Chapter VI: Models for sweet sorghum feedstock management for ethanol

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I. Introduction

Technological change, competition and globalization are leading to a restructuring of agri-business research and development processes and strategies across the world. Technology transfer is not simply copying technologies passively from others, but an active and creative process of adaptation that recognizes indigenous capabilities. The establishment of small-scale industries in rural areas will help in reducing poverty and unemployment. At the same time, it is an efficient way of preventing migration from the rural areas to urban by creating new employment opportunities in the villages. The majority of rural populations in developing countries and least developed countries are lacking agro based small-scale enterprises that give judicious income to farmers through value addition to their agri-produce. What is needed is a fresh and comprehensive approach, integrating crop production enhancement and value addition of the produce through village-based agro-industries, involving farmers as stakeholders in processing their own produce.

The advantages of small-scale agro-industries are that they: (i) do not require large amount of capital and high technologies; (ii) can create employment facilities with relatively small investment; and (iii) are flexible enough to adjust to changing conditions during periods of economic recession or crises. Therefore, a business model for small-scale farmers that helps them add value to their produce will result in improved livelihoods and help in protecting the environment at the same time.

II. Background and rationale

Food and energy security are critical for the sustenance of modern civilization. Considering the volatility 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 40-50 t ha^{-1}) 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 supply chain management.

III. 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).

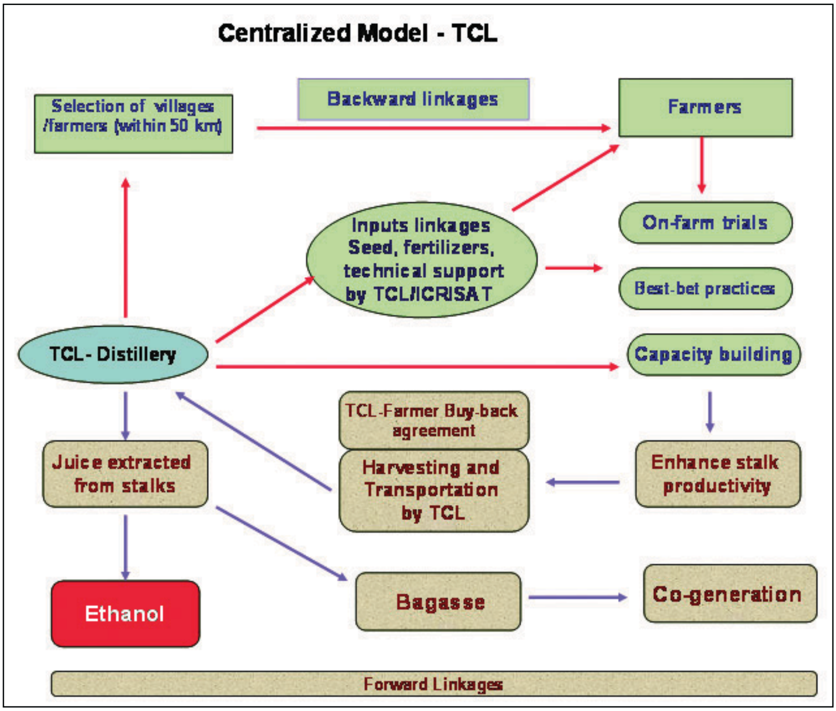

Fig. 1. Centralized model: linking farmers to distillery.

A) Rationale

In the centralized model, a typical 40 kilolitres per day (KLPD) ethanol distillery requires feedstock from 8000 ha of crop area per year spread over two seasons – 3500 ha in the rainy season (rainfed) and 4500 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:

- 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.

B) Institutional arrangement for linking farmers to biofuel industry

Under the centralized model, a cluster of villages within a 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 multilocation 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.

C) 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 Crushing Unit Model

A) 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).

