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Variability studies and identification of high yielding plus trees of cocoa (*Theobroma cacao* L.) in Tamil Nadu

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One hundred and fifty one (151) cocoa trees in the farmers' field of Tamil Nadu were assessed for their variability and yield performance. Ten year old trees in five different plantations of Tamil Nadu were observed for their morphological, pod, bean and yield characters. Variability among the tree, pod, bean and yield trait characters were also studied for all the trees selected. Plus trees or promising mother trees were identified from the trees having the following traits: Dry bean yield per tree (> 2.4 kg), number of pods per tree (60), number of beans per pod (> 35) and single dry bean weight (> 1 g). In this analysis, the trees which had necessary economic traits were screened. A total of 27 trees *viz*., KUL-2, 18, 25, SMJ- 3, 4, 10, 15, 18, 21, 25, 33, 34, 37, 50, SME - 2, 5, 6, 9, 16, 21, 24, 26, 28, 29, VPS- 12, 13 and 15 were found to be superior for important economic traits and identified as plus trees.

Key words: Cocoa, plus trees, growth, pod traits, yield, variability.

INTRODUCTION

Cocoa dried beans are the raw materials for cocoa powder and butter, chocolate, confectionaries, beverage and cosmetic industries (Prasannakumari et al., 2009). Cocoa is gaining tremendous importance for its growing demand across the world. In India, the production of cocoa confined majorly into Southern states *viz*., Kerala, Karnataka, Andhra Pradesh and Tamil Nadu (Elain Apshara et al., 2009). It occupies an area of 46,318 ha with the production of 12,954 MT and the national productivity is 550 kg dry beans per ha. Kerala leads in production of cocoa from an area of 11,044 ha with production of 6344 MT. The productivity of cocoa beans in the state is 592 kg per hectare. Tamil Nadu occupies third position in cocoa cultivation with an area of 9347 ha. It produces 900 MT cocoa beans with the productivity of 443 kg dry beans per hectare (DCCD, 2011). To meet the growing demand of cocoa beans, there is need for Identification of new high yielding trees. Selection of superior plants or parents, their subsequent development into clones and exploitation the hybrid vigour are considered as the easy approaches in perennial crops, especially in cocoa improvement (Christian, 2003). Hence, this study is undertaken to identify the promising tress of cocoa for high yield and quality for further crop improvement work.

MATERIALS AND METHODS

Field survey and experimental materials

In Tamil Nadu, Pollachi region comprising Sethumadai, Kulathupudur, Vettaikaranpudur and Sathyamangalam contributes more than 90% of the total cocoa production. Hence, surveys were undertaken in these regions from June to October 2008 to identify

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Table 1. Locations and trees under study.

S/N	Place	Number of selected trees
1	Kulathupudur Selvaraj Plantation (KUL)	26
2	Sethumadai Jayaraj Plantation (SMJ)	55
3	Sethumadai Engineer Plantation (SME)	29
4	Vettaikaranpudur Sabapathy Plantation (VPS)	21
5	Elur, Sathyamangalam Balraj Plantation (SEB)	20
Total		**151**

plus trees of cocoa. About 151 trees were selected based on yield, pod and bean characters. The trees were marked and observations were made for morphological and yield parameters.

Locations and trees under study

The location as well as the number of trees selected is given in Table 1. The age of cocoa trees identified was 10 years and above in all plantations and cocoa was intercropped in coconut plantation with age ranging from 15 to 20 years. All the area surveyed and trees identified were F_1 seedling progenies, raised through seedlings (of F_1's) supplied by Kerala Agricultural University and Central Plantation Crops Research Institute, Vittal. One row of cocoa was planted in between two rows of coconut at 10 feet distance and one cocoa plant in between two coconut trees in a row. The cocoa plants were given cultural practices as per the package of practices standardized by Kerala Agricultural University. Pruning was regularly done in the identified trees where in excess chupons arising from main stem and fan shoots were removed before and after each monsoon. All the plantations were flood irrigated during the study period. The preliminary observations were recorded in 2008 and later during subsequent year (May, 2009 to April, 2010) the data for yield and quality traits were recorded in the marked trees.

The tree morphology, pod, bean and yield traits were recorded. First branching height of the tree was measured in meters as the vertical distance from ground level upto the first jorquetting point, using a measuring tape. The girth of the tree was measured at 15 cm above the ground and expressed in centimeter. The fan branches arising from first jorquette was counted and expressed in numbers. Canopy spread of the tree was measured as North-South and East-West and expressed in metre. The pod length was measured from each selected tree and the length measured from stalk to apex and expressed in centimeter using scale and the average was calculated. Girth of the pod was measured at the centre of the pod by using thread and expressed in centimetre. The weight of each pod was measured in grams using a common balance and the data recorded. The thickness of pod wall at ridges and furrows were measured for each pod harvested after cutting open the pod and measured by using vernier callipers and expressed in millimeters. For all the above pod characters ten pods per each tree was taken and the average was calculated. Bean characters like number of beans per pod, wet bean weight per pod, single dry bean weight were calculated. Yield traits like number of pods per tree, dry bean yield per tree were worked out. The pod value can be defined as number of pods required to produce one kilogram of dry beans. The pod value was obtained using the yield data. The statistical mean was calculated using the method suggested by Goulden (1952).

Phenotypic coefficient of variation was computed according to Burton and Devane (1953).

$$\text{Coefficient of variation} = \frac{\text{Standard deviation}}{\text{Mean}} \times 100$$

The trees having the following traits like dry bean yield per tree (> 2.4 kg), number of pods per tree (60), number of beans per pod (> 35) and single dry bean weight (> 1 g) were screened as plus trees for further breeding works.

