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Short communication

Diversity analysis of KAU released cocoa (*Theobroma cacao* L.) varieties based on morphological parameters

Sujith S. Sajeevkumar*[1], J.S. Minimol[2], P.M. Ajmal[1] and B. Suma[2]

[1]*College of Horticulture, KAU P.O., Kerala Agricultural University, Thrissur 680656, Kerala, India*; [2]*Cocoa Research Centre, KAU P.O., Kerala Agricultural University, Thrissur 680656, Kerala, India*

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Abstract

Cross incompatibility is a major constraint in cocoa research and understanding similarity or dissimilarity among the varieties before establishing clonal gardens is essential for propagation and further improvement. Morphological analysis with respect to the selected quantitative and qualitative pod characters were taken for the present diversity analysis. Six qualitative and eight quantitative pod and bean characters of each variety were recorded as per the standard descriptors. The genetic associations among the varieties were estimated through Jaccard's similarity coefficients using NTSYSpc version 2.1. Cluster analysis was done on the similarity matrix and dendrogram was constructed using Unweighted Pair-Group Method (UPGMA). Diversity analysis based on qualitative and quantitative traits grouped the ten cocoa varieties into five clusters at 68 per cent similarity level. Homology between qualitative and quantitative clustering pattern was also worked out and significant variation was observed in distribution pattern of varieties under study. The polyclonal garden layout designed based on the present diversity analysis can be made use of for ensuring maximum pod set when cocoa is intercroped with coconut.

Keywords: Cocoa, Dendrogram, Diversity, Layout, NTSYSpc, Similarity, UPGMA

Cocoa (*Theobroma cacao* L.), referred to as 'chocolate tree', is an important cash crop in many tropical countries. Cocoa is grown as a mixed crop with coconut and arecanut in traditional zones of Kerala and Karnataka. In Tamil Nadu and Andhra Pradesh, cocoa is an inter crop in coconut, and to some extent, in oil palm gardens (Alban et al., 2016). Morphological markers generally represent genetic polymorphisms based on visible traits, which are easily identified and manipulated. Investigations so far revealed that morphological markers are useful for classifying the diversity of cocoa populations and germplasm collections (Efombagn et al., 2009). Smith and Smith (1989) concluded that morphological characterization is the first step in the description and classification of germplasm. Similarly, Minimol et al. (2011) reported that the fruit apex form plays an important role in determining fruit shape. Several studies of morphological diversity have been conducted on flowers, fruits and leaves of cocoa germplasm accessions. Domesticated *T. cacao* has a wide diversity in plant morphology and the three cocoa groups viz., Criollo, Forastero and Trinitario were mainly classified based on their morphology especially the pod and bean characters (Wood and Lass, 1985). Exploiting the potential of Asia's largest cocoa germplasm (640 accessions) maintained by Cocoa Research Centre (CRC), Kerala Agricultural University (KAU), 10 cocoa varieties have been released by the centre. In India, 90 percent of cocoa gardens are established with the planting materials supplied from KAU (Sujith and Minimol, 2016). Hence, the morphological

*Author for correspondences: Phone: 91-7025333804, Email: sssujith303@gmail.com

Table 1. Clustering based on qualitative characters for cocoa varieties

Cluster no	No. of varieties	Name of varieties
I	5	CCRP 1,CCRP 7,CCRP 8, CCRP 9,CCRP 10
II	1	CCRP 2
III	1	CCRP 3
IV	2	CCRP 4,CCRP 5
V	1	CCRP 6

analysis of pod and bean characters of released cocoa varieties from the research centre will from the basis of future crop improvement programmes in the country.

All the ten varieties released from CRC, KAU *viz.* CCRP1, CCRP2, CCRP3, CCRP4, CCRP5, CCRP6, CCRP7, CCRP8, CCRP9 and CCRP10 has been included in the study.

