4. Sweet Sorghum

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Executive summary

Trial 1K. Evaluation of initial and advanced sweet sorghum varieties and hybrids trial (IASSVHT) entries:
This trial was conducted at 13 locations to evaluate sixteen initial and advanced trial hybrids and varieties stalk yield, biomass, sugar content and bioethanol yields along with three checks (SSV 84, CSV 19SS & CSH 22 SS) in kharif 2007. Entries SPSSH 27(JK Agric), SPSSV 11 (Advanta hybrid) and SPSSH 24 (ICRISSAT) in hybrids and SPSSV 15 (RSSV104-Rahuri), SPSSV 20 (ICSV 93046-ICRISAT) and SPSSV 27(RSSV138-Rahuri) in varieties were superior for juice yield, sugar yields and bioethanol yields than checks.

Table 2K: Evaluation of sweet sorghum germplasm for high biomass and stalk characteristics:
Forty-eight promising sweet sorghum germplasm selected from among 150 germplasm lines from 2005-5006 were evaluated along with two checks i.e. SSV 84 and CSV 19 SS at Parbhani, Rahuri and Hyderabad in augmented design for stalk yield, brix content and biomass.

Twenty two entries namely EC538169, IS5352, IS5353, IS 5356, IS5360, IS5362, IS6936, IS7073, IS7080, IS7541, IS7543, IS7546, IS7549, IS11152, IS11496, IS12135, IS17813, IS17814, IS17825, SSV74, EG25, and KARS 95 had shown superior performance than check CSV19 SS in terms of fresh stalk yield & quality and could be used as potential donors for the sweet sorghum improvement aimed at high stalk yield, sugar content and high biomass production.

Trial 3K. Influence of stage of harvesting on changes in quality, stalk yield and biomass in sweet sorghum:
Bioethanol yields increased from flowering until hard-dough stage. Both sugar yields and bioethanol yields increased by 11 % when sweet sorghum crop harvested at hard-dough stage than at physiological maturity. CSH22 SS recorded highest bioethanol yield at hard-dough stage.

Mean fresh and dry bagasse yields recorded at maturity across treatments and cultivars was 20.6 t/ha and 4.9 t/ha, respectively. While, mean fresh bagassse % stalk and dry bagasse (fibre) % stalk recorded was 61.4% and 14.6% across the cultivars and treatments.

Mean moisture % stalk and moisture % bagasse recorded was 73.5% and 76.4% across the cultivars and treatments. Significantly higher moisture % stalk and moisture % bagasse were recorded at flowering followed by a decline until physiological maturity. Stalk harvesting at hard-dough stage is ideal as it contains less moisture than at soft-dough stage or flowering.

Resistance to biotic stresses:

Shoot fly: SPSSV 4 alone recorded least deadheart formation and significantly not different from SPSSV nos. 20, 27, & 28; and SPSSH 25.

Spotted stem borer. The entries SPSSV nos 4, 15, 20, 27, & 28; and SPSSH nos 19 & 25 showed low deadheart formation and on par with CSV 19SS & CSH 22SS, including the resistant check, IS 2205. The entry, SPSSV 4 alone showed multiple resistance not only to shoot fly and but also deadhearts, leaf injury, and peduncle damage symptoms due to spotted stem borer and significantly not different from the commercial check, CSV 19SS. In addition, SPSSV nos 15 & 20, and SPSSH 19 recorded resistance to all the damage parameters of spotted stem borer.

Diseases: Among the test entries, SPSSV 30 showed high degree of resistance to grain mold and downy mildew. The rust reaction recorded significantly low in SPSSV nos 15, 20, 27 & 29; and SPSSH nos 24 & 27. The entries SPSSV 29 and SPSSH 24 & 27 had multiple disease resistance to downy mildew, rust, and zonate leaf spot. Whereas the commercial check, CSH 22SS showed multiple resistance to downy mildew and zonate leaf spot.

Basic genetic studies in sweet sorghum

Frequency distribution of F_2 showed that brix is governed by polygenic genes and cane and juice yield by olygogenic genes. The mean performance showed that F_1 mean for brix tended towards P_2 indicating that high brix is dominant. The F_1 means for cane yield and juice yield were greater than those of both the parents, indicating that these traits are governed by over dominant genes. Generation mean analysis showed that additive and dominance gene actions were important for all the traits, and negative dominance x dominance gene interaction was predominant indicating presence of epistatic interaction.

Detailed report: 2007-2008

The objectives of sweet sorghum evaluation program are:

i) To assess the performance and stability of sweet sorghum entries across a range of environments (latitudes) and identify superior genotypes those are better than standard checks (SSV 84, CSV19 SS and CSH 22 SS).
ii) To characterize plant traits that contribute higher stalk yield, juice yield and total sugar content leading to higher ethanol recovery
iii) To characterize test environments for soil and climatic variable that determines sweet sorghum productivity and quality.

