi province. Farmers were authorized a subsidy of \$405 (2 616 Yuan) for each hectare of forest used for biofuels production, and a subsidy of \$365 (2 358 Yuan) for each hectare growing biofuel crops. On the basis of "non-loss and tiny-profit" principle, subsidy to distilleries would be in the range of \$213 to \$320 /t of ethanol.

2nd generation biofuels

2nd generation biofuels includes use of feedstock from agriculture and forest residues.

The production cost of 2nd generation biofuels is full of uncertainties. Production cost for 2nd generation biofuels in the literature ranges between USD 0. 60/liter and 1. 30/liter (4 937. 4 and 10 697. 7 Yuan /ton (Ralph, et al, 2010). Although the Chinese government has put lots of attention on technology R&D of 2nd generation biofuels, it will not play vital role on target achievement by 2020.

Trade and Consumption related policies

Since 2008, China made ethanol use mandatory in six provinces (Heilongjiang, Jilin, Liaoning, Henan, Anhui and Guangxi) and 27 cities in Hubei, Hubei, Shandong and Jiangsu. These locations were selected due to their close proximity to grain production. The state-run management system prohibits the private sector from importing fuel ethanol even when market prices are high. China continues to implement a temporary import tariff of five percent on Denatured ethanol (HS code: 220720). This tariff has been drastically decreased to 30 percent in 2009 to encourage additional imports of by-products and raw materials.

For indentured ethanol, the import tariff remains unchanged at 40 percent. The 17 percent on VAT imports and five percent consumption tax are applied to both denatured and undenatured ethanol.

Economic assessment of ethanol from sweet sorghum

The earliest study on economic assessment of ethanol from sweet sorghum and competing feedstock was carried out by NDRC, 2007, published in APEC (Asia Pacific Economic Co-operation), 2008, found that ethanol from sweet sorghum stalk is the lowest at 4 000 RMB per tonne compare to 4 500 from cassava/sweet potato and 5 000 from corn (1 US $ = 7.61RMB).

Another study GSI, 2008 found that the variable cost of ethanol production from maize grain was most competitive at US $ 0.37/liter followed by sweet sorghum US $ 0.45 per liter and for Cassava and sweet potato the variable cost ranges between US $ 0.46 ~ 0.52 per liter.

Another study by Shiyan et al, 2010 (World Bank) found that the variable cost of ethanol production from sweet sorghum varies between US $ 0.65 ~ 0.71 per liter; cassava US4 0.59 to 0.80 per liter; sweet potato US $ 0.58 ~ 0.68 per liter.

Under the CFC project data on processing cost and value of byproducts generated during ethanol production were not available from the distillery. Taking processing cost from the literature and assuming byproduct value ranging between US $ 0.32 ~ 0.38 per liter variable cost of ethanol per liter ranged between 0.65 ~ 0.59 which is below the world market price of ethanol. If the byproduct value is US $

0.25 per liter the variable cost is US $ 0.72 per liter. Thus full utilization of all byproducts like bagasse, Calcium carbonate, vinasse, fusel oil etc., is critical for generating positive economic returns.

Given the Chinese government's overall biofuel policy in a way that doesn't compete with arable land grain is not used as feed stock and is environmental friendly the future of non-food grain biofuel feed socks is the way forward. The government also is providing subsidies and tax breaks for ethanol produce from non-grain feed stocks.

Issues and way forward

The lack of available land on which feedstock crops can be produced is the most significant constraint on the expansion of China's biofuels production. The government has identified 35 to 75 million hectares of marginal land that might be suitable for biofuel feedstock crops. The economic, social and environmental impacts of using these lands for biofuel production will depend on local circumstances. The extent to which marginal land could viably support biofuel crops is uncertain. If biofuel crops divert water and fertilizer from food crops, it could affect food availability and prices.

Ensuring low and stable feedstock costs is one of the major challenges facing the development of starch-and sugar-based biofuels in China. Supply of cassava would be a concern as China depends on its imports for cassava supply. In 2001, China became the largest cassava importer in the world. By 2006 China's share of worldwide cassava (fresh or dry) imports reached its peak of 88.5%. In the case of sweet sorghum, domestic production is very limited due to lack of existing domestic market. The storage and pretreatment of sweet sorghum also presents challenges.

Social issues

Raising rural incomes and alleviating rural hardship is a key policy priority for the

Chinese government. The Chinese government sees strong potential for biofuels to help build a "new socialist countryside" by providing rural development opportunities that will help lift incomes, absorb the surplus rural labor force and alleviate hardship for China's rural poor.

The extent to which the use of non-grain feedstock will lift farmer's income is uncertain. The NDRC estimates that if cassava ethanol production reaches 1 million tons and the fresh cassava price is RMB 470 per ton, household income for those cultivating cassava could increase by RMB 940 (US $ 137) per year (this figure is based on 2.7 million households each cultivating 2 mu (0.13 ha) cassava).

There is a need to examine more critically the contract farming arrangements to ensure benefits to the farmers. Farmers may be selling to a captive market with very limited option for alternative markets thus giving an upper hand to the distillery.

Food v/s fuel: Although the policies for biofuel in China are now attempting to engineer a move towards non-grain feedstock, the reality is that the majority (up to 80 per cent) of the feedstock for ethanol production will be maize or wheat in the near future.

Environmental issues

The use of biofuels can lead to a reduction in harmful pollutants, although this does depend on the vehicle in which they are used. Cultivation of forests and grassland result in a significant release of carbon dioxide because of either burning or decay of organic matter in plant biomass or soils (Forgone et al., 2008). The resulting "carbon debt" of land conversion can be repaid by biofuel use over time. But until that time, net GHG emissions will be higherthan that for fossil fuels. The production of potential feedstock such as sweet sorghum, which is drought resistant and can be grown in saline-alkaline soils (FAO, 2002), could benefit the environment by controlling erosion, storing carbon and helping to reverse desertification. The potential positive impacts could include erosion control and increased forest cover. Potential negative impacts could include biodiversity loss, increased pest and fire risk, erosion, and water-quality impacts due to pesticide and fertilizer runoff (cultivation of marginal.

While most renewable energy technologies have reached or even surpassed the 2010 targets, the non-grain fuel ethanol is lagging behind in meeting its target of 2 million tons for 2010 and 10 million tons for 2020. Non-grain feedstock such as cassava, sweet sorghum and sweet potato grown in low productive arable lands or marginal lands has enough potential to meet ethanol targets in 2020. Various policy measures, particularly, financial incentives, such as direct subsidies to non-grain sugar and starch based ethanol and cellulosic ethanolwould be needed to overcome the costs barriers to biofuels in China.

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Chapter 10: Sweet Sorghum Bagasse Based By-products as Feed Resources

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The sustainability of number-driven growth in livestock output would be severely constrained by declining per capita land availability and feed and fodder scarcity, implying higher prices. Further, due to population boom, the available land is mostly diverted for cultivation of cereal and commercial crops to meet the urgent human needs resulting in decrease in land for fodder cultivation and forcing ruminants to depend on crop residues/ agricultural by-products. The rising cost and availability of conventional crop residues like sorghum stover, maize stover and paddy straw, which are widely used for feeding milch buffaloes and cattle, is a growing concern. Therefore, exploration of alternate sources of crop residues/ agricultural by-products is urgently needed to increase fodder supply and to decrease feeding costs. Under the prevailing circumstances, sweet sorghum by-products like sweet sorghum bagasse, an agro-industrial by-product of ethanol industry and sweet sorghum stover can be used as livestock feed resources.

