Chapter V: Mechanization of sweet sorghum production and processing

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I. Introduction

Sweet sorghum is a unique multipurpose crop and of late widely promoted as biofuel crop. Its ability to produce grains for food/feed and stalks for fuel/feed makes it one of the popular choices in the dryland regions. This crop is now widely grown in many of the countries as a feasible biofuel crop under different climatic conditions because of short its growing period and low water requirement (Soltani and Almodares 1994) as compared to sugarcane. When compared to other biofuel crops, sweet sorghum is best suited for ethanol production because of its higher total reducing sugar content (Huligol et al. 2004). Further, its suitability for mechanized crop production, seed propagation and higher ethanol production capacity of sweet sorghum have drawn the attention of researchers. The bagasse from sweet sorghum after the extraction of juice has a higher biological value in terms of micronutrients and minerals than the bagasse from sugarcane when used as animal feed (Seetharama et al. 2002). It can also be processed as a feed for ruminant animals. The crushed stalk contains similar levels of cellulose as sugarcane bagasse, and therefore is a good prospect as raw material for pulp and briquette making (for fuel purposes). Many attempts were made to use sweet sorghum for ethanol production in a centralized model of crushing the stalk for juice at the industry level. However, this model had some difficulties as the raw material availability was restricted for small period in a year apart from the problems of transportation of stalk from the farmer's fields to distillers.

To address this, a decentralized model that involved the production and crushing of sweet sorghum stalks at the village level was tried in Medak district of Andhra Pradesh. This model involves collecting sweet sorghum stalk at the village level and crushing them in small-scale crushers established in nearby areas. To make this model viable, we attempted to reduce the cost of cultivation by mechanizing the crop production from sowing to harvesting under on-farm conditions as mechanization of crop production appropriately handled may reduce the crop production cost by 30%. The experiences of our work on mechanization of sweet sorghum production is discussed here.

II. Mechanization of sweet sorghum sowing operation

In sweet sorghum crop, the best sowing window is limited to 2 to 5 days after monsoon arrival, depending on the moisture availability. Success of sweet sorghum farming depends on the completion of sowing operation within this limited period. Otherwise the entire crop cycle becomes affected by the delayed sowing.

The recommended plant to plant spacing was 20 cm and row to row spacing was 60 cm. However in our interactions, most of the farmers were not convinced about this spacing as they had preconceived apprehensions about yield. So the seed drill setting was changed to 20 cm and 45 cm respectively. In conventional practice, sowing operation was done by a country plow to open the furrow, which was followed by two women laborers to place the seed and fertilizer. This used result in poor germination as there was no synchronization between the workers. To overcome this, improved seed drills implements suitable for the cluster were introduced to improve timeliness and precision so that sowing could be completed within the short sowing window. The implements included in the trials were: 4-row bullock drawn planters, 6-row and 9-row tractor drawn planters which were designed and developed by Central Research Institute for Dryland Agriculture (CRIDA) that were extensively popularized in dryland regions of India. Specifications of 4-row and 9- row planters are given below (Table 1).

Table 1. Specifications of the CRIDA planters.

Specification	4-row Planter	6-row planter
Weight (kg)	120	240
Source of power	Bullock	Tractor (35 hp)
Plant to plant spacing (cm)	20	20
Row to row spacing (cm)	45	45
Row coverage	3	4
Field coverage (ha^{-1} day)	3-3.5	7-8
Cost of operation (₹ ha^{-1})	800	600

Initially, to propagate the concept of mechanization among the project's farmers in Medak district, a field demonstration cum training was arranged in farmers' fields at Ibrahimbad village. This sought to demonstrate the working of the planter and to create awareness about crop mechanization. During field testing, the performance of the 4-row bullock-drawn and 6-row tractor-drawn planters was found to be satisfactory. The farmers could not use the 9-row tractor-drawn planter since their land holdings are very small. Some modifications with regards to the seed metering mechanism were made to achieve 20 cm plant to plant spacing. Though the row to row distance of 60 cm is recommended for sweet sorghum, the farmers would not adopt it because of strongly held preconceived ideas that the reduction in plant population would result in less yield. So a demonstration was conducted with 45 cm row to row spacing. As part of the training programme, farmers were also trained in repair and maintenance of planters which helped them understand the basic principles of the machinery. The poor response received for bullock-drawn planters was because it covers lesser area in the limited sowing window available. The field evaluation of CRIDA's 6-row planter is given in Table 2. The crops grown with the CRIDA planter (Fig.1) and conventional method (Fig. 2) are shown below for comparison.

