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Performance of selected cocoa (*Theobroma cacao* L.) clones under arecanut and coconut

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Cocoa as a commercial crop gained importance in India from 1970 onwards and since then Central Plantation Crops Research Institute (CPCRI) was involved in germplasm introduction and evaluation. Multipurpose trees like coconut (Nelliat *et al*., 1974; Liyange, 1985; Bavappa *et al*., 1986; Thomas *et al*., 2010) arecanut (Shama Bhat and Bavappa, 1972; Abdul Khader *et al*., 1984; Sujatha *et al*., 2011), rubber (Blencowe, 1971) and oil palm are used as shade trees in Malaysia, India, Papua New Guinea and Brazil for cocoa. Most of the breeding trials in cocoa were initiated and conducted under arecanut to test the adaptability, stability and yielding potential of collected lines. Though few experiments were conducted on single and double hedge system of planting under coconut, there was not much work on evaluation on suitable cocoa clones for their comparative performance both under arecanut and coconut. Cropping systems of coconut with cocoa are common in several countries (Daswir *et al*., 1988; Abbas and Dja'far, 1989; Osei Bonsu *et al*., 2002).

In India, Andhra Pradesh ranks first in cocoa area with 16,969 ha (DCCD, 2011) which is mainly under coconut and cocoa is grown as an intercrop in Tamil Nadu as well. Total coconut and arecanut area in India as per 2008-2009 data is 1895 and 388 thousand hectares respectively and these gardens offer sufficient interspaces and shade for cocoa cultivation. To fulfill the requirement of Indian chocolate industry and to increase the average productivity from the present 380 kg per ha, identification of high yielding cocoa lines with quality beans is essential. Hence, an effort was taken to compare and assess the performance of selected cocoa lines both under arecanut and coconut plantations.

Twenty five mixed cocoa lines of exotic origin, Malaysian and Kew collections in two sets were multiplied as clones and planted under randomized block design during 1992 at CPCRI, Regional Station, Vittal in Karnataka, under 2.7 m x 2.7 m spaced arecanut at a distance of 2.7 m x 5.4 m and at the then Research Centre, Kannara, Thrissur in Kerala state under 7.5 m x 7.5 m spaced coconut at a distance of 2.5 m x 7.5 m. The treatments were replicated twice with six trees per block and growth and yield observations were recorded. Growth characters such as plant height, girth, height at first branching and canopy volume were compiled from 12 year old trees. The canopy area was calculated considering the canopy surface as cone shaped and using the formula πrl, where, $r = (EW+NS)/4$ and $l = \sqrt{r^2 + h^2}$ and h = canopy height. The pod yield of individual trees in each clone during each harvest was compiled and given as average pod yield per tree per year for six years after yield stabilization from ninth to fourteenth year. Pod characteristics such as individual pod weight and bean number per pod were measured from five pods of each tree. Beans were fermented, dried, processed and observed for single dry bean weight (SBW) shelling percentage and dry bean yield (DBY) per tree per year. Quality parameter in terms of fat content of dry bean was estimated by petroleum ether extraction method using Soxhlet apparatus and expressed in percentage. The data were subjected to statistical analysis using WINSTAT software.

All the exotic clones were observed for their growth behavior under arecanut and coconut shades

which exhibited considerable differences. Under arecanut, none of the clones of set I recorded significant results, whereas the clones of set II showed significant difference in their growth habit (Table 1). The height ranged from 2.76 to 4.65 m, girth from 27.7 to 51 cm, height at first branching 1.30 to 1.77 m and canopy area from 2.38 to 12.2 m^2 under arecanut. Whereas under coconut, height ranged from 2.89 to 4.85 m, girth 28.8 to 46.8 cm, height at first branching 0.74 to 1.70 m and canopy area 3.04 to 23.4 m^2 in cocoa. In general, under arecanut most of the cocoa clones showed vigorous growth than under coconut except first branching heights.

