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Pedigree analysis of sugarcane parental breeding pool used in evolving 'Co' varieties in India

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Abstract

The pedigree of the commercial sugarcane varieties ('Co' canes) evolved from Sugarcane Breeding Institute, Coimbatore, India during 1970-2009 was studied. A total of 1088 'Co' canes with known pedigree were evolved, among them 934 were from bi-parental crosses. The decade wise usage of breeding stocks revealed that clones Co 86011 (during 2000-2009), Co 7201 (during 1990-1999), CoC 671 (during 1990-1999 and 1980-1989) and Co 775 (during 1970-1979) were the most successful parents in evolving 'Co' canes. Fifty nine breeding stocks produced ≥ 5 'Co' canes each, contributed nearly 80% gametes to the total 'Co' canes evolved during 1970-2009. The pedigree study revealed that most of them (54) have POJ 2878 in recent ancestry indicating that their genetic variability is from limited origin. The breeding clones Co 775, CoC 671, Co 7201, Co 6806, Co 1148, Co 419 and Co 740 were the most successful parental stocks for evolving higher number of 'Co' canes across the studied period 1970-2009. The inbreeding coefficient or the coefficient of parentage (CoP) ranged from 0.00 (BO 17, Co 617, Co 853, Co 281, Q 63, Co 88002 and IG-91-1100) to 0.55 (Co 1307) with the average value of 0.09. Thirty-five parental clones have lower CoP than the average and their gametic contribution is evident to nearly 50% of the 'Co' canes evolved during the studied period. This indicated that even though having originated from limited clones of basic species, the genetic base of more than half of the breeding stocks is broader. More basic species clones are to be incorporated into the breeding programme for keeping higher level of genetic diversity in future sugarcane varieties.

Key words: Sugarcane, pedigree, coefficient of parentage, breeding pool, genetic diversity.

Introduction

Sugarcane is the second most important industrial crop after cotton. It is mainly grown for white sugar and contributes 70 per cent of the world sugar production. Besides sugar, the crop has multifarious uses *viz*., ethanol production, chewing purpose, jaggery production, paper making, co-generation of electricity, cane top as fodder etc. Development of suitable location specific varieties is the prime concern to meet the sugar and energy demand of ever increasing world population. Sugarcane Breeding Institute (SBI), Coimbatore, is playing a pivotal role in the sugarcane varietal development in India since its inception in 1912. Coimbatore canes ('Co' canes) are the superior sugarcane clones identified by SBI as suitable for commercial cultivation in different parts of the country. The institute had developed successful 'Co' canes like Co 213, Co 281, Co 285, Co 290, Co 312, Co 419, Co 740, Co 997, Co 1148, Co 6806, Co 86032, etc, which revolutionized sugarcane cultivation in India. 'Co' varieties also contributed to the development of sugarcane agriculture in many other countries, either as varieties for commercial cultivation or as breeding stocks.

Initially, the breeding programme at SBI utilized original species clones of *Saccharum officinarum*, *S. barberi* and *S. spontaneum* and released successful hybrids which replaced native *S. barberi* and *S. sinense* clones under cultivation in sub-tropical India. Later, varietal improvement was accelerated by utilizing these initial hybrids developed in India and similar hybrids from Java as parents. After that, a kind of recurrent selection was followed by inter-mating the improved genetic stocks from India and a few from other countries as well. Since 1912, the SBI has evolved more than 2900 'Co' canes. Many of the 'Co' canes were potential

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parents utilized for continuous evolution of new and improved 'Co' varieties year after year. Every year hundreds of cross combinations are being tried. However, only few of them produced superior progeny. It is possible to identify the group of elite parental clones based on the number of elite clones evolved from them. The estimation of genetic divergence among these parental clones can reveal the potential of the present Indian breeding pool to produce superior sugarcane varieties that can successfully meet the various challenges of sugarcane cultivation.

Genetic divergence can be calculated from pedigree, phenotypic, biochemical or molecular information [1]. However there is disagreement on the best source of information for measuring genetic divergence; usually different estimates are not related [2-4]. Further, isozyme or DNA markers may represent only a small portion of the genotype [5]. Coefficient of parentage is a better predictor of genetic variances than similarity indexes derived from discrete morphological or biochemical markers [6]. Unlike morphological, biochemical and molecular information, pedigree data do not require the observations to be recorded on the plant material and is not influenced by the environment or the technique used [1].

The co-ancestry between two individuals has been assumed to measure genetic diversity and genetic relationship between varieties. Co-ancestry is defined as the probability that a random gene chosen from an individual is identical by descent to a random gene at the same locus of another individual [7]. The technique of co-ancestry has been used to measure the genetic diversity in different crops like barley [8], canola [9], oat [10], peanut [11], potato [1], rice [12], soybean [13], straw berry [14], sugarcane [15] and wheat [16].

