Assiut J. Agric. Sci., (44) No. (3) 2013 (63-76)

Genetic Analysis and Expected Response to Selection for Some Agronomical and Juice Quality Traits in Sugarcane (*Saccharum officinarum* L.)

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Abstract:

In the present investigation, 12 diverse genotypes of sugarcane (*Saccharum officinarum* L.) were studied to assess their genetic potential for yield, yield contributing characters and juice quality traits. The mean squares of years, genotypes and their interaction were highly significant in all studied traits, except years and interaction of stalk diameter. The phenotypic and genotypic coefficient of variation (GCV and PCV) was moderate to high for stalk height, stalk weight, number of stalks/m^2, cane yield, sugar yield, and reducers %. Low values of GCV and PCV were found in stalk diameter, recoverable sucrose %, Brix (%), Pol %, Purity (%) and Fibers %, which indicating lower variability in these traits. Maximum genetic gain along with high heritability was observed for stalk height, cane yield, stalk weight, and sugar yield. Reducers% showed high genetic gain and moderate heritability while, number of stalks/m^2 showed moderate genetic gain and heritability estimates. High amount of heritability associated with low to moderate genetic gain were observed for Purity% and stalk diameter. Low genetic gain with moderate amount of heritability were observed for recoverable sucrose %, Brix%, Pol%, and Fibre%.

The positive correlation between cane or sugar yield and each of number of stalks/m^2, stalk weight, stalk diameter and stalk height indicated that the improvement in any of these traits might result in positive response of the cane yield. The undesirable negative correlations between Brix% and stalk weight as well as between Pol% and each of stalk weight and stalk height suggested that number of stalks/m^2 might be used as selection criteria to improve sugar yield. Among the tested genotypes two varieties namely G2000 -79 and EI 264-2 were found to produce high number of stalks/m^2 and sugar yield over the three seasons indicating that these genotypes could be used in selection programs to improve sugar yield. The UPGMA clustering analysis revealed that all genotypes were clustered together in three main groups with overall 87.7% genetic similarity. The clustering was show to be influenced mainly with stalk height and cane yield while, it was not able to classify genotypes based on their pedigree in most cases.

Keywords*: sugarcane, Saccharum officinarum, genetic variability, heritability, genetic advance, correlation, UPGMA cluster analysis*

Received on: 2/4/2013 **Accepted for publication on:** 18/6 /2013

Referees: Prof. Adel S. Tagian Prof. Atef A. Elwfaa

Introduction:

Sugarcane (*Saccharum officinarum* L.) is an important industrial crop in Egypt. Cane is the main source for refined sugar as well as molasses industry and the by-products from crushing are used as raw materials in the plywood and paper pulp industries. According to the USDA sugar annual report prepared by Hamza (2012), the total cane area harvested in Egypt for centrifugal sugar in 2012/2013 is forecast at 112,000 HA, unchanged from the previous year. While, sugar consumption is forecast at 2,950 TMT for the 2012/2013 compared to 2,850 TMT for the 2011/2012. Plant breeders are continuously endeavouring to improve the genetic potential of yield and sucrose recovery of this crop so as to meet the demands of an ever increasing population and limitation of cultivated area in Egypt.

Successful breeding program for yield improvement in sugarcane requires information on (a) the fundamental nature and the magnitude of variability present in the genetic material, which involved in the inheritance of sugar yield and its components, (b) genotype/environmental interaction, and (c) the efficiency of such genetic patterns in the selection process. The heritable portion of the overall observed variation can be ascertained by studying genotypic (GCV) and phenotypic (PCV) coefficient of variation, heritability and predicted genetic advance. The coefficient of variation indicated only the extent of variability present in the character and does not indicate the heritable portion. This could be ascertained from heritability estimates, which in broad sense include both additive and non-additive gene effects (Lush, 1949). The knowledge of heritability is helpful in assessing merits and demerits of a particular trait as it enables the plant breeder to decide the course of selection procedures to be followed under a given situation. 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 (Johnson *et al*., 1955). Genetic variability, heritability and expected genetic advance for yield, yield contributing characters and juice quality traits in sugarcane were studied by several investigators (Ahmed *et al*., 2007; Chaudhary, 2001; Okaz *et al*., 2011 and Ahmed and Obeid, 2012).

Correlation among phenotypic traits may reflect biological processes that are of considerable evolutionary interest, correlation can be the result of genetic, functional and physiological or developmental characters (Wagner & Schwenk, 2000). While, Falconer (1989) reported that the association between two or more characters is due to peliotropic gene action or linkage. In plant breeding, correlation coefficient analysis measures the mutual relationship between two plant characters and it determines characters association for genetic improvement of yield and other economic traits (Ahmed *et al*., 2010). Simple correlations between sugarcane traits have been reported by Javed *et al*., 2000; Abo El-Ghait and Mohamed, 2005; Soomro *et al*., 2006; Ahmed *et al*., 2007; Silva *et al.,* 2008; Ahmed *et al*., 2010; Khan *et al*., 2012 and Tyagi *et al*., 2012.

