Sweet sorghum breeding – 2013-14

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Executive summary

Trial 1a: Evaluation of initial and advanced sweet sorghum varieties and hybrids (IASSVHT)-Kharif 2013

1. Twenty IASSVHT trial entries comprising 13 varieties, 5 hybrids (including hybrid check CSH 22SS) along with 2 varietal checks (CSV 19SS & CSH 24SS) were evaluated at 11 locations during kharif 2013.
2. SPH 1755 with a flowering of 81 days was the most early test entry in the entire trial and had 7% superiority for early flowering over the check hybrid (88 days)
3. For total fresh biomass, among hybrids, SPH 1755 had a numerical superiority of 13%. SPV 2196 among the varieties recorded a significant superiority of 28% while SPV 2195, SPV 2270, SPV 2268 and SPV 2205 had a numerical superiority ranging from 13-18% over CSV 24SS and these entries were promising for fresh stalk yields too
4. For grain yield, SPH 1738 (6%) and SPV 2267 (7%) exhibited superiority over respective checks.
5. For brix content, the hybrid SPH 1754 and variety SPV 2268 recorded a numeric superiority of 5% over the respective checks.

6. For juice yield, the hybrids SPH 1755 and SPH 1754 exhibited significant superiority over the check while in varieties, significant superiority of 4 to 24% over the check variety CSV 24SS was observed.
7. For total sugar yield and calculated bioethanol yields, the hybrids SPH 1754 and SPH 1755 and varieties, SPV 2196, SPV 2270, SPV 2272, SPV 2202, SPV 2205 and SPV 2268 were superior to respective checks.

Trial 1b: Evaluation of initial and advanced sweet sorghum varieties and hybrids (IASSVHT)-Rabi 2013-14

1. The variety SPV 2268 was the earliest to flower in the entire trial
2. SPH 1755 (108 days) among hybrids and SPV 2268 (107 days) among varieties were early maturing.
3. For total fresh biomass, the variety SPV 2271 had a numerical superiority of 23% over the check CSV 24SS.
4. For fresh stalk yields, SPV 2195, SPV 2196, SPV 2200, SPV 2271 , SPV 2272, SPV 2202, SPV 2241 and SPV 2201 were superior to the checks.
5. For juice brix, SPV 2268 and SPV 2196 were significantly superior over the check variety.
6. With respect to juice yields, the varieties SPV 2196, SPV 2200, SPV 2195, SPV 2272, SPV 2201, SPV 2202, SPV 2271, SPV 2241, SPV 2205 and SPV 2268 were significantly superior to the check variety CSV 24SS.
7. For total soluble sugars (TSS), the variety SPV 2268 was significantly superior to the varietal check.
8. For calculated ethanol yields, all the hybrids were numerically superior by 16 to 51%. Among varieties, SPV No`s 2196 , 2195, 2201, 2241 and 2268 were significantly superior.

Trial 3: Identification of high biomass sorghums for lignocellulosic biofuel traits-Kharif 2013

1. RSSH 50, RSSH 18 and CSH 13 were promising for total fresh biomass (>60t/ha). RSSH 50 recorded highest (87 t/ha) fresh biomass and was significantly superior to the check.
2. RSSH 50 recorded the highest dry biomass of 33.5 t/ha.

Detailed report

Trial 1a: Evaluation of initial and advanced sweet sorghum varieties and hybrids (IASSVHT)-Kharif 2013

Twenty IASSVHT trial entries comprising 13 varieties, 5 hybrids (including Hybrid check CSH 22SS) along with 2 varietal checks (CSV 19SS & CSV 24 SS) were evaluated at 11 locations during kharif 2013. The promising entries for different traits are presented in Table 1.

