

GENETIC DIVERGENCE ANALYSIS IN PLANT AND RATOON OF SUGARCANE (*SACCHARUM OFFICINARUM* L.) TO ASSESS THE POTENTIAL OF GENOTYPES UNDER DIFFERENT TIME OF SOWING AND HARVESTING SCHEDULE

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Abstract: The twenty genotypes of sugarcane (*Saccharum officinarum*) were sown on two different dates and harvested at two stages thus comprising four environment for each plant cane and its ratoon crop. The objective of the study was to assess the genetic divergence among these clones based on five quantitative and five qualitative traits under different environments. The cane height, Stalk girth, numbers of millable cane, stalk weight and cane yield were major contributors ranging from 15.29 % to 10.98 % towards the total divergence where as the quality traits brix, CCS percent, sugar recovery, sucrose percent and CCS-yield in t/ha were minor contributors varying from 8.21 % to 5.29 % in both crops. The genotypes were grouped into five clusters in all environments with varying numbers of genotypes. The low intra-cluster distance is recorded from 0 to 1.76 in the cluster of all environments indicated the closeness of the clones that cannot be used as parents in the breeding program of hybridization. The genotypes environment interaction leads to different composition of cluster and consequently the genotypes which exhibit divergence in one environment may exhibit lack of divergence in the other. Therefore, the E₂ environment of plant cane sown in March and harvested at 12 months and E₁ ratoon of March sown plant cane and harvested at 10 month work considered suitable to work out the genetic divergence due to maximum expression of genotypes for cane yield and sugar recovery. In E₂ environment of plant cane the cluster I was largest comprised of seven genotype and cluster III was smallest comprising of two genotypes whereas in E₁ ratoon the cluster III was largest comprising of eight genotypes and cluster IV comprising solidary genotypes. In E₂ plant cane the cluster III and IV were found desirable for cane yield and cluster V for high sugar. Hence the genotypes should be selected for breeding purpose either from cluster II and IV from cluster III and V due to their higher intra-cluster distances. In E₁ ratoon the cluster II, IV and V were found desirable for cane yield and accordingly the selection of genotypes should be done either from cluster III and IV or from cluster I and II or from cluster II and V for involving them in the breeding program due to their more inter cluster distances. The critical analysis of clustering pattern and the characteristics of clusters in different environment of both crop the genotypes CoS-8436, CoS-91269, Co-1148, CoS-8432, CoLK-8102, CoJ-83, CoS-767, CoS-88216, CoS-86218 and CoS-88230 have been identified desirable for high cane yield or sugar or for both and found consistently exhibiting divergence with their corresponding genotypes.

Keywords: Cane yield, Genetic divergence, Genotype, Ratoon, *Saccharum officinarum*

INTRODUCTION

Sugarcane (*Saccharum officinarum*) is an important commercial crop and it is widely grown in tropical and subtropical climates over the world. India is the largest producer of sugar followed by Brazil. In India Uttar Pradesh (UP) is the major sugarcane growing state. However, the average yield of sugarcane in UP is lower than the national average. Besides the sugar recovery in UP (9.34 %) is also lower than national average (9.9%) (Anonymous 1997). The extreme of hot summer, excessive rain for in rainy season, cold and frost in winter season adversely affect the crop growth. Sugarcane in India is grown under varied agro-ecological conditions. The yield potential and quality of varieties are governed to a large extent by genotype and environmental conditions in which they are planted. The sugarcane crop is sown by growers timely as well a late after the harvest of rabi crop which adversely affect cane yield and sugar

recovery. The premature crop harvest not only gives the low yield but also give the low sugar recovery. Therefore, the crop should be harvested according to the age of the crop in order to ensure the increase both in yield and sugar recovery. To increase the average yield of sugarcane the varieties of early maturity with good yield, ratooning ability and resistant to various diseases have to be evolved. The recovery of sugar is dependent on several factors viz climate, physiological maturity, variety and mill efficiency. Among the factors, genotype occupies the prime place in influencing sugar yield. The recovery is usually low at the start of the season because of immaturity of the cane as part of the cane is still at vegetative phase and again at the end of the season with the onset of the summer season because of over maturity and consequent inversion of sugar. The growers have to retain the crop for longer duration for various reasons which required and investigation to quantify the loss of quality under delayed harvest. But the investigation on

