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CONTENTS

Successful pilot production of bio-ethanol from sweet sorghum in sub-tropical north India

The importance of sweet sorghum as an alternate feedstock for bio-ethanol production is gaining popularity because of inadequate availability of molasses coupled with its high and variable cost (Rs. 2500-5000/t). The Government of India is encouraging blending of ethanol with gasoline (5-10%) in a phased manner. A number of pilot studies by various sugar and alcohol industry in southern and central India have demonstrated that the sweet sorghum is a potential alterative feedstock for ethanol production. Further, utilizing its residue (bagasse) in cogeneration of power (similar to that in sugarcane) or still better, by using as cattle feed (as sorghum bagasse is highly digestible) is encouraging.

Sweet Sorghum being put in the cane carrier at NSI, Kanpur

Sweet sorghum standing on the field at Kanpur, UP (left: harvested sweet sorghum stalks)

The National Sugar Institute (NSI) (Est. 1936) Kanpur and NRC for Sorghum (ICAR) Hyderabad has successfully produced bio-ethanol from sweet sorghum on a large scale utilizing the 100 TCD experimental sugar factory (ECF) at NSI. NSI functions under administrative control of Ministry of Consumer Affairs, Food and Public Distribution, Government of India (web site: http://nsi.gov.in/). It is a unique organization involved in teaching, research, technology development and extension in the areas of sugar engineering, sugar technology, and fermentation alcohol technology. NRCS has supplied the quality seeds and production technology for cultivation of sweet sorghum crop on a 2.5 ha farm at Kanpur.

The sweet sorghum cultivated in the farm of NSI, was harvested and supplied to Experimental Sugar Factory (ESF) of NSI during the crushing season of 2005-06. The same was crushed in the mills for extracting the sorghum juice. The juice analysis showed that it was fully matured with following characteristics: Brix - 16.40%; purity - 58.4%; TRS - 15.8%; pH - 5.4.

The extracted juice was concentrated to syrup state of 60° Bx., which was utilized for the production of alcohol on a laboratory scale in the Biochemistry Division of NSI. The yield obtained is 36 liters of alcohol per ton of sweet sorghum stalk crushed. Also, 90 liters of alcohol per 1000 liters of juice was obtained; however by using enzyme treatment, 117 liters alcohol per ton of sweet sorghum could be obtained.

GK Shukla, SK Gupta and Lakhendra Singh,
National Sugar Institute, Kanpur (nsikanpur@sancharnet.in)

SS Rao, CV Ratnavathi and B Dayakar Rao
NRCS, Hyderabad (nrcshyd@ap.nic.in)

Maghi sorghum germplasm collection from Andhra Pradesh

Maghi (Late Kharif) sorghum germplasm was explored in collaboration with the Hyderabad Regional Station of National Bureau of Plant Genetic Resources (NBPGR), during December 15-18, 2005 in Khammam district of AP. The team members were Dr M. Elangovan (NRCS), Sri P Someswara Rao and Sri Abraham (NBPGR). Chintur mandal in Khammam district is the major maghi zsorghum growing region in Andhra Pradesh. A total of 36 accessions were collected. Majority of the landraces belongs to *pachcha jonna*, and *konda jola*. *Koya* tribe grows *konda jonna*. *Kakhi jonna*, *tella jonna* and *pili jola* are other important landraces collected. The seedling is raised in the month of July-August and *transplanted* in the field during August-September. The crop takes six months to maturity and harvested exactly during the *"Sankranti"* festival. It matures in December-January.

Konda Reddys does not prefer to grow released varieties because of short plant height. They believe that grains of improved cultivars cause body pain when used as food (no scientific basis). *Lambada* tribe used to grow the *maghi* sorghum landraces extensively, but now the area has come down because of the loan provisions by the Government for cultivating commercial crop such as cotton.