Information about genetic diversity and the relationship among elite breeding clones is essential to determine the most efficient crosses in any varietal development programme. The present study was to investigate the genetic diversity in the parental gene pool based on coefficient of parentage/inbreeding and on their utilization pattern in development of 'Co' canes during last four decades (1970-2009).

Materials and methods

The parentage of 'Co' canes identified during last four decade *viz.*, 1970-1979, 1980-1989, 1990-1999 and 2000-2009 was assembled from the annual reports of Sugarcane Breeding Institute, Coimbatore. The list of elite pollen and pistil parents was prepared from the parentage of 'Co' canes developed during each decade. A particular parental clone was assigned the status of elite parent, if the same was either male or female parent for at least five 'Co' canes. The decade wise relative frequencies of commonly used pistil and pollen parents were calculated from the total number of 'Co' canes evolved during that decade. For calculating the relative frequency of pollen parents, the 'Co' canes developed from only the bi-parental combinations were considered and those 'Co' canes developed from poly-crosses, open-pollination, somaclonal variations and mutations were not considered.

The ancestry of elite parental clones (male and female) was traced back to the basic species level from different sources [17-19]. The parental information was used for the construction of pedigree trees. The coefficient of parentage (CoP), also termed as coefficient of inbreeding or coefficient of co-ancestry, was worked out from the pedigree of elite breeding stocks using the formula described by Falconer [20].

$$Fx = \Sigma \, ½^{n} \, (1+F_A)$$

Where F*x* = coefficient of parentage/inbreeding, *n* = number of steps in the path from maternal to paternal parent, summation (Σ) is overall paths of relationship, and F_A is inbreeding coefficient of common parent.

The pedigree chart along with CoP of two representative cultivars in lowest and highest CoP group is given in Fig. 1 (Co 281, CoP=0.0) and Fig. 2 (Co 1307, CoP=0.55) The CoP value between parents of unknown pedigree was assumed to be zero, and each genotype was assumed to receive half of their genome from each of its parent. But in sugarcane, during initial generations of nobilization, *S. officinarum* has contributed diploid (2n) gametes [21], which could be unreduced or doubled haploid or haplo-duplex while *S. spontaneum*, *S. barberi* have contributed the reduced (n) gametes. Hence the chromosome compliments from *S. officinarum* was initially at increased level compared to *S. spontaneum*, and after the first generation of backcrossing with *S. officinarum* the n + n gametic transmission occurred and subsequently a few chromosomes of *S. spontaneum* were eliminated [22]. Because the genomic dose from *S. officinarum* and *S. spontaneum* species is unequal, the paths of gene flow were traced from *S. officinarum* clones only.

The utilization pattern of elite breeding stocks was measured by considering the number of 'Co' canes evolved using them as pollen and pistil parents. Their combining pattern with the other parent within elite and

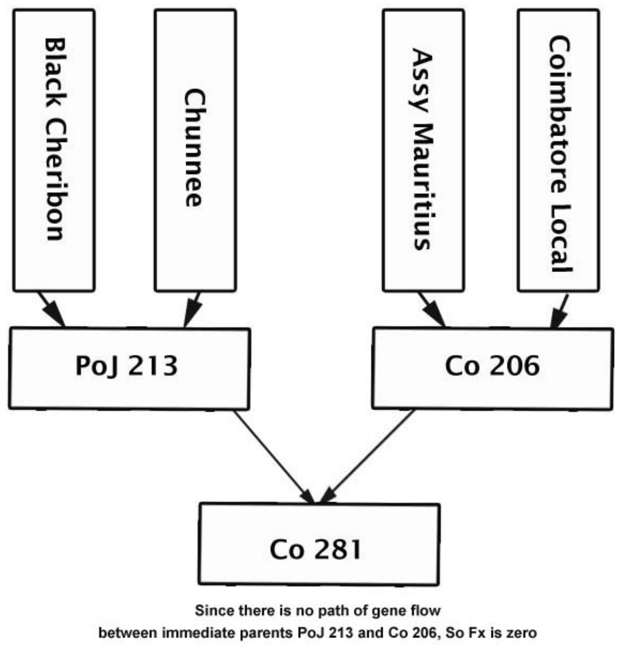


Fig. 1. Pedigree chart for Co 281 (Fx=0)