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development of sugarcane variety which has sustainable sugar accumulation beyond 12 months has not been done. Thus there is need for identification of early maturing suitable varieties with high sucrose which retain high juice sucrose uniformly for long time without any deterioration so as to maintain a steady state in the sugar recovery. There is also need to identify genotypes with high cane yield and sugar recovery which are widely adopted and suitable for diverse condition. These goals can be achieved through the application of different breeding approaches like introduction, selection and hybridization which required the knowledge of the genotype x environmental interaction, heritability, genetic advance, character association and D² analysis. It is well known that in any hybridisation programme the divergent genotypes should be selected.

In plant breeding, the genetic diversity plays an important role because hybrid between lines of diverse origin, generally display a great heterosis than those between closely related parents. Genetic diversity arises due to geographical separation or due to genetic barriers to crossability. The selection of the genetically diverse genotype is important for exploitation of heterosis and development of desirable segregates. According to Atkin et al. (2009) and Sanghera *et al.* (2014) the most important factor in sugarcane breeding and production is the choice of a variety. Different varieties have different yield potential, pest and disease resistance and are bred for different ecological and desirable conditions. The present investigation was carried out to work out genetic divergence for cane yield, quality and its component characters in sugarcane to find out the battery genotypes to be used in future breeding program.

MATERIALS AND METHODS

The experimental material for the present study comprised of twenty varieties of sugarcane (*Saccharum officinarum*) belonging to different maturity groups. The field experiment of twenty varieties of sugarcane was conducted during the year 2017-18 and 2018-19 as plant cane and their ratoon crops at Research farm, Aakanksha College, Meerapur, Muzaffarnagar, UP. A randomized block design was used having twenty treatments replicated thrice. The crop was shown on two different dates i.e. 20-25th March and 22- 25th April during two session harvested at 10 and 12 months stage for recording data on germination percentage number of Millable cane/ ha at harvesting, stalk height, girth and weight, other quality characters like brix, sucrose percent, purity percent in juice, CCS (Commercial Cane sugar) percent in juice were taken from October to April month, CCS in t / ha, recovery percent and yield in t / ha in plant cane and all above characters were recorded in ratoon crop except

germination percentage but including number of shoots / ha at 100 days.

The quality characters were calculated as follows:

Juice extraction percent =

$$\frac{\text{Average juice wt. obtained from cane stalk}}{\text{Average wt. of the cane crushed}} \times 100$$

Pol percent / Sucrose % in juice was measured by polariscope.

Juice brix % was measured by brix hydrometer

Recovery percent =

$$\frac{\text{Pol} - \text{Brix} - \text{Pol}_x \times \text{Juice extraction percent}}{100} \times 2$$

CCS percent (commercial cane sugar percent)

$$= [\text{Sucrose \% in juice} - (\text{Brix \% in juice} - \text{sucrose \% in juice}) \times 0.4] \times 0.73$$

CCS yield (t/ha) = CCS percent \times cane yield (t/ha).

Cane yield = Number of Millable cane \times single cane weight.

The genetic diversity was measured following D² statistics that measure group distance based on multiple characters (Mahalanobis 1936). Rao (1952) suggested the application of Mahalanobis D² statistics for assessment of genetic diversity in plant breeding.

