RESEARCH ARTICLE

Co 06022 - A SUGARCANE EARLY MATURING AND DROUGHT TOLERANT VARIETY SUITABLE FOR TAMIL NADU AND PONDICHERRY

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Abstract

A promising sugarcane early maturing clone Co 06022 was selected from the cross GU 92-275 x Co 86249 at ICAR-Sugarcane Breeding Institute (ICAR - SBI), Coimbatore. This clone registered higher mean performance for cane and sugar yield in two plant and one ratoon crops compared to standard varieties under AICRP(S) in Peninsular zone during 2010-2012. Co 06022 exhibited superior performance for cane yield and sugar yield in AICRP(S) of Tamil Nadu at Coimbatore and Pugalur locations. Based on superior performance of Co 06022 in Tamil Nadu centres, evaluation trials along with standard varieties (CoC 24 and TNAU Si 7) were conducted in fifteen locations that represent different agro-climatic regions of the state under Adaptive Research Trial (ART) programme in collaboration with Tamil Nadu Agricultural University (TNAU) during 2014-2016. The clone Co 06022 recorded an overall mean cane yield of 135.8 t ha^{-1} with commercial cane sugar (CCS) yield of 17.68 t ha^{-1} compared to the best standard CoC 24 with cane yield of 124.0 t ha^{-1} and CCS yield of 15.59 t ha^{-1}. It recorded 9.53% and 13.41% increased cane and CCS yield over CoC 24 respectively, while the per cent increase over TNAU Si 7 was 13.03% and 13.99% respectively for cane yield and CCS yield. In addition, Co 06022 is moderately resistant to red rot disease and tolerant to drought and salinity stresses. This has thick canes with erect growing habit and has non lodging nature. Molecular profiling clearly distinguished Co 06022 from other varieties. The variety can be identified by green root zone, cylindrical internodes, greyed orange medium wax coated canes with semi drooping leaves, light brownish green dewlap, absence of ligular process on one side and short lanceolate to transitional on the other side, green with purple tinge along sides of easily detrashable leaf sheath. Co 06022 is an early maturing and highly drought tolerant variety recommended for commercial cultivation in Tamil Nadu.

Key words : Sugarcane, early maturing variety, Co 06022, cane yield, CCS yield

Introduction

Sugarcane (*Saccharum* spp.) is the second most important commercial crop in India. It is grown in more than 4.4 M ha of area in both tropical and subtropical regions of the country. Annually around 300 million tonnes (mt) of cane are produced and crushed for production of sugar jaggery / khandsari in India (Cooperative Sugar, 2018). India contributes about 20 per cent of the area and 22.6 per cent of the world sugar production. Major sugarcane growing states are Uttar Pradesh, Maharashtra, Karnataka, Tamil Nadu, Bihar, Andhra Pradesh and Gujarat in India. In Tamil Nadu, sugarcane occupied about 2.0 lakh ha with productivity 87.1 t ha^{-1} during 2016-17 (Cooperative Sugar, 2018). At present prominent midlate maturing variety Co 86032 occupies more than 80% of sugarcane area in Tamil Nadu since its release for commercial cultivation about two decades back. Other early (CoC 24, CoC 25, TNAU Si 7) and midlate (CoC 23, Co 0212, Co 06030, CoV 09356, CoV 92102) maturing varieties together occupy around 20%

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area in factory locations of Tamil Nadu. Though Tamil Nadu ranked first in terms of sugarcane productivity (87.1 t ha^{-1}) among major sugarcane growing states in India (Cooperative Sugar, 2018), it is much lower than the production potential of 212 t ha^{-1} in sugarcane (Waclawovsky et al., 2010). One of the major constraints for achieving production potential of sugarcane is frequent episodes of severe drought periods. It is a high water demanding tropical crop with the highest productivity per drop of water consumed. Water deficit stress during various stages of crop growth period accounts for 30-70 per cent of loss in productivity of sugarcane, whereas, the sucrose accumulation and sucrose recovery are reduced up to 5%, which in turn leads to huge loss of sugar productivity. The efficiency of sugar industry is mainly dependent upon the availability of improved sugarcane varieties with better juice quality and tolerance to biotic and abiotic stresses. The increased requirement of sugarcane production can be met through identification of location specific varieties for enhanced production per unit area/unit time. Development of suitable varieties superior to existing varieties assumes importance for increased sugarcane production in Tamil Nadu. Apart from drought stress, sugarcane diseases also seriously affects cane and juice yield in major sugarcane varieties (Viswanathan et al. 2014). Therefore, to meet the immediate requirement of sugarcane farming community and sugar factory, development of drought tolerant high yielding and high sugared varieties with good ratooning ability is essential. Hence, the research efforts were made to identify location specific high sugar and high yielding varieties at (ICAR – SBI) Coimbatore in collaboration with Tamil Nadu Agricultural University (TNAU), Coimbatore.