In addition, Similarity can be used to measure the relatedness and genetic distance between the genotypes (Welsh and McClelland, 1991). Knowing genetic distances between cultivars is useful in a breeding program because it allows efficient sampling and utilization of germplasm resources. A breeder may choose cultivars that are distantly related to obtain transgressive segregation for a quantitative trait e.g. yield (Kongkiatngam *et al.*, 1996).

The geneticists and breeders in Egypt are interested in the estimation of genetic parameters in order to formulate the most advantageous breeding procedures to develop high yielding sugarcane varieties suitable in our climate. Therefore, the objectives of this study were to determine the genetic variability, heritability, expected genetic advance and simple correlation for yield, yield contributing characters and juice quality traits of 12 diverse sugarcane varieties. Hierarchical cluster analysis and genetic distance between the tested varieties based on vegetative stage were also studied.

Materials and Methods:

The present investigation was carried out at the Experimental farm of Genetics Department, Faculty of Agriculture, Assiut University, Assiut, Egypt, during three successive seasons (March, 2008/2009, March, 2009/2010 and March, 2010/2011) to evaluate the performance of 12 sugarcane (*Saccharum officinarum* L.) genotypes. The tested genotypes were kindly obtained from the research station of Sugar and Integrated Industries Company which namely; EH 16-9, EI 8-129, EI 264-2, EI 266-2, EI 24-2, G84 – 47, G99-103, G2000 -79, G.T.54C-9, NCO310, N26 and PH8013 (Table 1).

The genotypes were laid out in a randomized complete block design with four replicates. The plot size was 54m^2, consisted of twelve rows, each of seven meters in length spaced at 70 cm apart. The agronomic practices were carried out as recommended in the region. The date of harvesting was at 11 months age for the three seasons.

Data recorded:

At harvest, the performance of sugarcane genotypes in the three seasons were evaluated for 12 characters including 7 yield and yield contributing characters and 5 of juice quality traits. The yield and yield contributing characters were; stalk height, stalk diameter, stalk weight, number of stalks/m^2, fiber %, cane and sugar yield, while the juice quality traits namely; juice Brix%, Pol%, Purity%, Reducers% and Recoverable sucrose%. A sample of 25 cane stalks from each genotype were collected after harvest to determine juice quality traits, sugar yield and percentage of fiber. Analysis of juice quality traits, sugar yield and fiber % was carried out in Sugar and Integrated Industries Company (SIIC) as per the methods described by Schneider (1979) and A.O.A.C. (1995).

Statistical Analysis:

The combined analysis of variance over the three seasons was carried out according to Steel and Torrie (1980). The genotypic and phenotypic variances (δ^2g and δ^2p) as well as 'Genotype x Year' interaction (δ^2_{gy}) were calculated from the partitioning mean squares expectation (Table 2) as follow: $\delta^2 g = (M3 - M2)/yr$, $\delta^2_{gy} = (M2 - M1)/r$ and $\delta^2 p = \delta^2_g + (\delta^2_{gy} / y) + (\delta^2_e / ry)$, where δ^2e (environmental variance) = M1

Genotypic and phenotypic coefficients of variation (PCV and GCV) were assessed following the method adopted by Kang *et al* (1983). Broad sense heritability (H^2) was estimated according to the method described by Fehr (1987). The expected genetic advance (GA) and genetic gain (GG) over mean were calculated by the method given by Robinson *et al.* (1949).

Phenotypic correlation:

Simple phenotypic correlation was computed using MSTATC computer programme (MSTATC, Michigan State Univ., 1992).

Phylogenetic tree analysis based on morphological characters: The mean values of all traits were analyzed using the software package MVSP program (version 3.1) to calculate the percentage of similarities and genetic distances between all tested varieties. The hierarchical UPGMA cluster analysis (Kaufman & Rousseeuw, 1990) was used to investigate patterns of phenotypic diversity existing in these varieties.

Results and Discussion:

I- Genotype Performance and Analysis of Variance:

Sugarcane genotypes in commercial cultivation are complex polyploid. The heterozygous and polyploid nature of this crop have resulted in generation of great genetic variability. The information on the nature and the magnitude of variability present in the genetic material is of prime importance for a breeder to initiate any effective selection program. (Tyagi and Singh, 1998). In the present investigation, 12 diverse genotypes of sugarcane were studied to assess their genetic potential for yield, yield contributing characters and juice quality traits (Table 3). The analysis of variance indicated that the mean squares of years, genotypes and their interaction were highly significant in all studied traits, except year and interaction of stalk diameter (Table 4). Thus, it is implied that there was reasonably sufficient variability in the material used in the present study, which provides ample scope for selecting superior and desired genotypes by the plant breeders for further improvement. These results in agreement with those obtained earlier by Chaudhary, 2001; Ahmed *et al*., 2007; and Okaz *et al*., 2011.