RESULTS AND DISCUSSION

Morphological characters of cocoa trees

Morphological observations taken from the cocoa trees are presented in Table 2. The first branching height showed variation ranging from a minimum of 0.36 m to a maximum of 2.25 m with the mean of 1.22 m. The first branching height was minimum (0.36 m) in SEB 18, followed by 0.45 m in SEB 17 and was maximum in KUL 2 (2.25 m) and in SMJ 46 (2.10 m). The coefficient of variation for the jorquetting height was 26.90%. Observations on tree girth of all trees studied varied from a minimum of 22.30 cm (SEB 10) followed by 22.80 cm (SEB 7) to the maximum of 51.00 cm (SME 24) followed by 50.20 cm (VPS 17). The mean value for tree girth was 35.22 cm and the coefficient of variation was 16.13%. Number of fan branches arose from the jorquette of all trees was recorded. The number of fan branches per tree varied from 2 to 5 with the mean value of 3.90. The coefficient of variation for the trait fan branches was 22.69%. The tree spread in east to west ranged from 2.40 m to 7.53 m with the mean value of 4.46 m. The maximum spread of 7.53 m was recorded in the tree KUL 2 and the minimum spread (2.40 m) in the tree SEB 13. The tree spread across north-south ranged from 1.69 m to 8.28 m with the mean value of 4.50 m. The maximum spread of 8.28 m was recorded in the tree VPS 4 and the minimum spread of 1.69 m was recorded in the tree SMJ 47.Jorquetting height in cocoa is an important criterion for selection of plus trees as higher the jorquetting height, more could be the yield as the lengthier jorquette could allow more number of flower cushions in the trunk, thus leading to higher yield. The positive correlation between these two traits in this study also supports this. Further a tree with good tree girth, more number of fan branches and tree spread reflect the vigour of the trees indirectly

Table 2. Tree morphology and pod characters of cocoa trees.

Trees	First branching height (m)	Tree girth (cm)	Number of fan branches	Tree spread (m)		Pod length (cm)	Pod girth (cm)	Pod weight (g)	Pod wall thickness at ridges (mm)	Pod wall thickness at furrows (mm)
				EW	NS					
KUL 1	1.14	28.2	4	4.52	3.61	13.84	24.88	348.50	11.6	8.4
KUL 2	2.25	41.0	4	7.53	6.62	17.25	25.93	487.47	11.7	8.3
KUL 3	1.01	34.5	3	4.82	6.68	14.91	24.86	384.40	11.9	8.8
KUL 4	0.87	46.5	4	6.02	6.32	16.08	27.08	610.50	17.4	15.6
KUL 5	0.90	32.4	4	3.76	3.31	12.96	22.70	292.13	11.1	8.8
KUL 6	1.02	34.3	2	4.21	4.21	13.33	27.77	385.00	12.3	9.9
KUL 7	1.80	41.0	5	3.61	4.52	13.44	22.57	272.50	11.7	8.6
KUL 8	0.69	33.0	3	3.49	3.61	13.37	22.57	256.67	11.6	8.5
KUL 9	1.83	36.4	5	3.43	4.09	14.57	27.28	430.00	13.0	10.3
KUL 10	1.53	39.2	3	3.61	4.33	17.28	28.32	609.00	15.4	10.7
KUL 11	1.14	34.6	3	4.30	4.39	14.50	25.50	423.75	12.0	9.3
KUL 12	1.08	36.2	3	4.30	4.00	14.33	27.81	420.00	14.7	11.4
KUL 13	1.38	28.0	4	3.16	3.28	17.20	27.50	590.00	17.9	12.7
KUL 14	0.84	33.1	4	3.76	3.34	16.30	27.30	532.00	18.2	15.3
KUL 15	1.47	29.0	3	3.91	3.91	12.95	25.80	393.00	12.5	10.3
KUL 16	1.14	27.2	4	2.65	2.20	14.44	25.64	381.60	13.8	8.4
KUL 17	1.41	29.4	4	3.70	4.42	13.66	27.16	366.25	12.4	7.1
KUL 18	1.35	34.4	5	4.06	5.42	14.94	23.86	377.50	13.8	7.7
KUL 19	1.14	32.6	4	3.79	3.52	13.20	28.20	420.00	12.1	9.1
KUL 20	0.78	29.6	2	3.31	3.52	13.60	23.10	305.00	11.2	8.6
KUL 21	0.90	33.0	3	2.71	4.15	13.65	22.73	362.50	11.4	7.9
KUL 22	0.63	37.3	3	3.97	3.91	19.00	26.43	461.88	14.9	10.1
KUL 23	1.41	40.5	2	5.72	3.16	13.00	24.10	330.00	11.8	8.3
KUL 24	1.50	34.4	4	3.61	4.39	14.46	23.80	312.40	14.2	8.9
KUL 25	1.32	29.8	4	4.82	4.42	13.56	25.01	345.00	12.7	9.8
KUL 26	1.35	25.6	4	4.97	4.27	12.50	26.50	305.25	13.8	10.1
SMJ 1	1.95	31.3	5	6.32	4.52	10.66	23.97	312.31	11.7	9.7
SMJ 2	1.38	31.8	3	5.12	4.82	15.72	24.69	445.50	14.0	9.0
SMJ 3	1.32	40.2	5	5.12	6.92	14.56	25.09	409.50	11.3	8.8
SMJ 4	1.35	32.1	4	4.52	5.27	15.00	26.53	455.00	10.4	9.1
SMJ 5	1.14	37.2	4	4.82	5.72	17.30	27.62	583.33	14.3	10.3
SMJ 6	1.35	28.0	5	4.21	4.70	15.18	24.08	372.50	12.7	8.6
SMJ 7	1.41	28.0	4	4.52	4.79	16.41	26.41	525.00	14.9	8.1
SMJ 8	1.17	33.3	4	4.21	4.36	18.12	26.33	645.00	17.5	11.0
SMJ 9	1.53	31.8	5	3.91	5.00	12.98	24.10	316.67	12.3	8.1
SMJ 10	1.50	34.5	3	4.64	4.21	15.28	24.98	421.67	12.8	9.0
SMJ 11	1.14	41.3	4	5.12	3.82	14.03	22.96	339.00	13.7	9.1
SMJ 12	1.41	33.2	5	4.21	4.73	15.46	22.31	327.86	11.9	8.0
SMJ 13	1.32	44.2	5	4.21	5.72	18.29	29.00	628.33	17.5	13.4
SMJ 14	1.62	29.2	3	3.88	4.06	15.85	24.20	362.50	13.6	8.4
SMJ 15	1.44	42.1	4	5.12	5.12	15.55	27.13	462.00	11.5	10.0
SMJ 16	1.29	34.5	3	3.58	4.30	15.51	25.55	456.00	12.0	10.4
SMJ 17	1.20	35.5	4	4.82	5.06	12.94	25.71	395.29	12.8	8.4
SMJ 18	1.26	38.0	3	5.27	4.52	16.68	25.99	471.88	9.4	8.3
SMJ 19	1.14	39.2	3	6.02	4.82	14.10	25.46	422.00	11.6	8.9
SMJ 20	1.29	37.2	3	5.12	4.52	16.10	25.20	428.13	14.1	10.6
SMJ 21	1.62	34.2	3	4.97	4.82	17.40	25.22	446.00	13.1	9.8
SMJ 22	0.63	39.2	3	5.57	5.12	17.88	26.6	614.00	14.2	10.9