Table 1. Growth performance of exotic cocoa clones under arecanut (A) and coconut (C)

Sl. No.	Clone	Height (m)		Girth (cm)		HAFB (m)		Canopy area (m^2)	
		A	C	A	C	A	C	A	C
1	VTLC 1	4.02	3.57	45.2	37.0	1.15	1.31	16.3	11.2
2	VTLC 2	4.17	4.04	50.3	39.6	1.05	1.27	21.5	22.3
3	VTLC 3	3.47	4.27	43.3	40.3	0.88	1.17	15.5	17.3
4	VTLC 4	3.87	2.79	51.7	31.2	1.18	1.24	16.5	10.9
5	VTLC 5	3.83	3.92	51.5	34.1	0.94	1.37	16.9	14.7
6	VTLC 6	3.86	3.53	44.7	39.9	1.15	1.61	16.3	15.8
7	VTLC 7	3.65	2.94	44.3	34.3	1.12	1.51	14.2	10.3
8	VTLC 8	3.97	3.41	47.5	34.8	0.80	1.60	18.4	13.6
9	VTLC 9	3.88	2.97	51.8	34.3	0.98	1.17	16.8	10.4
10	VTLC 10	3.55	4.24	44.0	33.7	0.95	1.57	15.0	14.6
11	VTLC 11	3.53	4.19	47.0	36.3	1.08	0.95	15.6	19.5
	SEd	0.44	0.26	6.29	3.36	0.50	0.32	4.23	3.22
	CD (5%)	NS	0.58	NS	7.48	NS	NS	NS	7.17
12	VTLC 68	4.65	4.00	41.4	35.2	1.30	1.10	12.2	12.1
13	VTLC 61	3.93	3.19	41.4	39.1	1.42	1.22	7.66	9.56
14	VTLC 62	3.20	3.21	34.1	35.3	1.16	1.36	5.47	4.99
15	VTLC 66	3.78	3.71	51.0	34.9	1.61	1.50	7.11	6.39
16	VTLC 67	2.76	2.89	32.0	29.1	1.42	1.44	2.38	3.04
17	VTLC 57	3.69	4.06	37.5	46.8	1.73	1.41	6.34	12.1
18	VTLC 65	3.51	3.90	38.4	41.1	1.54	1.56	5.68	8.40
19	VTLC 63	2.88	4.11	32.5	41.6	1.33	1.17	3.61	10.6
20	VTLC 64	2.79	3.22	27.7	28.8	1.33	1.10	2.90	3.51
21	VTLC 59	3.27	3.67	34.1	47.2	1.50	1.65	4.28	6.18
22	VTLC 58	3.74	4.20	39.2	41.7	1.77	1.70	5.88	8.12
23	VTLC 56	3.93	3.39	41.4	38.2	1.42	1.54	8.68	6.24
24	VTLC 70	3.78	4.85	50.9	45.4	1.61	0.82	7.11	23.4
25	VTLC 75	3.55	3.96	40.2	39.8	1.62	0.74	5.40	11.0
	SEd	0.22	0.63	3.92	7.95	0.19	0.27	1.23	3.80
	CD (5%)	0.48	1.36	8.42	17.05	NS	0.58	2.65	8.15

*observations in 12 yrs old trees. HAFB: Height at first branching

The pod yields were compiled after yield stabilization and presented for six years from ninth to fourteenth year of tree growth (Table 2). Among the set I clones the mean yield ranged from 23.5 to 51.3 pods per tree per year under arecanut whereas, it ranged from 30.0 to 71.2 pods per tree per year under coconut. Among set II clones, the yield ranged from 25.9 to 55.3, under arecanut whereas, it ranged from 18.2 to 61.0 pods per tree per year under coconut (Table 3). In general, the pod yields were the highest under coconut, though the morphological vigour is comparatively lesser than arecanut. The shade and light transmission pattern in coconut gardens might have favoured more flowering and fruit set. Similar results were obtained at cocoa and coconut research institute of Papua New Guinea (Efron *et al*., 2003). Their study showed that planting small clones at higher density was economically beneficial than the big and medium clones. The mean data showed that the clones, VTLC-56, VTLC-57, VTLC-1, VTLC-6, recorded an average of 55.3, 55.4, 51.3, 50.4, pods per tree per year respectively under arecanut and under coconut, the clones, VTLC-66, VTLC-1, VTLC-57, VTLC-59, VTLC-65 and VTLC-6 were found to be good with yield efficiency of 61.0, 57.6, 56.1, 54.3, 54.3 and 52.4 pods per tree per year respectively. Among all the exotic clones, VTLC-1, VTLC-6, VTLC-8 and VTLC-57 recorded high and stable pod yields per tree per year under both the canopies.