Sweet sorghum (*Sorghum bicolor* (L) Moench) is well adapted to the semi-arid tropics and is one of the most efficient dry land crops to convert atmospheric CO_2 into sugar. Because sweet sorghum requires less water and has higher fermentable sugar content than sugarcane, which contains more crystallizable sugars, it is better suited for ethanol production than sugarcane or other sources. The emerging bio-fuel needs, therefore offer expanded markets for sweet sorghum in India, China and several African countries for ethanol production. The stillage from sweet sorghum after the extraction of juice has a higher biological value than the bagasse from sugarcane when used as forage for cattle, as it is rich in micronutrients and minerals (Reddy et al., 2005). A crop yielding 40 ton fresh stalk/ha and 60%

extractability would yield about 6 ~ 7. 5 ton/ha dried stalk residue. The residue left after extracting the juice from stalks can compensate the fodder loss.

Despite the increasing industrial usage, farmers still consider sweet sorghum a multipurpose crop from which they also expect grain for human consumption and fodder from the stover. While the demand for sweet sorghum for ethanol production provides important income for dry land farmers, it also diverts biomass away from livestock, thus adding to the feed scarcity problem. Using the bagasse remaining after juice extraction (for ethanol) and the stripped leaves could compensate for fodder loss and provide an additional source of income. Thus, fodder quality of feed made of leaf stripping and bagasse is similar to premium stover from grain sorghum (Blummel et al. 2009). However, the stalk residue after extraction of juice is generally considered to be low in protein and energy and has poor digestibility mostly due to highly lignified cell walls. The incorporation of concentrates into ruminant diets is intended to increase dietary energy, proteins, minerals and vitamins and to optimize the efficiency of feed utilization. But, the palatability and utilization of unconventional feedstuffs and agro-industrial by-products can be improved by incorporating into complete diets (Reddy and Reddy 1999). The present chapter addresses the nutritional value of sweet sorghum by products like sweet sorghum bagasse and sorghum stover and their utilization in the livestock feeding as alternative feed resources. This work was undertaken under NAIP-ICAR - ICRISAT project.

Sweet sorghum Bagasse (SSB)

Physical and Chemical evaluation of SSB

The bulk density (kg/m^3) of ground SSB was substantially higher by 62. 5% than chopped SSB (4. 0 v/s 6. 5 kg/cft) with a reduction in particle size from 1. 5 ~ 2. 0 cm to 665. 303 μ. The increased bulk density on grinding was due to decreased particle size. This in turn would help in economic handling, transport and storage. The particle size (μ) modulus of uniformity, modulus of fineness and molasses absorbability (%) of ground SSB were 665, 5 : 2 : 3, 5. 3 and 33, respectively. It was higher than the particle size of sorghum stover ground through 8 mm sieve. The result indicated that, the fibre from SSB was less brittle and more resistant and yielded more coarse particles. The average absorbability of molasses by ground SSB was 33.0 per cent indicating that 100 kg of ground straw with an average particle size of (665.303 ± 1.52) μ has absorbed 33 kg molasses (Nalini Kumari et al., 2013a).

SSB contained 3.94% crude protein and it was comparable with sorghum stover (3.8%) and lower than maize stover (5.5%). The major elements Ca and P content was 0.82% and 0.47%, respectively and the trace elements Cu, Mn, Zn and Fe content of SSB was 57.40mg/kg, 47.67mg/kg, 48.78mg/kg and 0.27mg/kg, respectively. The gross energy content of SSB was 16.85 MJ/kg of dry matter (Nalini Kumari et al., 2013a).

Metabolizable energy (ME) content of SSB is comparable with sorghum stover and maize stover (Fig. 1). The *in vitro* dry matter digestibility of SSB was 40.27%. The nutritive value of SSB in terms of digestible crude protein (DCP) and Total digestible nutrients (TDN) was 1.58 and 51.59% in Murrah buffaloes and 1.86 and 50.59% in Deccani sheep, respectively.

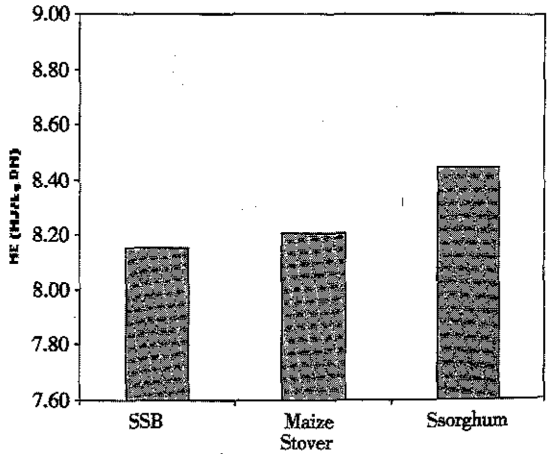

Fig. 1 Comparision of ME of SSB and stovers.

SSB silage

After extracting the juice, the moisture content of the SSB along with leaves can be around 50-60 per cent and it can be made to ensile the fresh material-whole without any further addition of moisture or additives to make it cost effective. Ensiling of whole and chopped SSB silage without any additives for 30 days period resulted in good quality silage as assessed by the appearance and smell of the silage (Nalini Kumari et al., 2013b). They reported that, there was no significant difference found in the chopped and unchopped SSB silage in dry matter (DM) intake of Deccani sheep. The DM digestibility of unchopped SSB silage based ration was significantly ($P < 0.05$) higher compared to chopped SSB silage based ration. The reduced DM digestibility of chopped silage can be explained by a reduction in ruminal digestion and it might be due to increased passage rate of particles which resulted in lowered ruminal retention time. Chopping significantly ($P < 0.05$) depressed (7.73%) the CF digestibility of SSB silage. There was no significant difference observed in the N balance between the treatment groups. It revealed that, the SSB can be made into silage in whole form without reducing the particle size as the disintegrated fibre during the extraction of juice makes the fibre to be acted upon by the microbes in the rumen similar to that of reduced particles in chopping.

Processing of SSB into complete feed

Any improvement in the nutritional quality of crop residues and agro-industrial by-products will enhance nutrient supply to the livestock. Now a days there has been tremendous increase in the development and application of processing methods of feeds for ruminants. Processing methods reduce the wastage, increase the bulk density and increase palatability and feed consumption. It also contributes to the ease of handling, feeding, storage and transport.

In a complete feed, all feed ingredients inclusive of roughages are proportioned, processed and mixed into a uniform blend, which is freely available to the animal to supply adequate nutrients. The product is fed as sole source of nutrients. This system ensures the supply of balanced nutrients, controls the ratio of concentrate to roughage, helps in improved utilization of low grade fibrous agricultural residues. The complete feed can be prepared either in mash form or pellet (expander extrusion) form.

Roughage to concentrate ratio in complete rations

The level of roughage and concentrate in the complete feed is apparently of major importance for efficient utilization of dietary nutrients for production. The degree to which concentrates affect fiber digestion may depend on the nature and proportion of the concentrate as well as the quality of the roughage (Matejovsky and Sanson, 1995). Therefore, there may be an optimal concentrate supplementation level for a given kind of roughage, which allows the animal to use the nutrients in the roughage most efficiently. Characteristics and level of roughage in ruminant rations are crucial for maintaining desirable VFA patterns in the rumen and could influence the microbial protein production and animal performance. High microbial protein production decreases the need for supplementing rumen undegradable feed protein by proportionally increasing carbon and nitrogen fixation into microbial cells there by reducing fermentative carbon (C) losses in CO_2 and CH_4 and nitrogen (N) losses in the urine (Blummel et al., 1999).