M. Elangovan, NRCS, Hyderabad (elangovan@nrcsorghum.res.in)
P Someswara Rao, Economic Botany, NBPGR (RS) – Rajendranagar, Hyderabad

Profile of AICSIP Centre of GBPUA&T, Pantnagar, Uttaranchal

Historical background: The Forage Sorghum Research Programme in the GB Pant Agricultural University for Agriculture and Technology was initiated in 1969-70. Work on breeding and nutritional quality analysis was started with evaluation of large world germplasm collection. Some early selections, viz., IS 4776, IS 6953, CS 3541, Leoti, Rio, Vidisha 60-1 and IS 607 having desirable fodder attributes (sweetness of stalk, low HCN content and resistance to shoot fly and stem borer) were popularized. Later, a hybrid programme was also started in 1971. Identified donors for traits such as low HCN, high digestibility, shoot fly resistance (IS 4776), high TSS, juiciness of stem (Cultivar: Rio, Leoti, IS 607) fast growth and earliness (IS 6953), high forage yield (Vidisha 60-1), juiciness and good grain quality (CS 3541) were exhaustively used for hybridization.

In 1976, the Pantnagar started serving as a centre of All-India Coordinated Sorghum Improvement Project of ICAR with the mandate of developing high yielding early flowering, disease resistant varieties of forage sorghum. The first single-cut forage sorghum variety UP Chari 1 was released from the SVRC and CVRC in 1983. Subsequently other varieties, viz., UP Chari 2 (1984), Pant Chari 3 (1989), Pant Chari 4 (1994) and Pant Chari 5 (1999) were also released. In October 1999, the NATP project entitled "Breeding high sugared multi-cut forage sorghum hybrids and varieties with enhanced nutritional quality" was sanctioned and the mandate of the centre became to develop high yielding, early flowering, single-cut and multi-cut forage sorghum varieties and multi-cut forage sorghum hybrids between sorghum x sudan grass having high resistance to foliar diseases and insect pest and high nutritional quality.

Mandate

1. To develop single-cut and multi-cut varieties and hybrids of forage sorghum suitable for cultivation in the north-western states of India.
2. To meet the need based requirements of newly formed Uttaranchal state for fodder production.

Objectives

1. Development of high yielding single or multi-cut varieties with high sugar; dual purpose varieties and hybrids of forage sorghum with higher energy, palatability and voluntary intake values.
2. Genetic improvement of parental lines/stock for value addition in terms of increased digestibility, protein content, total soluble solids (TSS) and resistance to diseases and insect pests, reduced HCN content and anti-nutritional quality factors through conventional and new biotechnological tools.
3. Crop management of potential hybrids and varieties under various cropping system and cutting management for high yield returns.
4. Popularization of newly developed varieties and hybrid of forage sorghum among the farmers through organizing the front-line demonstrations at the farmers fields.
5. Screening of germplasm/ breeder's material and elite lines for resistance to major diseases viz., anthracnose and zonate leaf spot (Pantnagar is a hot spot for foliar diseases).
6. Disease monitoring/survey and management through chemicals, bio-agents and cultural practices.

Research achievements

1. Four varieties of single-cut forage sorghum viz., UP Chari 1, UP Chari 2, Pant Chari 3 and Pant Chari 4 were released upto 1999. During the quinquennial review for the 2000 to 2004 period, one variety of single-cut forage sorghum viz Pant Chari 5 (2000), one variety of multicut forage sorghum viz Pant Chari 6 (2004) and one multi-cut forage hybrid (sorghum x sudan grass) of sorghum viz CSH 20 MF (2005) were released.

2. Multicut variety of high fodder yield potential with quality fodder. *viz.*, Pant Chari 6, released from SVRC Uttaranchal, on 2.11.2004.
3. Multicut hybrid CSH 20 MF was released from Central Variety Release Committee (CVRC) in 2005.
4. Many potential varieties/hybrids of single cut and multicut fodder sorghum *viz.*, UPFS 38, UTFS 40 (single cut/dual purpose), UPMC 512, UTMC 523 (multicut variety) and UTMCH 1301 and UTMCH 1302 (multicut hybrids) are in the advanced stage of testing in the All-India coordinated trials.
5. Genetics on inheritance of yield and resistance (disease and insects) were studied.
6. Potential donors for high protein, high TSS, low HCN and disease and insect resistance have were identified and being used in the hybridization programme.