Twenty five exotic clones were compared for their yield contributing characters and their mean values are given in Table 4. Among them, the pod weight ranged from 199 to 570 g and number of beans per pod ranged from 30 to 45 under arecanut, whereas both pod weight and number of beans were the lowest under coconut, which ranged from 250.6 to 520.2 g with 30 to 43 beans. But most of the clones had >350 g single pod weights. Lachenaud (2003) suggested that individual pod weights mainly contributed to the total pod weight, harvest efficiency and bean filling. There were reports on difference in the number of beans among cocoa groups and populations (Allen, 1988) and the studies on Forastero, Trinitario and Amelonado types by Lachenaud *et al.* (1998) showed that the average number of beans per pod was between 33.3 to 42.1 and most of the clones in this study also showed the same trend. More than 40 number of beans were observed in 13 clones under arecanut and 9 clones

Table 2. Pod yield performance (no. of pods tree^{-1} yr^{-1}) of exotic cocoa clones set I under arecanut (A) and coconut (C)

Clones	Year after yield stabilization													
	1		2		3		4		5		6		Mean	
	A	C	A	C	A	C	A	C	A	C	A	C	A	C
VTLC 1	46.6	51.9	45.5	89.0	50.3	54.8	48.8	42.3	60.2	48.5	56.7	59.5	51.3	57.6
VTLC 2	15.3	40.6	16.8	64.5	27.6	82.9	36.9	60.8	55.7	40.8	45.2	44.5	32.9	55.6
VTLC 3	25.2	41.4	24.3	35.5	34.7	40.9	68.8	33.8	82.6	41.2	47.6	36.8	47.2	38.3
VTLC 4	18.7	74.9	20.2	41.7	16.4	28.7	25.3	34.5	37.5	37.6	39.3	33.9	26.3	41.9
VTLC 5	28.3	27.5	24.0	36.2	31.3	26.1	49.2	31.1	63.3	38.8	42.7	40.6	39.8	33.4
VTLC 6	37.3	51.5	32.0	47.5	45.1	75.5	49.7	55.3	72.6	48.1	66.0	36.8	50.5	52.4
VTLC 7	18.3	32.8	12.4	57.8	20.8	30.1	24.7	31.6	28.9	36.9	35.9	36.8	23.5	37.6
VTLC 8	24.2	75.7	29.3	83.9	39.6	106.1	47.1	63.6	56.2	44.0	59.2	54.0	42.6	71.2
VTLC 9	38.7	32.7	32.0	37.5	37.3	36.2	52.7	25.9	43.5	38.5	55.7	37.1	43.3	34.6
VTLC 10	16.3	15.9	17.0	36.4	23.2	22.2	23.0	34.9	35.4	41.3	33.0	29.5	24.7	30.0
VTLC 11	21.0	32.5	29.0	36.5	37.8	30.6	53.8	38.1	46.3	39.5	50.9	36.2	39.8	35.6
SEd	2.72	0.04	3.33	0.27	2.63	0.75	1.91	2.25	2.40	2.62	2.81	2.55		
CD (5%)	4.63	0.10	5.67	0.60	4.48	1.66	3.26	5.01	4.09	5.84	4.78	5.69		

Table 3. Pod yield performance (no. of pods tree^{-1} yr^{-1}) of exotic cocoa clones set II under arecanut (A) and coconut (C)

