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Genetic divergence in early maturing sugarcane clones for the cane yield and yield attributing traits

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ABSTRACT

Fifteen early maturing sugarcane clones including two checks were planted in Randomized Block Design with three replications during *spring season* 2017 at research farm of RPCAU Pusa to evaluate the variability and clustering pattern for cane yield and yield attributing traits. Observations were recorded for the eighteen traits *viz.,* germination % at 45 days after planting, number of shoots at 120 days, plant height at 150, 240 days and at harvest, cane diameter at harvest, millable canes at harvest, single cane weight at harvest, brix, pol, purity and ccs at 8 and 10^{th} month stage, sugar yield and cane yield at harvest and after its statistical analysis, all the characters were found differed significantly for all the genotypes. All the early maturing sugarcane clones were grouped into four distinguished clusters among fifteen genotypes. Cluster I contained maximum number of clones (6) followed by cluster IV (4), cluster III (3) and cluster II (2). Maximum intra-cluster D^2distance was observed in cluster I and maximum inter-cluster D^2distance was observed between cluster II and cluster IV. The trait, Pol percent at 10^{th} month stage showed maximum character contribution percent towards divergence followed by sugar yield at harvest, cane yield and brix at 10^{th} month stage. Keeping all the genetic information and their conclusive interpretations, it can be safely concluded that to attained these objectives, bi-parental mating or poly-cross technique used for developing high yielding sugarcane clones involving genotypes belonging to cluster II and cluster IV as well as cluster III and cluster IV may be tried.

Keywords: Sugarcane early maturing clone, variability, genetic divergence.

Introduction

Sugarcane is an important cash crop of world as well as India. It alone provides 75 percent of the sugar traded worldwide. In India it is grown in 49.53 lakh hectares with total production of 352.16 million tonnes and productivity of 71.09 tonnes/ha. Cultivation of sugarcane in India dates back to the Vedic period. The earliest mention of sugarcane cultivation is found in Indian writings of the period 1400 to 1000 B.C. It is now widely accepted that India is the original home of *Saccharum species*. *Saccharum officinarum* most probably developed in the East Indonesian/New Guinea area. The present day sugarcane is considered to be the outcome of polyploidization and hybridization consisting predominantly of *S. officinarum L.* (2n = 80), known as 'noble cane' and 'wild cane' *S. spontaneum* (2n = 40–120), along with minor contributions from *S. robustum, S. sinense, S. barberi* and related genera such as *Miscanthus, Narenga and Erianthus*. The genus Saccharum is complex and consists of six species viz. S. *officinarum*, S. *barberi*, S. *sinenses*, S. *edule*, S. *spontaneum* and S. *robustum*, out of these S. *spontaneum* and S. *robustum* is the wild in nature while other four are cultivated species. The sugarcane varieties are man-made hybrid clones involving *Saccharum officinarum* and S. *spontaneum* with a few genes incorporated from, S. sinense, S. barberi and to a limited extent S. *robustum*.

Early maturing sugarcane varieties have been improving the performance of factories by increasing the average sugar recovery especially during the early part of the crushing season. The early maturing varieties record a high sucrose level as compared to the mid-late ones and mature within 10 months. At present, Bihar has only 22% sugarcane area under early maturing group while it should be 50%. For smooth running of sugar factory, high yielding early varieties will be beneficial to farmers for raising his incomes. As per Indian sugar 2018 the productivity in sugarcane in Bihar for the year 2016-17 was 50 t/ha while in present investigation some of the early maturing sugarcane clones has yield potential up to 106 t/ha. We know that the breeders involved in sugarcane improvement will have to face the tough challenge of increasing the productivity of early maturing varieties of sugarcane. There is lot of breeding works like, Bi-parental mating, involving two specific parents possessing general thriftiness followed by subsequent selection in the successive settling generations, forms the major approach to varietal development of sugarcane for general commercial cultivation. Evidently, for this, a large number of clones are to be evaluated at the seedling as well as clonal generations for cane yield and juice quality characters. Yield is a complex character but in sugarcane it acquires additional dimension of complexity as it turns out to be a union of cane yield as well sugar in cane which is highly dependent on a number of component attributes. Furthermore, polygenic control of yield and its component characters, larger magnitude of genetic, clonal and environmental interactions with the final yield make the task of breeders more difficult.

