THE SUGAR TECHNOLOGISTS' ASSOCIATION OF INDIA

e-PROCEEDINGS

78th Virtual Annual Convention

20th - 21st October 2020

New Delhi

THE SUGAR TECHNOLOGISTS' ASSOCIATION OF INDIA

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THE SUGAR TECHNOLOGISTS' ASSOCIATION OF INDIA
(Registered under Indian Societies Act XXI of 1860)

The Sugar Technologists' Association of India (STAI) is the national level apex association of professionals associated with the sugar industry and allied fields. It is a non-government not for profit organization, founded in the year 1925 and is headquartered at New Delhi. Presently it has nearly 3000 members working with various sugar mills, refineries, distilleries, research institutes, technology providers and other professionals from sugarcane agriculture, sugarcane biology, sugar technology, factory engineering and co-products. The association, headed by the President, is managed by an elected council comprising of 30 professionals representing different regions of India. The council, elected every three years by STAI members, is assisted by the Standing Committees on Research and Investigation, Advisory Committee on Publications and the Indian National Committee of ICUMSA.

KEY OBJECTIVES OF THE ASSOCIATION

- To provide opportunities for the acquisition and dissemination of information, exchange of knowledge amongst the members and to provide facilities for presentation of papers and delivery of lectures on subjects connected with and useful to the profession.
- To promote schemes of research relating to the sugar industry and allied fields.
- To establish and maintain a library and to publish and circulate papers, books, journals, magazines, newsletters and other scientific literature connected with the profession.

INTERNATIONAL AFFILIATIONS

- STAI is the sole representative from India on the council of the International Society of Sugar Cane Technologists (ISSCT), a global association of scientists, technologists, managers, institutions and companies/corporations concerned with the technical advancement of the cane sugar industry and its co-products. The ISSCT has been in existence for over 95 years during which it has organized 30 Congresses, usually at 3-year intervals.
- Following STAI office bearers/senior members are presently serving on various committees of ISSCT
  - Mr Sanjay Awasthi, President-STAI, as an elected member of the ISSCT Executive Committee for the term 2016-2022.
  - Prof. Narendra Mohan, Director, NSI, Kanpur & Vice President, STAI (Ex-Officio) as a member of the Factory Processing Committee for the term 2019-2022.
  - Dr. M.S. Sundaram, MD, JPMA, Pune and Senior Member STAI as a member of the Factory Engineering Committee for the term 2019-2022.
  - Mr. R.L. Tamak Executive Director & CEO – Sugar Business, DCM Shriram Limited and Senior Member, STAI as a member of Co-products Commission for the term 2019-2022.

- STAI is the sole representative from India on the Committee of International Commission for Uniform Methods of Sugar Analysis (ICUMSA). Dr (Mrs.) V.S. Keskar is the Convenor of the Indian National Committee on ICUMSA and is also the referee for the Subject GS9 – Plantation White Sugar.
- STAI is also a member of International Association of Professionals in Sugar and Integrated Technologies (IAPSIT)

INTERNATIONAL EVENTS

STAI has successfully hosted the IX ISSCT Congress in 1956 at New Delhi, the XXIII ISSCT Congress in 1999 at New Delhi, ISSCT combined Factory Engineering & Processing workshop in 1994 at Pune and ISSCT Factory Processing Workshop in 2003 at Goa.

The **XXXI ISSCT Congress** has been awarded to STAI to be held in Hyderabad from **5-8 December 2022.** STAI also successfully hosted the 23rd session of ICUMSA in 2002 at Pune and the 4th Session of IAPSIT in 2011 at New Delhi.

NATIONAL EVENTS

STAI has so far successfully organized 77 Annual Conventions and 11 Joint Conventions in collaboration with affiliated associations. The association organizes 4-5 one day seminars every year in association with affiliated associations, research institutions and various other stakeholders. The Annual Convention held by rotation in different cities, is spread over three days that includes memorial lectures, plenary sessions and technical sessions on different disciplines for presentation of research papers. International Sugar Expo is also held concurrently with the convention on various products and services.

