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Somu G
Ph.D. Scholar, Department of Genetics and Plant Breeding, University of Agricultural sciences, Bengaluru, Karnataka, India

Nagaraja TE
Professor (Plant breeding), AICRP on Sugarcane, Zonal Agricultral Research Station, V.C. Farm, Mandya, Karnataka, India

Variability studies in progenies of general cross combinations of sugarcane (*Saccharum* spp.)

Somu G and Nagaraja TE

Abstract
Exploitation of variability in a crop like sugarcane with a complex ploidy and a high level of heterozygosity is a complicated process. The main difficulty in improvement of sugarcane is selection at seedling stage. Further, it is a vital stage of selection because it provides the base population for remaining and more effective stages of selection. New sugarcane cultivars are developed through the selection of vegetatively propagated genotypes, obtained from true seed after hybridization of superior parents. The study was undertaken to determine the potential of general cross combinations in sugarcane, obtained by open pollinating the female parents CoSnk 05103, Co8313, Co 1148, CP 44-101 and CoSnk 03632 to generate variants for eight traits and frequency distribution pattern of variants, hence generated. 1666 seedlings raised from five general cross combinations, comprising high sugared commercial varieties were investigated. Left skewed distribution (Skewness<0) was observed in all GCs, thereby indicating that most values are concentrated on the right of the mean. Leptokurtic distributions in progeny of GCI, GCII and GC III derived from CoSnk 05103 and Co8313, inferred that distribution of progeny presented higher peaks around the mean compared to normal distributions, which leads to thick tails on both sides. This signified that the most of the seedlings from CoSnk05103 and CoSnk03632 performed superior to the population mean and in the direction of higher scale.

Introduction
Modern sugarcane (*Saccharum* spp.) is an important grass that contributes 60% of the raw sugar produced worldwide and has a high biofuel production potential. It was created about a century ago from the combination of the polyploid species *S. officinarum*, and *S. spontaneum* (D' hont *et al*., 1995) [3]. Proper exploitation of variability in a crop like sugarcane with a complex ploidy and a high level of heterozygosity is a complicated process (Babu *et al*., 2009) [1]. The main difficulty in improvement of sugarcane is selection at seedling stage. Further, it is a vital stage of selection because it provides the base population for remaining and more effective stages of selection (Ram Bakshi *et al*., 2009) [4]. New sugarcane cultivars are developed through the selection of vegetatively propagated genotypes, obtained from true seed after hybridization of superior parents. Selection at early stages in sugarcane breeding programmes is generally based on refractometer Brix and tiller number and millable cane are the important characteristics. Many breeders indicated that heritability of juice quality in sugarcane, including Brix (Shanthi *et al*., 2005) [6], is moderate to high and therefore can be improved with the correct selection pressure. Brix was highly correlated with sucrose and selection for high sucrose could begin as early stage and most of the genetic variation for Brix could be attributed to additive effects (Ram bakshi *et al*., 1997).

The study was undertaken to determine the potential of general cross combinations in sugarcane, obtained by open pollinating the female parents CoSnk 05103, Co8313, Co 1148, CP 44-101 and CoSnk 03632 to generate variants for eight traits and frequency distribution pattern of variants, hence generated. 1666 seedlings raised from five general cross combinations, comprising high sugared commercial varieties were investigated. The different traits of test seedlings evaluated in seedling nursery, *inferred* the generation of highly variable population with significant differences in test genotypes. Highly significant negatively skewed leptokurtic distribution of the progeny for Brix content in GCs obtained from Co 8313, CoSnk 05103, and CoSnk 03632 female parents indicated that the *tail* on the left side of probability density function was *longer* than the right side and the bulk of the values lie to the right of the mean.

Correspondence
Somu G
Ph.D. Scholar, Department of Genetics and Plant Breeding, University of Agricultural Sciences, Bengaluru, Karnataka, India

This indicated that Co 8313, CoSnk 05103, and CoSnk 03632 are potential female parents to generate high frequency of elite seedlings for Brix. The study suggested the scope of general cross combinations, which are less laborious, cost effective and generally yield more fluffs, to generate elite segregants for quantitative traits like sucrose content in sugarcane.