Furthermore, since maximum expression of heterosis is expected with mating, involving diverse genotypes a thorough knowledge of relative genetic distance between different clones is also necessary. It may act as a guide in the selection of parents to be involved in crossing.

Materials and Methods:-

The materials used for the study comprised of 13 clones viz, CoP 11436, CoP 11438, CoP 12436, CoP 14436, CoP 15436, CoP 15437, CoP 16437, CoP 16438, CoP 17436, CoP 17437, CoP 17438(SRI, Pusa), CoLk 12207(RRS, Motipur), CoSe 12451(Seorahi, UP) and two checks CoP 11437, BO 153 (SRI, Pusa). All the 15 clones including two checks were planted in Randomized Block Design with three replications during spring season 2017. Total 18 traits *viz.*, germination % at 45 days after planting, number of shoots per hectare at 120 days (000/ha), plant height at 150 days (cm), plant height at 240 days (cm), plant height at harvest (cm), cane diameter at harvest (cm), millable canes at harvest (000/ha), single cane weight at harvest (kg), brix at 8^{th} month stage (%), pol in juice at 8^{th} month stage (%), purity at 8^{th} month stage (%), brix at 10^{th} month stage (%), pol in juice at 10^{th} month stage (%), purity at 10^{th} month stage (%), ccs at 8^{th} month stage (%), ccs at 10^{th} month stage (%), sugar yield at harvest (t/ha) and cane yield at harvest (t/ha) were recorded during the course of investigations in the fifteen clones on par plot basis with the help of following methods,

Germination was recorded after 45 days of planting. The formula for calculation of germination percentage is Number of buds germinated divided by Number of buds planted into 100. Number of shoots was counted at 120 DAP on per plot basis. It includes the mother plants as well as the tillers that have come out of the mother plant. Then it was converted into thousands per hectare. The cane height was measured with the help of a measuring tape (cm) from the ground surface to the top most internodes of cane stalk. The average of the five samples of cane stalks represented the cane height. The plant height is measured at 150, 240 days and at harvest. Thickness was measured at the middle of cane stalk in centimeters (cm) with the help of a vernier caliper. Average of five sample canes represents the cane thickness of the plot. Canes bearing appreciable height i.e. more than 1m were considered as millable canes. The millable canes were counted on the whole plot basis at harvest. The numbers of millable canes (NMC) per plot were converted into NMC thousand per hectare. The weight of five randomly selected canes

from each plot was measured in kilogram (kg) and the average single cane weight was calculated. Sample of five randomly selected cane stalks were crushed in a cane crusher. The juice was poured in graduated measuring cylinders of 500 ml and brix hydrometer was suspended in this cylinder. When the brix hydrometer stopped oscillating in the cylinder, then the reading was recorded. Approximately 100 ml juice of each sample was taken in a beaker and about 1-1.5 gm of basic lead acetate anhydrous was added to it, stirred and kept for some time for the precipitation of the non-soluble substance. The precipitated impurities were filtered off and clear filtrate juice was collected. The clear filtered juice was filled in 20 cm long Polari-meter tube. This tube was placed in the body of Polari-meter and pol reading was recorded. Using Schmitz table (Spencer and Meade, 1955), the sucrose percent in juice was noted for corresponding values of the brix and pol reading. The percentage of sugar in total solid in a sugar product called purity percentage. The juice purity percentage was calculated by using the following formula: Purity Percent = $\frac{\text{Pol in juice}}{\text{Juice Brix}} \times 100$. CCS % at 8^{th} and 10^{th} month stage was calculated from sucrose in juice and brix reading as per formula given below: CCS percent = [S-(B-S) × 0.4] × 0.73 Where, S = Sucrose percent in juice (pol %) B = Brix percent in juice. Sugar yield (CCS t/ha) at harvest was calculated by multiplying CCS percent with cane yield per plot and it was converted in t/ha. Sugar yield (CCS t/ha) =$\frac{\text{CCS (\%)in cane} \times \text{Cane yield (t/ha)}}{100}$. The cane yield was taken at the time of harvesting. Cane yield (t/ha) was recorded during harvesting after weighing the all canes in a plot and converted it into t/ha.