TECHNICAL SERVICES

Research & Investigation Activities - STAI has a pool of experts and a cumulative store house of knowledge. It is instrumental in developing & promoting vital process technologies & state of the art equipment for sugar and allied industry applications. Mr. D.K. Goel is the Convenor of the STAI's Standing Committee on Research and Investigation that takes up R&I projects in following areas, with active involvement of various stakeholders:

- Sustainable Sugarcane Agriculture
- Factory Engineering and Energy Efficiency
- Sugarcane Processing Technologies and Sugar Quality
- Zero Liquid Discharge in Distilleries
- Recycling of Sugarcane/Sugar Factory Wastes
- Co-Products : Cogeneration, Ethanol, Downstream Chemicals

AWARDS

STAI recognises the contribution of industry professionals by presenting various awards in different fields of science and technology. The aim of these awards is to recognize the contribution of its members to the sustainable growth of the industry and to inculcate the habit of contributing research papers which must be of direct value to the Industry.

The following awards are presented during the annual convention :

a. Awards for Contribution to the Sustainable Growth of Sugar & Allied Industry

- **Life Time Achievement Award** – This is presented to industry veterans for their outstanding life-time contribution to the development and growth of the Sugar & Allied Industry.
- **Industry Excellence Award** – This is presented to sugar factories/entrepreneurs for their significant contribution to the technological advancement of Sugar & Allied Industry.

- **Isgec Gold Model** for "Engineering for Excellence" – Process Technology & Process Engineering.
- **J.P. Mukherji Gold Medal** for the "Best Engineer of the Year".
- **Dr. P.J. Manohar Rao Gold Medal** for "Excellence in Co-Products".

b. Awards for Research Papers Presented during the Annual Convention

The research papers may contain results of original research work done by the authors or the results of adaptation of known processes/equipments/material of construction to the Indian conditions.

- **Dr. Bansi Dhar Gold Medal** for the best research paper related to "Innovation in the area of Energy Efficiency & Conservation in Sugar Industry".
- **Noel Deerr Gold Medal** for the best research paper in the areas of – Sugarcane Agriculture, Factory Engineering, Factory Processing and Co-products.
- **STAI Silver Medals** for second best research paper in the areas of – Sugarcane Agriculture, Factory Engineering, Factory Processing and Co-products.

RECOGNITIONS

- STAI is recognized by the Department of Science and Technology, Govt. of India as a Scientific and Industrial Research Organization.
- President-STAI, is as an expert member on the Advisory Board of the National Sugar Institute, Kanpur and also on NSI's Standing Advisory Committee on Sugar Standards.
- President-STAI, is as an expert member on the Sugar Industry Sectional Committee (FAD2) of the Bureau of Indian Standards.
- President-STAI, is a special invitee on the Sub-Committee under the Sugar Development Fund, Dept. of Food and Public Distribution, Govt. of India.

ANNUAL PUBLICATIONS

- Directory of Cane Sugar Factories and Refineries (India and other SAARC countries) and Distilleries (India, Nepal and Bhutan)
- Annual Convention Proceedings and Souvenir
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CO 12009 (SANKALP) – NEW MIDLATE VARIETY FOR PENINSULAR ZONE

S. Alarmelu*, G. Hemaprabha & Bakshi Ram

ABSTRACT

Co 12009 is a high yielding and midlate maturing variety identified through hybridization of [{(Co 7201 x (Co 62174 x SES 91)} x Co 88037)}] x Co 62198 of which SES 91 clone is a genetic base involving S. spontaneum. This is a third back cross of F_1 hybrid involving Co 62174 and SES 91 and back crossed with three commercial hybrids viz., Co 7201, Co 88037 and Co 62198 at three stages of nobilisation .This clone showed improved vigour and high sucrose in the different clonal stages. The entry performed well in AICRP trials conducted across the States of Peninsular zone for cane yield, sugar yield, sucrose % and pol % cane with an overall mean of 119.65 t/ha of cane yield, 17.31 t/ha of commercial Cane Sugar, 19.91 % of juice sucrose and 15.47 % of Pol in cane at 360 days of harvest in comparison with three zonal checks viz., Co 86032 (Midlate), CoC 671 (Early) and CoSnk 05103 (Early). The variety registered an overall improvement of 10.40 %, 18.08 % and 15.32 % over the best midlate standard Co 86032 and early standards viz., CoC 671 and CoSnk 05103 respectively for sugar yield. This high yielding variety recorded an improvement of 9.03 %, 7.92 %, and 23.42 % in comparison with the standards Co 86032 (109.73 t/ha), CoSnk 05103 (110.85 t/ha), and CoC 671 (96.93 t/ha) respectively. Co 12009 recorded 19.91 sucrose % which was 1.80 and 6.99 percent increase over the midlate standard Co 86032 and early standard CoSnk 05103 respectively.Co 12009 showed 1.97 per cent improvement in Pol % in cane over the other qualifying variety CoM 12085 (15.17 %). It is an excellent ratooner with an improvement of 13.70 % and 10.43 % for sugar and cane yield respectively over the midlate standard Co 86032. The variety combines resistance to red rot and wide adaptability in varied environments.

