DOI : 10.5958/0974-0112.2017.00037.8

Indian J. Hort. 74(2), June 2017: 168-172

Comparative study on clonal and seedling progenies of selected cocoa (*Theobroma cacao* L.) genotypes

S. Elain Apshara*

ICAR-Central Plantation Crops Research Institute, Regional Station, Vittal 574243, Karnataka

ABSTRACT

Cocoa (*Theobroma cacao* L.) is grown as a component crop in palm-based cropping systems in South India. Systematic seed gardens were established for hybrid seed production in a limited scale and clonal propagation methods were standardized in cocoa. Since the area expansion programmes require more planting material in a short span with easy management, this attempt was made to assess and compare the performance of selective genotypes, *i.e.* clones and seedlings. The clones exhibited sufficient vigour, larger canopy, lower branching and early bearing nature. Yield compiled over six years showed that VTLC-5, VTLC-1 and VTLCC-1 had more pods both as clone and seedling. Eight clones recorded > 45 pods/ tree/ year, >40 beans/ pod and high dry bean yields ranged from 1.54 to 2.08 kg at the age of tenth year and seven seedlings recorded >40 pods/ tree/ year with >35 beans/ pod and dry bean yields ranged from 1.57 to 1.88 kg. It was suggested that, to get early, uniform and high yield, clonal plants are preferable, but it requires systematic training and pruning in the initial years of growth to maintain optimal canopy. From the average dry bean yield of clones and seedlings, it was suggested that the genotypes VTLCH-3, VTLCH-4, VTLCH-2 and VTLCH-1 may also be utilized for seedling production. All these high yielding genotypes had single dry bean weight of one gram and above; and favourable shelling percentage, nib recovery and fat contents making them suitable for chocolate industry as well.

Key words: Cocoa, clones, performance, seedling population.

INTRODUCTION

National Horticulture Mission identified cocoa as a potential plantation crop because of its demand both in domestic and international markets, which necessitated identification of productive genotypes for area expansion. Indian chocolate industry and confectionaries required 60,000 tonnes of dry beans for the year 2025 as against the current production of 45,000 tonnes (DCCD, 3). About 2,20,000 ha to be brought under cocoa to meet out this demand for which 150.7 million quality seedlings are required. It was also estimated that around 1,895 and 388 thousand ha area is available under coconut and arecanut, respectively (DES, 4) to be utilised for cocoa cultivation for which more planting materials are required in a short span with easy management. Only narrow range of clones is available now and work must continue both on selection and breeding to identify outstanding clones. Because of the existence of incompatibility in cocoa, systematic seed gardens with self incompatible but cross compatible parents are required for production of hybrid seeds (Wood and Lass, 14). Softwood grafting and budding methods were standardised with success rate of 90 per cent to get true-to-type and productive clones of known parentage. Though the genotype is fixed in the clone over environmental influence, the cost and time involved in production of clones is found to be higher than seedlings (Herklots and Murray, 6). Farmers also expressed difficulty in maintaining the crop in the intercropping system because of the typical growth habit of cocoa, which is branching in multiple tiers. Earlier in the cocoa breeding programmes individual trees were selected from local landraces/ seedling populations and used in hybridization programmes without assessing them in clonal trials which lead to confusing results. Later clonal selection programmes were initiated in the beginning of this century for early evaluation and to confirm the genetic gain combining with desirable traits (Adomako and Adu-Ampomah, 1). Further, open-pollinated pods were harvested from these clonal trees and used as 'clonal seeds' for large scale multiplication (Herklots and Murray, 6). With this background, this study was conducted to compare the growth and yield performance of clones and seedlings of selective genotypes and to identify potential genotypes to be utilised both as clones and seedlings.

MATERIALS AND METHODS

Twelve cocoa genotypes including clones and hybrids were selected, multiplied as soft wood grafts

*Corresponding author's E-mail: elain_apshara@yahoo.co.in

and open-pollinated pods were collected from clonal trees and raised as seedlings. Both these clones and seedlings were planted at a spacing of 3 m × 3 m in the arecanut garden at CPCRI, Regional Station, Vittal, Karnataka in 2005, in a randomized block design with 6 trees/ plot in three replications. Normal recommended dosage of 100:40:140 NPK was applied and 20 l water/ day as drip during six months of rainless period was given. All genotypes were evaluated for their height (m), girth (cm), first branching height (m), number of branches and canopy area (m^2) and the data on ten-year-old trees are presented. Considering the canopy as cone shaped, the canopy area was measured using the formula πrl, whereas, r = EW + NS/ 4 and l = $\sqrt{r^2 + h^2}$, h = canopy height and expressed in m^2. Number of pods yielded by individual trees of each genotype during each harvest was compiled for six years from 5 to 10 years. Five pods per genotype were used to measure the pod characteristics and beans were processed through fermentation and drying and 100 beans were used to measure the bean traits. Fat was estimated by Soxhlet's apparatus with solvent extraction method. Data were analysed with MSTATC programme.