Statistical Analysis

The data collected for eighteen traits were analyzed for analysis of variance, estimation of standard error and critical difference by standard analysis of variance technique as given by Panse and Sukhatme (1967). Test of significance for difference between characters means was carried out by referring to the F- table given by Snedecor & Cochran (1967). A measure for group distance based on multiple characters was given by Mahalanobis (1928). Following the analysis of variance and covariance, the data was subjected to multi-variate analysis. It was calculated

according to Rao (1952). Original variable means were transformed to uncorrelated variables by the pivotal condensation method.

D^2 values were calculated for 105 pairs of combinations, as the sum of differences of the varieties over all transformed variables.

$$D^2 = d_{ij} (X_{i1} - X_{i2}) (X_{j1} - X_{j2})$$

Where,

d_{ij} = inverse of estimate of variance-covariance matrix.

Suppose if we take three characters,

The

$$D^2 = d_{11} (X_{11} - X_{12})^2 + d_{22} (X_{21} - X_{22})^2 + d_{33} (X_{31} - X_{32})^2 + d_{12} (X_{11} - X_{12}) (X_{21} X_{22}) +$$

$$d_{13} (X_{11} - X_{12}) (X_{31} - X_{32}) + d_{23} (X_{21} - X_{22}) (X_{31} - X_{32})$$

To simplify the computational procedure, the variables x_1, x_2 and x_3 were transformed to a new set of uncorrelated variables, y_1, y_2 and y_3. Distance D^2 as computed by x_1, x_2 and x_3 will be the same when computed by y_1, y_2 and y_3.

Hence, the reduced formula will be,

$$D^2 = D_1^2 + D_2^2 + D_3^2$$

Now, D^2 values which are sum of squares of the differences in transformed uncorrelated values for various characters were calculated and significance of D^2 values were tested treating as X^2 (chi-square) values at 5 and 1 percent levels of significance.

Grouping of clones in to various clusters:-

At first, D^2 values of all individual populations in (n-1) combinations were arranged with ascending order. After arranging the D^2 values in this manner, a method suggested by Toucher (Rao, 1952) was used for cluster formation.

The two populations having smallest distance from each other were considered first to which a third population having smaller average D^2 values, from the first two population was added. Then came the nearest fourth population and so it went on. At a certain stage, when it was felt that after adding a particular population, there was disrupt increase in the average D^2 values, the population was not added into that cluster. Similarly, a second cluster was formed. This process was repeated till all the populations were included into one or the other cluster.

After formation of the clusters on the basis of D^2 values, the average intra-cluster D^2 values were obtained by the formula:

Average intra-cluster D^2 values = $\frac{\sum D_1^2}{N}$

Where,

$\sum D_1{}^2$ = sum of distances between all possible combinations (n) of the populations included in a cluster.

In this way, average inter-cluster D^2 values were also obtained between any two groups.

The square roots of the D^2 values represented the distance between and within the two groups.

Table. – 1 Analysis of variance for eighteen characters in early maturing clones of sugarcane