Initial –cum- advanced sweet sorghum varietal & hybrid trial (IASSVHT) with 16 entries was organized in Kharif 2007 at fourteen locations (Parbhani, Rahuri, Akola, Phaltan, Coimbatore, Sameerwadi, Almel, Mandya, NRCS, Perumallapalle, Rudrur, Anakapalle, Pantnagar, and Ludhiana).

Soil and crop management

Soils: The soils where trials were planted varied from medium deep black (vertisols) and red sandy loam soils (Alfisols).

Sowing: Planting was mainly done between second week of June and second week of July at all centres. The particulars of sowings and other cultural practices are furnished in the Table 1.

Crop culture: A uniform plant spacing of 60 x15cm was followed at all centers except at Coimbatore where it was 45 x15cm.

Water management: The crops were raised on dryland conditions at all locations. At Rahuri, Sameerwadi, Coimbatore and Sameerwadi the crops received 2-4 irrigations, because of the prevalence of drought conditions during the GS I and GS 2 stages of crop growth.

Agroclimatic situation

Rainfall, RH and temperature data for Kharif 2007 season recorded at different centers are described below (Tables 2-4).

Perumallapalle: A total of 740 mm rainfall was received during crop growth period (std weeks 24 to 44). . The crop was raised with a post-sowing irrigation as the onset of the monsoon delayed. There was a prolonged dry spell of 3 weeks in GS 1 stage. Maximum and minimum temperatures varied from 30-37 and 22-26^{0}C, respectively.

Rudrur : The total rainfall received was 747 mm, which was just below normal. Heavy down pour occurred during GS3.
Hyderabad (NRCS): The total rainfall received during the crop growth period was just 520 mm, which was 31 % below normal (754 mm). The distribution of rainfall was uniform excepting two drought spell occurring in GSI stage. Because of this uniform distribution, the crop was grown entirely on rainfed conditions. Weekly mean maximum and minimum temperatures recorded were ranged from 28-34^0 C and 18-26^0 C, respectively.

Coimbatore: The total rainfall received during kharif season was 566 mm. The rainfall distribution was highly erratic with the receipt of low rainfall in June , July and August and September. About 80% rainfall occurred during rabi season i.e., from the second week of October to end of December. This assured rainfall during rabi season (NE monsoon) does not favour kharif sorghum cultivation unless protective irrigations were given. Thus, the crop was raised with 4 supplemental irrigations. Weekly mean maximum and minimum temperatures ranged from 21-24^{o}C and 28-32^{o}C, respectively.

Phaltan: The total rainfall received at Phaltan was 564 mm with a peak rainfall occuring in the seconfd week of June (179 mm) The amount and distribution were adequate to grow a good kharif crop during the current year. . However, the crop expose to two mid-season droughts in the month of July. Weekly mean maximum and minimum temperatures recorded were ranged from 29-34^{o}C and 21-24^{o}C, respectively.

Akola: The rainfall received during the crop growing period was season was 745 mm, which was just normal for this location. The distribution of was adequate to raise the successful dryland kharif crop. . Heavy down pour occurred in the last week of June.

Pantnagar: The total rainfall received during crop period was 1418 mm, which was more than normal. The crop was grown entirely on rainfed condition.

Rahuri: The total rainfall received during crop period was 550 mm with peak rainfall occurring in the last week of August The distribution was just adequate to grown the kharif crop this year. There were adequate rains occurred in the month of June, followed by severe drought spells in July and August. The pattern of rainfall distribution indicated that there has been a shift in typical rabi pattern to kharif type this year. The rainfall received during the rabi cropping period (mid September to end of Dec) was151mm. This rainfall received in September was adequate to plant the typical rabi sorghum too. Weekly mean maximum and minimum temperatures recorded were ranged from 29-35^{o}C and 12-23^o C, respectively

Almel : At Almel, the total rainfall received was 629 mm as against a normal of 590mm. The peak rainfall of 280 mm occurred during mid June. The rainfall distribution was adequate to grow Kharif crop. Weekly mean maximum and minimum temperatures recorded were ranged from 28-35^{o}C and 18-23^{o}C, respectively

Trial 1K. Evaluation of initial and advanced sweet sorghum varieties and hybrids trial (IASSVHT) entries for stalk yield , biomass, sugar content and bioethanol yields.

Sixteen IASSVHT trial entries comprising seven varieties, and six hybrids along with three checks (SSV 84, CSV 19SS & CSH 22 SS) were evaluated at 13 locations during kharif 2007. The promising entries for different traits in both hybrids and varieties are presented in the Table 1.

