

RESEARCH ARTICLE**INCONSISTENT SUGAR RECOVERY PATTERN IN SUGAR MILLS: NEED FOR VARIETAL MANAGEMENT TO ENHANCE YEAR-ROUND RECOVERY****Bakshi Ram****Abstract**

The study was undertaken to establish the importance of varietal management in achieving higher sugar recovery throughout the crushing season in sugar factories. Information on juice quality parameters (sugar recovery and pol %) were averaged on quarterly or fortnightly basis. Monoculture of the variety Co 86032 in Tamil Nadu State is one of the important factors responsible for lower sugar recovery as the difference in sucrose % in juice at 240 (16.31%) and 360 (19.33%) days is about 3.00%. Sugar recovery follows a bimodal trend with two peaks, i.e. a high peak in February and a low peak during August-September in Tamil Nadu. Sugar recovery was $\geq 9.0\%$ from I fortnight of January to II fortnight of April whereas $\geq 8.0\%$ sugar recovery was recorded during I fortnight of December and I fortnight of May. Peak sugar recovery observed during February-March might be mainly due to the effect of around 12 month crop age and the prevalence of cooler climatic conditions. In the special season, sugar recovery remained between 8% and 9%. High temperature and high humidity prevalent during the period are expected to be the major reasons for lower sugar recovery during the special season. Lower peak during special season indicated that crop age alone is not responsible for higher sugar recovery. Clones like Co 13001, 2013-197, SBI 2007-291, Co 14007, Co 15007 and Co 11015 have been identified as suitable for achieving higher sugar recovery early in the season (8-10 months crop age). Study on the influence of climatic factors like maximum and minimum temperatures, rainfall and relative humidity (RH) showed differential response on sugar recoveries of three varieties viz. CoS 767, CoS 8436 and CoS 88230. Results of the effect of waterlogging conditions on pol % indicated advantage in early harvest of canes from waterlogged area for achieving higher sugar recovery in sugar mills with areas both under waterlogging and uplands. Therefore, in order to improve the overall sugar recovery in sugar mills, there is a need for high quality varieties suitable for crushing not only during the early crushing season but also towards the end of crushing season.

Key words: Sugarcane, varieties, sugar recovery, climatic factors, monoculture, new selections

Introduction

Evolving sugarcane varieties requires consistent and rigorous efforts, generally spanning over 12 – 14 years. While the first 6 – 7 years involve selection of superior clones at research stations, the second half is spent in evaluating the clones in comparison to the existing or ruling varieties at different locations in any particular zone under the All India Coordinated Research Project on Sugarcane

(AICRP(S)). After such elaborate efforts, a sugarcane breeder is in a position to identify a promising improved clone that is fit to be released as a variety for commercial cultivation.

The role of high sugared varieties in improving sugar recovery of mills is well understood. Early maturing, high sugared varieties like CoJ 64 and CoC 671 played a major role in increasing the sugar recovery of sugar mills in some of sub-tropical and tropical

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Indian states, respectively. Since early maturing and high quality varieties impact sugar recovery in any sugar mill significantly, the importance of high quality varieties in improving the sugar recovery is undisputed.

Sugarcane breeders throughout the country are putting in their efforts to evolve varieties with high yield and better juice quality than the existing varieties. Since 2000, the concerted efforts of the breeders throughout the country have led to the development of many promising varieties in different agro-climatic zones. A total of 89 varieties (36 in tropical and 53 in sub-tropical states) have been released by various Sugarcane Research Stations in the country. New varieties are released in different agro-climatic zones through a sound evaluation system in operation under AICRP(S). The mean improvement in 36 new tropical varieties was

10.31%, 1.82% and 13.33% whereas that of 53 new sub-tropical varieties was 12.50%, 1.56% and 12.87% in cane yield, sucrose % and CCS yield, respectively (Fig. 1). Improvement in new varieties was higher in terms of cane yield in sub-tropical region whereas it was greater for sucrose content in tropical region during 2000 - 2013. This is expected due to preferential selection by the breeders for different traits in the two regions. In spite of the improvement in these three important traits, sugarcane varietal replacement has been marginal throughout the country.

In the present paper, an attempt has been made to examine the pattern of sugar recovery recorded in representative sugar mills in sub-tropical and tropical India, the role of climatic factors in sugar accumulation in the two regions and the need for varietal management to enhance year round sugar recovery in sugar mills.