Trait	Donors
High protein	Pant Chari 5, IS 6953, SDSL 92125, G D 54615
High TSS	Rio, IS 607, SSV 84, Pant Char 4, GD 54707
Low HCN	SDSL 92140, IS 4776, SDSL 92120, SDSL 92111
Foliar diseases resistance	Pant Chari 5, CSV-15, IS 6953, IS 7002, IS 355
Shoot fly resistance	Pant Chari 4, IS 4776, GD 54686

7. Among single-cut forage sorghum varieties, S 437-1 was found most suitable genotype which produced maximum green fodder yield (596 t/ha) as well as dry matter with the application of 120 Kg N /ha.
8. In multi-cut forage sorghum hybrids/ varieties, UPMCH 1101 was superior for green forage and dry matter yield than others, when crop was fertilized with 150 kg N/ha.
9. Integrated weed management with spray of Atrazine @1.0 kg ha^{-1}at pre-emergence stages and one hand weeding at 20-25 days after sowing was found to be most effective.
10. Intercropping of sorghum with pigeon pea, cowpea and oil seed crop in rows of 2:1 was found to be most remunerative.
11. Several genotypes including SPV 475, SPV 1685, CSV 13, CSV 15, SPH 1375, SPH 1420, CSH 14, CSH 16, CSH 18, G-01-03, G-09-03, GMRP 91, RS 629, MPR 75, UTFS 45, UTMC 523 were identified with high level of resistance to anthracnose and zonate leaf spot diseases.
12. Foliar diseases *viz.*, anthracnose caused by *Colletotriclum graminicola* and zonate leaf spot caused by *Gloeocercospora sorghi* have been identified as major destructive diseases of sorghum in North- West region. Cultures of these pathogens have been maintained.
13. Tan type cultivars contained higher HCN than purple type thus making the former more resistant than the latter. HCN content was found toxic for the germination of spores of *C. graminicola*.

Sorghum Research Team,
All India Sorghum Improvement Project (AICSIP), Pantnagar, Uttaranchal

New germplasm source identified for shootfly resistance at NRCS, Hyderabad

During rabi 2005-06, 100 new germplasm lines which includes collection from Maharashtra (21 acc.), introduced from Mali (3 acc.) and Sri Lanka (6 acc.), and collections by NBPGR (Regional Stations) – Hyderabad (33 acc.) and Ranchi (37 acc.) were screened at Arboretum field, NRC for Sorghum, Hyderabad for shootfly resistance. Three lines viz., EP–123 (IC 420938), EP-128 (IC 420943) and EP–133 (IC 420948) are less susceptible to shoot fly. All of them were not as resistant as the check (IS 18551). They had high yield with super grain quality.

PG Padmaja, M Elangovan and **Prabhakar,**
NRCS, Hyderabad (nrcshyd@ap.nic.in)

Sorghum pathology research imperatives in India

A number of diseases caused by prokaryotes, fungi, viruses and nematodes occur on sorghum and these cause economic production losses in sorghum. For the dual-purpose rainy season sorghum, the important diseases, in order of priority, are: grain mold, ergot, anthracnose, leaf blight and rust. For the post-rainy season grain sorghum, they are: charcoal rot and rust, and ergot in seed production plots.

Grain mold (Species of *Fusarium, Curvularia, Aletrnaria, Phoma*, and others) is a serious problem of the rainy season sorghum. Wet weather during crop maturity promotes grain mold development resulting in discoloration of grains and thus making it unfit for human and consumption. Molded sorghum contains mycotoxin that are highly injurious to human and cattle.

The future research should focus on the following: understanding the Fusarium species complex and identifying species that produce mycotoxin-fumonisins / moniliformin; screening advanced breeding lines (A-/B- and R-lines) against individual and multiple pathogens to identify resistance; improving resistance level in the elite breeding lines by transferring resistance-traits, such as grain color, glumes coverage, and grain hardness; developing an integrated mold management method including timely harvesting, rapid drying the panicles, and storing grain under proper storage conditions.