Clones	Year after yield stabilization													
	1		2		3		4		5		6		Mean	
	A	C	A	C	A	C	A	C	A	C	A	C	A	C
VTLC 68	24.8	15.7	18.3	14.0	26.0	23.5	43.8	13.6	46.7	13.6	54.8	28.6	35.7	18.2
VTLC 61	24.8	33.9	26.3	73.0	29.2	52.3	36.4	40.0	43.2	29.9	30.7	25.9	31.7	42.5
VTLC 62	26.2	38.1	26.9	40.5	30.5	24.0	49.8	34.2	46.6	16.6	67.2	31.4	41.2	30.8
VTLC 66	26.7	76.3	13.4	85.1	21.8	69.3	34.2	33.1	21.5	47.7	32.8	54.7	25.1	61.0
VTLC 67	28.1	28.6	29.9	50.5	40.3	25.8	56.4	27.8	52.0	32.5	58.1	23.7	44.1	31.5
VTLC 57	34.2	51.0	48.4	56.5	53.6	55.9	61.0	58.9	60.2	56.0	63.3	58.2	53.4	56.1
VTLC 65	29.7	54.8	24.9	69.5	35.8	83.8	59.0	53.7	63.4	33.8	36.9	30.4	41.6	54.3
VTLC 63	28.2	20.9	14.7	17.9	26.1	25.8	28.0	18.5	35.9	17.9	22.5	27.9	25.9	23.8
VTLC 64	25.9	14.6	18.9	40.0	30.7	56.8	40.7	37.9	27.1	22.6	33.7	25.9	29.5	32.9
VTLC 59	43.9	46.2	24.3	53.9	38.8	81.0	53.6	80.0	40.2	38.8	64.7	26.1	44.2	54.3
VTLC 58	39.7	15.8	26.8	78.9	34.3	65.8	47.8	55.6	48.8	49.8	42.5	58.1	40.0	54.0
VTLC 56	39.6	25.0	25.9	59.9	26.0	51.5	112.3	45.3	70.8	27.4	57.1	23.8	55.3	38.8
VTLC 70	14.9	42.6	14.7	43.4	25.9	87.5	27.5	59.6	36.2	39.5	41.9	42.4	26.9	52.5
VTLC 75	28.2	32.2	24.7	93.5	40.0	55.8	35.4	34.3	52.7	28.8	20.5	35.4	33.6	46.7
SEd	4.50	1.26	2.63	2.12	1.94	1.73	5.32	1.32	2.20	2.20	2.75	3.13		
CD (5%)	9.64	2.70	5.64	4.54	4.15	3.71	11.42	2.83	4.73	4.72	5.90	6.72		

under coconut. More than one gram single dry bean weight was observed in 10 clones under arecanut and 14 clones under coconut. The dry bean weights were comparable with each other among 20 clones both under arecanut and coconut which contributed much to the total dry bean yield per tree per year. Not much difference was observed with pod index which is the approximate number of pods required to produce 1 kg dry beans. More than fifteen clones exhibited favorable pod index under both canopies. Four clones had less pod index under arecanut and another five clones had less pod index under coconut. It is reported that farmers of major cocoa producing countries prefers low pod index because less work is involved in harvesting and pod breaking (Eskes and Lanaud, 2001).

The dry bean yield, which is the combination and product of number of pods, number of beans and single dry bean weight, ranged from 0.70 to 2.48 kg under arecanut and 0.43 to 2.78 kg under coconut. 17 clones under arecanut and 22 clones under coconut recorded more than 1 kg dry bean yield per tree per year and 3 clones under arecanut and 6 clones under coconut recorded more than 2 kg dry bean yields. The shell content ranged from 12.9 to 29.2 per cent under arecanut and under

Table 4. Comparative performance of main yield components of exotic cocoa clones under arecanut (A) and coconut (C)