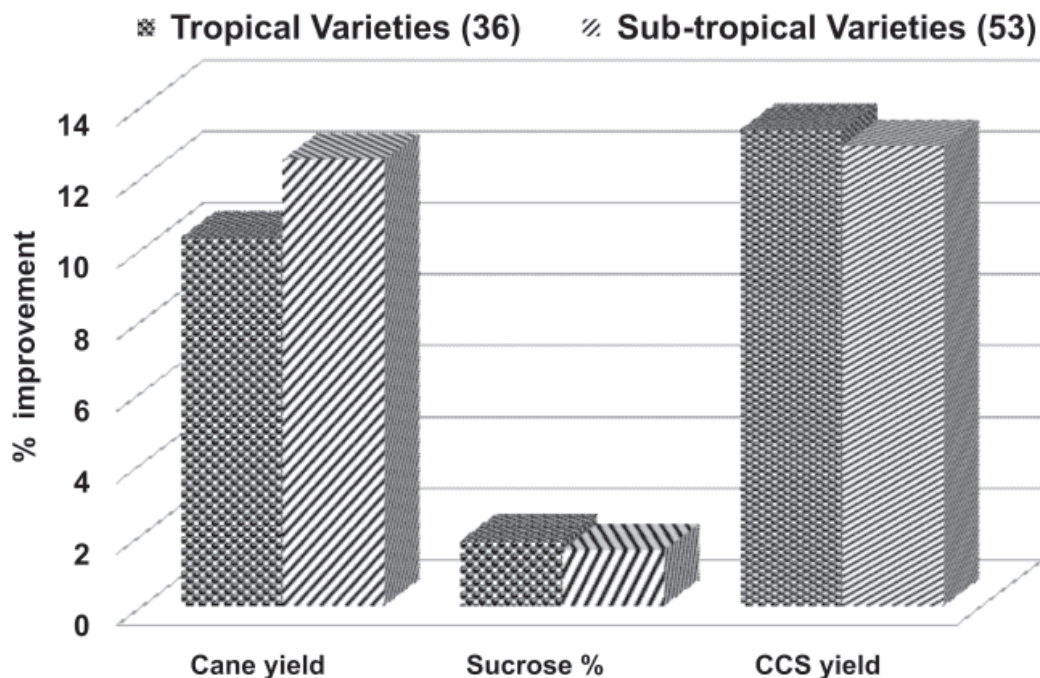


Fig. 1. Per cent improvement in economic traits of newly released varieties over the standards in AICRP(S) trials since 2000

Materials and methods

The early maturing variety CoJ 64 has played a major role in increasing the sugar recovery % of sugar mills in some sub-tropical Indian states. To study the effect of early varieties on recovery pattern in sugar mills, data from the Haryana Co-operative Sugar Mills Ltd., Rohtak, which crushed negligible early maturing varieties during 1990- 91, and Daurala Sugar Works, Daurala (Meerut), which crushed 100% early maturing varieties during 1994-95, have been examined as the representative factories.

Data made available by the Saraswati Sugar Mills (SSM), Yamunanagar (Haryana), were utilized to study the influence of climatic factors on sugar recovery of three varieties. Observations recorded at Simbhaoli Sugar Mills, Simbhaoli, Uttar Pradesh (UP) state, have been used to study the impact of waterlogging on sugar recovery of variety CoS 97264.

In order to study the sugar recovery pattern in the sugar mills of Tamil Nadu state, daily sugar recovery figures for 3 years (2012-13, 2013-14 and 2014-15) were obtained from 14 sugar mills of Tamil Nadu

located at Pennadam, Polur, Kalayanallur, Mundiampakkam, Semmedu, Kethandapatti, Palacode, Vasudevanallur, Madurai, Sivaganga, Appakudal, Varadarajnar, Thirumandankudi and Tuhili. Fortnightly averages of sugar recovery values for each month were worked out and presented in the form of Tables and Figures for analysis.

Results and discussion

Sugar recovery pattern in sub-tropical India

In the case studies examined for the impact of early maturing varieties on sugar recovery (Fig. 2), the Haryana Co-operative Sugar Mills Ltd. started its crushing during I fortnight of November with 7.37% sugar recovery. The area under early maturing varieties in this sugar mill was negligible resulting in less than 9% sugar recovery up to I fortnight of December 1990. On the other hand, sugar recovery of Daurala Sugar Works was 9.08% during I fortnight of October. The higher recovery recorded even during October itself was the result of 100% crushing of early maturing varieties (mainly CoJ 64) during October 1994. These recovery patterns in the two sugar mills indicated the importance of varieties being crushed by the sugar mills.