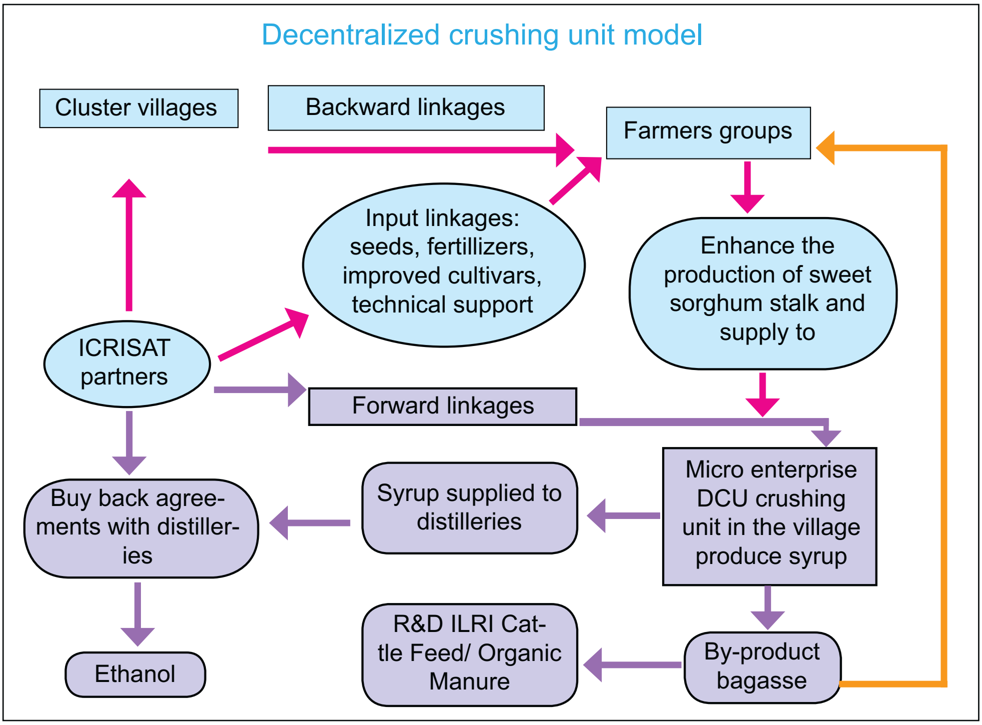

Fig. 2. Decentralized model: Linking farmers to DCU.

B) 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 (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

C) Issues with DCUs

- High initial investment for the establishment of DCU.
- Assurance by distillery only for small quantities of syrup procurement from DCU.
- Criteria for price fixation for syrup for industry and payment schedule.
- Basis for payment to farmers (stalk weight, syrup (Brix %) or any other).
- Procedure for giving back bagasse to farmers or use of bagasse by the DCU.

D) Establishment of DCUs

i) Selection of villages and site for DCU

An exhaustive survey needs to be conducted to select appropriate villages for establishing DCUs for syrup production. In the ICRISAT-NAIP (National Agricultural Innovation Project) initiative on 'Sweet Sorghum Ethanol Value Chain Development' the villages were selected on the basis of (i) their accessibility; (ii) natural resources (soil, water, topography, etc); (iii) social harmony; (iv) dryland cropping systems; (v) sources of irrigation; (vi) farmers' response to the idea and their willingness to participate in the project activities; and (vii) the feasibility of growing sweet sorghum and finding a suitable site for setting up a DCU. Scientists from ICRISAT and a non-governmental organization (NGO) teamed up to select the villages and to identify an appropriate site for establishing the DCU. After the reconnaissance survey in different areas of Medak district in Andhra Pradesh, India, tentative clusters of villages (Ibrahimbad, Erragunta Thada, Seethaya Thanda, Durgaya Thanda, Umla Thanda, Sikindalpur Thanda and Laxman Singh Thanda under Narsapur Mandal) were identified. In-depth discussions were held with the village administration, ie, 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 panchayat land (community land) to set up the DCU.

After analyzing the merits and demerits of the different clusters, it was found that the Ibrahimbad cluster in Medak district was suitable for large-scale sweet sorghum cultivation and for establishing the pilot DCU. Subsequently, seven villages were identified (Table 1) in this cluster within a 5-7 km radius from Ibrahimbad, the nucleus village.

