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Selection of potential clones from Wayanad cocoa (*Theobroma cacao* L.) collections

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Cocoa (*Theobroma cacao* L.) has become an integral part of palm-based cropping systems and is being cultivated successfully as a commercial crop for the past four decades in South India. Cocoa was introduced into India by the British from East Indies in 1798 and around eight plantations were established with Criollo type of cocoa near Courtallam in Tirunelveli district of erstwhile Madras state (Tamil Nadu). Systematic plantings were undertaken at Kallar and Burliar Stations in the Nilgiris which reaped high harvests and seedlings from these plantations were supplied to many other areas in Coimbatore and Kolli hills of Tamil Nadu. One garden at Pambooly was transferred to Travancore Government (Kerala) in 1853 and, in 1857, it was decided to grow cocoa in Wayanad and other parts of Malabar region as the climate prevalent in these regions were congenial to cocoa cultivation (Ratnam, 1961).

Further, Forastero type of cocoa, from Malaysia and West Africa, was widely taken to rubber and coffee growing zones in Western Ghats in Malabar, Madras and Mysore states, which receives rainfall from both South West and North East monsoons with a short dry spell (Wood, 1964). In 1965, Cadbury India Pvt. Ltd. established a research cum demonstration unit in Chundale in Wayanad district of Kerala. The gardens developed at Wayanad region form an important genetic resource because they are one among the oldest introductions made on cocoa in India. Since those populations have adapted to the environment for a long time, an attempt was made to collect, conserve and evaluate them under arecanut based cropping system. Growth performance and yield potential of cocoa over years were assessed in this study to select elite clones among Wayanad collections, to be utilised for enhancing productivity in cocoa farming.

Fifteen Wayanad cocoa collections were planted during 1997 at ICAR-CPCRI, Regional Station, Vittal, Karnataka at a spacing of 2.7 m x 5.4 m under 2.7 m x 2.7 m spaced arecanut garden. Four trees each of these clones were conserved and evaluated in completely randomised design with single tree plots and observed for their growth parameters at the age of sixteen years. The annual pod yield was compiled for six years, from tenth to seventeenth year of bearing. Individual pod characters were measured from five pods of each clone harvested during the main season of June to August. Processed, fermented and dried beans were observed for bean characteristics in 100 beans from each clone. Fat was estimated by petroleum ether extraction method using Soxhlet apparatus and expressed in percentage. Data were analysed using MSTAT program.

All growth parameters showed significant difference among the clones. Sixteen year old trees of Wayanad clones grew to a height of 3.73 to 4.97 m and their girth ranged from 33 to 51 cm. Trunk girth has been traditionally used to measure yield efficiency in cocoa (Thong and Ng, 1978) or the trunk cross sectional area which ultimately represents the vigour of genotypes. The first branching height, East-West and North-South

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Table 1. Growth performance of Wayanad cocoa collections

Clones	Height (m)	Girth (cm)	H A F B (m)	E W (m)	N S (m)	Branches (no.)	Canopy area (m^2)
WYN 1	4.79	50.0	1.25	4.36	4.86	15.7	30.5
WYN 2	4.38	47.3	1.11	4.03	4.03	10.3	24.3
WYN 3	4.67	44.0	1.30	4.06	3.70	13.3	23.7
WYN 4	3.84	40.0	1.47	4.15	3.47	9.67	18.2
WYN 5	4.84	49.3	1.52	4.58	5.08	13.7	31.1
WYN 6	4.97	49.0	1.83	3.81	3.90	11.7	22.3
WYN 7	4.05	33.0	1.27	3.38	3.54	10.0	17.8
WYN 8	4.03	45.3	1.66	4.02	4.14	10.0	20.0
WYN 9	3.73	45.7	1.38	3.65	4.01	11.3	18.3
WYN 10	3.92	44.7	1.07	3.82	3.68	12.3	20.1
WYN 11	4.16	40.0	1.30	3.63	3.16	11.0	17.7
WYN 12	3.76	36.7	0.97	3.52	3.37	9.00	17.8
WYN 13	4.94	51.0	1.68	4.27	5.05	13.3	29.3
WYN 14	3.97	44.7	0.74	4.27	4.40	11.0	25.0
WYN 15	4.12	37.3	1.86	4.12	3.77	12.3	20.1
CV%	9.12	8.9	24.0	13.4	13.8	19.7	18.7
SE	0.11	1.2	0.09	0.16	0.16	0.7	1.2
CD (5%)	0.23	2.4	0.19	0.33	0.33	1.4	2.6

HAFB: Height at first branching, EW: East West, NS: North South

spread of canopy and number of branches were maintained and managed with annual pruning and training practices in the intercropping system. All these factors contributed to the total canopy area which ranged from 17.7 to 31.1 m^2 among the clones and differed significantly. Number of pods produced by a tree is an important determinant of yield and pod yields are in general, expressed in correspondence with the canopy area particularly in the mixed cropping scenario. Maximum cocoa yields were obtained in earlier trials with a canopy of 16- 20 m^2 in spacing of 2.7 m x 5.4 m (Balasimha, 2002) under arecanut.