Morphological observations on distinguishable eight quantitative and six qualitative characters were recorded on five pods collected from each variety using reported descriptors (Bekele and Butler, 2000). The values thus obtained were averaged on cluster basis and the similarity or dissimilarity among clusters on specific characters were compared. Agglomerative hierarchical clustering based on Jaccard's similarity coefficient was done using the UPGMA method (Jaccard, 1908) NTSYSpc version 2.1 (Rohlf, 1992). Dendrogram was constructed and presented in Fig. 1. Ten varieties were grouped into five clusters at 68 per cent similarity level (Table 1). Cluster I consisted of maximum number of members i.e., five (CCRP 1, CCRP 7, CCRP 8, CCRP 9 and CCRP 10). Clusters II, III and V had one variety each i.e., CCRP 2, CCRP 3 and CCRP 6 respectively. Members of cluster IV included CCRP 4, and CCRP 5. Hybrids CCRP 8, CCRP 9 and CCRP 10 were grouped in a single cluster. Table 2 depicts cluster based qualitative observations made on the varieties under study. All the members of cluster I except CCRP 7 possessed pods of Cundeamor shape, medium rugosity, acute pod apex and dark purple beans. Cluster IV had CCRP 4 and CCRP 5 with Angoleta shaped yellow pods, intense pod rugosity and dark purple beans. Though CCRP 2 and CCRP 3 were grouped into two different clusters, except for pod apex form, they were similar in all other five characters. Cluster V consisted of a single variety CCRP 6 which was different from CCRP 4 and CCRP 5 with respect to colour of ripe pod and pod rugosity.

Varieties under cluster I which comprised hybrids CCRP 8, CCRP 9 and CCRP 10, produced Cundeamor (ridged and with bottle neck) shaped pods, were with acute fruit apex, Amelonado with round or acute and Angoleta with obtuse end indicating that the fruit shape could be identified by its apex form. The results were in tune with an earlier study by Minimol et al. (2011) stating that fruit shape was influenced by fruit apex. The other characters like rugosity and colour of cotyledon also supported the fact that all the varieties were forastero types. Rugosity was medium, except in CCRP 6 (intense), and colour of cotyledon ranged from pink to dark pink. The same features were described by Wood and Lass (1985) for forastero types.

The ten varieties differed significantly with respect to all the eight quantitative characters viz., pod weight, pod length, pod breadth, husk thickness,

Table 2. Prominant qualitative characters of varieties included in each cluster

Cluster ID/ Observations	Pod shape	Colour of ripe pod	Pod apex form	Pod basal constriction	Pod rugosity	Colour of bean
I	Cundeamor	Greenish yellow	Acute	Slight	Medium	Dark purple
II	Amelonado	Yellow	Rounded	Slight	Medium	Light purple
III	Amelonado	Yellow	Acute	Slight	Medium	Dark purple
IV	Angoleta	Yellow	Obtuse	Slight	Intense	Dark purple
V	Angoleta	Yellowish green	Obtuse	Slight	Medium	Light purple