Ergot or sugary disease (*Claviceps sorghi*) is a serious problem in hybrid seed production plots. Care should be taken to ensure rapid pollination of A-lines by adjusting planting dates of A- and R-lines to synchronize flowering and providing adequate row ratio of A- and R- lines. Triazole fungicides, such as propiconazole and tebuconazole have proved cost effective in seed production fields when sprayed at flowering time. Future research on ergot should focus on: finding genetic resistance in germplasm accessions with rapid pollination trait; hybrids should be developed using parental lines with good nicking of flowering, rapid self-pollination and seed set; alternative approaches, such as reduction of inoculum, and seed treatment with captan and thiram to eliminate external seedborne inocula.

Foliar diseases, such as anthracnose (*Colletotrichum graminicola*), leaf blight (*Exserohilum turcicum*), and rust (*Puccinia purpurea*) are widespread. Research on these

diseases should be on: on-farm monitoring of cultivar performance for resistance; establish existence of races using host differentials; collection, maintenance and characterization of host-specific race isolates; identify resistance types (polygenic- characterized by few and small lesions; and monogenic - characterized by hypersensitive reaction and little or no lesion development); and develop an integrated management method involving host resistance as a major component.

Charcoal rot (*Macrophomina phaseolina*) is important in post rainy season hybrid sorghum. The severity of charcoal rot is related to soil moisture deficit during the grain fill stage. The research should focus on: variability in *M. phaseolina* populations in different sorghum growing areas; identifying host-specific pathotypes/races; identification of resistance genes and their linkage to stay-green and/or drought-tolerant genes; and develop and integrated disease management method.

In recent years **maize stripe virus** (MStV) has emerged as an economically important foliar disease of sorghum in India. This disease requires close monitoring and research should be initiated to identify genetic resistance.

RP Thakur, ICRISAT, Patancheru, Andhra Pradesh
(r.thakur@cgiar.org)

New early-maturing rabi sorghum elite lines with drought tolerance

Rabi sorghum is grown over a total area of 5.6 million hectares mainly in the states of Maharashtra, Karnataka and Andhra Pradesh with average productivity of 634 kg/ha. In spite of such low productivity, rabi sorghum continues to be an important component of dryland economy in these states with fairly consistent area over many years. The low yields are mainly due to various Evaluation of CRS-1 in Coordinated breeding trials from 2000-01 to 2002-03 indicated that it matured earlier and showed significantly superior grain yield than M35-1 with better tolerance to shoot fly and charcoal rot (Table 1).

Centre	AICSIP code	Pedigree
CRS-1	SPV-1537	Selection from Hegari land race from Hegari village, Bijapur district, Karnataka
CRS-4	SPV-1671	(Selection from Chakur Bidri x SPV-1537) 3-1

Table 1: Performance of CRS-1 (SPV-1537) in coordinated trials from 2000-01 to 2002-03

Sl. No.	Varieties	Days to flower	Plant height (cm)	Days to maturity	Grain yield (kg/ha)	% increase over	Dead-heart (%)	Charcoal rot (%)
1	CRS-1	70	122	111	970	-	34.7	35.0
2	RSLG-262	73	144	113	941	3.08	33.7	32.5
3	Sel. 3	69	142	108	602	61.1	54.3	27.4
4	M35-1	74	144	114	797	21.7	42.2	35.1
5	CSV-216R	80	151	120	763	27.1	25.2	37.9
	CD at 5%	3.0	13.5	5.0	185		1.3	2.1
	C.V. %	2.3	6.0	2.5	19.9		16.2	10.5

In coordinated breeding trials during 2004-05, CRS-4 matured earlier than M35-1 with better tolerance to charcoal rot and shoot fly (Table 2). In coordinated physiology trials from 2002-03 to 2004-05, CRS-4 matured earlier and gave significantly superior grain yield than M35-1 (Table 3).

In both leaf N (%) and specific leaf nitrogen, CRS-1 and CRS-4 showed 21% and 42% superiority over checks. Grain yield of CRS-4 was higher by 27% over check CSV 216R. In both years, it consistently out yielded checks. For harvest index, both CRS 1 and CRS 4 gave 34 and 45% superiority over check (Table 4).