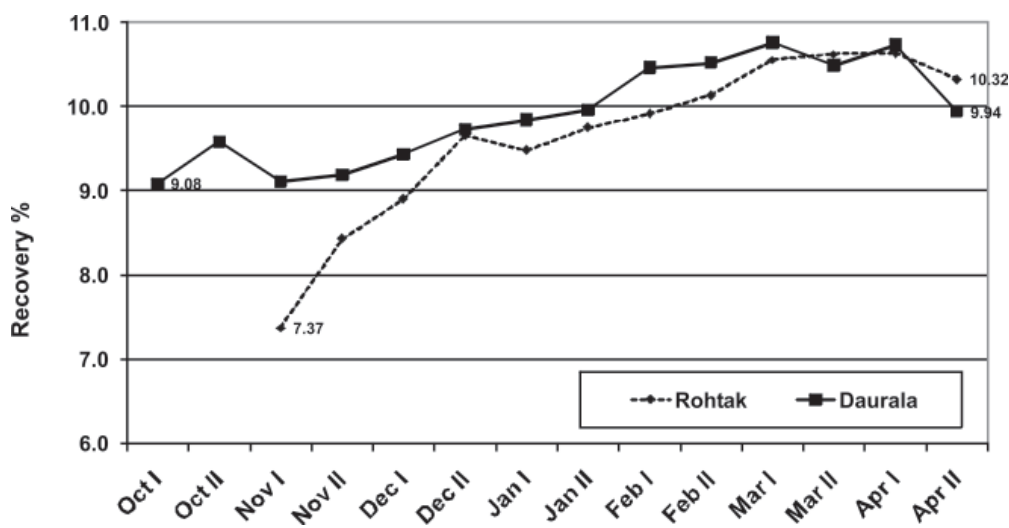


Fig. 2. Impact of extent of cultivation of the early maturing variety CoJ 64 on sugar recovery

Effect of climatic factors on sugar recovery in sub-tropical India

The influence of climatic factors like maximum and minimum temperatures, rainfall and relative humidity (RH) prevailing in SSM, Yamunanagar (Haryana), on sugar recovery of three varieties, viz. CoS 767, CoS 8436 and CoS 88230 was studied during 2001-02 (Table 1). CoS 8436 (10.94 %) was the best variety for sugar recovery followed by CoS 88230 (10.46 %) and CoS 767 (9.90 %). These figures indicate the genetic potential of the three varieties. Sugar recovery of the three varieties increased from II fortnight of November to II fortnight of December 2001. The minimum and maximum temperatures remained above 10°C and 20°C, respectively, from II fortnight of November to I fortnight of December. Almost static recovery was recorded from II fortnight of December to II fortnight of January. During this period, the minimum and the maximum temperatures remained below 10°C and 20°C, respectively. With a steady rise in the maximum temperature (>20°C) from I fortnight of February onwards, a steady improvement in recovery % was observed up to I fortnight of March in all the three varieties. Thereafter, the sugar accumulation pattern differed in the three varieties. CoS 767 showed decline in sugar recovery once the maximum temperature rose above 30°C whereas the other two varieties showed increasing trend in sugar recovery up to a maximum temperature of 35°C. All the three varieties showed deterioration in sugar recovery when the maximum temperature exceeded 35°C. This indicated that CoS 8436 could withstand high maximum temperature of up to 35°C and minimum temperature of up to 25°C whereas the other two varieties could tolerate maximum and minimum temperatures of up to 30°C and 20°C, respectively. Maximum temperature and rainfall during crushing period showed positive effect on sugar recovery,

the greater effect being that of maximum temperature. Increase in maximum temperature showed the highest effect on sugar recovery of CoS 8436 followed by CoS 88230 and CoS 767. Minimum temperature and RH showed negative effect on sugar recovery, the higher effect being that of minimum temperature. Minimum temperature adversely affected the sugar recovery the most in CoS 8436 followed by CoS 88230 and CoS 767. These results indicated that CoS 8436 is the most responsive to variations in maximum and minimum temperatures followed by CoS 88230 and CoS 767. The effect of rainfall during crushing period was positive and low. However, its effect was the maximum on CoS 767 followed by CoS 8436 and CoS 88230. Similarly, the negative effect of RH was the most on sugar recovery of CoS 767 followed by CoS 8436 and CoS 88230. These four meteorological traits explained 69, 57 and 53 % of the total variability in sugar recovery of CoS 8436, CoS 88230 and CoS 767, respectively. Hence, the delayed harvest of CoS 8436 during April-May would result in high sugar recovery. Harvest of CoS 8436 could be delayed towards the end of the crushing season by encouraging its planting after wheat harvest (summer planting). These results indicated the importance of varieties for attaining higher sugar recovery towards the end of the season also in sub-tropical India.