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

S.No	Village name	Number of households
1	Ibrahimbad	192
2	Errakuntla Thanda	67
3	Seethya Thanda	21
4	Durgaiah Thanda	20
5	Umla Thanda	19
6	Sikindlapur Thanda	123
7	Laxman Thanda	54
	Total	514

As there was no panchayat land available in the village, a couple of farmers offered their land on lease for establishing a DCU. Of three sites inspected, 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 five-year period @ Rs 10,000 (USD 200) per annum. It was proposed at the meeting that the lease amount would be paid by the group of sweet sorghum farmers and this was agreed upon unanimously by the farmers. The land owner agreed to abide by the village farmers' decision on the annual land rent and the concurrence of the gram sabha (village meeting) was taken to this effect. A lease agreement was signed between the land owner and the farmer group in the presence of the village administration to facilitate the establishment of the DCU.

ii) 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 Ibrahimbad village and located alongside a main road that connects the cluster village to the Narsapur Mandal headquarters in Medak district, Andhra Pradesh. 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. 3).

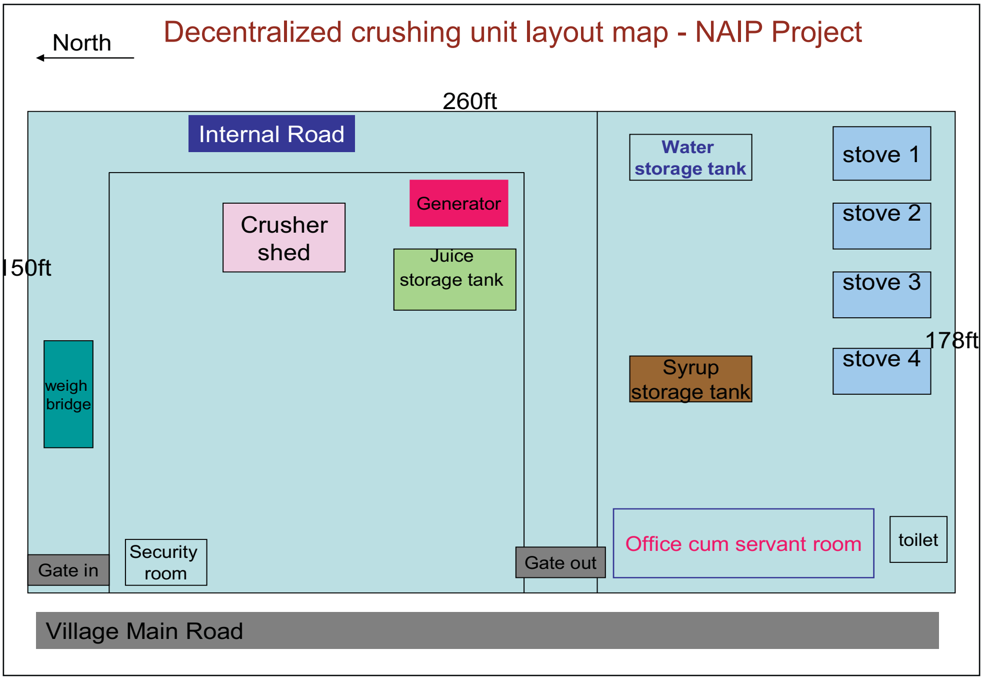

Fig. 3. Layout of the decentralized crushing unit at Ibrahimbad village, Medak.

iii) Plant and machinery

In order to procure reliable and efficient machinery for the DCU, enquiries were made with local jaggery making farmers and industry personnel. The following pieces of equipment and machinery were procured for the DCU.

- Crusher
- Weigh bridge
- Generator
- Chulhas (stoves)
- Juice boiling pans
- Juice boiling accessories (stirrer, dragger, sieves and scum storing drum)
- Electric motors and pumps
- Supply pipelines
- Juice storage tank
- Steel baskets
- Motors

a) 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 hr^{-1} crushing capacity was chosen after consultations with local dealers, jaggery making farmers and a couple of crusher manufacturers. To improve the crushing efficiency, the rollers of the crusher were modified to suit sweet sorghum stalks to increase juice extraction. The crushing efficiency is 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 300 liters t^{-1} of stalk compared to sugarcane crusher which was around 260 l t^{-1}. The crusher being critical in DCU should have minimal maintenance costs and relatively fewer mechanical problems. Its spare parts and repairing facilities are easily available. The specifications of the crusher are presented in Fig. 4.

