High yielding sweet sorghum variety Madhura-2 for both Kharif (Monsoon) and Rabi (Post-Monsoon)

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Introduction

The bicolor race of sorghum is complex, heterogeneous and consists of several distinct subraces. These include sweet sorghums or the sorgos (in American usage) which consist of sweet-stalked cultivars from which syrup or molasses can be extracted or which are used as forage for livestock (Harlan and de Wet, 1972). Sweet sorghum is a multipurpose crop which can be suitably harnessed for producing value-added products like jaggery, syrup and ethanol; besides being used for food, feed and fiber (Rajvanshi et al., 1989, Ghanekar et al., 1992, Nimbkar, 1995). Nimbkar Agricultural Research Institute (NARI) pioneered the development of sweet sorghum after introducing it to India in the mid-1970s. Besides syrup and jaggery production, NARI also was the first in India to produce ethanol from sweet sorghum juice developing the complete technology from crop growing to solar-powered ethanol distillation.

Madhura was the first sweet sorghum hybrid developed through NARI's breeding program in the early 1990s. Now sweet sorghum has emerged as a potential alternative crop to sugarcane for bio-ethanol production in India (Siddique et al., 2011). A pilot scale testing to determine the suitability and feasibility of using sweet sorghum for ethanol production revealed its usefulness for industrial scale exploitation (Anonymous, 2005). The experience of commercial scale use of sweet sorghum for ethanol production as tried jointly by ICRISAT and Rusni distillery at Hyderabad wasalso encouraging (Reddy et al., 2013).

Inspite its suitability for commercial exploitation, the industrial utilization of the crop on regular basis has not commenced yet. It is mainly because of the reasons mentioned below which are important for the economic viability of an industrial unit based on agricultural raw material as a feedstock.

1. Lack of availability of sweet sorghum feedstock round the year. Existing sweet sorghum cultivars released for commercial cultivation are suitable **only for kharif** season and no suitable variety is available for rabi and summer sowings.

2. Lack of high yielding cultivars giving high brix of juice of between 18-20 to make it remunerative to farmers as well as cost-effective for the Industry.

3. Absence of government initiatives for fixing a competitive price for sweet sorghum ethanol to encourage ethanol production from sweet sorghum.

4. Little attention to develop alternate products like syrup and specialized chemicals from sweet sorghum.

5. Absence of standard package of practices for growing sweet sorghum to obtain high biomass and stripped stalk yields under kharif and rabi conditions.

Therefore, for successful establishment of sweet sorghum-based industry in the country it is necessary to overcome the above-mentioned limitations.

With its concerted efforts for over four decades in improvement of sweet sorghum, **NARI has developed a sweet sorghum strain NARI-SS-5** (christened as **Madhura-2**) which not only out yielded the released varietal cultivars but also the hybrid cultivar by a considerable margin in kharif and it has also been found to be highly suitable for production under rabi conditions. This is especially important as none of the released cultivars are recommended for production under rabi conditions. Thus the development of Madhura-2 has made it feasible to successfully produce sweet sorghum in both kharif and rabi seasons, thus making the feedstock available for at least seven to eight months a year if staggered sowing is followed, so that an industrial unit can be successfully operated on it.

Performance of Madhura-2 in Kharif (monsoon)

As seen in Table 1 and Figures 1, 2 and 5 (appended at the end of paper) Madhura-2 gave significantly higher total sugar index, computed ethanol yield, total fresh biomass, fresh stalk yield and juice yield than all the three checks when averaged over locations and years. For juice brix it was on par with all the checks. Grain yield of Madhura-2 was on par with that of the varietal checks, but significantly less than that of the hybrid check. Percent increase or decrease in the values of various parameters over the three checks is given in Table 2.

Table 1. Total sugar index, computed ethanol yield and their components for Madhura-2 in Kharif (monsoon) AICSIP trials (Pooled over locations and years from 2012-2014)

Entry	Total sugar index (q/ha)	Computed ethanol yield (l/ha)	Total fresh biomass (t/ha)	Fresh stalk yield (t/ha)	Juice brix (%)	Juice yield (l/ha)	Grain yield (q/ha)
Madhura-2 (NARI-SS-5)	19.0	1013	52.17	38.57	16.64	15073	16.40
CSV-19-SS (National Check)	15.7	837	41.94	29.54	16.61	11447	15.56
CSV-24-SS (National Check)	14.9	794	43.60	31.19	16.35	10978	17.73
CSH-22-SS (Hybrid Check)	15.9	846	47.62	34.00	16.68	12722	19.62
CD 0.05	6.8	363	8.56	5.80	1.10	2539.4	3.51

q, quintal; t, tons; l, liters; ha, hectares

Table 2. Average standard heterosis for Madhura-2 over the checks for sugar and component traits estimated from pooled AICSIP data of different locations and years (2012-2014)