Effect of waterlogging on pol % in cane in sub-tropical India

Pol % in cane was studied in the cane samples taken from the ratoon crop of variety CoS 97264 grown under waterlogged and upland conditions in Simbhaoli Sugar Mills (UP) area. Observations of pol % were recorded daily from October 27, 2004 to December 15, 2004 and averages were worked out on quarterly basis in each month (Fig. 3). The large difference of 1.68% in pol % recorded under

Table 1. Mean sugar recovery % of three varieties and weather parameters in SSM, Yamunanagar, during 2001-02

Fortnight/ month	Weather parameter				Sugar recovery (%)		
	Rain - fall (mm)	RH (%)	Max. Temp. (°C)	Min. Temp. (°C)	CoS 767	CoS 8436	CoS 88230
II Nov	0.0	91	24.5	15.3	8.57	9.39	9.14
I Dec	0.0	90	21.6	10.8	9.30	9.85	9.54
II Dec	30.0	89	19.0	8.5	9.45	10.52	10.07
I Jan	2.8	88	17.0	7.2	9.46	10.45	10.29
II Jan	12.0	89	18.8	7.4	9.76	10.59	10.28
I Feb	76.4	89	20.1	8.5	10.16	11.04	10.40
II Feb	33.4	90	24.8	10.4	10.06	11.17	10.51
I Mar	35.6	91	26.3	10.8	10.24	11.71	10.82
II Mar	6.0	91	31.5	19.2	9.98	11.79	11.08
I Apr	0.0	92	33.7	22.2	11.02	11.73	11.33
II Apr	0.0	33	36.0	25.4	10.86	11.86	11.27
I May	2.0	39	39.0	29.0	9.96	11.20	10.79

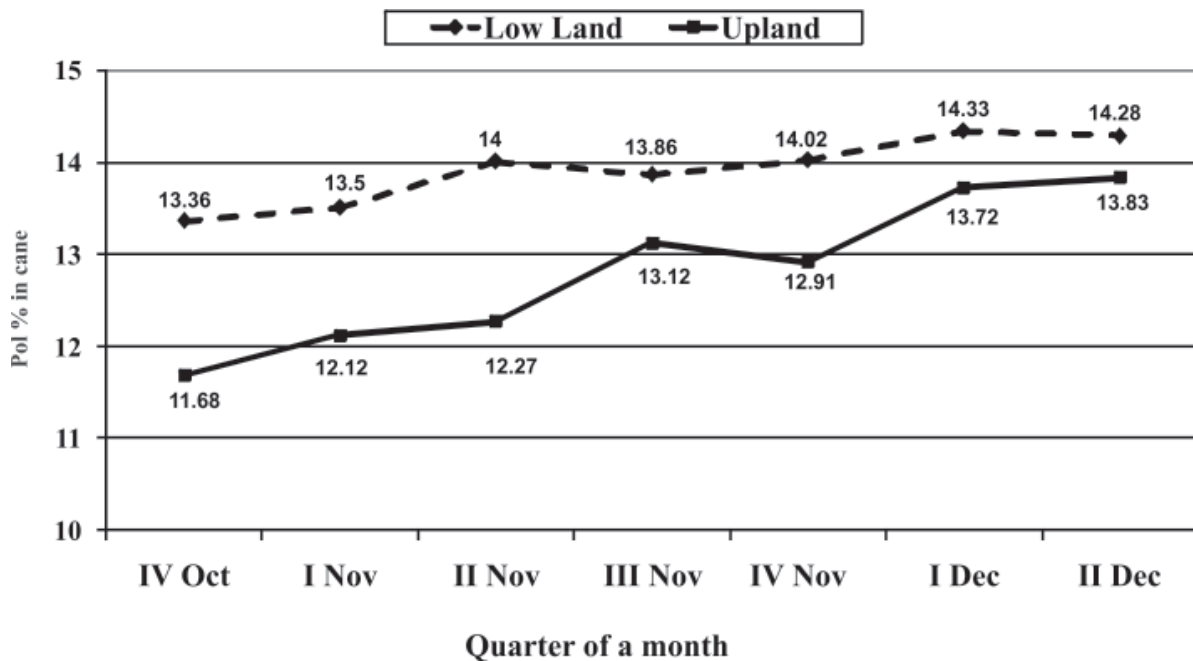


Fig. 3. Pol % in cane in CoS 97264 under upland and waterlogging conditions in Simbhaoli Sugar Mills (UP)