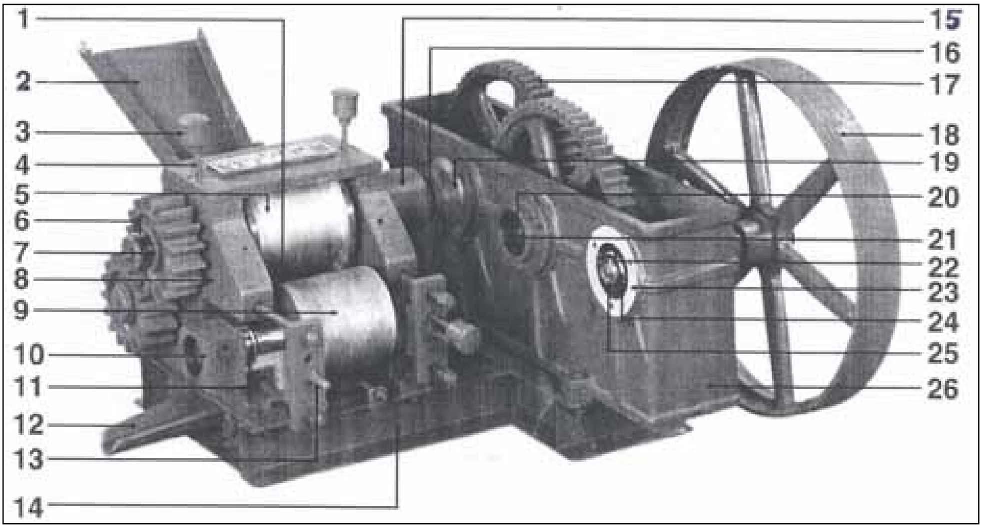

Fig. 4. Crusher parts.

1. A rail scraper
2. Feeder
3. Grease cup
4. Grease pipe
5. Railer
6. Key for upper gear
7. Steel gear (16 teeth)
8. Side plate
9. BC railer
10 Bearing holder
11. Railer bush GM
12. Juice outflow channel
13. Head screw 14. Base frame plate
15. Joint coupling
16. Axial
17. Steel gear 62 teeth
18. Pulley
19. Hosing
20. Center bolt
21. Counter axel
22. Bearing seal
23. Hosing packing
24. Bearing 32211
25. Main drive
26. Gear box

The crusher at DCU-Ibrahimbad, Medak Dist. has a capacity of 2 t hr^{-1}. It can be operated with a 20 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 l 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.

b) Weigh bridge: Farmers bring their stalks in tractors, bullock carts and sometimes on trucks. It is important to weigh the stalks coming to DCU for crushing as 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 recorded in a computer attached to the weigh bridge which issues stalk weight slips with the farmer's name and other details.

c) Generator: Three-phase (industrial) power supply is required to run the crusher. That makes it convenient and cheaper. There was no industrial power line close to the 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 a year in the rainy season.

d) Chullas: These are earthen stoves for boiling the juice. They are made of bricks and cemented with pressed mud. Each chulla measures 2 m in diameter, and is embedded at 1 m. depth beneath the soil surface. An exhaust outlet 3 m high was erected 2 m from the chullas, also made of bricks and pressed mud. Each chulla has a 3 m long air passage channel below the soil surface connecting the stove and exhaust tower. The bagasse feeding opening is of 0.4 m length, located on the rim of the chulla.

e) 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 2 m and a depth/height of 0.5 m . 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. One additional set of boiling pans are necessary for the convenience of continuous operations.

f) 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.

g) 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 connecting 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 (1 m length and 1 m width) are used to shift the bagasse from the crushing site to the drying yard.

iv) Other facilities

a) 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.

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

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

IV. 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, major emphasis was placed on sweet sorghum cultivation in the rainy season. Inputs like seed, fertilizer and herbicide were supplied on credit to enable local farmers cultivate sweet sorghum. The costs of the inputs were recovered while making payments for the stalks supplied by farmers to the 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, farmers' participatory field trials and demonstrations in the cluster villages were undertaken to enhance productivity.

Under the present project, the services of an NGO, and 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. The objective of including the NGO and farmers' association in project activities from the beginning of the project and in all activities is to strengthen these community based organizations (CBOs) in operation and management of the DCU, so that these stakeholders will continue the project activities even after completion of the project period to sustain project interventions.