Table 1. Promising initial and advanced sweet sorghum varieties and hybrids for stalk yield, biomass, sugar content and bioethanol yields, Kharif 2007 (Mean of 13 locations)

S. No	Trait	Mean	Min	Max	Range	C D (0.05)	Var. check - CVS19SS	Hyb. check- CSH22SS	Promising entries superior to check
1	Time to 50% flowering (d)	82.0	77.0	91.0	14.0	5.0	81.0	85.0	SPVSS11 and SPSSV 30 were earlier than checks by 4 days.
2	Time to maturity (d)	119	113	127	14	4.0	116.0	123.0	SPVSS11 and SPSSV 30 earlier than checks.
3	Plant height (cm)	330	283	358	75	17.0	345.0	330.0	SPSSH 25 and SPSSH 19 taller than check.
4	Fresh stalk yield (t ha^{-1})	40.2	29.4	46.5	17.1	5.5	37.7	46.5	SPSSV 20, SPSSV 27, SPSSV 28, and SPSSV 4 in varieties gave 11.0-13.5 % more than var. check and none was superior to check in hybrids
5	Fresh biomass (t ha^{-1})	58.0	39.2	67.5	28.3	23.5	61.7	65.6	None was superior to checks
6	Grain yield (Kg ha^{1})	1656	1144	2251	1107	566	1399.0	1642.0	SPSSH 25, SPSSH 24, SPSSH 27 and SPVSS11 gave 18-37 % more in hybrids and , SPSSV 29, SPSSV 15 gave 23 & 11 % in var.
7	Juice brix %	16.8	15.8	19.6	3.8	1.0	16.8	16.3	SPSSV 30 showed 19.6% brix.
8	Juice yield (L ha^{-1})	14952	11688	18208	6500	2828	13730	16181	SPSSH 27 and SPSSV 11 gave 12.5 % more in hybrids, and SPSSV 20 (22%) and SPSSV 27 (11%) were superior in varieties
9	Juice extraction (%)	37.2	31.8	41.8	10.0	3.3	37.2	37.2	SPSSV 11 and SPSSV 20 gave 10-14 % more.
10	Total soluble sugars (%)	13.8	12.6	16.4	3.8	1.3	13.7	12.9	SPSSH 27, SPSSV 11, and SPSSH 24 in hybrids, and SPSSV20, SPSSV 15 and SPSSV 27 in varieties.
11	Sucrose (%)	11.9	10.6	14.6	4.0	1.9	11.7	10.7	SPSSV 30 (25 %) superior
12	Sugar yield (t ha^{-1})	1.99	1.66	2.53	0.80	0.45	1.71	1.99	SPSSH 27 (27%), SPSSV 11(19%), and SPSSH 24 (13%) in hybrids and SPSSV20 (22%), SPSSV 15(11%) and SPSSV 27(14%) in varieties were superior.
13	Bioethanol yield (L ha^{-1})	1123	925	1440	515	272	980	1132	SPSSH 27 (27%), SPSSV 11 (17%) and SPSSH 24 (10%) in hybrids and SPSSV 15 (15%), SPSSV 20 (23%) and SPSSV 27 (14%) in varieties were superior.

NB: Values in the parentheses indicate the percent superiority over checks.

Plant stand: Plant stand recorded at harvest between was 0.67-0.86 lakh/ha with a mean of 0.75 lakhs/ha. The corresponding values as percent normal was 58-75 and 65% , respectively (Tables 1.1-1.4).

Days to 50% flowering: Mean days to flowering varied from 77 to 91 days. SPVSS11 (77) and SPSSV 30 (78) were the earliest ones among the entries (Table 1.5). Variation among locations revealed that average days to flowering was the lower at Coimbatore, Sameerwadi, Akola and Perumallapalli than other locations. The flowering had delayed at Ludhiana (Mean: 100 days). In general, cultivars planted at lower latitudes in south flowered early compared to delay flowering at higher latitude in subtropical areas like Ludhiana. Days to maturity were also followed the similar tred those of flowering at all locations.

Plant height: It was ranged from 283cm (SPSSH 25) to 358cm (SPSSH 19) with a mean of 330cm.

Total fresh biomass: It varied from 39 to 67 t/ha with a mean of 58 t/ha across the locations. None was significantly superior to CSH22 SS. However, SPSSH 27 and SPSSV 20 recorded marginal superiority over checks (Table 1.8).

Fresh stalk yield: The fresh stalk yield differed significantly across locations. None was superior to check CSH22 SS in stalk yield among the test hybrids and varieties. The stalk yield ranged from 29.4 to 46.5t/ha with a mean of 40.2t/ha (Table 1.9). Among the varieties, SPSSV 20, SPSSV 27, SPSSV 28, and SPSSV 4 gave 11.0-13.5 % more stalk yield than best check CSV19 SS. The average stalk yield did not vary between both variety checks i.e., SSV 84 and CSV 19SS. The stalk yields recorded at Sameerwadi (50 t/ha), Parbhani (48 t/ha) and Almel (47 t/ha) were relatively higher than other locations because of availability adequate moisture during the crop growing period. Stalk yield had shown high significant positive correlation with fresh biomass and juice yields (0.803 & 0.842 res.; p= 0.01.)