Sl. No.	Characters	Mean sum of squares		
		Replication d.f.=2	Genotype d.f.=14	Error d.f.=28
1	Germination % at 45 DAP	18.42	37.95**	5.61
2	Number of Shoots at 120 DAP (000/ha)	100.16	169.62**	38.18
3	Plant height at 150 DAP (cm)	24.38	637.77**	76.40
4	Plant height at 240 DAP (cm)	102.84	1628.97**	176.08
5	Plant height at harvest (cm)	143.16	1440.10**	238.96
6	Cane diameter at harvest (cm)	0.024	0.073**	0.019
7	Millable canes at harvest (000/ha).	139.21	176.33**	59.87
8	Single cane weight at harvest (Kg).	0.004	0.046**	0.004
9	Brix at 8^{th} month stage (%)	0.08	1.93**	0.31
10	Pol in juice at 8^{th} month stage (%)	0.10	2.17**	0.20
11	Purity at 8^{th} month stage (%)	0.04	4.35**	0.74
12	Brix at 10^{th} month stage (%)	0.20	5.37**	0.13
13	Pol in juice at 10^{th} month stage (%)	0.09	2.18**	0.09
14	Purity at 10^{th} month stage (%)	1.76	12.21**	0.54
15	CCS at 8^{th} month stage (%)	0.05	1.24**	0.11
16	CCS at 10^{th} month stage (%)	0.06	0.78**	0.05
17	Sugar Yield At harvest (t/ha)	0.26	6.87**	1.12
18	Cane Yield At harvest (t/ha)	31.15	353.68**	67.10

* Significant at 5%, ** significant at 1%

Table: - 2 Grouping of clones into various clusters among fifteen genotypes of early maturing sugarcane clones

Clusters	Number	Clones
I	6	CoP11436
		CoLk12207
		CoP12436
		CoSe12451
		CoP14436
		CoP17438
II	**2**	CoP11437 (C)
		BO153 (C)
III	**3**	CoP15436
		CoP17437
		CoP17436
IV	**4**	CoP16437
		CoP16438
		CoP11438
		CoP15437

Table: - 3 Inter and Intra Cluster D^2 Distance of fifteen early maturing sugarcane clones

Clusters	I	II	III	IV
I	244.484	525.944	497.238	548.349
II		194.295	856.131	983.844
III			113.88	301.324
IV				161.183

Table: - 4 Cluster Means for eighteen characters of early maturing sugarcane clones

	Germination % at 45 DAP	Shoots per hectare at 120 DAP (000/ha)	Plant height at 150 DAP (cm)	Plant height at 240 DAP (cm)	Plant height at harvest (cm)	Cane diameter at harvest (cm)	millable cane Per hec at harvest (000/ha)	Single cane weight at harvest(Kg)	Brix at 8 month stage (%)	pol at 8 month stage (%)	Purity at 8 month stage (%)	Brix at 10 month stage (%)	pol at 10 month stage (%)	Purity at 10 month stage (%)	CCS at 8 month stage	CCS at 10 month stage	Sugar yield at harvest (CCS tonne/ha)	Cane yield (tonne/ha)
Cluster I	34.22	96.19	120.96	221.42	258.01	2.43	97.19	0.84	18.41	16.07	87.30	20.77	18.04	86.96	11.05	12.37	10.08	81.48
Cluster II	34.00	113.46	96.17	195.46	239.96	2.55	105.37	0.84	19.52	17.42	89.22	22.50	18.79	83.52	12.10	12.63	11.24	88.99
Cluster III	32.22	93.65	114.08	192.39	231.33	2.47	101.28	0.83	19.42	17.16	88.34	19.18	16.92	88.18	11.87	11.69	9.81	83.72
Cluster IV	36.08	100.48	122.50	239.23	273.92	2.77	93.23	1.09	19.10	17.00	89.06	20.45	17.98	87.97	11.80	12.41	12.56	101.26

Table: - 5 Character Contribution percent divergence of early maturing sugarcane clones

Character	Contribution %
1. Germination % at 45 DAP	0.01
2. Shoots at 120 DAP (000/ha)	0.01
3. Plant height at 150 DAP (cm)	0.01
4. Plant height at 240 DAP (cm)	0.01
5. Plant height at harvest (cm)	1.90
6. Cane diameter at harvest (cm)	0.01
7. Millable canes at harvest (000/ha)	0.01
8. Single cane weight at harvest (Kg)	2.86
9. Brix at 8 months stage (%)	0.01
10. Pol in juice at 8 months stage (%)	0.95
11. Purity at 8 months stage (%)	0.01
12. Brix at 10 months stage (%)	12.38
13. Pol in juice at 10 months stage (%)	44.76
14. Purity at 10 months stage (%)	0.01
15. CCS at 8 months stage (%)	2.86
16. CCS at 10 months stage (%)	0.01
17. Sugar Yield At harvest (t/ha)	18.10
18. Cane Yield At harvest (t/ha)	16.19

