

Improved varietal technology

for enhanced productivity in sorghum

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Sorghum is a multipurpose crop that can be grown for a variety of uses like food, feed, forage and fuel, and is well adapted to different soil and weather conditions. There is distinct seasonal adaptation of grain sorghum cultivars and commodity-specific cultivars for green forage (rainfed single-cut, irrigated multi-cut), bioethanol production (sweet stalked sorghum) mark the clear-cut separate classes that exemplify the adaptation and diversity in sorghum as a crop. The research efforts over five decades have resulted in the release of more than 80 improved cultivars at the national level and more than 200 at state level with traits of high grain yield, biotic and abiotic resistance, fodder types, and sweet sorghum genotypes etc.

Keywords: Forage sorghum, Grain sorghum, Hybrids, Sweet sorghum, Varieties

SORGHUM is one of the important dryland crops which have been the lifeline of the rural communities in the arid and semi-arid regions of the globe. It is a unique crop of drylands that is the last crop to be standing under moisture stress and the fastest to recover once showers are received, coupled with highest dry matter production potential. In India, it was one of the major cereal staples during 1950s and occupied an area of more than 18 m ha, but the area has come down gradually and during 2020-21 it was recorded to be 7.38 m ha (4.38 m ha under grain sorghum and about an estimated area of 3 m ha under forage sorghum).

Sorghum crop in India is being grown in two main seasons: *kharif* (rainy) season as a rainfed crop while in *rabi* (post-rainy) season under residual soil moisture/limited-irrigated conditions. The requirements for these two seasonal adaptations are quite diverse due to different agro-climatic conditions. *Kharif* crop is exposed to vagaries of weather and highly diverse and adverse environments as this season is characterized by monsoon rains. On the other hand, *rabi* sorghum is essentially grown under receding soil moisture and the crop is generally exposed to terminal drought stress. The Most of the rainy season grain produce is used for industrial and poultry uses, while the majority of *rabi* season production is used for human consumption. In both the seasons, stover forms an important source of animal feed. The overall increase in productivity of *kharif* is far more than *rabi* sorghum. However, the loss both in area and production is greater

in *kharif* sorghum than in *rabi*. The coverage with high yielding varieties (HYVs) of sorghum is nearly 80% in *kharif* and their potential under moderate input is also high (4–6 t/ha). The area loss may be due to the fact that the expansion in irrigation which has made other crops such as rice, sugarcane, cotton, etc. more attractive and remunerative thus rendering sorghum to be less competitive. The decline in consumption demand of sorghum grain was also a major factor for the decline in area. The increased productivity of sorghum has not been able to compensate the loss in area turning the production to be negative.

But sorghum is finding a niche area under rice fallows, under the zero tillage conditions where grain productivity as high as 7–8 t/ha. Now it occupies a prime area of more than 45000 hectares and is expanding further, where *kharif* hybrids are prominently grown. In the last two decades, the nature and utilization of sorghum grain has undergone a change from being a staple food to industrial uses such as livestock and poultry feed, potable alcohol, starch and ethanol production. In addition, new value added/processed food products for human consumption are emerging such as popped sorghum, papad, semolina and other ready to cook and ready to eat foods, which, though in nascent stage, are likely to be significant avenues for diversifying utilization of sorghum and thus increasing its demand.

Historical perspective of sorghum improvement in India

Focused sorghum research in India started with the establishment of the Project on Intensification of Regional Research on Cotton, Oil seeds and Millets (PIRRCOM) in 1958. In 1966 the sorghum research was shifted from New Delhi to Hyderabad as a part of IARI Regional Research. Realizing the success of hybrid sorghum in the United States of America in 1962, the Indian Council of Agricultural Research (ICAR) launched the Accelerated Hybrid Sorghum Improvement Project (AICRP-Sorghum) from the existing IARI, RRS in Hyderabad. Subsequently, in 1987 a full-fledged “National Research Centre for Sorghum (NRCS)” was established which has evolved in to Indian Institute of Millets Research (IIMR) in 2015. Currently AICRP-Sorghum functions with a total of 18 centres spread across 9 states. Sorghum improvement efforts since 1960s were focused on improved grain and fodder yields. However, with demand of sorghum as forage crop and in recent years as sweet sorghum, an alternate source of bioethanol; intensive efforts towards these ends have also been initiated. A number of hybrids and open pollinated varieties have been released for