Key Words: Co 12009, Midlate variety, Cane yield, sugar yield

INTRODUCTION

Sugarcane varieties play an important role in sugarcane production and its sustainability. Cane yield is an important character and new improved varieties will have to be developed combining different industrial attributes. Hence the work of developing new varieties is a continuous process and newer varieties are introduced for cultivation in different seasons and locations. Varietal differences exist among early and midlate maturing varieties. Hence selection of high yielding varieties with high sucrose content suited for different maturity phases is an essential objective for sugarcane breeder. Decline in cane yield and vigor in sugarcane varieties is expected to occur after a considerable period of cultivation (Humbert, 1959). The varietal improvement programme at the ICAR-Sugarcane Breeding Institute,

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Coimbatore, is focused in developing superior varieties with the potential to increase sugar yields and combining high cane yield, sucrose content and resistance to pests and diseases. Sugarcane varietal development programmes are time consuming, hence it is important to periodically assess the clones to select competitive genotypes for yield components and provide genetic gains (Dumont *et al* 2019). Efforts are continuously being made to identify alternate sugarcane varieties that combines diverse background, high yield, and varied adaptability with wide performance to the changing climatic / ecological conditions through multilocation testing (AICRP) to improve the productivity in tropical India. The midlate maturing sugarcane variety Co 12009, is a variety with a new genetic base of SES 91 *(S. spontaneum)* identified through multilocation testing in tropical zone of India that combines high yield and quality in comparison with Co 86032 at twelve months of age indicating its potential as a high yielding variety with wide adaptability under varied environments and red rot resistance. The paper deals with the performance and potential of the midlate variety Co 12009 in Peninsular Zone.

MATERIALS AND METHODS

Co 12009 was evolved through hybridization of [{(Co 7201 x (Co 62174 x SES 91)} x Co 88037)}] x Co 62198 of which SES 91 clone is a new genetic base involving *S. spontaneum.* It is the nobilized third back cross product of F_1 hybrid involving Co 62174 and SES 91 and back crossed with three commercial hybrids *viz.,* Co 7201, Co 88037 and Co 62198 at three stages of nobilisation. It is a midlate maturing clone, identified as Co cane during the year 2012 from ICAR-Sugarcane Breeding Institute, Coimbatore. The clone was evaluated during early generation of selection at SBI, RC, Agali and in subsequent clonal stages at ICAR- SBI, Coimbatore for yield and quality parameters during the period of 2004-2012. The clone was tested in IVT (2015-16) under All India Coordinated Research Project on Sugarcane [AICRP(S)] in 14 centres of Peninsular and due to its superior performance for cane yield and juice quality, it was promoted to Advanced varietal (multilocation) testing (2017-2019) in major tropical belt of sugarcane (Coimbatore, Akola, Basmathnagar, Kolhapur, Mandya, Navsari, Padegaon, Perumalapalle, Powerkheda, Pravaranagar, Pugalur, Pune, Sameerwadi, Sankeshwar and Thiruvalla centres) .The trials were laid out in randomized block design (RBD) replicated thrice with a plot size of eight rows of 6m length spaced 90 cm apart. Standard sugarcane cultivation practices were followed (Sundara,1998). Plant protection measures were carried out to raise a healthy crop. Observations were recorded at harvest (360 days) on number of millable canes ('000/ha), cane thickness (cm), cane height (cm), single cane weight (kg),CCS (t/ha) and cane yield (t/ha). Quality parameters (Brix %, Sucrose% and CCS %) were recorded at 300 and 360 days. Red rot reaction of this clone was evaluated under natural and artificial conditions with predominant red rot causing pathotype in Peninsular region. Statistical analysis was carried out using standard procedure (Singh and Chaudhary, 1985).

