

# Selection in Sugarcane Germplasm under the Egyptian Conditions

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## Abstract

Two hundred and ninety four sugarcane germplasm, collected from different geographical origins in the world were planted at Mattana Agricultural Research Station (latitude of 25° 17' N and longitude of 32° 33'), Luxor Governorate, Egypt for evaluation and selection of the best ones. Genetic variation and genetic advance were studied under very wide of genotypes variation. The experimental work was conducted at two stages. The 1<sup>st</sup> one (March, 2014) was to evaluate the 294 genotypes for cane and sugar yields in a randomized complete block design with three replications and to select the best ones, based on sugar yield with 5% selection intensity. The 2<sup>nd</sup> stage aimed to evaluate the selected genotypes from the 1<sup>st</sup> stage for yield and quality traits and to compare them with the two prevailed commercial variety GT54-9 and the new one namely G2003-47 for two years as a plant cane grown in 2015-2016 season and its 1<sup>st</sup> ratoon in 2016-2017, in a randomized complete block design with two replications.

The results revealed highly variation among the evaluated 294 genotypes in all studied traits. High estimates of broad-sense heritability (H %) were obtained for all studied traits, which ranged between 87.19% for brix and 99.82% for stalk length. All evaluated traits had high heritability estimates with high genetic advance values under 5% selection intensity, indicating the high probability of selecting individuals with better performance in the next stages. Results of the 2<sup>nd</sup> stage showed that cane yield, sugar recovery, sugar yield, purity, sucrose percent and stalk length were highly heritable characters in both plant and its 1<sup>st</sup> ratoon cane crops, while stalk diameter and stalk weight were highly heritable only in the plant cane and 1<sup>st</sup> ratoon, respectively. Genotypic coefficient of variation (GCV%) estimates were greater than 10% for stalk length, sugar recovery and sugar yield and reached 17.80% for stalk weight, indicating the presence of genetic variability and potential of selection for these traits. The overall mean of the two seasons pointed out to six genotypes showing the superiority in sugar yield/fad, which were: EH88/5-27 (8.78 tons/fad), SP72-5181 (9.58 tons/fad), G2008-64 (10.13 tons/fad), G2008-20(10.50 tons/fad), G2007-61 (8.45 tons/fad), and G2006-36 (9.78 tons/fad) (fad = 4200m<sup>2</sup>) higher than that produced by the two check cultivars: GT54-9 (6.45 tons) and G2003-47 (8.43 tons/fad).

**Keywords:** Sugar cane (*Saccharum* spp); Germplasm; Genetic variance; Heritability; Genetic advance; Selection

## Introduction

Sugarcane is an ancient crop with a complex genetic history. Until the 20th century, sugarcane industries throughout the world relied on “noble canes” (*Saccharum officinarum* L.) for sugar production. However, since early in the 20th century most of the production world-wide has been derived from polyploid, aneuploid interspecific hybrids of two or more basic *Saccharum* species [1].

Sucrose yield in sugarcane is a product of cane yield and sucrose content of the cane. While both cane yield and sucrose content are important, increasing sucrose content has been a priority in the Egyptian sugarcane breeding programs. Most sugarcane breeding programs worldwide use modified recurrent selection for sucrose to increase the sucrose content of new cultivars [2]. Sugar yield from a cane crop is a complex attribute governed by a number of contributing factors. The relative importance of the components in the selection process may be determined only by knowing their respective contribution to sugar yield. The extent to which this component will respond to selection is also subject to genetic parameters such as variability, heritability and genetic advance [3].

The cane yield of sugarcane is influenced by many contributing traits combined with the environmental factors. Improvement in cane and sugar yields is the main objective of most of the breeding programs, especially for abiotic stresses [4].

Germplasm is the most important source of variability for various quantitative and qualitative traits required in a breeding program. Sugarcane varieties are the complex polyploids consisting of interspecific hybrids combining the genomes mainly of the *Saccharum* species like *Saccharum officinarum*, *Saccharum barberi*, *Saccharum sinense*, and *Saccharum spontaneum*. The world collection of sugarcane germplasm maintained at the Sugar Crops Research Institute, Agricultural Research Centre, Egypt, includes about 500 foreign hybrids, originating from the major sugarcane breeding stations.

Proper evaluation, screening, and documentation of the germplasms under specific condition would provide an estimate of their potential value as suitable donors for breeding purpose. Characterization and conservation of diversified plant genetic resources are the prerequisites for generation of genomic resources, which can be used by the breeders to develop stress tolerant cultivars [5].

In Egypt, sugarcane is usually grown commercially over four to five ratoon crops, and good performance in ratoon crops is an important attribute of sugarcane cultivars. In sugarcane breeding programs, genotypes normally are evaluated across one or more ratoon crops in most stages of selection. However, evaluation across ratoon crops in a multistage selection program significantly increases the time and resources needed for selection.

In the present study, an attempt was made to generate the information on genetic variability, heritability, and characters association among the yield contributing traits in old (out of cultivation) and new (under cultivation) accessions of germplasms to find out whether there are any genetic changes in both the populations and to identify parent for developing varieties suitable through breeding.

## Materials and Methods

Two hundred and ninety four sugarcane germplasm, collected from different geographical origins in the world were planted at Mattana Agricultural Research Station (latitude of 25° 17' N and longitude of 32° 33'), Luxor Governorate, Egypt for evaluation and selection of the best ones. Genetic variation and genetic advance were studied under wide genotypic variation. The experimental work was conducted at two stages as follows:

### Stage I

Each genotype of the evaluated germplasm (Table 1) was planted during the 1<sup>st</sup> week of March, 2014 in two rows of 5-m in length and 1-m width in a randomized complete block design with three replications. After 12 months from planting, the following data were recorded:

1. Millable cane height (cm) was measured from soil surface up to the top visible dewlap.
2. Millable cane diameter (cm) was measured at the middle part of stalks.
3. Brix% (total soluble solids percent) was determined using “Brix Hydrometer” according to A.O.A.C. [6].
4. Sugar content % was determined using the following equation of: Sugar content % = brix% x 0.69 [7].
5. Cane yield/fad (ton). (Fad = 4200 m<sup>2</sup>).
6. Theoretical sugar yield was assessed as follows: Sugar yield = cane yield (ton) x sugar content %.