cultivation till date, specifically to suit different seasons across India both at the national level by the ICAR and at the state level by State Agricultural Universities (SAUs). The popularity of nationally released sorghum hybrids (CSH 1 to CSH 35), varieties (CSV 1 to CSV 36), forage hybrids (CSH 20MF and CSH 24MF) and sweet sorghums (CSV 19SS, CSV 24SS and CSH 22SS) are a standing testimony of success of Indian sorghum programme not only in terms of yield enhancement, but also in terms of diversification of parental lines and progressive advances in incorporation of resistance against major pests and diseases. Some of the prevalent public sector sorghum hybrids/varieties that are adapted to *kharif* include CSH 14, CSH 16, CSH 25, CSH 30, CSH 35, CSV 15, CSV 20, CSV 23, CSV 27, CSV 31 while cultivars that are suitable for *rabi* include CSH 15R, CSH 19R, CSV 14R, CSV 216R, CSV 22R, CSV 26R, CSV 29R and M 35-1 (Table 1).

Kharif grain sorghum

The area under *kharif* sorghum is reduced drastically from 11.5 m ha in triennium ending (TE) 1970 to 5.0 m ha in TE 2000 and now stands at about 2.0 m ha. Despite

Table 1. List of popular and recently released cultivars at national level through public sector breeding efforts

Cultivar	Year of release	Grain yield (q/ha)	Fodder yield (q/ha)	Plant height (cm)	Maturity (days)	Recommended for
<i>Kharif</i> sorghum hybrids						
CSH 14	1992	38	88	181	102	All <i>kharif</i> sorghum growing areas in the medium to heavy soil for low rainfall areas
CSH 16	1997	43	97	180	110	All <i>kharif</i> sorghum growing areas
CSH 25	2007	44	127	205	110–115	All <i>kharif</i> sorghum growing areas
CSH 30	2013	44	141	216	105	Maharashtra, Karnataka, MP, Gujarat and Andhra Pradesh
CSH 35	2016	41	126	210–215	109	Maharashtra, Karnataka, Madhya Pradesh and Gujarat
CSH 41	2018	47	124	190	106–110	All <i>kharif</i> sorghum growing areas
CSH 42	2021	40	117	170–180	98–105	Karnataka, Andhra Pradesh, Madhya Pradesh and Gujarat
CSH 45	2022	44	121	180–190	105	Karnataka, Maharashtra, Rajasthan and Telangana
<i>Kharif</i> sorghum varieties						
CSV 17	2002	25	68	133–140	97	Low rainfall and drought prone <i>kharif</i> sorghum growing areas
CSV 20	2006	31	133	240	109	All <i>kharif</i> sorghum growing areas
CSV 27	2012	28	193	235	116	All <i>kharif</i> sorghum growing areas
CSV 41	2019	32	159		106–110	Andhra Pradesh, Telangana, Tamil Nadu, Rajasthan and Gujarat.
CSV 42	2020	38	140	262	115–118	Karnataka, Maharashtra, Madhya Pradesh and Gujarat
<i>Rabi</i> hybrids						
CSH 15R	1995	32	56	190	110	All <i>rabi</i> sorghum growing areas
CSH 39R	2018	27	69	212	115	All <i>rabi</i> sorghum growing areas
<i>Rabi</i> varieties						
CSV 26R	2012	13–16	45–60	180–200	112–115	All <i>rabi</i> sorghum growing areas- suitable for shallow soil
CSV 29R	2013	25–30	50–75	180–200	115–120	All <i>rabi</i> sorghum growing areas- suitable for medium to deep soils

the decrease in the area of cultivation, there has been impressive enhancement of productivity from 560 kg/ha in 1970 TE to 1000 kg/ha in 2000 TE. Maharashtra, Karnataka, Telangana, Andhra Pradesh and Tamil Nadu are the major states where both *kharif* and *rabi* sorghums are cultivated. Sorghum improvement till 1960s focused on selections from local land races, which were tall with low harvest index, photosensitive, late maturing after onset of monsoon and with localized adaptation. With the launching of Accelerated Hybrid Sorghum Project through Rockefeller Foundation a wide range of germplasm was made available in India. This led to significant improvement principally through manipulation of plant height and maturity. Major achievement of Accelerated Hybrid Sorghum Project was the availability of male sterile (MS) lines from the USA and diverse germplasm from Africa and South East Asia. With the release of CSH 1, the first commercial hybrid in 1964, sorghum became the second crop after maize in developing high yielding hybrids using cytoplasmic-genetic male sterility system and variety CSH 1 gained much popularity among farmers.