Experimental Material

The material for the study comprised of seedlings developed from the fluffs of different cross combinations effected at National Hybridization Garden, Sugarcane Breeding Institute, Coimbatore under AICRP (Sugarcane) and three standard checks *viz.* CoVC 99463, Co 86032 and Co 62175 were used

in this study for vigour and quality parameters during eksali 2014. The details of the different crosses and checks used in the present investigation are presented in Table 1. All seedlings of crosses were evaluated as per the specifications of AICRP (Sugar cane) at ZARS, V.C. Farm, Mandya. Six meters of row length with four feet of row to row spacing was maintained, seedling to seedling spacing one foot was used for evaluation during *eksali* 2014. All the recommended package of practices were adopted to raise the better crop stand. The main objective of the study was to estimate the genetic variability for number of tillers, number of millable canes, number of internodes, intermodal length and HR Brix per cent (top, middle and bottom).

Table 1: Pedigree of the genotypees of different cross combinations and checks in seedling nursery of sugarcane

S. No	Genotypes	Pedigree
General Cross (GC) combinations		
1	GC 14-61 (GC I)	CoSnk 05103 GC
2	GC 14-62 (GC II)	Co 8313 GC
3	GC 14-63 (GC III)	CoSnk 03632 GC
4	GC 14-65 (GC IV)	Co 1148 GC
5	GC 14-64 (GC V)	CP 44-101 GC
Standard Checks		
1	CoVC 99463	Co 6806 PC
2	Co 86032	Co 62198 × CoC 671
3	Co 62175	Co 951 × Co 419

GC = General Crosses

Results and Discussion

1666 seedlings derived from different crosses were evaluated for different trais was used for all statistical analysis. The individual seedlings were evaluated on unreplicated plots, descriptive statistics were worked out for each cross, the class intervals were constituted for all traits under study. The frequency distribution of progeny for millable cane and Brix content for each general cross combination was determined and represented graphically.

The analysis of variance was performed individually for each character and total variation was partitioned into different sources of variation. The results are presented in Table 2.

Analysis of variance revealed significant differences due to genotypes for all eight characters viz., number of tillers/plant, number of millable canes/plant, number of internodes, cane diameter, internode length, Brix per cent (top), Brix per cent (middle) and Brix per cent (bottom) in all cross combinations.

Table 2: Analysis of variance for eight characters in progenies of General cross Combination

S. No	Traits	Source of Variation					Error (MSS)
		Genotypes (MSS)					
		GC I	GC II	GCIII	GC IV	GC V	
		N=410	N=931	N=291	N=11	N=23	
1.	Tillers/plant	12.16**	9.61**	21.59**	23.85**	13.16**	1.23
2.	Millable canes /plant	9.03**	7.53**	15.92**	14.80**	9.45**	0.50
3.	Number of internodes	5.47*	7.79*	10.89*	8.60*	18.26**	3.30
4.	Cane diameter (cm)	0.11**	0.36**	0.80**	0.15**	0.18**	0.03
5.	Internode length (cm)	7.05**	8.87**	11.47**	5.46**	5.89**	1.17
6.	Brix per cent (Top)	5.34**	4.85**	5.72**	1.82**	6.22**	0.40
7.	Brix per cent (Middle)	5.33**	4.84**	5.81**	1.67**	6.13**	0.26
8.	Brix per cent (Bottom)	4.83**	4.48**	5.37**	1.74**	5.86**	0.16

* Significant at 5 % probability level
** Significant at 1% probability level

The heterogeneity was observed within cross**.** The treatments were, therefore adjusted and compared using respective critical differences. Highly significant differences in the test genotypes for all traits indicated the generation of highly variable population from general cross combinations in sugarcane.

The general statistics for each type of general cross combination viz., CoSnk 05103 (GC I), Co8313 (GC II), CoSnk 03632 (GC III), Co 1148 (GC IV) and CP 44-101 (GC V) were described in Table 3-5.

The highest mean value for millable canes per plant was

recorded (Table 3) in GC IV (10.00) followed by GC III (9.83) with range of 7.00 to 21.00 and 2.00 to 18.00 respectively, lowest mean was recorded in GC I (5.71). High variance (15.92) was observed in GC III followed by GC IV (14.80). Negative curtosis in GC I and remaining crosses shows positive kurtosis.