Genotype	Origin	Genotype	Origin	Genotype	Origin
NA 56-79	Argentina, Norte	G 98-28	Egypt, Giza	G 2005-64	Egypt, Giza
59 A 506	Guatemala	G 2009-38	Egypt, Giza	G 84-68	Egypt, Giza
58 A 116	Guatemala	G 2009-73	Egypt, Giza	G 2009-86	Egypt, Giza
IS 76-183	Bangladesh, Ishurdi	G 2009-3	Egypt, Giza	G 2009-67	Egypt, Giza
62 B 201	Barbados	G 98-132	Egypt, Giza	G 85-166	Egypt, Giza
54 B 469	Barbados	G 95-19	Egypt, Giza	G 2009-37	Egypt, Giza
B 37-61	Barbados	G 2005-83	Egypt, Giza	G 2009-27	Egypt, Giza
B 36-21	Barbados	G 75-393	Egypt, Giza	G 2009-84	Egypt, Giza
IAC 5120	Brazil, Campinas	G 68-421	Egypt, Giza	G 95-21	Egypt, Giza
Sp 59-56	Brazil, Sao Paulo	G 69-55	Egypt, Giza	G 2004-27	Egypt, Giza
SP 80-3280	Brazil, Sao Paulo	G 87-149	Egypt, Giza	G 2009-11	Egypt, Giza
SP 80-1842	Brazil, Sao Paulo	G 2009-24	Egypt, Giza	G 2009-2	Egypt, Giza
SP 72-5181	Brazil, Sao Paulo	G 2009-34	Egypt, Giza	G 2009-12	Egypt, Giza
SP 70-1143	Brazil, Sao Paulo	G 73-185	Egypt, Giza	G 2009-40	Egypt, Giza
SP 81-1763	Brazil, Sao Paulo	G 2009-71	Egypt, Giza	G 2009-73	Egypt, Giza
SP 79-2233	Brazil, Sao Paulo	G 2008-58	Egypt, Giza	G 70-112	Egypt, Giza
SP 79-2233	Brazil, Sao Paulo	G 99-160	Egypt, Giza	G 2004-25	Egypt, Giza
SP 81-3250	Brazil, Sao Paulo	G 70-53	Egypt, Giza	G 84-47	Egypt, Giza
CB 38-22	Brizel, Campos, Rio de Janeiro	G 2009-5	Egypt, Giza	G 2009-99	Egypt, Giza
ROC 10	China	G 2009-45	Egypt, Giza	G 2006-3	Egypt, Giza
84 C 130	Cuba, Central Jaranu	G 74-96	Egypt, Giza	G 2007-13	Egypt, Giza
83 C 81	Cuba, Central Jaranu	G 2007-28	Egypt, Giza	G 2007-133	Egypt, Giza
83 C 37	Cuba, Central Jaranu	G 2009-42	Egypt, Giza	G 2005-47	Egypt, Giza
83 C 59	Cuba, Central Jaranu	G 2009-22	Egypt, Giza	G 2005-44	Egypt, Giza
GT 54-9	Egypt - Taiwan	G 2007-14	Egypt, Giza	G 74-99	Egypt, Giza
EN 4-2	Egypt- South Africa ( Natal)	G 99-80	Egypt, Giza	G 2006-36	Egypt, Giza
EN 5-2	Egypt- South Africa ( Natal)	G 2009-10	Egypt, Giza	G 2008-76	Egypt, Giza
EN 8-11	Egypt- South Africa ( Natal)	G 2008-64	Egypt, Giza	G 73-36	Egypt, Giza
EN 3-4	Egypt- South Africa ( Natal)	G 2000-5	Egypt, Giza	EH 87/81-6	Egypt, Hawamdeia
EN 3-6	Egypt- South Africa ( Natal)	G 2003-49	Egypt, Giza	EH 85/14-4	Egypt, Hawamdeia
EN 1-38	Egypt- South Africa ( Natal)	G 2003-38	Egypt, Giza	EH 87/101-4	Egypt, Hawamdeia
EN 5-1	Egypt- South Africa ( Natal)	G 73-189	Egypt, Giza	EH 87/31-11	Egypt, Hawamdeia
G. 47-84	Egypt, Giza	G 84-47	Egypt, Giza	EH 87/28-4	Egypt, Hawamdeia
G 99-122	Egypt, Giza	G 2009-14	Egypt, Giza	EH 87/15-1	Egypt, Hawamdeia
G 2002-9	Egypt, Giza	G 73-211	Egypt, Giza	EH 89/101-5	Egypt, Hawamdeia
G 2000-8	Egypt, Giza	G 2006-41	Egypt, Giza	EH 88/5-7	Egypt, Hawamdeia
G 2000-5	Egypt, Giza	G 2008-59	Egypt, Giza	EH 83/7-4	Egypt, Hawamdeia
G 2003-4	Egypt, Giza	G 2009-19	Egypt, Giza	EH 85-335	Egypt, Hawamdeia
G 2000-3	Egypt, Giza	G 98-24	Egypt, Giza	EH 88/5-50	Egypt, Hawamdeia
G 2003-47	Egypt, Giza	G 2008-20	Egypt, Giza	EH 87/102- EH 14	Egypt, Hawamdeia
G 2003-15	Egypt, Giza	G 2009-18	Egypt, Giza	EH 87/128-9	Egypt, Hawamdeia
G 2003-38	Egypt, Giza	G 2007-61	Egypt, Giza	EH 87/31-14	Egypt, Hawamdeia
G 2003-11	Egypt, Giza	G 2009-15	Egypt, Giza	EH 87/26-5	Egypt, Hawamdeia
G 2002-10	Egypt, Giza	G 2009-21	Egypt, Giza	EH 85/3-60	Egypt, Hawamdeia
G 75-313	Egypt, Giza	G 2009-41	Egypt, Giza	EH 88/5-27	Egypt, Hawamdeia
82 G 98	Egypt, Giza	G 2009-31	Egypt, Giza	EH 94-181-1	Egypt, Hawamdeia
G 87-149	Egypt, Giza	G 84-47	Egypt, Giza	EH 85/3-8	Egypt, Hawamdeia
Genotype	Origin	Genotype	Origin	Genotype	Origin
EH 87/25-35	Egypt, Hawamdeia	CO 182	India, Coimbatore	EI 44-2	Salvador
EH 88/27-1	Egypt, Hawamdeia	CO 617	India, Coimbatore	EI 4-20	Salvador
EH 85/3-39	Egypt, Hawamdeia	CO 467	India, Coimbatore	EI 62-15	Salvador
EH 94-119-72	Egypt, Hawamdeia	CO 475	India, Coimbatore	EI 4-40	Salvador

