Establishment and maintenance of decentralized sweet sorghum crushing-cum-syrup making unit

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Abstract

In the light of environmental concerns associated with fossil fuel use and the increased demand for energy in different counties, bio-fuels research and development has come to center stage. Sweet sorghum is a SMART crop with triple product benefit - food, feed and fuel. It is a good candidate for commercial ethanol production with potential opportunities for benefiting the dryland farmers from the emerging bio-fuel markets. The commercial ethanol production from sweet sorghum requires feedstock supplies for longer periods in a year. ICRISAT (International Crops Research Institute for the Semi-Arid Crops) and DSR (Directorate of Sorghum Research, Rajendranagar, AP, India) and other partners are working on supply chain management and addressing other issues in the sweet sorghum ethanol value chain. Principally, sweet sorghum supply chain involves centralized and decentralized models. Under centralized model farmers supply the sweet sorghum stalks directly to the distillery where as in decentralized model farmers supply stalks to Decentralized Crushing-Syrup Making Unit (DCU) located in the village it self. These stalks are crushed at the DCU and the sweet juice is boiled to produce concentrated syrup that can be stored for more than 9 months and used for ethanol production, particularly in the off-season augmenting the feedstock supply to the distillery. Use of DCU for crushing and syrup production at village is a new idea and there is no publication available on the requirements for establishment of a DCU and its maintenance. In this bulletin, attempts have been made to briefly describe the experiences of ICRISAT and partners in establishment and maintenance of DCU covering all the aspects of DCU, from selection of site for its establishment, logistical requirements, plant and machinery, operation and maintenance of DCU and its role in sweet sorghum supply chain management.

Cover photo: Director General of ICRISAT William D. Dar inaugurated DCU at Ibrahimbad village, in medak dist. Andhra Pradesh, India.

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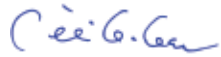
Preface

Food and energy security are most critical for the sustenance of modern civilization.

Considering the volatility in the availability of fossil fuels, their costs and the associated environmental pollution, there is renewed global interest in biofuels. Sweet sorghum is a unique biofuel crop that gives food, feed and fuel. Of late, there has been a growing global interest in the use of sweet sorghum for ethanol production. Sweet sorghum juice-based (first generation) ethanol production is a commercial reality, and efforts are underway to use it as a feedstock for second generation (ligno-cellulosic) ethanol production. However, there are certain critical issues that need to be addressed before taking sweet sorghum ethanol production to a higher level of commercialization for its socio-economic benefits to reach a large number of smallholder farmers in the semi-arid tropics (SAT). Enhancing crop productivity in farmers' fields, developing sweet sorghum genotypes and technologies that help in year-round scheduling of feedstocks, supply chain management, and increasing the shelf-life of the juice are some of the issues that need immediate attention. While addressing these issues, ICRISAT and its partners have been working on both centralized and decentralized models to ensure year-round supply of feedstock to distilleries for ethanol production.

The centralized model involves farmers supplying sweet sorghum stalks directly to the distillery whereas the decentralized model involves farmers supplying stalks to the Decentralized Crushing Unit (DCU) located in the village. These stalks are crushed at the DCU and the sweet juice is boiled to produce concentrated syrup that can be stored for more than nine months. This syrup can then be used for ethanol production, particularly in the off-season, thereby augmenting feedstock supply to the distillery. In addition, the DCU helps in reducing the bulkiness of feedstocks and pumps the bagasse back to farmers for use as animal feed or for composting. This ensures direct employment to about 20-25 people in the village during this operation. ICRISAT and its partners are working on the economics of syrup production at the DCU to make it a sustainable unit that serves as a low-cost micro-enterprise. This publication on "Establishment and Maintainance of Decentralized Sweet Sorghum Crushing-cum-Syrup Making Unit" comprehensively covers all aspects of setting up a

DCU, right from the process of site selection and logistical requirements to plant and machinery needs, operation and maintenance. The publication will serve as a useful guide for micro entrepreneurs and farmer groups to establish more DCUs in order to take sweet sorghum ethanol production to a higher level of commercialization.