Table 2. Contd.

SMJ 23	1.02	43.5	3	4.94	5.42	16.30	27.58	551.25	12.6	10.5
SMJ 24	0.93	41.5	4	5.12	4.73	19.55	27.97	625.71	15.2	12.0
SMJ 25	1.14	34.2	4	4.91	4.52	15.08	27.83	546.67	16.1	10.5
SMJ 26	1.23	33.5	4	4.36	5.66	14.94	27.88	544.38	14.3	10.9
SMJ 27	1.95	38.2	5	4.91	5.42	17.90	27.48	633.33	14.8	11.2
SMJ 28	1.53	27.2	5	4.82	4.73	18.00	26.57	563.33	16.2	11.0
SMJ 29	1.47	35.0	4	4.18	3.31	14.90	25.44	415.00	12.7	9.5
SMJ 30	1.38	30.5	3	3.79	4.82	15.38	23.21	374.00	11.9	9.1
SMJ 31	0.96	31.2	5	4.24	4.36	15.53	29.63	621.67	15.7	12.4
SMJ 32	2.07	37.2	5	4.55	5.00	15.20	28.35	575.00	13.5	10.3
SMJ 33	1.35	42.1	4	4.70	4.61	17.68	25.78	498.75	14.3	10.0
SMJ 34	1.05	32.0	4	3.31	4.06	16.12	26.00	458.00	13.5	9.9
SMJ 35	1.35	28.2	5	3.43	4.21	15.77	26.79	452.27	11.5	7.9
SMJ 36	1.38	43.1	2	4.36	6.02	17.15	30.1	628.75	13.3	10.7
SMJ 37	0.93	35.4	4	3.91	3.49	13.10	26.13	513.33	12.8	8.3
SMJ 38	1.41	30.2	5	4.70	4.97	17.70	29.70	680.00	12.8	7.5
SMJ 39	1.56	36.8	4	5.42	4.79	14.20	24.72	382.00	14.1	9.5
SMJ 40	1.44	25.0	4	4.45	4.42	13.52	24.76	347.00	10.4	7.1
SMJ 41	1.65	26.3	5	3.43	3.55	12.60	25.70	349.00	12.4	8.4
SMJ 42	1.17	28.0	4	4.39	3.91	12.94	25.28	351.00	11.1	7.9
SMJ 43	1.29	33.6	4	6.53	5.24	13.36	24.38	415.00	10.8	7.5
SMJ 44	0.93	32.2	5	3.94	4.12	17.52	30.22	666.00	13.4	11.3
SMJ 45	1.83	28.2	3	4.21	4.12	16.53	23.62	403.33	11.4	9.2
SMJ 46	2.10	31.8	5	4.09	4.55	14.20	27.35	473.33	10.7	7.9
SMJ 47	1.47	30.5	5	6.23	1.69	14.67	28.13	491.67	12.3	10.4
SMJ 48	0.90	32.3	4	4.82	6.32	15.21	23.91	399.29	12.7	8.2
SMJ 49	0.93	29.5	4	3.01	4.30	16.00	24.92	502.00	12.6	7.9
SMJ 50	1.02	39.1	4	4.82	5.72	13.94	25.68	376.00	11.2	8.4
SMJ 51	1.14	34.2	3	4.52	4.21	14.10	25.80	423.33	12.5	9.2
SMJ 52	1.02	39.1	5	4.91	4.82	12.82	23.86	358.00	12.6	9.2
SMJ 53	1.26	33.5	4	5.72	3.91	16.08	25.54	476.00	13.1	8.8
SMJ 54	1.08	28.2	3	5.12	6.02	13.15	23.35	283.33	8.3	7.0
SMJ 55	1.02	37.8	5	4.61	5.12	14.13	24.69	392.86	14.9	9.3
SME 1	1.44	30.1	4	3.01	4.52	11.95	22.95	250.00	11.1	7.5
SME 2	1.65	43.4	4	4.82	5.42	17.31	26.04	571.00	14.8	9.6
SME 3	1.59	38.4	4	4.21	5.36	14.90	25.65	434.75	11.7	8.9
SME 4	1.71	34.3	2	4.21	3.91	13.98	24.35	406.88	10.9	8.8
SME 5	1.08	37.8	3	5.12	4.36	15.05	22.93	375.00	8.2	7.1
SME 6	1.56	33.8	5	3.91	3.91	16.47	24.06	465.00	10.3	8.2
SME 7	1.50	39.5	4	3.31	3.55	13.79	32.01	642.78	15.2	12.7
SME 8	1.20	36.8	4	4.52	3.61	16.33	27.21	510.00	12.1	8.3
SME 9	1.29	41.0	4	3.91	4.52	18.10	28.14	594.00	13.4	9.9
SME 10	1.32	36.7	5	3.91	4.52	16.42	26.27	525.56	13.1	9.7
SME 11	1.20	41.0	4	5.42	5.12	14.73	27.64	457.86	12.4	7.5
SME 12	1.44	35.9	4	5.12	4.52	15.69	25.33	474.88	13.7	9.1
SME 13	1.74	32.3	4	5.72	5.12	15.30	24.31	344.29	11.6	7.8
SME 14	1.17	38.4	5	4.21	5.42	15.48	27.16	415.00	11.8	7.6
SME 15	1.29	41.9	4	4.52	5.12	14.51	24.80	357.86	11.3	9.1
SME 16	0.99	42.8	4	5.12	5.42	14.80	24.92	387.00	14.4	9.3
SME 17	1.11	33.5	5	4.67	4.21	16.96	27.4	402.50	16.1	13.2
SME 18	0.99	34.4	4	4.52	5.42	12.30	28.33	447.67	12.2	10.8
SME 19	0.93	42.0	4	6.62	4.97	15.33	23.37	328.33	12.3	8.6