EH 85/2-19	Egypt, Hawamdeia	CO 284	India, Coimbatore	EL 18-1	Salvador
EH 87/40-17	Egypt, Hawamdeia	CO 997	India, Coimbatore	EI 58-28	Salvador
EH 85/19-2	Egypt, Hawamdeia	CO 662	India, Coimbatore	EL 8-1	Salvador
EH 87/31-11	Egypt, Hawamdeia	CO 798	India, Coimbatore	EI 58-28	Salvador
EH 89/8-27	Egypt, Hawamdeia	CO 331	India, Coimbatore	EI 27-2	Salvador
EH 87/26-11	Egypt, Hawamdeia	CO 1129	India, Coimbatore	EI 21-4	Salvador
EH 1-5	Unknown	CO 281	India, Coimbatore	EI 60-26	Salvador
EH 73-11	Unknown	KOEng Java	Indonesia	EI 242-16	Salvador
EH 16-9	Unknown	IN 84-003	Indonesia	EL 4-10	Salvador
EH 67-11	Unknown	IR 16-5	Iran	EL 18-4	Salvador
EH 16-1	Unknown	IR 28-10	Iran	EL 13-6	Salvador
EH 26-3	Unknown	PS 87-2378	Java, Pasuruan	EI 27-2	Salvador
EH 128-2	Unknown	PS 79-54	Java, Pasuruan	EI 44-5	Salvador
EH 26-2	Unknown	PS 81-640	Java, Pasuruan	NCO 339	South Africa – India
E 37-10	Mauritius	PS 80-1007	Java, Pasuruan	84 N 5	South Africa, Natal
84 E 1	Mauritius	PS 82-1098	Java, Pasuruan	N 26	South Africa, Natal
86 E 409	Mauritius	PS 77-155	Java, Pasuruan	N 11	South Africa, Natal
69 E 18	Mauritius	PS 80-1424	Java, Pasuruan	K 81113	Sri Lanka, Kantalai
E 32-70	Mauritius	M 57-35	Mauritius	F 150	Taiwan
86 E 131	Mauritius	M 35-157	Mauritius	F 36-81	Taiwan
43 E 35	Mauritius	M 253-48	Mauritius	F 161	Taiwan
IK 76-63	Unknown	M 55-157	Mauritius	84 K 1	Thailand
IK 76-79	Unknown	Mix 58-1868	Mexico	CP 63-35	USA (Florida, Canal Point)
A 63-10	Guatemala	Mix 2001-80	Mexico	CP XXXXX	USA (Florida, Canal Point)
A 63-20	Guatemala	Mix 58-1866	Mexico	CP 46-115	USA (Florida, Canal Point)
62 D 509	Guyana , Demerara	Mix 2001-80	Mexico	CP 63-46	USA (Florida, Canal Point)
83 D 49	Guyana , Demerara	PH 10	Philippines	CP 57-614	USA (Florida, Canal Point)
86 D 1	Guyana , Demerara	EI 43-84	Salvador	CP 72-35	USA (Florida, Canal Point)
86 D 296	Guyana , Demerara	EL 4-4	Salvador	CP 67-412	USA (Florida, Canal Point)
BO 3	India, Bihar, Orissa	EI 17-178	Salvador	CP 43-44	USA (Florida, Canal Point)
BO 22	India, Bihar, Orissa	EI 4-40	Salvador	CP 76-331	USA (Florida, Canal Point)
BO 18	India, Bihar, Orissa	EI 33-17	Salvador	CP 44-101	USA (Florida, Canal Point)
BO 21	India, Bihar, Orissa	EI 36-80	Salvador	86 L 37	USA (Louisiana)
BO 41-24	India, Bihar, Orissa	EI 8-129	Salvador	L 60-25	USA (Louisiana)
CO 214	India, Coimbatore	EI 58-37	Salvador	L 61-49	USA (Louisiana)
CO 1157	India, Coimbatore	EI 7-44	Salvador	L 62-96	USA (Louisiana)
CO 775	India, Coimbatore	EI 21-20	Salvador	86 L 37	USA (Louisiana)
CO 284	India, Coimbatore	EI 4-49	Salvador	CI 47-143	USA, Florida, Clewiston
CO 744	India, Coimbatore	EI 8-10	Salvador	CI 47-83	USA, Florida, Clewiston
CO 624	India, Coimbatore	EI 45-43	Salvador	PR 1059	USA, Puerto Rico
CO 603	India, Coimbatore	EI 60-13	Salvador	PR 1013	USA, Puerto Rico
CO 859	India, Coimbatore	EI 4-21	Salvador	US 59-161	USA, South Florida
CO 775	India, Coimbatore	EI 8-129	Salvador	69 H 5	USA, Hawaii
CO 349	India, Coimbatore	EI 47-2	Salvador	H 86-371	USA,Hawaii
CO 395	India, Coimbatore	EI 24-2	Salvador	H 86-486	USA,Hawaii
BP 41-227	Unknown	EI 23-4	Salvador	S	Unknown
EPC 10232	Unknown	EI 264-2	Salvador	NS 3-3	Unknown

Table 1: Geographic origins of tested cane materials.

**Stage II**

A total number of 14 sugarcane genotypes from stage I were selected as the best ones based on sugar yield at 5%

selection intensity, to be evaluated in stage II as a plant cane and its 1<sup>st</sup> ratoon crops. They were replanted during the 1<sup>st</sup> week of March, 2015 in three rows of 5-m in length and 1-m in a randomized complete block design with two

replications. Two standard cultivars (the commercial variety GT 54-9 and new variety G2003-47) were used as checks. Planting was achieved by placing twenty five 3-budded cane cuttings in each row. The field was irrigated right after planting and all other agronomic practices were carried out as recommended by Sugar Crops Research Institute. Harvest took place at age of 12 months in both plant and 1<sup>st</sup> ratoon cane crops. In addition to the traits recorded at stage I, the following traits were determined for each genotype in stage II:

1. Sucrose percentage of clarified juice was determined using automated Sacharimeter according to A.O.A.C. [6].
2. Juice purity percentage was calculated according to the following equation of: Juice purity % = (sucrose % / brix %) x 100 [8].
3. Sugar recovery % was calculated according to the following equation, described by: Sugar recovery % = [sucrose % - 0.4 (brix % - sucrose %)] x 0.73 [9].
4. Cane yield/fad (ton) was determined from cane weight of each plot (kg), which was converted into ton per fad.
5. Sugar yield/fad (ton) was calculated according to the following equation as described by Mathur: Sugar yield/fad (ton) = cane yield/fad (ton) x sugar recovery% [10].