waterlogging and upland conditions during IV quarter of October 2004 narrowed down to 0.45% during II quarter of December 2004. Purity % of juice was also higher under waterlogging conditions. The study indicated the advantage of early harvesting of canes from waterlogged area in comparison to upland area for attaining better sugar recovery in sugar mills.

Sugar recovery pattern in Tamil Nadu state

Fortnightly average sugar recovery of 14 sugar mills in Tamil Nadu over three years (2012-13, 2013-14 and 2014-15) has been depicted in Table 2 and the three year averages of fortnightly sugar recoveries have been depicted in Fig. 4. Most of these sugar mills (with a few exceptions) start crushing in December and end by May. Sugar recovery follows a bimodal trend with two peaks, i.e. a high peak in February and a low peak during August-September. Sugar recovery was $\geq 9.0\%$ between I fortnight of January and II fortnight of April whereas it was generally $\geq 8.0\%$ between I fortnight of December

and I fortnight of May. Peak sugar recovery observed during February-March might be mainly due to the effect of crop age, as mostly 12 or more months old cane is being crushed during these months. Another factor responsible for higher sugar recovery might be the cooler climatic conditions prevailing during mild winter months in the state. Sharp decline in sugar recovery was observed after I fortnight of April which continued till June end. This decline in sugar recovery is expected due to crushing of overage / immature canes, prevalence of high temperature and other crop conditions like lodging of canes, availability of moisture, etc. In the special season, sugar recovery remained between 8 and 9%. As this period is not favourable for sugar accumulation, the peak recovery remained below 9% with a few exceptions. High temperature and high humidity prevalent during the period are expected to be the major reasons for lower sugar recovery during the special season. The fall in sugar recovery during II fortnight of September might be related to rainy season and crushing of immature canes.

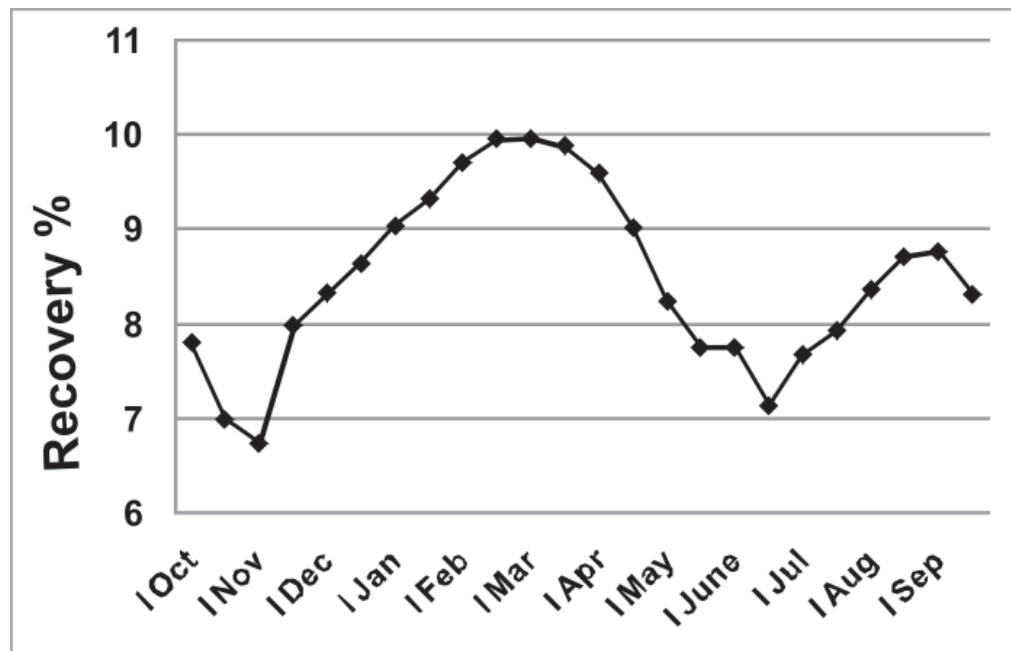


Fig. 4. Mean sugar recovery % in Tamil Nadu state (2012-13, 2013-14 and 2014-15)