An *in vitro* study was conducted by Nalini Kumari et al. (2012a) to evaluate the optimum roughage to concentrate ratio in complete rations using SSB as sole roughage source. Eight rations were prepared with roughage to concentrate ratio of 100: 0 to 30: 70. Significantly ($P < 0.01$) higher *in vitro* gas production volume (ml) at 24 h incubation, *in vitro* organic matter digestibility (IVOMD) and metabolizable energy (ME) were recorded for the rations with roughage (R) to concentrate (C) ratio of 80R: 20C to 30R: 70C compared to 100R: 0C and 90R: 10C rations. Whereas, truly digestible organic matter (TDOM) was significantly ($P < 0.01$) higher for the rations 90R: 10C to 30R: 70C compared to sole SSB. Among all the rations, 30R: 70C has shown highest ($P < 0.01$) IVOMD, ME and TDOM and the trend observed in ME, TDOM values reflected that, as the concentrates proportion increased, these values were also proportionately increased. The partitioning factor (PF, mg/ml) value obtained was ranged from 2.79 ± 0.01 to 3.18 ± 0.01 for the experimental rations. The rations from 90R: 10C to 30R: 70C were significantly ($P < 0.01$) higher in PF, microbial biomass production (MBP) and efficiency of microbial biomass production (EMBP) compared to the ration contained 100 per cent SSB. There was no significant difference observed for PF and EMBP among the rations from 60R: 40C to 30R: 70C, wherein the SSB proportion decreased from 60 to 30 per cent in the rations. Whereas for MBP, no significant difference was observed in the rations from 50R: 50C to 30R: 70C. It was suggested that SSB can be included in complete rations for ruminants at the level of 50 ~ 60 per cent for economic milk and meat production.

In another study, Nalini Kumari et al. (2013c) assessed the effect of different roughage to concentrate ratios of SSB based complete rations (60R: 40C to 30R: 70C) on the growth performance and carcass characteristics of lambs. Statistically, differences in daily weight gain and feed conversion ratio among the lambs fed four experimental rations were not significant ($P > 0.05$). The cost per kilogram gain was significantly ($P < 0.01$) higher in ram lambs fed 30 and 40% SSB based rations (Table 1). No significant difference and trend was observed in preslaughter weight, empty body weight, carcass weights, dressing percentage, wholesale cuts and edible and non-edible portions of experimental animals. The efficiency of microbial synthesis was comparable among all the rations (Nalini Kumari et al., 2012b). The results of the experiment indicated that SSB can be included at 60 % level in the complete diet for economical mutton production from growing lambs.

Expander extruder processing

The expander extrusion system combines the featured of expanding (application of moisture, pressure and temperature to gelatinize the starch portion) and extruding (pressing the feed through constrictions under pressure). Expander and extrusion of complete rations proved successful, which stimulates bacterial action in the rumen, increase the bulk density, palatability and nutritive value, reduces wastage, increased efficiency in utilization of feeds by 5% ~10% and 3% ~5% improvement in rate of weight gain and reduced cost of feed per unit produce (Samanta et al., 2003; Praveen Kumar et al., 2004).

Table 1 Average daily gain, Feed conversion efficiency and cost of feeding in growing Nellore x Deccani ram lambs fed rations with different ratios of SSB and concentrate.

Parameter	Complete ration			
	60% SSB	50% SSB	40% SSB	30% SSB
Initial body weight (kg)	10.68	10.65	10.53	10.60
Final body weight (kg)	24.60	25.37	25.98	26.13
Average daily gain (g)	77.31	81.76	85.83	86.30
Feed intake (g/d)	866.82	847.53	867.45	853.10
Feed conversion ratio (kg feed/kg gain)	11.42	10.57	10.17	9.96
Cost/kg gain (₹)	62.83[c]	69.00[bc]	76.76[ab]	85.43[a]

[a,b,c] values bearing different superscripts in a row differ significantly ($P < 0.01$)

Studies in buffaloes

In a six months growth trial, 50: 50 SSB to concentrate contained complete feed was prepared and fed to the growing Murrah buffalo bull calves in three forms i. e. mash form, expander extruded pellet form and the chopped SSB mixed with concentrate (Sheshaiah et al., 2012a). The effect of complete feed of SSB in mash form was compared with conventional sorghum stover based complete feed in same form. Significantly higher feed intake (kg/d) was observed in buffalo calves fed expander extruded ration compared to those fed chopped ration might be due to easier consumption of expander extruded pelleted ration compared to chopped form of the ration (Table 2). Significantly higher average daily gain (ADG, g) and lower feed conversion ratio (FCR) in buffalo calves fed expander extruded pelleted ration compared to chopped, mash and sorghum stover mash rations might be due to higher feed intake and efficient digestibility of nutrients in expander-extruder rations than chopped and mash form of the rations. However, the average daily gain (g) and FCR was almost similar in buffalo calves fed either sorghum stover or SSB rations (Table 2). The cost (₹) per kg gain in buffalo calves fed expander extruded pelleted ration was significantly lower ($P < 0.01$) compared to those fed chopped, mash and sorghum stover mash rations. This might be due to lower FCR and lower cost of SSB than sorghum stover.

Table 2 Effect of feeding differently processed sweet sorghum bagasse based complete rations on growth rate, feed efficiency and cost economics in bull calves

Parameter	Complete ration			
	Sorghum stover mash	SSB		
		Chopped	Mash	Pellets
Initial weight (kg)	136.90	137.00	137.30	136.90
Final weight (kg) **	209.60^{b}	205.20^{b}	209.70^{b}	224.70^{a}
Weight gain (kg) **	72.70^{b}	68.20^{b}	72.40^{b}	87.80^{a}
Average daily gain (g/d) **	484.67^{b}	454.66^{b}	482.67^{b}	585.33^{a}
Feed intake (g/d) *	4.50^{ab}	4.42^{b}	4.49^{ab}	4.56^{a}
Feed conversion ratio (kg/kg gain) **	9.29^{b}	9.84^{b}	9.36^{b}	7.80^{a}
Cost/kg gain (➢) **	74.55^{a}	63.22^{b}	61.07^{b}	52.44^{c}

^{a,b}values bearing different superscripts in a row differ significantly, $*P<0.05$; $**P<0.01$

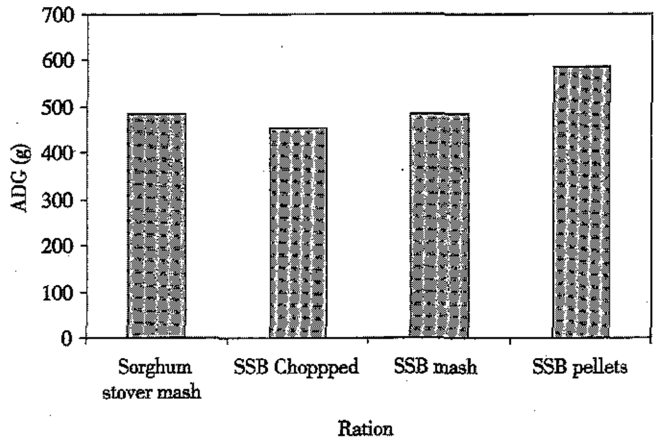

Fig. 2 Effect of differently processed SSB based complete ration on ADG in buffalo bull calves

In another experiment, the above feeds were fed to lactating Murrah buffaloes. The feed intake (kg/d) was significantly higher for pelleted ration in comparison to chopped, mash rations and sorghum stover based rations but, the feed intake (kg/d) was comparable among rations SSB based chopped, mash rations and sorghum stover based rations (Sheshaiah and Ramana Reddy, 2012b). The milk yield and 6% FCM yield (kg/day) and total solids, solids not fat (SNF), milk fat and protein yield (g/d) was significantly higher in the buffaloes fed expander extruder ration than those fed SSB based chopped, mash rations and sorghum stover based rations (Table 3). The higher daily milk and milk constituent yield might be due to efficient digestibilities of nutrients and higher feed intake in lactating graded Murrah buffaloes fed expander extruded ration than those fed chopped, mash rations and sorghum stover based rations.