### Statistical Analysis

The collected data were statistically analyzed according to the procedures outlined by Snedecor and Cochran to estimate the following criteria [11]:

#### a. Estimation of Variance Components

Genotypic and phenotypic components of variance were estimated with the help of following formulae:

Genotypic Variance ( $\sigma^2 g$ ) = gMS - eMS

Phenotypic variance ( $\sigma^2 p$ ) =  $\sigma^2 g$  + eMS

#### b. Coefficient of Variability

Both genotypic and phenotypic coefficient of variability were computed for each character as per method suggested by Burton and Devane (1953)

Genotypic Coefficient of Variation (GCV) % was estimated as:

$$(GCV) \% = (\delta g / \text{general mean}) \times 100.$$

Phenotypic Coefficient of Variation (PCV) % was estimated as:

$$(PCV) \% = (\delta p / \text{general mean}) \times 100.$$

Where:

$\delta g$  = genotypic standard deviation

$\delta p$  = phenotypic standard deviation

Heritability (H) in broad sense was computed for each character as the ratio of genetic variance to the total variance as suggested by Hanson, et al. (1956)

$$H = \sigma^2 g / \sigma^2 p \times 100$$

Where,

$\sigma^2 g$  and  $\sigma^2 p$  are genotypic and phenotypic variances respectively.

Expected genetic gains from selection as % of mean (GA %) were calculated following the formula adopted by Falconer:

$$GA = K \times H \times \delta p$$

GA as % of mean = (GA / general mean) x 100

Where:

K= 2.06 for 5% selection intensity,  $\delta p$  = phenotypic standard deviation and H = broad sense heritability.

To compare between treatment means, LSD at 5% level of significance was used according to Steel and Torrie [12]. All statistical analyses were performed using analysis of variance technique of (MSTAT-c) computer software package and Genes computer software package.

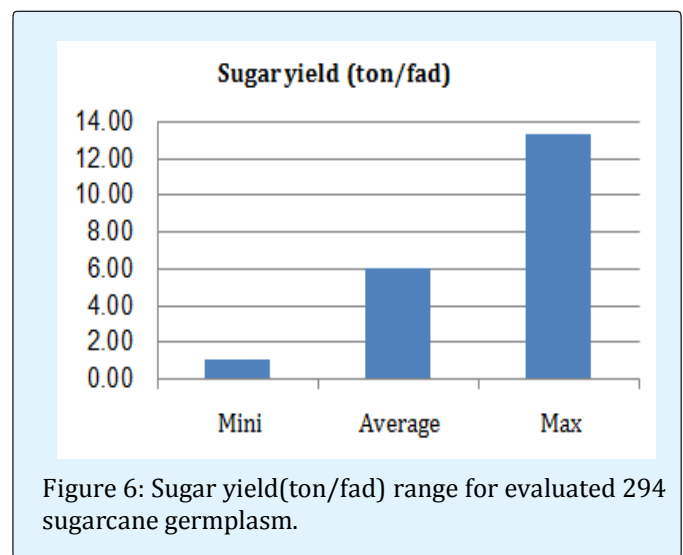
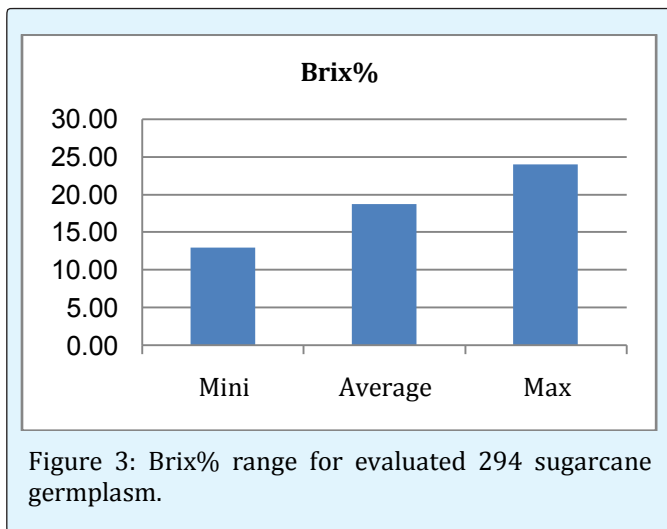
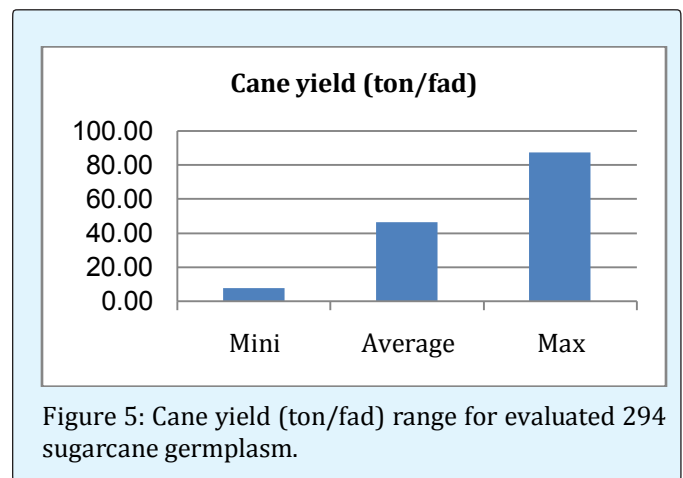
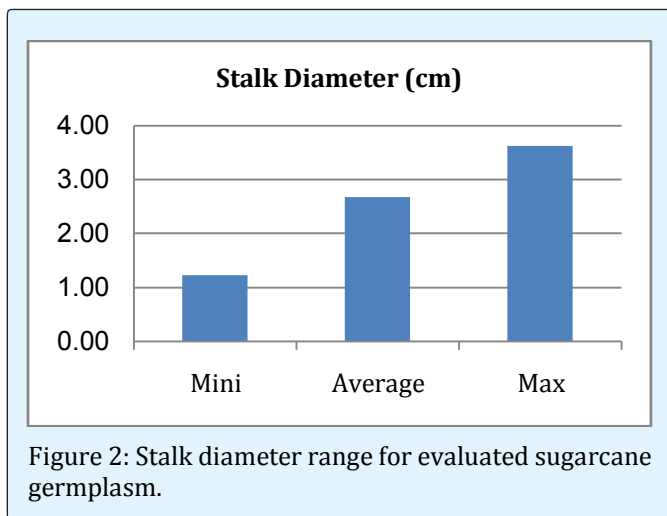
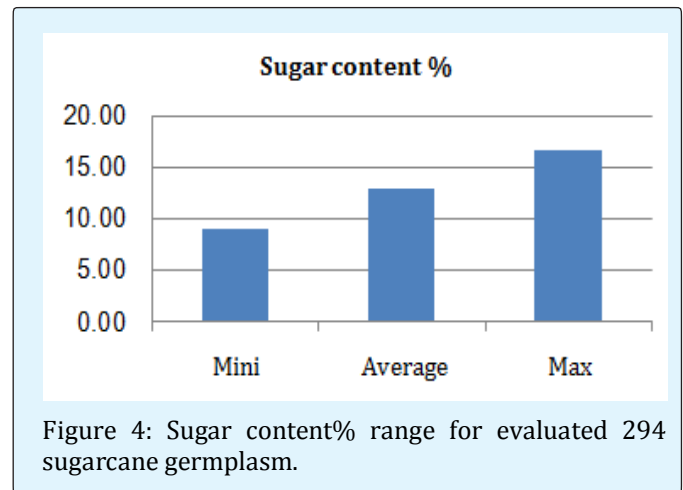
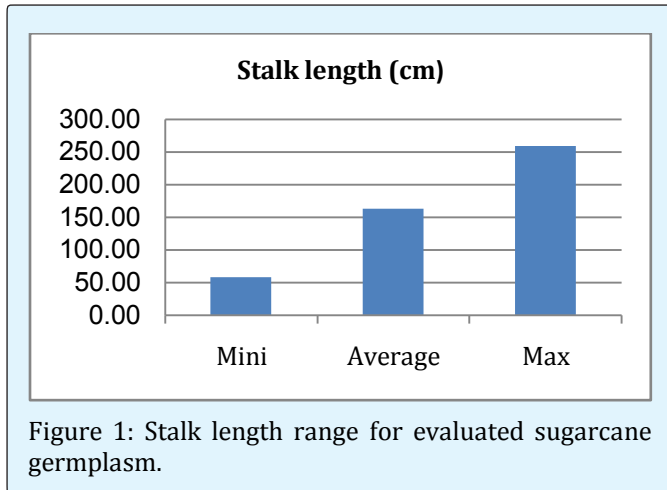
## Results and Discussion