V. Crushing and syrup production

1) Procurement of raw materials

Procurement of raw materials is critical to the success of the model as it involves winning the confidence of farmers through timely harvest (Box 1), stalk procurement and prompt payment. Under the ICRISAT–National Agricultural Innovation Project under the aegis of the Indian Council for Agricultural Research (ICRISAT-NAIP-ICAR), the services of 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 a steady supply of stalks for crushing at the DCU (Box 1) and payments for stalks were made on pre-agreed price (buy-back agreement) per ton of stalk.

Box 1

Stalk supply work contract model

Issues: During 2008 (the first year of project implementation) some difficulties were observed in harvesting of stalks, loading, transporting, unloading and crushing of stalks leading to delayed crop harvesting, delayed transport, delayed crushing and finally low juice recovery due to desiccation of stalk. The labor problem was rampant in all the project villages and it also coincided with harvesting of paddy crop in the villages.

Educating farmers: The crushing capacity at DCU was increased by 50% by adding additional crusher for 2009 season. All the farmers were educated from day one during the 2009 season that the sweet stalks should be harvested at right time (physiological maturity) and the stalks should be transported to DCU on the same day on a cart by cart basis soon after harvesting. They were also told that attending to harvesting on time and transporting cart by cart to the DCU would help to retain the original weight of the crop.

Innovation: Looking into the economics of syrup production, timely harvesting, stalk supply, crushing and converting into syrup on the same day is beneficial for both to the farmers and syrup making unit. Keeping in view the requirements of the DCU and prevailing labor problems, the project and sweet sorghum farmers in the village evolved a work contract model through negotiations with the bullock cart owners that involves harvesting, loading of stalks in farmers filed, transportation and unloading of stalks at DCU at one go by the cart owners/ their appointees. ICRISAT scientists and AAI facilitated the dialogue between bullock cart owners and farmers to arrive at common price for the entire task. As per this understanding, the farmers have to pay the contractor Rs 220 per ton of stalk for the entire task. It is being run smoothly.

Benefits:

- The sweet sorghum crop was harvested in a timely manner.
- There was no time lag between harvesting of stalks and their transportation to DCU.
- Timely crushing of stalks at DCU lead to increased juice recovery.
- This enabled farmers to attend to other work (most farmers are working at DCU during this period)
- This served to give gainful employment to a group of laborers through sweet sorghum harvesting and transportation.
- There was increased efficiency of the DCU in terms of timeliness of operations like crushing stalks and producing syrup.

2) Crushing

Sweet sorghum stalks should be crushed on the same day of harvesting. Any delay in crushing results in low juice recovery and eventually low syrup yield. The DCU established at Ibrahimbad village, Narsapur Mandal, Medak district, Andhra Pradesh, has the capacity to crush 2 t hr^{-1} and 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 the start of crushing operations depends upon the 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. Generally sugarcane crushers are used for crushing sweet sorghum; here, however we have modified the crusher rollers to improve crushing efficiency (Box 2).

BOX 2

Improved efficiency of the crusher

The development of a high juice recovery 3-roller crusher with 25 hp motor was developed with the help of private sector company Adarsh Engineering Company, Nagpur, Maharashtra. The rollers of the crusher were designed specifically for sweet sorghum so as to crush the stems completely, as sweet sorghum stems are softer than those of sugar cane. The grooves on the rollers are flat with a channel on either side to drain out the juice conveniently. As a collective effort (public-private-partnership), the crusher was evaluated for its performance using different cultivars, which were crushed after 24-hr to 36-hr after harvest. It was observed that the average juice recovery from the sweet sorghum cultivars (RSSV 9, CSH 22SS and ICSV 93046) ranged from 350 to 425 l t^{-1} of stalk. The percentage increase in juice recovery when compared to the sugar cane crusher (260 l t^{-1}) was found to increase by 34 %. With this increased efficiency, the average productivity of syrup has increased by 25% and overall syrup production cost decreased by 22%. This innovation will have positive effect on viability of DCU operations and economics.

