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Improved sorghum cultivation and value-addition perspectives

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14. Current status of sweet sorghum biofuel industrial experiences for pilot–production of bioethnol

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Rationale for producing biofuel from sweet sorghum: India's growing dependence on petroleum imports and concomitant vulnerability to external price shocks lead to economic setbacks, and trade imbalance. The Government of India mandate blending of ethanol (10%) with gasoline has necessitated the searching alternative feedstocks other than sugarcane molasses. The prices of molasses are highly variable with its inadequate supply and inconsistency over the years led to the search for alternate feedstock such as sweet sorghum. Sweet sorghum is a multi-purpose crop grown for food, feed, fodder, and fuel. The stem accumulates sugars up to 10-15% in its stalk as similar with sugarcane. The ethanol is produced from stem sap, while, the grains are produced on the top of the plant are used as food. Thus, ethanol production from sweet sorghum does not compromise food security. Ethanol is produced from sweet sorghum stem juice through fermentation technology as similar with molasses based process. The crop matures in about 3.5-4.0 months contrary to sugarcane of 12-18 months.. Thus, ethanol production from sweet sorghum does not compromise food security unlike corn. Ethanol is produced from stalk juice through fermentation technology as similar with molasses based process.

Agricultural yields: The yields realizable in optimum conditions include fresh stalk yields (35 to 40 t $ha^{-1)}$, juice brix (16-18%), sucrose (8-11%), and juice yield (12-14 KL ha^{-1}).

Industrial yields: The yields realized in various pilot studies include ethanol recovery (6-9% of juice), unit ethanol yield (35-40 L per one tonne of stalks crushed), and total ethanol yields (1200-1500 L/ha /one crop cycle, bagasse yield (5-7 t ha^{-1}). Power from bagasse cogeneration process can be produced to the extent of 3.5 MW ha^{-1} of crop.

Cultivar option: Currently available crop cultivars are CSH 22SS, SSV84, SSV74, and CSV 19SS, CVS 24SS (public sector), and Madhura, & SPSSV 11 and SPSSV 30 (private sector).

Economics: The cost of cultivation of sweet sorghum is about Rs15, 000 ha^{-1} comprising of paid-out costs with a net income of Rs.16, 250 –25, 000 ha^{-1} based on yield levels and price (Rs.500-700/ t) offered by the biofuel industries.

Industries tested sweet sorghum feedstock in pilot-studies in collaboration with DSR: DSR had organized pilot-studies in collaboration with biofuel distilleries such as M/S Renuka Sugars, Belgaum; Sagar Sugars, Chittoor AP; Praj Industries, Pune; National Sugar Institute, Kanpur; Somaiya Organo-chemicals, Sakarwadi; India Glycols Ltd, Khashipur; KCP Sugars, Laxmipuram, AP; Nav Bharat Ventures, Samalkot, AP; M/S Tata chemicals Ltd, at Nanded, Praj Industries Ltd, Pune, etc.

Bioethanol (biofuel) from sweet sorghum stalks produced in pilot studies
Juice from stalks of sweet sorghum can be fermented to produce ethanol using the existing crushing machinery and distillery available at sugar factories complexes. The details of pilot studies organized are presented below.

1. Renuka sugar factory, Belgaum, Karnataka

DSR organized first pilot-study in collaboration with Renuka sugar factory, Belgaum, Karnataka (during 2001-2003) and the recovery of ethanol obtained was about 40-50 L/ tonne of stalk crushes(Huligol et al 2003),

2. DSR successfully organized pilot test on sweet sorghum for ethanol production in collaboration with National Sugar Institute (NSI), Kanpur, 2005 (Image 1).

Subsequently in 2005, second pilot-study was successfully organized in collaboration with National Sugar Institute (NSI), Kanpur (Min of Food, Government of India). At NSI, 100 TCD experimental mill was used to produce bioethanol from sweet sorghum juice (syrup). The alcohol yield realized was about 40L per tonne of stalks crushed (Image 1).

Image 1. Sweet sorghum pilot study: Sweet Sorghum cane being put in the cane carrier and Prof GK Shukla, Director, NSI , Kanpur and other faculty are overseeing the crushing process (Shukla et al 2006)

3. NRCS collaborated in organizing the big mill test(BMT) of sweet sorghum at Sagar Sugars & Allied Products, Nelavoy, Chittoor, AP, 8 -10 Sept 05.(Image 2)

In the BMT of sweet sorghum the 100 tonnes sweet sorghum cane was used comprising both Cvs.PAC 52093 and SSV 84. The crops were planted during the last week of May 2005 and grew to a height of over 3.0-3.5m. The detrashed (excluding sheath) cane was fed to the feeder channel either directly from trucks or from conveyors and the cane was crushed in the fibrizer and passed through diffuser. Water was added to the juice at the last mill for facilitating higher juice extraction. Subsequently, the extracted juice was dewatered and sent to clarification tank from where it was directed to fermentation and subsequent distillation of ethanol.