The significance of years and genotype/year interaction variances indicated that the studied genotypes interacted differently with the tested seasons. Over years, data presented in Table (3) showed that maximum percentages for juice Brix (21.70%), Pol (16.14%) and Recoverable sucrose (13.96%) were observed in the genotype EH 16-9, while this genotype showed the minimum values of stalk height (150.67 cm), stalk weight (586 g), Reducers (0.93%), cane (24.86 ton/fed.) and sugar (3.5 ton/fed.) yield. The genotype EI 8-129 revealed the highest values of stalk diameter (2.87 cm) and weight (1383 g), and the lowest number of stalks/m^2 (60.0 stalks). Although, G99-103 possessed maximum stalk height (301.00 cm) and cane yield (56.99 ton/fed.), it displayed the minimum values of Pol % (14.1%), Purity (82.9%) and Reducers (11.45%). The genotype G2000-79 showed the highest number of stalks/m^2 (89.4 stalks) and sugar yield (6.77 ton/fed.). The maximum value of fiber % was produced by PH8013 (12.0%) while N26 (10.27%) displayed the minimum value of this trait. EI 266-2 displayed the highest percentage of juice purity (90.5%), while NCO310 displayed the lowest stalks diameter (2.2 cm) and Brix (18.64%). Similar results were also obtained by Nair *et al*., 1980; Chaudhary, 2001 and Ahmed and Obeid, 2012.

2- Partitioning of phenotypic variance and genetic components

After partitioning the mean squares (Table 5), it was found that genotypic variance (δ^2_g) was higher than the environmental one for stalk height ($\boldsymbol{\delta^2_g}$ = 1905.224, $\boldsymbol{\delta^2_e}$ = 56.233), stalk weight ($\boldsymbol{\delta^2_g}$ = 35733.06, $\boldsymbol{\delta^2_e}$ = 16795.78), number of stalks/m^2 ($\boldsymbol{\delta^2_g}$ = 46.68, $\boldsymbol{\delta^2_e}$ = 11.00), cane yield ($\boldsymbol{\delta^2_g}$ = 70.54783, $\boldsymbol{\delta^2_e}$ =10.519), sugar yield ($\boldsymbol{\delta^2_g}$ = 0.6215, $\boldsymbol{\delta^2_e}$ = 0.244), Purity % ($\boldsymbol{\delta^2_g}$ = 4.921, $\boldsymbol{\delta^2_e}$ = 3.968) and Reducers % ($\boldsymbol{\delta^2_g}$ = 0.145, $\boldsymbol{\delta^2_e}$ =0.030). 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 for most of these traits was also reported by other researchers (Nair *et al*., 1980; Ahmed *et al*., 2007 and Chaudhary, 2001). While, the genotype/year interaction variance was also important in the expression of number of stalks/m^2 Recoverable sucrose %, sugar yield, Brix (%), Pol %, Reducers % and Fibers % which they displayed δ^2_{gy} values higher than δ^2_e and δ^2_g (Table 5). These results in agreement with Chaudhary, 2001.

3- Phenotypic and Genotypic Coefficients of Variation

Since most of the economic characters are complex in inheritance and are greatly influenced by several genes interacting with various environmental conditions, the study of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) is not only useful for comparing the relative amount of phenotypic and genotypic variations among different traits but also very useful to estimate the scope for improvement by selection. The reliability of a parameter to be selected for breeding programme among other factors is dependent on the magnitude of its coefficient of variations (CV) especially the GCV. However, the differences between genotypic and phenotypic coefficient of variability indicate the environmental influence. While a lower value of CV generally depicts low variability among the tested sample, a high proportion GCV to the PCV is desirable in breeding works. Moderate to high GCV (9.38 to 20.44%) and PCV (12.47 to 30.61%) were observed for stalk height, stalk weight, number of stalks/m^2, cane yield, sugar yield, and Reducers % (Table 5). These traits also showed low difference between genotypic and phenotypic coefficient of variability, which indicate low environmental influence in the expression of these traits and there is good possibility to improve the genotypes through these characters. In contrast, lower values of GCV (2.53 to 7.00%) and PCV (2.81 to 7.54%) were found in stalk diameter, Recoverable sucrose %, Brix (%), Pol %, Purity (%) and Fibers %, which indicating lower variability in these traits. Moderate estimates of PCV and GCV for stalk height and diameter were also reported by Chaudhary, 2001.

4-Heritability and Genetic advance:

Genotypic and phenotypic coefficients of variation along with heritability as well as genetic advance are very essential to improve any trait of sugarcane because this would help in knowing whether or not the desired objective can be achieved from the material (Tyagi and Singh, 1998). Heritability estimates are useful in deciding the characters to be considered while making selection, but selection based on this factor alone may limit the progress, as it is prone for changes with environment, material …etc. (Athwal and Gain Singh 1966). In other words, 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 (Johnson *et al.*, 1955 and Chaudhary, 2001).