It was observed that mechanized sowing helped save time by 65% when time was of the essence. The bullock-drawn planters were introduced, but it was found very difficult to popularize among the farming community owing to its poor per day coverage.

Table 2. Performance of the CRIDA planter for sweet sorghum.

Method of sowing	Average plant to plant spacing (cm)	Average row to row spacing (cm)	Biomass yield t ha^{-1}
Farmers' practice (country plough)	10	40	20
CRIDA's 6-row planter	20	45	23

Fig. 1. Mechanized sowing.

Fig. 2. Farmers' practice.

1. The effect of mechanized sowing on crop growth

As expected, mechanized sowing improved the crop growth in terms of plant height and stem girth which influence the juice recovery of sweet sorghum. The plant height and thickness of stalk for the three years were recorded to address the performance of seed drills and their influence on productivity is presented in Table 3.

The stem diameter and height of the crop under mechanized sowing was higher compared to the performance under farmers' practices, which may be attributed to the proper placement of fertilizer and seed in with the planter when compared to the way the farmers tend to. The well spaced row sowing improved yields considerably apart from making the stem grow higher and therefore more suitable for crushing.

Table 3. Effect of sowing method on crop morphology.

Methods	Plant height at harvest (cm) (in 100 m x 100 m plot)	Stem diameter at harvest stage (mm)
Farmers' practice	294	17.4
Mechanized sowing	315	21.2

2. Mechanization of intercultural operations

In majority of dryland regions, weeds compete with crops for moisture, nutrition, light and space among several other factors required for plant growth. Moisture conservation is key for achieving high yields in drylands as crops are grown under limited moisture conditions. Intercultural tools remove weeds between crop rows but create soil mulch which helps in moisture conservation. Effective and timely weed control in sweet sorghum crop plays a very important role in improving crop productivity. Conventionally farmers use hand tool slike *khurpi* (hand shovel), wooden hoes, bullock drawn *guntaka* (blade) etc, which covers less area per day and is labor intensive. This leads to prolonged operations leaving weeds in the field for longer, depleting soil resources (Srinivas et al. 2010). Therefore, new power operated tools such as the power weeder and improved manual weeder were identified for weeding in sweet sorghum and introduced in the villages. The details of the mechanization process introduced are given below.

A) CRIDA manual weeder

The CRIDA manual weeder has a wheel mounted on a pipe frame, which has the weeding tool mounted on the frame and runs behind the wheel. Its efficiency is about 10 times faster than weeding with the khurpi (shovel). It is operated by the push-pull mode and is comfortably operated by women. It also improves the ergonomic efficiency of the operator.

B) Bullock-drawn weeders (*guntaka*)

Bullock-drawn power weeders can be used comfortably between the rows and it has the added benefit of earthing up as well during weeding. They are available at the local markets with 30 cm and 45 cm blades which can be easily drawn by a pair of bullocks.

C) Mini power weeder

This is a self-propelled moving type intercultural implement. It has rotary tynes as the moving element which are mounted below the front end of the frame. The handle body with clutch and gear lever arrangement is attached to the rear side. A 1.5 hp engine provides power for forward movement and a rotary blade attached to the frame removes the weed and pulverizes the soil. This machine has better maneuverability in the field during operation. Weed control was effective and created soil mulch which is desirable under dryland conditions.

