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Evaluation of selective cocoa (*Theobroma cacao* L.) clones from Central and South America in their initial years of growth

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Cocoa (*Theobroma cacao* L.) has originated from Amazon basin and other tropical areas of South and Central America. Genetic resources from these regions with their establishment potential, high yield, disease resistance and other desirable commercial qualities, have been utilised in breeding programs of Cocoa Research Institutes of Ghana, Nigeria, Trinidad and Fiji for development of superior varieties (Martin, 1987; Adu Ampomah, 1996). In India, initial introductions were made from Malaysia and Nigeria at ICAR-CPCRI, Regional Station, Vittal and subsequently collections were made from Central and South American region to widen the genetic base. Also, these collections have been assessed for their morphological, physiological and molecular characteristics in their initial years of establishment (Elain Apshara *et al*., 2013). Results of evaluation trials in Indonesia have claimed that progress in breeding with new clones is 20-40 per cent over hybrids (Napitupulu, 1993). Genetic evaluation of germplasm collections for their diversity, quantitative and qualitative characteristics is very essential in selection of promising genotypes and further improvement in hybridization programs (Minimol *et al.*, 2015). Hence, the evaluation of newly collected 15 specific clones comprising of Bolivar (B), Pound (POU), Rio Branco (RB), Rosario Izupa Mexico (RIM), Santa Cruz (SCZ) and Trinitario Selected Hybrid (TSH) were carried out to assess their adaptability, precocity in bearing, variability in pod characteristics and yielding potential.

The clones were planted during 2007 with 2.7 m x 5.4 m distance under 2.7 m x 2.7 m spaced arecanut. Five trees from each clone were evaluated for their cropping efficiency in the arecanut based cropping system from fifth to ninth year of growth. Growth characters *viz*., plant height (m), girth (cm), first branching height (m), number of branches and canopy area (m^2) were recorded. During the main harvest season in the month of June, five pods from each tree were observed for pod weight (g), husk thickness (cm) and beans number per pod. The husked fresh beans were fermented, dried and observed for single dry bean weight (g), shelling (%), nib recovery (%) from 50 beans. Fat (%) from powdered nibs were estimated by Soxhlet extraction method using petroleum ether as solvent. The data were analysed using SAS programme.

From the growth characters of nine year old trees, provided in Table 1, it was observed that only girth and canopy area of clones differed significantly. Vigour with respect to girth or trunk circumference and canopy size influences the yielding potential of the crop in all clonal evaluation trials (Efron *et al*., 2000). Among the clones studied, girth of trees ranged from 25 to 32 cm and canopy

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Table 1. Morphological characters of Central and South American cocoa clones (9 years old)

Clones	Height (m)	Girth (cm)	HAFB (m)	Branches (No.)	Canopy area (m^2)
B 5/3	3.20	30	1.08	3.0	13.10
B 7/14	2.60	30	0.84	4.8	9.43
POU 7/B	2.79	30	1.55	4.0	8.11
POU 16/A	2.90	28	0.82	3.3	10.90
POU 18/A	3.05	28	1.03	2.3	5.58
RB 33/3	3.15	31	1.23	7.4	11.40
RB 46	2.96	32	1.20	8.3	10.4
RB 49	2.93	28	1.21	3.6	8.76
RIM 41	3.11	28	1.31	5.8	9.96
RIM 189	3.15	28	0.94	6.0	12.60
SCZ 1	3.25	28	1.17	6.5	10.10
SCZ 4	2.85	29	1.16	5.0	8.30
SCZ 9	2.91	26	1.20	4.1	9.10
SCZ 20	3.03	27	1.06	4.9	10.30
TSH 516	2.84	29	0.90	3.5	10.00
SEd	NS	10	NS	NS	24
CD (5%)	-	5	-	-	11

HAFB: Height at first branching

area ranged from 8-15 m^2, which is maintained by annual structural pruning. Studies at French Guiana on family competition effects of trees showed that vegetative vigour explained 34 per cent of the potential and the use of the production: vigour ratio as the main selection criterion in cocoa breeding (Lachenaud and Montagnon, 2002). In our study, optimal trunk strength and canopy area contributed to the high yielding nature of clones and made them suitable in the arecanut based intercropping system.