Morpho-phenological traits

Days to 50% flowering varied from 79-88 days. The test hybrids SPH 1755 and SPH 1754 were significantly early (6-7%) compared to the check CSH 22SS. SPH 1755 with a flowering of 81 days was the most early test entry in the trial and had 7% superiority for early flowering over the check hybrid (88 days). SPV 2267 (79 days), SPV 2270 (79 days), SPV 2269 (80 days) and SPV 2205 (84 days) were significantly early compared to the check variety CSV 24SS (88 days). Variation among locations revealed that average days to flowering was the lower at Palem (71 days) followed by Coimbatore and Akola (73 Days). Delayed flowering was experienced at Pantnagar location (Mean - 100 days).

Days to maturity of test entries ranged from 117 to 125 days. The hybrids which flowered early were also significantly early maturing (5-6%) compared to the hybrid check. The hybrids SPH 1755, SPH 1754 and

SPH 1739 were quite early and matured in 118, 118 and 120 days respectively. The varieties, SPV 2205, SPV 2267, SPV 2269 and SPV 2270 exhibited significant superiority (4-6%) for early maturity.

Plant height varied from 259 cm (SPV 2267) to 321 cm (SPV 2195) with a mean of 289 cm. Among the hybrids, none could exhibit any significant superiority, while, among varieties, SPV 2195 (14%) and SPV 2270 (7%) were significantly superior over the check variety CSV 24SS (283 cm).

Biomass traits

Total fresh biomass differed across locations and it varied from 29.4 to 44.1 t/ha (mean of 36.6 t/ha). None of the test hybrids were significantly superior to the check CSH22 SS. However, SPH 1755 had a numerical superiority of 13%. Among the varieties, SPV 2196 with a biomass yield of 42.7 t/ha recorded a significant superiority of 28% while SPV 2195, SPV 2270, SPV 2268 and SPV 2205 had a numerical superiority ranging from 13-18% over CSV 24SS. Lowest mean biomass yields were reported from Anakapalle followed by Phaltan, Perumallapalle and Coimbatore. Highest mean biomass yields were observed at Rahuri followed by Surat.

Fresh stalk yield ranged from 23.5 to 37.5 t/ha with a mean of 30.1 t/ha. None of the test hybrids had any significant superiority over the check CSH 22SS. However, SPH 1755 recorded a numerical superiority of 16% over the check hybrid. Among the varieties, SPV 2196 had significant superiority (24%) over the check variety CSV 24SS. The varieties SPV 2270, SPV 2195, SPV 2205 and SPV 2268 had a numerical superiority ranging from 12-19% over CSV 24SS.

Grain yield ranged from 1472 to 1930 kg/ha with a mean of 1572 kg/ha. None of the test hybrids was significantly superior to the check CSH 22SS, however SPH 1738 (6%) and SPH 1755 (4%) showed numerical superiority. The varieties SPV 2267 (7%) and SPV 2205 (3%) exhibited numeric superiority over check variety CSV 24SS.

Quality traits

Juice brix at physiological maturity varied between 16.3 and 18.0% with a mean of 16.9%. The hybrids SPH 1754 (5%) and SPH 1738 (5%) recorded numerical superiority over CSH 22SS while among test varieties, SPV 2268 with a brix of 18% recorded a numeric superiority of 5% over the check CSV 24SS (17.1%). Highest mean brix content (19.7%) was recorded at Surat.

Juice extraction ranged from 31.1% to 40.7% (mean of 37.0%). Among the test varieties, except SPV 2269 and SPV 2270, all other varieties had a numerical superiority of around 5% over the check CSV 24SS while SPV 2200 (16%) and SPV 2202 (12%) were significantly superior to the check. Among the hybrids, SPH 1739 (7%), SPH 1754 (7%) and SPH 1755 (5%) recorded numerical superiority over the check hybrid CSH 22SS.

Juice yield ranged from 7790 L/ha to 11360 L/ha with a mean of 10240 L/ha. The hybrids SPH 1755 (5%) and SPH 1754 (3%) exhibited significant superiority over the check hybrid CSH 22SS. Significant superiority of 4 to 24% over the check variety CSV 24SS was observed in all the varieties except SPV 2267 and SPV 2269.