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1. Introduction

Most developing and less developed countries are rural nations with about 70% of their population depending on agriculture for a living. Agriculture is also a source of raw materials for the industrial sector of many developing countries. The majority of farmers in these countries are small and marginal farmers who have to contend with poor infrastructure, lack of agricultural development services, limited knowledge of improved crop production technologies, low value addition to their produce and difficulties in accessing credit and markets.

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. Establishment of small-scale industries in rural areas will help reduce 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. What is needed is a fresh and comprehensive approach, integrating production enhancement and value addition to crop 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 quantities 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.

In that context, this publication primarily deals with the establishment and maintenance of the decentralized crushing units (DCUs), in particular their logistical requirements, cost of establishment, processing (crushing) of sweet sorghum stalks and constraints and opportunities in operating them. This model is based on our experiences in implementing the ICRISAT-NAIP sweet sorghum ethanol value chain development project with the help of our partners in India (Directorate of Sorghum Research, Hyderabad; Central Research Institute for Dry Land Agriculture, Hyderabad, Sri Venkateshwara Veternary University, Tirupati, Indian Institute of Chemical Technology, Hyderabad, International Live Stock Research Institute (ILRI), Rusni Distilleries Ltd. and an NGO, Aakruthi Agricultural Associates of India).

2. Background and Rationale

Food and energy security are critical for the sustenance of modern civilization. Considering the volatility in 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 farmers in rainfed areas an opportunity to increase their income while at the same time protecting the environment without sacrificing food and fodder security in rainfed areas. Sweet sorghum is a C_4 plant with high photosynthetic efficiency. It produces high biomass (up to 40-50 t ha^{-1}) in a short time (4 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 and bagasse for animal feed/compost). The International Crops Research Institute for the Semi-Arid Tropics (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 chain of activities involved in producing sweet sorghum-based bioethanol encompasses sweet sorghum production, harvesting, processing stalk juice for ethanol production and its utilization.

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 crushing units located in the village) models for the benefit of farmers and industry. A combination of the two models, centralized and decentralized, can meet the objective. 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 syrup can be stored for up to 9-12 months at room temperature which increases the availability of raw material (syrup for ethanol production) to the industry. Decentralized crushing reduces the legwork inherent in dealing with high volumes of stalk and the costs of transportation under the centralized model.

In the centralized model, a typical 40 kilo litres 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 a 30-km radius of a distillery so that the

time for and cost of transportation of stalks is reduced. However, the centralized model has some limitations:

i). Farmers located more than 30 km from the distillery will be burdened by high transportation costs owing to the bulkiness of stalks.

ii). Delay in crushing stalks beyond 24 hours of harvest causes a 6% reduction in juice yield.

iii). Delay in harvesting and transportation of stalks to distilleries leads to reduction in stalk weight, causing financial loss to the grower.

iv). 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.

v). Growing other crops like vegetables, Soy bean, Maize, Paddy, and Wheat may be more economical than sweet sorghum under irrigated conditions.

The decentralized model overcomes some of these difficulties.

3. Decentralized Crushing Unit (DCU)

The purpose of setting up decentralized crushing unit at the village level is to crush sweet sorghum stalks and extract and boil the juice to produce syrup. It aid supply chain management particularly by reducing the volume of feedstocks 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 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.

4. Establishment of Decentralized Crushing Unit

i) Selection of villages and site for DCU

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

In the ICRISAT-NAIP project 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 nongovernmental 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 state of India, tentative clusters villages (Ibrahimbad, Erragunta Thanda, Seethaya Thanda, Durgaya Thanda, Umla Thanda, Sikindalpur Thanda, and Laxman Singh Thanda under Hatnora and Narsapur Mandals, Medak district) 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 soils, yields of different crops, markets, political affiliations and the possibility of securing panchyath land (community land) to set up the DCU (Fig. 1).