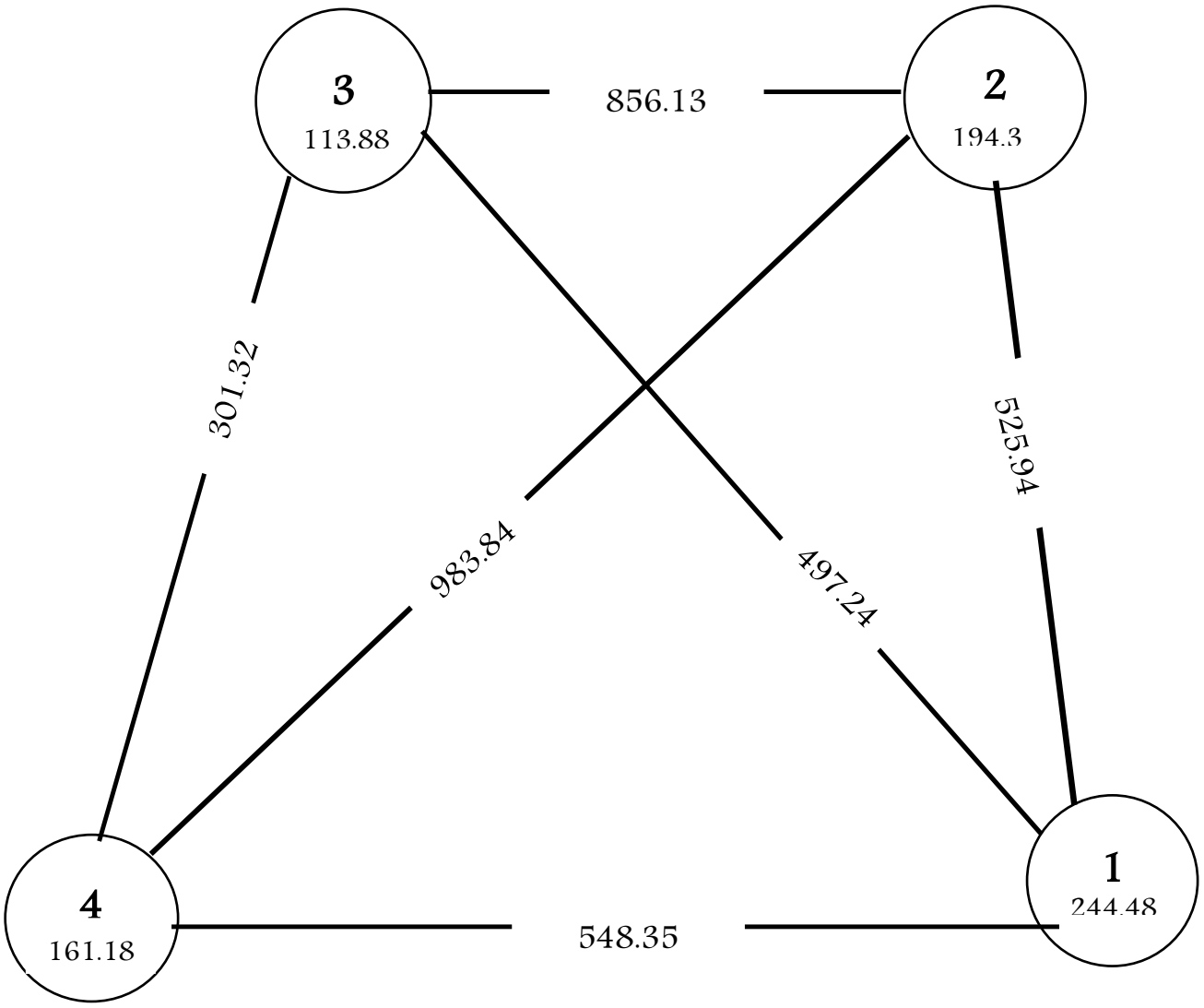

Figure 1 – Cluster diagram of 15 early maturing sugarcane clones

Result and Discussions

The ANOVA for 18 characters of early maturing sugarcane clones has been presented in Table-1. The analysis of variance showed high significant difference for all the traits. The results pointed out that clones differed significantly it means wide range of variability existing among the clones for all the characters. These variations had their bases in genetic differences among the clones.