RESULTS AND DISCUSSION

The growth habit of both clones and seedlings of cocoa genotypes showed significant difference in all the characters studied (Table 1). Among the clones, the plant height ranged from 3.22 to 4.01 m, whereas in seedlings it ranged from 3.25 to 3.88 m and seven clonal genotypes were taller than seedlings; however girth was more in eight seedling genotypes. The jorquetting or the first branching heights were lower invariably in all the clones irrespective of genotypes giving a bushy appearance, which is predicted, as the grafts are prepared from fan branches of mother trees (Wood, 13). Number of branches and canopy area was higher in clones compared to seedlings. Though systematic training and pruning measures were taken up to maintain the jorquetting heights, number of branches and canopy spread in the cropping system, significant genotypic difference was observed within clones and seedlings with regard to plant habit. For mixed cropping and for high density planting systems, it is suggested to select shorter plants with compact canopy to obtain high yield efficiency combining with other traits and productivity, which was proved with trials with Trinitarios at Costa Rica and Brazil (Monteverde *et al.*, 11), which facilitated short jorquette both in parents and progenies. The optimal canopy area of 15-20 m^2 is recommended for optimal productivity especially in the grafted plants and under arecanut-based intercropping systems (Thomas and Balasimha, 12). In the clonal evaluation trials, the relationship between vigour of plant, pod yield and yield efficiency are important when planted at one density (Lachenaud, 8) and in our trial too the plants with high vigour showed high pod yield.

Pod yield per tree per year and the stability of yield over years was found reliable selection criterion in identifying potential cocoa genotypes and also exhibited positive correlation with total yield (Mallika *et al.*, 10). Yield data was compiled over 6 years in

Table 1. Growth parameters of clones and seedlings of cocoa genotypes.

Genotype	Height (m)		Girth (cm)		Jorquetting (m)		No. of branches		Canopy area (m^2)	
	Clone	Seedling	Clone	Seedling	Clone	Seedling	Clone	Seedling	Clone	Seedling
VTLCH-1	3.26	3.65	31.2	35.4	1.03	1.57	8.94	5.90	15.0	12.2
VTLCH-2	3.50	3.39	33.5	36.4	0.95	1.49	11.0	6.53	16.1	11.2
VTLCH-3	3.95	3.52	35.8	38.7	1.18	1.43	11.2	8.58	20.1	14.1
VTLCH-4	3.31	3.54	31.8	35.5	1.10	1.67	10.8	5.33	16.7	10.6
VTLCC-1	3.65	3.25	34.7	32.3	1.12	1.21	10.3	7.89	15.9	11.1
VTLC-05	3.76	3.88	35.7	38.8	1.11	1.24	10.4	8.66	18.4	16.6
VTLC-07	3.39	3.60	29.4	36.0	0.95	1.53	9.45	7.06	17.2	14.9
VTLC-19	3.63	3.54	36.8	36.4	0.90	1.81	9.33	8.27	17.4	10.8
VTLC-30	3.75	3.63	39.7	33.2	1.08	1.70	10.8	7.85	20.4	11.4
VTLC-61	3.22	3.54	33.2	37.5	1.22	1.37	10.4	6.66	15.2	14.4
VTLC-66	4.01	3.55	40.3	35.8	1.16	1.58	8.56	7.06	21.3	10.9
VTLC-1	3.74	3.26	38.4	38.3	1.00	1.44	10.2	7.65	20.1	12.0
CD at 5%	0.75	0.60	10.1	5.90	0.43	0.50	3.15	3.62	8.14	5.22