The increase in productivity is due to introduction of short-duration dwarf high yielding hybrids which are especially well adopted in the state of Maharashtra. The hybrids played a key role in pushing up productivity and production in *kharif* sorghum. Among the hybrids, the role played by CSH 1, CSH 5, CSH 6, CSH 9, CSH 14 and CSH 16 needs a special mention. While CSH 5 and CSH 6 had a yield potential of 3400 kg/ha, this was raised to 4000 kg/ha in CSH 9. It is now further advanced to more than 4100 kg/ha in CSH 16, CSH 25, CSH 35 and CSH 41 with distinctly superior quality grain and fodder yield. High yielding varieties, CSV 1 to CSV 41 at central level and many more at state level were released. Though there was impressive growth in terms of availability of highly productive cultivars, the area and production have drastically gone down because of lack of demand for the grain.

Opportunities for *kharif* sorghum: The utilization of *kharif* sorghum grain as a raw material in various industries is increasing, given the limited prospects of *kharif* sorghum for human consumption. The major thrust is to create demand of *kharif* grain for the nonfood sector,



CSH 41-Medium maturing hybrid



CSH 30-Early maturing hybrid



CSV 41-Dual purpose variety



CSV 27-Dual purpose variety

particularly for feed, biofuel, starch and beverage industries. Molded *kharif* grain, which fetches lower market value, is a cheap raw material for production of potable or industrial alcohol. Sorghum is the second-best grain after barley for malting. The main industries currently using sorghum in India are the poultry feed (2.0 million tonnes (MT) annually), animal feed (0.60 MT) and alcohol distilleries (about 0.49 MT). Sorghum is used when maize is in short supply and priced up to 20% higher than sorghum. The emerging role of *kharif* grain as feed in the domestic and international circuits is a viable opportunity that needs to be harnessed. The genetic potential of this crop to provide cultivars with good malting quality, competitive starch production and useful source of beta glucan may also receive higher recognition. There is hardly any other single dryland cereal crop which is endowed with so many desirable traits and untapped utilities. Industrial linkages for expansion, marketing and commercialization by brand promotion of sorghum products will secure a stable and profitable market for sorghum.

Major constraints for *kharif* sorghum production

- Decline in area of cultivation due to reduced demand for food.
- Development of high yielding cultivars with early maturity resulted in coincidence of grain development and maturity with late rains during certain years resulting in poor quality molded grains.
- *Kharif* grain is not as remunerative as that of *rabi* because the seed is not round and lustrous.

Research and development strategies to overcome the major constraints: For *kharif*, high productivity, grain mold resistance and possibly mechanical combine harvest may minimize losses and keep sorghum competitive. Hybrids with additional traits and suitable crop canopy are now required to overcome the production problems. ICAR-Indian Institute of Millets Research (IIMR) is targeting to develop a cafeteria of cultivars to choose for different situations and specific uses.

Intercropping systems and improving cropping intensity: Climate change issues in terms of fluctuating monsoonal rains both in quantum and distribution calls for risk mitigating approaches through intercropping systems that help optimize sorghum production. Combining photosensitive pigeon pea with improved and early maturing sorghum hybrids had been successful across Maharashtra and Karnataka. Development of erect leaved sorghum hybrids with greater yield potential will help decrease the competition among intercrops and thus improve the overall productivity of the systems. Combining cereal–pulse intercropping also helps addressing the sustainability and soil health issues in the long term.

Summer cultivation of sorghum: Due to dry summer weather, grains are highly priced owing to clean and superior grain quality and have tremendous scope for export purposes. Summer sorghum caters the needs of fodder during peak shortages. Strategies to optimize genotype performance by nutrient interactions can

also help stabilize the yield potential in summer. Individual State Governments across the southern states of Maharashtra, Karnataka and Telangana have been promoting various irrigation projects to expand the irrigated area thus facilitating the local farmers. Expansion of irrigated tracts will help promote food crops that have greater potential in terms of productivity especially during summer season.

Red sorghum for feed and export: Specialized red *kharif* sorghum cultivars for grain export to international market are another emerging opportunity. In order to meet the feed demand in high rainfall regions, red grain sorghum is targeted as potential raw material for poultry which imparts rich yellowness to yolk of egg. These are more tolerant to grain molds and breeding programmes are targeting development of red grain sorghum cultivars with early maturity, combining tolerance to grain molds and major pests in high yield background.