Figure 1. Meeting with village administration members and local leaders.

After analyzing the merits and demerits of the different clusters, it was found that 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	496

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 DCU establishment.

ii) Design and layout of the site

Under the ICRISAT-NAIP 'Sweet Sorghum Ethanol Value Chain Development' project, one acre of land was acquired from a farmer on a five-year lease to set up a decentralized crushing unit in the village. The site is close to the village located alongside a main road that connects the village to the mandal headquarters. It has a 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).

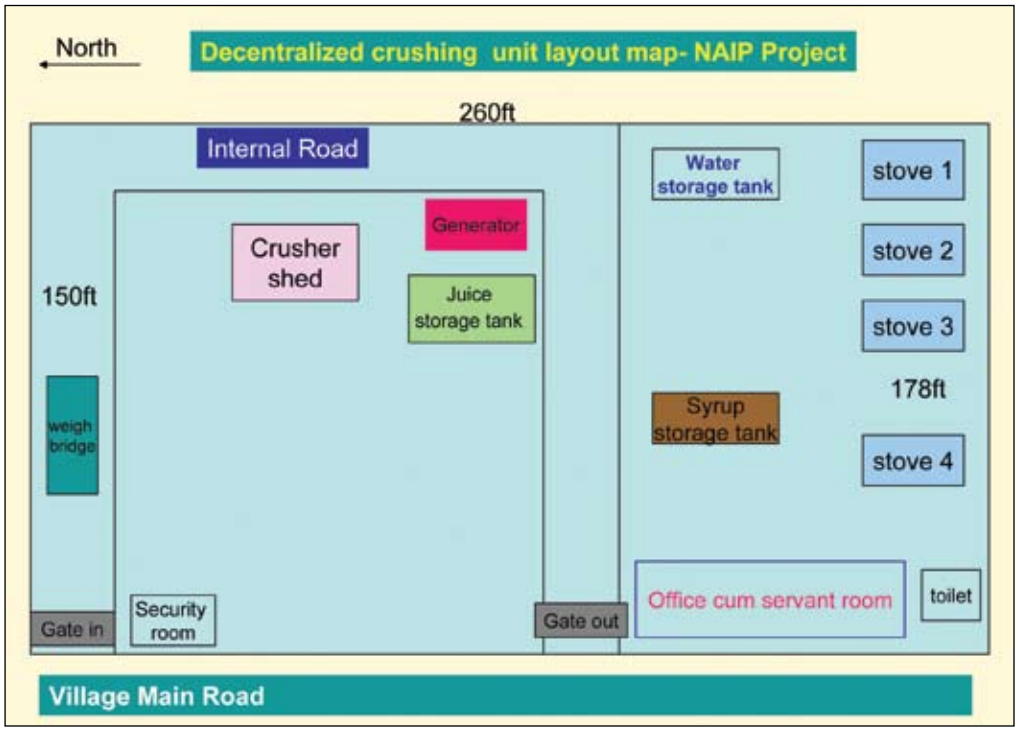


Figure 2. Layout of the decentralized crushing unit at Ibrahimbad village.

iii) 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 are required for the DCU and the cost of the establishment is given Annexure 2.

- 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 per hour crushing capacity was chosen after consultations with local dealers, jaggery making farmers and a couple of crusher manufacturers (Fig. 3). It has a high crushing efficiency, entails 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 1.

Figure 3. Crushing operations in progress where the motor is connected to the crusher with a pulley and V-belts.

The crusher at DCU-Ibrahimbad has a capacity of 2 t per hour (Fig. 4a). It can be operated with a 20 HP electricity motor connected with a pulley and V-belts (Fig 3). 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 placed beneath the soil surface for convenience. The juice in the drum is pumped by a motor into boiling pans through an industrial hosepipe (Fig. 4).