Cocoa breeding was mostly focussed on maximization of yield (Kennedy *et al*., 1987) and has mainly centered on components such as pod numbers per tree, bean numbers per pod and bean size (Toxopeus and Wessel, 1970; Toxopeus and Jacob, 1970; Ang and Shepard, 1978; Yapp and Phua, 1987). In Sri Lanka and Malaysia, the locally adapted clones significantly contributes to the cocoa economy through their high yield and tolerance to pests and diseases than the developed hybrids (Seneviratne and Hearath, 2000; Haeser *et al*., 2013). Average pod yield per year per tree of Wayanad collections are given in Table 2, which showed significant difference over the years and among clones. From the pod yields over eight years, it was observed that five clones, WYN-5, WYN-13, WYN-10, WYN-9 and WYN-6 exhibited stable and high yielding potential with an average of 61.8, 56, 52.5, 50.8 and 50 pods per tree. At the farm level, planters are more concerned about the number of pods which is the primary component in the yielding phenomena.

As a part of morphological characterisation of collections, pod characters were recorded which differed significantly among the clones (Table 3). The method based on counting the healthy and diseased pods and weighing the whole healthy pods has been used as a standard method for estimation of dry cocoa yield in varietal trials in Ivory Coast (Lachenaud, 1984,1991). A few breeding trials used the average pod weight x wet bean ratio of 0.25 and wet:dry bean ratio of 0.35 as conversion index for estimation of dry bean yield (Tahi *et al*., 2007). On an average pod weight of >350 gram is considered optimal and it was observed in eight

Table 2. Average pod yield of Wayanad cocoa collections

Clones	No. of pods tree^{-1} year^{-1} (10-17 years old)								Mean
	2007	2008	2009	2010	2011	2012	2013	2014	
WYN 1	27.0	31.3	41.0	63.7	58.0	52.0	59.0	43.3	46.0
WYN 2	21.7	22.3	31.7	62.0	42.7	61.0	33.0	50.3	40.6
WYN 3	26.0	31.0	32.0	35.7	34.0	39.3	62.3	48.9	38.7
WYN 4	22.0	39.0	45.0	53.7	56.0	57.7	33.3	45.7	44.1
WYN 5	35.0	45.5	57.3	82.3	52.0	102	54.0	66.3	61.8
WYN 6	34.7	46.0	40.3	41.7	59.0	52.5	63.0	62.9	50.0
WYN 7	28.3	31.3	36.7	57.0	41.0	64.0	44.7	46.3	43.7
WYN 8	50.0	33.0	30.0	43.3	34.0	48.7	38.0	46.7	40.5
WYN 9	32.0	37.0	45.0	64.7	50.0	68.7	54.0	54.7	50.8
WYN 10	40.0	43.3	47.0	60.7	59.0	72.3	45.0	52.7	52.5
WYN 11	21.3	30.3	36.0	34.3	33.0	45.7	39.0	35.3	34.4
WYN 12	35.3	46.3	48.0	49.0	36.7	55.7	48.3	37.0	44.5
WYN 13	45.0	57.0	52.3	56.0	55.7	58.0	61.0	63.3	56.0
WYN 14	22.7	32.0	44.0	52.3	42.3	58.5	42.7	56.3	43.9
WYN 15	27.0	31.3	41.0	42.0	34.0	45.5	29.0	34.3	35.5
CV%	12.9	8.4	7.7	3.8	25.2	25.0	12.7	8.8	
SE	1.4	1.1	1.2	0.8	3.2	5.9	2.0	1.6	
CD (5%)	2.8	2.1	2.3	1.5	6.5	12.0	4.1	3.2	

Table 3. Pod characters of Wayanad cocoa collections

Clones	Pod weight (g)	Pod length (cm)	Pod breadth (cm)	Husk: bean	Ridge (cm)	Furrow (cm)	Bean no.
WYN 1	322	14.4	7.31	2.18	1.05	0.77	39.0
WYN 2	254	15.8	5.84	2.41	1.14	0.76	41.8
WYN 3	515	17.5	8.52	3.01	1.40	0.98	41.1
WYN 4	277	15.2	6.11	2.41	0.93	0.53	43.7
WYN 5	524	19.9	7.91	2.82	1.30	0.83	45.3
WYN 6	425	18.3	7.81	3.50	1.33	0.88	40.1
WYN 7	312	15.8	6.92	2.72	0.89	0.64	41.1
WYN 8	388	17.2	7.70	2.66	1.00	0.78	39.0
WYN 9	430	16.1	7.85	3.10	1.47	1.17	40.1
WYN 10	403	16.1	8.44	3.18	1.41	0.98	37.9
WYN 11	315	17.0	6.86	2.77	0.91	0.67	44.3
WYN 12	347	17.1	7.17	2.04	1.03	0.66	40.0
WYN 13	488	14.0	8.14	2.44	1.08	0.94	42.0
WYN 14	278	16.8	7.02	2.28	1.25	0.78	45.4
WYN 15	376	14.4	7.10	2.69	1.17	0.94	39.6
CV%	12.9	5.0	3.74	18.33	10.66	11.75	7.7
SE	17.7	0.3	0.10	0.17	0.04	0.35	1.2
CD (5%)	36.4	0.6	0.20	0.35	0.09	0.72	2.4