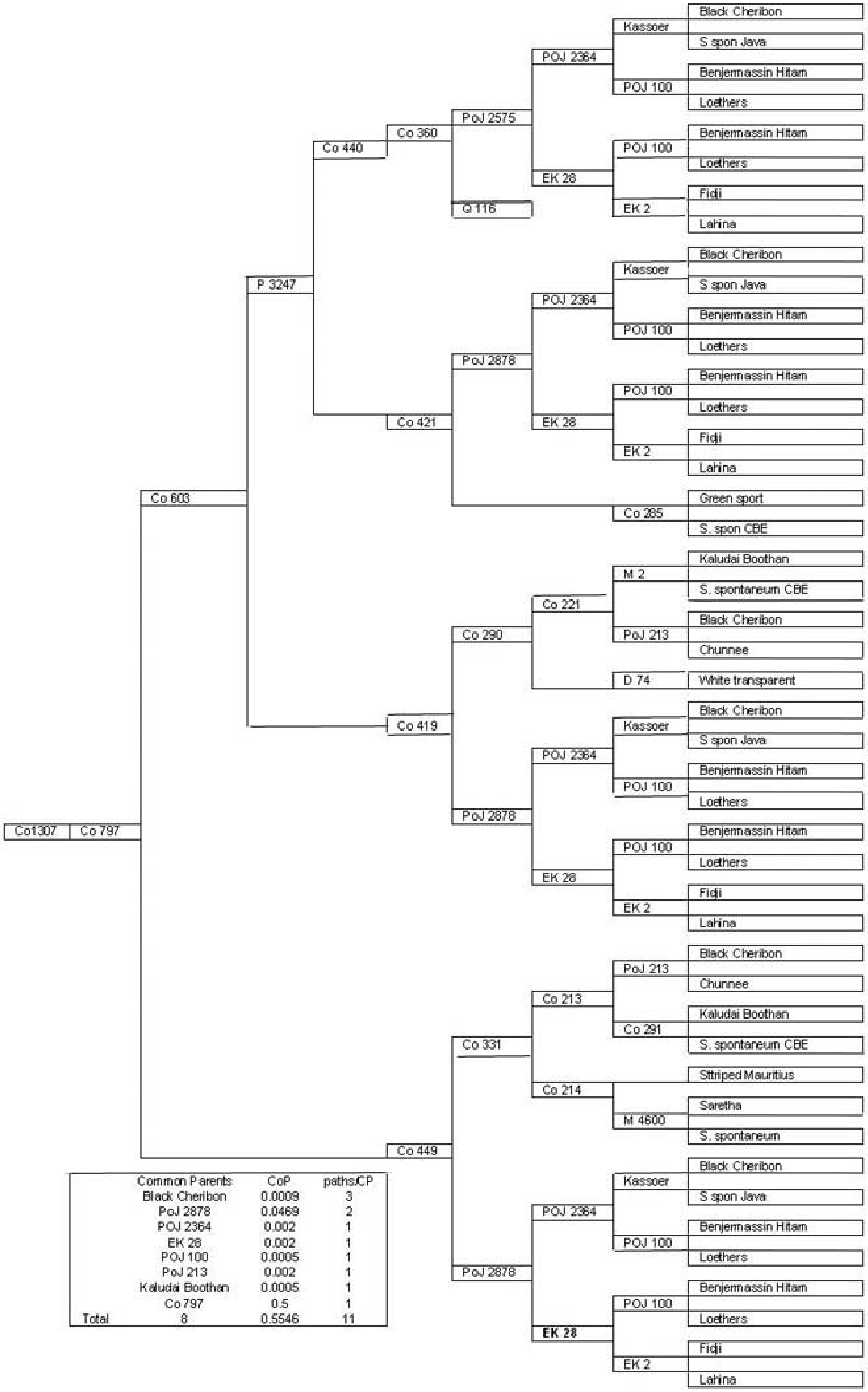
outside elite breeding clones was traced and the numbers of 'Co' canes developed from such combinations were counted and documented (Table 2). Similarly, the clones ('Co' canes) evolved from elite parental stocks with unknown males (open pollination, polycrosses) or from females only *viz.,* mutants, somaclonal variants, selfs, etc., were calculated.