Maximum genetic gain (assuming 5% intensity of selection) along with high heritability was observed for stalk height (GG=38.06%, H^2=95.3), cane yield (GG=36.7%. H^2=85.5%), stalk weight (GG=35.81%, H^2=87.1%), and sugar yield (GG=23.9%, H^2=67.99%), reflecting the preponderance of additive gene action in determining these characters (Table 5). This also provides the evidence that larger proportion of phenotypic variance has been attributed to genotypic variance, and reliable selection could be made for these traits on the basis of phenotypic expression. These results find support from the earlier studies by Khan *et al.* (2007) and Chaudhary (2001) that there was greater magnitude of broad sense heritability and high genetic advance in stalk characters and cane yield.

The percentage of Reducers showed high genetic gain (28.1%) and moderate H^2 (44.6%) providing low chance for its further improvement, however, care must be taken while breeding for this complex trait as it is considerably influenced by environmental factors . The moderate genetic gain (14.55%) and heritability (56.6%) estimates for number of stalks/m^2 indicating that there exists a scope to improve this character to a considerable extent by adopting suitable breeding procedures.

The high amount of heritability associated with low to moderate genetic gain for Purity% (GG=4.7%, H^2=81.3%) and stalk diameter (GG=13.2%, H^2=86.3%), indicating that non-additive gene action governing these traits, and these characters could be improved through the use of hybridization and hybrid vigor. Meanwhile, the most critical point is that high heritability causes for these traits might be due to prevailing of favorable environmental conditions during the seasons rather than genetic cause. Phundan and Naryanan (1993) reported that high heritability value coupled with low genetic advance for the character, indicating the influence of error variance on this trait is high. These results and explanations are also in agreement with those obtained by Ahmed and Obeid (2012).

Low genetic gain with moderate amount of heritability were observed for recoverable sucrose % (GG=7.8%, H^2=60.3), Brix% (GG=3.8%, H^2=42.04), Pol% (GG=4.1%, H^2=45.6), and Fibre% (GG=4.95%, H^2=56.3) (Table 5). These results indicating that the influence of error variance on these traits is high and suggested a low scope in the improvement of these characters. As these characters also exhibited low genotypic and phenotypic coefficient of variations, therefore, improvement by direct selection may not be possible, but through indirect selection of other correlated traits may be feasible.

5- Correlation between characters:

Yield is a quantitatively inherited character involving various traits. Therefore, selection of genotypes with high cane and sugar yield based on a single trait might often be misleading. Stevenson (1965) pointed that there may not be specific genes controlling the complex characters, but the sum total of their components might be influencing the important economic characters namely; cane and sugar yield. According to Panse and Sukhatme (1964), among the cane yield components affecting the final yield of sugarcane are the number of millable cane, single stalk weight, stalk diameter, and stalk height. In the present study, these characters were found to associate positively with cane and sugar yield, indicated the improvement in any of these traits might result in positive response of the cane yield (Table 6). Consequently, the correlation between cane yield and sugar yield was positive and highly significant. In addition, significant positive correlations were also found between stalk height, diameter and weight. This might indicated simultaneous improvement of these three characters under selection. Similar results were also observed by Abo El-Ghait and Mohamed, 2005; Soomro *et al.*, 2006; Ahmed *et al.*, 2007; Silva *et al.,* 2008; Ahmed *et al.*, 2010; Khan *et al.*, 2012 and Tyagi *et al.*, 2012.

Since stalk height and stalk weight displayed higher values of heritability, genetic advance over mean and positive correlation with yield comparing those in number of stalks/m^2 and stalk diameter, thus selection criteria for cane yield would be based on these two characters. In contrast, undesirable significant negative correlations were observed between Brix% and stalk weight as well as Pol% and each of stalk weight and stalk height (Table 6). Thus, selection for sugar yield seemed to be difficult and will produce genotypes with lower juice quality of pol/brix if stalk height and/or stalk weight were used as selection criteria; the limit for such difficulty is being set by number of stalks/m^2. Among the tested genotypes two varieties namely G2000 -79 and EI 264-2 were found to produce high number of stalks/m^2 and sugar yield over the three seasons indicating that these genotypes could be used in selection programs to improve sugar yield. These results in agreement with Singh *et al*. (1985) and Javed *et al*. (2000) who reported that number of stalks were the most important character contributing directly to higher yield. It is possible that selection for stalk number could be effectively done based on visual observation in diverse genotypes such as those in the present study. While, number of stalks in contribution with stalk weight and height are desirable traits for selection criteria in sugarcane varietal improvement programs (Khan *et al*., 2004; Soomro *et al*., 2006 and Tyagi *et al*., 2012).

With respect to chemical characters of sugarcane juice, significant positive correlation was found between Brix % and Pol % as well as between Purity% and Pol % (Table 6). This indicated that improvement of Pol% simultaneously improve the juice quality of Brix% and purity%. In addition, the significant positive correlations between Recoverable sucrose % and each of the three juice quality traits (Brix %, Pol % and Purity%) indicated possibility of simultaneous improvement under selection for these traits. Significant positive correlation was also observed between Brix % and number of stalks/m^2. Similar results were also found by Tyagi and Lal, 2007 and Ahmed *et al*., 2010.