All the clones were grouped into four distinguished cluster based on the method discussed previously. Table-2 mentioned the grouping of clones into various clusters among fifteen genotypes of early maturing sugarcane clones. Cluster I contained maximum number of clones (6) viz, CoP11436, CoLk12207, CoP12436, CoSe12451, CoP14436, CoP17438 followed by cluster IV (4) viz, CoP16437, CoP16438, CoP11438, CoP15437, cluster III (3) vizCoP15436, CoP17437, CoP17436 and cluster II (2) viz, CoP11437(C), BO153(C). The average intra- and inter-cluster distances were calculated from the D^2-values of respective clones within and between the clusters. References to Table-3 and figure-1 indicated that the intra-cluster D^2-values ranges from 113.88 to 244.484 (III-III, I-I) suggesting that substantial amount of diversities were present within the cluster itself. Maximum intra-cluster D^2distance was observed in cluster I (D^2= 244.484) and maximum inter-cluster D^2distance was observed between cluster II and cluster IV (D^2= 983.844). Figure 3 showed the Intra- and Inter-cluster D^2distancebetween the clusters. Table: - 4 showed the Cluster Means for different characters of early maturing sugarcane clones. Cluster II was observed to have highest cluster mean for number of shoots per hectare at 120 days, millable cane per hectare at harvest, brix at 8^{th} month stage, pol percent at 8^{th} month stage, purity at 8^{th} month stage, brix at 10^{th} month stage, pol percent at 10^{th} month stage, ccs at 8^{th} month stage and ccs at 10^{th} month stage whereas cluster IV was observed to have highest cluster mean for germination at 45 days of planting, plant height at 150, 240 days and harvest, cane diameter at harvest, single cane weight at harvest, sugar yield at harvest and cane yield. Cluster III was observed to have highest cluster mean for only one character purity at 10^{th} month stage. None of the characters was observed for highest cluster mean in cluster I. Table: - 5 showed the towards character contribution percent divergence of early

maturing sugarcane clones. Pol percent at 10th month stage showed maximum character contribution percent towards divergence followed by sugar yield at harvest, cane yield, brix at 10th month stage etc.

The analysis of variance for all the eighteen characters indicated that clones, differed significantly for all the characters it means, presence of sufficient variability, scope for further selection, breeding superior clone and desirable genotypes. These variations had their bases in genetic differences among the clones and considerable improvement can be achieved by all these characters during selection. The finding of earlier workers namely Singh *et.al.* (2010), Ahmad *et.al.* (2010), Khan *et.al.* (2012), Ijaz *et.al.* (2013), Sanghera *et.al.* (2014), Kumar (2014), Sanghera *et.al.* (2015), Pandya *et.al.* (2015), Hiremath *et.al*. (2016), Sanghera *et.al.* (2017), Mehareb *et.al.* (2017), Patil *et.al*. (2017) and Ranjan and Kumar (2017) have already been reported the significant differences among the genotypes for all the characters.

Exploitation of heterosis largely depends on the degree of genetic divergence between the parents selected for breeding programme. Genetically diverse parents are expected to yield superior hybrids. Generally divergence study in performed to seek superior parents for having maximum heterosis by utilizing optimum level of diversity. The population that belong to heterogeneous environments are not necessarily genetically more diverse. Genotypes which are grouped together are less divergent as compared to those which belong to different clusters. Clusters separated by maximum statistical distance show the maximum divergence. Therefore, while selecting parents for crossing programme, two point should be considered:

1. The choice of clusters with maximum statistical distance and
2. Selection of two genotypes from already chosen clusters,

Crossing of genetically diverse parents with desirable gene controlling economic quantitative and quality characters may give elite progenies due to assembling of those desirable genes.