Results and discussion

Decade-wise 'Co' canes produced and their gametic contribution

In sugarcane, an elite parent should possess good combining ability as well as regular flowering habit and should contribute desirable traits to its progeny *viz*., high productivity and sucrose content, resistance to diseases, drought tolerance and wider-adaptability. The decade wise genetic contribution of female and male clones (Table 1) indicated their extent of usage and potential to develop high number of superior cultivars. For decade I (1970-79), the parental information of only 229 'Co' canes was available and 177 of them were developed from bi-parental crosses. Sixteen breeding stocks were involved in evolution of $\leq$ 5 'Co' canes. These 16 clones produced 73.63% of 'Co' canes when used as pistil and 69.98% when used as pollen parents. Co 775 (67), Co 419 (41), Co 6806 (34), Co 740 (32) were most successful breeding clones in evolving more number of 'Co' canes during this decade. The contribution of Co 775 as male parent by producing 26.5% of the 'Co' canes was the highest. During decade II (1980-89), the highest numbers of 'Co' canes (357) were evolved and 23 breeding stocks contributed their 82.6% female gametes and 82.06% male gametes in evolving them. The maximum 'Co' canes (87) originated from CoC 671 followed by Co 775 (58) and Co 6806 (53). Decade III (1990-99) witnessed the development of a total 234 of 'Co' canes. Co 7201 and CoC 671 were the most successful parents as each of them have produced 43 'Co' canes, mostly as pistil parents. Co 62174, Co 7717, CoT 8201 and BO 91 were the other successful breeding clones. Among them, BO 91 contributed as pistil while others as pollen parent. A total of 23 breeding clones fall in the category of elite parental stocks, which produced $\geq$ 5 'Co' canes, with 64.56% relative contribution as pistil and 64.13% as pollen parents. During decade IV (2000-09) a total of 268 'Co' canes were produced and 233 of them were from bi-parental crosses. A total of 21 breeding stocks could produce $\geq$ 5 'Co' canes with their relative contribution of 67.90% as pistil and 66.55% as pollen parents. Breeding clone Co 86011, followed by Co 8371 were most successful as they were involved in development of 46 and 43 'Co' canes, respectively. Clones Co 86011, Co 775, CoT 8201, Co 88013 and MS 68/47 were the prominent pollen parents, while Co 8371, Co 7201, CoC671, Co 86002, CoC 90063 and CoLk 8102 were the prominent pistil parents.

On an average, about 100 of cross combinations with diverse background are being effected every year, but only limited breeding clones proved successful. The high success of breeding stocks Co 775, CoC 671, Co 7201, Co 6806, Co 1148, Co 419, Co 740, Co 6304, Co 86011, etc., indicated that these parental clones, contributed more selectable genetic variability through their gametes, which produced higher proportion of agronomicaly superior offsprings. Sugarcane breeders deliberately use those parents that produce elite progenies for further crossing as evident from the high number of typical clones still involved in the parentage of newer cultivars [23]. In general, new elite parental stocks replaced the older parental stocks as the breeding cycle advances, because the new parents were improved ones over the older ones for yield and quality. The same was observed in decade wise usage scenario also. Co 419 was the second most important parent during 1970-79 but was 9th during the decade 1980-89 and disappeared completely from the list of most successful parents during 1990-99 and 2000-09. Similar trend was observed with Co 740 and many other



	Common Parents	CoP	paths/CP
	Black Cheribon	0.0009	3
	PoJ 2878	0.0469	2
	POJ 2364	0.002	1
	EK 28	0.002	1
	POJ 100	0.0005	1
	PoJ 213	0.002	1
	Kaludai Boothan	0.0005	1
	Co 797	0.5	1
Total	8	0.5546	11

Fig. 2. Pedigree chart for Co 1307 (Fx=0.55)

Table 1. Decade-wise genetic contribution of elite breeding stocks in evolving 'Co' canes.