However, the total solids, solids not fat, milk fat and protein per cent in lactating graded Murrah buffaloes fed differently processed SSB complete rations and sorghum stover complete mash were comparable among all the rations. The feed conversion ratio (kg/kg milk yield and kg/kg FCM yield) and cost of feed (₹) per kg milk yield and per kg FCM yield was significantly lower in lactating buffaloes fed SSB based expander extruded ration compared to chopped, mash rations and sorghum stover based rations while, the difference in feed conversion ratio was not significantly different among these rations (Table 3). The lower feed conversion ratio kg/kg milk yield and kg/kg FCM yield in lactating buffaloes fed expander extruded ration might be due to efficient utilization of nutrients resulting higher milk yield, 6% FCM yield (kg/d) over other three rations. The cost of feed (₹) per kg milk yield and per kg FCM yield in the lactating buffaloes fed sorghum stover based ration was significantly higher due to lower feed efficiency and higher cost of sorghum straw compared to SSB.

Table 3 Effect of feeding differently processed sweet sorghum bagasse based complete rations on quality, quantity and economics of milk production in lactating graded Murrah buffaloes

Parameter	Complete ration			
	Sorghum stover mash	SSB		
		Chopped	Mash	Pellets
Milk yield (kg/d)	5.29[b]	5.17[b]	5.54[b]	6.91[a]
6% FCM yield (kg/d)	6.29[b]	6.24[b]	6.51[b]	7.74[a]

（续表）

Parameter	Complete ration			
	Sorghum stover mash	SSB		
		Chopped	Mash	Pellets
Milk constituents yield (g/d)				
Total solids	937.92^{b}	940.94^{b}	998.31^{b}	1 217.54^{a}
Solids not fat	549.10^{b}	546.99^{b}	546.69^{b}	731.08^{a}
Milk fat	388.82^{b}	393.44^{b}	411.62^{b}	486.46^{a}
Milk protein	228.53^{b}	226.45^{b}	242.65^{b}	306.80^{a}
Feed intake (kg/d)	12.04^{a}	11.76^{b}	12.13^{a}	12.16^{a}
Feed conversion ratio (kg/kg FCM)	1.91^{b}	1.88^{b}	1.86^{b}	1.57^{a}
Cost of feed/ kg FCM (₹)	15.36^{a}	12.11^{b}	12.16^{b}	10.57^{c}

^{a,b}values bearing different superscripts in a row differ significantly ($P<0.05$)

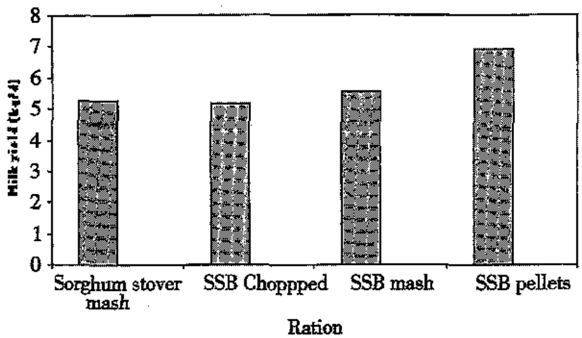

Fig. 3 Effect of differently processed SSB based complete ration on milk yield (kg/d) in lactating Murrah buffaloes

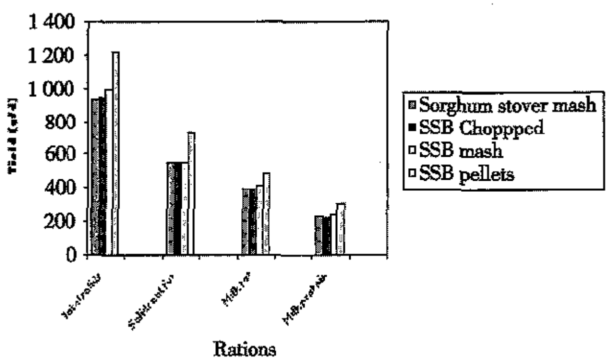

Fig. 4 Effect of differently processed SSB based complete diet on milk constituents

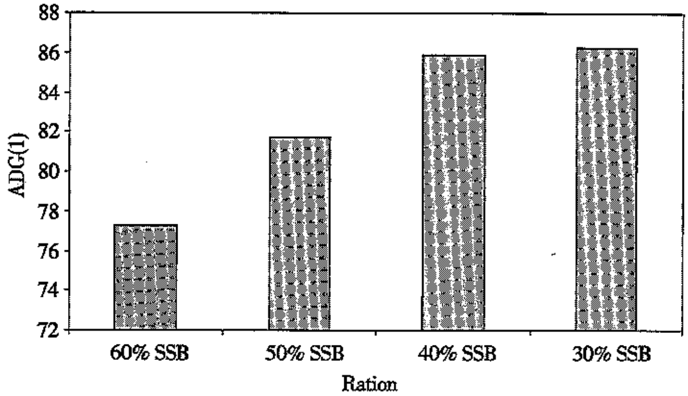

Fig. 5 Effect of different SSB to concentrate proportions of complete ration on ADG inNelloreX Deccani ram lambs

Studies in sheep

The SSB based complete diet containing 50 : 50 roughage to concentrate ratio was processed into chopped, mash, expander extruded form and compared with sorghum stover based complete diet (50 : 50) in mash form in Nellore x Deccani ram lambs through a growth-cum-metabolism trial. Processing complete diets into different forms significantly influenced fortnightly body weight changes of lambs during 180 days of feeding. The total weight gain, average daily gain and feed conversion efficiency of ram lambs fed expander extruded SSB based complete diet was significantly higher than chopped, mash and sorghum stover mash diets and it was comparable among the these three diets (Table 4). Though feed intake was not significantly different among all the rations, lambs fed pellet and mash diets consumed 16.74 and 6.14 per cent more compared to chopped form which might be attributed to the increased palatability.

The efficient utilization of absorbed nitrogen due to matching supply of energy and minerals provided optimum environment on pelleted diet reflected in an increased ADG. The expander extruded SSB based complete diet was more economical to gain one kg of body weight than the chopped and sorghum stover mash and it was com-

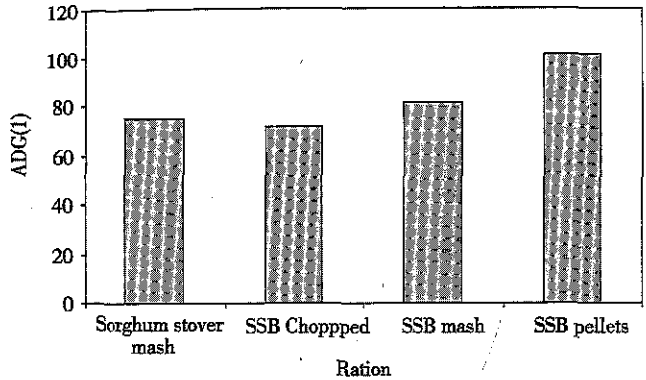

Fig. 6 Effect of differently processed SSB based complete diet on ADG in NelloreX Deccani ram lambs

parable in ram lambs fed sorghum stover and SSB based mash diets. The feed intake of lambs fed SSB mash and sorghum stover mash diet was comparable, which indicated the higher palatability and acceptability of