Per day stalk yield: Per day stalk yield ranged from 264 to 406 kg/ha/day with an average of 354 kg. None was significantly superior to check CSH22 SS. (Table 1.23).

Grain yield: Grain yield ranged from 1144 to 2251 kg/ha with a mean of 1656. In experimental hy rids, SPSSH 25, SPSSH 24, SPSSH 27 and SPVSS11 gave 18-37% more grain yields than check CSH22 SS. In varieties, SPSSV 29, and SPSSV 15 yielded higher (23 and 11% more) than check SSV84 (Table 1.14).

Juice brix: Brix at physiological maturity varied between 15.8 and 19.6% with a mean of 16.8%. Among the test varieties, SPSSV 30 (19.6%) recorded significantly superior brix than check SSV84. Brix values recorded at Sameerwadi and Pantnagar were lower than other locations (Table 1.10). Interes tingly, brix content has shown very high positive correlation with sucrose content, and total soluble sugars (0.897, and 0.892 res.; p=0.01)

Juice extraction: Juice extraction ranged from 31.8 to 41.8% with a mean of 37.2%. Among the test hybrids, SPSSV 11 recorded 10% higher extraction rate over check CSH22 SS although the later produced more stalk yield than former (Table 1.11). Similar trend was observed at all locations. Among the test varieties, SPSSV 20 gave 14% more extraction than the check SSV84. Juice extraction values recorded were lowest at Rahuri followed by Akola, Almel and Parbhani. Juice extraction should be above 40% is desirable for high juice recovery in sweet sorghum. Furthermore higher juice extraction had shown a positive relationship with sugar yield and ethanol recovery (p=0.05).

Juice Yield: In juice yield, experimental hybrid SPSSH 27 gave 12.5% more value than check CSH22 SS followed by SPSSV 11. It was ranged from 11.7 to 18.2 KL/ha with a mean of 15.0 KL/ha (Table 1.12). Among the v arieties, SPSSV 20 (22% more), SPSSV 27 (11% more) gave superior yields than check CSV19 SS. The trends in juice yields at different locations were similar to that of juice extraction. Very high significant positive relationship was between juice and sugar yield and bioethanol yields (0.858 and 0.869 res.; p=0.01).

Components of total sugars: Total soluble sugars (TSS) ranged from 12.6 to 16.4% with an average of 13. 8%. SPSSV 30 was significantly superior to check SSV84. In non-reducing sugars (sucrose) too the range was 10.6-14.6% with a mean of 11.9% . Similarly, CCS (%) and CCS (t/ha) ranged from 7.58--9.95 % and 2.01-3.82 t/ha, respectively (Tables 1.16-1.20). The relationship between sucrose and TSS was significantly positive (0.973; p=0.01).

Total Sugar yields: Sugar yields ranged from 1. 66 to 2.53 t/ha with a mean of 1.99 t/ha. Among the test hybrids, SPSSH 27(27 % more), SPSSV 11(19%) and SPSSH 24 (13%) were superior to check CSH22 SS. In varieties too, SPSSV20 (22%), SPSSV 15(11.4%) and SPSSV 27 (13.6%) produced greater sugar yields than check.SSV84. Both total sugar yields and bioethanol yields were significantly positively correlated (0.996; p=0.01).

Ethanol yield: Calculated bioethanol yields were ranged from 925 to 1440 L/ha with mean of 1123 L/ha. In hybrids, SPSSH 27 (27 % higher), SPSSV 11(17%) and SPSSH 24 (10%) gave more bioethanol yields than check CSH22 SS (Table 1.21). Among the test varieties, SPSSV 15 (15%), SPSSV 20 (23%) and SPSSV 27 (14%) gave superior bioethanol yields than the best check SSV 84. The bioethanol yields of crops grown under supplemental irrigated conditions were found to be higher than dryland situation as could be seen from the data of Sameerwadi, Anakapalle, and Perumalapalle. Both higher per day ethanol and stalk yields had shown significant positive relationship with bioethanol yields (p=0.01).

Per day bioethanol yields: Per day bioethanol yields varied from 8.3 to 13.4 L/ha/day with a mean of 10.2 L. SPSSH 27 and SPSSV 11 have shown significant superiority over CSH22 SS (Table 1.22). In varieties, the per day bioethanol yields was almost similar to check.

Table 2K: Evaluation of sweet sorghum germplasm for high biomass and stalk characteristics

Forty-eight promising sweet sorghum germplasm along with two checks i.e. SSV 84 and CSV 19 SS were evaluated at Parbhani, Rahuri and Hyderabad in augmented design for stalk yield, brix content and biomass. Date on phenology, stalk yields and quality are presented in tables 2.1 to 2.5. Mean, ranges and promising entries for each trait are presented in Table 2.