RESULTS AND DISCUSSION

The analysis of variance revealed significant differences among all the clones for all the quantitative and qualitative traits studied namely number of millable cane, cane height, cane girth, single cane weight, cane yield, brix, sucrose percent, CCS percent, CCS (t/ha) and sugar recovery in plant cane and ratoon crops. The cane height and girth contributed maximum (15.29%) towards genetic divergence followed by number of millable cane (15.23%), stalk weight (13.45%) and cane yield (10.98%). These characters were considered most important for Genetic diversity. The lowest contribution was made by CCS t/ha (5.29%) followed by sucrose percent (7.02%), sugar recovery (7.98%), CCS percent (8.11%) and Brix (8.21%) (data not shown). The observations are supported by the finding of Nair et al (1998) and as per their report the cane height contributes maximum towards divergence and cane weight was significantly added genetic diversity among sugarcane genotypes. Rao et al (1985) and Nair et al 1998 reported that clump weight significantly adds to genetic diversity among sugarcane clones. Punia et al 1983 reported that quality character purity percentage was least contributor in genetic divergence for sugarcane. Similarly Kang et al (2013) also reported that cane height and cane weight contributes significantly towards genetic divergence in sugarcane. Bisht et al (2017) reported maximum contribution of cane height (15.397%) towards genetic divergence followed by sugarcane weight (14.016%) and the lowest contribution by quality traits. Kumar et al

(2019) reported less contribution of quality characters towards genetic divergence i.e. CCS present at harvest (10.83%) and purity percent (8.33%) at 11 month harvest in ratoon.

In plant cane the mean cane yield of all the genotypes was recorded higher at 12 months harvest stage as compared to 10 month harvest. But in ratoon crop the cane yield average was recorded higher at 10 month harvest stage as compared to 12 month harvest. In E₂ environment (March sown and harvest at 12 month) of plant cane yield and sugar recovery was recorded higher as compared to E₂ environment of its ratoon. Marsi and Amein (2015), Nishad and Kumar (2020) also reported higher cane yield and its components in plant cane than those in first and second ratoon crops.

The clustering pattern of twenty sugarcane genotype in different environments in plant cane and ratoon is presented in table 1 and 2. In plant and ratoon crops the genotypes were grouped into five cluster in each environment i.e. E₁ E₂ E₃ and E₄ with varying number of genotypes. The intra and inter cluster distances were also worked out to have an estimate of divergence within the cluster and between the cluster (Table 2). The diagonal figures in box represent average intra-cluster distances a brief description of the analysis of divergence is presented in the following text:

The lowest intra-cluster distance was recorded in cluster V(1.176) of E₁, cluster III(1.103) of E₂, cluster II(1.331) of E₃, III(0.00) of E₄ environments of plant cane and cluster III(0.00)of E₄ of plant cane and cluster IV(0.00) of E₁, cluster V(1.492) of E₂, cluster V(0.001) of E₃ and cluster II(0.77) of E₄ environment of ratoon crop revealed that the clones in these cluster are identical and cannot be used as parents in crossing for obtaining desirable segregates. The composition of the clusters differed under two conditions due to pronounce environment, interaction and consequently the genotype which exhibit divergence in one environment may exhibit lack of divergence in other environment. This however does not mean that the breeder should study divergence in only one environment. On the contrary this really suggests the need of studying divergence in varying environmental conditions. When the genotypes are to be selected after the study of divergence in different environment to different approaches may be followed:

1 One may select the genotypes on the basis of divergence exhibited in richest and the most productive environment like March Sown and harvest at 12 months stage in E₂ environment of plant cane and E₁ environment of ratoon of march sown plant cane and harvest at 10 month stage in the present study

2 In E₂ environment of plant cane, the genotypes were grouped into five clusters out of which cluster I was large comprised of seven genotypes and the cluster III was smallest comprising only two genotypes. For this purpose the genotypes CoS-802, CoS-84211, CoS-687, CoJ-84, CoP-4212 , CoS-88216 , CoS-86218 from cluster I, genotypes Co J83 CoS-767 ,CoS-79 18 from cluster II, genotypes CoS-91269, Co-1158 from cluster III ,genotypes Bo-91,Co-11 48,CoLK-8102, CoS-8432 from cluster IV and genotypes CoS-88230, CoJ- 64, CoS-8436,and CoS-90269 from cluster V may be considered in E₂ environment of plant cane. If inter cluster distances are taken into consideration for selection of genotypes for crossing and obtaining desirable segregants than the genotypes should be selected either from cluster II and IV or from cluster II and V or from cluster III and V since these clusters exhibited maximum inter cluster distances. The critical analysis of cluster means in this environment indicated that cluster III and IV were desirable for cane yield.