Table 2: Performance of CRS-4 (SPV-1671) in coordinated trials in 2004-05

Sl. No.	Varieties	Days to flower	Plant height (cm)	Days to maturity	Grain yield (kg/ha)	Fodder yield (q/ha)	Dead-heart (%)	Charcoal rot (%)
1	CRS-4	70	171	111	2436	50.7	29.2	23.6
2	M35-1	72	173	114	2545	56.3	33.6	31.9
3	RSLG-262	75	188	117	2334	5805	30.7	26.2
4	CSV-216R	75	191	115	2562	53.7	28.8	29.3
	CD at 5%	3.0	13.0	4	589.5	10.4	2.2	1.6
	C.V. %	4.0	5.8	3.0	21.6	17.0	9.8	14.5

Table 3: Performance of CRS-1 and CRS-4 in Coordinated Physiology trials from 2002-03 to 2004-05

Sl. No.	Varieties	Days to flower	Days to mature	Plant height (cm)	Grain yield (kg/ha)	% Increase over M35-1	Fodder yield (q/ha)	Harvest index
1	CRS-1	67	110	119	752	5.3	27.7	25.6
2	CRS-4	67	110	142	815	14.1	29.2	27.7
3	Mauli	68	110	137	726	1.6	28.3	25.4
4	M35-1	71	114	126	714	-	30.9	28.5
	CD at 5%	2.7	2.8	18.8	100		10.1	4.9
	C.V. %	3.43	2.1	9.46	13.1		16.2	15.8

Table 4: Performance of CRS 1, CRS 4 and CRS 6 in Rabi 02/03 and Rabi 03/04 at NRCS, Hyderabad

Sl. No.	Parameter	Row details	CRS 1	CRS 4	CRS 6	Maulee	CSV 216R	M 35-1
1	Time to 50% flowering (days)	Mean of Rabi 02-03 & 03-04	74.5	69.7	75.0	71.8	78.3	76.7
		Decrease over CSV 216R (days)	3.8	8.7	3.3	6.5		1.7
2	Total chlorophyll content at flower (mg g-1 fresh weight)	Mean of Rabi 02-03 & 03-04	2.67	3.01	2.13	2.27	1.98	2.90
		Comparison to CSV 216R	35.0	51.9	7.4	14.4		46.3
3	SPAD chlorophyll meter reading at soft dough stage	Mean of Rabi 02-03	40.6	44.1	37.9	45.6	35.3	40.2
		% increase over CSV 216R	15.0	24.9	7.3	29.0		13.9
4	Leaf nitrogen (%) at boot	Mean of Rabi 02-03 & 03-04	2.62	3.30	2.74	2.74	2.73	2.71
		% change over CSV 216 R	-3.8	20.9	0.4	0.4		0.0
5	Specific leaf nitrogen at boot (mg g_{-1} cm-2 LA)	Mean of Rabi 02-03 & 03-04	8.22	16.85	10.96	9.71	11.87	11.14
		% increase (+)/ Decrease (-) over CSV 216R	-30.7	41.9	-7.6	-18.2		-6.1
6	Grains panicle $^{-1}$	Mean of Rabi 03-04	728	1078	985	876	998	814
		% change over CSV 216 R		8.0	-1.3	-12.3		-18.5
7	Grain yield (kg /ha)	Mean of Rabi 02-03 & 03-04	3099	4515	2877	4092	3550	3603
		% change over CSV 216 R	-12.7	27.2	-18.9	15.3		1.5
8	Harvest Index (%)	Mean of Rabi 02-03 & 03-04	33.8	36.7	30.5	27.8	25.3	21.8
		% increase over CSV 216 R	33.7	45.2	20.7	9.7		-13.8
9	Grain Production efficiency in GS-3	Mean of Rabi 02-03	77.5	114.3	64.4	116.6	82.2	94.7
		% change over CSV 216 R	-5.7	39.1	-21.6	41.9		15.3
10	Source-sink ratio (seeds m^{-2} LAI^{-1})	Mean of Rabi 02-03 & 03-04	3497	5352	3901	3983	3044	2667
		% increase over CSV 216 R	14.9	75.8	28.1	30.8		-12.4
11	Grain yield(kg) LAI^{-1}	Mean of Rabi 02-03 & 03-04	1192	1741	1093	1269	957	1001
		% increase over CSV 216 R	24.6	81.9	14.2	32.6		4.6
12	Membrane Injury at flowering (%)	Mean of Rabi 03-04	62.2	48.6	55.5	60.7	53.6	55.7
		% increase over CSV 216 R	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Similarly, CRS-4 has shown a distinct superiority in source-sink ratio (76% more) and grain yield per unit leaf area (82% more) followed by CRS-6 and CRS-1. Interestingly, CRS-4 recorded 9.4% lower membrane injury under heat stress confirming its superior desiccation tolerance than checks.