case of clones since they had early bearing nature and over 5 years in seedlings (Table 2). Precocious bearing was observed in clonal plants irrespective of genotype, which is in agreement with earlier workers (Wood, 13). Herklots and Murray (6) when tested the clonal cuttings of ICS-45, they gave high yield in their fourth year than seedlings, which gave high yield only in the seventh year. They also identified that even in marginal lands, the clones performed better. In Trinidad, cuttings from three clones of ICS-1, 45 and 95 when compared with seedlings from open-pollinated pods of same three clones as clonal seeds, performance of clones excelled the seedlings when assessed over 13 years, while clones even started yielding from second year onwards. In present trial, both clones and seedlings showed gradual increase in pod yield with increasing tree ages. In the sixth year the pod yield ranged from 11.6 to 22.9 pods/ tree and 8.87 to 10.4 pods/ tree, which showed considerable increase in the tenth year, ranged from 39.3 to 50.4 and 32.7 to 45.8 in clones and seedlings, respectively. Eight genotypes had >45 pods and seven genotypes had >40 pods/ tree/ year as clone and seedling respectively at the age of tenth year. From our results, it was observed that the genotypes VTLC-5, VTLC-1 and VTLCC-1 yielded high both as clones and seedlings. From the mean of both clones and seedlings in tenth-year-old trees, it was observed that VTLCH-1, 2, 3, 4 also yielded high, since they are originally of hybrid progeny and their hybrid vigour is fixed in clones as well as the clonal seeds. It showed the possibility of harvesting these pods directly from clonal trees and can be used for planting material production. High yielding nature of these hybrids was earlier documented by Bhat *et al.* (2) in the progeny trials as well as in the clonal evaluation trial in the initial years of growth (Elain Apshara *et al.*, 5). This will further reduce the need of establishing bi-clonal orchards to produce particular hybrid with its two parents.

Pod characteristics respect to weight, length, breadth, husk: bean ratio and number of beans per pod showed significant difference among the genotypes (Table 3). Pods from clonal plants were bigger than seedlings except in two genotypes. The cumulative factors, number of pods, total pod weight and average single pod weight contribute to the harvest efficiency of a hybrid in cocoa. Length and breadth of pods directly contributed to the size and weight of pods. The required bean number of 35 beans per pod was observed in all genotypes both as clones and seedlings. Number of bold beans represents the apparent fertility (Lachenaud *et al.*, 9) and variation was observed with number of beans per pod in Ivory Coast (Lachenaud, 7). Other traits related to bean are given in Table 4. The wet to dry bean ratio ranged from 2.56 to 3.76 in clones and from 2.25 to 3.32 in seedlings. The highest ratio in few clones may be because of the big pods which constituted more husk.

Beans of one g and above are preferred by the processing units. Fermented and dried beans were measured for their single bean weight, which ranged from 0.88 to 1.15 in clones and 0.87 to 1.16 in

Table 2. Pod yield performance of clones and seedlings of cocoa genotypes.

Year / Genotype	5	6		7		8		9		10		Mean (clone + seedling) 10th year
	Clone	Clone	Seedling	Clone	Seedling	Clone	Seedling	Clone	Seedling	Clone	Seedling	
VTLCH-1	12.7	17.7	11.7	19.4	18.1	21.6	18.2	32.3	28.2	45.2	40.2	42.7
VTLCH-2	14.8	14.1	11.9	24.1	21.8	32.7	22.9	33.2	23.9	45.1	40.4	42.8
VTLCH-3	14.0	14.3	13.4	24.6	29.8	26.5	29.1	41.8	32.0	45.5	41.3	43.4
VTLCH-4	11.8	12.7	14.5	20.8	20.0	40.5	20.5	38.7	27.7	47.6	40.0	43.8
VTLCC-1	19.0	22.8	10.6	29.9	20.1	37.4	21.1	46.3	21.7	45.9	41.0	43.5
VTLC-05	22.7	22.9	12.7	31.4	31.8	44.2	31.5	52.0	39.0	50.4	45.8	48.1
VTLC-07	16.5	19.4	12.2	28.1	17.6	27.9	17.1	30.2	28.0	40.9	33.3	37.1
VTLC-19	16.0	20.0	8.87	26.3	15.1	25.6	15.9	28.4	28.7	39.3	38.3	38.8
VTLC-30	19.8	19.2	11.9	30.7	24.1	39.8	24.3	42.1	25.7	44.8	35.9	40.4
VTLC-61	11.7	12.3	10.9	24.5	27.6	35.4	28.6	36.1	42.1	46.5	32.7	39.6
VTLC-66	11.2	11.6	11.1	24.4	15.7	28.2	15.1	31.2	33.9	44.5	35.8	40.2
VTLC-1	15.9	19.8	10.4	26.2	27.7	28.1	27.1	39.7	31.3	47.8	43.6	45.7
CD at 5%	1.57	6.82	6.26	NS	NS	5.64	6.12	NS	NS	6.85	1.06	

Table 3. Pod characters of cocoa clone and seedling genotypes.