During this process, juice and bagasse sample were analyzed for quality parameters such as POL% juice, purity, TRS (%), Juice Brix etc. Initial results given by the process lab shows that sweet sorghum clarified juice recorded following quality parameters. Juice Brix: 7.64%, POL%: 3.08, Purity: 40.31%, pH: 8.5, TRS: 5.30% etc. It is estimated about 35-40 Lit of ethanol per one tonne of sweet sorghum cane. The Management of M/S Sagar Sugars had expressed happiness over successful conduct of first big mill test and fermentation and distillation process.

Other personnel who has involved in BMT include R Venugopal, Sr GM (Agri.), Mr Surendran, Asst. VP, Mr. Pandian, DGM (Cane), Surendra Naidu (DCM), Balasubramanian, AGM (Distl), SN Murthy, Sr Mngr (Process) etc.(Sagar Sugars, Chittor); Anil Mandke,(Praj Indust., Pune) and, Mr Rama Krishnaiah, Asst Cane Commi, (Chittor), etc

Image 2. Sweet Sorghum bigmill test organized at Sagar Sugars, Chittoor, AP, October 2006

4. Tata chemicals sweet sorghum based bioethanol plant at Nanded and experience of sweet sorghum plantation in farmers' fields at Nanded (Image 3):
Under contract farming, farmers were supplied with 5kg of Phorate granules, 3kg seed, and 1 bag of Urea (50kg) on credit basis. Majority of the farmers applied phorate in soil along with seed as prophylactic measure followed by endosulfon spray at about 3-4-leaf sage. The sowing was done with locally available bullock drawn seed drills wherein the row to row distance was just 30cm only. Although TCL advised them to followed wider row 45 or 60 cm, this could not be adopted as farmers followed their traditional practice. Thinning is done in some farmer fields. Because of closer row planting, the crop lodged in some places especially when crop reached the hard-dough stage. The crop produced good ear heads.

In general, the pest infestation was less because of plant protection measures taken as required. However, there were few pests that occurred on sorghum and recorded infestation due to stem borer (< 10%), aphids (< 5%) and shoot bug (< 3%). The brix content observed from ten farmer fields varied from 10.5 to 16.5%. Brix at hard-dough (15.5%) was higher than at soft-dough or flowering (10.5-12.0%). In demonstration fields laid out by TCL R&D, where different grades of TCL customized fertilizers are under test with sweet sorghum. More aphid population (10-30%) was noticed where Tata's customized fertilizers (TCF) were applied. Relatively dark green leaves were noticed due to application of TCF treatments. In another trial on dates of planting, 4 sweet sorghum cultivars (CSH 22 SS, SPSSV 11, NTJ2, JK Recova) were planted in combination of three management practices (recommended, farmers method, need based). The experiments were planted at 10-day interval and so far 5-dates of sowing were completed (22/07/08 to 26/09/08). As sowing delayed the more incidence of shoot fly was noticed besides reduction in plant height. CSH 22SS is showing better performance in different sowing dates.

The constraints expressed by the TCL officials include whether sweet sorghum can be staggered beyond middle of July, whether there are any suitable varieties for rabi with high sugar and stalk yields? Under the buy-back arrangement farmers are paid @ 500/ tone (excluding harvesting and transporting charges) where TCL bear all harvesting & transportation costs. Alternatively, the TCL is exploring to use the PKV developed harvester in the coming season which needs modification of machinery. The farmers which are growing the sweet sorghum are the active members of the Tata Kisan Sansar (T KS). The plant has capacity to crush the 900 tonnes/day (TCD) and produce 30 KLPD that means it requires the stalks to be harvested from at least 60 acers @ 15t/acre and supplied daily. The Engineers suggested that the stalk girth of sweet sorghum should be more to avoid jamming in the rollers. Based on the earlier experiences from previous pilot studies, the sweet sorghum fermentation process generates almost zero-effluents in the spent wash. The spent wash is conveniently mixed with press mud to make organic fertilizers.

Even rectified spirit or ENA produced for sweet sorghum is of excellent quality to that of grain alcohol based with no aldehydes, sulphur, etc. The TCL officials acknowledged the services rendered by the DSR in arranging the planting materials, production technology, training and other services.

Image.3. 30 KLPD, 900 TCD; 4 tandem mills -sweet sorghum based plant set by M/s Tata chemicals Ltd, Nanded, processing of sweet sorghum for bioethanol. Sweet sorghum is grown over 7000 acres in 2008 and 2009.

5. KCP.SICL, Lakshmipuram(AP)sweet sorghum big-mill test (BMT) experience, 17 April 2007

As per the invitation received from AGM (Cane), DSR scientists visited the KCP Ltd., participated the BMT test and evaluated the sweet sorghum stalk yield and quality for ethanol production. The company planned to introduce sweet sorghum as relay or sequence crop after paddy/ turmeric to suit the availability feedstock after the sugarcane crushing in mid April. The company has grown and developed the sweet sorghum crop as per the technical advice and seed materials supplied by NRCS. Three cultivars namely SSV 84, CSV19 SS and Urja (from Praj Ind. Pune) were planted in one acre (0.407 ha) field (deep Vertisols (≥ 1.0 m deep) belonging to the sugarcane contract farmer of Kokkiligadda vill. during first week of January 2007.