Figure 4. The juice collected in the drum is pumped in the syrup making pan using a elcctric motor.

b) Weigh bridge: 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 stalks they supply (on fresh weight basis). In this project, we installed a surface mounted weigh bridge with a capacity to weigh up to 50 tons to weigh stalk loads brought by farmers on bullock carts, tractors, and trucks (Fig. 5&5a). If a weigh bridge facility is available within the village limits or nearby DCU, such an investment can be avoided.

c) 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 Ibrahimbad village, power supply to the DCU at Ibrahimbad was arranged by installing a captive 40 KVA generator.

d) Chulhas: 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 made under the soil surface connecting to the inside of the chulha. The bagasse feeding opening is 1. 6 ft length in the rim of the chulha (Fig. 6).

Figure 4a. Farmer feeding sweet sorghum stalk into crusher.

Figure 5. Farmer load the harvested sweet sorghum stalks on bullock carts and supply to DCU.

Figure 5a. Sweet sorghum stalks on a bullock cart being weighed at the weigh bridge.

Figure 6. A chulha with its bagasse feeding opening (long arrow) and air passage channel holes inside the (short arrows) chulha.

e) Boiling pans: The standard boiling pans (sugarcane juice boiling pans) are made of galvanized 18-gauge mild steel (MS) 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 (Fig. 7). The syrup from the boiling pans must be collected after sufficient cooling and stored in plastic drums with wide mouths for easy filling and decanting.

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 (Figs. 8). All these accessories are commonly used for sugarcane juice boiling and making jaggery and were procured 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 hose pipe. The juice collection tank is placed near the crusher (in a pit)

Figure 7. Juice boiling in the pan and feeding bagasse into the chulha.

Figure 8. Metal sieves and Wooden dragger.

connected with an outlet pipeline from the crusher delivery channel (Fig. 6). Steel baskets (3 ft × 3 ft) are used to shift the bagasse from the crushing site to the drying yard (Fig. 9).

Fig 9. Baggasse carrying in a steel basket after crushing.

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 troubleshooting. We made arrangements with local technicians to render their services as and when required.

c) 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. Under the ICRISAT-NAIP project we established a proper shed. Its specifications are presented in Annexure 2.

5. Command Area Development and Supply Chain Management

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 for sweet sorghum cultivation in the rainy season. In order to enable local farmers cultivating sweet sorghum, the required seed, weedicide and fertilizers were supplied on credit. The cost of these inputs were recovered while making payments for the stalks supplied by farmers. Appropriate extension services were provided by conducting awareness camps, training programs on crop production, integrated pest, disease and nutrient management, field trials and demonstrations in the selected villages.

Under the present project, the services of an NGO, Aakruthi Agricultural Associates of India, 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) and developing harvesting schedules for the supply of sweet sorghum stalks to the DCU.

6. Crushing and Syrup Production

i) Procurement of raw materials

This is critical to the success of the model as it involves winning the confidence of farmers through timely harvest, procurement and prompt payment. Under the ICRISAT-NAIP project the services of Aakruthi Agricultural Associates of India 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. The farmers were paid Rs. 600 per t of stalk. The total area covered under sweet sorghum in the 2008 rainy season was 48 ha, of which 40 ha were finally harvested and supplied to DCU.

ii) Crushing

Ideally, sweet sorghum stalks should be crushed on the same day of harvesting (Fig.10). Any delay in crushing results in low juice recovery and eventually low

Fig. 10. Crushing of sweet sorghum stalk.

