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Reduction in Intergeneration Time Interval in Selection of Sugarcane Varieties through Population Testing

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Abstract Traditionally, the variety testing scheme spans over a period of 13 to 15 years. In most countries all releases are based on small plot (i.e. seven stage) trials and small mill analysis. Rarely field planting and large mill tests are carried out with a crush of an hour which is the minimum time required. The current selection programme suffers from old concepts with sample testing and extrapolation of the data, which does not withstand the rigours of field conditions. The gap between the trial plots and field is large on both counts namely Pol% cane and yield. This paper discusses the population-testing concept to facilitate large mill testing and cutting down intergeneration time interval for releasing varieties. In the current scheme, the intergeneration time interval for releasing varieties is reduced from 13 years to 6 to 8 years. This was possible with a change in the variety testing concept. It was a population testing concept which includes early selection based on heritable characters like brix, fibre, pest and disease resistance and later 2.0 ha and more under field conditions. The best clones are taken for multiplication at three locations using single eye buds. The principle is that instead of using small plots, larger populations at three locations are used. The three varieties viz., PI 96-0151, PI 97-0843 and PI 97-1946 were multiplied along with Co 86-032. These varieties were tested in the large mill for their performance and behaviour under field conditions and compared with the standard variety Co 86-032. All the three varieties recorded higher yield and POCS% when compared with Co 86-032. The early and advance yield trial results are discussed and confirmed. We can release the varieties through large population test, much earlier as the system provides conclusive information on varietal performance under field conditions thus reducing the intergeneration time interval in selection of varieties for commercialization.

Keywords: *selection, sample testing, population testing, intergeneration time interval*

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1. Introduction

Since the comprehensive review of selection as in [8], innovations as in [2], selection methods for large clonal populations of sugarcane, as in [9,10], and early stages of varietal selection in Fiji as in [3], no major ground breaking studies were undertaken. In the past, the systems used for selection was based on statistical designs borrowed from cereal crops and vegetables which was found to be unsatisfactory for sugarcane. The release of varieties was found to be time consuming i.e. anywhere between 12-14 years and therefore sugarcane varieties could not be changed in a hurry and hence were cropped for milling for a longer period than was economical. On the other hand there was a constant pressure from the farmers and the millers for change of varieties in a shorter time, especially when faced with emergency like red rot disease in the coastal belts of India, rust in Australia, Ramu stunt in Papua New guinea and rust (*Puccinia melanocephala*) in Cuba.

The concept of statistically designed trial assumes that the trial is a sample of a population. It also assumes that G x E studies with randomization of the replicates within and at various locations will eliminate the variations caused by environmental factors. It also assumes that uniformity trials with confidence limits will be adequate to choose size of samples to be used for the study. Unfortunately for sugarcane, the trial designs were good to predict heritable characters such as sucrose percent juice, resistance to pests and diseases. However the parameters, which are governed by an array of environmental factors influencing qualitative and to some extent quantitative characters such as yield and flowering has very low correlation with the population under varying conditions. While the statistical principles are sound, its application to sugarcane suffers because even after six stages of testing many varieties fail to reach commercial levels. It was also found that the difference between the trials and field performance was always large. The current system does not help the breeder with good decision making processes to release varieties as demanded by the industry due to lack of data from large scale field planting.

Generally the formula $\mu = x \pm z\,\sigma x$ is used for the determination of population mean. Even in such cases, a sample standard deviation which is an estimator of the population standard deviation, is used to counteract an interval estimate as in [7].

Thus it was decided to use the principles of first selecting for heritable characters as in [3], combined with mass stool population screening as in [1], and finally by population testing for all characters both heritable and those influenced by environment such as yield, response to nutrients and water, and summer temperatures. The aim was to find a suitable method of testing without sacrificing any of the selection norms. The second objective was to commercialise varieties within the shortest possible time for which comprehensive tests were required such as true population yield and maturity patterns as influenced by various field conditions.