Table 2. Promising sweet sorghum germplasm for flowering, stalk yield, brix content and biomass, Kharif 2007 (Mean of 3 locations)

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S No	Trait	Mean	Min	Max.	Range	CSV19SS (Check)	Promising entries superior to check (CSV19 SS)
1	Time to flowg.(d)	90	68	134	166	80	NSSV258, NSSV260, NSSV261, Wray, EC 538169, EC 538170 etc.
2	Fresh stalk yield (g/plant)	553	187	925	783	553	EC538169, IS5352, IS-5353, IS-5356, IS-5360, IS-5362, IS-6936, IS-7073, IS-7080, IS-7541, IS-7543, IS-7546, IS-7549, IS-11152, IS-11496, IS-12135, IS-17813, IS-17814, IS-17825, SSV-74, EG 25, and KARS 95 (22 no)
3	Total fresh biomass (g/plant)	882	258	1530	1272	1000	EC538169, IS 5352, IS-5353, IS5356, IS5360, IS5362, IS7080, IS7543, IS7549, IS11152, IS12135, IS17813, IS17814, IS17825, and SSV 74
4	Juice brix at mat. (%)	16.7	11.8	20.8	9.0	17.7	IS 7073, EC 538169,and SSV-74
5	Grain yield (g/plant)	23.9	16.3	51	34.7	29.8	EC 538169, IS 5352, IS 5353, IS-5356, IS 7541, IS 17813, and SSV 74
6	Dry biomass (g/plant)	224	34	434	400	234	IS-5353, IS-5356, IS-5360, IS-5362, IS-7080 IS-7541, IS-7543, IS-7546, IS-7549, IS-11152, IS-11496, IS-17813, IS-17814, IS-17825

Days to flowering had shown significant positive correlation with stalk yield (r=0.718; p=0.01), while, its relationship with brix was negative (r= -0.580; p=0.01). Similar trend was observed for fresh biomass too.

Conclusion: Twenty two entries namely EC538169, IS5352, IS5353, IS 5356, IS5360, IS5362, IS6936, IS7073, IS7080, IS7541, IS7543, IS7546, IS7549, IS11152, IS11496, IS12135, IS17813, IS17814, IS17825, SSV74, EG25, and KARS 95 had shown superior performance than check CSV 19 SS in terms of fresh stalk yield and could be used as potential donors for the sweet sorghum improvement aimed at high stalk yield and biomass.

Trial 3K. Influence of stage of harvesting on changes in quality, stalk yield and biomass in sweet sorghum

This trail was organized at Hyderabad and Rahuri with an objective of quantifying the effect of stage of harvesting (from flowering to phy. maturity) on changes in stalk yield, sugar content, biomass and bioethanol in sweet sorghum. Four cultivars along with four dates of harvesting treatments were tried in FRBD. Factor-A, comprising four cultivars include SSV84 (V1), CSH22SS (V2) CSV19SS (V3) and PAC52093 (V4), while, stages of harvesting (Factor B) included were ;T1- harvesting at 50% flowering; T2-harvesting at 15 days after 50% flowering (soft-dough stage); T3-harvesting at 30 days after 50% flowering (hard -dough stage); and T4-harvesting at physiological maturity (control).

Stalk Yields: Fresh stalk yield at maturity varied from 31.0 to 48.43 t/ha across cultivars and treatments with a mean of 38.7 t/ha. There were significant differences among cultivars for stalk yield but not among treatments. Similarly, the interaction effects were not significant. Stalk yield increased from flowering (T1) to soft dough-stage (T2) followed by a declined at hard-dough. Harvesting at soft-dough stage gave maximum stalk yields. Among the cultivars, CSH22SS yielded highest (45.8 t/ha) than others.

Juice brix: Brix values varied from 10 to 19% across cultivars and treatments. The differences in brix were significant among cultivars and treatments. Brix value increased significantly from flowering to maturity. SSV84 recorded significantly higher brix than other cultivars. Among the growth stages, brix value recorded was significantly higher at physiological maturity than preceding stages

Juice extraction and yields: In general juice extraction declined from flowering (T1:35.9%) to maturity (T4:26.1%) among the growth stages. Differences were significant among cultivars and treatments. The extraction percent ranged

between 23 and 39 % across the cultivars and treatments. Similarly, juice yields declined from flowering (15.2 KL /ha) to physiological maturity (11KL/ha).

Sugar Yields: Sugar yields ranged from 0.95 to 2.09 t/ha across cultivars and treatments. Sugar yields differed significantly among cultivars and treatments but the interaction effects were found non-significant. Sugar yields increased from flowering (T1:1.19 t) to hard-dough stage (T3:1.80 t/ha) followed by the marginal decline at maturity (T4:1.62 t/ha). Sugar yields increased by 11 % when sweet sorghum crop harvested at hard-dough stage (T3) than at physiological maturity (T4).