S.No.	Commonly used Parental stocks	No. of 'Co' canes evolved using parental stocks as			Relative contribution of elite parental stocks as	
		Female	Male	Total	Female	Male
Decade I (1970-79)						
1	Co 775	20	47	67	8.73	26.55
2	Co 419	30	11	41	13.10	6.21
3	Co 6806	0	34	34	19.20	19.20
4	Co 740	32	0	32	13.97	0.00
5	Co 1148	18	6	24	7.86	3.39
6	Co 1287	6	15	21	2.62	8.47
7	Co 1158	19	0	19	8.30	0.00
8	Co 658	8	10	18	3.49	5.65
9	NCO 310	15	3	18	6.55	1.69
10	BO 17	4	11	15	1.75	6.21
11	Co 62174	5	9	14	2.18	5.08
12	Co 312	9	3	12	3.93	1.69
13	Co 6602	8	2	10	3.49	1.13
14	Co 508	0	6	6	3.38	3.38
15	Q 63	5	0	5	2.18	0.00
16	Co 842	3	2	5	1.31	1.13
	Total	182	159		79.46	67.20
Total 'Co' canes evolved during decade		229	177			
Decade II (1980-89)						
1	CoC 671	34	53	87	9.52	16.11
2	Co 775	6	52	58	1.68	15.81
3	Co 6806	24	29	53	6.72	8.81
4	Co 7201	40	0	40	11.20	0.00
5	Co 7314	28	8	36	7.84	2.43
6	Co 62198	19	15	34	5.32	4.56
7	Co 1148	3	31	34	0.84	9.42
8	Co 6304	24	9	33	6.72	2.74
9	Co 419	26	3	29	7.28	0.91
10	Co 740	18	10	28	5.04	3.04
11	CoA 7601	11	9	20	3.08	2.74
12	Co 7704	17	1	18	4.76	0.30
13	Co 7717	1	13	14	0.28	3.95
14	MS 68/47	2	11	13	0.56	3.34
15	Co 658	4	8	12	1.12	2.43
16	BO 91	11	0	11	3.08	0.00
17	CoJ 58	8	0	8	2.24	0.00
18	Q 63	8	0	8	2.24	0.00
19	Co 7204	7	0	7	1.96	0.00
20	Co 62174	1	5	6	0.28	1.52
21	Co 7409	0	6	6	0.00	1.82
22	(57 NG 110 x NG 77-28)	0	5	5	0.00	1.52
23	Co 1158	3	2	5	0.84	0.61
	Total	295	270		82.6	82.06
Total 'Co' canes evolved during decade		357	329			

Decade III (1990-99)						
1	Co 7201	43	0	43	18.38	0.00
2	CoC 671	41	2	43	17.52	1.03
3	Co 775	0	28	28	0.00	14.36
4	Co 62174	0	18	18	0.00	9.23
5	Co 7717	2	14	16	0.86	7.18
6	CoT 8201	0	13	13	0.00	6.67
7	BO 91	11	0	11	4.70	0.00
8	Co 6806	7	2	9	2.99	1.03
9	C 79218	0	9	9	0.00	4.62
10	Co 86250	0	9	9	0.00	4.62
11	Co 6304	5	3	8	2.14	1.54
12	Co 1148	1	7	8	0.43	3.59
13	Co 7704	4	4	8	1.72	2.05
14	Co 740	7	0	7	2.99	0.00
15	Co 88002	7	0	7	2.99	0.00
16	Co 312	6	0	6	2.56	0.00
17	Co 88006	6	0	6	2.56	0.00
18	MS 68/47	0	6	6	0.00	3.08
19	Co 62175	3	3	6	1.29	1.54
20	Co 87008	5	0	5	2.14	0.00
21	Co 1307	0	5	5	0.00	2.56
22	CoA 7602	3	2	5	1.29	1.03
	Total	151	125		64.56	64.13
Total 'Co' canes evolved during decade		234	195			
Decade IV (2000-09)						
1	Co 86011	11	35	46	4.10	15.02
2	Co 8371	41	2	43	15.3	0.86
3	Co 85002	16	18	34	5.97	7.73
4	Co 7201	25	0	25	9.33	0.00
5	CoC 671	22	1	23	8.21	0.43
6	Co 775	2	19	21	0.74	8.15
7	CoT 8201	0	16	18	0.00	6.87
8	Co 88013	0	16	16	0.00	6.87
9	Co 89003	7	8	15	2.61	3.43
10	Co 86002	10	4	14	3.73	1.72
11	CoC 90063	14	0	14	5.22	0.00
12	CoLk 8102	14	0	14	5.22	0.00
13	Co 8353	8	1	9	2.99	0.43
14	MS 68/47	0	8	8	0.00	3.43
15	CoS 8436	4	3	7	1.12	1.29
16	Co 8347	3	4	7	1.49	1.72
17	BGC2 5021	5	0	5	1.87	0.00
18	IG 91-1100	0	5	5	0.00	2.15
19	OH 44	0	5	5	0.00	2.15
20	Co 1148	0	5	5	0.00	2.15
21	Co 86249	0	5	5	0.00	2.15
	Total	182	155		67.9	66.55
Total 'Co' canes evolved during decade		268	233			

parental stocks. But some breeding stocks are prolific in terms of producing successful 'Co' varieties *viz.,* Co 775 and CoC 671, which remained among top parental stocks for four and three decades, respectively.