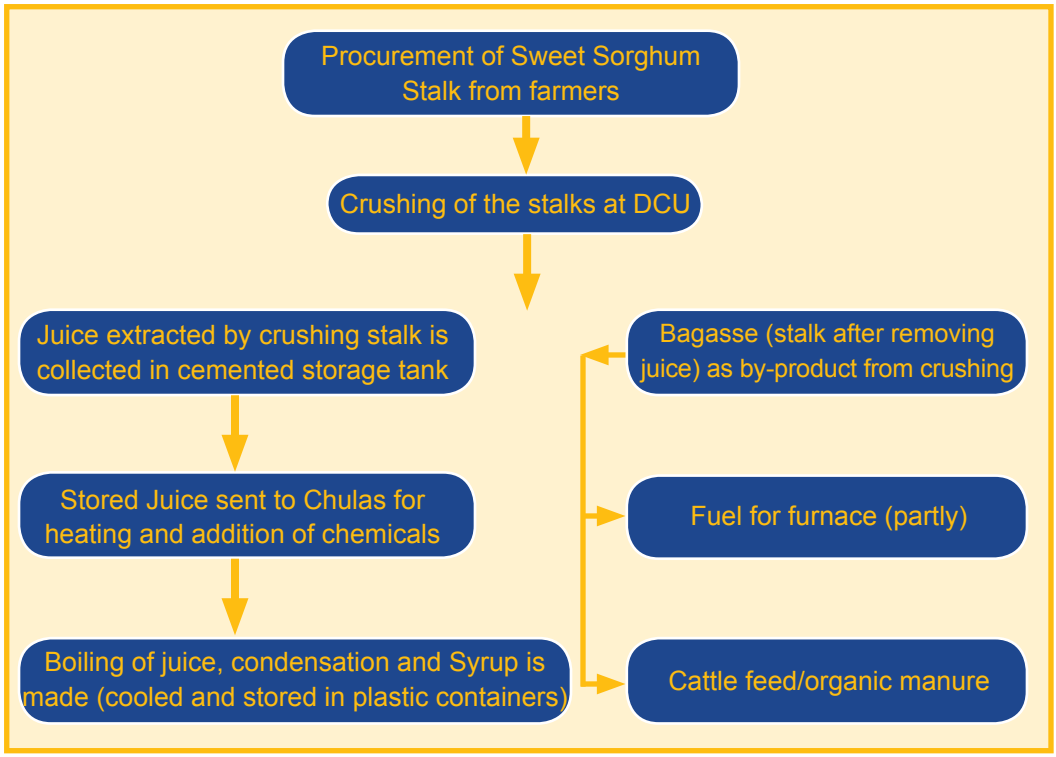
syrup yield. The DCU established at Ibrahimbad has the capacity to crush stalk from a 20 ha area during the rainy season (Kharif) in 30 days of operation working one shift of 8 hours per day. In the present project, crushing operations were started on 4th October, 2008. The area and quantity of stalks to be harvested and supplied to the DCU was scheduled on a weekly basis after discussion with the farmers. A total of 557 t of stalks was procured from the farmers and crushed at DCU during the 2008 rainy season.

iii) 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 constant boiling and stirring. Chemicals like calcium (Garika Soda), castor oil, limestone, super phosphate, and okra (ladies finger) fruit powder are added to the boiling juice in different concentrations to avoid froth formation and coagulation of unwanted materials float on the surface of the boiling juice.

The juice in the pan is constantly stirred. During the boiling, some undesirable contents coagulate. These materials (skimmings) are removed frequently

Flow chart depicting operations at DCU



(Fig.11) 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 when the temperatures reaches 226-230°F (108°C to 110°C) or when the syrup attains a density of 70° Brix when tested with a syrup hydrometer or sugar refractometer. The final syrup is allowed to cool to 140-160°F and stored in plastic containers (Fig.12).

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 wide-mouth containers at room temperature. The shelf life of the syrup at 70° Brix stored at room temperature is around 9-12 months. In the DCU at Ibrahimbad, a total of 557 t of sweet sorghum stalks were crushed and 23 t of syrup produced during the 2008 rainy season.

Fig 11. Removal of froth and unwanted coagulants from surface of boiling juice.

Fig 12. Syrup from pans are poured into wide mouth syrup storage cans.