Components of total sugars

Total soluble sugars (TSS) ranged from 13.75 to 14.98% with an average of 14.33%. All of the hybrids were numerically superior (2-5%) over the check hybrid CSH 22SS. SPV 2268 recorded the highest TSS (14.98%) while SPV 2200 recorded the lowest TSS (13.75%). The range of reducing sugars was 1.38 to 1.92% while the range of non-reducing sugars was 10.2 to 12.5%. Among varieties, SPV 2269 recorded the highest non reducing sugar content of 12.5% and was 14% significantly superior to the check CSV 24SS. The CCS (%) ranged from 5.71 to 7.43%.

Total sugar yields: Sugar yields ranged from 1.07 to 1.42 t/ha with a mean of 1.26 t/ha. The hybrids SPH 1754 and SPH 1755 were numerically superior to the check CSH22 SS by 16 % and 10% respectively. Among the varieties, SPV 2196, SPV 2270, SPV 2272, SPV 2202, SPV 2205 and SPV 2268 were numerically superior to varietal check CSV 24SS by 13 to 19%.

Ethanol yield: Calculated bioethanol yields ranged from 570 to 756 L/ha with mean of 669 L/ha. The hybrids SPH 1754 followed by SPH 1755 recorded numerical superiority of 16% and 10% over the check hybrid. For the test varieties, the trend was similar to total sugar yields.

Conclusions

1. SPH 1755, SPV 2196, SPV 2270, SPV 2195, SPV 2205 and SPV 2268 were promising for total biomass, fresh stalk and juice yields
2. For total sugar yields and calculated bioethanol yields, the hybrids SPH 1754 and SPH 1755 and the varieties SPV 2196, SPV 2270, SPV 2272, SPV 2202, SPV 2205 and SPV 2268 were superior to respective checks

Trial 1b: Evaluation of initial and advanced sweet sorghum varieties and hybrids (IASSVHT)-Rabi 2013-14

The set of entries evaluated during kharif 2013 were assessed during rabi 2013-14 for their performance for identifying stable genotypes. The trial was conducted at 4 locations viz., Rahuri, Phaltan, Parbhani and Hyderabad.

Morpho-phenological traits

Days to 50% flowering varied from 63-80 days. The variety SPV 2268 was the earliest to flower in the entire trial. The hybrids SPH 1755 (65 days) and SPH 1739 (66 days) were significantly early to flower as compared to the check hybrid CSH 22SS (70 days). Flowering was early at Phaltan and Rahuri compared to the other locations. The range of flowering in rabi season was more compared to kharif season.

Days to maturity of test entries differed across locations. All the hybrids were significantly early maturing amongst hybrids while among varieties, the variety SPV 2268 matured early (107 days).

Plant height ranged from 202 cm (SPV 2267) to 307 cm (SPV 2195) with a mean of 233 cm.. None of the hybrids were superior compared to check hybrid while the varieties SPV 2195, SPV 2200, SPV 2201, SPV 2202, SPV 2205, SPV 2241, SPV 2269, SPV 2270 and SPV 2272 were significantly superior to the check variety CSV 24SS. It was gratifying to note that the varieties SPV 2195 and SPV 2270 had superiority for this trait in Kharif too.

Biomass traits

Total fresh biomass varied from 32.9 to 51.8 t/ha (mean of 39.6 t/ha). An increase of around 11% in mean biomass yields was observed in rabi as compared to kharif. None of the test hybrids were significantly superior to the check CSH22 SS. Almost all the test varieties except SPV 2205, SPV 2267, SPV 2268 and SPV 2271 had significant superiority over the check variety (25-58%). The variety SPV 2271 had a numerical superiority of 23% over the check CSV 24SS. The varieties SPV 2196 and SPV 2195 performed consistently across seasons. Lowest mean biomass yields were reported from Parbhani while highest mean biomass yields were observed at Phaltan.