In the present investigation, all the fifteen genotypes were grouped into four clusters. Clustering pattern showed that the genetic diversity was more important than geographical diversity because genotypes belonging to different places of origin were also present in the same clusters. This confirms the findings of Patil et.al. (2017).

Maximum inter-cluster distance was observed between cluster II and cluster IV followed by between cluster II and cluster III, cluster I and cluster IV, cluster I and cluster II, cluster I and cluster III with a least value between cluster III and cluster IV. Maximum intra-cluster distance was shown by cluster I followed cluster II, cluster IV and cluster III.

Theoretically, a breeder may anticipate maximum manifestation of heterosis in hybrids derived from crossing of genotypes having maximum genetic distance. On this ground, crossing should be effected between the genotypes that belong to cluster II and cluster IV.

However, in selecting varieties from the already chosen groups, the maximum genetic distance suggested that genotypes with high index for specific characters that fall into different clusters could be inter-crossed to generate good number of sugarcane progenies having greater potentiality for breeding purpose by virtue of their desirable characters (Sanghera*et.al*. 2015), similar suggestion was also given by (Ahmad *et.al* 2010). It may be possible that genotypes having maximum genetic diversity possess low yielding ability and other characters with poor performance. Further-more, maximum expression of heterosis is often limited with the hybrids derived from genotypes that are neither closely nor distantly related.

The mean performance of the genotypes belonging to cluster IV with regards to characters for which selection may be practiced was high. However, the mean performance of the genotypes belonging to cluster II and cluster III that was separated by high genetic distance from cluster IV. A critical analysis of cluster means for different traits indicated that Cluster II was observed to have highest cluster mean for number of shoots per hectare at 120 days, millable cane per hectare at harvest, brix at 8^{th} month stage, pol percent at 8^{th} month stage, purity at 8^{th} month stage, brix at 10^{th} month stage, pol percent at 10^{th} month stage, ccs at 8^{th} month stage and ccs at 10^{th} month stage whereas cluster IV was observed to have highest cluster mean for germination at 45 days of planting, plant height at 150, 240 days and harvest, cane diameter at harvest, single cane weight at harvest, sugar yield at harvest and cane yield. Cluster III was observed to have highest cluster mean for only one character purity at 10^{th} month stage. The maximum genetic distance suggested that genotypes with high index for specific characters that fall into different clusters could be intercrossed to generate good number of sugarcane progenies having greater potentiality for breeding purpose by virtue of their desirable characters. Similar suggestions were given by Sanghera*et.al*. (2015)

Through the mean performance of the genotypes that fell into cluster II and cluster III was not as good as those of cluster IV, still high expression of heterosis for cane yield can be expected if complementary gene action is present with regard to cane yield. Hence, crossing between genotypes belonging to cluster II and cluster IV as well as cluster III and cluster IV may be advocated for maximum expression of heterosis in regard to cane yield.

Therefore, on the basis of present finding and their conclusive reasoning, bi-parental mating or poly cross technique involving genotypes belonging to cluster II and cluster IV as well as cluster III and cluster IV may be advocated in order to generate seedling to superior genetic background. Clonal selection in subsequent generation should be based on number of millable canes, number of shoot at 120 days and plant height at harvest for developing high yielding sugarcane varieties. Observations on germination at 45 days of planting, single cane weight, cane diameter should also be recorded and clonal surpassing these characters of standard varieties be advanced to next clonal generation. Quality attributes like brix, pol and purity percent cannot be ignored. These quality characters should also be recorded at 8^{th} and 10^{th} month of planting in order to develop short duration early varieties.

Summary and conclusion

The range of variations alluded possibility of improvement among the clones for the characters. However, the analysis of variance appraised significant differences for all the characters. Keeping all the genetic information and their conclusive interpretations, it can be safely concluded that to attained these objectives, further sugarcane breeding programme bi-parental mating or poly-cross technique used for developing high yielding sugarcane clones involving genotypes belonging to cluster II and cluster IV as well as cluster III and cluster IV may be tried

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