Table 4 Effect of feeding differently processed SSB based complete diets on growth rate, feed intake, feed efficiency and cost of feeding in growing Nellore x Deccani ram lambs

Parameter	Complete Ration			
	Sorghum stover mash	SSB		
		Chopped	Mash	Pellets
Initial body wt. (kg)	10.57	10.57	10.65	10.53
Final body wt. (kg) **	24.13[b]	23.53[b]	25.37[b]	28.77[a]
Average daily gain (g) **	75.37[b]	72.04[b]	81.76[b]	101.30[a]
Feed Intake (g/d)	804.70	790.31	847.53	910.791
Feed conversion efficiency (kg feed/kg gain) *	10.69[b]	11.13[b]	10.57[b]	9.05[a]
Cost/kg gain (₹) *	75.15[b]	71.56[b]	69.00[ab]	60.89[a]

SSB as [a,b]values bearing different superscripts in a row differ significantly, ** $P<0.01$; * $P<0.05$.

roughage source and it was also equally acceptable and palatable with sorghum stover. Among all the groups, the average dry matter (DM) intake (g/kg w0.75), digested DM, organic matter and crude protein were higher ($P<0.01$) in lambs fed expander extruded diet. The cellulose digestibility was higher ($P<0.05$) in lambs fed SSBP diet than those fed SSM and SSBC diets. Intake of digestible crude protein (DCP, g/d) and metabolizable energy (MJ/d) were higher ($P < 0.01$) in lambs fed SSBP diet. The expander extruded diet had higher ($P < 0.01$) DCP and N ($P < 0.05$) balance compared to other three diets. Expander extrusion of SSB based complete diet resulted in improved ($P < 0.01$) efficiency of microbial protein synthesis (Nalini Kumari et al., 2014).

The pre slaughter weight was significantly higher in lambs fed expander extruded form ration compared to those fed chopped, mash and sorghum stover mash rations. The carcass weight of pelleted diet fed lambs was 33.37, 21.44 and 24.93 per cent higher than chopped, mash and sorghum stover mash diets. Processing could not influence the dressing percentage, proportions of whole sale cuts, edible and inedible portions, yield of visceral organs, and per cent yield of bone, meat and fat and bone, meat ratio in different wholesale cuts as well as carcass and meat quality.

SSB based complete feed blocks

A feeding trial with growing bulls was conducted at ILRI, comparing the SSB based (50%) complete feed block with sorghum stover based (50%) feed complete block. It is promising to observe that, there was no difference in feed intake between the SSB based block (7.52 kg/d) and sorghum stover based feed block (7.31 kg/d) fed bulls. There was also no significant difference between the daily live weight gains of the bulls fed SSB based block (0.73 g/d) and sorghum stover based feed block (0.82 g/d) which confirms the value of SSB as feed block ingredient (Blummel et al., 2009).

Sweet sorghum stover (SSS)

Sweet sorgum stover is the residue of the sweet sorghum crop after harvesting the grains. In an experiment, Babu (2013) evaluated the growth performance of the lambs fed SSS based complete ration having 60R: 40C roughage to concentrate ratio and compared with traditional crop residues like sorghum stover and maize stover based complete diets. The average daily gain, feed conversion efficiency and dry matter intake of the growing lambs were comparable, but the cost per kg gain was significantly ($P < 0.05$) lower in the SSS based complete ration fed lambs. The digestibility of nutrients among the ram lambs fed various experimental rations was similar. All the lambs were in positive N balance. No significant difference was observed in pre slaughter weight, empty body weight, carcass weights, dressing percentage, wholesale cuts, edible and non-edible portions, lean percent, fat per cent, bone percent and meat: bone ratio among the experimental lambs. The results indicated that the sweet sorghum stover, a newer roughage source could be used as an alternative to sorghum stover and maize stover and can be incorporated at 60 per cent level in the complete diets of growing lambs in mash form without affecting the performance, nutrient digestibility and carcass characteristics.

Conclusion

The results of the experiments indicated that, SSB, an agro-industrial by product and sorghum stover, agricultural by product can replace the traditional sorghum stover as feed resources for ruminants and the SSB can be effectively conserved as silage. The SSB and sorghum stover allow incorporation into complete feed at 60 per cent level in feeding of growing lambs to meet the growth requirements provided, sufficient digestible protein is made available in the form of concentrate in the ration for economic rearing of ram lambs. Further, feeding of complete rations in the form of expander-extruder pellets proved superior over chopped and mash form of SSB and mash form of sorghum stover rations.

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Chapter 11: SWOT Analysis of Sweet Sorghum as Biofuel Crop in China

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1 Introduction

In recent years, there is considerable debate on alternative feedstocks for bioethanol production to meet the mandated blending requirements with fossil fuels (petrol). Worldwide, a number of feedstocks ranging from cereal grains, to sugarcane juice to molasses (obtained from conversion of cane juice to sugar) are commonly used. However, these feedstocks are being critically examined for their role in increasing food costs and compromising on food security. Sweet sorghum has emerged as an alternative duel purpose crop whose stalks are converted into juice for ethanol production and grain for food.

In China, maize grain is the main feedstock for ethanol production followed by wheat. However, since 2009, owing to food security concerns due to rising price of maize grain, the government has stopped giving licenses to new distilleries using grain for ethanol production and instead the policy emphasis shifted to non-food grain crops like cassava, sweet sorghum and sweet potato to meet the ethanol blending target.

ZTE, in Inner Mongolia, was one of the first distilleries in China to start a 30 000 ton / year ethanol plant using sweet sorghum as feed stock. The sweet sorghum stalk is obtained through contract farming arrangement with farmers in close proximity of the plant. These contract farming models, used for production and supply of sweet sorghum stalks to ZTE which does the crushing for production of ethanol, have been successfully implemented over the last 4 years from 2010—2014. Presently, the company is pilot testing the ethanol blending with petrol before starting commercial production. A number of issues in using sweet sorghum as an alternative feedstock for ethanol have emerged that need to be addressed for a more sustainable sweet sorghum ethanol value chain.

Prior to carrying out a comprehensive analysis of the sweet sorghum to ethanol value chain, a SWOT analysis was carried out at ZTE distillery, Inner Mongolia which looked at production of sweet sorghum. A SWOT analysis i. e., Strengths, Weaknesses, Opportunities and Threats was carried out for sweet sorghum ethanol value chain established at ZTE Inner Mongolia, PR China from 2010-2014. Such an analysis is useful to researchers, policymakers and also all the stakeholders in the value chain for creating a sustainable sweet sorghum-ethanol value chain.

2 The SWOT analysis

A SWOT analysis is a strategic planning tool used to evaluate the Strengths, Weaknesses, Opportunities and Threats involved in a project or a business venture. It involves specifying the objectives of the project, and analyze the strengths and weaknesses of the project that are internal to the project and hence under the control of stakeholders for taking advantage of the strengths and or overcoming the weaknesses. The opportunities and threats emanate from the external environment (infrastructure, institutions, policy etc) which are not under the control of the value chain stakeholders. However, knowledge of such opportunities and threats can be helpful in taking timely corrective action as required.

The general matrix used for SWOT analysis is

Strengths	Weaknesses
Opportunities	Threats

The schematic view of the contract farming models has already been presented in the earlier chapters. A summary of the major strengths, weaknesses, threats and opportunities of the ZTE distillery pertaining to the function of the entire sweet sorghum bioethanol value chain is provided in this chapter.

