I J PS INTERNATIONAL JOURNAL OF PLANT SCIENCES
Volume **7** | Issue 2 | July, 2012 | 442-449

A CASE STUDY

Sweet sorghum as biofuel crop for arid and semi-arid regions

■ SANDEEP SINGH TOMAR AND S. SIVAKUMAR

SUMMARY

The economic vulnerability of non renewable energy sources like oil and natural gas reserves, declining global productivity of fossil fuels and the fact that oil and natural gas reserves are finite have created a need to develop alternative fuels from renewable sources. Moreover, the heightening of global warming as a consequence of excessive fossil fuel burning increased the importance of new and eco-friendly sources of energy. Also, the increasing price of fossil fuel and gas due to decreasing supply has created a worldwide need to identify and develop alternative sources of energy. Therefore, development and implementation of technology to improve energy production using biologically available material without sacrificing food security is imperative. Sweet sorghum [*Sorghum bicolor* (L.) Moench] is listed as one of the potential feedstock sources for biofuel production. While sweet sorghum grain can be fermented into ethanol in a similar way as maize, the greatest potential of the crop is based on its massive biomass and sugar rich juices.

Key Words : Sweet sorghum, Ethanol, Grain yield, Juice yield

How to cite this article : Tomar, Sandeep Singh and Sivakumar, S. (2012). Sweet sorghum as biofuel crop for arid and semi-arid regions. *Internat. J. Plant Sci.*, **7** (2) : 442-449.

Article chronicle : Received : 10.02.2012; **Accepted :** 16.05.2012

Sorghum (*Sorghum bicolor*) is one of the major cereal crops consumed in India after rice (*Oryza sativa*) and wheat (*Triticum aestivum*). It is mainly a dry land cereal crop. The crop is primarily produced in the Deccan Plateau, central and western India apart from some parts of northern India (Rao, 2008). The three states namely Maharashtra, Karnataka and Andhra Pradesh together account for close to 80 per cent of the all-India production (Rao *et al*., 2010). During 2008-2009, India was the largest grower and also producer of sorghum in the world followed by Nigeria, Sudan and UAS (FAOSTAT, 2010). FAO statistics indicate world grain sorghum production at 58.5 mt from 48.07 mha area with a productivity level of 1391 kg per ha (FAO STAT, 2010). In India, annual sorghum production was 7.25 mt from an area of 9.18 m ha with a productivity of 962 kg per ha in 2008-2009 (ASCR, 2009).

Sorghum is currently a major staple food crop of rural India and because it is grown mostly by marginal and poor farmers, it has a significant impact on our countries food security. Sorghum has been classified under family *Graminae*, subfamily *Poaceae*, tribe *Andropogonae* and genus *Sorghum*. Sweet sorghum belongs to same species as grain sorghum and fodder sorghum, with a potential to accumulate sugars (10-20 %) in its stalks as in sugarcane (Hunter and Anderson, 1997). Since, sweet sorghum is relatively a new crop to India, the statistical data on its area and production is very meager.

Introduction of sorghum in India :

The origin(s) of the domestication of sorghum and its diversification into five major race and thousands of distinct genotypes is partially known (Smith and Frederiksen, 2000). Genus Sorghum showed the greatest variation in the region of the northeast quadrant of Africa comprising Ethiopia, the Sudan and East Africa (Doggett, 1970). Because of this, Africa is considered as the place of origin as it contains maximum number of wild and cultivated species (Chopra, 2001). India is considered as the second centre of origin. It is assumed that during first millennium B.C, sorghum was probably taken to

MEMBERS OF THE RESEARCH FORUM

Author to be contacted :
SANDEEP SINGH TOMAR, Department of Millets, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, COIMBATORE (T.N.) INDIA
Email: sandeeptomar483624@gmail.com

Address of the Co-authors:
S. SIVAKUMAR, Department of Millets, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, COIMBATORE (T.N.) INDIA

India from eastern Africa probably through sea route as food grain (FAO, 1990). Kimber (2000) suggested that sorghum could have been introduced to Asia, in particular India and China, by human migrations around 1045 B.C. To date, Ethiopia and surrounding countries are considered the geographical area of origin (Dhillon *et al*., 2007; Kimber, 2000; Vavilov, 1951), and these countries are well recognized in world sorghum improvement programmes.