3) Bagasse

The solid bagasse which remains after crushing sweet sorghum stalks is a by-product of the DCU which has several potential uses. Bagasse is used as fuel in chullas at DCU for boiling juice in syrup making. Other potential use is as source of animal feed, directly after chopping or after ensiling. It has also been used as a source of pulp for the paper industry. At DCU, 50% of bagasse is consumed as fuel for making syrup and the rest as fodder for livestock supplied to farmers and fodder agents (Box 3).

BOX 3

Bagasse as fodder

Issues: During 2008 (the first year of project implementation)some difficulties were observed in sweet sorghum bagasse utilization. A large amount of bagasse piled up while crushing the sweet sorghum stalks for juice extraction. Though we encouraged the farmers to take the bagasse for use as animal feed, they did not come forward with the apprehension that animals don't like the bagasse. We have since conducted on-farm experiments with farmers' participation where the bagasse was fed to their milch cattle that demonstrated higher intake by the animals that resulted in increased body weight, milk output and marginal increase in fat content of the milk.

Educating farmers and fodder agents: Keeping in view our experiences during the 2008 rainy season, we started sensitizing farmers about the advantages of using sweet sorghum bagasse as animal feed from the beginning of the 2009 rainy season. Simultaneously, we also sensitized the fodder agents who supply the sorghum stover to the dairy industry in Hyderabad on the utility and markets opportunities of sweet sorghum bagasse as animal feed.

Innovation: Our partners SVVU and ILRI took a lead role in facilitating fodder value chain development. ILRI installed a chopper at the DCU to chop the fresh and dried bagasse. The fodder agents were roped in from the beginning of the crushing season and supplied with the samples of fresh and chopped bagasse. The fodder agents arranged to lift the fresh baggasse immediately after crushing from DCU and supply to private dairy farms on the same day. The agents initially offered Rs 0.5 kg^{-1} for the bagasse citing that it may not be favored in the fodder market. But on the contrary, by the end of the crushing season the consumers demand for sweet sorghum baggasse went up and agents offered Rs 1.2 kg^{-1}. The demand for bagasse has given a clear indication that private dairy farms are preferring sweet sorghum bagasse in place of other feeds. Therefore, there is a great scope for promoting sweet sorghum bagasse as animal feed through innovative linkages and value chain development.

Benefits:

- The sweet sorghum bagasse augments the fodder requirements of the farmers.
- It makes available a new fodder variant in the market.
- It creates an opportunity for additional incomes to farmers.
- Increased availability of fodder in the fodder market.
- Safe disposal of sweet sorghum bagasse at the DCU.

4) Syrup making

A) Syrup making process

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 constant boiling and stirring. Chemicals like calcium (garika soda), castor oil, limestone, super phosphate and okra (lady's finger) fruit powder are added to the boiling juice in different concentrations to avoid froth formation and for coagulation of unwanted materials that float on the surface of the boiling juice (Box 4).

BOX 4

Producing syrup from sweet sorghum juice

1. 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.

2. Filtration of juice

- The juice extracted from the crusher is strained through a wire screen to remove big particles of crushed material
- 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.
- After crushing the juice has to be boiled immediately to stop the fermentation process to restore the conversion of fermentable sugars.
- The juice extraction and pumping juice into pans is a simultaneous process to stop fermentation.

3. 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.

Box 4 Continued

- Steady evaporation is the most important process of making syrup.
- Evaporation should be done with uniform heating for obtaining good quality syrup.
- Slow heating is required to prevent syrup from burning.
- Initially coagulation starts when juice temperature increases.
- As the temperature increases during boiling the juice scum is formed on the surface of the juice which is removed.
- Syrup quality improves with continuous removal of coagulated materials from the surface of the boiling liquid in the pan.

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

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

- Super phosphate (single) 2 kg.
- Lime (sodium carbonate) 1 kg.
- The chemicals, which remove dirt from the juice, are mixed with the liquid before boiling.
- Hibiscus (ladies finger powder)- 10 g added after filling the juice in the pan
- Caustic Soda (Sodium hydroxide) - 50 g to be added during boiling.
- Castor oil – 100 g (causes froth on the boiling juice, which collects all the dirt, which is later decanted)
- Sodium hydrosulphite – 50 g (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.