Materials and Methods

Experimental materials

A total of five early maturing sugarcane clones, two (Co 06012 and Co 06022) from ICAR-SBI, and one each 25 C 006, 07 Si 017 and 07 G 030 from Sugarcane Research Station (SRS), Cuddalore, SRS, Sirugamani and Agricultural Research Station (ARS), Melalathur respectively were tested along with two standard varieties (CoC 24 and TNAU Si 7) for yield and quality characters. Performance of Co 06022 was also evaluated in All India Coordinated Research Project (AICRP) on Sugarcane trials in 14 locations of peninsular zone during 2010-2012 with standards CoC 671 and Co 94008 (AICRP Annual Report on Sugarcane 2010-2011 and 2011-2012).

Experiment sites

This clone Co 06022 was evaluated in 14 locations of Peninsular zone under AICRP(S) programme during 2010-2012. The various sugarcane research centers were Coimbatore, Akola, Basmath Nagar, Kolhapur, Mandya, Navsari, Padegaon, Powerkheda, Pravaranagar, Pugalur, Pune, Sameerwadi, Sankeshwar and Thiruvalla that spread across six states. Two AICRP(S) centres (Coimbatore and Pugalur) were located in Tamil Nadu.

Performance of this clone was tested in collaboration with TNAU, Coimbatore at the farmers and sugarcane factory farm locations. Test locations were across different agroclimatic of zones of Tamil Nadu namely Coimbatore region (The Amaravathi Cooperative Sugar Mills Ltd., Udumalpet; Bannari Amman Sugars Ltd., Sathaymangalam; Sakthi Sugars Ltd., Bhavani; Ponni Sugars Ltd., Erode), Vellore region (The

Ambur Cooperative Sugar Mills Ltd., Ambur; The Vellore Cooperative Sugar Mills Ltd., Vellore), Trichy region (E.I.D. Parry (India) Ltd., Pugalur; E.I.D. Parry (India) Ltd., Pettavaithalai; Farmer's field, Trichy) and Cuddalore region (E.I.D. Parry (India) Ltd., Nellikuppam; Rajshree Sugars & Chemicals Ltd., Mundiyampakkam; The Pondicherry Cooperative Sugar Mills Ltd., Puducherry; Farmer's field, Cuddalore; New Horizon Sugar Mills Ltd., Ariyur; Kariyamanickam Research Farm, Pondicherry) under Adaptive Research Trial (ART) programme on sugarcane improvement.

Experimental design and cultural practices

Experiments were conducted during 2010-2012 under AICRP(S) in 14 locations (AICRP Annual Report on Sugarcane 2010-2011 and 2011-2012), and 2014-15 and 2015-16 under state ART trials with two plant and one ratoon crops in each of the 15 locations that represented four major sugarcane growing regions in Tamil Nadu. AICRP(S) trials were planted in a plot size of eight rows of 6m length and 0.90m apart while ART trials were laid out in a plot size of five rows of 6 m length spaced 0.90m apart under randomised block design (RBD) with three replications.

Standard sugarcane cultivation practices were followed (Sundara, 1998). Commercial cane sugar (CCS) yield was calculated from cane yield and CCS %. The cane yield recorded in test plots were converted into quantity per hectare (t/ha). Five canes were randomly selected from each plot at 240 days and 300 days (at harvest) and crushed in a small power crusher and juice was analysed for brix, pol (%) and purity (%) as per standard methods of Meade and Chen (1977). Commercial cane sugar (CCS %) was worked out based on the formula {(Sucrose % x 1.002) – (Brix x 0.292)}. The data on quality parameter (CCS %) was recorded on 8 and 10 months after planting whereas yield data recorded at 10 months. CCS yield was calculated by using the formula [(CCS % x Cane yield t ha^{-1})/100]. The data of the two plant and one ratoon crops over 15 different locations of four different regions were pooled and analysed. The analysis of variance (ANOVA) for cane yield and juice quality parameter traits was worked out using Haryana Agricultural University (HAU) Stat programme (HAU OPSTAT, 14.139.232.166/ opstat/ default.asp). Red rot reaction of this clone was evaluated under natural and artificial conditions with predominant red rot causing pathotype Cf 671 in Peninsular regions as well in Tamil Nadu state.