Significant negative correlations were observed between the percentage of Reducers and other juice characters, Brix (%), Pol % and Purity % (Table 6). In addition, the percentage of Recoverable sucrose was negatively related to Reducers % and stalk height. Therefore, selection aiming at increasing juice characters, in terms of Brix (%), Pol % and Purity %, should lead to reduce glucose, fructose and other reducers in the juice and consequently improve the percentage of recoverable sucrose. Similarly, Ahmed et al., 2010 found negative association between stalk height and all quality characters as well as between stalk weight and each of juice Brix, Pol and Purity percentages. Tyagi et al. (2012) found that juice sucrose percent had a non-significant negative association with sugar yield and cane yield.

6- Phylogenetic tree analysis based on morphological characters:

The mean values of the tested morphological and chemical traits were analyzed using the software package MVSP programs (version 3.1) to calculate the percentage of similarities and genetic distances between all tested genotypes (Table 7). The highest similarity (Si) and shortest genetic distance (Gd) were observed between the genotypes N26 and G84 – 47 (Si=98.5, Gd= 0.015) followed by G.T.54C-9 and EI 266-2 (Si=98.2, Gd= 0.018), G.T.54C-9 and EI 264-2 (Si=97.7, Gd= 0.023), PH8013 and NCO310 (Si=97.6, Gd= 0.024) and between EI 24-2 and EI 264-2 (Si=97.3, Gd= 0.027). While, the lowest similarity (Si) and longest genetic distance (Gd) were observed between the genotypes EH 16-9 and G99-103 (Si=79.4, Gd= 0.231) followed by EH 16-9 and G2000 -79 (Si=80.4, Gd= 0.218), NCO310 and G99-103 (Si=82.7, Gd= 0.190), NCO310 and G2000 -79 (Si=83.6, Gd= 0.179) and between PH8013 and G99-103 (Si=83.6, Gd= 0.179).

The phenogram (Fig. 1) resulting from the UPGMA clustering of values given in Table (7) revealed that all genotypes were clustered together in three main groups within overall 87.7% genetic similarity (GS). When the dendrogram was compared with the tested traits, it was found that the clustering was show to be influenced mainly with stalk height and cane yield. In this instance, the two varieties G2000 -79 and G99-103, which showed the highest values of stalk height (279.67 and 301.0 cm) and cane yield (56.74 and 56.99 ton/fed), were clustered together in the first group with a branched-off 96.9% GS. In contrast, the genotypes PH8013, NCO310 and EH 16-9 displayed shortest stalks (155 – 177 cm) and lowest cane yield (24 – 37 ton/fed) were clustered together in the 3rd group within a branched-off 93.8% GS.

The second group divided into two sub-clusters (2a, 2b) with a branched-off 95.4% GS. Both N26 and G84 – 47 were found in the first sub-cluster (2a) with almost 98.5% GS. These two genotypes showed moderate stalk height (225 – 222 cm) and low cane yield (37.98 – 39.15 ton/fed). The second sub-cluster (2b) contained the other 5 genotypes which showed intermediate values of stalk height (234 – 258 cm) and cane yield (43 – 49 ton/fed). The two genotypes G.T.54C-9 and EI 266-2 were clustered together firstly (GS=98.2%) and subsequently with EI 24-2 and EI 264-2 (GS= 97.3) and then with EI 8-129 at almost 96.3% GS.

The UPGMA clustering was not able to classify genotypes based on their pedigree in most cases. In this instance, the two genotypes EI 24-2 and EI 264-2 which having BU459 common parent were clustered together in 2b subcluster. Meanwhile, NCO310 was common parent for

G84 – 47 and G.T.54C-9, these genotypes distributed in cluster 3, 2a and 2b respectively.

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Table (1): The studied sugarcane genotypes and their parentage.

Genotype	Parents	
	♂	♀
G.T.54C-9[a]	F37-925 (Pas 38X F83)	NCo.310
N:CO.310	CO321	CO421
EI 24-2	BU459	PR1117
EH 16-9	LCP81-30	CP81-325
EI 8-129	BT1562	B1-2
EI 264-2	MP1723-94	BU794
EI 266-2	MP1731-94	LCO382
PH8013	Phil.64-2227	CAC71-312
G84 – 47	open	NCo.310
G99-103	Us.74-3	CP.76-1053
G2000 -79	Ministry of Agriculture	
N26	Ministry of Agriculture	

[a] = The commercial cultivar G.T.54C-9.

Table (2). Expectation of mean squares (M.S) for the combined analysis of variance.

S.V.	d.f.	M.S.	Expected values of M.S.
Year	(y-1)		
Rep (Year)	(r-1) y		
Genotypes	(g-1)	M3	$\delta^2_e + r\,\delta^2_{gy} + ry\,\delta^2_g$
(G x Y)	(g-1)(y-1)	M2	$\delta^2_e + r\,\delta^2_{gy}$
Error	(r-1)(g-1) y	M1	δ^2_e
Total	(rgy-1)		

Where; y = No. of years, r = No. of replicates, g = No. of genotypes

Table (3). Over all mean values of yield, yield contributing characters and juice quality traits among 12 sugarcane genotypes evaluated in 2009, 2010 and 2011.