D) Power weeder

The power weeder (Fig. 3) was demonstrated in the cluster village for creating awareness among farmers. The farmers were satisfied with its working and appreciated it for its utility in sweet sorghum crop with its efficiency and superior maneuverability in the field. It works with 1.5 hp petrol engine. Clutch can be used to engage and disengage the rotor during operation. Training cum demonstration was planned at Ibrahimbad village to test its feasibility and also to create awareness during the season.

Fig. 3. Woman farmer using CRIDA manual weeder at her farm.

E) Farmers' experience with power weeders

Many farmers felt that the power weeders were very useful in the present conditions of labour and bullock power shortage, where it equally essential that weeding and intercultural operations be completed in time. They had observed that delay in weeding operation by 10 days affected crop yields significantly. The cost of power weeding worked out to around Rs 625 ha^{-1}. The plant damage was also minimized with the power weeders when compared to the other methods.

3. Mechanization of harvesting operations

It was observed that the harvesting operation of sweet sorghum cost 30% of the whole cost of cultivation apart from high drudgery involved. Women, who are mostly involved in this operation, suffer a lot under the scorching heat. Since there were no small- to medium-scale harvesters available in the market, experiments were conducted with the modified self-propelled reapers which were normally used for paddy and other fodder crops. These modifications were carried out at CRIDA, Hyderabad, India, based on initial feedback from the farmers after testing the equipment in the field.

A) Modification of front mounted reaper as sweet sorghum harvester

A front mounted reaper which can be attached to the tractor was modified to suit the harvesting operation of sweet sorghum crop (Fig. 4). The reaper was a multi-crop harvester and is suitable to harvest soybean, paddy, wheat and other crops. It consists of a cutting bar and guiding wheels to bring the crop close to the cutting blade. The cut crop stalks are conveyed to the side to form a windrow via a belt.

Fig. 4. Demonstration and training of the power weeder.

Since the height of the sweet sorghum crop was more than 240 cm, the reaper was not suitable for harvesting it. Besides, the stalk thickness was more than the normal sorghum, and so the cutting blades were not suitable either. Modifications were carried out by increasing the height of the reaper to support the sweet sorghum stalk and conveying them to the top of the harvester. One more set of guiding wheels were fixed to the conveyer (as shown in Fig. 5) to bring the stem close to the vibratory cutting blade.

Field testing of the modified tractor-drawn front mounted reaper revealed that it required some more modifications to cut and carry the stalks properly. Hence it was decided that modification work should be carried on a small-scale harvester for effective cutting and conveying the sweet sorghum stalk.

B) Modification of self propelled harvesters

Three models of advanced and commercially available self-propelled reapers (harvesters) were modified to harvest sweet sorghum crop. The height of the front frame was increased to 120 cm and an additional chain for conveying the stalks was also arranged (Fig. 6).

Fig. 5. Field testing of the modified harvester.

Fig. 6. Field testing of the modified reaper.

The models which are modified and tested were:

- 6.5 hp petrol engine driven P D KV, Akola model
- 5 hp diesel engine driven Kisankraft reaper
- 5 hp diesel engine driven Greaves reaper

Field tests revealed that these reapers were not suitable to harvest the sweet sorghum crop which grows taller than 2.4 m in height. As the stem girth was also more than the conventional sorghum, it was found hard to cut the stem with the scissor type cutting mechanism.

C) Results from mechanized harvesting experiments

All the three models of harvesters were evaluated in field trials and the physical and experimental observations are given below.

- The success rate of the self propelled harvester in the sweet sorghum crop was only 70%.
- It was found difficult to operate in loamy and sandy soils as the traction power is poor.
- Perfect stem cutting was not achieved in the trials of conventionally sown fields as large number of plants per hill was observed in many places.
- Precision machine control provisions were not available in the three models because of the difficulty in operating in loamy soils.
- Some promising results were achieved with the newly designed self propelled harvester; however, some more modifications are needed to commercialize the same for sweet sorghum harvesting operation.