Total of 1666 progenies from different cross combinations were studied (Table 4). The highest mean value for cane diameter was recorded in GC V (2.24) and GC IV(2.17) with range of 1.50 to 3.10 and 1.60 to 2.90 respectively. High variance (0.36) was observed in GC II. All cross

combinations shows positive kurtosis for cane diameter except GC V.

Progenies from different cross combinations studied (Table 5), the highest mean value for bottom Brix per cent was recorded in GC IV (19.09 %) followed by GC III (18.93 %) and GC I (18.89 %) with range of 17.00 to 21.50, 10.50 to 22.70 and 9.50 to 22.50 respectively, while lowest mean was recorded in GC V (17.08). High variance (5.86) was observed in GC V followed by GC III (5.36) and lowest was observed in GC IV (1.74). All the cross combinations shows negative skewness for bottom Brix per cent. crosses viz., GC IV and GC V shows negative kurtosis and remaining crosses shows positive kurtosis for bottom Brix per cent.

Left skewed distribution (Skewness<0) was observed in all GCs, thereby indicating that most values are concentrated on the right of the mean. Graphically, the frequency distribution in the progeny of each GC was presented in Fig. 1-4. Leptokurtic distributions in progeny of GCI, GCII and GC III derived from CoSnk 05103 and Co8313, inferred that distribution of progeny presented higher peaks around the mean compared to normal distributions, which leads to thick tails on both sides. This signified that the most of the seedlings from CoSnk05103 and CoSnk03632 performed superior to the population mean and in the direction of higher scale and hence, surfaced as potential female parents to generate high frequency of elite seedlings for Brix content. The non- significant skewness was observed in the progeny of Co 1148 with the low percentage of extreme segregants.

Based on Brix value, the categorization of seedlings in three classes viz., poor (<16.0 Brix content), average (16.1-20.0 Brix content) and elite (> 20.1.0 Brix content), was done (Table 6). Cp-44-101 generated the highest per cent of elite (33.0) seedlings followed by GCIII (29.60), GCIV(27.30) and GCI(26.80) and GCII Co8313(14.70) having Brix content >20 per cent (Surinder *et. al.*, (2012) [7].

Table 3: Descriptive Statistics for number of millable canes/plant in Progeny of Different Cross Combinations

S. No	Cross Combination	No. of seedlings evaluated	Mean	SE	Minimum	Maximum	Variance	Skewness	Kurtosis
1.	GC 14-65 (GC IV) Co 1148 GC	11	10.00	1.77	7.00	21.00	14.80	2.72	8.24
2.	GC 14-64 (GC V) CP 44-101 GC	23	7.78	0.84	4.00	18.00	9.45	1.75	4.54
3.	GC 14-62 (GC II) Co 8313 GC	931	5.90	0.10	2.00	18.00	7.53	1.02	1.20
4.	GC 14-61 (GC I) CoSnk 05103 GC	410	5.71	0.17	2.00	15.00	9.03	0.81	-0.15
5.	GC 14-63 (GC III) CoSnk 03632 GC	291	9.83	0.27	2.00	18.00	15.92	0.85	1.75
	Total	1666							

GC = General Crosses

Table 4: Descriptive Statistics for cane diameter (cm) in Progeny of Different Cross Combinations

S. No.	Cross Combination	No. of seedlings evaluated	Mean	SE	Minimum	Maximum	Variance	Skewness	Kurtosis
1.	GC 14-65 (GC IV) Co 1148 GC	11	2.17	1.55	1.60	2.90	0.15	0.78	0.21
2.	GC 14-64 (GC V) CP 44-101 GC	23	2.24	1.04	1.50	3.10	0.18	0.31	-0.38
3.	GC 14-62 (GC II) Co 8313 GC	931	1.99	0.09	1.10	3.30	0.36	2.06	5.49
4.	GC 14-61 (GC I) CoSnk 05103 GC	410	1.98	0.12	1.30	2.80	0.09	0.57	0.01
5.	GC 14-63 (GC III) CoSnk 03632 GC	291	2.12	0.20	1.10	3.10	0.80	13.06	2.03
	Total	1666							