In E₁ environment of ratoon crop the genotypes were grouped in five cluster based on genetic divergence and the cluster III was largest comprising eight genotypes while cluster IV comprising solitary genotype. The genotypes CoS 802, CoS 90269,CoS-88216, CoS-7918 from cluster I, genotype CoS-88230, CoS-91269, CoS-767, CoS-7918 from cluster II, genotype CoJ- 64, CoS-8436, CoP84211, CoS 687, CoJ-83, CoJ-84, CoP-84212, CoS-86218, from cluster III genotype – Bo-91 from cluster IV and genotype Co1148, Co1158 andCoLK 8102 from cluster V may be considered as per intercluster distance the genotypes should be selected from crossing purpose either from cluster I and II or from cluster III and IV or from cluster II and V due to their maximum inter cluster distances. The clusters IV and V were found desirable for cane yield as per their high mean values for this trait.

Table 1. Genetic divergence analysis, cane yield and recovery of plant sugarcane under different environment

E ₁ March Sown plant cane harvested at 10 month				
Cluster	No. of genotype	Genotype name	Cane yield (t/ha)	Recovery (%)
I	4	CoS-802, CoP84211, CoP-84212, CoS-7918	38.45	8.19
II	5	CoS-90269, CoJ-83,CoS-767,CoJ-84, CoS-86218	40.38	9.41
III	2	CoJ-64,CoS-687	37.30	10.20
IV	7	CoS91269, CoS8436, Bo91, Co1148, Co1158, CoS588-216, CoLK8102	49.61	9.23
V	2	CoS88230, CoS8432	49.64	11.09

Average inter and intra cluster distance for twenty genotype						
Cluster	I	II	III	IV	V	Cluster Distance 217.38/48.12
I	2.319					
II	3.147	1.439				
III	4.636	3.057	1.669			
IV	3.931	3.903	4.562	1.876		
V	3.931 6.314	3.903 4.464	4.562 3.995	1.876 3.784	1.176	
E₂ March Sown plant cane harvested at 12 month						
Cluster	No. of genotype	Genotype name			Cane yield (t/ha)	Recovery (%)
I	7	CoS802, CoP-84211, CoS-687, CoJ-84, CoP84212, CoS-88216, CoS-86218			45.56	10.42
II	3	CoJ-83, CoS-767, CoS-7918			43.13	9.69
III	2	CoS-90269, Co-1158			58.87	9.26
IV	4	Bo-91, Co-1148, CoLK-8102, CoS-8432			59.61	10.71
V	4	CoS-88230, CoJ-64, CoS-8436, CoS-90269			48.92	11.22
Average inter and intra cluster distance for twenty genotype						
Cluster	I	II	III	IV	V	Cluster Distance 256.09/51.30
I	1.710					
II	2.466	1.947				
III	4.390	4.752	1.103			
IV	3.869	5.404	4.325	1.864		
V	3.196	5.051	6.076	3.429	1.965	
E₃ April Sown plant cane harvested at 10 month						
Cluster	No. of genotype	Genotype name			Cane yield (t/ha)	Recovery (%)
I	5	CoS-802 CoS-90269, CoJ-83, CoS-767, CoS-86218			35.37	9.47
II	2	CoJ-64, CoS-687			32.52	10.66
III	5	CoP-84211, Co-1158, CoJ-84, CoP-84212, CoS-90269, CoS-7918			36.00	8.43
IV	5	CoS-91269, Bo-91, Co-1148, CoS-88216, CoLK-8102,			45.10	9.19
V	3	CoS-88230, CoS-8436, CoS-8432			42.38	10.18
Average inter and intra cluster distance for twenty genotype						
Cluster	I	II	III	IV	V	Cluster Distance 191.37/47.93
I	1.532					
II	3.818	1.331				
III	3.260	5.615	2.206			
IV	3.871	5.949	3.455	1.798		
V	4.052	4.453	4.277	2.601	1.779	
E₄ April Sown plant cane harvested at 12 month						
Cluster	No of genotype	Name of Genotypes			Cane yield (t/ha)	Recovery (%)
I	5	CoS-802, CoP-84211, CoS-687, CoS-90269, CoJ-83			39.12	09.32
II	2	CoS7918, CoS86218			39.2	08.46
III	2	CoJ-64, CoS8436,			42.59	10.42
IV	6	CoS91269, CoS767, Bo-91, Co1148, Co1158 CoLK8102			53.56	8.95
V	5	CoS88230, CoJ-84, CoP84212, CoS88216, CoS8432			51.33	09.35
Average inter and intra cluster distance for twenty genotype						
Cluster	I	II	III	IV	V	Cluster Distance 229.75/47.37
I	1.647					
II	3.392	1.918				
III	4.035	5.439	00			
IV	5.516	3.722	7.225	1.674		
V	2.729	4.31	6.021	4.557	2.015	