3 Strengths

- Availability of high genetic variability of sweet sorghum lines (as energy crop) with partner organization (SRI) provides good breeding opportunities in order to develop new improved cultivars suitable for ethanol production.
- Genetics of crop are relatively well known, genetic diversity is extensive and maintained.
- Crop can grow in broadenvironmental and soil ranges from tropical to temperate regions. It could be a promising energy crop for small and large scale value chains.
- Sweet sorghum is a C4 plant with high photosynthetic efficiency and can produce high biomass in short time. It is characterized by high water, radiation and nutrient use efficiencywhen compared with other energy crops (e.g. maize, sugar cane).
- Fullmechanization of cultivation is possible, thus allowing for industrialized value chains.
- Commercial proven technologies for crop production and stalks processing for ethanol production are available.
- By-products like leaves and bagasse can be used asfodder, feed, and fuel and for co-generation. Vinasseand calcium carbonate are other by-products with economic value.
- Local research facilities at regional agricultural research station at Inner Mongolia established by SRI, facilitated ZTE to test all the sweet sorghum cultivars developed by private and public sector seed companies and screened for their resistance to pest and diseases, adaptability, stalk and sugar yields.
- The company has diversified business activities and products and has strong financial health to withstand any uncertainties in their business plans and to meet the requirements in promotion of biofuels.
- Farmers are willing to grow sweet sorghum by devoting a part of their land for its

cultivation, because of the support of the company and also because of assured market.

- As an efficient C4 plant, sorghum is one of the most efficient cropsto convert atmospheric CO_2 into sugar and starch.

4 Weaknesses

- Specific varieties of sweet sorghum (as energy crop) with high Brix% for ethanol production are insufficient. Availability of commercial well-defined (sweet sorghum with the objective to maximise sugar content (Brix %) and stalk yields) cultivars are limited.
- Genetic improvement and management of crop for increasing sugaryield has lagged behind other crops.
- There exists a knowledge gap on biotic and abiotic stress management (e.g. pests and diseases, soils, and water).
- Sweet sorghum as energy crop is still relatively new to many farmers. If not actively promoted, there is a threat to be not sufficiently recognized by the farmers.
- Sugars in the crop degrade rapidly. The fresh stalks have to be processed quickly (within 24 hours) and cannot be stored for a long period. Delay in harvesting and crushing reduces juice and sugars in the stalks.
- Harvesting technologies for separating seed, stalk and leaf are not yet mature. Henceharvesting is laborious and time consuming. The crop has short harvesting season, usually 20-40 days, resulting in a limited feedstock supply period through the year.
- The economics of crop cultivation and returns are almost on par with the Maize crop. Any tilt in the economics of sweet sorghummay cause the farmersto switch back to maize cultivation thus affecting ethanol production.
- Sale of the stalks depends on the company (ZTE) which is having a buy-back agreement with the farmers. Farmers have no other choice/company to sell the stalks, and thus the company influences the stalk price and hence the farmers are thusvulnerable.

5 Opportunities

- Emergence of new market opportunities for ethanol fuel (e. g. aviation, heavy vehicles, households, rural electrification) may provide opportunities for ethanol.
- The Government of China has an ambitious target for ethanol blending program in the foreseeable future.
- Discussions on food-fuel conflicts create opportunities for dual purpose crops such as stalk and grains. This may also improve public acceptance of ethanol from sweet sorghum.
- Government policies in China are favourable for promoting ethanol from non-food crops that can be grown in marginal environments.
- By-productsof ZTE like bagasse as source of alternative fodder and feed to livestock, and vinasse (the liquid remaining after separation of ethanol) can be used as fertilizer and methane gas production. Hence, scope for exploring new products and markets.

6 Threats

- Increasing global prices of agricultural commodities may also affect and reduce the competitiveness of ethanol.
- Technological breakthrough in production of ethanol from biomass (2^{nd} generation technology) could reduce competitiveness of ethanol from sweet sorghum.
- Limited information is available on cost of production of ethanolfrom sweet sorghum in comparison with other crops.
- Move towards alternative modes of transport, including electric andhybrid automobiles, may affect biofuel markets worldwide.
- Changes in ethanol-promoting policies as well as trade policies may negatively affect the prospects of ethanol.
- General increasing resource competition (land, water) for food, fuel, and fibres may lead to conflicts and reduce available land for crop cultivation.

Chapter 12: Future Prospects of Sweet Sorghum for Ethanol

A Ashok Kumar, Belum VS Reddy,
Ch Ravinder Reddy and P Parthasarathy Rao

1 Introduction

The world is movingfast towards industrialization and urbanization leading to rapid economic development. Energy is the most critical inputfor this development and to all the nations; energy security has become as important as food and nutritional security. Since the advent of industrialization in the seventeenth century, fossil fuels have been major energy sources. However, in the recent times, demand for developing renewable energy sources such as biofuels is increasing owing to the limitations of fossil fuels in terms of availability and cost, and also due to the environmental pollution associated with their extraction and use. During the last 1 ~2 decades the emphasis on promoting alternative energy sources, such as biofuels, is accelerating. Corn, sugarcane, sugar beet, Atrophy, and Panama are some of the well-known biofuel feedstock crops used for production of ethanol and biodiesel – the two most prominent biofuels. Sweet sorghum is one such alternative biofuel feedstock for bioethanol as it is unique with negligible food-fuel tradeoff associated with its use, unlike corn and other grains. Moreover, it doesn't require huge quantities of water and fertilizers for its cultivation like sugarcane. Sweet sorghum is also suited to a wide range of agro-ecologies, from tropics to temperate climates and from low input to intensive agriculture, making it amenable to cultivation in many parts of the world. Further it tolerates drought and heat better than corn, sugar beet and sugarcane, which are common in most parts of the world.

The experiences of ICRISAT, as project executing agency in implementing sweet sorghum ethanol value chain projects, are presented in this chapter. ICRISAT facilitated the implementation of the NAIP-ICAR sub-project on 'Value Chain Model for Bioethanol Production from Sweet Sorghum in Rainfed Areas through Collective Action and Partnership' in India and the CFC-FAO project on 'Enhanced livelihood opportunities of smallholders in Asia: linking smallholder sweet sorghum farmers to the bio ethanol industry' that focused on developing and establishing sustainable sweet sorghum bioethanol value chain models in India and China by addressing issues in the value chain components. The sweet sorghum value chain encompasses sweet sorghum production and transportation of stalks to distillery or crushing unit, crushing stalks for juice extraction, syrup production from juice, ethanol production from juice and or syrup, ethanol blending with gasoline and utilization of the by-products, bagasse, vinasse, etc. For successful implementation of the value chain models, based on the core competencies, a consortium of partners under NAIP project involving public sector research and development organizations (ICRISAT, DSR, IICT, CRIDA, ILRI and SVVU) and private sector ethanol distillery (Rusni Distilleries Ltd.) in India, and under CFC project, MAU-Parbhani, Tata chemicals Ltd. (private sector distillery) in India and Sorghum Research Institute, China and ZTE in Inner Mongolia (private sector distillery), China was created. Both these consortia are unique in the sense that the private-public-people-partnership (PPPP) formed the core of the consortiato achieve the goals by harnessing the synergies of the partners. This chapter describes major issues encountered during implementation of the work plans, the issues related to sustaining the sweet sorghum based ethanol value chain in India and China under the two projects implemented by ICRISAT, and the way forward.