Rabi sorghum

Maharashtra, Karnataka, Telangana, Andhra Pradesh and Tamil Nadu are the major states where *rabi* sorghum is extensively cultivated. Over the years, *rabi* sorghum area has remained stable as it is cultivated as dual-purpose crop, for grain and fodder purposes. Moisture stress in growth stage 2 (GS2) due to unique situation of growing the crop on receding soil moisture in medium to shallow soils, susceptibility to shoot fly, charcoal rot, and low temperature affecting crop growth as well as fertility restoration in hybrids are the major factors responsible for low yield.

Major constraints for *rabi* sorghum production

- Non-availability of quality seed of recent releases is one the biggest problem in *rabi* sorghum. The seed supply chain needs to be strengthened for the availability of quality seed at the start of planting window for *rabi* sorghum.
- Terminal Moisture stress coupled with charcoal rot disease and lodging limits the crop potential. Terminal drought is one of the major production constraints limits the use of purchased inputs like hybrid seeds and fertilizers. Therefore, research on drought tolerance involving development of early maturing *rabi* sorghum varieties and incorporation of stay-green and other drought QTL/genes needs to be taken up.
- Non-adoption of recommended package of practices (plant population, disease and pest management) by the farmer.
- Lack of Hybrids: Another important issue is the lack of substantial heterosis in *rabi* hybrids as land races (which are low community performers) are used (mainly to maintain the consumer preferred grain size and luster) in the development of both A/R parents. Restoration under cold (<12°C) is another important requirement in hybrids as most hybrids are susceptible to cold at anthesis.

Achievements through genetic enhancement

- Grain yield: Recent releases like CSV 29R (Deep and medium soils), CSV 26R (shallow soils) perform better over M35-1 for both grain yield and fodder yield. A major hurdle is that they need to be effectively brought into seed production chain to replace M35-1. Many varieties at state level are available, which are superior to M35-1 for their grain and fodder yield and also for roti quality. Breeding diversified A and R lines involving exotic durra and other sorghum races can be of much help in developing heterotic hybrids adapted to *rabi* season. CSH39 has been recently released with diversified parents with *rabi* adaptive traits.
- Insect/disease tolerance: *Rabi* sorghum genotypes show better shoot fly tolerance compared to *kharif* sorghum genotypes. Charcoal rot is the major disease that comes along with terminal drought. Varieties, DSV4 and DSV5 have been released from the Dharwad centre as charcoal rot resistant
- Terminal drought: RSLG262 (Phule Maulee), CSV-26R, Phule Chitra are some important lines developed for terminal drought tolerance.
- Grain quality: In *rabi* sorghum always the breeding efforts revolved around grain quality in terms of physical appearance and *roti* making qualities. Among recently released varieties, CSV22, CSV29R, CSV26R, Phule Vasudha, Phule Chitra, Parbhani Moti, Parbhani Super Moti, PKV Kranti have very good *roti* making qualities besides being high yielders. *Roti* quality sorghum is also used for other purposes like RSSGV 46 (hurda purpose), RPASV 3 (papad making), SMJ 1, RSJ 1, PKV Ashwini (hurda purpose), AKJ 1 (flaking purpose), Phule Panchami, KMJ 1 (popping purpose) etc.

Strategies to address the major constraints

- Diversification of CMS base and R lines for increased heterosis through use of genetic diversification involving multi-parent (MAGIC) crosses, diverse germplasm lines (dorra race genes from Yemen, Cameroon, Ethiopia) are required.
- Breed for dwarf CMS (100–120 cm) and medium tall restorers (150 cm): Bringing major dwarfing genes and earliness using proper donors into A/B and R lines for making hybrids less lodging, easy harvesting and amenable crop mechanical harvesting. The change in plant architecture is expected to increase heterosis levels in hybrids
- *Rabi* adapted and high input responsive hybrids for irrigated conditions: In recent times, with the availability of irrigation water in command areas, there is growing interest in cultivation of *rabi* sorghum. Hybrids which are responsive to high inputs need to be developed for these niche areas on a mission mode approach.
- Incorporate stay-green trait in varieties and parents of hybrids (CMS and restorers): Among biotic stresses drought is the main production constraint in *rabi* sorghum. Though sorghum has drought