D) Development of single row self-propelled harvester

As sweet sorghum was taller (around 320-350 cm) than the normal sorghum with higher stem girth (ranging from 16-30 mm), it was found very difficult to use the commercial self-propelled reapers which were available in the market. Apart from the problems of cutting, conveying the stalk to the side was found very difficult because of its size and weight. To solve this problem, a new machine was conceptualized and developed at CRIDA's workshop.

This is mainly powered by 6.5 hp petrol engine which reduced normal vibrations. A 3-tier conveying system with chain mechanism was developed by anchoring the two sides with mild steel mesh panels. A horizontal 3-blade cutting disc was used to cut the stems as the machine moved forward (Fig. 6). The RPM of the blade was adjusted to 850. The conveying speed was adjusted to synchronize with walking speed (3-3.5 km per hour). Initial trials showed promising results and the design is under final refinement before commercializing it. It was also planned to develop a tractor-drawn harvester to make it suitable for 2-3 rows.

4. Improvements in crushers to increase the juice recovery

A) Trials with existing crusher

As one of the main objectives of the project was to increase the juice recovery of the stem, studies were conducted on existing crushers and also on modified crushers which were selected based on the availability of power at the location.Two models of modified crushers were used in the cluster area and the performance was evaluated in comparison to the existing crusher. Three samples weighing 100 kg were fed to the crushers and the weight of the juice recovered was recorded.

The specifications of the tested crushers are:

- Crusher 1: 20 hp 2-roller crusher
- Crusher 2: 10 hp 4-roller crusher
- Crusher 3: 10 hp 3-roller crusher

All the three crushers were installed at the decentralized unit and the performance was evaluated during the season (Table 4).

Table 4. Performance of crushers.

Type of crusher	Juice recovery (%)	
	Conventional sown crop	Mechanized sown crop
10 hp, 4-roller	21.40	23.26
10 hp, 3-roller	28.00	31.40
20 hp, 2-roller (conventional)	26.20	28.40

The 3-roller crusher with 10 hp power gave juice recovery of 31.40% which is 3% more than the conventional crusher of 3-roller with 20 hp power. This can be attributed to the zig-zag arrangement of well designed flutes on the rollers which were very suited to the sweet sorghum fiber configuration by compressing them more. It also helped in reducing energy requirement of the crushers by 30%, when compared to the conventional method. As the existing crusher did not give the expected juice recovery, it was planned to work with the changes in the existing designs and specifications.

Fig. 7. The 3-pass 6-roller crusher and its testing.

B) Development of 3-pass 6-roller crusher for increased juice recovery and energy reduction

A 3-pass 6-roller (Fig. 7) crusher was designed, fabricated and tested for extracting more juice with less energy consumption. This was operated by 10 hp electrical motor. During the crushing, the stems pass through different rollers with differently configured flutes for effective shear and compression. Trials of the crusher were made and the juice recovery was found to be increased by 6% compared to existing crushers.

C) Development of high recovery 3-roller 25 hp crusher

A crusher fabricated according to the specific needs of the sweet sorghum stems was installed at Parbhani (Maharashtra) cluster under the Common Fund for Commodities – Food and Agriculture Organization (CFC-FAO) Project. As a collective effort, the crusher was modified by making crossed flutes on the rollers and it was evaluated for its performance at the cluster in order to use the same at Ibrahimbad cluster in Andhra Pradesh. It was observed that the juice recovery was found to be 45% with a capacity of 1200 kg per hour which was lesser than the designed capacity of 2000 kg per hour. It was also observed that some more modifications in the feed input mechanism may increase the input capacity with the same applied power (Fig. 8).

Fig. 8. The 3-roller 25 hp crusher.

III. Conclusion

Mechanization was partly successful in sweet sorghum crop production and our efforts helped identify the gaps in the presently available technologies. Much more refinement in harvesting machinery is needed to reduce the harvesting cost and drudgery in harvesting operation to make the crop a viable biofuel crop. Further refinement in crushing technology is also needed to reach the targeted recovery of 45% juice to enable a DCU to break even. Future efforts in this direction are underway at CRIDA.

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