Gametic contribution of elite breeding clones

During 1970-2009, fifty nine breeding stocks were under the category of elite parental stocks as they produced ≥ 5 'Co' canes each. They contributed their female gametes to 867 (79.7%) and male gametes to 746 (79.9% of bi-parental hybrid) of the 'Co' canes produced (Table 2). During the period under study, a total of 1088 'Co' canes were evolved and among them 934 were from bi-parental mating. So these bi-parental 'Co' canes received 1868 gametes (half each from male and female parent). Fifty nine elite parental clones transmitted 1613 gametes, which is 86.34% of the bi-parental 'Co' canes gametes. The parental usage scenario across the decades showed that on an average 27.3 of 'Co' canes were evolved per breeding stock. These stocks when used as female parent produced an average of 14.7 'Co' canes. The contribution of 18 parental clones as female was higher than average and they together evolved 60% of the 'Co' canes. Similarly, the average contribution of 59 breeding clones in evolving 'Co' canes as male was 12.6 each. Seventeen of breeding clones produced higher number of 'Co' varieties than average when used as male which accounted of 64% of the total 'Co' canes evolved during the studied period. Nine of the parental clones such as Co 775, CoC 671, Co 6806, Co 1148, Co 419, Co 6304, Co 7314, Co 62198 and Co 85002 were very successful male as well as female parents indicating their high breeding value.

Among the 59 elite breeding clones studied, only 48 were used as female and they contributed their gametes to 68% of 'Co' canes when inter-mated within elite and to 11.7% of 'Co' canes when mated with other males. Similarly, only 46 of the parental clones were used as male and they produced 67.5% of the 'Co' canes with elite clones and 12.4% of the 'Co' canes with other clones. Clones Co 88006, CoS 8436, Co 7321 and Co 7717 produced more number of 'Co' canes only when pollinated by a male parent amongst the elite breeding clones. This may be due to their high specific combining ability with elite pollen parents.

Similarly clones Co 7409, IG 91-1100 and 57 NG 110 x 28 NG 77 contributed their male gametes to specific females only. During the period under study, 154 (14.15%) 'Co' canes were produced without bi-parental mating (open pollinated, poly-crosses, selfs) or without mating (mutants, somaclonal variants) and 98 (63.7%) of them were developed using the 59 elite breeding stocks.

Coefficient of parentage/inbreeding

A parental stock with higher CoP will have more identical alleles by descent in its genome than a stock with lower CoP. The CoP varied from nil in BO 17, Q 63, Co 88002, Co 617, Co 853, Co 281, IG 91-1100, Co 87008 and 57NG110 x 28NG77 to 0.55 in Co 1307 (self of Co 797). Other clones with high CoP are Co 6807 (0.51, a self of Co 775), Co 508 (0.5, a self of Co 214), Co 62175 (0.42, first backcross of Co 419), Co 62198 (0.21), Co 740 (0.21), Co 85002 (0.17), Co 8312 (0.17) and Co 842 (0.16). The average CoP of the 59 elite parental clones was 0.09. It is in concurrence with the results (CoP = 0.048) observed in barley [8]. However, higher CoP was reported in Australian canola [9], and modern Russian wheat cultivars [24]. Twenty two breeding clones which have equal or higher CoP to the average, together contributed their gametes to 295 'Co' canes (27%) as female and to 231 bi-parental 'Co' canes (25%) as male. On the contrary, 37 breeding stocks with lower than the average CoP contributed 567 'Co' canes (52%) as female and 468 'Co' canes as males (50%) of the total 'Co' canes developed during this period. The higher success of genetically more diverse parental clones in evolving 'Co' varieties clearly indicate that they contributes more heterotic combinations in their offspring. So, it is advisable to choose parents with lower CoP in order to have more allelic diversity in the varieties getting evolved from them, which can have better adaptability and tolerance to abiotic stress factors. However, few breeding stocks like Co 6806 (0.15), Co 740 (0.21), Co 62198 (0.21) and MS 68/47 (0.15) having higher CoP values also produced more number of Co canes (21.04%). This may be due to the fact that they might have accumulated more selectable (additive) component of variability for yield and quality traits. In depth pedigree study revealed that 54 out of 59 elite breeding stocks has POJ 2878 either as immediate parent (3), or grand parent (27), or great grand parent (21) or great-great grand parent (3). It is found in the pedigrees of almost all dominant cane varieties grown around the world [29]. Though it was not successful as commercial variety in India, it might have desirable QTLs with tight linkage for agronomic and quality traits to make it a very successful genetic contributor among Indian breeding stocks. Similarly, other initial genetic stocks like POJ 213, Co 213, Co 285, Co 290, Co 291 and Co 312 are also present in most of the pedigrees. The

Table 2. Utilization pattern of successful breeding stocks with elite and non-elite stocks in evolving 'Co' canes.