Pod yield ranged from 7 to 31 in the 5th year of bearing (Table 2) and increased from 22 to 39 in the 9th year of bearing. Tree adaptability and yield stability have been used to screen agronomically superior cultivars for yield, bean quality and disease resistance in Brazil (Carvalho *et al*., 2002; 2003). Among the clones studied, pod yield stabilised in 12 clones from 7th year onwards. Substantial variability was reported between cultivars for pods per tree, pod weight, fresh bean weight per fruit and bean size when several multivariate methods have been used in divergence analysis of populations (Dias and Kageyama, 1998; Fallo and Cilas, 1998). In our collections also, pod and bean characters varied among the clones with pod weight ranging from 218 to 555 g with husk thickness of 0.67 to 1.58 cm and number of beans per pod ranging from 31 to 45 with single dry bean weight of 0.62 to 1.06 g (Table 3). The dry bean yield is compiled here from ninth year

Table 2. Pod yield of Central and South American cocoa clones for five years (No. of pods $tree^{-1}$ $year^{-1}$)

Clones	2012	2013	2014	2015	2016
B 5/3	7.33	10.8	34.4	24.5	24.3
B 7/14	9.30	15.4	33.4	24.3	25.0
POU 7/B	12.7	26.2	31.3	34.0	21.6
POU 16/A	18.0	16.0	35.8	35.5	35.0
POU 18/A	11.0	25.6	12.8	25.0	27.8
RB 33/3	31.0	11.6	33.4	34.2	28.9
RB 46	12.3	9.20	24.6	25.0	25.0
RB 49	18.0	16.6	18.8	22.5	24.4
RIM 41	10.3	15.0	36.8	30.8	25.3
RIM 189	9.0	16.0	24.2	27.8	26.8
SCZ 1	14.0	17.8	37.8	37.3	37.6
SCZ 4	15.3	9.40	20.8	28.5	26.8
SCZ 9	12.0	12.0	34.4	34.3	29.9
SCZ 20	10.3	18.6	35.2	35.6	38.0
TSH 516	17.0	16.0	37.2	35.0	35.0
SEd	1.96	2.71	3.22	12.5	3.5
CD (5%)	3.18	5.76	6.94	27.1	7.0

pod yield, single dry bean weight and number of beans per pod, which ranged from 0.49-1.46 kg $tree^{-1}$ $year^{-1}$. The industrial value of clones was assessed and the shelling, nib recovery and fat percentages ranged from 10-25, 75-90 and 30-53 respectively (Table 3).

The clones, SCZ-1, SCZ-20, TSH-516 and POU-16A, with a vigour of around 28 cm and 10 m^2 canopy, yielded on an average 35 pods with >40 beans of 0.97-1.01 g weight recorded 1.37 to 1.46 kg

Table 3. Pod and bean characters of Central and South American cocoa clones

Clones	Pod wt. (g)	Husk (cm)	No. of beans pod^{-1}	SBW (g)	DBY (kg tree^{-1} yr^{-1})	Shell (%)	Nib recovery (%)	Fat (%)
B 5/3	550	1.58	31	0.65	0.49	25	75	35
B 7/14	555	1.58	40	0.68	0.68	23	79	36
POU 7/B	446	1.26	41	0.62	0.55	14	86	40
POU 16/A	350	0.90	45	0.97	1.43	10	90	50
POU 18/A	218	0.88	42	0.64	0.75	21	79	36
RB 33/3	284	1.30	39	0.71	0.80	14	86	42
RB 46	302	1.27	33	1.06	0.87	10	90	40
RB 49	334	1.14	41	0.83	0.83	12	88	38
RIM 41	278	0.95	38	0.90	0.87	17	83	37
RIM 189	268	0.67	37	0.96	0.95	18	82	30
SCZ 1	352	0.90	40	1.01	1.46	14	86	52
SCZ 4	242	0.91	34	0.62	0.56	13	88	40
SCZ 9	420	1.38	38	0.94	1.07	11	89	53
SCZ 20	352	1.00	42	1.00	1.45	14	86	50
TSH 516	360	0.94	43	0.98	1.37	13	88	50
SEd	12.9	0.09	3.96	0.05	0.04	1.45	2.46	6.93
CD (5%)	25.9	0.18	7.94	0.10	0.07	2.90	4.93	12.8

SBW: Single dry bean weight, DBY: Dry bean yield

dry bean yields with favourable industrial value. These clones, which showed high adaptability and bearing behaviour, are selected as potential clones and will be utilised in hybridization programs and multi location trials. However, the stability in performance will be assessed for further more years for the heritable characters like number of beans and bean size to explore their true potential.

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