Genotypes	Stalks height (cm)	Stalk diameter (cm)	Stalk weight (g.)	Stalk number/m^2	Brix (%)	Pol (%)	Purity (%)	Reducers (%)	Fiber (%)	Recoverable sucrose %	Cane yield (ton/fed)	Sugar yield (ton/fed)
EH 16-9	150.67	2.4	586	71.6	21.70	16.14	88.03	0.93	11.93	13.96	24.86	3.50
EI 8-129	239.33	2.87	1383	60.0	19.11	14.66	89.87	2.57	11.17	12.82	49.97	6.46
EI 264-2	249.00	2.37	961	82.4	20.64	15.76	89.67	1.48	11.43	13.81	47.35	6.54
EI 266-2	257.67	2.50	1147	65.1	19.53	15.01	90.5	1.40	11.60	13.21	44.62	5.91
EI 24-2	234.33	2.27	893	81.4	19.72	14.54	86.5	2.17	11.47	12.34	43.57	5.53
G84 - 47	222.33	2.27	847	75.1	20.677	15.43	88.27	1.40	11.90	13.33	37.98	5.07
G99-103	301.00	2.6	1332	78.2	20.17	14.10	82.9	2.00	11.90	11.45	56.99	6.55
G2000 -79	279.67	2.57	1085	89.4	20.30	14.60	83.07	1.70	11.60	11.91	56.74	6.77
G.T.54C-9	258.33	2.47	1063	75.1	19.4	14.53	88.2	2.97	11.73	12.51	47.81	5.97
NCO310	172.00	2.2	1003	61.4	18.64	14.73	86.43	2.33	11.30	12.43	37.24	4.65
N26	225.33	2.33	966	67.7	20.27	15.35	88.37	1.90	10.27	13.27	39.15	5.22
PH8013	177.67	2.67	913	66.3	21.21	15.95	89.03	1.50	12.00	13.91	37.33	5.19
LSD 0.05	5.249	0.138	90.72	2.322	0.517	0.458	1.394	0.121	0.276	0.477	2.270	0.346
0.01	6.938	0.183	119.91	3.069	0.683	0.605	1.843	0.160	0.364	0.630	3.001	0.457

Table (4). Mean squares from combined analysis of variance for yield, yield contributing characters and juice quality traits among 12 sugarcane genotypes evaluated in 2009, 2010 and 2011.

S.V.	D.F.	Mean Squares (MS)					
		Stalk height	Stalk diameter	Stalk weight	Stalk number/m^2	Brix (%)	Pol (%)
Year	2	8511.79**	0.503	560713.15**	3324.611 **	10.652 **	5.289**
Rep (Year)	9	180.294	0.147	18411.637	7.738	0.419	0.276
Genotypes	11	23994.08 **	0.409**	492290.366**	989.479**	9.379 **	5.060**
(G x Y)	22	1131.39**	0.056	63493.61**	429.371**	5.436**	2.752**
Error	99	56.233	0.039	16795.778	11.003	0.545	0.428
S.V.	**D.F.**	**Purity %**	**Reducers (%)**	**Fiber %**	**Recoverable sucrose %**	**Cane yield**	**Sugar yield**
Year	2	34.014 **	8.076**	5.745**	7.454**	2500.838**	60.470**
Rep (Year)	9	2.323	0.068	0.218	0.192	8.553	0.085
Genotypes	11	72.651**	3.890**	2.908 **	7.807**	989.825**	10.969**
(G x Y)	22	13.596**	2.156**	1.271**	3.096**	143.251**	3.511**
Error	99	3.968	0.030	0.155	0.464	10.519	0.244

** significant at 0.01 level.

Table (5). Estimates of genetic variance (δ2g), "genotype × year" interaction (δ2gy) variance, phenotypic variance (δ2p), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), broad sense heritability (H2), genetic advance (GA) and genetic gain over mean (GG) for yield, yield contributing characters and juice quality traits among 12 sugarcane genotypes evaluated in 2009, 2010 and 2011.