Table 2. Fortnightly mean sugar recovery % of 14 sugar mills in Tamil Nadu during three years

Zone	Sugar Mill	2012-13	2013-14	2014-15
North Eastern zone	Shree Ambika Sugars Ltd, Pennadam	7.69 - 9.88 [#]	8.24 - 10.25	8.12 - 9.97
	Dharani Sugars and Chemicals Ltd., Polur	7.71 - 10.66	8.30 - 10.09	8.15 - 10.02
	Dharani Sugars and Chemicals Ltd., Kalayanallur	5.96 - 10.00	7.31 - 10.46	7.00 - 9.95
	Rajshree Sugars and Chemicals Ltd., Mundiampakkam	6.83 - 9.85	8.19 - 10.45	7.56 - 9.64
	Rajshree Sugars and Chemicals Ltd., Semmedu	7.28 - 10.12	7.94 - 10.27	7.63 - 9.66
	Tirupattur Co-operative Sugar Mills Ltd., Kethandapatti	9.09 - 11.32	9.15 - 11.41	9.17 - 10.51
North Western zone	Dharmapuri District Cooperative Sugar Mills Ltd., Palacode	9.48 - 11.52	9.04 - 9.94	8.75 - 10.36
Southern zone	Dharani Sugars and Chemicals Ltd., Vasudevanallur	7.18 - 9.83	6.05 - 9.67	7.00 - 9.21
	The National Co-op. Sugar Mills Ltd., Madurai	8.14 - 10.67	8.12 - 10.33	7.49 - 9.49
	Sakthi Sugars Ltd., Sivaganga	7.68 - 10.74	8.19 - 10.26	6.43 - 9.31
Western zone	Sakthi Sugars Ltd., Appakudal	4.98 - 10.27	6.58 - 10.38	6.21 - 10.00
	Rajshree Sugars and Chemicals Ltd., Varadarajnagar	8.07 - 10.69	8.85 - 10.93	7.95 - 10.47
Cauvery Delta zone	Thiru Arooran Sugars Ltd., Thirumandankudi	7.39 - 9.34	7.17 - 10.09	6.26 - 9.81
	Shree Ambika Sugars Ltd., Tuhili	7.89 - 9.02	7.41 - 10.09	7.79 - 10.06
	Overall range	4.98 - 11.52	6.05 - 11.41	6.21 - 10.51

[#] Figures indicate range

The overall ranges of fortnightly averages (Table 2) varied from 4.98 % (Appakudal) to 11.52 % (Palacode) during 2012-13; from 6.05 % (Vasudevanallur) to 11.41% (Kethandapatti) during 2013-14; and from 6.21% (Appakudal) to 10.51% (Kethandapatti) during 2014-15. Wide variation in

the differences between the minimum and maximum sugar recoveries, i.e. to the tune of 6.54, 5.36 and 4.3%, existed during 2012-13, 2013-14 and 2014-15, respectively, among these sugar mills. Efforts have to be made to narrow these wide differences through breeding and varietal scheduling.

Similarly, the difference between the minimum and maximum sugar recovery during the three years varied from 1.52% of Dharamapuri District Co-op. Sugar Mills, Palacode to 4.29% of Sakthi Sugars Ltd., Appakudal, with an average of 2.45% in all the 14 sugar mills (Table 2). Zone-wise mean differences between minimum and maximum sugar recoveries varied from 1.52% in North Western zone to 3.35% in Western zone. This variation in differences between minimum and maximum sugar recoveries might be due to a large number of factors, like maturity of sugarcane varieties, time of crushing, climatic conditions, varietal composition, etc. Crushing of a single variety can be the most important factor in this wide variation in a particular sugar mill. A suitable blend of sugarcane varieties with different maturity period is the easiest way to reduce the gap between the minimum and maximum sugar recovery of a sugar mill and improve the overall sugar recovery of the sugar mill.