Table 2. Contd.

SME 20	1.17	38.6	4	5.69	5.36	14.7	24.47	295.00	11.3	8.3
SME 21	0.93	44.5	5	5.72	5.36	15.08	21.09	238.11	10.7	7.0
SME 22	1.20	39.4	4	5.39	4.73	15.60	25.80	423.75	13.4	9.8
SME 23	1.56	34.4	5	4.21	6.32	12.33	22.58	256.67	11.7	7.4
SME 24	1.14	51.0	5	6.59	4.82	14.23	26.61	398.75	13.3	9.4
SME 25	1.29	36.5	4	5.72	5.09	13.00	24.83	318.00	11.7	8.8
SME 26	1.23	30.0	3	4.24	3.55	12.10	26.00	275.00	8.2	6.2
SME 27	1.44	40.2	4	4.21	3.91	14.08	25.88	410.00	11.4	8.8
SME 28	1.56	46.0	4	7.22	5.72	17.84	23.16	378.13	12.3	8.1
SME 29	1.47	31.8	5	6.32	4.21	15.78	26.10	459.00	10.6	7.3
VPS 1	1.02	34.2	2	3.61	4.82	17.42	25.58	400.10	12.2	9.1
VPS 2	0.69	39.2	2	5.81	3.61	15.62	25.16	389.33	11.1	8.9
VPS 3	0.63	38.0	2	4.33	4.52	15.67	25.42	363.78	12.2	9.3
VPS 4	1.17	42.6	3	7.31	8.28	15.97	25.84	410.90	10.1	8.5
VPS 5	0.99	31.0	3	3.13	3.31	14.73	26.80	424.30	13.7	9.7
VPS 6	0.93	24.5	2	2.41	3.76	13.30	25.18	327.00	12.1	9.6
VPS 7	0.93	27.7	3	3.52	3.31	17.03	29.41	621.50	12.8	8.2
VPS 8	0.93	30.8	3	5.72	4.21	20.10	32.00	815.00	17.1	10.8
VPS 9	1.59	33.1	4	5.42	4.61	15.81	24.87	353.14	15.2	9.7
VPS 10	1.02	40.0	4	4.21	5.42	15.27	24.20	353.29	11.4	7.8
VPS 11	0.96	36.3	2	4.36	4.70	16.60	26.50	460.00	11.1	10.1
VPS 12	0.66	40.5	3	4.55	4.21	17.87	29.00	564.67	16.6	11.8
VPS 13	1.23	40.7	3	4.21	3.61	16.30	29.44	475.50	15.7	14.9
VPS 14	1.17	28.4	4	5.12	4.09	15.25	25.75	430.50	11.1	9.9
VPS 15	0.72	47.8	4	5.00	4.42	16.47	27.27	598.33	15.7	11.3
VPS 16	0.81	34.6	4	3.91	4.24	14.20	26.38	398.00	9.8	8.5
VPS 17	0.60	50.2	3	4.97	4.82	16.65	27.58	443.75	12.3	8.9
VPS 18	1.23	35.0	4	4.21	4.82	15.02	24.04	347.00	13.8	9.8
VPS 19	1.17	39.5	4	4.24	6.02	15.10	29.47	528.83	12.5	10.4
VPS 20	0.93	36.0	3	5.42	4.76	13.90	26.50	444.00	12.8	9.2
VPS 21	1.11	30.2	3	3.34	4.52	19.60	32.50	751.00	19.0	10.5
SEB 1	1.20	41.0	3	2.71	3.91	15.76	23.73	275.66	14.5	9.4
SEB 2	1.20	44.0	4	3.61	4.21	14.70	23.50	295.25	11.1	8.5
SEB 3	1.05	43.6	3	3.91	3.91	14.30	23.50	327.00	14.5	8.8
SEB 4	1.05	29.6	5	4.21	4.82	14.40	28.20	450.00	15.4	12.5
SEB 5	1.65	30.5	5	3.91	4.52	12.40	29.50	410.00	12.2	9.3
SEB 6	1.80	35.4	5	5.12	3.61	16.30	25.00	350.00	12.2	7.8
SEB 7	0.90	22.8	5	3.01	3.31	16.56	25.70	425.00	14.5	10.6
SEB 8	1.05	39.0	4	3.31	4.21	13.20	25.90	365.00	13.8	8.6
SEB 9	1.05	27.6	5	4.21	3.31	14.76	25.73	315.60	16.2	10.8
SEB 10	1.35	22.3	5	2.71	3.31	10.20	26.00	306.00	12.1	6.2
SEB 11	1.20	35.6	5	4.52	3.91	11.20	27.20	320.50	13.2	8.9
SEB 12	1.35	28.6	5	3.91	3.91	14.20	25.20	310.25	13.5	9.4
SEB 13	1.35	27.6	5	2.40	3.61	15.05	24.50	305.00	11.8	9.2
SEB 14	0.75	34.7	5	4.21	3.91	16.10	25.20	345.50	14.2	8.8
SEB 15	0.90	46.0	5	3.31	2.71	13.70	25.40	355.45	12.1	9.6
SEB 16	1.35	26.0	4	2.41	2.71	14.50	24.50	345.50	11.2	9.5
SEB 17	0.45	30.5	3	3.61	3.31	14.70	24.50	335.45	12.7	10.5
SEB 18	0.36	40.2	5	2.41	3.01	15.40	24.70	331.25	11.1	9.9
SEB 19	0.90	34.2	5	3.91	4.21	15.70	24.20	315.45	9.7	6.2
SEB 20	0.60	45.4	3	5.72	6.02	11.75	26.50	310.00	8.5	7.4
Mean	1.22	35.22	3.90	4.46	4.50	15.11	25.89	427.48	12.86	9.36