Comparison of sweet sorghum efficiency with other commercial crops :

Sweet sorghum produced in India costs $1.74 to make one gallon of ethanol, compared with $2.19 for sugarcane and $2.12 for corn (Reddy *et al*., 2005). Sorghum is a water-use efficient crop and this crop has the potential to assume minimum yield even if there failure of monsoon and climate. Sweet sorghum require 310 kg water/kg of dry matter where as Corn require 370 kg water/kg of dry matter production (Chapman and Carter, 1976; Reddy *et al*., 2007). Sorghum is suitable for growing under dry conditions with annual rainfall ranging from 550- 750 mm (Rao *et al*., 2008). Since it is a water-use efficient crop adaptable to hot dry climatic region and wide range of soil condition, this crop has the potential to be a good alternative feedstock for ethanol production.

Sweet sorghum matures in 115-120 days .On the other hand sugarcane matures in 12-18 months while maize kernel in 4-4.5 months. Ethanol produced from sugarcane molasses, juice and from maize are suffered from two major problems-increased usage of water and pollution. In a study conducted by Vasanthadada Sugar Institute (VSI) Pune, India the pollution level in sweet sorghum based ethanol production has 1/4 th of biological oxygen dissolved (BOD) *i.e.*, 19,500 mg/ liter and lower chemical oxygen dissolved (COD) *i.e.*, 38,640 mg /liter compared to molasses based ethanol production(Rao *et al.*, 2008; Reddy *et al.*, 2007) .

Sweet sorghum- A multi-purpose crop :

Sweet sorghum is a multi-purpose crop which can be cultivated for food, feed and fuel. The sugary juice from its stalk used for making syrup, jaggery and industrial production of ethanol. Stalks have high demand for paper manufacturing due to its better cellulose quality (Ratnavathi *et al*., 2004). Grains are used for food and, leaves and stem residues are used as main source of animal fodder (Rao *et al*., 2008). Since in case of sweet sorghum juice extracted after physiological maturity from stalks is used for ethanol production, the food, feed and fodder demand of small farmers will not be affected.

Baggase from sweet sorghum has more value then sugarcane when used as feed for animal (Reddy *et al*., 2007). The stillage after juice extraction will be used as feed or will be used for power generation. It has high biological value and it is rich in micronutrients. In addition to sweet stalk, grain yield of 2-2.5 ton/ha can be obtained from sweet sorghum cultivation meant for biofuel (Rao *et al*., 2008).

Sweet sorghum is suitable for mechanized crop production. Ethanol quality from sweet sorghum is superior with high octane number and less hazardous pollutants such as aldehydes and sulphur compared to ethanol molasses from sugarcane.

Progress of sweet sorghum as bio-fuel in western countries:

Biofuels such as ethanol and biodiesel are now being produced and consumed in limited quantities around the world as renewable substitutes for petroleum-derived fuels. In the United States, the energy bill enacted in 2005 mandated the increased use of renewable fuels. Encouraged by the new policy, many energy companies took the opportunity to explore and develop novel sources of renewable energy. At present U.S. appear to be focusing on cellulosic ethanol as the most likely candidate for a viable biofuel for the future. US department of agriculture (USDA) has been proposed sweet sorghum as an ideal energy crop that can produce grain and easily convertible sugar as well as large amounts of cellulosic biomass. Currently, sweet sorghum is grown for syrup, forage and silage in USA and other countries (Wang *et al.*, 2009). Pilot plants that can process sorghum juice are being built in the U.S. An example is the Tampa Bay Area Ethanol Consortium (Florida), which is building a scale-up pilot plant demonstration facility to demonstrate the production, harvest, transportation, storage, handling and conversion of multiple feedstocks, among them sweet sorghum, to enable stable, year-round production (Saballos, 2008) and production target is 8 million liter /yr.

Ceres, a leading developer of bio-energy crops is planning to go for sweet sorghum trials in Brazil which will facilitate the introduction and scale-up of the new energy crop, since sweet sorghum fits existing infrastructure and can extend the ethanol production season. Ceres is currently working with multiple ethanol mills, technology providers and equipment companies to facilitate the introduction of sweet sorghum hybrids into existing ethanol mills (Anonymous, 2010).