RESULTS AND DISCUSSION

The clone Co 12009 was evaluated under AICRP(S) during 2015-2016 (IVT) and 2017-2019 (in AVT trials) in the States of Andhra Pradesh, Chhattisgarh, Gujarat, Karnataka, Kerala, Maharashtra, Madhya Pradesh, Tamil Nadu and Telengana of Peninsular Zone and based on its superiority was promoted for Advanced Varietal testing.

Overall Mean Performance of Co 12009 in Advanced Varietal Trials across the Zone

AVT (two plant and one ratoon crops) were conducted in 14 centres during 2017-2019. The entry recorded superior performance in comparison with three checks *viz.,* Co 86032 (Midlate), CoC 671 (Early) and CoSnk 05103 (Early) for cane yield and sugar yield. (Table 1). Co 12009 recorded 119.65 t/ha of cane yield, 17.31 t/ha of commercial Cane Sugar, 19.91 % of juice sucrose and 15.47 % of Pol in cane at 360 days of harvest and topped in 18 and 21 trials

compared to all the standards for cane yield (t/ha) and sugar yield (t/ha) and respectively. Out of 33 locations tested, Co 12009 topped in 10 centres for juice sucrose % and 15 locations for Pol % cane. The entry performed well across the zone for cane yield, sugar yield, sucrose % and pol % cane.

Co 12009 recorded an average CCS yield of 17.31 t/ha from three crops (2P+1R) with an overall improvement of 10.40 %, 18.08 % and 15.32 % for sugar yield over the best midlate standard Co 86032 ( ) and early standards *viz.*, CoC 671 ( )and CoSnk 05103 ( ) from 21 trials. Co 12009 with an overall mean cane yield of 119.65 t/ha showed an improvement of 9.03 %, 7.92 %, and 23.42 % in comparison with the standards Co 86032 (109.73 t/ha), CoSnk 05103 (110.85 t/ha), and CoC 671 (96.93 t/ha) respectively. Co 12009 recorded 19.91 sucrose % which was 1.80 and 6.99 percent improvement over the midlate standard Co 86032 and early standard CoSnk 05103 respectively. In both plant and ratoon crops the clone showed improvement over both the standards.

The mean Pol% in cane in Co 12009 was 15.47 % which was 2.25 and 6.84 per cent improvement over the zonal standards Co 86032 and CoSnk 05103 respectively. Co 12009 showed 1.97 per cent improvement in Pol % in cane over the qualifying variety CoM 12085 (15.17 %). The clone recorded a mean CCS % of 14.10 across the zone with an overall improvement of 2.28 % over Co 86032.

Co 12009 is an excellent ratooner with an improvement of 13.70 % and 10.43 % for sugar yield and cane yield respectively over the midlate standard Co 86032. It recorded 30.11 % and 34.19 % improvement for sugar yield and cane yield respectively over the early standard CoC 671.

Co 12009 recorded juice sucrose of 17.46 % at 300 days in comparison with Co 86032 (17.35 %) and with an improvement of 0.61 % and 6.86 % over the other check CoSnk 05103 (16.34 %). It recorded an overall improvement (2P+1R) of 3.67 %, 3.10 %, 5.30 %, 8.16 %, and 13.28 % over Co 86032 in Kolhapur,Mandya, Padegaon,Sameerwadi and Sankeshwar centres respectively. The clone performed well under 125 % RDF (recommended dose of fertilizer) condition for cane yield and it was superior to all the three standards viz., CoC 671, Co 86032 and CoSnk 05103 with an improvement of 11.50 %, 4.50 % and 5.76 % respectively. Under wide row spacing of 120 cm, Co 12009 recorded cane yield of 158.83 t/ha with an improvement of 16.24 %, 11.61 % and 10.41 % over CoC 671, Co 86032 and CoSnk 05103 respectively.