2 Issues

2.1 Consortium building and management

Selection of partners and bringing together all the partners on the same platform is the first step towards developing a consortium. It is most difficult though not impossible, as the work culture and administrative practices of the public sector are different from the private sector. The public sector is bound by the agreements and procedures and therefore the partnership is more durable. On the other hand, the private sector is more influenced by the financial aspects of the enterprise and also by the nature and composition of its partners, working or otherwise. Private sector usually does not share the technology, its implementation process and financial implications like the costs and benefitsnor do theyusually reveal thefacts about the crucial processing and machinery used. They also do not share the information on production and outputs of the distillery including byproducts and this is more pronounced in big industrial giants like ZTE, because of their company policy. Therefore, private sector partnership is loosely bounded in the consortium by virtue of its objectives, competitiveness, proprietary and profitability motive.

The private sector partner, Rusni distilleries and TCL in India could not sustain their operationsthroughoutthe project period under the centralized model for several reasons. Lack of experience in backward linkages with farmers who supply stalk to the distillery is one of the factors that had a bearing on the success of the value chain. However, factors like *inadequate working capital*, *disharmonious relationships* among company partners, and unfavorable government pricing policy for ethanol weresome of the important ones that determined the economic viability of the distillery leading to its closure. As a result, ethanol production from the juice or syrup in the value chain on a commercial scale was hampered in India during the project period. Contrary to this, ZTE in China is very professional, resource rich and committed and hasmore supportive biofuel policy of China and is thus able to successfully implement the sweet sorghum to ethanol venture.

2.2 Value chain

Value chain describes the chain of all value addition activities from production to final consumption. The chain encompasses inputs-processing-outputs-utilization, and the stakeholders involved in these activities. The innovations in sweet sorghum based ethanol value chain developed in these projects can be successfully commercialized only if all the stakeholders in the value chain are benefitted, i. e., the farmers, input suppliers, the Decentralized Crushing Unit (DCU) Cooperative and the distillery. We assessed the viability to all stakeholders in value chain, using the extensive data available from our work in Indiaand the details aregiven below.

(1) Viability to the farmers: Sweet sorghum is a new crop to the farmers in the project clusters in India though some farmers used to cultivate grain sorghum in the project areas. The cultivars and cultivation practices for sweet sorghum are different from grain sorghum. It took some time for the farmers to get tuned to sweet sorghum cultivation. During the rainy seasons (Kharif) of 2008—2009, the average net income realized by farmers from sweet sorghum cultivation was Rs 6490 ha^{-1} excluding family labor. However, during 2009—2010 and 2010—2011, the net returns were negative due to adverse climatic conditions that affected all crops in the project sites. The negative net returns from sweet sorghum were the lowest among the rainfed competing crops like grain sorghum, sole maize and maize and pigeonpea intercrops in Ibrahimbad cluster villages (project location), in the Medak district of Andhra Pradesh, India.

(2) During the project period, sweet sorghum average stalk yields with minimum 11.8t/ha (centralized area) had increased to maximum of 20t/ha and grain yields ranged from 0.9 to 1.2t/ha. However, to sustain the farmers' interest in cultivating sweet sorghum, the current sweet sorghum productivity should increase from 20 ~ 30t/ha and grain from 0.9 ~ 2.0t/ha with a higher realization price of Rs 1 200t^{-1} for stalk and Rs 12 000t^{-1} for grain. It is not difficult to achieve the proposed yields of stalk and grain as the farmers who adopted all of the improved technologies have realized the set targets under rainfed conditions in India.

(3) Viability of Decentralized Crushing Unit (DCU): Sustainability of any rural agro-industry depends on economic and operational feasibility and market linkages and the DCU is no exception. There are several factors that influence the cost of syrup production. These are: juice extraction efficiency (of the machine), sugar content (Brix %) in the juice, conversion of juice into syrup, and labor and staff employed in managing the crushing unit. This model was tested only in India and hence the results mentioned here are

based on our experiences and learnings in India.

In the course of sweet sorghum ethanol value chain project implementation, the juice recovery increased from 26% in 2008—2009 to 30% in 2010—2011, reflecting an increase of 15% in juice extraction efficiency. There is only one sweet sorghum hybrid released in India (CSH 22SS) and thishybrid was used in all the years and it performed well in the farmers' fields. However, there is a need to developcultivars that give an increased Brix% (from 15% Brix to 18%) which will contribute to increase in the viability of the unit. It is not difficult to achieve the target in the next five years as there is significant variability for Brix% and juice volume in the breeding populations being handled.

Labor is the most important input in DCU operations. The labor cost in sweet sorghum syrup production was high (29% of total cost) in 2008-2009 but towards the end of the project it was reduced by 10%. However, there is good scope for improving labor efficiency through improved mechanization and processing at DCU. It is possible to improve the crushing efficiency by modifying the crusher rollers. The modifications made in the crusher helped in increasing the juice recovery from 260 l to 300 L. t^{-1} of stalks (efficiency increased by 15%). Further, the by-product, bagasse feed-chain could contribute to the revenue by the sale of up to 50% of the bagasse to help bring down the operating cost of DCU. The bagasse was sold as fodder at Rs1. 0 kg^{-1} with minimal processing (chopping). The above factors helped in reducing the cost of syrup production from Rs 32 kg^{-1} (first year of crushing) to Rs 22. 5 kg^{-1} in the last year of its operations; the average production cost of syrup during the four year period, 2008—2009 to 2010—2012 being Rs 27. 2 kg^{-1}. Further, there is a scope for exploring value addition for syrup for use in food industry and demand for bagasse from alternative industries like fuel and paper industry, thus strengthening the viability of DCU.

During the project period, the distillery offered a maximum of Rs 10 kg^{-1} of syrup on the basis that 3 kg of syrup (70% Brix) is required to produce one liter of ethanol (which was then priced at Rs 27 l^{-1}). In such a scenario (selling syrup at Rs 10 kg^{-1} when the production cost is Rs 27. 2 kg^{-1}), DCU should look for alternative markets for syrup, such as food/pharmaceutical/ feed industry which give higher price. A part of the syrup produced in the DCU was sold for instance at Rs 22.5 kg^{-1} to the dairy farms. While we worked on increasing the efficiencies and reducing the unit cost of syrup, the DCU provided an opportunity to enhance the period of raw material availability to distillery for ethanol production.

2.3 Viability for distillery (Centralized area)

(1) Ethanol productivity in India: Productivity of ethanol per ton of sweet sorghum stalk stood at 40 l at Rusni Distilleries. It is thus not economical to produce ethanol at the prevailing market prices. Therefore production needs to be improved to 55 l t^{-1} of stalk through 1) Improving the crushing efficiency to increase juice recovery from the present 300 L. t^{-1} to 500 L. t^{-1} of stalk; 2) using feedstock with increased Brix% (at least 16%); and 3) increasing the fermentation efficiency by 3% above the present level. Thus, it is hoped that changes, if effected as above, would help enhance ethanol yield.

(2) Marketing: Ethanol blending targets are not really enforced in many countries. It is left as an option because of which the demand is not forthcoming to ethanol. Ethanol recovery at 55 L. t^{-1} at the sale price of Rs 27 l^{-1} will fetch the industry Rs 1 485 t^{-1} of stalk crushed. This leaves Rs 485 towards cost of production of ethanol after meeting the raw material cost at Rs 1 000-t as seen in the project. However, ethanol market price (Rs 27 l^{-1}) needs to be increased to Rs 32 l^{-1} to make the industry viable. The industry should also explore the market for vinasse, by-product from ethanol production that would further contribute towards the viability of the industry, apart from the bagasse.