Bioethanol yields: Calculated bioethanol yields varied from 508 to 1110 L/ha across cultivars and treatments (Table 3). Differences in bioethanol yields were significant among cultivars and non-significant between the treatments. Bioethanol yields increased from flowering until hard-dough stage, while it declined at physiological maturity. Bioethanol yields had increased by 11 %, when sweet sorghum crop harvested at hard-dough stage (T3) than at physiological maturity (T4). Among the cultivars, CSH22 SS recorded highest bioethanol yield at hard-dough stage than others. The per day bioethanol yield trends observed were similar to that of bioethanol yields among cultivars & treatments.

Table 3. Influence of stage of crop harvesting on calculated bioethanol yield in sweet sorghum.

Cultivar/ stage of harvest	At 50% flowering	At Soft –dough (15DAF)	At hard-dough (30DAF)	At physiological maturity	Cultivar mean
Calculated bioethanol yield (L ha^{-1})					
SSV84	508	762	845	728	711
CSH22SS	660	1100	1102	959	958
CSV19SS	633	547	954	794	732
PAC52093	742	1002	926	975	911
Treat. mean	636	855	956	864	828
			CD (0.05)		
Stage of harvest			250		
Cultivar			250		
Interaction			NS		

Bagasse yields and moisture % fresh stalk Mean fresh and dry bagasse yields recorded at maturity across treatments and cultivars was 20.6 t/ha and 4.9 t/ha, respectively. The bagasse yield had increased from flowering to hard dough stage among the treatments. CSH 22 SS recorded significantly higher bagasse yields than other cultivars (Table 3.6). Similarly, mean fresh bagassse % stalk and dry bagasse (fibre) % stalk recorded was 61.4% and 14.6% across the cultivars and treatments and both these parameters increased from flowering to hard dough stage as similar to bagasse yields. On the other hand, the mean moisture % stalk and moisture % bagasse recorded was 73.5% and 76.4% across the cultivars and treatments. Among the treatments, significantly higher moisture % stalk and moisture % bagasse was recorded at flowering and it was decreased until physiological maturity. The result suggests that harvesting at hard-dough stage is ideal as it contains less moisture than at flowering and soft dough stage.

Resistance to biotic stresses (ASSVHT trial of Entomology and Pathology)

1. Insect pests: During kharif 2007, advanced sweet sorghum varietal and hybrid trial (ASSVHT) trial comprising twenty entries conducted at 3 locations (Rahuri, Akola, and Warangal) were evaluated for resistance to shoot fly (*Atherigona soccata* Rond.) and spotted stem borer (*Chilo partellus* Swin.) (Table 11.1). The incidence of shoot fly was low, moderate, and high at Warangal, Akola, and Rahuri, respectively. Since the infestation of the susceptible check, DJ 6514 was low at Akola and Warangal, the reaction of shoot fly at both these locations as well as high CV a Warangal was not considered for all India average. Among the test entries, SPSSV 4 alone recorded least deadheart formation and significantly not different from SPSSV nos. 20, 27, & 28; and SPSSH 25.

The damage parameters of resistance to spotted stem borer recorded include deadhearts was recorded at Rahuri and Warangal, but leaf injury and peduncle symptoms at Akola, The expression of deadhearts was relatively higher at Rahuri compared to Warangal (although being a 'hot spot' for stem borers). The entries SPSSV nos 4, 15, 20, 27, & 28; and SPSSH nos 19 & 25 showed low deadheart formation and on par with CSV 19SS & CSH 22SS, including the resistant check, IS 2205. On the other hand, no significant differences were observed for leaf feeding injury. While, the peduncle damage was significantly high in SPSSV 20, 29, & 30; SPSSH 29, 24, 25, 26, & 27; and CSH 22SS. This suggests that these entries had a significant effect on grain yield components.

Conclusions: The entry, SPSSV 4 alone showed multiple resistance not only to shoot fly and but also deadhearts, leaf injury, and peduncle damage symptoms due to spotted stem borer and significantly not different from the commercial

check, CSV 19SS. In addition, SPSSV nos 15 & 20, and SPSSH 19 recorded resistance to all the damage parameters of spotted stem borer.

2. Diseases: ASSVHT was evaluated for resistance to diseases [grain mold, and foliar diseases (downy mildew, rust, zonate leaf spot, target leaf spot, anthracnose, leaf blight, and sooty stripe)] at two locations (Dharwad and Udaipur) (Table 12.1). Among the test entries, SPSSV 30 showed high degree of resistance to grain mold and downy mildew. The rust reaction recorded significantly low in SPSSV nos 15, 20, 27 & 29; and SPSSH nos 24 & 27. Other diseases such as zonate leaf spot, target leaf spot, anthacnose, leaf blight, and sooty stripe did not show significant differences for their reaction between the entries.