Characters	Kharif (Monsoon)			Rabi (Post-Monsoon)		
	Percentage increase over national check			Percentage increase over national check		
	CSV-19-SS	CSV-24-SS	CSH-22-SS	CSV-19-SS	CSV-24-SS	CSH-22-SS
Total sugar index (q/ha)	21.02	27.52	19.50	75.81	118	109.62
Computed ethanol yield (l/ha)	21.01	27.56	19.71	78.65	120.83	117.87
Total fresh biomass yield (t/ha)	24.39*	19.66*	9.55	16.86	30.07*	13.64
Fresh stalk yield (t/ha)	30.57	23.66	11.83	36.37	59.62	43.02
Juice brix (%)	0.18	1.77	-0.24	6.37	32.15*	29.19*
Juice yield (l/ha)	31.68	37.30	18.48	50.44	70.86	50.16
Grain yield (q/ha)	5.43	- 7.48	-16.39	38.84	-11.90	-25.32

* Significant at 0.05 level

The replacement of grain sorghum with sweet sorghum in Kharif growing areas in the country may prove a boon to the farmers if the utilization of its juice for blending withsugarcane juice for sugar or ethanol production in the existing industry is carried out. There has been a drastic reduction in kharif sorghum area due to tough competition faced from Btcotton and soybean.

Sweet sorghum is likely to be more profitable than grain sorghum due to the high value of stalks coupled with income from grain rather than income from grain alone with some fodder as in the case of grain sorghum. Moreover, rain-affected grain as well as

fodder of grain sorghum fetches very low price which further reduces profits from the crop. Sweet sorghum is also a low-input and more pest-tolerant crop as compared to Bt cotton and soybean. Therefore with assured production and monetary returns comparable to the competing crops, sweet sorghum is likely to increase the present sorghum area in the Kharif.

Performance of Madhura-2 in Rabi (post-monsoon)

No sweet sorghum variety is recommended for commercial production under rabi conditions in India. ***Madhura-2 is the first high-yielding genotype found to be suitable for growing under rabi conditions.*** Since it gives high sugar in the stalk in addition to grain, its popularization under rabi conditions would greatly enhance monetary returns from the crop to the farmers. The higher income from sweet sorghum than grain sorghum would encourage its production under rabi conditions in traditional and non-traditional areas of sorghum in the country.

As seen in Table 3 and Figures 3, 4 and 5 when averaged over locations and years, Madhura-2 gave significantly higher total sugar index, computed ethanol yield, total fresh biomass, fresh stalk yield and juice yield than all the three checks. The estimated ethanol yield of Madhura-2 at different locations in a 3-year evaluation varied from 263 to 944 l/ha (Data not shown). Thus higher estimated average ethanol yield of Madhura-2 over the checks and high ethanol yield of 944 l/ha under a productive environment confirms the suitability of sweet sorghum variety Madhura-2 for ethanol production even under rabi conditions. For juice brix it was on par with CSV-19-SS and significantly better than the remaining two checks. Madhura-2, CSV-24-SS and CSH-22-SS were on par for grain yield and were significantly superior to CSV-19-SS. As can be seen from Table 2 Madhura-2 was vastly superior to the three checks in rabi compared to kharif and thus should especially be recommended for planting in this season.

Table 3. Total sugar index, computed ethanol yield and their components for Madhura-2 in Rabi (post-monsoon) AICSIP trials (Pooled over locations and years from 2012-2014)

Entry	Total sugar index (q/ha)	Computed ethanol yield (l/ha)	Total fresh biomass (t/ha)	Fresh stalk yield (t/ha)	Juice brix (%)	Juice yield (l/ha)	Grain yield (q/ha)
Madhura-2 (NARI-SS-5)	10.9	658	39.71	28.46	13.85	11453	25.36
CSV-19-SS (National Check)	6.2	368	33.98	20.87	13.02	7613	18.27
CSV-24-SS (National Check)	5.0	298	30.53	17.83	10.48	6703	28.79
CSH-22-SS (Hybrid Check)	5.2	302	34.95	20.00	10.72	7627	33.97
CD 0.05	5.2	274	6.86	6.7	2.27	4421	9.58