S.No.	Elite stocks	CoP	No of 'Co' canes evolved from elite stocks						Other than bi-parenta 'Co' canes	Total "Co" canes	Crossing pattern of elite stocks			
			As Female with male			As Male with female					As Female with		As Male with	
			Elite	Other	Total	Elite	Other	Total			Elite	Other	Elite	Other
1	Co 775	0.01	28	0	28	126	20	146	2_{PC}	174	8	0	19	14
2	CoC 671	0.04	82	13	95	51	5	56	$3_{M}, 1_{PC}, 2_{S}, 10_{SV}$	151	16	12	8	4
3	Co 7201	0.07	69	39	108	0	0	0		108	19	16	0	0
4	Co 6806	0.15	25	4	29	55	11	66		95	11	3	12	5
5	Co 1148	0.08	19	3	22	43	6	49	$9_{OP}, 2_{S}$	71	3	3	17	3
6	Co 419	0.01	53	3	56	13	1	14	1_{OP}	70	8	2	4	3
7	Co 740	0.21	56	2	58	9	1	10	1_{OP}	68	10	2	3	1
8	Co 6304	0.03	29	2	31	12	5	17	1_{PC}	48	9	2	8	5
9	Co 86011	0.04	11	1	12	28	6	34	$1_{OP}, 1_{PC}$	46	3	1	6	6
10	Co 7314	0.03	30	1	31	12	2	14		45	7	1	5	2
11	Co 8371	0.09	34	7	41	2	0	2		43	4	5	1	0
12	Co 62174	0.04	5	1	6	29	6	35	4_{OP}	41	1	1	8	6
13	Co 62198	0.21	16	3	19	15	5	20		39	1	2	6	3
14	Co 85002	0.17	14	2	16	18	0	18	2_{OP}	34	5	2	3	0
15	Co 7717	0.14	4	0	4	24	4	28	$2_{PC}, 1_{SV}$	32	1	0	7	3
16	Co 7704	0.09	20	4	24	5	0	5	$1_{PC}, 9_{SV}$	29	4	3	4	0
17	CoT 8201	0.04	0	0	0	24	5	29		29	0	0	5	3
18	Co 658	0.02	12	0	12	16	0	16		28	4	0	6	0
19	MS 6847	0.15	2	0	2	22	3	25		27	1	0	9	3
20	Co 1158	0.13	19	3	22	1	3	4	5_{OP}	26	5	2	1	3
21	CoA 7601	0.10	10	4	14	8	3	11	2_{SV}	25	4	3	4	2
22	Co 1287	0.06	7	0	7	17	0	17	4_{OP}	24	2	0	5	0
23	BO 91	0.13	15	6	21	0	1	1	5_{OP}	22	5	4	0	1
24	N Co 310	0.01	14	1	15	7	0	7	$1_{OP}, 1_{PC}$	22	3	1	4	0
25	Co 312	0.13	16	1	17	5	0	5		22	7	1	4	0
26	Co 88013	0.04	0	0	0	13	3	16		16	0	0	2	3

27	CoC 90063	0.05	15	1	16	0	0	0		16	2	1	0	0
28	BO 17	0.00	3	1	4	11	0	11		15	1	1	2	0
29	Co 89003	0.04	7	0	7	4	4	8	7_{OP}	15	0	0	1	4
30	Co Lk 8102	0.04	6	8	14	0	0	0	1_{OP}	14	1	5	0	0
31	Co 86002	0.04	10	0	10	3	1	4		14	4	0	3	1
32	CoA 7602	0.07	8	1	9	1	3	4	1_{PC}	13	4	1	1	3
33	Q 63	0.00	12	0	12	0	0	0		12	3	0	0	0
34	Co 62175	0.42	5	2	7	2	1	3	1_{OP}	10	3	2	2	1
35	Co 86250	0.07	0	0	0	10	0	10		10	0	0	2	0
36	Co 6602	0.01	8	0	8	0	2	2	7_{OP}	10	1	0	0	1
37	Co 88002	0.00	9	1	10	0	0	0	2_{PC}	10	3	1	0	0
38	Co 678	0.03	7	0	7	2	0	2		9	3	0	1	0
39	Co 8353	0.10	5	3	8	0	1	1		9	2	1	0	1
40	Co 7321	0.04	4	0	4	5	0	5		9	1	0	2	0
41	CoJ 58	0.01	7	1	8	0	0	0		8	2	1	0	0
42	Co 8347	0.09	3	0	3	4	0	4		7	3	0	2	0
43	Co 975	0.04	7	0	7	0	0	0	1_{OP}	7	3	0	0	0
44	CoS 8436	0.10	4	0	4	1	2	3		7	1	0	1	1
45	Co 86249	0.09	0	1	1	0	5	5		6	0	1	0	3
46	Co 508	0.50	6	0	6	0	0	0		6	2	0	0	0
47	Co 1307	0.55	0	1	1	3	2	5		6	0	1	1	2
48	CoC 772	0.07	4	2	6	0	0	0	1_{PC}	6	1	1	0	0
49	Co 7409	0.04	0	0	0	6	0	6		6	0	0	1	0
50	Co 88006	0.04	6	0	6	0	0	0		6	1	0	0	0
51	Co 6807	0.51	0	1	1	5	0	5		6	0	1	5	0
52	Co 617	0.00	0	0	0	5	0	5		5	0	0	2	0
53	Co 853	0.00	4	1	5	0	0	0	1_{OP}	5	2	1	0	0
54	Co 281	0.00	5	0	5	0	0	0		5	3	0	0	0
55	IG 91-1100	0.00	0	0	0	5	0	5		5	0	0	1	0
56	Co 8213	0.17	0	0	0	0	5	5		5	0	0	0	2
57	Co 842	0.16	3	0	3	3	0	3	3_{OP}	6	0	0	2	0
58	Co 87008	0.00	2	3	5	0	0	0	2_{OP}	5	0	2	0	0
59	Hyb*	0.00	0	0	0	5	0	5		5	0	0	1	0
	Average	0.09	12.5	2.15	14.69	10.7	1.97	12.64	2.61	27.34	3.17	1.46	3.07	1.51
	Total	5.5	740	127	867	630	116	746	154	1613_A	187	86	181	89