Identification and release of variety with resistance to new pathological or entomological stresses, and improved adaptation to abiotic stresses like drought have a great impact on productivity. This variety with resistance to red rot and adaptation to varied environments is a boon for Peninsular zone. Co 12009 was MS-MR (Plug) at Coimbatore, Navasari and Thiruvalla centres and resistant (Nodal) to red rot in all centres and smut in all centres except Pune. However, no natural incidence of smut was observed during the evaluation period. Co 12009 is less susceptible to top borer in Mandya. It was less susceptible to moderately susceptible for early shoot borer, internode borer, mealy bug (except in Padegaon) and scale insect.

Special characters of Co 12009

Co 12009 is a high yielding, high quality, midlate variety and combines red rot resistance. This variety performed well at Coimbatore, Akola, Kolhapur, Mandya, Navsari Padegaon, Pravaranagar, Rudrur and Sankeshwar centers of Peninsular Zone showing its wide adaptability to varying environments. The variety has a new genetic base involving *S. spontaneum* clone SES 91. It possesses good field stand, excellent field habits like early vigorous growth, high

single cane weight, dark green foliage and tall canes with long internodes. It has excellent ratoon potential and also performed well under 125 % RDF (recommended dose of fertilizer) condition and wide row spacing for cane yield and it was superior to all the three standards *viz.,* CoC 671, Co 86032 and CoSnk 05103. Co 12009 is viewed as a potential midlate variety and is expected to produce higher cane and sugar yield in the states of Peninsular Zone. The variety is characterized by greenish wax coated canes with zigzag, cylindrical to bobbin shaped long internodes, and prominent bud groove.

Performance in locations

In Coimbatore, Co 12009 recorded a cane yield of 119.60 t/ha with an improvement of 21.60 % against Co 86032 (98.36 t/ha). It recorded sugar yield of 17.05 t/ha in comparison with standards Co 86032 (13.78 t/ha), CoC 671 (13.80 t/ha) and CoSnk 05103 (14.74 t/ha) and showed an increase of 23.68 %, 23.56 % and 15.65 % for sugar yield. The clone performed well in Padegaon, Pravaranagar, Pune, Kolhapur and Sameerwadi centres for cane and sugar yield.

CONCLUSION

A cafeteria of varieties should be identified and cultivated to ensure continuous and quality cane supply for entire crushing season. Co 12009 possess high and stable yield and better quality characteristics in plant and ratoon crops across the 14 centres of Peninsular zone in comparison with the popular variety Co 86032. It combines red rot resistance and would certainly suit for cultivation in Peninsular zone.

ACKNOWLEDGEMENT

The continuous support and facilities provided by Director, ICAR- Sugarcane Breeding Institute and Dr. G. Hemaprabha Head, Division of Crop Improvement is gratefully acknowledged. Grateful appreciations are extended to the Technical staff ,ICAR- SBI in conduct of the trials.

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TABLE 1 – Overall mean performance of Co 12009 for yield and quality parameters AICRP : Advanced Varietal Trials (2017-2019) at 360 days

Character	No. of topped trials/ locations	Co 12009	Co 86032 (Standard)	CoC 671 Standard	CoSnk 05103 (Standard)
CCS t/ha	18/33	17.31	15.68	14.66	15.04
% improvement over the standards	I Plant		16.57	13.15	24.15
	II Plant		4.02	14.80	12.06
	Ratoon		13.70	30.12	10.20
	Mean		10.40	18.08	15.32
Cane yield (t/ha)	21/33	119.65	109.73	96.93	110.85
% improvement over the standards	I Plant		12.32	19.02	15.41
	II Plant		5.56	20.20	7.74
	Ratoon		10.43	34.19	0.69
	Mean		9.03	23.42	7.92
Sucrose %	10/33	19.91	19.55	20.81	18.61
% improvement over the standards	I Plant		3.26	-4.87	6.57
	II Plant		0.30	-4.20	6.49
	Ratoon		2.52	-3.85	8.07
	Mean		1.80	-4.30	6.99
Pol % cane	15/33	15.47	15.13	16.20	14.48
% improvement over the standards	I Plant		5.50	-5.70	9.13
	II Plant		-1.35	-4.13	4.86
	Ratoon		3.46	-3.53	8.81
	Mean		2.25	-4.51	6.84