Madhura-2 can be used to promote commercialization of sweet sorghum in rabi sorghum areas as a supplementary crop to sugarcane to produce ethanol. This will provide the sugar industry with a cost-effective source of sugar. If this is promoted systematically in rabi sorghum areas not only will it benefit the existing sorghum growers but is likely to cover new areas due to enhanced income from the fresh stalk to be supplied to the sugar industry after harvesting the grain. The grain quality and yield of Madhura-2 were found to be at par with those of the conventional cultivars. Therefore there would be no loss as far as the grain production is concerned.

Large scale planting of the newly developed strain of sweet sorghum Madhura-2 in both kharif and rabi conditions may pave the way for establishment of sweet sorghum-based industry either for manufacturing of sugar derivatives or for bio-energy products like ethanol.

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Figures

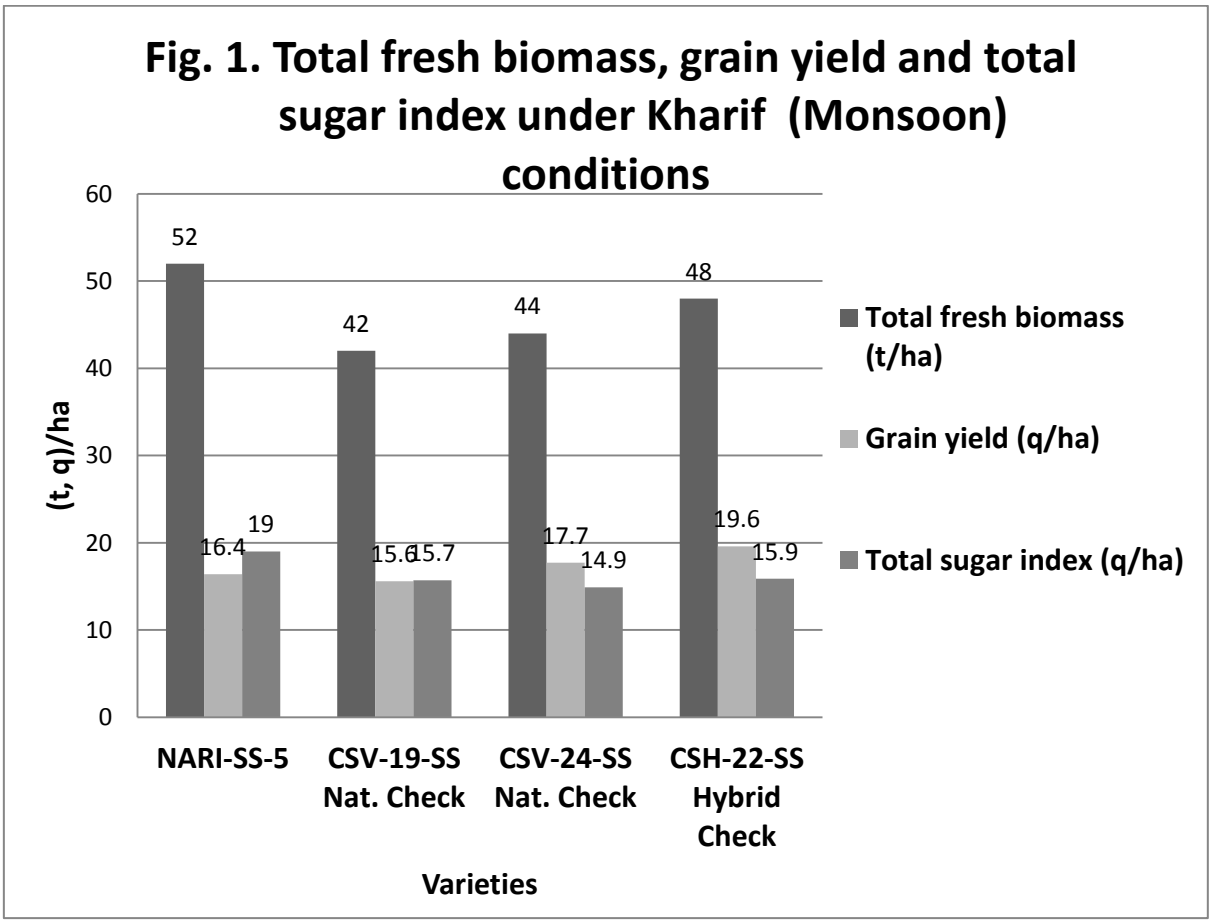


Fig. 2. Fresh stalk yield (t/ha) and brix (%) under Kharif (Monsoon) conditions

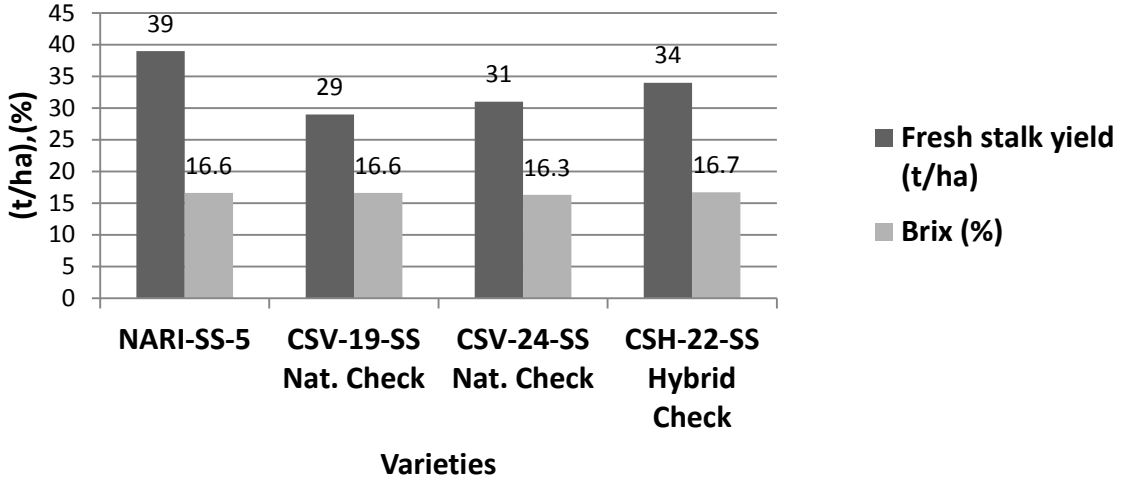


Fig. 3. Total fresh biomass, grain yield and total sugar index under Rabi (Post-Monsoon) conditions

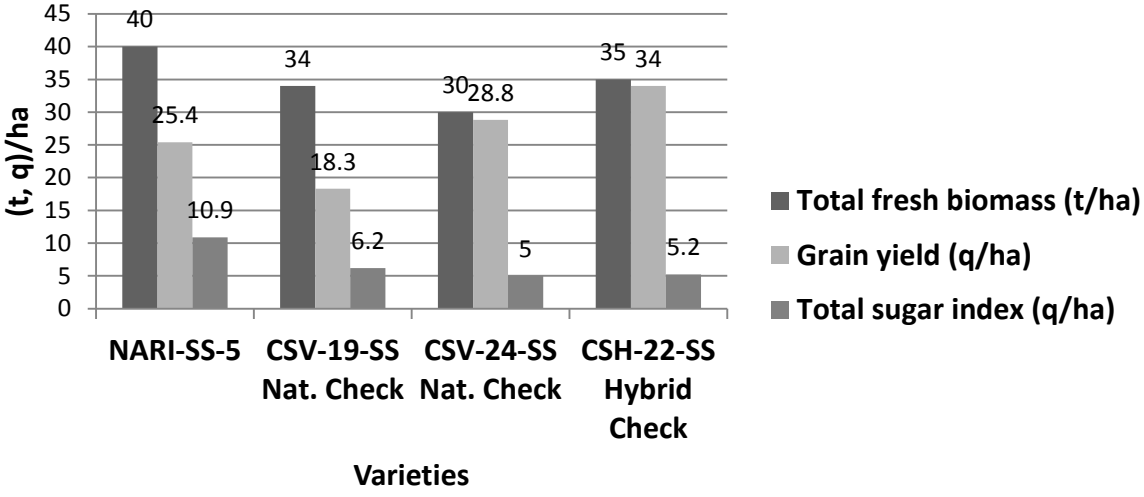


Fig. 4. Fresh stalk yield (t/ha) and brix (%) under Rabi (Post-Monsoon) conditions