7. Operation and Management of the DCU

Under the ICRISAT-NAIP subproject, the DCU was established to crush stalk for two seasons (rainy and postrainy) for a period of 2−3 months 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. Utmost care should be taken while the DCU is in operation. In the interests of safety, the crushing unit should be properly shielded and workers should be trained to conduct themselves in the DCU particularly near the crushers and the chulhas. All operators, daily-wage laborers and project staff were trained in handling the operations of the DCU before starting crushing. Efforts are now underway to establish a farmers' group (farmers' association or a local community-based organization) to operate and manage the DCU. The project will provide the required hands-on training in overall management of the DCU including operating the crushing unit, routine maintenance of the machinery, accounts and book keeping. (Fig. 13)

Figures 13. Training program for rural educated youth on operation and management of DCU.

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 (fig. 14). 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, Ibrahimbad is being supplied to Rusni Distilleries (P) Ltd, Hyderabad for ethanol production and efforts are in progress to identify alternative markets for syrup marketing especially targeting food industries which use sugar syrup as a sweetener in their products.

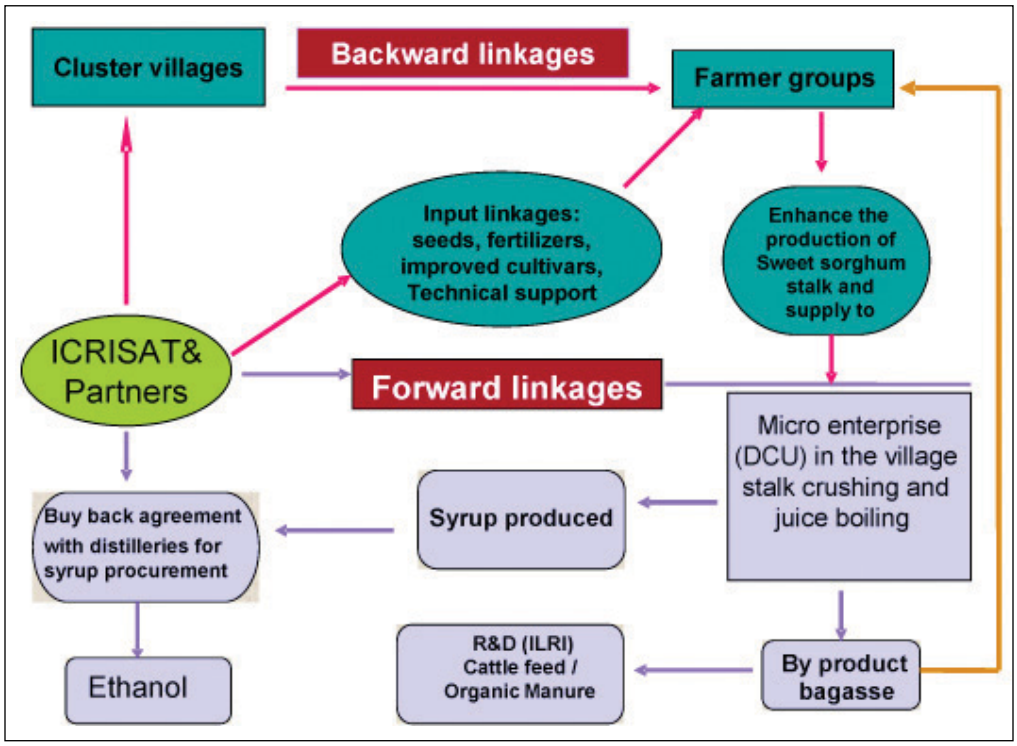


Figure 14. Forward and backward linkages with the farmers' group and ethanol industry.