Drought tolerance of this clone was evaluated along fourteen AVT clones (4 early and 10 midlate) in strip plot design with standards Co 86032 and Co 99004 at Coimbatore during 2010-2011 (Gomathi, 2012). For imposition of water deficit stress these entries were planted with plot size 6 rows x 6m x 0.90m.These entries were maintained by following the regular cultivation practices. After 2 months of planting, the plants were subjected to water deficit stress by withholding the irrigation for 90 days (stressed) and control plot were given regular irrigation (unstressed). Reduction of soil moisture content was measured by following the gravimetric method (Black 1965). After the stress period, plants were subjected regular irrigation. The yield and quality data were recorded at harvest.

Molecular profiling

Total genomic DNA was isolated by following the methods described elsewhere (Doyle and Doyle

1987) from young leaves of side shoots produced by mother plant grown under field conditions. The quality of DNA after RNase treatment was assessed on 1.2% agarose gel, and quantified using NanoDrop spectrophotometer (ND-1000, version 3.1.1, USA). A total of eleven primers (NKS 1, NKS 2, NKS 3, NKS 9, NKS 11, NKS 30, NKS 31, NKS 34, NKS 42, NKS 45 and NKS 46) were used for developing molecular profiling. PCR reactions were performed in a 20 µl reaction mixture containing 0.3 units of *Taq* DNA polymerase, 1.5 mM $MgCl_2$, 200 µM of each dNTPs, 0.2 µM primers and 20 ng of genomic DNA. The PCR reactions were carried out in Thermal cycler (Eppendorf Master Cycler, Germany) using single primer in each reaction by following procedure of Hemaprabha and Simon (2012). Banding profiles were documented using UV-trans illuminator.

Results and Discussion

Performance of Co 06022 across peninsular zone under AICRP(S)

The clone Co 06022 matures in 300 days and grouped under early category (ICAR-SBI, Annual Report 2005-2006). In 8 centres of Peninsular zone where the clone was tested in two plant and one ratoon crops under AICRP(S), Co 06022 showed higher mean performance for cane and sugar yield (CCS yield) than the best check (Table 1).

Co 06022 recorded an average CCS yield of 14.63 t/ha from three crops against the standard CoC 671 (13.38 t ha^{-1}) and Co 94008 (12.87 t ha^{-1}). It showed 9.35 % improvement over CoC 671 and 13.69 % over Co 94008. Co 06022 recorded an average (three crops) cane yield of 110.7 t ha^{-1} against CoC 671 (95.90 t/ha) and Co 94008 (97.91 t ha^{-1}). It showed improvement of 15.32 % and

Table 1. Overall mean performance of Co 06022 in centres of peninsular zone of AICRP(S)*

Entry/ Character	Co 06022				CoC 671				% increase of Co 06022 over CoC 671	Co 94008				% increase of Co 06022 over Co 94008
	PI	PII	R	Mean	PI	PII	R	Mean		PI	PII	R	Mean	
CCS yield t ha^{-1}	15.57	16.23	13.37	14.63	13.96	14.71	12.43	13.38	9.35	13.05	13.92	12.26	12.87	13.69
Cane yield t ha^{-1}	121.6	123.8	98.7	110.7	102.9	107.2	87.0	95.9	15.32	100.6	110.0	90.50	97.91	13.06
CCS %	13.41	13.20	13.67	13.49	13.63	13.72	14.28	13.98	-3.52	12.51	12.69	13.48	13.04	3.45
Sucrose %	19.02	18.68	19.33	19.09	19.28	19.37	20.15	19.74	-3.27	17.81	17.93	19.02	18.44	3.50

Where, PI- I Plant; PII-II plant; R- Ratoon crop

Source: Principal Investigators' Report, AICRP on Sugarcane, Varietal Improvement 2010-2012;* Performance of Co 06022 in eight locations (Coimbatore, Kolhapur, Mandya, Navsari, Pravara nagar, Pugalur, Pune, Sankeshwar).

13.06 % over CoC 671 and Co 94008 respectively. In both plant and ratoon crops the clone showed superior performance for sugar yield and cane yield over both the standards.