Population Testing Scheme

Schedule 2

The scheme followed was as follows:

Year	Stage	Plot Size	No. of Varieties	Basis
1	1	Single seedlings	50,000	Brix, fibre, visual observation : heritable features. Standards - 10%. ICT*
2	2	2 locations 1 row x 5m	2000	Brix, fibre, visual, field characters. Standards – 20%.
3	3	3 locations 4 rows x 5m x 4 replicates. Three locations.	100-150	Smut, red rot, observations for pests, biochemical composition and field data. Standards - 15%. MSP**
4	4	4 locations. Seed multiplication	30	Biochemical, field data. Use of single eye buds
5&6	Population Test.	4 locations Multiplication 20 ha scattered into one ha blocks or more.	5	Biochemical, field, environmental. Multiplication through single eye buds, tissue culture. Maturity testing, all field characters including yield and environmental. Population test.
7 – 8	6	Large mill test and commercialization	5	Concurrent

* Intensive care trial for heritable characters.

** Mass Stool Population.

All multiplication was through single eye buds for uniformity of populations.

The multiplication and field studies were undertaken under small farm ie one hectare cultivation practices. The test varieties and standards were planted at the same time in 1 ha blocks spread in different areas of the mill. All field data was observed and recorded. Maturity samples were drawn and analysed at 10th, 11th and 12th month. At harvest, yield data was recorded and samples i.e stalks were analysed along with cane crushed in large mill.

The biochemical analysis was carried as per CSR method as in [5]. Smut was tested using pin- prick method and red rot through nodal and plug methods. Borer observations were carried out in the trials. Field characters were graded on 1-9 scale.

2. Large Mill Tests

For large mill test, prior arrangements were made with the cane operations for harvest and transport, mill engineers and process personnel to allocate time and space in the mill. At least a hundred tonnes cane was used which was equivalent to an hours crush. This test was replicated at three mills of E.I.D. Parry (I) Ltd. Similar tonnage of the standard variety of the same age was crushed for comparison as in [4].

2.1. Data Systems

All data was generated over successive vegetative generations. i.e. continuous data system from stage 1 to 6 (over the years) through large blocks of population testing in a continuous manner was recorded and used for selection. Data was also pooled from various locations.

3. Results and Discussion

The data from stages 5 and 6 are summarised below in Table 1 and Table 2. It must be noted that the sucrose data provided is from small mill analysis and hence higher by 12% when compared with first roller juice of the mill as in [6]. The yield data is the extrapolation from the trial plots. This is invariably much higher than the actual field performance data as seen in Table 4 and Table 5.

Table 1. Average performance of PI 97 Series varieties in Preliminary Yield Trial (Stage – V) conducted in 2003 – 04 season

Sl. no.	Clone	Brix%	Pol%	Purity%	Fibre%	POCS%	TC/TS	Yield t/ha	TS/ha
1	PI 97-0003	20.80	18.64	89.59	13.30	14.14	7.07	133.88	18.81
2	PI 97-0373	22.40	19.74	88.13	13.72	14.71	6.80	157.75	23.20
3	PI 97-0527	21.95	19.45	88.62	15.34	14.25	7.02	137.63	19.61
4	PI 97-0710	21.75	19.53	89.79	13.98	14.71	6.80	114.25	16.80
5	**PI 97-0843**	**22.22**	**20.47**	**92.14**	**14.88**	**15.53**	**6.44**	**143.13**	**22.23**
6	PI 97-0897	21.05	19.33	91.63	13.86	14.82	6.75	137.00	20.30
7	PI97-0967	20.90	19.15	91.63	14.54	14.53	6.88	145.75	21.18
8	PI 97-1101	22.05	19.87	90.12	14.90	14.83	6.74	106.75	15.84
9	PI 97-1254	23.35	20.00	85.64	14.32	14.46	6.92	120.50	17.34
10	PI 97-1371	21.25	19.47	91.62	14.80	14.73	6.79	82.63	12.17
11	PI 97-1484	21.95	20.20	92.00	16.41	14.99	6.67	130.00	19.50
12	PI 97-1997	22.85	21.17	92.66	14.77	16.15	6.19	161.63	26.71
13	PI 97-2045	18.78	16.26	86.58	15.42	11.68	8.56	138.00	16.12
14	PI 97-2137	21.80	20.22	92.73	15.95	15.19	6.58	137.25	20.86
15	PI 97-2243	22.52	20.54	91.19	14.03	15.64	6.39	166.50	26.06
16	**PI 97-1946**	**21.40**	**19.25**	**89.96**	**13.96**	**14.53**	**6.88**	**165.63**	**24.07**
17	CoC 67-1	21.45	18.94	88.29	13.49	14.18	7.05	146.63	20.80
18	Co 86-032	21.41	18.98	88.65	13.18	14.32	6.98	115.06	16.48

Note : The crosses were made in Dec – January and seedlings planted during April.