Source : Principal Investigators' Report, AICRP on Sugarcane, Varietal Improvement (2017-2019)

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e-Proceedings of 78th Annual Convention of STAI: 229 – 233 2020

GENETIC IMPROVEMENT FOR SUGAR YIELD TRAITS OF CO CANES EVOLVED DURING A CENTURY OF BREEDING AT ICAR SUGARCANE BREEDING INSTITUTE

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ABSTRACT

Sugarcane improvement through breeding at ICAR Sugarcane Breeding Institute during the first one hundred years of its existence has led to the identification of 2156 Coimbatore canes (Co canes) of which 1454 Co canes under maintenance at its headquarters at Coimbatore have been well documented. In the present study, these Co canes were grouped based on their time of development into three groups viz. early period (1918-1967), mid period (1968-1992) and latest period (1993-2017) with 235, 677 and 539 Co canes respectively. Analysis of the data on nine sugar yield contributing traits of Co canes under each time period showed significant difference in the mean values of all the nine characters, except NMC of mid and latest periods, for which the difference was non-significant. It was clear that the latest period was superior over the preceding two periods and the mid period was superior to the early period, thus demonstrating steady improvement over time reflecting the efficiency and success of sugarcane improvement programme in vogue at ICAR SBI. The best Co canes with maximum expression for the nine characters are mentioned for the benefit of sugarcane breeders for utilization in breeding programmes aimed at varietal development or trait specific improvement. The study also highlighted the need to maintain the tempo of genetic gain and showed the need to improve NMC for better gains in cane yield.

Keywords: Sugarcane, Co canes, genetic gain, sugar yield traits

INTRODUCTION

A systematic improvement of sugarcane through breeding started in 1912 from the breeding efforts by Dr. C.A. Barber and his Chief Botanical Assistant and Collaborator Dr. T. S. Venkatraman in Coimbatore. Since then sugarcane improvement world over was through interspecific hybridization followed by intercrossing and/or backcrossing (Heinz 1987). During 1917-1918 the first batch of elite selections called as Coimbatore canes (Co canes) were developed and Co 205 became a historical success to rewrite the varietal development approach in global sugarcane research. Right from Co 205, and other improved Co canes of inter-specific and tri-specific origin evolved by ICAR-SBI spread in larger areas initially in subtropical India and subsequently in tropical India and replaced low yielding traditional sugarcane clones which were in cultivation prior to 1947. Several high performing varieties occupied sizeable area in different parts of the country from time to time. The varietal impact was so spectacular that

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India gained much from sugarcane crop to achieve a record sugar production of 33.29 MT during 2018-19 (https://indiansugar.com/Statics.aspx).

Since 1918, during a century of sugarcane improvement, 3156 Co canes were developed at the Institute. The database of Co canes developed at ICAR SBI in the first one hundred years of Co cane development (1918 to 2017) with the data on 14 characters of 1454 Co canes under maintenance at Coimbatore has been published (Hemaprabha et al 2018). The information contained in the catalogue was analysed to understand the extent of genetic improvement over years and to prioritize parental selection for better genetic gains for specific characters.

MATERIALS AND METHODS

The Co canes developed in the first one hundred years of breeding were classified into three time periods: early period representing the first 50 years (1918-1967), mid period between 51-75 years (1968-1992) and latest period between 76-100 years (1993 – 2017). The data on four component characters of cane yield viz. cane length, cane diameter, single cane weight and number of millable canes (NMC) and juice quality parameters viz. were early sucrose accumulating potential measured in terms of Hand refractometer Brix at 240 days of age and juice brix percent, sucrose percent, commercial sugar percent (CCS%) and purity percent at 360 days were obtained from the database of Co canes (Hemaprabha et al. 2018) and were statistically analysed group wise to assess the improvement realised for the nine characters of sugar yield over time. The significance of within as well as between group differences was tested by analysis of variance (ANOVA) for each variable. Means were separated by using the least significant difference test (LSD) at a probability level of 5%. Significant differences among the time periods of the nine traits were indicated by different letters (a, b and c).