Performance of Co 06022 in AICRP(S) centres of Tamil Nadu

Co 06022 exhibited superior performance for cane yield and sugar yield in Coimbatore and Pugalur locations in Tamil Nadu. Among the four entries tested at Coimbatore during 2010-2012, Co 06022 was the best with high cane yield (122.74 t ha^{-1}) and sugar yield (15.84 t ha^{-1}) and that was superior to Co 85004 (105.29 t ha^{-1}) and CoC 671 (14.66 t ha^{-1}) respectively (Durai, 2013). In an average, Co 06022 recorded 12.91% and 25.73% increase in sugar yield and 20.45 % and 20.83% increase in cane yield over the standards CoC 671 and Co 94008 respectively. The percent improvement for sugar yield over CoC 671 and Co 94008 was 25.77% and 43.76 % in the first plant crop, 10.86% and 19.10% in the second plant crop and 7.80% and 20.98% in the ratoon crop respectively. The percent improvement for cane yield over CoC 671 and Co 94008 registered by the clone was 27.37 % and 24.79% in the first plant crop, 22.66% and 16.88% in the second plant crop and 15.66% and 21.19% in the ratoon crop respectively. This clone performed better than the standards in both the centres.

Based on the better performance of Co 06022 at these AICRP(S) centres, potential and suitability of this clone was evaluated in different agro-climatic regions of Tamil Nadu under ART programme in collaboration with TNAU, Coimbatore.

Performance of Co 06022 under drought conditions

Frequent failure of monsoon resulting in shortage of water led to decline in productivity of sugarcane

Table 2a. Mean of two plant crops performance of Co 06022 in four different agro-climatic regions of Tamil Nadu

Entries / Characters	Coimbatore	Vellore	Trichy	Cuddalore	Mean	% increase over the check
Cane yield t ha^{-1}						
Co 06022	158.3	126.6	134.8	141.2	140.2	
CoC 24	143.7	109.6	129.5	129.9	128.2	9.36
TNAU Si7	133.8	106.6	126.2	127.4	123.5	13.52
CCS %						
Co 06022	13.34	12.97	12.92	12.92	13.04	
CoC 24	12.12	12.87	12.42	12.57	12.49	4.40
TNAU Si7	13.06	12.88	12.77	12.69	12.85	1.48
CCS yield t ha^{-1}						
Co 06022	21.11	16.42	17.42	18.24	18.30	
CoC 24	17.41	14.10	16.08	16.33	15.98	14.52
TNAU Si7	17.48	13.73	16.12	16.16	15.87	15.31

Table 2b. Ratoon performance of Co 06022 in four different agro-climatic regions of Tamil Nadu

Entries / Characters	Coimbatore	Vellore	Trichy	Cuddalore	Mean	% increase over check
Cane yield t ha^{-1}						
Co 06022	135.1	124.5	133.9	131.9	131.4	
CoC 24	116.3	110.4	129.0	123.6	119.8	9.68
TNAU Si7	113.9	109.0	121.9	122.3	116.8	12.50
CCS %						
Co 06022	13.88	12.98	12.86	12.93	13.16	
CoC 24	12.84	12.93	12.43	12.63	12.71	3.54
TNAU Si7	13.54	12.83	12.79	12.72	12.97	1.46
CCS yield t ha^{-1}						
Co 06022	18.76	16.16	17.21	17.06	17.30	
CoC 24	14.93	14.28	16.02	15.61	15.21	13.74
TNAU Si7	15.42	13.98	15.60	15.55	15.14	14.27

in Tamil Nadu. This situation forced farmers to search for drought tolerant sugarcane variety with relatively less water requirement. Co 06022 exhibited significantly superior performance for cane yield and sugar yield under drought conditions (Table 3) and registered 13.36% and 9.05% increase in sugar yield and cane yield over the best standard Co 86032 respectively. The percent improvement for CCS % and sucrose % over Co 86032 was 3.94% and 4.23% respectively. Therefore, Co 06022 could be a potential early maturing drought tolerant variety in Tamil Nadu.