Table 2. Genetic divergence analysis, cane yield and recovery of ratoon sugarcane under different environment

E₁ Ratoon of March Sown plant cane harvested at 10 month						
Cluster	No. of genotype	Name of Genotypes	Cane yield (t/ha)	Recovery (%)		
I	4	CoS802, CoS90269, CoS588-216,	46.10	08.95		
II	4	CoS88230, CoS91269, CoS767, CoS8432	62.24	10.52		
III	8	CoJ64, CoS8436, CoS687, CoP84211, CoS7918, CoJ83, CoJ84, CoP84212, CoS86218	46.87	10.44		
IV	1	Bo91	56.64	09.42		
V	3	Co1148, Co1158, CoLK8102	58.78	09.41		
Average inter and intra cluster distance for twenty genotype						
Cluster	I	II	III	IV	V	Cluster Distance 270.63/48.74
I	1.856					
II	5.544	1.555				
III	3.988	3.610	1.980			
IV	4.032	3.993	4.713	1.011		
V	3.687	4.162	4.057	3.923	1.669	
E₂ March Sown plant cane harvested at 12 month						
Cluster	No of genotype	Name of Genotypes	Cane yield (t/ha)	Recovery (%)		
I	4	CoS802, CoS90269, CoJ84, CoS 88216	43.65	09.83		
II	3	CoS90269, CoS767, Bo91	55.28	09.76		
III	4	CoJ64, CoP84211, CoS687, CoJ83	39.42	10.41		
IV	3	Co1158, CoS7918, CoS86218 CoLK8102	47.41	08.75		
V	6	CoS88230, CoS8436, Co1148, CoP84212, CoS8432	53.42	10.10		
Average inter and intra cluster distance for twenty genotype						
Cluster	I	II	III	IV	V	Cluster Distance 239.18/48.85
I	1.793					
II	4.048	1.531				
III	2.988	4.680	2.062			
IV	3.835	4.922	5.568	1.885		
V	3.353	3.278	3.629	4.907	1.492	
E₃ April Sown plant cane harvested at 10 month						
Cluster	No of genotype	Name of Genotypes	Cane yield (t/ha)	Recovery (%)		
I	5	CoS-802, CoP-84211, CoS-687, CoS-90269, CoJ-83	42.67	09.87		
II	2	CoS-7918, CoS-86218	43.21	08.79		
III	5	CoS-91269, Bo-91, Co-1148, Co-1158, CoLK-8102,	58.61	09.51		
IV	7	CoS-88230, CoS-8436, CoS-767, CoJ-84, CoP-84212, CoS-88216, CoS-8432	54.98	10.36		
V	1	CoJ-64	39.98	11.99		
Average inter and intra cluster distance for twenty genotype						
Cluster	I	II	III	IV	V	Cluster Distance 239.45/50.52
I	1.305					
II	3.324	0.778				
III	4.059	4.995	1.745			
IV	3.762	6.184	2.742	1.875		
V	5.418	8.402	7.4366	5.045	0.001	
E₄ April Sown plant cane harvested at 12 month						
Cluster	No of genotype	Name of Genotypes	Cane yield (t/ha)	Recovery (%)		
I	5	CoS-802, CoP-84211, CoS-687, CoS-90269, CoJ-83	39.12	09.32		
II	2	CoS-7918, CoS-86218	39.2	08.46		
III	2	CoJ-64, CoS-8436	42.59	10.42		
IV	6	CoS-91269, CoS-767, Bo-91, Co-1148, Co-1158 CoLK-8102,	53.56	8.95		
V	5	CoS-88230, CoJ-84, CoP-84212, CoS-88216, CoS-8432,	51.33	09.35		