The newly developed early maturing rabi sorghum elite lines offer great scope to test them as varieties under receding soil moisture conditions of rabi or for use as donors in developing early maturing varieties with resistance to drought in rabi sorghum. CRS-4 gave consistently good performance under drought conditions followed by CRS-1. These entries can be grown directly under rainfed conditions in medium to shallow type of soils which constitutes about 50% of rabi sorghum area. CRS-4 could also be used as a parent for developing mapping population for identifying QTLs governing drought tolerance.

Prabhakar, SS Rao, IK Das and MS Raut, NRCS, Solapur and Hyderabad (nrcshyd@ap.nic.in)

Genetic enhancement of sorghum stover quality: Collaborative research between NRCS and ILRI

Sorghum improvement has traditionally focused on increasing grain yield potential. Since the quantity and quality of stover are important criteria in a farmer's decision to grow a particular variety, scientists have begun to pay attention to stover quality as well, as the farmers' belief of poor stover quality in modern cultivar is leading to their lower adoption rate. In the semi-arid areas of India, sorghum (33 million ton) and pearl millet (19 million ton) are the most important crop residues. Therefore, there is a need to concentrate on sorghum stover that is more sustainable and responsive to smallholder farmers' needs.

Technologies are available to improve the nutritive value of crop residues by chemical and biological means. However, there has been little adoption of these techniques by resource-poor farmers for social and economic reasons. An alternative and more practical strategy would be to increase the nutritive value of crop residues through genetic enhancement.

Quantity and quality of feed heavily influence livestock productivity. It is possible that genetic variation in the quality of sorghum stover could be exploited to develop improved breeding material with stover of higher nutritive value. In dryland farming situations where both grain and crop residues are important, priority must be given to the development of improved dual-purpose cultivars of high biomass yield and quality with a minimal trade-off in grain production. There is a weak relationship between grain yield and quality characteristics in cereal crop residues, so potential exists for selecting or breeding varieties with improved straw and stover value without sacrificing production, particularly in low-input systems. However, in rabi sorghums grown in moisture stressed conditions, the relationship between grain yield and stover quality may be negative, though there is no competitive relationship between grain yield and digestible stover yield. This genetic research should result in greater quantities of and more digestible feed available to livestock. Studies have indicated that a 1% increase in digestibility of sorghum straw increases bovine milk yield by 5–6%.

Stover quality of AICSIP grain sorghum entries: The AICSIP sorghum entries and samples from production trials have been analysed for stover quality in collaboration with International Livestock Research Institute (ILRI). The *in vitro* dry mater digestibility (IVDMD) of the stover from grain sorghum entries had been in the range of 37-58% of dry matter, across several locations and seasons, during rabi 2004 and kharif of 2004 and 2005. Similarly, the protein content has also remained in the range of 3-11%. However, the individual entries showed comparative trend of IVDMD variation across locations and years, indicating minimal genotype x environment interactions. The performance of both kharif and rabi cultivars (varieties and hybrids) in terms of IVDMD of stover largely remained the same across two years on a comparative basis, though the absolute values varied (Fig. 1 and 2). The productivity of the cultivars in terms of digestible dry matter was also consistent across years. The overall focus of research in the national sorghum research programme is on developing genotypes with greater biomass, superior quality of stover with higher level of protein and less lignin, higher digestibility, post-anthesis drought tolerance (stay-green) and tan pigment. Linkages of NRCS with AICSIP centres are being strengthened through sharing of material and new projects. Further, strong linkage exists between ILRI's animal nutrition program located at ICRISAT centre at Patancheru, and NRCS, Hyderabad. Increased biomass must be digestible to contribute to livestock productivity increases. Therefore, there is a need for collaborative approach involving both crop and animal scientists. For the latter, we are trying to link-up with Indian Grassland and Fodder Research Institute (IGFRI) at Jhansi and National Institute of Animal Nutrition and Physiology (NINAP), Bangalore.