tolerance, post-flowering drought causes extensive yield losses to the crop. Major QTLs contributing towards stay green trait has been identified and are being attempted to be transferred to superior cultivars. Crossing between high yielding adapted lines and screening under stress situation has yielded release of several *rabi* adapted cultivars both at state and central level. Marker assisted breeding has been followed to incorporate two key stay-green QTL (stg3a and stg3b) into *rabi* genotypes. Preliminary analysis of trials conducted at Hyderabad, Solapur and Vijayapura, indicated significant improvement in water extraction ability and Transpiration efficiency of MAS products compared to the recurrent parents. Incorporation of QTLs also improved grain and fodder yield over recurrent parents. The results are encouraging to transfer the QTL into other recent releases like CSV29R, CSV26R and in M35-1.



CSV29R-*Rabi* sorghum variety in farmers' field



CSH39R-*Rabi* sorghum hybrid

Forage sorghum

Forage sorghum is cultivated in about 2.6 to 3.0 million ha area in India each year. They are principally cultivated in Punjab, Haryana, Delhi, western and central Uttar Pradesh, northern Madhya Pradesh, Parts of Telangana, Andhra Pradesh and Karnataka. In these states, it is grown during *kharif* and summer seasons, either as single-cut (mostly in *kharif*, as rainfed) or as a multi-cut (summer and *kharif*) forage crop. Intensive

cropping, short growing season, poor growth of perennial grasses during winter, nutritional quality and the need for continuous supply of green fodder created demand for forage sorghum in northern India.

The genus *Sorghum* includes two economically important species *bicolor* (large grained type) and *sudanense* (sudan grass, smaller red to black coloured grains), among others. While *bicolor* is used for food, feed and forage in India, the other is specifically for forage purpose. The major objectives in forage sorghum breeding are to develop varieties both for single cut and multi-cut with high tonnage, better quality, good seed yield and resistance to insect pests and diseases.

In India, concerted breeding efforts for the improvement of forage sorghum were initiated in 1970 under the All India Coordinated Sorghum Improvement Project (AICSIP) and subsequently many improved single-cut and multi-cut varieties and hybrids were developed. In 1990s, development of multi-cut sorghum varieties and hybrids received lot of emphasis in India. Sorghum × sorghum cross-derived single-cut varieties were bred during 1980s and 90s for high fodder yield, better quality and wide adaptability. At this juncture, private sector also came forward to join the efforts. In addition to high green and dry fodder yields and wide adaptability, newer varieties also possessed relatively higher seed production potential (compared to sudangrass and derivatives), resistance to foliar diseases and better quality fodder.

After the 90s, several cultivars have been developed and notified in single-cut forage in public sector whereas multi-cut forage hybrids were developed by private sector. The latest varieties also exhibited higher per day productivity, dry matter digestibility and total soluble sugars with comparable protein content. The release of latest multi-cut variety CSV 33 MF, a mutant derived from Co(FS)-29, which has forage yield potential of more than 100 t/ha from 3 cuts, is also amenable for up to 7–8 cuts in favourable conditions. The hybrids and varieties released after 2000 have also been improved for forage quality besides forage yield per se. Those entries with HCN toxicity potential above threshold are rejected in the initial multi-location trial onwards. Crude protein content as well as digestibility of forage is incorporated in the variety promotion criteria.

The present nationally released bench marks for forage sorghum are CSV 35F variety and CSH40F hybrid for single-cut, CSV 33MF variety and CSH 43MF hybrid for multi-cut (Table 2). Indian institute of Millets Research along with AICRP (Sorghum) centres has been constantly addressing the challenges in forage sorghum improvement since its beginning. Facilitating germplasm procurement, distribution and utilization, diversification of genetic base, laying down stringent standards of forage quality and resistance to stresses and collaborating with animal scientists have been the major milestones in augmenting the forage sorghum productivity in the country. Recognizing the major role played by private sector in catering to the huge demand

for forage sorghum, licensing and IPR sharing with private entrepreneurs (hybrids CSH 20MF, CSH 24MF CSH 43MF) has promoted the synergy which has helped the public hybrids to reach the forage sorghum farmers at an accelerated pace.

Advantages of new forage sorghum cultivars

- The improved cultivars have higher digestibility indicating more milk and meat production in livestock. It is estimated that for every 1% increase in digestibility, there is 2–3% increase in milk yield.
- These cultivars are more tolerant to stem borer and lodging, thereby minimize losses compared to earlier cultivars. Tan-coloured cultivars are resistant to foliar diseases, do away with hazardous chemical control.
- These have been tested for cyanogen (HCN inducing) safety under recommended cultivation conditions and found highly safe.