RESULTS AND DISCUSSION

The grouping of the Co canes based on time period showed that there were 235 Co canes under early period, 677 Co canes in mid period and 539 Co canes of the latest period. The mean data of nine characters for the three time periods are presented in Table 1. Significant within as well as between group differences were observed all characters, indicating that the Co canes differed in the economic performance over time. Mean NMC of the mid period was the highest, though differences were not significant from the latest period Co canes and both categories showed superiority over the early period. For all other characters the latest Co canes constituted the superior group, followed by the mid period, while the early group was the poorest, thus showing steady improvement in performance over time. A similar study based on decade wise improvement of commercial Co canes in cultivation also had shown improvement over time particularly for juice quality traits (Hemaprabha et al. 2012). Mean values for NMC above 100,000/ ha, single cane above one kg, cane height above 200 cm, H.R Brix at 240 days of 19.88 units, sucrose content of 19.41%, CCS of 13.62% and above 90% juice purity were indications of the Co canes bred during the latest periods.

Percent improvement for specific characters showed that maximum improvement was achieved for single cane weights than other characters. The improvement was 33.71%

for latest period over the early period and 26.99% for mid period over early period. CCS% was also improved substantially with 20.35% (latest period over the early period). A similar trend was observed for sucrose content. The characters like NMC, cane diameter and juice purity showed improvement in lesser magnitudes. The increase in improvement needs to be sustained through following the appropriate breeding strategies. In this direction, the results of this study are significant and indicated the trends in improvement and the characters to be focussed for better gains. NMC was found to be a character that needs to be focussed for improving cane yield.

Table 1 – Mean values for cane and juice quality traits of three time periods

Time periods	NMC 000/ha	SCWT (Kg)	Cane diameter (cm)	Cane length (cm)	H.R Brix 8m	Brix %	Sucrose %	CCS %	Purity %
Early period	93.48[a]	0.89[a]	2.39[a]	178.43[a]	17.84[a]	18.48[a]	15.88[a]	10.85[a]	85.89[a]
Mid period	107.49[b]	1.13[b]	2.58[b]	198.50[b]	19.12[b]	19.71[b]	17.73[b]	12.38[b]	89.93[b]
Latest period	103.01[b]	1.34[c]	2.79[c]	222.36[c]	19.88[c]	21.33[c]	19.41[c]	13.62[c]	91.04[c]
Percent improvement									
Mid over early	14.98	26.99	7.78	11.25	7.17	6.62	11.66	14.16	4.70
Latest over mid	-4.17	18.78	8.17	12.02	3.93	8.25	9.46	9.97	1.23
Latest over early period	9.25	33.71	14.23	19.76	10.22	13.36	18.18	20.35	5.65

PROPORTION OF SUPERIOR CO CANES OF THE LATEST TIME PERIOD

Considering the fact that the recent products of sugarcane improvement are more improved than the rest and that these clones were exposed to environmental stresses, particularly water deficit stress during the course of their evolution, the proportion of Co canes above the GM and best trait specific Co canes were identified (Table 2). Improvement in sucrose was again evident from the observation that 91.09 % of the co canes of the latest period showed above 18% juice sucrose. Cane height and single cane weight also showed high proportion of clones above mean values. The Co canes mentioned in Table 2 have the best expression for the nine characters and hence can serve as potential donors based on per se performance. The pedigree of these Co canes needs to be examined in order to harness their potential in sugarcane improvement programmes.

Table 2 – Proportion of the Co canes above the grand mean and trait specific Co canes with maximum expression for nine traits of the latest generation (1993-2017)

Characters with threshold values	Proportion of Co canes above GM	Best trait specific Co canes of the latest period
NMC ≥100,000	52.32	Co 0312, Co 17004, Co 93021, Co 93027, Co 99001, Co 0321, Co 07016, Co 0101, Co 14005, Co 0403, Co 14016, Co 93017, Co 0401, Co 94005, Co 0201, Co 93001, Co 0406, Co 93013, Co 06019, Co 07001 (>140000/ha)
SCWt≥1 Kg	93.51	Co 16020, Co 16018, Co 16023, Co 0325, Co 93004, 94008, Co 98005, Co 98003, Co 16026, Co 16011, Co 98010, Co 98004, Co 0114, Co 97016, Co 0310 (>1.88 Kg)