Fig. 1: IVDMD (%) of kharif dual purpose sorghum genotypes

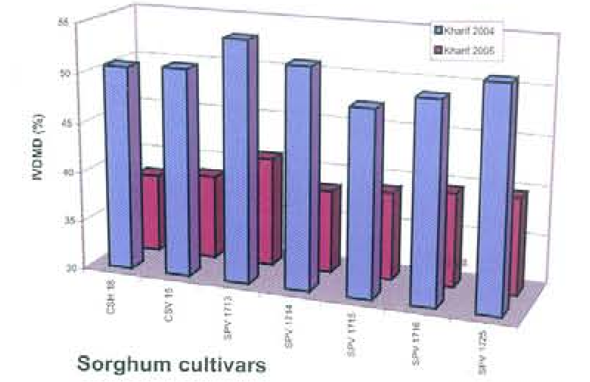
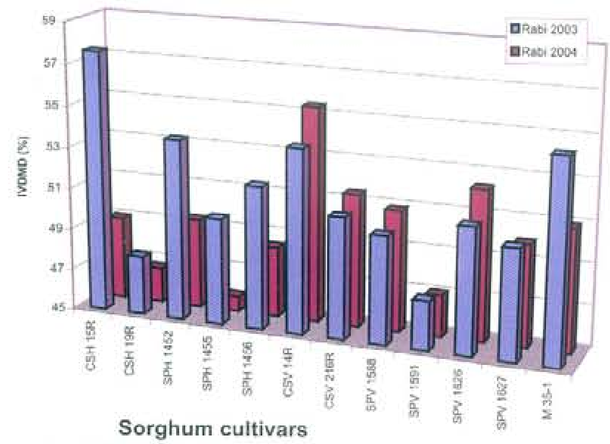


Fig. 2 IVDMD (%) of rabi sorghum stover



Efforts of ICAR to enhance sorghum stover quality: With more emphasis on diversifying the use of sorghum in the national agriculture scenario, the stover yield and quality improvement have been receiving due emphasis in the recent times. The increase in the market price of stover had also been high compared to that of grain. Some of the new initiatives in the national sorghum programme are listed below.

1. With the emphasis on developing dual purpose varieties, dual purpose sorghum varietal and hybrid trials have been initiated under AICSIP since 2004.
2. All the grain purpose AICSIP entries are being evaluated for stover quality in collaboration with International Livestock Research Institute (ILRI), Patancheru, since 2002 so as to incorporate stover quality as a criterion in the cultivar release check list.
3. Brown mid-rib trait introgressed into dual purpose and forage cultivars; Dual purpose F_3 material was distributed to several AICSIP participants
4. Potential donors with higher protein and digestibility of stover are being identified from the breeding trials of NRCS
5. Potential high biomass sweet sorghum lines are used as donor parent in forage and dual purpose sorghum breeding. This is expected to provide more digestible energy in the stover.
6. Reducing HCN content using anti-sense approach is also underway in forage sorghums. If successful, the same can be used in dual purpose sorghum.
7. Mapping populations were developed/ are being developed for stover traits- stay-green, digestibility (IVDMD) and protein content.

Future research issues: Some of the researchable issues to be addressed to realize the full plant potential to maximize stover yield and quality without compromising grain yield are as follows.