Sweet sorghum has been recognized as an important ethanol crop which can be planted in marginal lands in China. Under agriculture policy option of the Chinese government and international agencies aiming at improving agricultural land use by promoting sustainable crops and valuing semi arid and other undeveloped lands in China sweet sorghum is taken as pilot crop (Gnansounou *et al*., 2005). By the technical assistance of the FAO, a project was launched in North China (Shandong and Shaanxi Provinces) to develop ''sweet sorghum for grain, sugar, feed, fibre and value-added by-products in arid and saline/alkaline regions in China'' (Chapman, 2002).

In 2002, large bio-ethanol project from sweet sorghum in China and Italy (ECHIT) was started (Chiaramonti *et al*., 2002).

It was aiming at elaborating a technical, economical and financial feasibility study on integrated bio-energy/bio-ethanol/DDG (Distillers' Dried Grains) production from sweet sorghum. In the Shaanxi province, a pilot plant is under construction to process about 50 tons per year of sweet sorghum stalks and extracts about 25000 L per year of juice and 5000 L of concentrated 70 per cent brix sugar syrup that can be either sold to the foodstuff industry or fermented to ethanol after dilution. In Beijing, around 20,000 tons per year of sweet sorghum is processed to alcohol and spirits (Gnansounou *et al*., 2005).

The Philippines signed a US$1.3 billion deal with U.K.-based NRG Chemical Engineering to build biofuel refineries and plantations (Saballos, 2008). Among the plans is the construction of two 300,000 ton sweet sorghum to ethanol plants (Anonymous, 2007).The government is also conducting planting trials of sweet sorghum varieties developed by ICRISAT to test for adaptability to the area (Anonymous, 2011).

Resource and development in India :

Sorghum is the main staple diet of the people of Karnataka, Maharashtra and Andhra Pradesh. Due to its versatile use, drought hardiness, stability of yield and adaptability over wide range of climates, sorghum has maintained its importance and dependability.

Kharif sorghum (June-July to September- October) area in India is 4.10 m ha while *rabi* sorghum (September-October to Februrary –March) occupies relatively more acreage of 5.2 m ha. However, there has been a decline in *Kharif* sorghum area @ 5 per cent per annum which is relatively higher than *Rabi* sorghum, which is @ 3 per cent (Seetharama, 2006). During the last 15 years , a total area of 7.22 mha has been diverted to other crops, resulting in current area of 8.78 mha (Rao, 2008) . If we compared with 1960's when 18 mha area in India was under sorghum cultivation, now only 50 per cent of 1960's area is under sorghum cultivation. Utilization of sweet sorghum for food feed and biofuel production is realized by industry and farmers with feasible economic returns, aided by government policies there will be good opportunity for regaining exhausted sorghum area of production at national level.

The major factor responsible for decline in sorghum area are (Rao, 2008) : Change in consumer preference for food grains, price competition from commercial crops like cotton, soybean, groundnut, sunflower, increase in land area under irrigation, which led to shift in commercial crops.

Even though, the *Kharif* sorghum productivity is higher (1000-1200 kg/ha) than *Rabi* sorghum (600-700 kg/ha) (ICAR, 2008), grain quality of *Kharif* sorghum is poor due to grain mold attack caused by continuous rainfall during the crop growth period. So in order to make *Kharif* sorghum a more remunerative crop, one has to look for its alternative uses. Accordingly, the research should be directed towards possibilities of utilizing the whole plant like looking for novel foods, syrups and as source of raw material to starch, beverages and ethanol industry.

Sorghum genetic resources :

Sorghum genetic resources are conserved at different centers across the globe consisting of approximately 168,500 accessions (Reddy *et al*., 2006). The major organizations engaged in conservation of sorghum genetic resources are ICRISAT, Hyderabad, Andhra Pradesh (India) and the National Plant Germplasm System (NPGS) in the U.S. Moreover, countries like Ethiopia, Sudan, South Africa, India and China maintain germplasm collections as they have large crop improvement programs (Rosenow and Dahlberg, 2000).