Average inter and intra cluster distance for twenty genotype						
Cluster	I	II	III	IV	V	Cluster Distance 226.28/46.50
I	1.319					
II	3.972	0.787				
III	4.359	7.839	1.641			
IV	4.062	4.976	5.707	2.096		
V	3.432	6.026	3.806	2.371	1.479	

Table 3. Desirable genotypes consistently exhibiting divergence under eight different environments

S.N.	Desirable in terms of high sugar recovery and stable genotypes	Genotypes which never clustered with the genotypes given in previous column
1	CoS88230, CoS91269	CoS-802, CoP-84211, CoS-687, CoJ-83, CoS-7918, CoS-86218
2	CoS8436,	CoS-802, CoS-7918
3	CoJ83	CoS-91269, Bo-91, Co-1148, Co1158 CoLK-8102, CoS-8432
4	CoS767	CoJ-64, CoS687, Co1148,
5	Co1148, CoS7918, CoS86218	CoS-802, CoJ-64, CoJ-84, CoP-84211, CoS-687, CoS-90269, CoJ-83
6	CoS88216	CoJ-64, CoJ-83
7	CoLK8102, CoS8432	CoS-802, CoJ-64, CoP-84211, CoS-687, CoS-90269, CoJ-83, CoS-7918, CoS-86218
8	CoS86218	CoS-88230, CoS-91269, Bo-91, Co-1148, CoLK-8102, CoS-8432

Selection of genotypes can also be made on the basis of divergence which was consistent over all the environment utilizing this criterion the divergence of high sugar cane yield and Stalk genotypes selected on the basis of stability estimates has been examined. The details of consistent divergence of ten high sugar and cane yielding stable genotypes have been presented in table 3 and the genotypes can be selected on the basis of this information for making fruitful crosses.

It is evident from the table 3 that CoS-88230 and CoS-91269 genotypes differ from six other genotypes (CoS-802, CoP-84211, CoS 687, CoJ-83, CoS-7918 and CoS-86218), CoJ-83 from other six genotypes (CoS-91269, Bo-91, Co-1148, Co-1158, CoLK-8102, CoS-8432), Co-1148 differs from other ten genotypes (CoP-84212, CoS-802, CoJ-64, CoJ-84, CoS-7918, CoS-86218, CoP-84211, CoS-687, CoS-90269, CoJ-83), CoLK-8102 and CoS-8432 genotypes differ from other eight genotypes (CoS-802, CoJ-64, CoP-84211, CoS-687, CoS-90269, CoJ-83, CoS-7918, CoS-86218 and CoS-86218 genotype differs from the other six genotypes (CoS-88230, CoS-91269, Bo-91, Co-1148, CoLK-8102, CoS-8432).

Therefore, the recommendation may be made that the above genotypes of sugarcane given in table 3, first column should be involved in the crossing program with other corresponding genotypes given in the second column against each genotype for obtaining desirable segregants. Hybridization between genetically distant genotypes for exploring hybrid vigour was frequently suggested in other crop species by Vivekananda and Subramanian (1993). The use of genotypes from various clusters with maximum

diversity has been emphasized by many workers in sugarcane as well (Punia et al 1983, Gill et al 1983, Arunachalam et al 1989, Hooda et al 1990, Shrivastava et al 1999 Ravishankar et al 2003, Ahmed et al 2010, Gowda et al 2017 and Nishad and Kumar (2020).

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