The year number is the year in which seedlings were planted.

Table 2. Trial Name : PI 97 Series Trial (Stage – VI): Large, Scale Field Trial (Conducted in 2004 – 05 season)

Clone	Brix%	Pol%	Purity%	Fibre%	POCS%	TC/TS%	Cane yield/ha	TS/Ha
PI 97-0843	**20.25**	**18.23**	**89.99**	**13.05**	**13.92**	**7.18**	**138.11**	**19.24**
PI 97-0852	19.75	17.50	88.57	11.49	13.49	7.41	111.42	15.04
PI 97-0897	16.90	14.71	86.86	13.00	10.97	9.12	125.64	13.78
PI 97-0967	19.75	17.69	89.54	13.66	13.35	7.50	93.31	12.29
PI 97-1484	19.05	16.87	88.50	13.76	12.62	7.92	118.17	14.92
PI 97-1919	20.85	18.83	90.27	13.51	14.33	6.98	117.6	16.85
PI 97-1946	**19.25**	**17.19**	**89.24**	**12.83**	**13.09**	**7.64**	**149.14**	**19.52**
PI 97-1997	19.87	17.75	89.30	12.93	13.51	7.40	99.85	13.50
PI 97-2137	17.30	15.21	87.89	12.61	11.49	8.70	128.45	14.76
PI 97-2243	18.95	16.73	88.24	13.66	12.50	8.00	108.08	13.51
CoC 67-1	20.00	18.05	90.14	12.59	13.90	7.20	120.27	16.70
Co 86-032	19.90	17.40	87.44	13.65	12.91	7.75	98.89	12.76
F(Cal)	5.4	5.2	67.2	4.9				
CD(0.5%)	1.4	1.5	0.2	1.2				
CV%	5.1	6.1	1.2	6.9				

The yield data from field planting is summarized in Table 3 below:

Table 3. Field harvest data

Variety	Area (ha)	Tonnes crushed	TC/TS	TC/Ha	TS/Ha
Co 86-032	132.0	100.5	9.32	109.2	11.35
PI 96 - 151	16.0	108	8.71	110.5	12.7
PI 97 – 843	55.0	96	8.78	121.4	13.25
PI 97 – 1946	65	102	8.53	124.3	14.58

When the two results were compared i.e. trial (which is sample of a population) and the field planted cane – the population, there was a large difference to indicate that the measure for these characters in sample testing was misleading for test varieties and therefore the sample testing did not fulfill the need of predicting the performance of the test varieties. However sample testing was found to be a reasonable indicator at early stages for heritable characters.

Table 4. Variations in yield between samples (trials) and population (field)

Varieties	Stage-5	Stage 6	Mean for Stages 5 & 6	Population yield	Area planted in ha.	Difference in cane Yield t/Ha %	
PI 97 – 0843	143.13	138.11	140.62	121.4	55	16.33	13
PI 97 – 1946	165.63	149.14	157.39	124.3	110	33.0	26
Co 86-032	115.06	98.90	107.00	109.2	327	(-2.0)	0.1

While sucrose also varied considerably the trend was retained.