Genotype	Pod wt. (g)		Pod length (cm)		Pod breadth (cm)		Husk: bean ratio		No. of beans/ per fruit		
	Clone	Seedling	Clone	Seedling	Clone	Seedling	Clone	Seedling	Clone	Seedling	Mean
VTLCH-1	432	347	15.7	14.3	7.0	6.3	3.05	3.00	40.5	40.2	40.4
VTLCH-2	505	350	17.0	15.9	7.5	7.8	3.06	2.26	41.1	39.6	40.4
VTLCH-3	432	370	16.5	14.8	7.3	6.9	2.69	3.30	44.1	38.9	41.5
VTLCH-4	445	441	16.8	18.6	7.1	7.9	2.96	2.53	40.7	40.3	40.5
VTLCC-1	434	366	17.4	16.5	6.6	8.0	2.57	2.79	43.5	38.6	41.1
VTLC-05	403	351	14.3	14.2	7.2	7.4	2.51	3.08	40.8	41.1	41.0
VTLC-07	501	484	16.9	16.1	7.5	7.5	2.81	3.41	41.1	36.9	39.0
VTLC-19	428	357	16.4	14.7	6.9	7.3	2.24	2.43	40.1	39.1	39.6
VTLC-30	408	453	15.8	15.9	7.1	7.3	2.68	2.95	35.2	38.5	36.9
VTLC-61	416	427	16.3	17.1	6.9	7.7	2.62	3.32	39.4	35.9	37.7
VTLC-66	504	423	16.2	18.1	7.5	7.1	2.56	3.81	40.3	38.5	39.4
VTLC-1	473	420	16.4	16.9	7.5	7.4	2.72	2.84	40.9	41.5	41.2
CD at 5%	190	182	2.78	2.67	0.99	1.49	0.75	1.43	7.95	7.76	

Table 4. Bean traits of clones and seedlings of cocoa genotypes.

Genotype	Wet: Dry		SBW (g)		DBY (kg)			Shell (%)		Nib recovery (%)		Fat (%)	
	Clone	Seedling	Clone	Seedling	Clone	Seedling	Mean	Clone	Seedling	Clone	Seedling	Clone	Seedling
VTLCH-1	3.01	2.50	1.00	1.00	1.83	1.62	1.73	16.9	16.4	83.1	83.6	50.0	50.5
VTLCH-2	3.02	2.25	1.04	1.00	1.93	1.60	1.77	16.7	15.5	83.3	84.5	51.0	50.0
VTLCH-3	3.15	3.32	1.00	1.00	2.01	1.61	1.81	14.3	13.2	85.7	86.8	50.0	50.0
VTLCH-4	3.18	3.25	1.00	1.00	1.94	1.61	1.78	16.6	16.4	83.4	83.6	50.0	50.0
VTLCC-1	3.16	3.27	0.99	0.99	1.98	1.57	1.78	16.1	16.5	83.9	83.5	49.9	49.8
VTLC-05	3.17	2.59	1.01	1.00	2.08	1.88	1.98	15.6	15.5	84.4	84.5	52.0	50.0
VTLC-07	3.34	2.81	1.07	1.16	1.80	1.43	1.62	12.1	10.0	87.9	90.0	54.0	53.0
VTLC-19	3.27	3.10	0.98	0.92	1.54	1.38	1.46	17.2	16.0	82.8	84.0	48.1	42.5
VTLC-30	2.56	2.53	1.15	1.12	1.81	1.55	1.68	13.2	16.5	86.8	83.5	55.0	52.0
VTLC-61	3.38	2.85	0.90	0.91	1.65	1.07	1.36	18.8	13.4	81.2	86.6	45.0	46.4
VTLC-66	3.03	3.22	1.04	0.97	1.87	1.34	1.61	14.7	16.2	85.3	83.8	53.0	45.2
VTLC-1	2.94	3.17	1.06	1.02	2.07	1.85	1.96	12.6	14.5	87.4	85.5	52.5	51.0