1. Determine the stage of maturity to harvest (harvest window, where and how wide?) to obtain optimal grain and stover yields and quality. Although grain content increases with advanced maturity, stover digestibility decreases. Therefore, it is important to harvest at the proper stage of maturity.
2. Optimum population density for dual purpose sorghum
3. Package of practices- The present one was developed with emphasis on grain alone
4. AICSIP criteria for the release of dual purpose types: How to integrate quality with stover yield and grain yield- refine the weightages for each trait
5. Correlations between laboratory measures of quality and simple-to-measure morphological characteristics: Is it strong enough or general enough to use them as selection criteria in breeding programmes.
6. Genetic control of stover quality- What are the potential genes that can serve as markers for their use in selection. Use of EST based SSR markers may be required to reveal these facts.
7. Influence of environment on the traits such as protein content and digestibility- The stability of the traits in the same genotype/ population in terms of their degree of expression should be studied in multi-locational experiments.

In HYVs, especially in hybrids, though the stover yields are very high, the stover nutritive quality is generally lower than other local varieties, with certain exceptions. This can now be remedied by enhancing the stover quality using brown-midrib, stay green, bloomlessness, and other characters. The issues of crop management are equally important. Significant incidence of foliar diseases is known to decrease the digestibility of the stover. The micronutrient composition of the stover will also have substantial influence on the nutrition of the livestock. Therefore, special attention is needed for plant nutrition, foliar diseases and safety from insecticides. The pyramiding of the genes that enhance the stover quality is the long-term goal of the collaboration between NRCS and ILRI. It is expected that such a collaboration would result in useful genotypes and technologies that would benefit sorghum farmers in the semi-arid tropics.

B Venkatesh Bhat[1], AV Umakanth[1], R Madhusudhana[1], AD Vishala[1], D Ravi[2], M. Blummel[2] and N. Seetharama[1]

[1] National Research Center for Sorghum, Rajendranagar, Hyderabad (nrcshyd@ap.nic.in)

[2] International Livestock Research Institute, ICRISAT, Patancheru- 502324, Andhra Pradesh (m.blummel@cgiar.org)

Sorghum germplasm collection at NRCS during October 2005 to July 2006

Germplasm collected through exploration

Sl.No.	State/Area	No. of accessions	Collector/Associates
1	Tamil Nadu	59	AICSIP-Coimbatore
2	Andhra Pradesh	36	NBPGR (RS) - Hyderabad
3	Andhra Pradesh	2	Sri E Suresh Kumar
	Total	**97**	

Germplasm acquired from other organizations

S.No.	Donor organization	No. of accessions	Remarks
1	NBPGR (RS) - Ranchi	21	Landraces
2	AICSIP - Palem	59	
3	ICRISAT, Patancheru	8	Sugary resistant lines
4	ICRISAT, Patancheru	3	Advanced sweet sorghum lines
5	ICRISAT, Patancheru	4	Initial sweet sorghum hybrid
6	ICRISAT, Patancheru	2	Wild sorghum
	Total	**97**	

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Published by :

Dr. N. Seetharama, Director
National Research Centre for Sorghum (NRCS)
Rajendranagar, Hyderabad - 500 030 (AP).
Website : www.nrcjowar.res.in

National Research Centre for Sorghum (NRCS)

Head Quarters :
Rajendranagar, Hyderabad 500030 (AP)
Tel : 040-24015349, 24018651
Fax : 040-24016378
E mail : nrcshyd@ap.nic.in
Website : www.nrcjowar.res.in

Centre on Rabi Sorghum (NRCS),
NH 9 Bypass, Shelgi, Solapur - 413 006 (MS)
Tel : 0217-2373456
Telefax : 0217-2373456
E mail : raut_nrcs@nrcsoghum.res.in

Off-Season Nursery (NRCS),
ARS Farm, Mulugu Road, Warangal - 506 007
Tel : 0870-2530963
Telefax : 0870-2530963
E mail : ashok_reddy_nrcsw@nrcsorghum.res.in

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Dharwad	Parbhani	Deesa	Pantnagar
Bijapur	Rahuri	Udaipur	Indore