The discussion of the obtained results begins with the first stage of selection among 294 sugarcane germplasm for the studied traits. Thereafter, data of the best selected 14 ones will be discussed.

### The First Stage

The results revealed higher range of variance among the evaluated 294 genotypes in the studied characters, *i.e.* stalk length, diameter, brix%, sugar content%, cane and sugar yields/fad (Figures 1-6). A wide variation was obtained in stalk length of genotypes at harvest, which ranged from 58 to 259 cm. Likewise, values of 1.22 to 3.62 cm were observed for stalk diameter of the tested genotypes. Juice brix showed a great variation ranged from 13 to 24%, while the recorded values of sucrose% ranged from 8.97 to 16.56%. Moreover, an extreme variance of 7.74-87.26 and 0.98-13.25 ton/fed was detected in cane and sugar yield, successively.





Component	Stalk length	Stalk diameter	Brix	Sugar content	Cane yield	Sugar yield
$\sigma^2e$	1.96	0.004	0.58	0.28	1.22	0.06
$\sigma^2g$	1114.47	0.2	3.97	1.89	191.41	3.98
$\sigma^2p$	1116.42	0.2	4.55	2.17	192.63	4.04
H%	99.82	98.16	87.19	87.19	99.37	98.43
GCV%	20.47	16.54	10.64	10.64	29.66	32.97
PCV%	20.49	16.7	11.4	11.39	29.75	33.24
GA%	42.13	33.76	20.47	20.47	60.9	67.39

Table 2: Variance components, coefficients of variation, broad sense heritability and genetic advance for studied traits of 294 sugarcane germplasm in stage one.

### Genotypic and Phenotypic Variance

After partitioning phenotypic variance, it was found that genotypic variance was higher than the environmental one for the six characters studied (Table 2). The magnitude of variance was the highest in stalk length ( $\sigma^2g = 1114.47$ ,  $\sigma^2e = 1.96$ ) followed by cane yield/fed ( $\sigma^2g = 191.41$ ,  $\sigma^2e = 1.22$ ). These results indicate that a negligible role was played by the environmental factors in the inheritance of these characters in sugarcane. The high genotypic variance in stalk height, diameter and brix was also reported by Singh and Singh [8].

### Genotypic and Phenotypic Coefficients of Variation

The estimates for phenotypic coefficient of variation (PCV) were closed with genotypic coefficient of variation (GCV) in all the traits, indicating lower influence of environment on genetic variation (Table 2). The highest phenotypic and genotypic coefficient of variation were observed for sugar yield (PCV = 33.24% and GCV = 32.97%) followed by cane yield/fed (PCV = 29.75% and GCV = 29.66%) and stalk length (PCV = 20.49% and GCV = 20.47%). High genotypic and phenotypic coefficients of variation for stalk height, stalk diameter, brix % and cane yield were reported by Singh RK, Singh GP [13].

### Heritability

Genotypic coefficient of variation is not a correct determine the heritable variation present and should be considered together with heritability estimates. Table, 2 illustrated that high heritability estimates were recorded for all characters, stalk length (99.82%), yield/fed (99.37%), sugar yield (98.43%), stalk diameter (98.16%), brix and sugar content (87.19%). These findings suggest that simple selection for these traits would be more effective. High heritability estimate for stalk diameter was reported by Chaudhary RR [14]. Similarly, Jamoza, et al. also found high heritability for stalk diameter and moderate heritability for cane yield [15].

### Genetic Advance

Heritability estimates along with expected genetic gain is more useful than the heritability value alone in predicting the resultant effect for selecting the best genotypes [16]. Genetic gain, expressed as percent of mean, came in the following descending rank: sugar yield (67.39%), cane yield/fed (60.90%), stalk length (42.13%), stalk diameter (33.76%), brix (20.47%) and sugar content (20.47%), indicating that there is a scope to improve cane yield to a considerable extent by adopting suitable breeding procedures (Table 2). High genetic advance in cane yield was also reported by Jamoza JE, Owuoche J, Kiplagat O, Opile W [15].

Total soluble solids and sugar content had high heritability with moderate genetic advance. Gravois and Milligan illustrated that moderate heritability with low genetic advance in sugar quality parameters indicate the presence of non-additive gene action [17]. Therefore, simple selection on phenotypic performance may not be effective. Gulzar et al. reported that moderate to high heritability coupled with high genetic advance were recorded for juice/cane, juice extraction % and sucrose per cent [18]. Tena, et al. found that moderate broad sense heritability estimates were found in sugar % and brix %, this suggests that a considerable proportion of the total variance is heritable and selection of these traits would be effective [19]. The results suggest that selection should be practiced on the basis of sugar yield, yield/fed, stalk Length and diameter for higher cane yield. Improvement in these traits would lead to a significant increase in yield in limited selection cycles.

### The second Stage

Data in Tables 3-5 cleared that the 14 selected genotypes from the first stage differed significantly ( $P = 0.05$ ) in all studied traits; stalk diameter, stalk length, stalk weight, brix%, sucrose%, juice purity%, sugar

recovery%, cane and sugar yields, in plant cane and first ratoon.