Set	Clones	Mean no. of pods tree^{-1} year^{-1}		Single pod weight (g)		Mean no. of beans pod^{-1}		Single dry bean weight (g)		Pod index		Dry bean yield (kg^{-1} tree^{-1} year^{-1})		Shell content (%)		Fat (%)	
		A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C
Set I	VTLC 1	51.3	57.6	376.0	366.0	42.0	40.0	1.15	1.10	21.6	22.6	2.48	2.54	13.0	11.0	50.5	52.5
	VTLC 2	32.9	55.6	468.0	352.5	41.2	31.2	0.90	0.96	29.7	28.1	1.22	1.67	20.0	15.0	41.0	42.1
	VTLC 3	47.2	38.3	376.0	366.5	35.8	32.0	0.81	1.06	31.4	31.2	1.37	1.30	25.5	12.0	44.9	49.2
	VTLC 4	26.2	41.9	568.0	320.0	43.0	30.8	1.15	1.00	25.1	24.9	1.30	1.29	12.9	15.0	50.0	50.7
	VTLC 5	39.8	33.4	394.0	376.0	39.8	33.3	0.93	0.94	29.1	28.4	1.47	1.04	21.2	13.0	49.3	52.1
	VTLC 6	50.4	52.4	450.0	341.5	43.0	36.3	0.98	1.10	24.3	23.6	2.12	2.09	18.7	15.0	50.5	52.0
	VTLC 7	23.4	37.6	410.0	373.5	38.0	35.5	0.91	0.90	29.9	28.0	0.81	1.20	25.0	20.0	49.0	46.6
	VTLC 8	42.7	71.2	570.0	326.0	36.8	35.8	0.90	1.09	27.5	28.1	1.41	2.78	25.3	16.0	48.0	53.0
	VTLC 9	43.2	34.6	400.0	441.5	40.0	35.1	1.09	1.03	25.1	25.2	1.88	1.25	14.7	13.0	50.0	55.0
	VTLC 10	24.7	30.0	445.0	373.5	45.0	34.4	0.90	0.98	26.8	27.5	1.00	1.01	19.0	18.0	47.0	48.9
	VTLC 11	39.7	35.6	508.0	408.0	42.6	33.1	0.96	1.20	24.5	26.6	1.62	1.41	16.6	14.0	42.0	52.2
Set II	VTLC 68	35.7	18.2	199.0	250.6	34.0	34.0	1.10	0.70	42.0	26.7	1.33	0.43	16.7	25.0	51.8	43.4
	VTLC 61	31.7	42.5	373.0	350.5	34.0	42.0	0.65	1.06	22.5	45.3	0.70	1.89	26.3	15.0	40.5	51.8
	VTLC 62	41.2	30.8	384.0	385.5	32.6	33.0	0.71	0.73	41.5	43.2	0.95	0.74	24.7	21.0	41.4	41.4
	VTLC 66	25.1	61.0	352.0	375.4	32.8	34.0	0.50	0.80	36.8	61.0	0.41	1.66	29.2	25.0	45.5	42.0
	VTLC 67	44.1	31.5	276.0	300.5	33.0	43.0	0.65	1.10	21.1	46.6	0.95	1.49	24.7	14.0	45.2	52.9
	VTLC 57	53.4	56.1	488.0	400.2	42.0	40.0	1.27	1.15	21.7	18.8	2.85	2.58	15.0	15.0	54.0	52.5
	VTLC 65	41.6	54.3	417.0	390.2	41.0	40.0	1.14	1.17	21.4	21.4	1.95	2.54	13.6	15.0	51.0	50.9
	VTLC 63	25.9	23.8	269.5	350.2	35.0	38.0	0.85	0.80	32.9	33.6	0.77	0.72	22.5	25.0	34.9	35.4
	VTLC 64	29.5	32.9	320.5	370.2	40.4	40.0	0.76	0.76	32.9	32.6	0.91	1.00	18.0	25.0	40.8	45.8
	VTLC 59	44.2	54.3	494.0	410.5	42.0	35.0	1.00	1.06	27.8	23.8	1.86	2.02	15.2	15.0	51.0	51.0
	VTLC 58	40.0	54.0	461.0	400.6	41.2	30.0	0.85	0.83	40.2	28.6	1.40	1.34	17.4	20.0	48.6	40.6
	VTLC 56	55.3	38.8	542.0	500.5	30.0	41.0	0.71	0.78	31.3	47.0	1.18	1.24	16.3	15.0	49.2	46.2
	VTLC 70	26.9	52.5	552.0	520.2	32.6	41.2	0.83	0.87	27.9	37.0	0.73	1.88	17.4	16.4	31.3	42.6
	VTLC 75	33.6	46.7	329.0	360.6	40.4	40.0	0.98	0.93	26.9	25.3	1.33	1.74	18.0	16.1	49.3	45.5

coconut it was 11 to 25 per cent. The fat content mostly corresponds to the size of the beans which ranged from 31.3 to 54.7 per cent under arecanut and 35.4 to 56.7 per cent. In general, 10-15 per cent shell and >50 per cent fat is considered as favourable for industrial quality. In our experiment, 14 clones had less shell and high fat contents under coconut.

With optimal canopy, high pod yield throughout the growing period, less pod index, more number of beans, high single dry bean weight and dry bean yield, required shell and fat contents, the clones VTLC-1, VTLC-57 and VTLC-6 were the best for both arecanut and coconut canopies. These clones can be utilized effectively in the area expansion programs in states of Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Maharashtra, Goa, Assam and West Bengal with favourable environment and available space with the main crops of arecanut and coconut.

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