Variances and genetic components	Stalks height	Stalk diameter	Stalk weight	Stalk number/m^2	Brix (%)	Pol (%)	Purity (%)	Reducers (%)	Fiber (%)	Recoverable sucrose %	Cane yield	Sugar yield
δ^2_g	1905.22	0.029	35733.06	46.68	0.329	0.192	4.921	0.145	0.136	0.393	70.548	0.622
δ^2_{gy}	268.79	0.004	11674.46	104.59	1.223	0.581	2.407	0.532	0.279	0.658	33.183	0.817
δ^2_e	56.23	0.039	16795.78	11.00	0.545	0.428	3.968	0.030	0.155	0.464	10.519	0.244
δ^2_p	1999.51	0.034	41024.2	82.46	0.782	0.422	6.054	0.324	0.242	0.651	82.485	0.914
GCV%	18.93	7.00	18.62	9.38	2.85	2.91	2.53	20.44	3.20	4.85	19.25	14.05
PCV%	19.39	7.54	19.96	12.47	4.40	4.31	2.81	30.61	4.27	6.25	20.82	17.04
H^2	95.29	86.31	87.10	56.61	42.04	45.61	81.29	44.58	56.29	60.34	85.53	67.99
GA, 5%*	87.78	0.33	363.42	10.59	0.77	0.61	4.12	0.52	0.57	1.003	16.00	1.34
GG, 5%	38.06	13.33	35.81	14.54	3.81	4.05	4.71	28.07	4.95	7.77	36.68	23.87
GA, 20%	59.65	0.22	246.98	7.20	0.52	0.42	2.80	0.36	0.39	0.68	10.88	0.91
GG, 20%	25.87	9.06	24.33	9.88	2.59	2.75	3.20	19.07	3.36	5.28	24.93	16.22

* GA and GG were calculated at 5% and 20% intensity of selection.

Table (6). Correlation coefficients among twelve agronomical and chemical characters studied on 12 sugarcane genotypes evaluated in 2009, 2010 and 2011.

Sugarcane traits	2	3	4	5	6	7	8	9	10	11	12
1- Stalk height	0.384*	0.692**	0.327	-0.132	-0.322*	-0.216	0.090	-.097	-0.347*	0.780**	0.669**
2- Stalk diameter	--	0.535**	0.126	-0.131	-0.189	0.051	0.031	-0.132	-0.100	0.507**	0.486**
3- Stalk weight		--	-0.148	-0.389*	-.0.409*	-0.002	0.188	-0.197	-0.301	0.702**	0.619**
4- No. of millable cane/m^2			--	0.391*	0.150	0.315	-0.190	0.113	0.021	0.584**	0.582**
5- Brix (%)				--	0.734**	0.083	-0.622**	0.303	0.612**	-0.024	0.138
6- Pol %					--	0.537**	-0.711**	0.168	0.945**	-0.184	0.093
7- Purity %						--	-0.362*	0.043	0.757**	-0.185	0.072
8- Reducers %							--	-0.156	-0.686**	-0.019	-0.215
9- Fibers %								--	0.138	-0.121	-0.101
10- Recoverable sucrose %									--	-0.179	0.129
11- Cane yield										--	0.949**
12- Sugar yield											--

***, ** significant at 0.05 and 0.01 levels, rspectively.**

Table (7). Percent of similarity (below diagonal) and genetic distance (above diagonal) between the twelve sugarcane varieties based on mean values of twelve agronomical and chemical characters.

	1	2	3	4	5	6	7	8	9	10	11	12
1- EH 16-9	--	0.165	0.159	0.167	0.144	0.110	0.231	0.218	0.166	0.069	0.119	0.060
2- EI 8-129	84.8	--	0.040	0.032	0.040	0.054	0.094	0.084	0.040	0.100	0.042	0.099
3- EI 264-2	85.3	96.1	--	0.031	0.027	0.047	0.073	0.053	0.023	0.131	0.052	0.109
4- EI 266-2	84.6	96.8	96.9	--	0.047	0.058	0.076	0.065	0.018	0.118	0.047	0.103
5- EI 24-2	86.6	96.1	97.3	95.4	--	0.030	0.087	0.069	0.038	0.102	0.033	0.095
6- G84 - 47	89.6	94.7	95.4	94.4	97.0	---	0.110	0.099	0.052	0.082	0.015	0.063
7- G99-103	79.4	91.0	93.0	92.7	91.7	89.6	--	0.031	0.059	0.190	0.114	0.179
8- G2000 -79	80.4	91.9	94.8	93.7	93.3	90.6	96.9	--	0.049	0.179	0.103	0.167
9- G.T.54C-9	84.7	96.1	97.7	98.2	96.3	94.9	94.3	95.2	--	0.129	0.056	0.118
10- NCO310	93.3	90.5	87.7	88.9	90.3	92.1	82.7	83.6	87.9	--	0.078	0.024
11- N26	88.7	95.9	94.9	95.4	96.7	98.5	89.2	90.2	94.6	92.5	--	0.063
12- PH8013	94.2	90.6	89.7	90.2	90.9	93.9	83.6	84.6	88.9	97.6	93.9	--