8. Constraints and Opportunities

Yield: It is difficult to replicate research station yields in farmers' fields that too in large-scale commercial cultivation. In most of the cases, farmers' yields are around one-third of the research station yields for a given genotype. During the 2008 rainy season, farmers in the Ibrahimbad cluster realized 23 t ha^{-1} stalk yield and 1.5 t ha^{-1} grain yield under rainfed conditions in this project. Efforts are on to enhance the yields through technical backstopping and capacity

building activities for the farmers' groups including seed treatment, application of micronutrients and integrated pest management to reduce the incidence of shoot fly and stem borer to enhance the yields of grain and stalk per unit area.

a) **Crushing**: The crop area should be planned as per the crushing capacity and boiling capacity at the DCU. Scheduling of harvesting is critical. It should be such that stalks are crushed on the same day of harvesting.
b) **Manpower:** Manpower is costly and often not available. Economizing on manpower requirement is critical to reduce syrup production costs.
c) **Syrup chemicals:** Untrained persons tend to use more chemicals than required during juice boiling. Identification of experienced persons and strict vigilance on use of chemicals not only helps in reducing costs but also increases syrup quality.
d) **Research and development:** There is a need to improve stalk and sugar productivity of sweet sorghum cultivars while maintaining the grain yield to increase the returns to farmers and industry. To achieve this, crop improvement and crop management research should go hand in hand. Efforts are underway at ICRISAT and with consortium partner institutions to develop promising hybrids for higher grain and stalk yields and better chemical composition of the stalk. Stability of sugars in the juice and syrup during storage are also being studied.

To summarize, availability of feedstock for longer periods in a year (9 months) is a critical factor limiting the expansion 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. Each decentralized unit provides regular 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, technical guidance for crop production and an assured market for their produce. Women's participation is high in all DCU operations, thereby aiding women 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 unit. This paves the way for micro entrepreneurship development in villages that increases the income and employments options and reduces migration to cities.

Annexure 1. Specifications of the Crusher

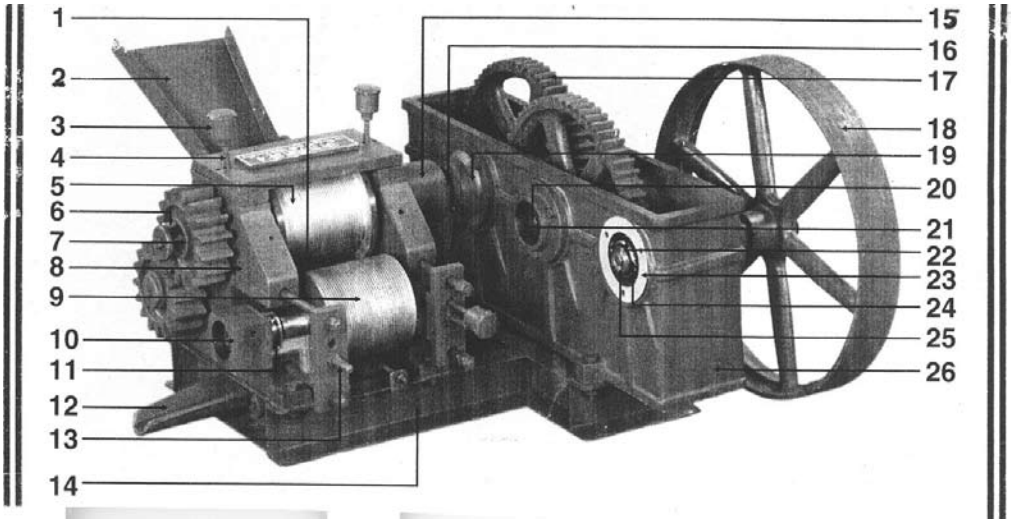


Figure 15. Parts of the crusher.