Lower peak during special season indicated that crop age alone is not responsible for higher sugar recovery as about 12 or more month crop age cane is crushed during special season. Under these

circumstances, the role of suitable varieties becomes very important. The present varieties under cultivation in the state of Tamil Nadu are not suitable for special season crushing. There is a need to identify suitable varieties with higher sugar recovery during II fortnight of April to September. Short duration varieties developed by the ICAR-Sugarcane Breeding Institute would help in improving the sugar recovery during special season. A set of short duration varieties were evaluated at M/s Sakthi Sugars Ltd., Sivagangai, and the results obtained are presented in Table 3. Three clones, namely Co 14002, Co 14004 and Co 11015 showed 1.61-2.86% higher recovery over Co 86032 at the crop age of 9 months during June. Of these, Co 11015 recorded 11.66, 10.54, 11.21 and 11.34% at 9 months (June 18), 10.5 months (August 1), 11.5 months (August 29) and 13 months (October 15) crop age, respectively.

A sort of monoculture of variety Co 86032 exists in Tamil Nadu as it occupies about 65% of sugarcane area with many factories accounting for more than 80% of their area under this variety. This effectively means that most of the sugar mills start and end

Table 3. Juice quality results of short duration varieties at Sakthi Sugars Ltd., Sivagangai, Tamil Nadu

Clone	Crop age and date of sampling							
	9 months		10.5 months		11.5 months		13 months	
	18.06.15 & 19.06.15	01.08.15 & 06.08.15	01.08.15 & 06.08.15	29.08.15	29.08.15	15.10.15	15.10.15	
	Pol (%)	Estimated recovery (%)	Pol (%)	Estimated recovery (%)	Pol (%)	Estimated recovery (%)	Pol (%)	Estimated recovery (%)
Co14002	16.12	10.93	13.10	8.73	15.57	10.54	8.19	4.56
Co14004	17.63	12.18	13.03	8.57	16.05	10.94	14.24	9.41
Co 11015	17.36	11.66	15.71	10.54	16.68	11.21	16.91	11.34
Co 86032	13.97	9.32	14.89	9.97	14.45	9.48	15.74	10.42

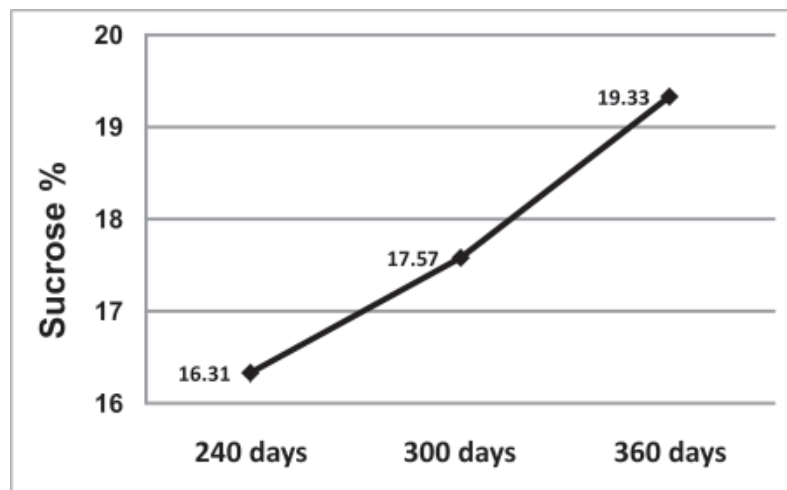


Fig. 5. Sucrose % in juice in Co 86032 at ICAR-SBI

crushing with Co 86032. The mean sucrose % of Co 86032 recorded at ICAR-SBI, Coimbatore, over the years (Fig. 5) indicates that the difference in sucrose % in juice between 240 (16.31%) and 360 (19.33%) days is about 3.00%. The sucrose accumulation in Co 86032 is slow during 240 to 300 days (1.26%) in comparison to sucrose accumulation during 300 to 360 days (1.76%), a typical characteristic of midlate maturing varieties. Therefore, in order to improve the overall sugar recovery in sugar mills, there is a need for high quality varieties suitable for crushing during the early crushing season i.e. 240 to 330 days.

The way out

The possibility of increasing sucrose content in cane mainly depends on the genetic variability among seedlings/clonal populations. Inter-crossing and selection for specific environments has produced varieties adapted to specific locations with high sugar content and yield. As a result, because of narrow genetic base, the variance among commercial cultivars is diminishing to experimental error level in commonly adopted inter-varietal crosses. Genetic divergence among sugarcane varieties on the basis

of juice quality traits showed that a bulk of parental population used in the hybridization programmes of various research centres included in a single cluster resulting in a plateau in the juice quality (Bakshi Ram, 1992). The per cent improvement in sucrose % is relatively small. There is a need to improve sugar recovery of sugar factories through varietal management.