5. Evaporation process

- The density of juice increases (Brix%) as the boiling temperature rises.
- When the temperature of the juice reaches 105 °C to 107°C, the Brix of the
- syrup should be 65-70 %.
- The Brix and temperature of the boiling juice must be monitored at regular intervals.

6. Cooling of syrup

- Syrup should be cooled immediately to avoid burning.
- Syrup should be brought down to 85°C to 80° C within 10-15 mins to avoid

7. Syrup yield

- Syrup yield: 50-55 kg t^{-1} (15-18% of juice v/w) at 70-80% Brix.
- Syrup yield depends on initial Brix% of juice and final Brix% of syrup.
- The color of the syrup varies with the genotype and season of growth.

Box 4 Continued

8. Syrup storage

- The syrup can be stored up to two years without any deterioration of sugars at room temperature (Annex. 1 and 2)
- Syrup should be stored in air tight containers, leaving some gap on top of the container.
- The syrup can be stored in plastic cans or in polythene coated bags at room temperature.

9. Points to remember

- Delay in harvesting of stalks, after more than 130 days will reduce the juice content in the stalks.
- Brix of the stalks should be more than 15% for producing good quality syrup.
- Filtration of juice must be done to remove stalk particles before boiling.
- Effective removal of coagulated material and scum during juice boiling is very important for good quality syrup.
- The syrup should not be heated above 105°C to 107°C.
- The syrup should be rapidly cooled within 10-15 mins.

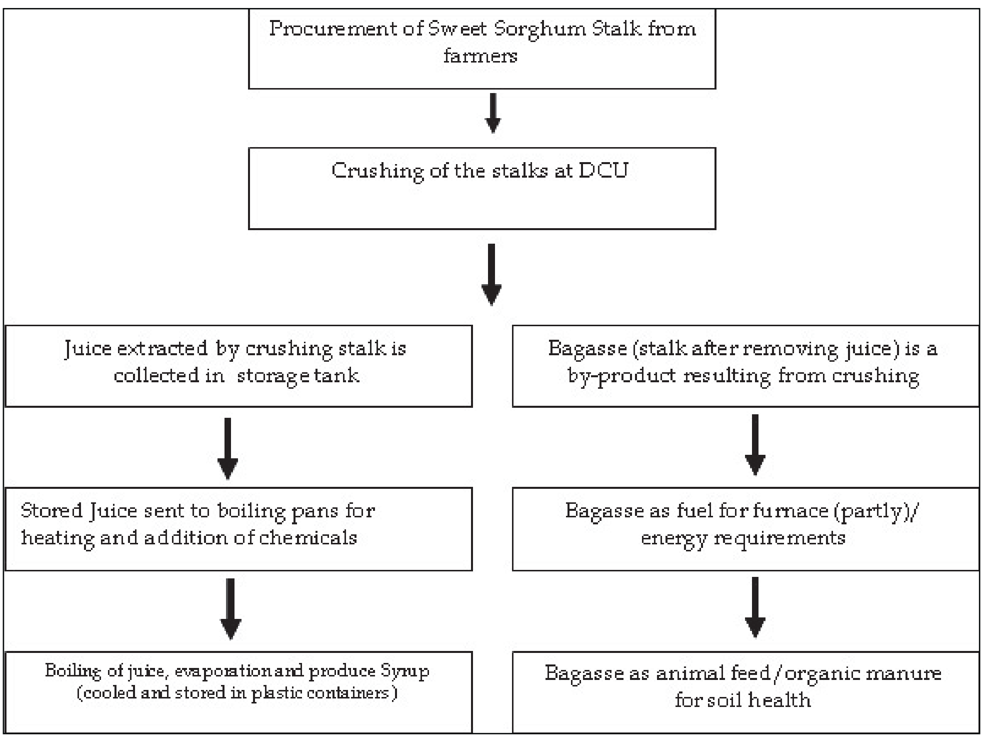

Fig. 5. Operations of the decentralized crushing unit.

The juice in the pan is constantly stirred. During the boiling, some undesirable contents coagulate. These materials (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 is increased gradually. The boiling pans are removed from the burners (chullas) when the temperature 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 air-tight plastic containers.