Presently, ICRISAT has 37,904 accessions from 95 countries and serves as a major repository for world sorghum germplasm (ICRISAT, 2009). The ICRISAT holdings comprises a diverse set of germplasm including landraces (85.3%), breeding material (13.2%), wild species (1.2%) and named cultivars (0.3%) (Reddy *et al*., 2006). Moreover, the germplasm maintained at ICRISAT contains representative specimens of the five basic sorghum races: bicolor, *guinea, caudatum, kafir* and *durra* and their hybrids (Reddy *et al*., 2006).

In India, DSR (Directorate of Sorghum Research) conserved 23,612 accessions at medium storage along with 1456 accessions as duplicate (DSR, 2011). Around 10,000 accessions of genetic resources are held at AICSIP (All India coordinated sorghum improvement programme) centers.

Genetic improvement of sweet sorghum in India and other countries:

Development of sorghums for energy utilization will require enormous breeding efforts and development of parental lines and breeding materials for deriving varieties and hybrids should be more rapid based on current knowledge of the genetics of desirable characteristics. In industrial terms, this increase will translate into higher sugar content and juiciness that will the cost of making ethanol and make better adaptability for millers and farmers.

In India, initially after independence development of pure line varieties were given importance and as a result several varieties were released in different states. But after the discovery of CMS (cytoplasmic nuclear system) in 1954 by Stephens and Holland, ICAR (Indian council of agricultural research) took efforts to undertake hybrid sorghum research project. As a result of these efforts by ICAR, first commercial sorghum hybrid (CSH 1) was released in 1964 (Reddy *et al.,* 2008). In 1972, with establishment of ICRISAT (International crop research institute for semi arid tropics) at Patencheru, Andhra Pradesh, India sorghum improvement for yield, resistance and wide adaptability got major attention.

Sweet sorghum research in India is carried out by

ICRIAST in association with DSR, Hyderabad and its All India Coordinated Sorghum Improvement Programme (AICSIP) centers, Rahuri, Parbhani, Akola, Coimbatore and Dharwad and this has lead to identification of promising varieties like SSV 84, SSV 74, SSV 119, CSV 19 SS and hybrids like CSH 22 SS (NSSH 104) (ICAR, 2008; Rao *et al*., 2008). SSV 84 was the first variety of sweet sorghum released in 1992 and CSH 22 SS was the first hybrid released in 2005. In 2002, ICRISAT initiated a program for the identification and development of sweet-stalked and high-biomass sorghum hybrid parents and varieties.

Through this work, lines were identified with sugar levels ranging from 16.8 per cent to 21.6 per cent and recommended for release for commercial cultivation in India (Reddy *et al*., 2005).

Table 1 : Area, production and yield of jowar during 2008-2009 in major

Producing states along with coverage under irrigation

Area - Million Hectares : Production - Million Tonnes ; Yield - Kg./ha 2008-2009

State	Area	% to All - India	Production	% to All - India	Yield
Maharashtra	4.07	54.06	3.59	49.50	881
Karnataka	1.38	18.35	1.63	22.48	1179
Madhya Pradesh	0.48	6.39	0.57	7.93	1193
Andhra Pradesh	0.28	3.70	0.44	6.02	1563
Rajasthan	0.58	7.66	0.33	4.59	577
Tamil Nadu	0.26	3.44	0.21	2.95	827
Gujarat	0.17	2.31	0.21	2.87	1195
Uttar pradesh	0.19	2.56	0.20	2.69	1010
Haryana	0.08	1.08	0.04	0.57	506
Orissa	0.01	0.12	0.01	0.08	629
Others	0.03	0.33	0.02	0.32	@
All India	7.53	100.00	7.25	100.00	962

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, India.

ICRISAT, in joint collaboration with DSR, is currently focusing on development of photoperiod insensitive, high brix (sugar) sweet sorghum hybrid parents and high yielding grain hybrids.

In China modern sorghum breeding began in 1920's and heterosis breeding has been the main method of breeding since 1965 (Zheng Yang, 1997). In China, sweet sorghum is primarily used for silage preparation. In 1970's some improved sweet sorghum varieties have been introduced from abroad, such as Rio, Roma, Ramada, and Wray, and some Agricultural colleges and Institutes have begun research into sweet sorghum breeding. The Sorghum Institute, Liaoning Academy of Agricultural Sciences (LAAS) began research in 1985 and successfully bred and released the new hybrids Liaosiza No. 1 in 1989 and Liaosiza No. 2 in 1995 (Zhu Cui Yun, 1998).