C. diameter ≥3 cm	25.05	Co 0208, Co 2000-08, Co 10021, Co 10020, Co 97014, Co 11007, Co 10019, Co 17008, Co 07005, Co 0305, Co 98004, Co 98010, Co 95007, Co 0203, Co 16011, Co 0407 (>3.30 cm)
C. height ≥200 cm	83.86	Co 93013, Co 10018, Co 16018, Co 0222, Co 10022, Co 16006, Co 10017, Co 99009, Co 10010 (300 cm)
HR Brix 240 days ≥20%	60.30	Co 17008, Co 11015, Co 15007, Co 14025, Co 14007, Co 16001, Co 15014, Co 12025, Co 09007, Co 09015, Co 17005, Co 13016, Co 14002, Co 08016, Co 16002, Co 16007, Co 14032, Co 14027, Co 15017, Co 14001 (>22.0%)
Brix ≥ 20%	86.46	Co 15017, Co 14011, Co 12025, Co 14025, Co 11015, Co 14027, Co 17005, Co 16001, Co 11021, Co 14007, Co 16002, Co 94012 (>24.00%)
Sucrose % ≥18.0%	91.09	Co 11015, Co 14007, Co 15017, Co 17005, Co 12025, Co 15007, Co 17003, Co 94012, Co 15008, Co 96002, Co 14030 (>22.00%)
CCS%≥13.00%	77.18	Co 15007, Co 12025, Co 17005, Co 17003, Co 15017, Co 96002, Co 94012, Co 15008, Co 10003, Co 13009, Co 13020, Co 17008, Co 15014, Co 10005, Co 11015, Co 14007, Co 13016, Co 14011, Co 14031, Co 14030 (>15.40)%
Purity% ≥90.0%	67.90	Co 09006, Co 0315, Co 11001, Co 10003, Co 95002, Co 13016, Co 11004, Co 0222, Co 08016, Co 10002, Co 07029, Co 95011, Co 98007, Co 08003, Co 99003 (>94.0%)

The results of the study gave encouraging indications of the role of systematic sugarcane improvement adopted at ICAR SBI and sugarcane area in the country occupied by Co varieties varied from over 60 % to 77 % at any point of time and the Institute released new varieties from time to time for the benefit of sugarcane cultivation in the country. The prominent varieties which made substantial contribution over time were Co 205, Co 285, Co 312, Co 419, Co 740, Co 1148, Co 6304, Co 6806, CoC 671 and Co 89003 and Co 86032 and Co 0238 of the recent time. In this study, not only varieties which became commercially successful, but also elite selections of commercial status are evaluated, so as to use the results for planning an efficient crossing programme for better gains through breeding and demonstrated the advantage of the latest varieties for each character.

A general observation is that quantifying the available variability and grouping clones based on diversity to intercross clones from different groups could derive heterotic types (Bhagyalakshmi et al. 1986, Singh et al. 2004, Ram and Hemaprabha, 2005). Similarly it has been demonstrated that genetic gain would be possible even for negatively associated characters like cane yield and sucrose content as the negative association was not absolute, and even high negative correlation of -0.80 between cane yield and sucrose % meant 36 % ($1 - r^2$) independent variability enabling simultaneous improvement of these traits (Ram, 2005) and hence would hold good for other combinations of traits having negative association. The results of the study are hence relevant for future breeding programmes aimed for developing new varieties as well as for trait specific genetic stocks.

It is clear that the potential for selecting better sugar yielding Co canes has increased over years of sugarcane breeding. Evolution of improved Co canes clearly showed that the genetic potential of the working germplasm has not been exhausted. Gene pools for desirable traits for incorporation and pyramiding are available within the germplasm used in commercial cane breeding activities. This would lead to improvements in cane yield and sugar yield of future cane varieties. Further advances would be possible with the use of a broadened gene pool and a breeding strategy that integrates genomic approaches to ensure efficient selection, and a final evaluation and selection with Institute- Sugar industry participation.

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