Performance of Co 06022 across Tamil Nadu under ART programme

The average plant crops performance of Co 06022 across Tamil Nadu in comparison to standard varieties CoC 24 and TNAU Si 7 are given in Table 2a & b. The data on quantitative characters revealed that the average cane yield was 140.2 t/ha and sugar yield was 18.30 t/ha, accounting for an improvement of 9.36% and 14.52% over the standard CoC 24 while 13.52% and 15.31% over standard TNAU Si 7. In the ratoon crop, the cane yield and sugar yield were 131.4 t ha^{-1} and 17.30 t ha^{-1} respectively, with an improvement of 9.68% and 13.74% over CoC 24 and, 12.50% and 14.27% over the TNAU Si 7. Superior performance of this clone compared to existing early cultivated varieties CoC 24 and TNAU Si 7 in ART programme suggest the suitability of this clone for commercial cultivation in Tamil Nadu. Parasuraman *et al.* (2013a and b) identified high sugar and cane yield early maturing clone suitable for North West zone of Tamil Nadu based on evaluation trial conducted at factory locations. In this study the per cent increase recorded by Co 06022 for CCS% was 4.40 and 3.54% respectively in plant crop and ratoon crops over CoC 24 while 1.48% and 1.46% over the TNAU Si 7. The early

Table 3. Performance of Co 06022 under drought condition during 2010-2011 season

Entry/ Character	Co 06022	Co 86032	Per cent increase of Co 06022 over Co 86032
CCS yield t ha^{-1}	12.98	11.45	13.36
Cane yield t ha^{-1}	96.51	88.50	9.05
CCS %	13.45	12.94	3.94
Sucrose %	19.70	18.90	4.23

Table 4. Reaction of Co 06022 to red rot pathogen evaluated at Coimbatore

Variety	Resistance reaction	
	Nodal	Cotton swab
Co 06022	Resistant	Resistant

maturing clone Co 99006 with higher improvement for quantitative and qualitative parameters over standard variety was identified for Tamil Nadu and Puducherry (Appunu et al. 2013). Appunu *et al*. (2014) also made similar observation for the clone Co 0212 among a group of midlate maturing promising clones tested in Tamil Nadu. Similarly, many midlate clones were identified after on-farm testing at state level (Jayachandran et al. 2004; Bora et al. 2011; Charumathi et al. 2010; Ganapathy and Purushothaman, 2017; Shanmuganathan et al. 2017). Though, CoC 24 is occupying considerable area in some factory locations under sugarcane cultivation in Tamil Nadu, the production potential of this variety is reported to be declining year by year due to its susceptibility to diseases *viz.,* yellow leaf disease (YLD) caused by ScYLV and red rot caused by *Colletotrichum falcatum*. YLD is responsible for varietal degeneration in sugarcane (Lehrer et al. 2010; Viswanathan, 2002). YLD severely infected genotypes recorded the reduced level of physiological functions such as photosynthetic rate (A), stomatal conductance (gs) and SPAD metre values thus resulted in significant reduction in growth/yield parameters, *viz.* stalk height, stalk thickness and number of internodes (Viswanathan et al. 2014). In addition to reduction in stalk weight, height and girth, YLD disease also reduced juice yield in the affected canes up to 34.15 %.

Red rot is the most common disease of sugarcane in India. It causes severe loss in yield and quality of the susceptible cultivars in the Indian subcontinent. In India, many major sugarcane varieties were eliminated from commercial cultivation due to sudden outbreak to red rot. Red rot pathogen infection has drastically reduced brix, sucrose percentage, purity and CCS per cent in the diseased canes. The affected canes recorded 25–75% reduced sucrose content than the healthy canes (Viswanathan and Samiyappan 1999). Another study revealed that red rot infection reduces 7.1–32.5% in juice extraction, 7.4–38.7% in pol % juice, 0.5–8.3% in purity co-efficient, 7.8–39% in commercial cane sugar and increase of 19.2–40.95% in reducing sugars (Satyavir et al. 2003). During the milling process, mixing of juice from healthy and diseased canes result