GC = General Crosses

**Table 5:** Descriptive Statistics for Brix per cent (bottom) in Progeny of Different Cross Combinations

| S. No.	Cross Combination	No. of seedlings evaluated	Mean	SE	Minimum	Maximum	Variance	Skewness	Kurtosis
1.	GC 14-65 (GC IV) Co 1148 GC	11	19.09	1.54	17.00	21.50	1.741	-0.320	-0.556
2.	GC 14-64 (GC V) CP 44-101 GC	23	17.08	0.82	12.00	20.50	5.864	-0.837	-0.74
3.	GC 14-62 (GC II) Co 8313 GC	931	18.37	0.07	10.00	23.00	4.482	-0.893	0.913
4.	GC 14-61 (GC I) CoSnk 05103 GC	410	18.89	0.12	9.50	22.50	4.833	-1.164	2.329
5.	GC 14-63 (GC III) CoSnk 03632 GC	291	18.93	0.15	10.50	22.70	5.366	-1.134	1.285
	Total	1666							

GC = General Crosses

Table 6: Performance of progeny in different general cross combinations

| S. No.	Crosses	% poor seedlings /population (<16.0 HR Brix)	% Average seedlings /population (16.1 -20.0 HR Brix)	% Elite seedlings/population (>20.1 HR Brix)
1.	GC 14-64 CP44-101 GC	26.10	40.90	33.00
2.	GC 14-63 CoSnk 03632 GC	13.70	56.70	29.60
3.	GC 14-65 Co 1148 GC	-	72.70	27.30
4.	GC 14-61 CoSnk 05103 GC	9.00	64.20	26.80
5.	GC 14-62 Co 8313 GC	15.40	69.90	14.70