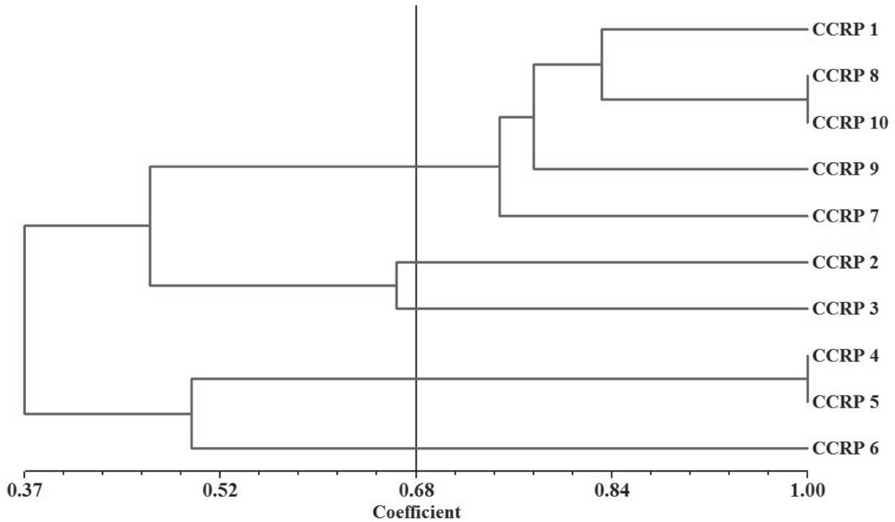

Figure 1. Dendrogram based on qualitative characters of 10 cocoa varieties

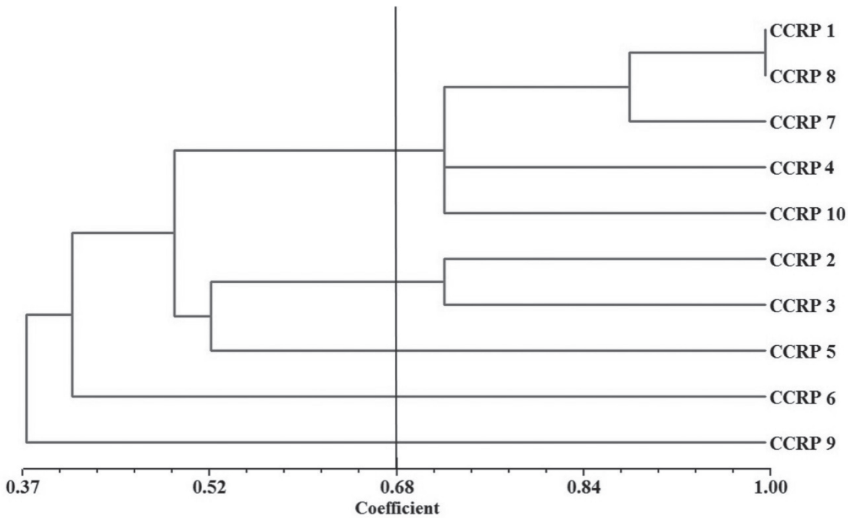

Figure 2. Dendrogram based on quantitative characters of 10 cocoa varieties

number of beans, wet bean weight/pod, single wet bean weight and single dry bean weight (Sujith and Minimol, 2016). The phylogenetic tree constructed at 68 per cent similarity level grouped the varieties under study into five clusters (Fig. 2). Among the five clusters generated, cluster III, cluster IV and cluster V comprised of a single variety each, i.e., CCRP 5, CCRP 6 and CCRP 9 respectively (Table 3). Significant difference was

Table 3. Clustering based on quantitative characters of cocoa varieties

Cluster No.	No. of cluster members	Cluster members
I	5	CCRP 1 CCRP 4 CCRP 7 CCRP 8 CCRP 10
II	2	CCRP 2 CCRP 3
III	1	CCRP 5
IV	1	CCRP 6
V	1	CCRP 9

Table 4. Mean values of yield contributing characters of cocoa varieties in each cluster

Cluster ID/ Observations	Pod weight (g)	Pod length (cm)	Pod breadth (cm)	Husk thickness (cm)	Number of beans	Wet bean weight (g)	Dry bean weight/ single seed (g)	Wet bean weight/ single seed (g)
I	480.15	15.61	8.11	0.92	41.24	115.57	0.90	2.82
II	383.52	13.82	8.29	0.85	37.40	74.64	0.82	1.99
III	486.20	16.36	8.78	0.91	42.80	116.10	0.86	2.76
IV	608.84	18.82	9.12	0.95	39.60	132.78	1.09	3.35
V	510.50	12.83	6.93	0.82	31.80	107.35	0.77	3.38

Table 5. Homology between qualitative and quantitative clusters

Qualitative cluster	No. of varieties	Quantitative cluster				
		I	II	III	IV	V
I	5	80(CCRP1, CCRP 7, CCRP 8 CCRP 10)	nil	nil	nil	20(CCRP 9)
II	1	nil	100 (CCRP 2)	nil	nil	nil
III	1	nil	100 (CCRP 3)	nil	nil	nil
IV	2	50 (CCRP 4)	nil	50 (CCRP 5)	nil	nil
V	1	nil	nil	nil	100 (CCRP 6)	nil

expressed for pod weight among different clusters. The highest pod weight was recorded in cluster IV (608.84 g) followed by cluster III (486.20 g), and cluster I (480.15 g) (Table 4). The least pod weight recorded was 383.52 g by cluster II, comprised of CCRP 2 and CCRP 3 (Table 5). However all the varieties expressed pod weight of more than 350g which was the selection criteria recommended by Francies et al. (2002). Cluster IV (CCRP 6) was found to yield pods with an average of 18.82 cm length which was found heighest, whereas, hybrid CCRP 9 (cluster V) produced small pods with average pod length of 12.83 cm. The greatest pod breadth of 9.12 cm was recorded for CCRP 6 (9.12 cm) and minimum was observed in CCRP 9 (6.93 cm). Length and breadth of the pods were found to be proportional. Husk thickness had a significant role in deciding pod weight (Rubeena, 2015). Husk thickness of one cm or less than one cm is the desirable character (Enriquez and Soria, 1966) and all the five clusters were on par with optimum husk thickness.