Table 2. Contd.

Maximum	2.25	51.00	5.00	7.53	8.28	20.10	32.50	815.00	19.00	15.60
Minimum	0.36	22.30	2.00	2.40	1.69	10.20	21.09	238.11	8.20	6.20
STDV	0.33	5.68	0.89	0.99	0.92	1.78	2.01	109.61	1.98	1.60
CV (%)	26.90	16.13	22.69	22.29	20.56	11.81	7.78	25.64	15.42	17.13

favouring higher yield. As all the base populations in this study were of seedling origin, considerable variation was noticed for these biometric traits with extreme values. Similar variability was reported by Elain Apshara et al. (2008, 2009) in cocoa, and Ushavani and Jayalekshmi (2009) in cashew.

Pod characters of cocoa trees

Pod characters recorded in this research are given in Table 2. Observations on pod length of all trees studied varied from a minimum of 10.20 cm (SEB 10) to a maximum of 20.10 cm (VPS 8). The mean value of the pod length of all trees was 15.11 cm. The coefficient of variation for the pod length was 11.81%. The average pod girth varied widely from 21.09 cm (SME 21) to 32.50 cm (VPS 21) with a mean pod girth of 25.89 cm. The coefficient of variation of the pod girth was 7.%. Observations on pod weight of all trees studied varied from a lowest of 238.11 g in SME 21 to the highest value of 815.00 g in VPS 8. The mean value of the pod weight of all trees was 427.48 g. The coefficient of variation for the pod weight was 25.64%. Observations on pod wall thickness at ridges in the trees observed varied from a minimum of 8.2 mm in SME 5 and SME 26 to a maximum of 19.00 mm in tree VPS 21. The mean value of the pod wall thickness at ridges was 12.86 mm. The coefficient of variation was 15.42%. The pod wall thickness at furrows showed good variation ranging from a minimum of 6.2 mm in SME 26, SEB 10 and SEB 19 to a maximum of 15.6 mm (KUL 4). The mean value was 9.36 mm. The coefficient of variation for the pod wall thickness at furrows was 17.13%

The quantitative characters of the pod like pod weight, pod length, pod girth and pod wall thickness at ridges and furrows also registered greater diversity among the trees. In cocoa, ideal genotypes should possess medium to large sized pods with thin to medium pod wall thickness. The wider variability for the pod weight, length, girth and volume existed in the population might be due to both genetic factors and environmental factors including soil moisture and nutrient status. Being a highly heterozygous crop, the pod characters range was strikingly high. Elain Apshara et al. (2008) studied the pod characters for 21 superior progenies of different cross combinations in cocoa and reported the variability for pod weight, pod length, pod girth and pod wall thickness. The results are in agreement with those obtained by Subramanian and Balasimha (1981), Mallika et al. (1996), Maharaj et al. (2006) and Elain Apshara et al. (2009) in cocoa.

Bean characters of cocoa trees

Bean characters studied are given in Table 3. Observations on number of beans per pod in all trees studied varied from a minimum of 25.50 in KUL 15 to a maximum of 50.50 in SMJ 7. The mean value of the number of beans per pod of all trees was 39.45. The coefficient of variation for the number of beans per pod was 11.01%. The wet bean weight per pod in all trees studied varied from a minimum of 73.79 g in SME 21 to a maximum of 210.50 g in VPS 7 with a mean value of 121.42 g. The coefficient of variation for the wet bean weight per pod was 20.00%. Single bean dry weight of all trees studied varied from a minimum of 0.59 g in tree SMJ 43 to a maximum of 1.71 g in tree SMJ 36 with an overall mean of 1.00 g. The coefficient of variation for the single bean dry weight was 17.93%.

In cocoa, pods possessing higher number of beans per pod, wet bean weight per pod before and after fermentation and dry bean weight per pod are preferred. The wider variation for the number of beans per pod, wet bean weight per pod before and after fermentation, dry bean weight per pod, single bean wet and dry weight, bean length and girth are mainly due to the genetic factors with possibility of external influence like environment and nutrient status. These results are in consonance with the findings of Enriquez and Soria (1968), Adomako and Adu-Ampomah (2003), Lachenaud and Oliver (2005), Assemat et al. (2005) and Elain Apshara et al. (2008, 2009) in cocoa.

Yield traits of cocoa trees

The yield traits recorded in the present study is given in Table 3. Observations on number of pods per tree in 151 trees studied varied from a minimum of 32 in SEB 15 to a maximum of 108 in SMJ 11, with an overall mean of 60.49. The coefficient of variation for the number of pods per tree was 22.39%.

The yield per tree of all trees studied varied from a minimum of 0.85 kg in SMJ 40 to a maximum of 3.96 kg in SME 24. The mean value of the dry bean yield per tree of all trees was 2.39 kg. The coefficient of variation for the yield per tree was 28.76%. Pod value of all trees

Table 3. Bean and yield characters of cocoa trees.