B) Syrup Storing

The finished syrup is strained with a mesh to remove any crushed plant materials or other inert foreign materials. The syrup is stored in clean, air-tight plastic containers with wide-mouth at room temperature. The shelf life of the syrup at 70% Brix stored at room temperature is around 24 months.

VI. Training stakeholders in DCU operations

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 (Fig. 5.) 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. Since utmost care needs to be taken while the DCU is in operation, particularly handling the crushers and chullas, training programs were conducted to enhance capacities of farmers' groups like farmers' associations, local CBOs, partner institutions, staff and NGOs, to operate and manage the DCU. The training programs included hands-on-training in overall maintenance and repairs, trouble shooting, stalk supply chain management and assessing quality parameters like juice and bagasse output, 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.

VII. Conclusion

The decentralized crushing system was established to overcome some of the shortfalls of the centralized system where the stalks have to be crushed for ethanol immediately after harvest within a short span of time to avoid drying-up of stalks and consequent loss of juice. The delay in transportation of stalks to the centralized distillery was a major obstacle in processing and higher recovery of ethanol. The establishment of decentralized crushing units on pilot basis close to the vicinity of cultivation of sweet sorghum helped in processing sweet sorghum juice to syrup, which can be stored upto a year (if required) before processing to ethanol. Economic assessment of crushing sweet sorghum and value addition under a decentralized unit as showed that production of syrup can be made viable by improving yield of sweet sorghum stalks, system efficiencies like crushing and labor use and mechanization of whole process. The decentralized system was managed by the growers of sweet sorghum (farmers' associations) who crushed it to produce syrup. This was a new area for them. Given this, the management of a crushing unit at farm level would vary significantly and hence the high processing cost.

The initial technology used for crushing sweet sorghum for producing syrup was not tailor-made for a crop like sweet sorghum. The value realized by supplying syrup to the distillery was also low because of further processing costs incurred by the processor to convert it to bioethanol. Consequently, the decentralized unit was incurring losses. A major challenge, therefore, is to bring down the cost of processing syrup in the decentralized unit. As indicated in the paper, this can be achieved only through a combination of several factors. For example, a modest decline in labor cost of processing by 40%, increase in syrup yield vis-a vis increasing efficiency in recovery of juice and syrup per ton of stalk through crushing and fermentation efficiency, increase in value addition by better utilization of bagasse can make sweet sorghum a remunerative feedstock for processing to bioethanol and has great potential for future bioethanol production in developing countries like India.

In view of the above mentioned benefits of sweet sorghum, efforts should be made in the direction of improving technology in processing of sweet sorghum syrup to reduce cost in bioethanol production, value addition in bagasse utilization and capital assistance for small scale entrepreneurs. In the long run this will be a boon for both smallholder farmers of rain-fed regions and industry in production of bioethanol.

VIII. 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 (5 t) at DCU, was supplied to Rusni Distilleries, Sangareddy 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's empowerment. The success and overall economical 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 model. This paves the way for micro entrepreneurship development in villages that increases the income and employments options and reduces migration to cities. With the establishment of DCU with essential plant and machinery, the costs minimized if a farmer establishes it with his own investment on his own land and involving his own family labor as given in Table 2.

Table 2. Cost of essential equipment, plant and machinery required for establishment of DCU at the village level.**

	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 (such as stirrers, dragger, sieve, scum storage drum etc)	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
e)	Rubber/PVC hose pipe 1" dia, 200 m length	0.16
f)	Syrup storage plastic drums industrial use (50 kg capacity)	0.30
g)	Crusher shed with local available materials (palm tree leaves/bamboo thatched sheets/paddy straw covering)	0.2
h)	Chulla shed with local materials (palm tree leaves/ bamboo thatched sheets/paddy straw covering)	0.2
i)	Foundation for generator placement	0.10
j)	One utility room construction with asbestos sheet	0.4
k)	Construction of 2 ft height basement for crusher placement 6 x 3 ft with iron channels, nuts and bolts fitting	0.19
l)	Construction of 3 chullas for boiling juice	0.49
m)	Electrical wiring, switches, control panel etc	0.10
	Total amount (INR)	11.66

** Works and equipment prices quoted by local agents/dealers in Andhra Pradesh, India.