Future strategies in forage sorghum: Forage sorghum improvement programmes are beset with lack of information on variability and useful genetic stocks for various traits. Therefore, concerted and planned efforts are needed to collect, evaluate, catalog and maintain germplasm exclusively for forage sorghum. To get a regular supply of green fodder for a longer period of time, multi-cut varieties having profuse tillering, quick regeneration, faster growth and capability of giving a minimum of 4–5 cuttings should be developed. The high yield and multi-cut potential of sudangrass should be further exploited in breeding programme to develop highly adapted and high yielding stable multi-cut variety of forage sorghum. Further advances in forage sorghum improvement should pay attention to stability in production of biomass and nutrient content through resistance breeding.

Sweet sorghum

Energy sorghum, which includes Sweet sorghum (1G feedstock) and biomass sorghum (2G feedstock) has recently gained favour as bioethanol feedstock amongst numerous candidate crops. Sweet sorghum is a short duration crop of about 4 months, which produces higher biomass yield with less input. India has achieved 10% blending of petrol with ethanol recently and the next target is 20% blending by 2025. The fact remains that ethanol production from sugarcane molasses alone does not ensure optimum supply levels needed to meet the demand at any given time. Sorghum as a dryland crop offers a sustainable solution to this problem as it can be grown for feed, fodder, fuel and fibre. One of the obstacles to this crop's expansion as a biofuel feedstock is the fact that sugarcane has established dominance over the production chain of sugar and ethanol, receiving the majority of the investments.

Status of sweet sorghum research

- ICAR-Indian Institute of Millets Research along with its partnering institutions under National Agricultural Research and Educational System and

Table 2. List of popular and recently released forage sorghum cultivars at national level through public sector breeding, efforts

Cultivar	Year of release	Single-cut/ multi-cut	Green fodder yield (q/ha)	Dry fodder yield (q/ha)	Area of adaptation
MP Chari	1978	Single-cut	300	95	All sorghum growing areas of the country particularly central and northern states
Sweet sudan grass S9-3	1978	Multi-cut	570	138	All forage sorghum grown areas
HC-171	1987	Single-cut	500	160	All India
Punjab Sudex Chari 1	1994	Single-cut	218	118	All forage sorghum growing areas in Punjab under irrigated conditions.
HC-308	1996	Single-cut	530	175	All India
Pusa Chari-615	2006	Multi-cut	700	195	NCR Delhi
CSH 24MF	2009	Multi-cut	786	192	All forage sorghum growing areas of India
Pratap Chari 1080	2010	Single-cut	375	130	Rajasthan forage sorghum growing regions with loam to light soils and moderate to low rainfall
CSV 32 F	2015	Single-cut	478	156	Maharashtra, Karnataka and Tamil Nadu
Punjab Sudax Chari 4	2016	Multi-cut	1113	237	Punjab
Fodder Sorghum CO 31	2018	Multi-cut	1920/ year	-	Tamil Nadu
CSV 21F	2016	Single-cut	378	113	Gujarat
CSV 33 MF	2017	Multi-cut	1039	280	All forage sorghum growing areas of India
CSV 35F	2018	Single-cut	529	145	Delhi, Gujarat, Rajasthan, Uttarakhand, Haryana, Uttar Pradesh, Punjab, Maharashtra, Tamil Nadu, Karnataka and Madhya Pradesh
CSH 40F	2018	Single-cut	560	155	Delhi, Gujarat, Rajasthan, Uttarakhand, Haryana, Uttar Pradesh, Punjab, Maharashtra, Tamil Nadu, Karnataka and Madhya Pradesh
CSV 38F	2019	Single-cut	465	145	Maharashtra, Tamil Nadu and Karnataka
CSH 43MF	2021	Multi-cut	965	219	Haryana, Punjab, Uttar Pradesh, Rajasthan, Gujarat, Uttarakhand, Maharashtra, Tamilnadu, Telangana and Karnataka
CSV 40F	2019	Single-cut	465	150	Maharashtra, Tamil Nadu and Karnataka
CSV 47F	2021	Single-cut	430	122	Maharashtra, Tamil Nadu and Karnataka
CSV 46F	2021	Single-cut	596	163	Gujarat, Rajasthan, Haryana, Punjab, Uttar Pradesh and Uttarakhand

ICRISAT have evolved sweet sorghum varieties, viz. SSV 84, CSV 19SS, CSV 24SS, CSV 49SS (Jaicar Raseela) and hybrids, viz. CSH 22SS, RVICH 28 and Phule vasundhara which can be utilized for 1st generation biofuel production i.e., sugar based biofuel production.