The crop was raised with supplemental irrigation (one in every 15 days) with adequate fertility. The days taken to 50 % flowering were 60d in SSV 84, 67 d in CSV 19SS and 72 d in Urja. Quality data collected at weekly interval from flowering to hard dough stage indicated that Urja has the highest brix (15.6%) followed by SSV 84(10.30%) and CSV 19SS (7.70%). Similarly, *CV* Urja recorded highest POL, Purity, and TRS than others.

The crop was harvested manually and brought to the factory on the next day. The detrashing was partly done (30% only) as the stalks grew very tall and the laborers have difficulty in removing the leaves with sickle. Leaves were removed manually only as leaf removal with sickle, which is a common practice in sugarcane, may cause breakage of stem in the middle part for sweet sorghum. The entire stalk from one acre was fed to the cane carrier after the sugarcane crushing is over. The crushing and extraction process was similar to sugarcane as there was no problem of jamming of 3 tandem rollers etc. The total stalk yield obtained from one-acre crop (avrg. 3 cultivars) as weighed at the electronic weighbridge was 14t/ acre (35 t ha^{-1}).

Samples from primary, mixed and last mill juice were collected for quality analysis on TRS, RS, Brix, CCS ethanol recovery (%) etc. The data from the primary juice revealed that sweet sorghum mixed sample has the 17-19% of brix, 11-12 % of POL with a purity of 62-64%. The results obtained in the big mill test on quality parameters are encouraging to upscale this crop for ethanol in the factory command area late rabi/ early summer situation but under contract farming of sugarcane model. The company expressed the need for cultivars to realize more stalk yield with superior quality traits.

6. Sweet sorghum pilot plantation at India Glycols, Kashipur, Uttrakhand, 16 Oct 2006

Met Sr. Vice President, adviser Cane & AGM (ETP) and discussed on the potential of utilizing sweet sorghum feedstock as supplementary to sugarcane in Uttaranchal.The SSV 84 & RSSV 9 sweet sorghum cultivars were planted on 8th May, 8th June and 8th July in the fields close to the distillery. The Crop grew to height of 2.8-3.3 m height. The crop development was good excepting some incidence of Anthracnose& Zonate leaf spot especially after flowering. The crops planted on 8th June were better than May and July fist week planted ones. Although the spacing adopted within the rows was ≤15 cm. It is estimated about 45 t/ha of stalk yield is realized. The brix values recorded at mid grain filll stage varied from 10-11.5%, while it has increased to 13.5-16.3% at harvest maturity. In general, the June first week planted crop recorded higher brix than May and July first week planted crop.

R&D Lab fermentation results for both May and June planted crops indicated that alcohol recovery was from 3.0-4.3% and 5.13-7.26% in May and June planted crop respectively. The results on alcohol recovery from sweet sorghum with SSV84 and RSSV 9 were encouraging at India Glycols Ltd. The company has decided to extend to large pilot study in the next summary, Kharif seasons in collaboration with NRCS. M/S India Glycols Ltd. proposes to compare competitiveness of sugarcane Juice with sweet sorghum Juice rather than molasses since it has already a facility (RAB plant) to utilize sugarcane juice directly to ethanol production. The company already planned to produce ethanol from cereal grains especially broken rice etc. We suggested to utilize sorghum grains as feedstock in comparison with Maize or broken rice etc. It has been decided that company will invite Director, NRCS in New Delhi in the next month for undertaking MOU/possible collaboration for joint projects under NAIP. Mr RS Sharma of M/S Compro Ltd. Delhi took a brief 15 min. live video coverage of the talks given by Dr N Seetharama Director NRCS, and Cane Adviser, Dr Jaising Saroj. The matter covered includes both current efforts and potential of sweet sorghum as a biofuel and biobased products crop in Uttaranchal and future plans.

7. Somaiya Organo chemicals (SOC), Sakarwadi, MS, 10, Oct. 2007 (Image 4)

The SOC has planted 200 acres of sweet sorghum crop during kharif 2007. The seed materials of SSV 84 supplied by NRCS were used for large scale planting. The crop condition and growth were good and it was grown to a height of > 3.0m.The technical guidance of NRCS was followed for implementing the crop development and management.The company had commissioned a three

mill tandem crushing unit with 240 TCD capacity exclusively for sweet sorghum and this facility helped the SOC in production of bioethanol in the existing stand alone 90 KLPD disillery.

Image 4. Sweet sorghum mill established at SOC, Sakarwadi, MS

Conclusions: Producing bioethanol from sweet sorghum with appropriate economic, environmental and social policies will enhance the India's food & energy security, and environmental sustainability; besides creating remunerative markets to the farmers. The large-scale crop cultivation is recommended under contract farming with buy-back arrangement between growers and agro-industry or entrepreneurs' as similar to existing sugarcane industry.

Way-forward:

- Pre-feasibility, commercialization and scaling-up of cultivation in collaboration with biofuel industries, entrepreneurs, farmers, NGOs, etc.
- Develop cultivars producing high stalk yield & biomass per unit time, input, energy and land area in different agro-ecologies.

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