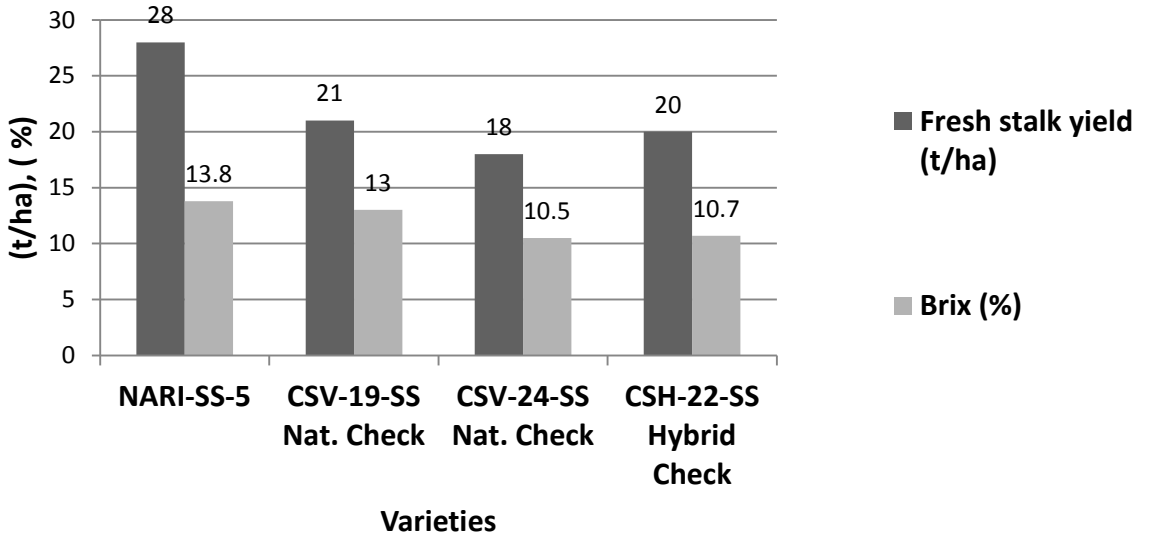
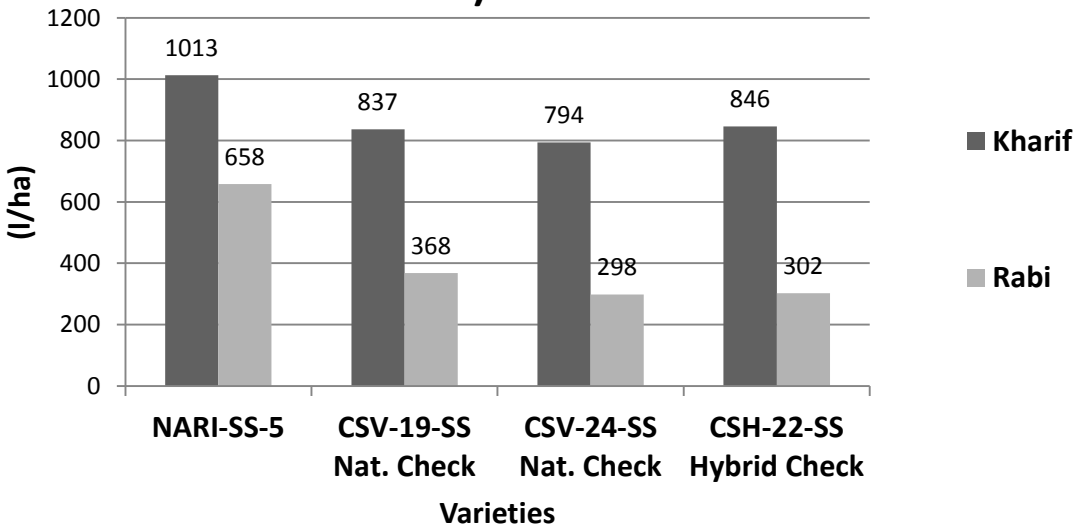


Fig. 5. Computed ethanol yield (l/ha) under Kharif (Monsoon) and Rabi (Post-Monsoon) conditions



Kharif 2015 crop of Madhura-2

Madhura-2 crop

Rabi 2012-13 crop of Madhura-2

Rabi 2014-15 crop of Madhura-2

Panicle of Madhura-2

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