Clonal evaluation on a large scale has been attempted at the ICAR-Sugarcane Breeding Institute. Information on agronomic characteristics of the clones belonging to different species of *Saccharum*, including sucrose % of flowering clones of three species (Table 4), could be used as a guide for parental selection of sugarcane. Efforts are on to tap the existing variability in sucrose % for developing sugarcane varieties with different maturity duration.

There is wide divergence in the strength and association of the genetic parameters affecting yield and quality and their consequent utility in enhancing selection gains. In an unselected population, yield and sucrose appear to be independently inherited and based on the assumption of linearity, joint

Table 4. Sucrose % in flowering clones of three species of *Saccharum*

Species	No. of clones	Mean	Range
<i>S. officinarum</i>	53	15.37	7.57 (M. gayam) – 20.02 (Gungera)
<i>S. barberi/sinense</i>	13	14.08	10.36 (Lal Khadi) – 18.61 (Manjuria)
<i>S. robustum</i>	51	8.23	4.23 (IM76-232) – 11.95 (NG77-57)

selection for these two economic attributes has been advocated. Correlation coefficients between juice quality and stalk yield traits varied amongst the various inter-specific hybrid mating groups (Bakshi Ram and Hemaprabha 1991, 1992). These workers reported positive association between stalk yield and juice quality in *S. robustum* and *S. spontaneum* mating groups (crossed with *S. officinarum*) where mean stalk yield and juice quality traits values were lower in comparison to the mean of checks. Progenies of *S. officinarum* crossed with

commercial hybrids and *S. barberi/sinense* showed near commercial values for sucrose % and stalk yield. However, association between sucrose % and stalk yield was negative in these progenies.

Efforts are on to improve the sucrose content in sugarcane clones through breeding at ICAR-Sugarcane Breeding Institute. Inter-crossing and selection for specific environments has produced varieties adapted to specific locations with high sugar content and yield. A list of elite clones, along with

Table 5. Sucrose % in juice of new sugarcane clones evolved at ICAR-SBI, Coimbatore

Clones	Sucrose % in juice				Suitable crop age for harvest
	240 days	300 days	360 days		
Co 13001	18.07	20.39	20.83	}	240 to 300 days
2013-197	18.70	20.34	20.68		
SBI 2007-291	18.20	21.14	20.41	-	240 to 360 days
Co 14007	18.38	22.55	22.78	}	240 to >360 days
Co 15007	18.54	22.39	22.68		
Co 11015	18.44	21.20	21.46		
Co 13003	17.00	21.41	21.54	-	300 - 360days
Co 15005	17.60	21.06	20.78	}	360 days and above
Co 14030	16.40	18.97	22.06		
Co 15008	16.28	18.44	22.11		
Co 15017	16.58	20.37	22.54		
Standard					
Co 86032*	16.31	17.57	19.33	-	After 300 days

*Average values over the years

their sucrose content at 240, 300 and 360 days and suggested crop age of harvesting, is given in Table 5. As these clones are new ones, their performances need to be confirmed by evaluating these clones over the locations and years. Identification and exploitation of superior sugarcane clones at different maturity stage would certainly help in improving the sugar recovery of sugar factories throughout the season in Tamil Nadu state.

Conclusion

Sugarcane breeders all over the country are working towards improving the sugarcane juice quality up to 12 months, i.e. the ascending pattern of the sugar recovery, e.g. Fig. 3 for Tamil Nadu state. There is a sharp decline in sugar recovery in Tamil Nadu after I fortnight of April. Efforts are required to study the reasons for the noted sharp decline in sugar recovery. This decline may be due to many factors like age of crop, crop condition (lodging, soil moisture etc.), prevailing temperature, varieties, etc. There is a need to put concerted efforts to improve the sugar recovery from I fortnight of April onwards

after thoroughly studying the reasons for the sharp decline. Varieties with higher sugar recovery, including those suitable for crushing during special season (July - September), need to be identified for achieving higher year-round recovery in sugar factories.

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References

- Bakshi Ram (1992) Genetic divergence of stalk yield and juice quality and their components in sugarcane. Intern J Trop Agric X:311-316.
- Bakshi Ram, Hemaprabha G (1991) Character inter relationships in cultivar x species progenies in sugarcane. Indian J Genet 51:89-95.
- Bakshi Ram, Hemaprabha G (1992) Genetic variability in interspecific progenies in sugarcane (*Saccharum* spp.). Indian J Genet 52:192-198.