Table 5. Difference in sucrose

Variety	Trial			Field			Difference& %	
	POCS%	TC/TS	TS/Ha	POCS%	TC/TS	TS/Ha	TS/Ha	%
Co86-032	11.2	8.95	12.62	10.4	9.62	12.54	0.08	0.63
PI 97 – 0843	13.0	7.75	18.25	11.36	8.8	13.78	4.47	32
PI 97 – 1946	12.2	8.2	19.18	11.73	8.52	14.58	4.60	31

The new system has helped Parry to release the following varieties which is shown in Table 6 below

Table 6

Area in (ha) under varieties commercialised by E.I.D. Parry.					
Variety	**Pugalur**	**Nellikuppam**	**Pudukottai**	**Petavaithalai**	**Total**
PI 96-0151	350	87.0	16.0	472	925
PI 97-0843	194	1453	434	681	2762
PI 97-1946	444	9.0	121	630	1204
PI 01-0683	30	54	40	5.0	129
PI 97-0656	142	0.00	10	0.00	152
PI 99-1160	44	27	10	1.0	82
PI 96-0464	0.00	60	0.00	0.00	60
PI 01-4315	5.0	11	0.0	12	28
PI 97-4888	0.00	33	32	0.00	65
Under multiplication					
PI 00 – 1750	Nil	20	Nil	Nil	20
PI 00 – 1034	80	10	10	Nil	100
PI OTHERS*	21	18.0	7.0	0.00	45
Total	**1230**	**1751**	**670**	**180**	**5452**

It is evident from these series of trials that the breeders spend a lot of time and effort with no clear signal as to what the end results would be. Since this is a perpetual problem, it is desirable to split the selection in two parts namely early stages testing wherein heritable characters are used and in the second part resort to population testing under field conditions as early as possible so that better judgement can prevail. Another major factor which emerged was the resistance to red rot (*Colletotrichum)*. In case of Co 86 – 032 which was rated as highly susceptible to red rot disease (in test plots) was found to be highly resistant under field conditions. The same was true for many other varieties and vice - versa. It shows that the pathologists' tests are erroneous and hence it is imperative that we have to re-orient our selection procedure to come up with tangible data generated from reliable tests to identify varieties which will show fair expression. It is obvious that the data generated by the breeders and pathologists from small plots or samples are estimates of how a variety will perform and not necessarily what will be its behavior in the field and how it will interact with diseases and pests. The real test comes when the varieties are subjected to field planting and assessed for their environmental interactions.

Recently, Sugeshwari and Krishnamurthi as in [11] evolved a far more reliable method for red rot. This can be used successfully. Thus, when various objectives are defined it leads to accept the concept of population testing as a better option for the clonally generated population after initially screening them for genetic parameters.

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Appendix 1

Parry R&D Centre., EID Parry (India) Ltd.
Parry Varietal Improvement Programme

		Test variety		Control variety		Day average	
	Name of the variety	**PI 96-0151**		**Co 86032**		**Overall**	
	Mill / Parameters	P.Juice	M.Juice	P.Juice	M.Juice	P.Juice	M.Juice
1	Brix %	18.60	15.30	18.60	15.00		
2	Temperature	30	31	30.00	32.00		
3	Corrected Brix %	18.78	15.56	18.78	15.34	15.82	12.056
4	Polarization (Machine reading)	65.00	52.10	65.50	52.50		
5	Pol% in Juice	15.78	12.81	15.87	12.88	12.551	9.358
6	Pol% in cane	12.90	10.47	13.02	10.57		
7	Purity %	84.03	82.33	84.50	83.96	79.34	77.62
8	Fibre %	13.28	13.28	12.96	12.96	12.5	12.5
9	POCS %	11.48	9.19	11.64	9.40	8.85	6.49
10	Ton of cane req / Ton of sugar (TC / TS)	8.71	10.88	8.59	10.63	11.30	15.42
11	Juice pH	4.96	4.84	4.91	4.83	4.986	
12	Reducing Sugar %	0.77	0.84	0.76	0.82		
13	Reducing Sugar per 100 Brix	4.10	5.40	4.05	5.35		
14	Ash % conductivity	0.85	0.70	0.68	0.80		
15	Starch (ppm)	587	542	564	528		
16	Dextran (ppm)	65	74	61	75		
17	Nitrogen (ppm)	1176	728	1232	672		
18	Phosphate(ppm)	260	225	252	218		
19	Pottasium(ppm)	2795	2240	2805	2430		
20	Colour(ICU)	18003	21996	18395	21369		
21	Bagasse Moisture %	50.8	50.80	51.13	21		
22	Pol% in Bagasse	2.3	2.20	2.086	22		
23	Cane crushed – tonnes	108	100.53	23			

Note : Hourly crushing capacity 104 t/h.