Conclusions: The entries SPSSV 29 and SPSSH 24 & 27 had multiple disease resistance to downy mildew, rust, and zonate leaf spot. Whereas the commercial check, CSH 22SS showed multiple resistance to downy mildew and zonate leaf spot.

Basic genetic studies on sweet sorghum

Like previous year, this year also, frequency distribution of F_2 showed that brix is governed by polygenic genes and cane and juice yield by olygogenic genes. The mean performance showed that F_1 mean for brix tended towards P_2 indicating that high brix is dominant. The F_1 means for cane yield and juice yield were greater than those of both the parents, indicating that these traits are governed by over dominant genes. Generation mean analysis showed that additive and dominance gene actions were important for all the traits, and negative dominance x dominance gene interaction was predominant indicating presence of epistatic interaction. Dominance and over dominance nature of genes for high brix, cane and juice yields can be utilized in development of superior hybrids for these traits. However, for pure line selection for these traits, there is a need for making selections at later generations.

Thirty two germplasm lines were evaluated for sweet stalk and for various agronomic traits. The germplasm lines, Urja (22.7%), EC 538171 (22.3%), EC 538164 (21.2%), and IS 6962 (20.0%) recorded highest brix against the check, RSSV 9 (20.3%). Correlation studies showed that stem diameter and number of leaves were significantly (-ve) correlated to high brix. However, juice yield and cane yield were significantly correlated to plant height, stem diameter, length and number of internodes etc.

Recommendations on the standardization of evaluation of sweet sorghum and the criteria for entering in to the coordinated trials

The recommendation for evaluation of sweet sorghum and criteria for entering the new entries are detailed below. In continuation of earlier recommendation of Surat workshop (1992) and subsequent meetings of Coimbatore (1997), and from annual group meetings of 2004-2006, the following criteria was formulated to evaluate and entering the new entries. The bench mark traits needed for entering the new genotypes in relation to the checks based on the four year data (2004-2007) are presented in the table 4A and 4B.

Minimum datasets for characterizing sweet sorghum genotypes :

1. Days to 50% flowering physiological maturity.
2. Juice extractability: A two-roller, or three roller electrically operated cane juice extractor is recommended.
3. Reducing sugars.
4. Juice brix at phy. maturity
5. Non-reducing sugars (Sucrose)
6. Total soluble sugars,
7. Juice yield,
8. Calculated sugar yields and bioethanol yields.
9. Fresh Stalk yield (after leaf striping)
10. Grain yield
11. Biotic stress resistance to stem borer, shoot fly, and shoot bug, and Downey mildew and foliar diseases, (rust, & anthracnose).
12. Agroclimatic data and soil edaphic particulars

Criteria for evaluation and promotion of the sweet sorghum entries:

1. The new genotypes should be evaluated in the replicated station trial for a minimum of one year before entering in to the coordinated trials and the data should be compared with checks (see table 4A,& 4B) and the details of new entry should be furnished in the data format while submitting the seed materials.
2. The optimum flowering range to be fit in to the kahrif cropping system would be 75 to 85 days