**Stalk Diameter:** Results in table 3 showed that the selected genotypes varied significantly in stalk diameter, in the plant cane and first ratoon, and their mean. The two genotypes namely SP72-5181 and G2006-36 recorded significantly higher than that of the two check varieties; GT54-9 and G2003-47 in the plant cane, first ratoon and their mean.

**Stalk Length:** Data in Table 3 revealed that the tested genotypes differed markedly in stalk length, in the plant cane and first ratoon. Stalk length varied from 225 cm for the genotype M57-35 in the plant cane and 231.5 cm for the commercial variety GT54-9 in first ratoon to (352.5 and 358.5 cm) for the genotype EI58-37 in the plant cane and first ratoon, respectively. The five genotypes; F150, EI58-37, F161, G2008-64 and G2003-49 gave significantly taller stalks as compared to two check varieties GT54-9 and G2003-47, in the plant cane and first ratoon. These

results are in agreement with those mentioned by Yousif, et al. Mehareb, et al, Mehareb and Abazied, Ahmed, who found that the tested varieties significantly differed in stalk height and diameter [20-23].

**Stalk Weight:** Results in Table 3 indicated that the evaluated genotypes differed substantially in stalk weight, in the plant cane and first ratoon, and the mean of the two cane crops. In the plant cane, the genotype F161 recorded the highest mean value of stalk weight. Three genotypes namely F161, G2008-64 and G2006-36 had significantly higher than that recorded by the two check varieties; GT54-9 and G2003-47. In first ratoon, most of genotypes were significantly higher than the two check varieties in this growth trait. Moreover, F150 recorded the highest mean value of stalk weight in the first ratoon and overall mean of the two seasons. These results are in agreement with those reported by El-Shafai and Ismail, Yousif, et al., Mehareb, et al., Mehareb and Abazied, Mehareb et al., who found that the studied varieties significantly differed in stalk weight [20-22,24,25].

Selected germplasm	Stalk diameter (cm)			Stalk length (cm)			Stalk weight (kg)		
	PC	FR	Mean	PC	FR	Mean	PC	FR	Mean
G 2003-47	2.9	2.7	2.8	260	267.5	263.75	1.35	1.45	1.4
EH 88/5-27	2.65	2.55	2.6	257.5	265	261.25	1.25	1.75	1.5
F 150	2.2	2.3	2.25	297.5	302.5	300	1.35	2.2	1.78
EI 58-37	2.65	2.55	2.6	352.5	358.5	355.5	1.25	1.05	1.15
M 57-35	2.65	2.5	2.58	225	232	228.5	1.15	1.3	1.23
F 161	2.85	2.65	2.75	277.5	285.5	281.5	1.75	1.45	1.6
SP 72-5181	3.35	3.25	3.3	237.5	245	241.25	1.45	1.6	1.53
G 2008-64	2.65	2.55	2.6	282.5	292.5	287.5	1.65	1.65	1.65
G 2003-49	2.7	2.6	2.65	277.5	285.5	281.5	1.25	1.3	1.28
L 62-96	2.85	2.7	2.78	270	274	272	1.1	1.3	1.2
G 2008-20	2.8	2.65	2.73	245	252	248.5	1.1	1.4	1.25
G 2007-61	2.6	2.45	2.53	270	278.5	274.25	1.2	1.7	1.45
SP 81-3250	2.75	2.45	2.6	260	266.5	263.25	0.9	1.7	1.3
CO 182	2.75	2.5	2.63	267.5	274	270.75	0.85	1.6	1.23
G 2006-36	3.1	2.95	3.03	267.5	276	271.75	1.6	1.8	1.7
GT 54-9	2.8	2.7	2.75	226.5	231.5	229	1.15	1.45	1.3
LSD 0.05	0.1	0.11		11.23	12.45		0.14	0.1	

PC (plant cane), FR (first ratoon).

Table 3: Mean performance of stalk diameter (cm), stalk length (cm) and stalk weight (kg) of the fourteen promising sugarcane genotypes at harvest in the plant and first ratoon cane crops.

**Brix %:** Data in Table 4 revealed that genotype *viz.* EI58-37 recorded the highest brix % in the plant cane, first ratoon and overall of both crops. Six genotypes namely EI58-37, SP 72-5181, G2008-64, G2003-49, L62-96, G2008-20 and G2006-36 had significantly higher values of

this trait than that recorded by the two check varieties; GT54-9 and G2003-47 in the plant cane, without significant variance among them, in the first ratoon. These results are in harmony with those of Mehareb, et al., Mehareb, et al., Mehareb and Abazied, who found



differences in brix % among the tested sugar cane varieties [21,22,25].

**Sucrose %:** Data in Table 4 reveal that sucrose% varied significantly among studied genotypes in the plant cane, first ratoon and overall. Two genotypes; EI 58-37 (19.20% and 20.20%) and G2003-49 (18.70% and 20%) were stable and gave significantly higher sucrose % than the two check varieties; GT54-9 (16.60% and 17%) and

G2003-47 (17.30% and 18.50%). In the plant cane and the first ratoon, respectively.

**Purity %:** Purity percentage presented in Table 4, the genotype SP81-3250 recorded the highest significantly mean purity % (89.75%) in plant cane but the genotype F 150 recorded the highest significantly mean purity % (88%) in the first ratoon and the genotype G2006-36 recorded the highest significantly mean purity % (85.03%) in the overall.

Selected germplasm	Brix %			Sucrose %			Purity %		
	PC	FR	Mean	PC	FR	Mean	PC	FR	Mean
<b>G 2003-47</b>	21.35	24.3	22.83	17.3	18.5	17.9	81	76.35	78.68
<b>EH 88/5-27</b>	19.65	22.1	20.88	14.5	19.25	16.88	74	86.95	80.48
<b>F 150</b>	21.1	23.1	22.1	15.8	20.3	18.05	75	88	81.5
<b>EI 58-37</b>	22.35	24.5	23.43	19.2	20.2	19.7	86	82.4	84.2
<b>M 57-35</b>	21.05	22.1	21.58	17.1	19.4	18.25	81	87.7	84.35
<b>F 161</b>	20.3	22.7	21.5	15.7	17.6	16.65	77.5	77.95	77.73
<b>SP 72-5181</b>	22.35	23.65	23	17.3	20.9	19.1	77.5	88.5	83
<b>G 2008-64</b>	20.2	23.1	21.65	17.1	18.3	17.7	84.7	79.35	82.03
<b>G 2003-49</b>	22.05	23.4	22.73	18.7	20	19.35	85	85.6	85.28
<b>L 62-96</b>	22.3	23.6	22.95	18.4	18.8	18.6	82.4	79.7	81.03
<b>G 2008-20</b>	22.2	23.6	22.9	17.7	18.95	18.33	79.7	80.3	79.98
<b>G 2007-61</b>	20.35	22.5	21.43	15.1	16.1	15.6	74.2	71.35	72.75
<b>SP 81-3250</b>	21.7	23.3	22.5	19.5	15.9	17.7	89.8	68.25	79
<b>CO 182</b>	20.4	22.7	21.55	16.3	17.9	17.1	79.7	79.25	79.45
<b>G 2006-36</b>	22.05	22.5	22.28	19.3	18.6	18.95	87.5	82.55	85.03
<b>GT 54-9</b>	20.9	20.1	20.5	16.6	17	16.8	79.2	84.35	81.78
<b>LSD 0.05</b>	<b>0.51</b>	<b>1.4</b>		<b>0.57</b>	<b>0.7</b>		<b>1.1</b>	<b>2.61</b>	