Appendix 2

Parry R&D Centre, E.I.D. Parrry (I) Ltd.,
Parry Varietal Improvement Programme.
Large Mill Test

Unit	Pettaivaithalai	Pettaivaithalai
Season	0506M	0506M
Date	03.03.06	03.03.06
Shift	III rd	III rd
Time	1.00AM to 1.40AM	11.20 to 12.00 PM

		Test variety		Standard variety		Day average	
	Name of the variety	**PI 97-1946**		**Co 86032**		**Overall**	
	Mill / Parameters	P.Juice	M.Juice	P.Juice	M.Juice	P.Juice	M.Juice
1	Brix %	18.65	16.06	18.36	15.45	17.45	14
2	Polarization (Machine reading)	65.30	53.80	64.90	52.80		
3	Pol% in Juice	15.86	13.20	15.76	12.98	14.37	11.3
4	Pol% in cane	13.06	12.54	12.96	10.67	11.86	9.21
5	Purity %	85.04	82.19	85.84	84.01	82.35	80.71
6	Fibre %	12.64	12.78	12.50	13.50		
7	POCS %	11.73	11.71	10.41	7.97		
8	Tons crushed	102	82.784				
9	Ton of cane req / Ton of sugar (TC / TS)	8.53	8.54	9.61	7.57		
10	Juice pH	5.18	5.09	5.03	4.98		
11	Reducing Sugar %	0.88	0.98	0.81	0.89		
12	Ash % conductivity	0.69	0.81	0.67	0.78		
13	Starch (ppm)	545	495	525	480		
14	Dextran (ppm)	51	57	<50	55		
15	Nitrogen (ppm)	980	560	1120	840		
16	Phosphate(ppm)	403	347	362	313		
17	Pottasium(ppm)	3044	2308	3016	2060		
18	Colour(ICU)	19530	22701	18011	22029		
19	Bagasse Moisture %	51.0	51.0				
20	Pol% in Bagasse	2.6	2.22				

Appendix 3

Large Mill Test

Unit	Pudukottai	Pudukottai
Season	0405S	0405S
Date	16.03.2006	17.03.2006
Shift	IIIrd	IIIrd
Time	11.20-11.55 PM	11.25-12.00 PM

		Test variety		Standard variety		Day average	
	Name of the variety	**PI 97-1946**		**Co 86032**		**Overall**	
	Mill / Parameters	P.Juice	M.Juice	P.Juice	M.Juice	P.Juice	M.Juice
1	Brix %	19.10	15.10	18.40	15.30		
2	Temperature	30	31	29	28		
3	Corrected Brix %	19.28	15.36	18.51	15.34	17.37	14.33
4	Polarization (Machine reading)	73.30	56.40	70.50	55.20		
5	Pol% in Juice	17.72	13.86	17.11	13.57	14.40	11.60
6	Pol% in cane	14.62	11.44	14.08	11.17	11.88	9.57
7	Purity %	91.91	90.23	92.44	88.46	82.89	81.00
8	Fibre %	12.48	12.48	12.68	12.68	12.5	12.5
9	POCS %	13.79	10.66	13.32	10.29	10.48	8.31
10	Ton of cane req / Ton of sugar (TC / TS)	7.25	9.38	7.51	9.72	9.54	12.04
11	Juice pH	5.04	4.98	4.9	4.82	5.0	
12	Reducing Sugar %	0.79	0.91	0.72	0.81		
13	Reducing Sugar per 100 Brix	4.10	5.92	3.89	5.28		
14	Ash % conductivity	0.85	0.74	0.77	0.64		
15	Starch (ppm)	510	485	530	490		
16	Dextran (ppm)	<50	61	<50	60		
17	Nitrogen (ppm)	1080	780	1120	840		
18	Phosphate(ppm)	385	310	420	370		
19	Pottasium(ppm)	2884	2468	2678	2396		
20	Colour(ICU)	19584	22564	18152	21897		
21	Bagasse Moisture %	50.6	50.7	50.6			
22	Pol% in Bagasse	1.67	2.33	2.15			
23	Cane crushed – tonnes	96	70				