Trees	Number of beans per pod	Wet bean weight per pod (g)	Single dry bean weight (g)	Number of pods per tree	Dry bean yield per tree (kg)	Pod value
KUL 1	40.9	93.80	0.78	45	1.44	31.35
KUL 2	44.9	173.67	1.35	65	3.94	16.49
KUL 3	40.3	140.00	1.25	54	2.72	19.85
KUL 4	41.6	145.40	1.33	57	3.15	18.07
KUL 5	33.5	111.67	1.05	67	2.36	28.43
KUL 6	37.3	127.67	1.21	55	2.48	22.14
KUL 7	33.5	90.50	0.75	65	1.63	39.80
KUL 8	34.0	110.33	1.06	58	2.09	27.75
KUL 9	33.8	96.25	0.92	56	1.74	32.13
KUL 10	48.2	133.00	0.95	51	2.34	21.83
KUL 11	41.5	109.00	0.85	62	2.19	28.35
KUL 12	36.6	111.43	0.80	58	1.70	34.18
KUL 13	42.0	125.00	1.02	46	1.97	23.34
KUL 14	44.5	140.00	0.92	49	2.01	24.43
KUL 15	25.5	103.75	1.38	55	1.94	28.42
KUL 16	38.2	117.40	1.06	48	1.94	24.70
KUL 17	32.9	92.50	0.86	52	1.47	35.36
KUL 18	39.8	116.67	1.08	89	3.83	23.26
KUL 19	42.0	115.40	0.91	66	2.52	26.16
KUL 20	39.0	120.00	0.98	75	2.87	26.16
KUL 21	29.3	86.88	0.98	57	1.63	34.89
KUL 22	41.0	105.25	1.05	55	2.37	23.23
KUL 23	35.0	84.00	0.59	69	1.42	48.43
KUL 24	39.8	96.40	0.71	66	1.87	35.39
KUL 25	36.9	130.50	1.28	63	2.97	21.20
KUL 26	31.0	90.00	0.61	70	1.32	52.88
SMJ 1	36.9	107.60	0.76	61	1.71	35.71
SMJ 2	39.3	129.80	0.95	55	2.05	26.78
SMJ 3	40.6	124.40	1.13	68	3.12	21.80
SMJ 4	40.6	125.33	1.16	66	3.11	21.25
SMJ 5	40.9	124.13	1.09	57	2.54	22.45
SMJ 6	43.2	111.33	0.80	63	2.18	28.96
SMJ 7	50.5	167.40	1.00	58	2.93	19.80
SMJ 8	42.5	124.83	0.90	54	2.07	26.14
SMJ 9	39.3	100.00	0.82	52	1.68	31.01
SMJ 10	40.2	119.71	1.09	78	3.42	22.81
SMJ 11	40.9	90.00	0.76	108	3.35	32.20
SMJ 12	41.3	108.33	0.91	77	2.89	26.61
SMJ 13	44.3	122.38	0.97	62	2.67	23.26
SMJ 14	44.5	138.40	1.04	56	2.59	21.61
SMJ 15	38.3	133.40	1.35	65	3.36	19.33
SMJ 16	38.0	96.50	0.75	60	1.71	35.09
SMJ 17	39.7	112.71	0.88	73	2.55	28.62
SMJ 18	42.6	122.25	1.04	66	2.93	22.56
SMJ 19	40.4	110.50	0.91	64	2.35	27.20
SMJ 20	38.4	98.25	0.87	55	1.84	29.95
SMJ 21	36.4	111.00	1.07	59	2.30	25.68
SMJ 22	46.4	175.00	1.33	57	3.52	16.20
SMJ 23	41.5	132.75	1.07	60	2.75	22.52
SMJ 24	41.4	146.25	1.22	58	2.93	19.78

Table 3. Contd**.**

SMJ 25	43.0	133.33	1.08	64	2.97	21.53
SMJ 26	45.9	147.50	1.07	54	2.65	20.37
SMJ 27	49.2	163.33	1.23	59	3.57	16.53
SMJ 28	42.4	129.44	0.93	52	2.05	25.36
SMJ 29	36.6	102.40	1.06	42	1.63	25.78
SMJ 30	31.3	113.75	1.25	56	2.19	25.56
SMJ 31	40.7	126.67	1.02	47	1.95	24.11
SMJ 32	46.5	156.50	1.01	47	2.21	21.29
SMJ 33	44.3	131.75	1.00	63	2.79	22.60
SMJ 34	45.0	126.00	1.00	64	2.88	22.22
SMJ 35	39.3	126.36	0.94	42	1.55	27.09
SMJ 36	36.8	181.25	1.71	55	3.60	15.29
SMJ 37	45.7	150.00	1.15	62	3.26	19.04
SMJ 38	49.3	208.33	1.24	44	2.69	16.35
SMJ 39	41.0	98.00	0.64	52	1.36	38.11
SMJ 40	33.0	87.60	0.68	38	0.85	44.56
SMJ 41	34.3	96.00	0.75	36	0.93	38.84
SMJ 42	38.4	113.00	0.95	49	1.79	27.41
SMJ 43	42.0	140.00	0.59	92	2.32	39.68
SMJ 44	39.2	145.00	1.16	48	2.18	21.99
SMJ 45	41.8	121.25	1.03	52	2.24	23.21
SMJ 46	40.2	185.67	1.55	51	3.18	16.06
SMJ 47	42.3	103.33	0.83	55	1.93	28.46
SMJ 48	39.3	116.43	1.06	52	2.17	24.01
SMJ 49	41.8	125.80	1.09	52	2.37	21.95
SMJ 50	40.0	133.40	1.03	63	2.60	24.27
SMJ 51	42.3	119.17	1.02	44	1.90	23.16
SMJ 52	36.8	112.40	0.88	51	1.65	30.88
SMJ 53	50.4	138.00	0.99	54	2.69	20.04
SMJ 54	37.4	90.00	0.87	57	1.85	30.76
SMJ 55	39.1	118.14	0.92	68	2.45	27.77
SME 1	40.0	115.50	0.99	52	2.06	25.25
SME 2	42.0	152.50	1.24	62	3.23	19.20
SME 3	37.5	116.38	0.92	63	2.17	28.99
SME 4	44.6	125.50	0.92	76	3.12	24.35
SME 5	36.3	120.00	1.01	67	2.46	27.28
SME 6	39.7	134.50	1.00	85	3.37	25.19
SME 7	41.3	137.44	0.96	67	2.66	25.20
SME 8	42.8	129.50	0.98	72	3.32	21.66
SME 9	47.2	152.20	1.08	71	3.62	19.62
SME 10	39.8	115.00	0.96	66	2.52	26.19
SME 11	38.9	107.43	0.96	97	3.62	26.81
SME 12	36.9	94.50	0.95	84	2.94	28.54
SME 13	38.1	94.40	0.87	58	1.92	30.17
SME 14	39.6	103.33	0.94	62	2.31	26.86
SME 15	42.0	109.00	0.85	85	3.03	28.01
SME 16	39.2	115.00	1.06	89	3.70	24.07
SME 17	39.8	107.86	0.85	87	2.94	29.60
SME 18	37.3	93.33	0.80	63	1.88	33.49
SME 19	36.3	116.43	0.98	54	1.92	28.11
SME 20	33.3	85.50	0.90	74	2.22	33.34
SME 21	38.7	73.79	1.06	69	2.83	24.35