Fresh stalk yield ranged from 20.8 to 42.3 t/ha with a mean of 27.1 t/ha. The hybrid SPH 1755 had a marginal superiority of 3% over the check hybrid. Among varieties, SPV 2195 (97%), SPV 2196 (53%), SPV 2200 (43%), SPV 2271 (42%), SPV 2272 (41%), SPV 2202 (40%), SPV 2241 (39%) and SPV 2201 (38%) were significantly superior to the check. SPV 2196 and SPV 2195 performed well in both the seasons.

Grain yield ranged from 1376 kg/ha (SPV 2268) to 3496 kg/ha (CSH 22SS) with a mean of 2671 kg/ha. The grain yields were higher during rabi compared to kharif. All of the test hybrids were inferior while the test varieties SPV 2272 (19%), SPV 2267 (13%) and SPV 2271 (10%) were numerically superior compared to the check variety CSV 24SS.

Quality traits

Juice brix at physiological maturity varied between 9.2 and 13.4% (mean of 10.8%). The brix was drastically reduced in rabi compared to kharif season. Among hybrids, SPH 1754 recorded a marginal superiority of 2% over the check hybrid. Among the varieties, SPV 2268 (29%) and SPV 2196 (27%) were significantly superior over the check variety. SPV 2268 recorded higher brix in both the seasons.

Juice extraction ranged from 26.% to 36.2% (mean of 32.2%). The hybrid SPH 1739 had a marginal superiority of 7% over CSH 22SS. Among the test varieties, SPV 2205 (34%), SPV 2200 (31%), SPV 2272 (28%) and SPV 2195 (25%) recorded significant superiority over the check. The variety SPV 2272 performed consistently over both the seasons.

Juice yield ranged from 5674 L/ha to 13278 L/ha with a mean of 9310 L/ha. The mean juice yields were reduced by 9% in rabi compared to kharif season. All the hybrids were inferior to the check hybrid, while all the varieties except SPV 2267 (25%) and SPV 2269 (22%) were significantly superior to the check variety with a superiority range of 58% (SPV 2268) to 134% (SPV 2196). The varieties viz., SPV No`s 2195, 2196, 2202, 2205, 2268, 2271 and 2272 performed consistently in both the seasons.

Components of total sugars

Total soluble sugars (TSS) ranged from 7.60 to 10.52% with an average of 8.52%. SPV 2268 recorded the highest TSS (10.52 %) and was significantly superior to the check variety by 27%. The range of reducing sugars was 1.43 to 1.85% while the range of non-reducing sugars was 8.64 to 9.91%.None of the test hybrids and varieties were significantly superior to the checks. SPV 2196 and SPV 2268 recorded a numerical superiority of 5%.

Total sugar yields: Sugar yields ranged from 0.17 to 0.93 t/ha with a mean of 0.48 t/ha. All the hybrids had a numerical superiority with a range of 16% (SPH 1738) to 50 % (SPH 1739) over the hybrid check. With respect to the varieties, SPV No`s 2196 (182%), 2195 (158%), 2201 (109%), 2241 (70%) and 2268 (58%) had significant superiority over the check.

The varieties SPV No`s 2196, 2272, 2202, 2205 and 2268 and hybrids SPH 1754 and SPH 1755 were promising for this trait in both the seasons.

Ethanol yield: Calculated bioethanol yields ranged from 89 to 495 L/ha with mean of 253 L/ha. The percentage decrease in ethanol yield from kharif to rabi was 62%. All the hybrids were numerically superior by 16 to 51%. For varieties, the trend was similar to that of total sugar yields.

The varieties SPV No`s 2196, 2272, 2202, 2205 and 2268 and hybrids SPH 1754 and SPH 1755 were promising for this trait in both the seasons.