PC (plant cane), FR (first ratoon).

Table 4: Mean performance of Brix %, Sucrose % and Purity % of the fourteen promising sugarcane genotypes at harvest in the plant and first ratoon cane crops.

**Sugar recovery %:** Data presented in Table 5 showed that the evaluated genotypes differed significantly concerning sugar recovery% at the plant cane and first ratoon and over both crops. In the plant cane, the highest sugar recovery% was recorded for the genotype SP81-3250 (13.55%) followed by the genotypes; G2006-36 (13.30%), EI58-37 (13.10%), G2003-49 (12.65%), and L62-96 (12.25%), respectively. All the previous genotypes gave significantly higher sugar recovery% as compared to the two checks GT54-9 (10.85%) and G2003-49 (11.45%). In the first ratoon, the genotypes; EH88/5-27 (13.20%), F150 (14.05%), EI58-37 (13.45%), M57-35 (13.35%), SP72-5181 (14.45%), G2003-49 (13.65%) and G2008-20 (12.45%) significantly surpassed the two checks GT54-9 (11.45%) and G2003-47 (11.80%).

**Cane yield:** Data of the plant cane, first ratoon and overall of the two crops, in Table 5 revealed that the 14 genotypes selected from the first stage differed significantly in cane yield. In the plant cane, six genotypes; EH88/5-27(19.00 and 6.50), SP72-5181(16.10 and 3.60), G2008-64 (26.50 and 14.00) , G2008-20 (26.20 and 13.70), G2007-61 (24.50 and 12.00)and G2006-36 (16.00 and 3.50) produced significantly tons of canes higher than that obtained by GT54-9 and G2003-47 check cultivar, successively, corresponding to EH88/5-27(17.80 and 5.80), SP72-5181(13.00 and 1.00), G2008-64 (24.60 and 12.60) , G2008-20 (27.75 and 15.75), G2007-61 (29.70 and 17.70)and G2006-36 (15.50 and 3.50) tons of canes, in the 1<sup>st</sup> ratoon cane crop. The overall mean of the two seasons showed the superiority of seven genotypes viz. EH 88/5-27( 18.40 and 6.15), SP 72-5181( 14.55 and

2.30), G 2008-64(25.55 and 13.30), G 2008-20 (26.98 and 14.73), G 2007-61(27.10 and 14.85), SP 81-3250 and G2006-36(15.75 and 3.50), which out-yielded GT 54-9 and G 2003-47 cultivars by tons of canes, respectively.

**Sugar yield:** Results of Table 5 revealed that the sugar yield differed significantly among the evaluated genotypes in the plant cane, first ratoon and overall. In the plant cane, four genotypes; G2008-64 (3.50 and 1.75 ton/fad), G2008-20 (3.45 and 1.70 ton/fad), SP81-3250 (3.00 and 1.25 ton/fad) and G2006-36 (3.55 and 1.80 ton/fad) recorded significantly greater sugar yield values than the two checks GT54-9 (6.45 ton/fad) and G2003-47 (8.20 ton/fad). In the first ratoon, four genotypes; EH88/5-27 (3.40 and 1.80 ton/fad), SP72-5181 (1.95 and

0.20 ton/fad), G2008-64 (3.25 and 1.65 ton/fad) and G2008-20 (4.05 and 2.45 ton/fad) recorded significantly greater cane yield values than the two checks GT54-9 (7.05 ton/fad) and G2003-47 (8.65 ton/fad). In the over two seasons, six genotypes; EH88/5-27 (2.03 and 0.35), SP72-5181 (2.83 and 1.15 ton/fad), G2008-64 (3.38 and 1.70), G2008-20(3.75 and 2.08), G2007-61 (1.70 and 0.02), and G2006-36 (3.03 and 1.35) tons/fad recorded greater sugar yield values than the two checks GT54-9 (6.45 ton/fad) and G2003-47 (8.43 ton/fad). This result is in agreement with those reported by El-Shafai, & Ismail, Yousif, et al., Mehareb, et al., Ahmed, et al., Mehareb and Abazied and Mehareb, et al., who found that the tested varieties significantly differed in cane yield and sugar yield [20-25].

Selected germplasm	Sugar recovery %			Cane yield (t/fad)			Sugar yield (t/fad)		
	PC	FR	Mean	PC	FR	Mean	PC	FR	Mean
G2003-47	11.45	11.8	11.63	71.5	73.35	72.43	8.2	8.65	8.43
EH 88/5-27	9.1	13.2	11.15	78	79.15	78.58	7.1	10.45	8.78
F 150	10	14.05	12.03	68	71.45	69.73	6.8	10.05	8.43
EI 58-37	13.1	13.45	13.28	61.5	60.9	61.2	8.1	8.2	8.15
M 57-35	11.3	13.35	12.33	60.4	62.8	61.6	6.85	8.4	7.63
F 161	10.15	11.4	10.78	72	70.2	71.1	7.3	8	7.65
SP 72-5181	11.15	14.45	12.8	75.1	74.35	74.73	8.4	10.75	9.58
G 2008-64	11.6	12	11.8	85.5	85.95	85.73	9.95	10.3	10.13
G 2003-49	12.65	13.65	13.15	61.1	62.35	61.73	7.8	8.5	8.15
L 62-96	12.25	12.3	12.28	65.1	67.05	66.08	8	8.3	8.15
G 2008-20	11.6	12.45	12.03	85.2	89.1	87.15	9.9	11.1	10.5
G 2007-61	9.45	9.85	9.65	83.5	91.05	87.28	7.95	8.95	8.45
SP 81-3250	13.55	9.4	11.48	69.5	77.45	73.48	9.45	7.3	8.38
CO 182	10.65	11.7	11.18	71.1	73.25	72.18	7.55	8.6	8.08
G 2006-36	13.3	12.4	12.85	75	76.85	75.93	10	9.55	9.78
GT 54-9	10.85	11.45	11.15	59	61.35	60.18	6.45	7.05	6.75
LSD 0.05	0.45	0.64		1.46	1.11		0.73	1.47	

PC (plant cane), FR (first ratoon).