Table 3. Contd**.**

SME 22	42.5	113.75	0.95	76	3.07	24.77
SME 23	33.5	94.33	0.83	64	1.78	35.96
SME 24	37.0	105.13	1.01	106	3.96	26.76
SME 25	38.3	120.71	1.04	65	2.59	25.09
SME 26	41.0	128.50	1.15	66	3.11	21.21
SME 27	39.1	102.25	0.92	63	2.27	27.79
SME 28	45.3	143.33	1.12	69	3.50	19.73
SME 29	48.4	178.00	1.34	59	3.83	15.42
VPS 1	39.0	116.33	0.95	73	2.70	26.99
VPS 2	39.3	106.22	0.76	82	2.45	33.46
VPS 3	37.3	104.50	0.98	69	2.52	27.33
VPS 4	40.7	137.70	1.12	58	2.64	21.94
VPS 5	35.3	126.38	1.31	39	1.80	21.62
VPS 6	40.4	125.40	0.93	63	2.37	26.62
VPS 7	42.5	210.50	1.33	54	3.05	17.69
VPS 8	41.0	192.50	1.50	57	3.51	16.26
VPS 9	42.8	112.88	0.85	76	2.76	24.59
VPS 10	38.9	108.33	0.87	81	2.74	29.58
VPS 11	50.0	155.40	1.09	48	2.62	18.35
VPS 12	37.3	126.00	1.13	60	2.53	23.73
VPS 13	35.0	135.40	1.24	63	2.73	23.04
VPS 14	38.0	125.00	1.00	57	2.17	26.32
VPS 15	41.3	140.00	1.09	64	2.88	22.20
VPS 16	40.0	116.33	0.98	73	2.86	25.51
VPS 17	39.3	119.25	0.89	59	2.06	28.63
VPS 18	36.4	95.00	0.88	62	1.99	31.22
VPS 19	36.7	102.17	1.03	60	2.27	26.48
VPS 20	42.8	135.20	0.99	52	2.20	23.60
VPS 21	43.0	170.00	1.33	51	2.92	17.49
SEB 1	40.0	103.50	0.94	66	2.48	26.60
SEB 2	31.0	88.50	0.86	68	1.81	37.51
SEB 3	26.0	101.00	0.96	75	1.87	40.06
SEB 4	36.0	131.70	0.98	53	1.87	28.34
SEB 5	40.0	127.30	0.98	48	1.88	25.51
SEB 6	35.0	154.00	1.10	50	1.93	25.97
SEB 7	38.0	125.35	1.02	38	1.47	25.80
SEB 8	34.0	110.00	0.85	36	1.04	34.60
SEB 9	36.0	115.50	0.98	40	1.41	28.34
SEB 10	33.0	89.50	0.87	41	1.18	34.83
SEB 11	38.0	98.50	0.90	64	2.19	29.24
SEB 12	35.0	90.00	0.85	54	1.61	33.61
SEB 13	38.0	105.00	0.92	48	1.68	28.60
SEB 14	39.0	118.50	0.98	46	1.76	26.16
SEB 15	36.0	112.00	0.82	32	0.94	33.88
SEB 16	39.0	115.50	0.90	36	1.26	28.49
SEB 17	38.5	118.50	0.98	43	1.62	26.50
SEB 18	35.0	125.50	1.10	35	1.35	25.97
SEB 19	36.5	105.50	0.92	46	1.54	29.78
SEB 20	32.5	115.00	0.97	91	2.87	31.72
Mean	39.45	121.42	1.00	60.49	2.39	26.54
Maximum	50.50	210.50	1.71	108.00	3.96	52.88
Minimum	25.50	73.79	0.59	32.00	0.85	15.29

Table 3. Contd**.**

STDV	4.34	24.29	0.18	13.54	0.69	6.28
CV (%)	11.01	20.00	17.93	22.39	28.76	23.68

STDV, Standard deviation.

varied from a minimum of 15.29 in tree SMJ 36 to a maximum of 52.88 in tree KUL 26, with an overall mean value of 26.54. The coefficient of variation for the pod value was 23.68%.