The average number of beans per pod was recorded and found to vary among the clusters. However there was no significant difference among members of clusters I and cluster III, which recorded highest bean count. Large number of beans alone cannot be considered as a selection criterion. More number of beans with less weight may yield less butter content. Yield expressed as wet or dry bean weight was highly variable (Pound 1932; Enriquez and Soria, 1966). Maximum wet bean weight is expressed by cluster IV (CCRP 6) with 142.86 g and the least was recorded by cluster II, weighing 67.42 g (Table 4). The most important economic part of cocoa is beans. Size of bean is considered as one of the important components of yield in cocoa (Soria, 1978). Bean characters expressed variations within the species (Adewale et al., 2010). However in the present study the peeled dry weight of single bean of all the varieties was more than 0.8 g which is the accepted standard (Wood and Lass, 1985). Homology between qualitative and quantitative clustering pattern was worked out for the varieties studied and presented in Table 5. Distribution pattern of varieties based on qualitative and quantitative clustering varied. In cluster I, CCRP 1, CCRP 7, CCRP 8 and CCRP 10 were common in both qualitative and quantitative clustering. Hybrids CCRP 8 and CCRP 9 were grouped in a single cluster with respect to qualitative data, but in case of quantitative clustering they were grouped into cluster I and cluster V respectively.

Genotypes of same genetic constitution will show

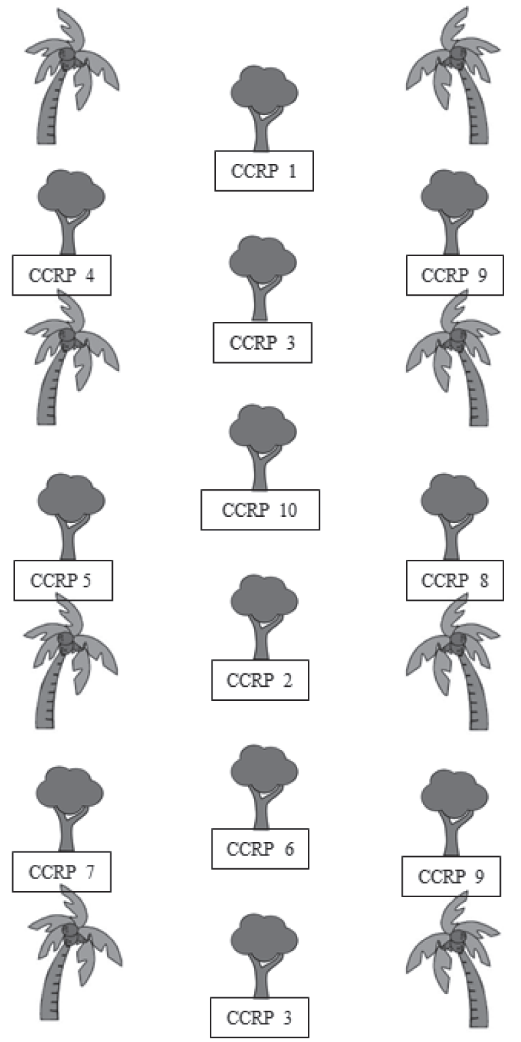

Figure 3. Proposed layout of cocoa as intercrop in coconut plantation

cross incompatibility and finally will result in yield reduction (Mallika et al., 2002). Hence while designing a poly clonal garden or planting bud woods for commercial cultivation, care should be taken not to plant varieties falling in the same cluster close to each other. A proposed field lay out of cocoa as intercrop in coconut plantation is designed and depicted in Fig. 3. Following the same pattern or with slight modification of the design as per the availability of varieties can minimize self and cross incompatibility issues and ensure maximum pod set.

Released varieties of KAU forms the basic planting material of cocoa garden in the country. In order to obtain maximum pod set from them, it is essential to design a layout by keeping maximum divergent parents together. The present investigation was one such successful effort to study and design a polyclonal garden layout. Moreover the designed layout will also help the farmers to set their cocoa garden with budded plants of released varieties. This will in turn result in maximum exploitation of yield potential of these varieties.

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