Table 5: Mean performance of sugar recovery %, cane yield (t/fad) and sugar yield (t/fad) of the fourteen promising sugarcane genotypes at harvest in the plant and first ratoon cane crops.

**Genetic Parameter:** Among the cane characters, showed wide range of variation in plant cane as well as in the ratoon crop (Tables 6-8), providing wide scope of selection for this traits. Wide range of variations for number of millable canes and stalk height was reported earlier by Ghosh and Singh [26].

**Genotypic and Phenotypic Variance:** The wide range of genotypic ( $\sigma^2g$ ) and phenotypic ( $\sigma^2p$ ) variation was observed for stalk length ( $\sigma^2g = 739.35$  &  $\sigma^2p = 850.42$ ) in

plant cane and ( $\sigma^2g = 721.53$  &  $\sigma^2p = 836.93$ ) in first ratoon followed by cane yield ( $\sigma^2g = 68.12$  &  $\sigma^2p = 70.01$ ) in plant cane and ( $\sigma^2g = 85.25$  &  $\sigma^2p = 86.33$ ) in first ratoon followed by purity ( $\sigma^2g = 22.82$  &  $\sigma^2p = 23.89$ ) in plant cane and ( $\sigma^2g = 30.14$  &  $\sigma^2p = 36.06$ ) in first ratoon. The lowest estimates of  $\sigma^2g$  and  $\sigma^2p$  were exhibited by stalk diameter ( $\sigma^2g = 0.05$  &  $\sigma^2p = 0.06$ ) in plant cane and ( $\sigma^2g = 0.04$  &  $\sigma^2p = 0.06$ ) in first ratoon (Tables 6-8). Similar findings were reported by Hapase and Hapase and Verma, et al., found variability of higher magnitude for

number of shoots per plot, number of millable canes and cane yield [27,28]. Also Kumar, et al., and Pawar, et al., found similar results for most of the cane yield and its contributing traits [29,30].

of variance in relation to their genotypic counterpart revealed that the estimates of  $\sigma^2g$  were higher than  $\sigma^2e$  for all of the characters. The higher magnitude of genotypic variance suggested little influence of environments in the expression of genetic variability.

A perusal of the estimates of environmental component

Parameters	Stalk length		Stalk diameter		Stalk weight	
	Pc	FR	Pc	FR	Pc	FR
$\sigma^2g$	739.35	721.53	0.05	0.04	0.05	0.08
$\sigma^2e$	111.06	115.4	0.01	0.01	0.02	0.002
$\sigma^2p$	850.42	836.93	0.06	0.06	0.07	0.08
Heritability%	86.94	86.21	85.5	78.32	74.51	97.74
GCV	10.08	9.7	8.45	7.98	17.25	17.8
PCV	10.92	10.55	9.13	8.99	20.1	18.07

PC (plant cane), FR (first ratoon).

Table 6: Components of variances, coefficients of variation, heritability for stalk length, stalk diameter and stalk weight in fourteen promising sugarcane genotypes for plant crop and first ratoon.

Parameters	Brix%		Sucrose%		Purity%	
	Pc	FR	Pc	FR	Pc	FR
$\sigma^2g$	0.65	0.35	2.17	1.68	22.82	30.14
$\sigma^2e$	0.22	0.14	0.28	0.4	1.07	5.92
$\sigma^2p$	0.87	0.5	2.45	2.08	23.89	36.06
Heritability%	74.37	71	88.52	80.84	95.52	83.58
GCV	3.77	2.56	8.53	6.93	5.9	6.78
PCV	4.38	3.07	9.09	7.75	6.04	7.4

PC (plant cane), FR (first ratoon).

Table 7: Components of variances, coefficients of variation, heritability for Brix%, Sucrose% and Purity% in fourteen promising sugarcane genotypes for plant crop and first ratoon.

Parameters	Sugar recovery		Cane yield		Sugar yield	
	Pc	FR	Pc	FR	Pc	FR
$\sigma^2g$	1.74	1.68	68.12	85.25	1.1	1.12
$\sigma^2e$	0.17	0.36	1.88	1.08	0.12	0.19
$\sigma^2p$	1.92	2.03	70.01	86.33	1.22	1.31
Heritability%	90.99	82.5	97.31	98.75	90.21	85.43
GCV	11.56	10.47	11.43	12.42	12.77	11.6
PCV	12.15	11.58	11.72	12.63	13.63	12.73

PC (plant cane), FR (first ratoon).

Table 8: Components of variances, coefficients of variation, heritability for Sugar recovery%, Cane yield and Sugar yield in fourteen promising sugarcane genotypes for plant crop and first ratoon Genotypic and phenotypic coefficient of variance.

The genotypic coefficient of variability (GCV) was moderate for stalk weight followed by sugar yield, cane yield and sugar recovery in both plant and ratoon crops, whereas, brix was lowest also in both plant and ratoon crops (Tables 6-8). The slightly high phenotypic

coefficient of variability (PVC) over GVC throughout the plant and ratoon crops indicated a good scope for selection of these characters. However, the differences between the estimates of GCV and PCV was comparatively narrow for all the characters, suggesting the possibility of

affective selection of these traits and indicating high prospects for genetic progress through selection under the conditions of this investigation. The same finding was observed by earlier workers, *viz.* Nair, et al., Singh, et al., Verma, et al., Gosh and Singh and Bhaskar [26,31-34]. The success of a variety improvement program depends largely on the amount of genetic variability present in the population.

The GCV values for stalk weight and its components like sugar yield, cane yield and sugar recovery were larger than the values for juice brix, purity and sucrose content. Singh and Singh also reported the large amount of genetic variation for stalk height, diameter and number of millable canes in clonal population and concluded that progress in breeding for higher sucrose yield can be made by emphasizing selection for high sucrose content at early ripening stage along with higher cane yield.

**Degree of Heritability:** It is evident from Tables 6-8 that cane yield, sugar recovery, sugar yield, purity, sucrose percent and stalk length were highly heritable characters in both plant and first ratoon, while stalk diameter and stalk weight were highly only in plant crop and first ratoon, respectively. It might be due to high genetic variance or low environmental variance or both. Thus, high values of heritability suggested the possibility of improvement of these characters through selection Singh and Singh, which may indirectly help in the yield and quality improvement Gravois, et al. [35-40].

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