Total (1), "Co' canes evolved during1979-2009 =1088, (2) Bi-parental canes = 934; total gametes in bi-parental canes = $934x2=1868_B$

% of total 'Co' canes 68 11.7 79.7 67.5 12.4 79.9 63.6 Gemetic contrib^n to bp canes $_{= (A/B*100)}$ 86.34%

Where Hyb*=57-NG 110 x 28-NG 77, $_{OP}$ = Open pollination, $_{PC}$ = Poly-cross, $_S$ = self, $_{SV}$ = somaclonal variant, $_M$ = mutant, bp = Bi-parental average CoP for breeding stocks as female (18 breeding stocks) which produced higher number of 'Co' canes than average number (14.7) was 0.093. The range of CoP among them varied from 0.01 (Co 775 and Co 419) to 0.21 (Co 740 and Co 62198) but majority of them had lower CoP than the average. Similarly 17 breeding clones, which produced higher number of 'Co' canes than the average as males had average CoP value of 0.074. The average CoP value for breeding clones which were very successful both as pollen and pistil parents was 0.081. Since the successful clones with highest of 0.21 and lowest of 0.01 CoP appeared in both male as well as female categories, the range of CoP was same for them. The lower average inbreeding coefficient in our study revealed enough genetic variability present in elite sugarcane breeding stocks though they have originated from limited number of basic ancestral clones. The sugarcane STMS marker based study [25] also suggested moderate genetic diversity in sugarcane breeding pool. However, other molecular markers based genetic diversity studies [26-28] on sugarcane hybrids in India indicated a narrow genetic base. The genetic diversity assessment using molecular markers varies with the marker system/technique, number of primers used, number and nature of plant material under study. Further, being a highly complex polyploid crop, the molecular marker system has its own limitations in sugarcane. So, pedigree analysis is a more realistic approach to assess the level of diversity present in the breeding material and will be more helpful to sugarcane breeders to design their cross combination.

Since, the analysis of inbreeding coefficients is solely based on accurate pedigree information; it may be questionable as in case of open bag pollination/pollen contamination or even unavailable as in case of poly-crosses and open pollination. The progeny from open pollination are from gametes contributed from unknown male parent including self. Many progeny from bi-parental crosses may also be partially self, in which inbreeding would be higher. Therefore, some of the inbreeding coefficients in this study could be higher than those worked out from pedigree. Further, sugarcane genome represents complex polyploid-aneuploid situation, where chromosome elimination is common, and due to the presence of multiples of same chromosome, it may not have any serious consequences on phenotype, even though this event reduce the genetic diversity more than the expected, particularly for disease resistance traits which were introgressed from parental wild species *S. spontaneum*.

The higher rate of success from early generation (4/5) recombinant *viz.*, Co 775, Co 419, Co 1148, Co 62198 and Co 1158 indicated that genetic stocks with novel (untapped) basic species clones can also be successful parents, which ultimately will be helpful in broadening the genetic base of future sugarcane varieties. Therefore, a new holistic strategy needs to be formulated towards utilization of untapped genetic resources of the basic species particularly *S. officinarum* and its related species and genera. Along with it the parental stocks with lower coefficient of inbreeding should be given more weightage in ongoing breeding programmes.

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