GC = General Crosses
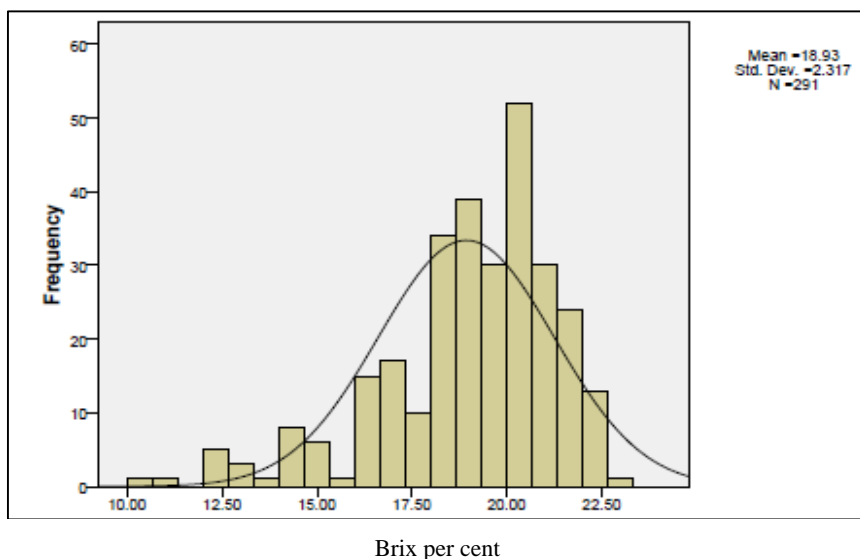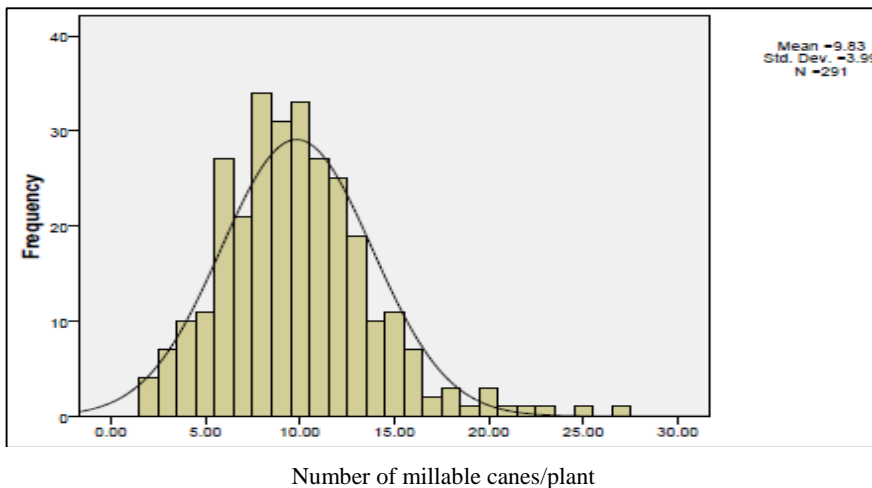
Fig 1: Frequency Distribution of Progeny of General Cross Combination of CoSnk 03632 (GC III) for number of millable canes/plant and Brix per cent
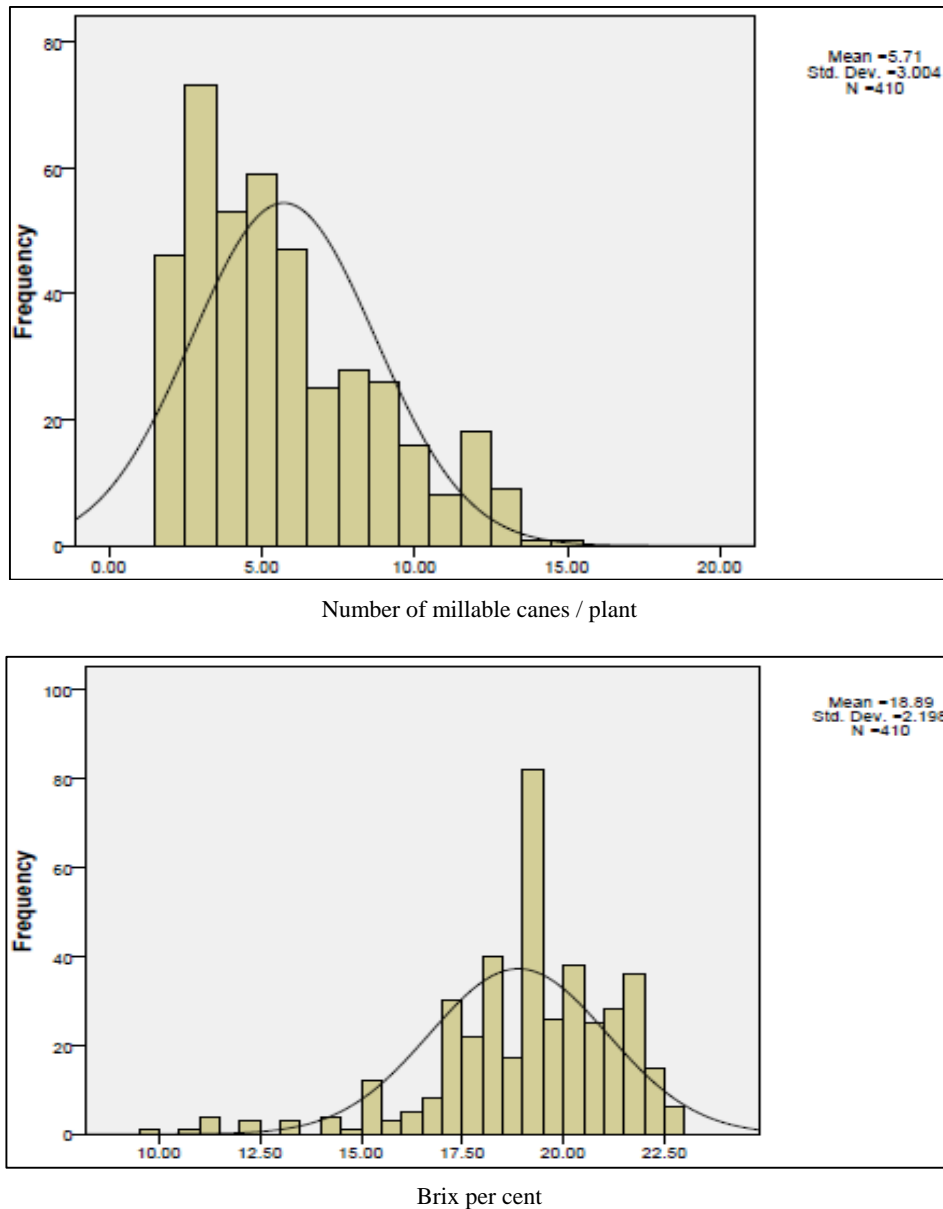