Table 4. Bean characters of Wayanad cocoa collections

Clones	Wet: dry	SBW (g)	DBY (kg)	Shelling %	Nib recovery	Fat (%)
WYN 1	2.91	1.01	1.81	18.3	83.3	50.0
WYN 2	3.58	0.83	1.43	11.0	87.0	47.0
WYN 3	3.03	1.10	1.76	22.1	80.0	50.5
WYN 4	2.14	0.81	1.67	10.5	92.3	42.0
WYN 5	2.35	1.00	2.78	15.6	86.0	50.0
WYN 6	2.73	1.00	2.01	15.3	90.6	50.0
WYN 7	3.08	0.96	1.71	22.4	75.3	49.5
WYN 8	2.92	0.99	1.55	21.7	75.0	49.6
WYN 9	2.70	1.02	2.07	14.7	87.0	50.2
WYN 10	3.21	1.22	2.43	14.5	86.0	50.5
WYN 11	3.39	0.85	1.29	24.0	76.0	41.0
WYN 12	2.85	0.87	1.55	25.3	77.0	43.0
WYN 13	3.38	1.08	2.54	14.8	89.4	51.0
WYN 14	3.65	0.80	1.56	13.1	77.0	40.0
WYN 15	3.70	0.79	1.22	28.3	75.2	39.0

SBW: singly dry bean weight, DBY: dry bean yield

clones in our study. Weight, length and breadth of the pods contributed to the total size of pods and husk:bean ratio ranged from 2.04 to 3.50. The husk thickness at ridge ranged from 0.89 to 1.47 cm and at furrow it ranged from 0.53 to 1.17 cm. Husk thickness of less than one centimetre is being used as a criteria for selection of pods with more beans or pod filling, whereas in the recent years thicker husks are preferred towards selection of clones for tolerance to pest and disease attack without compromising the bean number per pod. Number of beans per pod is one of the important genotypic traits contributing to yield, which ranged from 37.9 to 45.4 among the clones studied. All clones excelled in number of bold beans per pod, more than the average requirement of 35 beans.

Wet beans were processed and fermented for one week, dried and observed for bean characters (Table 4). Wet:dry bean ratio ranged from 2.14 to 3.70 where, a ratio of 3 is considered optimal for favourable pod index, representing the number of pods required to produce 1 kg dry beans. Wet beans at the rate of three kilogram per tree are considered nominal to get optimal remuneration from a tree. Single bean dry weight of one gram (bean index:100 beans per 100 g) and above is categorised as Grade I beans (GOI, 1997) and among the collections studied, seven clones bore bigger beans followed by two clones with Grade II beans of 0.96 and 0.99 g. Dry bean yield was directly computed from the average pod yield, number of beans and single dry bean weight, which ranged from a lowest

Table 5. Selected Wayanad clones and their desirable traits

Clones	Vigour (cm)	Canopy area (m^2)	Pod no. $tree^{-1}$	Bean no. pod^{-1}	Dry wt. (g $bean^{-1}$)	Dry bean yield (kg $tree^{-1}$)	Shell (%)	Recovery (%)	Fat (%)
WYN 5	49.3	31.1	61.8	45.3	1.00	2.78	15.6	86.0	50.0
WYN 13	51.0	29.3	56.0	42.0	1.08	2.54	14.8	89.4	51.0
WYN 10	44.7	20.1	52.5	37.9	1.22	2.43	14.5	86.0	50.5
WYN 9	45.7	18.3	50.8	40.1	1.02	2.07	14.7	87.0	50.2
WYN 6	49.0	22.3	50.0	40.1	1.00	2.01	15.3	90.6	50.0

of 1.22 to a highest of 2.78 kg tree^{-1}. At the industrial level, during chocolate manufacturing, due consideration is being given on the processing value of beans, which in general, is assessed by the shelling percentage, nib recovery and fat contents and it ranged from 10.5 to 28.3 per cent, 75 to 92.3 per cent and 39 to 51 per cent respectively, among the Wayanad collections.

From this evaluation it is concluded that the clones WYN-5, WYN-13, WYN-10, WYN-9 and WYN-6 exhibited vigour, produced more pods with optimal canopy and gave 2.78, 2.54, 2.43, 2.07 and 2.01 kg dry bean yields tree^{-1} year^{-1}, respectively (Table 5). These clones also possessed desirable bean traits with processing value making them suitable for all stake holders *viz*., planters, processors and industries. These clones can be multiplied and recommended for cultivation to get additional remuneration in mixed cropping systems and further evaluated in different agro-climatic conditions, as well.

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