Sweet sorghum in USA was introduced from China in 1853 and from last 150 years sweet sorghum varieties have been growing in various regions of USA (Smith and Frederiksen, 2000). The first variety "Chinese Amber" was introduced to America from Shanghai, China, in 1851. Most sweet sorghum varieties planted in the United States today were developed at the U.S. Sugar Crops Field Station at Meridian, Mississippi (Stevens, 2010). Four important varieties from that station are Theis, Keller, Dale, Topper 76-6 and M81E. Active sweet sorghum breeding programs are under way in several states in USA. In 2007, the University of Kentucky and the University of Nebraska jointly released a male-sterile hybrid named KNMorris (Morris, 2010).

In the late 1970´s Brazil initiated a bio-energy programme (Pro-Alcohol) anticipating an energy crises caused be a shortage of petroleum to meet Brazil's fuel needs. The oil crises of 1973 and 1976 renewed interest in the commercial production of sweet sorghum for biological transformation into ethyl alcohol for use as fuel and fuel additives. (Schaffert and Gourley, 1992).The sweet sorghum breeding improvement programme in Brazil (Schaffert *et al*. 1986) was initiated in 1980. Important varities of sweet sorghum in Brazil are Brandes, Honey, Sart, Rio, Williams, Wray, Theis, Redlan, MN 4080, MN 1500, MN 1048, MN 1030, Brandes, BR506, BR507.

Molecular development work for sweet sorghum :

Over the past 20 years, the genetics and genomics of sorghum have been extensively studied. This work has resulted in the publication of several genetic linkage maps containing both molecular (restriction fragment length polymorphisms - RFLPs, amplified fragment length polymorphisms - AFLPs, and simple sequence repeats - SSRs) and morphological markers (Chittenden *et al*. 1994; Woo *et al*., 1994; Bhattramakki *et al*., 2000; Menz *et al*., 2002). All these efforts culminated in a high-density sorghum genetic map which is available for evolutionary, genetic diversity, and QTL studies. Recently, the entire 730 Mb genome sequence of *Sorghum bicolor* has been obtained and added to the public domain (Paterson *et al*., 2009).

A majority of the published research is focused on marker assisted selection (MAS) for biotic and abiotic stresses, besides for yield related traits. Significant QTLs have been found for the traits *viz.,* sucrose percent, sucrose yield, sugar yield etc. (Natoli *et al*., 2002, Yun-long *et al*., 2006). Ali *et al.* (2008) has reported clustering of 68 sweet sorghum cultivars into 10 clusters using 41 SSR markers based on polymorphism information content (PIC), which is in agreement with the available pedigree and genetic background information. Yun-long *et al*. (2006) has constructed a genetic linkage map using 327 markers (40 RFLP, 265 AFLP and 42 SSR) and succeeded in identifying two QTLs, namely qSC-D and qSC-G, that explains 25 per cent phenotypic variance of sugar content. Sugar yield QTL is co-localized with juice yield and stem fresh weight but not with sugar concentration. Therefore, sugar yield per hectare may be best improved by increasing stem fresh weight owing to its high genetic variability and heterosis potential while maintaining maximum sugar concentration and stem juiciness (Murray *et al*., 2008). Ritter *et al*. (2008) reported QTLs for sugar-related traits in a population of 184 recombinant inbred lines (RILs) derived from grain and sweet sorghum. They used 247 AFLP, as well as sorghum and sugarcane SSR markers. Using composite interval mapping at a LOD score of 3.00, they detected 29 QTLs distributed in five different linkage groups for sucrose content (11 QTLs), sucrose yield (8 QTLs), and sugar yield (10 QTLs).In two different populations, Natoli *et al*. (2002) and Murray *et al*. (2008), both identified a QTL for stem sugar on chromosome 3, explaining 18 and 25 per cent of the trait variance, respectively. Natoli *et al*. (2002), in an F1 population derived from a sweet sorghum × sweet sorghum cross, estimated the chromosome 3 QTL effect was 56 per cent additive and 44 per cent dominant. Murray *et al*. (2008) used a recombinant inbred-line population derived from sweet sorghum × grain sorghum cross, so only additive effects could be calculated.