In cocoa, yield is determined by yield contributing characters such as number of pods per tree, dry bean yield per tree and pod value. In cocoa, lower pod value is preferred to have higher bean yield. These characters are influenced both by genetic as well as environmental factors including soil moisture and nutrient status. The results are in consonance with the findings of Latchman et al. (2000), Bekele and Bidaisee (2006), Adomako and Adu-Ampomah (2003), Lachenaud and Oliver (2005), Assemat et al. (2005), Lambert et al. (2006) and Elain Apshara et al. (2008, 2009).

Identification of plus trees or promising trees

Plus trees or promising mother trees were identified based on the economic traits like dry bean yield per tree (> 2.4 kg), number of pods per tree (60), number of beans per pod (> 35) and single dry bean weight (> 1 g). The trees which had necessary economic traits were screened. A total of 27 trees *viz*., KUL-2, 18, 25, SMJ- 3, 4, 10, 15, 18, 21, 25, 33, 34, 37, 50, SME - 2, 5, 6, 9, 16, 21, 24, 26, 28, 29, VPS- 12, 13 and 15 were found to be superior for important economic traits and identified as plus trees. These promising trees are potential genetic material for plant breeding programmes in cocoa. The results go in accordance with the findings of Desai, (2008) in cashew and Raveendra et al. (1987) in coconut. From the present study, it could be inferred that the diversity exists in cocoa plantations in Tamil Nadu and can be exploited in crop improvement research. Plus trees identified have to be observed for both yield and quality parameters for few more years. Promising trees have to be clonally raised and tested before using in breeding programmes.

REFERENCES

Adomako B, Adu-Ampomah Y (2003). Bean characteristics of progenies of upper Amazon cacao in Ghana. Trop. Agric. (Trinidad). 80:41-47.

Assemat S, Lachenaud P, Ribeyre F, Davrieux F, Pradon JL, Cros E (2005). Bean quality traits and sensory evaluation of wild Guianan cocoa populations (*Theobroma cacao* L.). Genet. Resour. Crop Evol. 52(7):911-917.

Bekele FL, Bidaisee GG (2006). Characterization of germplasm in the International Cocoa Genebank, Trinidad. **In:** Global Approaches to Cocoa Germplasm Utilization and Conservation. Final report of the CFC/ICCO/IPGRI project on "Cocoa Germplasm Utilization and Conservation: a Global Approach" (1998-2004). CFC, Amsterdam, The Netherlands/ICCO, London, UK/IPGRI, Rome, Italy.

Burton GW, Devane EH (1953). Estimating heritability in tall Fescue (*Festuca arudanacea)* from replicated clonal material. Agron J. 45:478-481.

Christian C (2003). How to improve the efficiency of individual cocoa tree selection in progeny trials? **In:** Abstracts of International workshop on cocoa breeding for improved production systems, INGENIC, Miklin Hotel, Accra, Ghana, 19-21 October 2003, P. 3.

DCCD (2011). Directorate of Cashew and Cocoa Development. (http://dccd.gov.in/stat2.htm).

Desai AR (2008). Molecular diversity and phenotyping of selected cashew genotypes of Goa and physiological response of cv. Goa-1 to in situ moisture conservation. Ph.D. (Hort.) Thesis. University of Agricultural Sciences, Dharwad, Karnataka.

Elain Apshara S, Bhat VR, Nair RV (2008). Comparative studies on elite cocoa progenies in their initial years of growth. J. Plantat. Crops. 36(1):38-44.

Elain Apshara S, Bhat VR, Ananda KS, Nair RV, Suma D (2009). Evaluation and identification of high yielding trees in Nigerian cocoa germplasm. J. Plantation Crops 37(2):111-116.

Goulden CH (1952). Methods of statistical analysis. John Wiley and Sons Inc., New York.

Lachenaud P, Oliver G (2005). Variability and selection for morphological bean traits in wild cocoa trees (*Theobroma cacao* L.) from French Guiana. Genetic Resour. Crop Evolut. 52(3):225-231.

Lambert S, Ismail D, Hidayat M, Burhanuddin M (2006). Field-Testing of Local Farmer's Selections in Sulawesi and Results on Their Quality Parameters. In: Proceedings of the International Workshop on Cocoa Breeding for Farmers' Needs, 15th - 17th October 2006, San Jose, Costa Rica, pp. 123-130.

Latchman B, Umaharan R, Maharaj S, Thevenin JM (2000). Field assessment of cacao germplasm for resistance to witches' broom and black pod diseases: year one. In: CRU Annual Report 1999. Cocoa Research Unit, University of the West Indies, St. Augustine, Trinidad and Tobago, pp. 39-46.

Maharaj KP, Maharaj S, Ramnath D (2006). Farm Practices, Knowledge and Use of Cocoa Planting Material in Trinidad: a Survey Report. **In:** Proceedings of the International Workshop on Cocoa Breeding for Farmers' Needs, 15th - 17th October 2006, San Jose, Costa Rica, pp. 41-52.

Mallika VK, Rekha C, Rekha K, Swapna M, Nair RV (1996). Evaluation pod and bean characters of cocoa hybrids in early years of bearing. J. Plantation Crops 24:363-369.

Prasannakumari Amma S, Nair RV, Lalithabai EM, Mallika VK, Minimol JS, Koshy Abraham (2009). Cocoa in India. Kerala Agricultural University, Mannuthy, Thrissur.

Raveendra TS, Ramanathan T, Nallathambi G, Vijayaraghavan H (1987). Metroglyph Analysis in Coconut (*Cocos nucifera* L.). Cocos 5:32-38.

Subramanian N, Balasimha D (1981). Variability in pod and bean characters in some cacao hybrids. Genetics, plant breeding and horticulture Proceedings of the fourth annual symposium on plantation crops PLACROSYM IV, Mysore 3-5 December 1981, pp. 168-174.

Ushavani D, Jayalekshmi VG (2009). Genetic analysis in cashew (*Anacardium occidentatle* L.). J. Plantation Crops 37(3):190-195.