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

Annexure 2: Cost of Establishment of DCU

List of equipment/work required for establishing a Decentralized Crushing Unit:

A. Plant and machinery		
S.No.	Particulars	Cost* (Rs '00000))*
a)	Sweet sorghum crusher: roller 10 inch dia. × 12 inch height with base of 5.5 ft × 3.5 ft rectangular base –(Motor for crusher 20HP, V Belts, gear oil) Crushing capacity: 2.0 t per hour (inclusive of taxes, transportation, erection and commissioning	2.70
b)	Syrup boiling pans – 2 m dia. and accessories (like stirrers, dragger, sieve, scum storage drum, etc) Capacity: 600 L per pan (4 nos.)	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)	Pumps and motors 1 HP with Pipe size suction and delivery of 40 × 40 mm with total head in 4 m with discharge capacity of 190 L per hour for pumping juice from the juice collection tray of the crusher to the storage tank from the where juice will taken for further processing with accessories (gun metal/ stainless steel impeller, base plate, foundation bolts, capacitor, starter) 1 n70°os.	0.13
f)	Weigh bridge (surface-mounted): Size: 7 × 3 m, mounted on 4 double-ended shear beam-type load cells of 30000 kg capacity each. Mounted accessories 4 sets. Steel structure made of fabricated main beams of 450 × 150 mm, 2 main joints and cross members made of 175 × 90 mm RS joints. Deck made out of 10 mm thick MS Plate with anti-skid strip welded with RED LED digital display.	4.71
g)	Rubber/PVC hose pipe 200 m length, industrial use, 1.0" diameter	0.16
h)	Syrup storage plastic drums industrial use (50 kg capacity)	0.30

B. Fabrication works		
a)	Crusher shed fabrication with steel sheet top columns and tress with base plate and nuts and bolts as required (15x20 ft) with civil works including transportation of material erection charges and taxes: 1	10.10
b)	Chulas shed fabrications steel sheet top Columns and tress with base plate and nuts and bolts as required (35x45ft ft) including transportation of material erection charges and taxes -1Nos.	3.29
c)	Steel doors, windows, GI sheet for roof	0.56

C. Civil works		
a)	Survey of land with civil engineer and blueprint drawings for gram panchyat approval	0.12
b)	Fencing with 8 ft hight cement poles and six lines of barbed wire for the crushing unit area (4840 sq. yd.)	0.43
b)	Foundation for generator placement 5 ft.x 6 ft x 0.8 ft. with R.C.C.	0.23
c)	Foundation and 0.9 x 0.9 X 7 ft, RCC Gate pillars (4nos) for 2 gates;	0.38
d)	Weigh bridge: construction of 4 pillars and beam with following specifications: column size : 1200 mm x 1200 mm x10 mm with 12 mm rods, Pillar size: 600mm x 600 mm x 1500 mm with 16 mm rods and 8 mm ring, Beam: 400mm x 300mm x 1500 mm with 12 mm roads and curbing angle 75 x75mm on either side of weigh bridge 10ft.	1.25
e)	Laying of internal roads with *morrum* (gravel) and 40 mm gravel stone -500 ft (12 ft wide)	1.34
f)	utility rooms construction: foundation 2 ft height above the ground, with 0.9” brick wall , 2 coats of plastering, sponge finish, Shabad flooring and steel zinc sheet tops: 1) Security-cum-weighbridge room (10 x 10 ft); 2) Generator Room (10 x 12 ft); 3) Store room (10 x12 ft) and 4)foundation for installation of motors (3nos)	2.61
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 chulhas for making syrup which includes digging of pit of depth 4ft-5ft , and construction of the chulha of 2m dia. using brick and mud with provision for feeding channel 3m length from one side of the Chula and exhaust chimney of 1.5m length of 4ft height with 1ft dia. on the other side of the Chula. -4nos	0.49

D. Electrical works		
a)	Electrical wiring, switches, control panel etc, for office room , security room crusher shed, chulas shed , and general lighting work for roads and Entrances	2.2
	Total amount (INR)	36.21
* Works and equipment prices quoted by local agents/dealers in Medak district of Andhra Pradesh, India.		

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About ICRISAT

ICRISAT
Science with a human face

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

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