Number of millable canes/plant
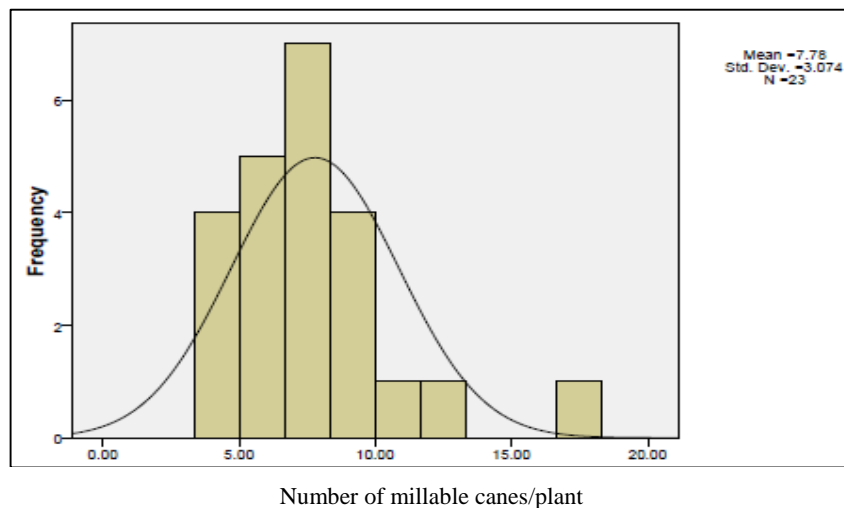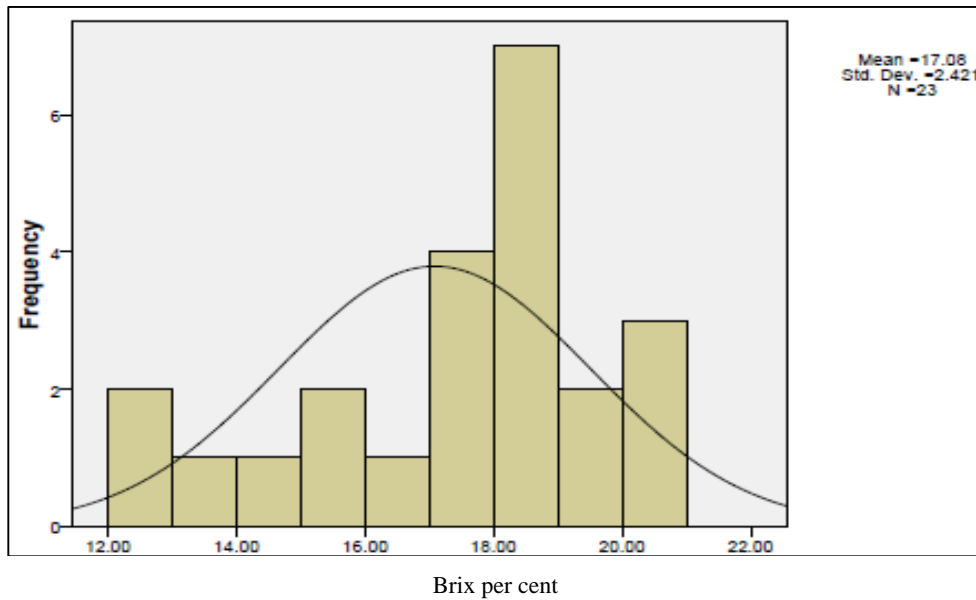
Fig 2: Frequency Distribution of Progeny of General Cross Combination of CP 44-101 (GC V) for number of millable canes/plant and Brix per cent
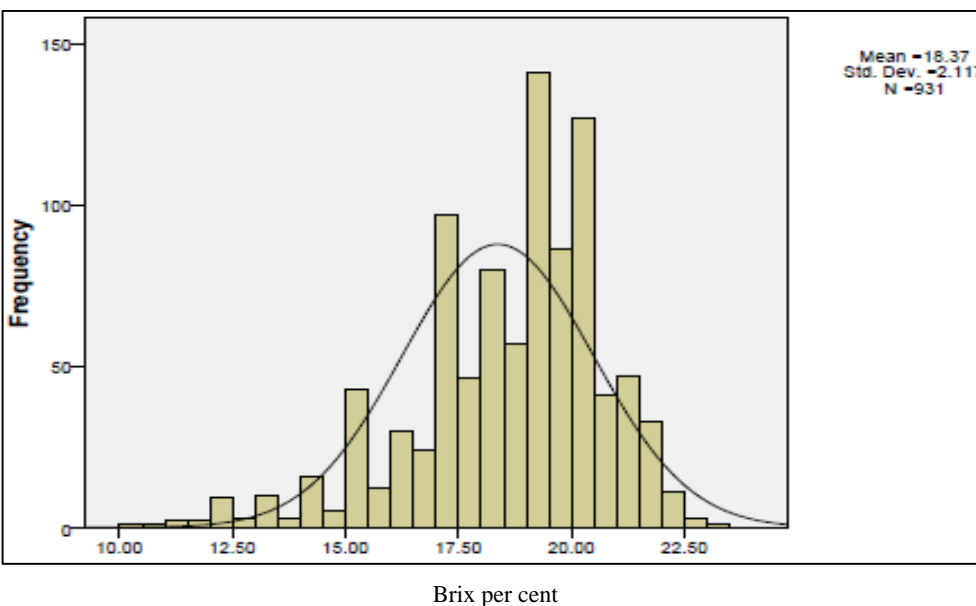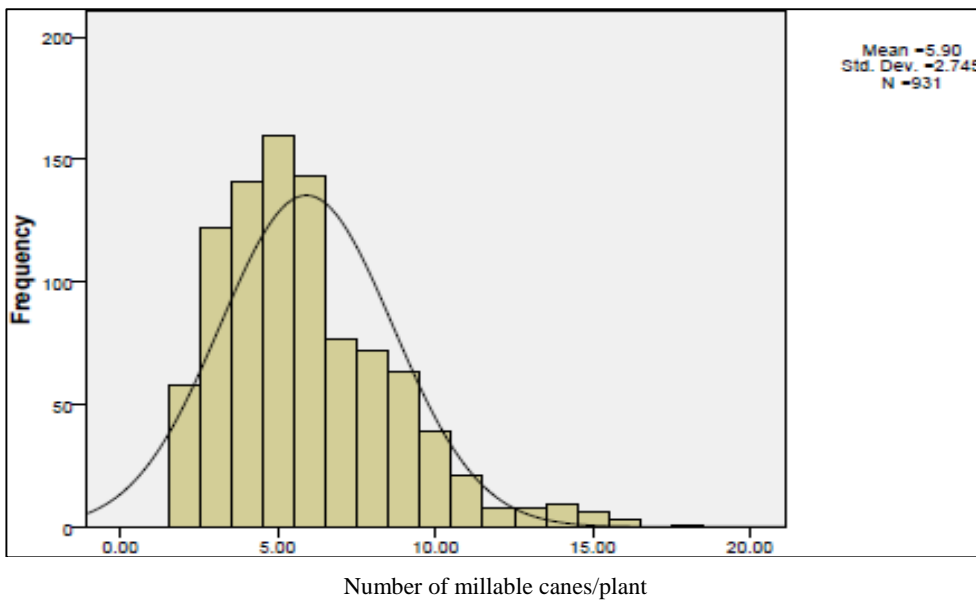
Fig 3: Frequency Distribution of Progeny of General Cross Combination of Co 8313 (GC II) for number of millable canes / plant and Brix per cent.

Fig 4: Frequency Distribution of Progeny of General Cross Combination of Cosnk 05103 (GC I) for number of millable canes / plant and Brix per cent

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