Shortfalls

- Non-receipt of data from one location and delay in receipt of data from some locations

Over all conclusions

- It was gratifying to note that the varieties SPV 2195 and SPV 2196 performed consistently for biomass and fresh stalk yields across seasons
- SPV 2268 recorded higher brix in both the seasons.

- For juice yield, the varieties viz., SPV No`s 2195, 2196, 2202, 2205, 2268, 2271 and 2272 performed consistently in both the seasons.
- For total sugar yields and calculated ethanol yields, the varieties SPV No`s 2196, 2272, 2202, 2205 and 2268 and hybrids SPH 1754 and SPH 1755 were promising in both the seasons .

Follow-up for kharif 2014

1. Based on the performance, the promising lines in initial trials will be advanced to advanced varietal and hybrid trials

Trial 3: Identification of high biomass sorghums for lignocellulosic biofuel traits- Kharif 2013

Twelve trial entries including sweet sorghum checks CSV 19SS and CSH 22SS were evaluated at 4 locations viz., Rahuri, Phaltan, Hyderabad and Surat during kharif 2013.

Morpho-phenological traits

Days to 50% flowering varied from 80-91 days with a mean of 86 days. The hybrid CSH 13 with a flowering of 81 days recorded a significant superiority of 11% for early flowering as compared to the check CSH 22SS. Among the varieties, SPSSV 30 flowered early (80 days) compared to other varieties. Early flowering was experienced at Hyderabad while at Phaltan, the flowering was delayed.

Days to maturity of test entries ranged from 119 (CSH 13) to 130 days (CSH 22SS). The trend was similar to days to flower.

Plant height varied from 256 cm (DSR 84) to 343 cm (RSSH 50) with a mean of 292 cm. The mean plant height was more at Hyderabad followed by Surat.

Biomass traits

Total fresh biomass differed across locations and it varied from 41.5 to 87 t/ha (mean of 61.6 t/ha). RSSH 50 recorded the highest biomass yields of 87 t/ha and was 36% significantly superior compared to CSH 22SS (63.8 t/ha). RSSH 18 was another promising entry for biomass (73.1 t/ha). The varieties with more than 10% superiority over CSV 19SS were SSV 74, RSSV 351, RSSV 350 and RSSV 369. Highest mean biomass yields were observed at Hyderabad while lowest mean biomass yields were reported from Phaltan.

Dry biomass yield ranged from 20.2 to 33.5 t/ha with a mean of 25.8 t/ha. RSSH 50 recorded the highest dry biomass of 33.5 t/ha. The other promising genotypes were SSV 74 (31.6 t/ha) followed by RSSH 18 (29.2 t/ha) and CSH 13 (28.4 t/ha).

Juice brix at physiological maturity varied between 16.7 and 20.4 % (mean of 18.1%). SPSSV 30 recorded the highest brix of 20.4% followed by RSSV-325 (18.7%) and SSV 74 (18.6%).

Grain yield ranged from 1038-1632 kg/ha. CSH 13 with a grain yield of 1632 kg/ha recorded 19% superiority over CSH 22SS (1372 Kg/ha). DSR 84, RSSH 18 and RSSV 325 were the other promising entries.

Table 1: Promising initial and advanced sweet sorghum varieties and hybrids for stalk yield, biomass, sugar content and bioethanol yields, Kharif 2013