Scope of sweet sorghum for future in India :

At present, in India, sugarcane is the only crop utilized commercially for sugar production by sugar industry and the by product (molasses) is used for ethanol production. The juice from sweet sorghum is much cleaner (low in aldehydes) and can be fermented with 90 per cent efficiency to produce clear and potable ethanol as compared to the juice from sugarcane. Due to Indian government's intiative for production and use of biofuels, considerable progress has been made in the development of sweet sorghum cultivars (Reddy *et al*., 2008).

The increasing price of fossil fuel and gas due to decreasing supply has created a worldwide need to identify and develop alternative sources of energy. Moreover, the heightening of global warming as a consequence of excessive fossil fuel burning increased the importance of new and eco-friendly sources of energy (Rooney *et al*., 2007).The growing need for renewable energy sources derived both by the declining supply of fossil fuel and the growing environmental concern has elevated the value of these crops and they have become among the major feedstock sources for biofuel production. Both the dry matter produced from high biomass sorghums and the sugary juice extracted from sweet sorghum stalks are among the major raw materials for bio-fuel production.

Sorghum possesses unique genetic traits, low lignin mutations that can reduce the cost and at the same time increase the efficiency of converting lingo-cellulosic biomass to fermentable sugar (Saballos *et al*., 2008). Also, the sugary juices can be directly fermented to ethanol in much the same way as sugarcane. In fact, sweet sorghum juice contains high percentages of reducing sugars which prevents crystallization and thus increases fermentation efficiency up to 90 per cent (Ratnavathi *et al*., 2004).

Government of India (GOI) has made it mandatory to blend petrol and diesel with ethanol (to reduce carbon monoxide emission in automobiles) initially up to 5 per cent and gradually hiking it to 10 per cent in the second phase (GOI, 2010). According to the Federation of Indian Chambers of Commerce and Industry (FICCI), India could save nearly 80 million litre of petrol annually if petrol is blended with alcohol by 10 per cent. The possible ethanol production from available sugarcane molasses but the molasses-based ethanol distilleries operate only for 180 days (during sugarcane crushing season) because of the limited availability of the molasses to run the distillery throughout the year as well as the problems associated with the spent wash to comply with pollution control standards. The underutilization of the existing molasses-based ethanol distilleries and the deficit in ethanol requirement can be made good if sweet sorghum cultivation is promoted for ethanol production.

Presently, the government is unable to implement compulsory blending ethanol in petrol (gasoline) due to the short supply of sugar molasses in 2008-2009 and 2009-2010 because of overall low sugarcane crop production in India (Srinivasan *et al*., 2010).

Impediments of sweet sorghum cultivation :

In case of sweet sorghum post rainy season productivity is 30-35 per cent lowers than rainy and summer season crop. This is because of short day length and low night temperatures. To meet industry demand for supplying raw material, especially during lean period of sugarcane crushing, it is important that sweet sorghum cultivars that would insensitive to photoperiod and temperature with high stalk and sugar yield should be developed (Rao *et al*., 2008).

The yield and quality of sorghum is also affected by a wide range of biotic and abiotic stresses. Shoot fly, stem borer, head bug are the major pests while anthracnose, grain mold and striga are among major diseases. Under abiotic stresses – problematic soils like saline and acidic are major constraints for sorghum cultivation. Because of all these constraints world sorghum is dismally low (0.7 tonn/ha) (Reddy *et al*., 2008).

Breeding of short, mid-late and late maturing genotypes is necessary in order to have a broad harvest window in sweet sorghum, and thus providing raw material to the distillery over a long period. But when cultivars with different maturity groups are grown in an area, pests like shootfly and midge may likely to infest in late maturing cultivars (Srinivasan *et al*., 2010).

Sorghum crop is traditionally challenged by marginal lands with poor fertility status and poor moisture holding capacity and sweet sorghum too encounter similar problems.

The self fermentation of juice inside the stalk prior to juice extraction is a major concern, mainly when juice extraction is delayed after harvest due to long distance between factory and the field (Srinivasan *et al*., 2010).