3. Sweet sorghum genotypes which produce a reasonable grain yield of 1.5 – 2.5 t/ha should be given priority since both food and fuel are the important traits from sweet sorghum for the promotion of this as bioenergy crop.
4. The entries need to be checked for their location specific adaptation for stalk yield and quality apart from all India superiority since the sweet sorghum is going to be cultivated in the near future as a commercial crop around the distilleries or biofuel complexes under contract farming.
5. The sweet sorghum (high energy sorghum) capable of yielding a minimum 36 t/ha of fresh under standard management practices (assured soil moisture, temperature regime) are being recommended for entering in to the initial and/or promotion to AVHT provided they satisfy the following specifications in juice yield and quality parameters.
6. Juice extractability of 35-40% or above in 2-roller extractor 40- 45% and above in a 3-roller extractor.
7. Juice quality conforming to Brix 15% or above having at least 12% sucrose, less than 2.5 – 3.0% reducing sugars.
8. For bioethanol fermentation, entries should have a minimum of 14-15% total soluble sugars (TSS) with any levels of starch in their juice.
9. Sugar yield from sweet sorghum is a function of total fresh stalk yield, juice extractability and the concentration of sugars. Therefore, selection based on the combination of above parameters should be followed rather than any single one along with the grain yield for promotion. .
10. Crushing stalks, Juice handling of juice, quality analysis should be done within the 12 hours of the harvesting of the crop.
11. Biochemical assay of samples having brix 15% and above for total sugars, reducing sugars and starch should be made by following similar procedure by all the centers. Trial data book let containing all parameters along with procedures to be supplied to centers by PI for uniformity.
12. Since large number of biofuel industries are interested to know the expected the genotype potential of ethanol yields, it has been decided to present the data on calculated ethanol yields as per the standard published literature taking the consideration on juice yields, total sugar content, and sugar yields.
13. A minimum 10% superiority on juice yields, sugar yields and bioethanol yields should be the criterion for promoting from IVHT to AVHT
14. In view of cumbersome procedures involved in the biochemical data collection, it has been decided to conduct one single initial and advanced varieties-cum-hybrid trial only. The optimum number of entries should be 16. The standard checks for varieties are CSV19 SS and SSV 84 and for hybrid, CSH22 SS.
15. A sample size of 10 plants drawn at randomly from different rows in the net plot leaving border rows from each replication should be taken for the estimation of stalk yield, juice yield and juice quality. Grain yield may be estimated according to the standard procedure.
16. Brix content should be measured using brix meter (ERMA, make Japan) having a range of 0-32 or any higher version of digital refractometers.
17. All centers should use similar crushing unit with two/three rollers of as the case may be and the stalks may be crushed by passing at least three times.
18. It has been decided that the concerned centre should interact with local distillery or sugar industry where ever the facility exists and get verified the juice quality parameters with industry standards especially distillery quality lab in the distillery.
19. It is strongly recommended that the person In-charge of the conduct of trial should have the knowledge of analyses of biochemical procedures. The person evaluating juice quality should be from the disciplines of Biochemistry, Plant Physiology, and Agronomy or Breeding who are well versed with procedures.
20. To introduce better uniformity in data collection and reporting a common training program for scientific and technical personnel involved in this evaluation may be imparted preferable at NRCS.
21. The centers entrusted with chemical analysis of juice may take extreme care in analysis using always-internal standard exchanged by these laboratories.

Table 4A.. Performance of sweet sorghum variety and hybrid checks in advanced trials across the years (K04-07) for phenology, stalk yield, and grain yield (Mean of 10 loc. In each year)

	Days to flowering (d)					Fresh stalk yield (t/ha)					Grain yield (kg/ha)				
	2004	*2005*	*2006*	*2007*	*Mean*	*2004*	*2005*	*2006*	*2007*	*Mean*	*2004*	*2005*	*2006*	*2007*	*Mean*
SSV 84	80.2	83	81	88	83	36.2	35.8	37.6	37.0	36.7	883	1182	1141	1490	1174
CSV19 SS	72.7	78	76	81	77	32.9	36.3	40.3	37.7	36.8	767	1229	1073	1399	1117
CSH22 SS	76.9	83	81	85	81	47.6	46.8	48.5	46.5	47.4	912	1542	1836	1642	1483
Trial Mean	76.9	82	79	82		34.8	37.5	41.2	40.2		1074	1345	1500	1656	
No entries(no)	12	14	12	16		12	14	12	16		12	14	12	16	
CV (%)	6.4	4.3	6.1	6.5		17.7	8.3	15.5	17.6		34.4	16.2	33.8	32.7	
CD (5%)	3.11	2.07	4	5		3.92	2.25	5	5.5		235	143.9	504	566	

Table 4B. Performance of sweet sorghum variety and hybrid checks in advanced trials across the years (K04-07) for brix, extraction, juice yields and total sugars (Mean of 10 loc. in each year).

	Juicy brix at phy.mat. (%)					Juice extraction (%)					Juice yield (L/ha)				Total soluble sugars (%)				
	2004	*2005*	*2006*	*2007*	*Mean*	*2004*	*2005*	*2006*	*2007*	*Mean*	*2005*	*2006*	*2007*	*Mean*	*2004*	*2005*	*2006*	*2007*	*Mean*
SSV 84	18.6	17.8	17.3	17.0	17.7	40.5	38.4	35.2	36.7	37.7	11314	12868	12683	12288	10.3	13.7	14.1	13.9	13.0
CSV19 SS	16.9	16.8	16.2	16.8	16.7	34.5	36.4	32.3	34.7	34.5	10320	13076	13730	12375	9.58	13.1	12.9	13.7	12.3
CSH22 SS	15.7	17.3	16.4	16.8	16.6	35.6	39.2	36.1	37.2	37.0	13958	17899	16181	16013	10.1	14.6	13.4	12.9	12.7
Trial Mean	16.7	17.1	16.7	16.8		35.6	39.4	36.2	37.2		12751	15246	14952		10.8	13.7	13.6	13.8	
No. entries(no)	12	14	12	16		12	14	12	16		14	12	16		12	14	12	16	
CV (%)	7.44	4.01	6.09	6.81		9.4	6.5	10.4	10.22		12.5	22.61	22.90		14	3.84	8.27	9.15	
CD (5%)	0.79	0.4	0.9	1.0		2.12	1.48	3.1	3.3		1010	2772	2828		0.99	0.32	1.2	1.3	