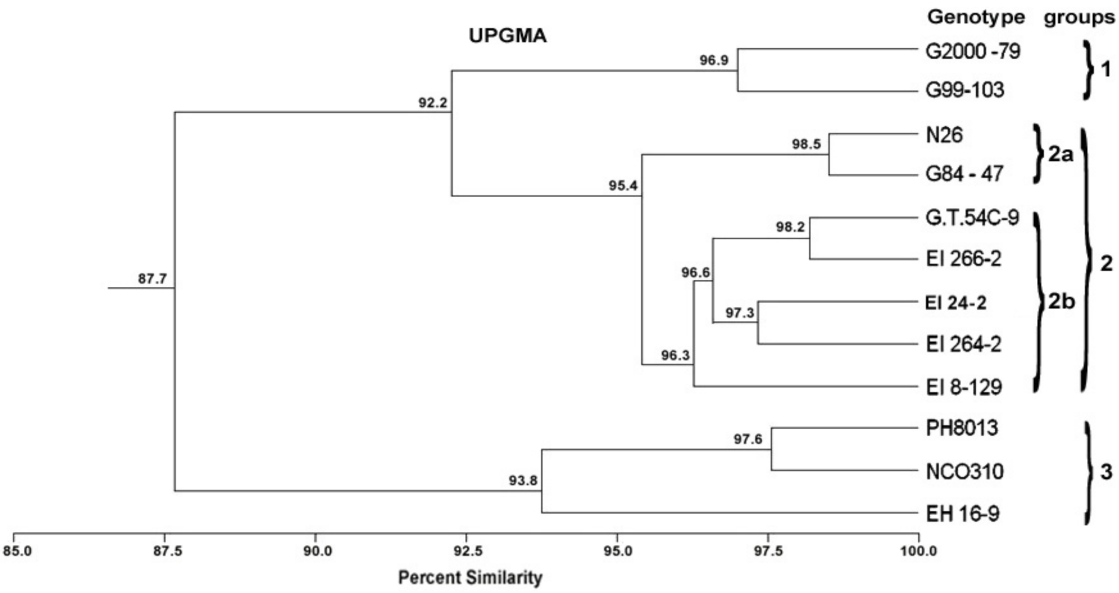

Figure 1: Dendrogram generated by UPGMA cluster analysis based on percent similarity between the twelve sugarcane varieties using mean values of twelve agronomical and juice chemical characters.

التحليل الوراثي والاستجابة المتوقعة للانتخاب لبعض الصفات المحصولية وجودة العصير في قصب السكر

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استخدم في هذه الدراسة 12 صنف من قصب السكر لتقييم امكانياتهم الوراثية للمحصول والصفات المرتبطة به وكذلك صفات جودة العصير. وجدت اختلافات عالية المعنوية بين كل من السنين والتراكيب الوراثية وكذلك التفاعل بينهما في جميع الصفات المحصولية فيما عدا متوسطات تباين السنين والتفاعل بين السنين والتراكيب الوراثية كانت غير معنوية في صفة قطر العود. اظهر معامل الاختلافات الوراثية ومعامل الاختلافات المظهرية قيم متوسطة لصفات طول ووزن العيدان ، عدد العيدان لكل متر مربع ، محصول القصب ، محصول السكر. بينما كانت معاملات الختلافات الوراثية والمظهرية ذات قيم منخفضة في صفات قطر العود ، نسبة السكر النظري ، بركس% ، نسبة الحلاوة ، نسبة النقاوة ، نسبة الالياف مما يدل علي وجود اختلافات قليلة في هذه الصفات. اقصي نسبة استجابة للانتخاب مع اكبر قيم لمعامل التوريث لوحظت في صفات طول ووزن العود ، محصول القصب ومحصول السكر. اظهرت نسبة مختزلات السكر استجابة عالية للانتخاب وقيمة متوسطة لمعامل التوريث بينما اظهرت صفة عدد العيدان لكل متر مربع قيم متوسطة لكل من الاستجابة للانتخاب ومعامل التوريث. لوحظ وجود قيم عالية لمعامل التوريث مع استجابة منخفضة الي متوسطة للانتخاب في نسبة نقاوة العصير وقطر العود. بينما وجدت استجابة منخفضة للانتخاب مع قيم متوسطة لمعامل التوريث في صفات نسبة السكر النظري ، بركس% ، نسبة الحلاوة والالياف.

وجد ارتباط معنوي موجب بين صفتي محصول القصب و السكر وكل من عدد العيدان لكل متر مربع ، طول وقطر ووزن العيدان مما يدل علي ان تحسين اي من هذه الصفات سوف يؤدي الي تحسين المحصول. وجود ارتباط سالب بين وزن العود وبركس% وكذلك بين نسبة الحلاوة وكل من طول ووزن العود يعضد استخدام عدد العيدان لكل متر مربع كعامل انتخابي لتحسين محصول السكر. وجد ان الصنفان 79- G2000 ، EI 264-2 اظهرت اعلى قيم لعدد العيدان لكل متر مربع ومحصول السكر في المواسم الثلاثة مما يدل علي ان هذان الصنفان يمكن استخدامهما في برامج الانتخاب لتحسين محصول السكر. اوضح التحليل العنقودى ان الاصناف المختبرة قد توزعت في ثلاثة مجموعات رئيسية بدرجة عامة من التماثل الوراثي مقدارها 87.7%. وجد ان توزيع الاصناف في التحليل العنقودى قد تأثر بصورة رئيسية بطول العود ومحصول القصب ، بينما لم يتمكن التحليل العنقودي من تقسيم الاصناف طبقا لسجل النسب في معظم الحالات.