(3) Supply chain management in India: Currently the operating window for distillery is only for two months with the available sweet sorghum cultivars which are productive only in the rainy season. No industry will be financially beingviable with such short harvest window. The feedstock supply window needs to be increased to at least four months. Further, the industry should be able to utilize other feedstocks, such as broken/molded grain, spoiled potato, cassava tubers, etc., for

ethanol production when sweet sorghum is not available. The extension of sweet sorghum feedstock supply is possible provided there are staggered plantings and cultivars of different maturities made available to farmers for cultivation in the rainy season. Thirdly, sweet sorghum varieties that have potentially high stalk sugar yields in postrainy season and in summer (where irrigation is available) should be developed through appropriate breeding methods. Fourthly, adopting and linking DCUs with distilleries will help provide syrup to distillery for use as feedstock. This will help to run the distilleries for several months in a year because syrup can be stored for more than a year unlike the stalk juice which gets fermented within two hours after crushing.

In China, the sweet sorghum crop duration is long (140 days) and it produces high yields. Developing cultivars with different maturity duration ensures feedstock supply for longer periods. One more advantage in China is that the temperatures are low (12 ~ 20℃) at the time of harvest and harvested sweet sorghum stalks can be heaped and supplied to the distillery within 48 hours without any deterioration in stalk sugars. There is no post rainy season in China as the temperatures are very low for crop cultivation. The ZTE has the provision of making syrup and storing during the season that can be used for processing during winter season. Sweet sorghum is also an excellent rotation crop in Inner Mongolia where continuous planting of sunflower has led to pest and diseases build up.

In China, the ZTE adopted two supply chain models; Model 1 (the company leased land) and Model 2 (contract farming) where the farmers produced stalks with buy-back agreement with the ZTE. In both the models, higher productivity was recorded (50 ~ 70t/ha) over a period of four years. This high productivity was not only because the crops were grown on saline - alkaline soils of Inner Mongolia but alsoowing to the adoption of improved cultivars, best-bet practices coupled with irrigation and favorable environment for crop growth. More than any aspect, the China biofuel industry is supported by government policy to enhance and sustain the production of ethanol from non-grain feedstocks like cassava, sweet potato and sweet sorghum. These crops can be grown on marginal lands and thus do not compete for land used for food crops. Going by the infant industry argument, the government has also announced some subsidies forviz. , biofuel crop production and ethanol production using non-food grain crops. The government is keen to achieve its target of renewable energy in total energy under its five year plans. Unlike India, the government ofChina is implementing the blending mandate of 10% ethanol with gasoline in selected provinces and cities. This assures demand from oil companies for biofuels.

(4) other issues in commercialization

Labor cost is a major factor that contributes to nearly 55% of the cost of production in sweet sorghum, with harvesting operations being the most labor intensive. The sugarcane crushers used initially in the project did not show good recovery of juice. So, the crushers need to be specifically designed for sweet sorghum. Attempts made by the project to develop and improve the harvesters and crusher rollers yielded partial success. There is scope for bringing in further refinements with harvesters and crushers with a view on commercialization.

The Government of India has come out with a Policy for minimum blending (10%) of ethanol with gasoline but the ground level regulations for implementation are lacking. To augment ethanol production and achieve the mandated blending targets, the Government should come up with a clear policy road map to promote alternative feedstocks like sweet sorghum as ethanol from sugarcane molasses alone will not be able to meet the ethanol blending requirements as demanded by the policy. Therefore, strong measures are required in terms of capital subsidy for industry on the basis of sops provided for infant industry status. Government should also take measures to strengthen entrepreneurial skills of farmers and recognize DCU as small-scale agro-industry enhancing business opportunitiesfor local entrepreneurs.

In China, pilot testing of ethanol from sweet sorghum is nearing completion and commercial production is expected to start from July 2014 (informed by ZTE official).

3 The way forward

Sweet sorghum cultivation is going to stay as the energy requirement of nations is exponentially growing each day and the renewable options that are viable are limited. However, it needs to go a long way to become a viable entity. Apart from sustaining the environment where it is targeted, the bottom line of any enterprise is to ensure economic benefits to all the stakeholders who in this case are the farmers, DCU cooperatives and distillery enterprises. In this value chain, apart from ethanol, there are other by-products like bagasse for animal feed or bio compost both at DCU as well as at the distillery. Efforts should be directed to further enhance the efficiency in all the operational issues raised above in a way to ensure benefits to all the players in both DCU and centralized areas.

(1) Cultivar development and crop production: Most of these recommendations apply to both India and China.

- Developing high yielding cultivars with high sugar and juice yields of different maturity duration and their dissemination to farmers
- Improving resistance to shoot fly to make the cultivars adaptable to different sowing dates and seasons
- Emphasizing strict adoption of recommended cultivation practices by all the farmers so as to achieve higher stalk productivity particularly in India (>30t/ha)
- Developing improved sweet sorghum harvesters to reduce the cost of cultivation
- Streamlining the stalk supply chain innovation to reduce the time lag between harvesting and crushing and reducing the relative cost of harvesting and transportation.

(2) Juice recovery and fermentation efficiency.

- Designing customized crushers for sweet sorghum to enhance the juice recovery from present level of 32% to 50% both at DCU and distillery in India

- Setting up enough crushers to handle the targeted feedstock on a daily basis to enhance juice recovery in India
- Reducing time lag between juice extraction and conversion to syrup so as to enhance syrup recovery.
- Increasing juice storability and fermentation efficiency for higher ethanol recovery by identifying appropriate fermentation inhibitors, yeast strains and enzymes to convert starch and sugars to ethanol

(3) By-product utilization

- Setting up a feed processing plant for studying the economics of different feed processing methods to add value to bagasse
- Developing value chain for bagasse utilization to enhance the price of bagasse
- Setting up studies to determine vinasse value and marketability

(4) Markets for syrup, ethanol and by-products.

- Even if the cost of syrup production is reduced to Rs 20 kg^{-1}, it is difficult to sustain the DCU when the syrup is sold at the rate of Rs 10 kg^{-1} to the distillery. So arrangements ought to be made to sell a portion of syrup to food/pharm/feed industries to make DCU viable in India
- To enhance bagasse value for use as animal feed (after meeting the fuel needs at DCU), working with fodder traders and dairy farmers to get higher price for bagasse is essential for improving the bagasse value chain in India.
- Attempts should be made at distillery to explore the use of vinasse as fertilizer
- Distillery should utilize bagasse for second generation ethanol production apart from using bagasse for cogeneration

The Government should take measures to implement strictly the policy of 10% blending of petrol with ethanol. It is likely that if the distilleries get higher support price for ethanol, they may offer higher price for syrup as well as stalks.

The distillery should have the facility to use multi-feedstocks to enable it to operate for optimum capacity utilization. Capacity utilization would be sub-optimal with a single feedstock that would increase capital costs. Further, the distillery should have good Research and Development support equipped with not only appropriate technical staff skilled in the production of ethanol from various feedstocks but also in input and supply chain management assets.

In China, the sweet sorghum value chain is operational owing to higher productivity, supply chain and processing efficiency and strong govt. policy backup which is making it a successful venture. In the years to come, it should stand on its own to increase the sustainability of the value chain. However, for scaling up there is a need to identify marginal lands where sweet sorghum can be grown i. e. , sweet sorghum growing domains where it would also be possible to set up distillery benefitting from government programs. Presently, such statistics related to marginal lands are limited. In addition, social, environmental and sustainability issues of growing sweet sorghum need to be addressed in depth.

It can be said with confidence that with the leads obtained from implementation of the projects in India and China and the measures suggested above will render sweet sorghum ethanol value chain sustainable, both economically and environmentally. This can be made possible by the collective action of researchers, farmer cooperatives, ethanol industry and policymakers. Considering large environmental and economic benefits to the society, it is important to pursue sweet sorghum ethanol at a higher scale for many years to learn more and improve the efficiency of value chain.

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