S. No	Trait	Mean	Min	Max	Range	C D (0.05)	Var. check CSV 24SS	Hyb. Check CSH22SS	Promising hybrids and varieties superior to checks
1	Time to 50% flowering (d)	85.0	79.0	88.0	9	4.0	88	88	**Hybrids:** SPH 1755 (7%) and SPH 1754 (6%) were significantly early **Varieties:** SPPV 2267 (10%), SPV 2270 (10 %), SPV 2269 (9%) and SPV 2205 (5%)
2	Time to maturity (d)	122	117	125	8	4.0	125	125	**Hybrids:** SPH 1755, SPH 1754 and SPH 1739 were significantly early to mature (1-6%) **Varieties:** SPV 2267, SPV 2269, SPV 2270 and SPV 2205 were significantly superior (4-6%)
3	Plant height (cm)	289	259	321	62	17.7	283	302	**Hybrids:** Nil **Varieties:** SPV 2195 (14%) and SPV 2270 (7%) were significantly superior.
4	Fresh biomass (t ha^{-1})	36.6	29.4	44.1	14.7	8.6	33.5	39.2	**Hybrids:** SPH 1755 was numerically superior (13%) **Varieties:** SPV 2196 (28%) recorded significant superiority, while, SPV 2205 (18%), SPV 2268 (16%), SPV 2270 (14%) and SPV 2195 (13%) were numerically superior
5	Fresh stalk yield (t ha^{-1})	30.1	23.5	37.5	14	5.4	27.6	32.3	**Hybrids:** SPH 1755 was numerically superior (16%) **Varieties:** SPV 2196 (24%) had significant superiority, while, SPV 2268 (19%), SPV 2205 (17%), SPV 2195 (16%) and SPV 2270 (12%) were numerically superior.
6	Grain yield (Kg ha^{-1})	1572	1472	1930	458	205	1695	1815	**Hybrids:** SPH 1738 (6%) had numerical superiority **Varieties**: SPV 2267 (7%) was significantly superior.
7	Juice brix %	16.9	16.3	18.0	1.7	1.0	17.1	16.9	**Hybrids:** SPH 1754 (6%) and SPH 1738 (5%) recorded numerical superiority **Varieties:** SPV 2268 recorded significant superiority of 5%

S. No	Trait	Mean	Min	Max	Range	C D (0.05)	Var. check CSV 24SS	Hyb. Check CSH22SS	Promising hybrids and varieties superior to checks
8	Juice yield (L ha^{-1})	10240	7790	11360	3570	173	9160	10430	**Hybrids:** 1755 (4.6%) and SPH 1754 (2.6%) exhibited significant superiority **Varieties:** All except SPV 2267 and SPV 2269 were significantly superior to CSV 19SS by 5-24%.
9	Juice extraction (%)	37.0	31.1	40.7	9.6	3.6	35.2	37.0	**Hybrids:** SPH 1739 (7%), SPH 1754 (7%) and SPH 1755 (5%) were numerically superior to CSH 24SS **Varieties:** SPV 2200 (15.65%) and SPV 2202 (11.96%) were significantly superior, while SPV 2201 (10%) had numeric superiority
10	Total soluble sugars (%)	14.33	13.75	14.98	1.23	1.12	13.91	14.24	**Hybrids:** SPH 1754 (5%) was numerically superior **Varieties:** SPV 2268 (8%) SPV 2205 (6%) and SPV 2269 (6%) were numerically superior
11	Sucrose (%)	11.28	10.2	12.5	2.3	1.51	10.9	11.9	**Hybrids: Nil** **Varieties:** SPV 2269 (14%) was significantly superior, while, SPV 2268 (13%) had numeric superiority
12	Sugar yield (t ha^{-1})	1.26	1.07	1.42	0.35	0.43	1.19	1.20	**Hybrids:** SPH 1754 (16%) and SPH 1755 (10%) were numerically superior. **Varieties:** SPV 2196, SPV 2202, SPV 2205, SPV 2268 and SPV 2272 were numerically superior (13-19%) to the check CSV 24SS
13	Bioethanol yield (L ha^{-1})	669	570	756	186	230	632	639	**Hybrids:** SPH 1754 (16%) and SPH 1755 (10%) were numerically superior **Varieties:** SPV 2205 (19%), SPV 2202 (16%), SPV 2272 (14%), SPV 2270 (13%) and SPV 2196 (13%) were numerically superior

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