- Most of these genotypes have been tested for biofuel production in various sugar mills of different states and the realized ethanol yields ranged from 40–50 litre/tonnes of cane crushed. These genotypes also offer promise as single-cut forages with high forage quality.
- Earlier techno-economic feasibility studies have indicated the cost of ethanol production from sweet sorghum to be cheaper than that of sugarcane molasses by ₹1.87/- and the current lucrative ethanol procurement prices for juice based ethanol offer a win-win situation for both the farmer and industry.
- The apprehension of sugarmills that sweet sorghum needs separate machinery for crushing was cleared through successful demonstrations of sweet sorghum crushing with the existing sugarcane machinery.
- Sweet sorghum juice was directly fermented and mixed with molasses for ethanol production in the

distilleries. A combination of 40:60 (Sweet sorghum juice+molasses) yielded the highest alcohol yield in one of the study and this would reduce the water requirement and processing costs of ethanol production

- This paves way for utilizing sweet sorghum during the off-season of sugarcane crushing thereby extending the mill operations.

Major constraints for sweet sorghum production

- Lack of policy support, as there is no clear cut road map for commercialization of sweet sorghum though the crop has been listed in the National Policy on Biofuels.
- Lack of awareness among sugar industries about sweet sorghum and its utility for biofuel production.
- Non-offering of competitive price for sweet sorghum cane to the farmers by the industry.
- Lack of varieties/hybrids adapted to different growth conditions resisting both biotic and abiotic stresses, including colder climate.
- Narrow harvesting window for sweet sorghum affecting offseason crushing in sugar industries.
- Lack of mechanization.



CSV 49SS (Jaicar Raseela)



Phule vasundhara



Lorries carrying sweet sorghum awaiting their turn for unloading at Shree Ganesh Khand Udyog Sahkari Mandli Limited, Bharuch, Gujarat for big mill test

Strategies for sweet sorghum commercialization

- Commercialization of sweet sorghum cultivation is possible if the required policy support in the form of incentives from Government for both producer and processor are extended.
- Genetic enhancement of cultivars for high sugar, cane yields and resistance to important biotic and abiotic stresses.
- Development of genotypes with different maturity durations and higher ratoon ability for widening the harvest window.
- Development and optimization of sweet sorghum crop management and IPM practices for higher productivity of sweet sorghum feedstock.
- Mechanization of sweet sorghum cultivation and processing.
- 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.
- Greater investment in research in sweet stalk and high biomass sorghums from Govt. of India is

needed to achieve the goal of enhancing biofuel production to support the government policy of reducing the oil imports.

SUMMARY

Sorghum has to face stiff competition by other cereals under better soils and rainfall where cash crops have replaced sorghum during *khari*. However, the fact that sorghum being a C4 plant is a high biomass producer and relatively tolerant to several stress factors. This makes it difficult to be replaced in least endowed areas, especially in the climate change scenario. The major thrust, in future, will be on enhancing area of sorghum in non-traditional areas and greater emphasis on alternate uses of sorghum and its utilization as a major food, feed, fodder and fuel (bio-energy) for industrial utilization. Simultaneously, researchers are pursuing other avenues such as growing sorghum as a biofuel crop for which significant work has been done, in addition to promotion of sorghum as functional health food.

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ICAR New Portals

The Council has created the following portals for effective governance by utilizing the information and communication technology.

ICAR Data Centre and Unified Communication portals to secure institute information and information transmission.

- ICAR-Enterprise resource planning (ERP) System to manage the human resource in information of the council including pay roll, finance and budgeting.
- KVK Knowledge Network Portal (<http://kvk.icar.gov.in>) to share basic information and facilities of KVKs with contingency plans, demonstration schedule, and advisories.
- Management System for Post-Graduate Education (MSPGE) enabling academic and e-learning modules while also being a repository of academic records
- E-Samvad, an online interface of the Council to answer citizens queries.
- KRISHI –A knowledge repository portal of digital information pertaining to research experiments, outputs, publications, etc.
- E-Krishi Manch, a dedicated portal for farmer-scientist interaction.