SBW = Single dry bean weight; DBY = Dry bean yield

seedlings and nine as clones and eight as seedlings recorded more than one g single dry bean weight. Among the clones, it ranged from 1.54 to 2.08 and 1.07 to 1.88 kg in seedling genotypes. Shelling and nib recovery percentages, which are important with the confectioner's point of view, were calculated. They ranged from 12.1 to 19.1% in clones and 13.2 to 20.6% in seedlings and 80.9 to 87.9% in clones and 79.4 to 90% among the seedlings, respectively. Fat content ranged from 40 to 55% in clones and 40.2 to 53% in seedlings. Beans of more than 1 g showed more than 50% fat contents. Based on vigour, optimal canopy, mean pod yield over years, single dry bean weight, number of beans, dry bean yield, shelling, nib recovery and fat contents the best performers were selected.

From this trial, it was suggested that in order to get early, uniform and high yield, clonal plants are preferable, but it requires systematic training and pruning in the initial years of growth to maintain optimal canopy. Ten-year-old trees of seven genotypes both as clones and seedlings recorded high pod and dry bean yields. VTLC-5, VTLC-1, VTLCC-1 and seedlings of four hybrids VTLCH-1, 2, 3, 4 can be utilized for seedling production for the immediate requirement of area expansion. All these high yielding genotypes had single dry bean weight of > 1 g, 13-17% shell, 84-86% nib recovery and 50% fat and thus suitable for chocolate industry as well. Further continuous evaluation is required in the later years of crop life for confirmation on both quantitative and qualitative parameters.

REFERENCES

1. Adomako, B. and Adu-Ampomah. 2003. Assessment of the yield of individual cocoa trees in four field trials. **In**: *International Workshop on Cocoa Breeding For Improved Production Systems*, INGENIC, Miklin Hotel, Accra, Ghana, 19-21 October, 2003, pp. 2.

2. Bhat, V.R., Sujatha, K., Ananda, K.S., Nair, R.V. and Virakthmath, B.C. 1998. Evaluation of cocoa hybrids (*Theobroma cacao* L.). *Abstract: PLACROSYM XIII*, December 16-18, Coimbatore, pp. 14.

3. D.C.C.D. 2014. Directorate of Cashewnut and Cocoa Development, Ministry of Agriculture, Govt. of India. www.dccd.gov.in.

4. D.E.S. 2009. Directorate of Economics & Statistics, Ministry of Agriculture, Govt. of India. www.des.gov.in.

5. Elain Apshara, S., Bhat, V.R. and Nair, R.V. 2008. Comparative studies on elite cocoa progenies in their initial years of growth. *J. Plantation Crops*, **36**: 38-44.

6. Herklots, G.A.C. and Murray, D.B. 2005. Cacao yields from clones and seedlings/ comparison of seedlings and cuttings as planting material. *INGENIC Newslett.* **10**: 30-32.

7. Lachenaud, P. 1995. Variations in the number of beans per pod in cocoa in the Ivory Coast. III. Nutritional factors, cropping effects and the role of boron. *J. Hort. Sci.* **70**: 7-13.

8. Lachenaud, P. 2003. Genetic effects of inter-tree competition in mixed cocoa stands on yield, vigour and cropping efficiency. 2003. **In**: *International Workshop on Cocoa Breeding for Improved Production Systems*, INGENIC, Miklin Hotel, Accra, Ghana, 19-21 October, 2003, pp. 5.

9. Lachenaud, P., Oliver, G., Bastide, P. and Paulin, D. 2005. Pod filling in Guianan wild cocoa trees. CIRAD Tree Crops Department, 34398, Montpellier, Cedex 5, France.

10. Mallika, V.K., Rekha, C., Rekha, K., Swapna, M. and Vikraman Nair, R. 1996. Evaluation of pod and bean characters of cocoa hybrids in their early years of bearing. *J. Plantation Crops*, **24**: 363-69.

11. Monteverde-Penso, E.J., Phillips, W., Machado, R., Brown, J.S., Schnell, R. and Motamayor, J.C. 2005. Can we select for shorter cocoa plants? *INGENIC Newslett.* **10**: 16-19.

12. Thomas, G. and Balasimha, D. 1992. Canopy architecture, photosynthesis and yield of cocoa. *Coffee Cocoa Tea*, **36**: 103-8.

13. Wood, G.A.R. and Lass, R.A. 1985. *Cocoa*, Longman Group Limited, Longman house, England, 620 p.

Received : October, 2015; Revised : January, 2017; Accepted : April, 2017