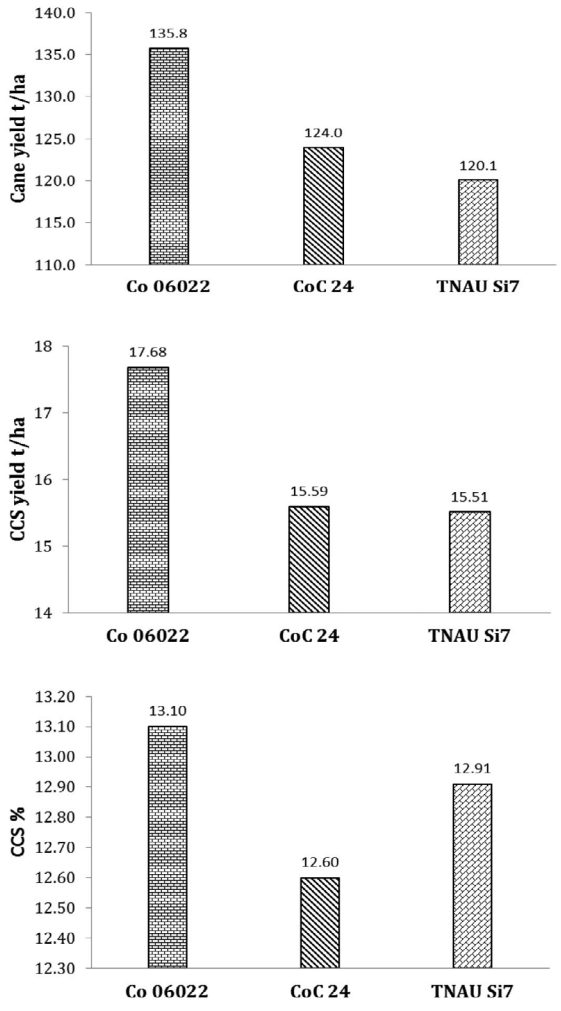

Fig. 1. Overall mean performance of Co 06022 for cane yield and quality parameters in CAE trials across Tamil Nadu: Mean of two plant and one ratoon crops.

in spoilage of entire juice due to inversion of sucrose. Usually ratoon crops suffer more than plant crops. Resistance to red rot in sugarcane varieties is very important hence varieties recommended for commercial cultivation should be resistant to red rot. Controlled condition testing (CCT) revealed that Co 06022 was resistant to red rot pathogen cf671 (Table 4). The overall performance of Co 06022 in two plant and one ratoon crops across Tamil Nadu is shown in Fig. 1

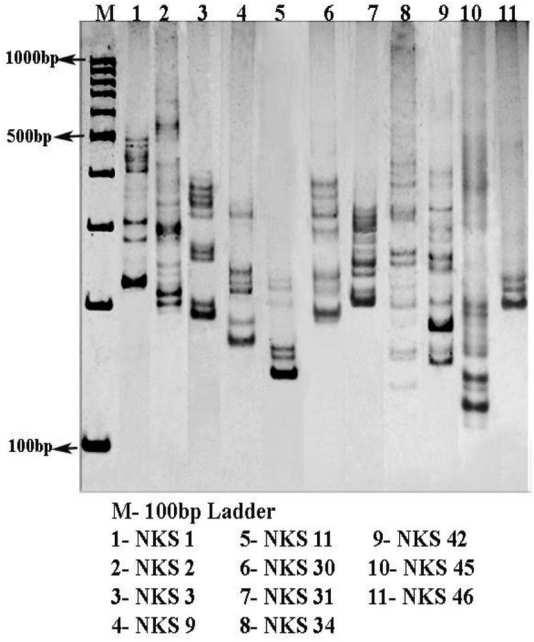

Fig. 2. Molecular fingerprint of Co 06022 using STMS markers

that highlighted the superiority of Co 06022 over early standards CoC 24 and TNAU Si 7. Therefore, the potential clone Co 06022 could be best alternate to existing early maturing varieties in Tamil Nadu.

Simple sequence repeat (SSR) is being used for analysis of phylogeny, clone or cultivar identification, parent evaluation, genetic mapping, inter-species relationships and genetic diversity. The molecular profiling of Co 06022 is shown in Figure 2. SSR based molecular finger printing has been successfully used for identification of sugarcane varieties based on presence and absence of specific markers (Saravanakumar et al. 2014; Sindhu et al. 2011). Hence molecular profiling developed with combinations could help in identification of this variety based on presence or absence of specific markers (Saravanakumar et al. 2014; Sindhu et al. 2011).

Conclusion

Co 06022 exhibited high and stable yield and quality performance across the locations of Tamil Nadu. It recorded superiority for sugar yield, cane yield and sucrose % juice over the early standards and also combines moderately resistance to red rot, tolerance to drought and salinity. This is a good ratooner with excellent field stand, with erect and thick canes. Hence this variety is expected to improve sugarcane and sugar productivity in all the agro-ecological regions of Tamil Nadu. This clone also possesses A_1 quality jaggery and exhibited 40-50% flowering at Coimbatore conditions.

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