Policies and programme from government of India (GOI) for promoting sweet sorghum cultivation

Under national policy on biofuel, Government of India, Bio-ethanol already enjoys concessional excise duty of 16 per cent and biodiesel is exempted from excise duty. No other central taxes and duties are proposed to be levied on bio-diesel and bio-ethanol (GOI, 2010).

Plantation of non-edible oil bearing plants, the setting up of oil expelling/extraction and processing units for production of bio-diesel and creation of any new infrastructure for storage and distribution would be declared as a priority sector for the purposes of lending by financial institutions and banks. National Bank of Agriculture and Rural Development (NABARD) would provide re-financing towards loans to farmers for plantations. Indian Renewable Energy Development Agency (IREDA), Small Industries Development Bank of India (SIDBI) and other financing agencies as well as commercial banks would be actively involved in providing finance for various activities under the entire biofuel value chain, at different levels (GOI, 2010).

Under the ICRISAT and National Agricultural Innovation Project (NAIP) value chain development sub-project, farmers in 12 villages in Medak district, Andhra Pradesh are provided with improved seeds, fertilizers and agrochemicals and technical expertise to get the best productivity under the rainfed conditions (Srinivasan *et al*., 2010).

Under Remote Village Electrification Programme of Ministry of New and Renewable Energy Sources (MNRE), Government of India projects are implemented in two remote hamlets- Vavdi and Vaddithar in Patan district, in northern part of Gujarat under supervision of IRADe (Integrated Research and Action for Development). The major focus of these projects is on meeting village energy requirements through biomass based conversion and other renewable technologies (IRADe, 2007).Indian Renewable Energy Development Agency Limited (IREDA) is a Public Sector Undertaking under the administrative control of the Ministry of Non-conventional Energy Sources (MNES), Government of India, engaged in the promotion, development and financing of renewable energy and energy efficiency projects in India.

The National Programme on Biomass Power Generation has been initiated by the Government of India through the Ministry of Non Conventional Energy Sources (MNES). It aims at optimum utilization of variety of biomass materials including dedicated energy plantation for power generation through the adoption of latest conversion technologies. These include combustion, incineration, pyrolysis,

Importance of sweet sorghum cultivation for rural improvement :

At national level producing more bio-fuels will generate new technologies, new industries, new jobs and new markets assisting economics growth in rural areas besides reducing environmental pollution. On an average the cost of cultivating sweet sorghum is Rs. 15,800 per hectare and net returns excluding family labour obtained was Rs. 6,500 per hectare (Srinivasan *et al*., 2010).

Brazil is good example where jobs created from bio-fuel industry to those created from fossil fuel industry is 22:1. Development of a domestic renewable energy will reduce the India's oil import. This would have strategic significance for India's energy security. In January 2003, the Indian government mandated the use of a five per cent ethanol blend in petrol sold in nine sugarcane producing states, and plans to expand this approach to rest of country in a phased manner (Gonsalves, 2006). The government is also hopeful to meet 20 per cent of the country's diesel requirement by 2011-2012 by implementation of the National Biodiesel Mission (Gonsalves, 2006). Since ethanol will be made from renewable and locally produced crop like sweet sorghum, thus helping Indian farmers in increasing their sales and improve their income.

Conclusion :

In past decade, real price in case of major food crop commodities like maize, wheat, rice, and sugar continuously reduced. The major reason for that was continuous improvement in agriculture production and trade (Liebowitz, 2009). But in past few years there was abrupt rise in commodity prices even though supply was abundant in most parts of world. In present scenario, feedstock value of crops for biofuel will determine the prices of those crops which can be used for both fuel and as food for human consumption or as animal feed (Cassman and Liska, 2007). In recent years, primary reason for food price rise was rise in international fossil fuel prices which was further associated with political instability in major oil exporting countries and rapid demand growth in developing countries like China and India (Cassman and Liska, 2007).

Sorghum (*Sorghum bicolor*), a relative of sugarcane and corn, is a cereal crop grown widely in India. Because sweet varieties produce fairly high levels of sucrose in the stem, this crop may have a promising future, both for ethanol and food production, if moderate improvements can be made in grain quality and yield. Indian farmers are already familiar with cultivating sorghum. Therefore, a switch to growing sweet sorghum for both food and fuel should be manageable with little or no change in cultural or farm practices.

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