Research Article
Journal of Plantation Crops, 2009, 37 (2): 111-116

Evaluation and identification of high yielding trees in Nigerian cocoa germplasm

S. Elain Apshara*, V.R. Bhat, K.S. Ananda, R.V. Nair and D. Suma
Central Plantation Crops Research Institute, Regional Station, Vittal, Karnataka
(Manuscript Received: 08-07-08, Revised: 17-02-09, Accepted: 08-06-09)

Abstract

Forty four Nigerian cocoa clones which are being conserved in the field gene banks of Central Plantation Crops Research Institute, Regional Station, Vittal, Karnataka were assessed for their growth and yield performance. Six year old trees were observed for their morphological characters and annual pod yields were compiled over eight years from five to twelve years of age after planting. Pod and bean characteristics were also studied for all the clones. Precocious, potential high yielders were identified from their vigorous growth habit in the introduced environment with sturdy stems and optimal canopy spread. Among the clones, NC-37, NC-23, NC-26, NC-50, NC-20, NC-51, NC-27 and NC-25 were identified as heavy bearers with an average of 61.9, 53.3, 49.4, 48.4, 45.1, 44.2, 43.9 and 43.0 pods per tree per year respectively and with high dry bean yields of more than one kilogram per tree per year. These clones recorded single bean weight of more than 1 gram, 10-15 per cent shelling percentage and more than 50 percent fat which made them suitable for industries as well.

Keywords: Cocoa, clones, growth, pod yield characters

Introduction

Since the consumption of cocoa products like chocolates is increasing fast, there is an urgent need to bring more area under cultivation of cocoa in India. At present 10,175 MT of cocoa is produced in the country and the predicted demand is expected to reach 30,000 MT during 2015 (Balasubramanian, 2002). Viewed in this background evaluation of cocoa germplasm and identification of high yielding trees become important (Bhat *et al*., 1990). As some of the germplasm collections from different countries showed high variability for yield (Shama Bhat *et al.*, 1990), an attempt was made to evaluate the Nigerian collections and identify the high yielding trees which can be used either for clonal multiplication for large scale planting or as parents in the breeding programs.

Materials and Methods

A total of 44 clones obtained from Nigeria were planted during 1995 at a spacing 2.7 m x 5.4 m with 2.7 m x 2.7 m spaced arecanut garden were evaluated for this study. They were under uniform management condition with annual application of 100:40:140 g NPK per tree per year and 20 litres of water per tree per day through drip during rainless periods. Eight trees planted in completely randomized design under each clone were observed for their height, girth, east west (EW) and north south (NS) spread of canopy, height at first branching (HAFB), pruning weights and canopy volume at the age of six years. The plant height is taken from ground level upto the tip of the canopy and expressed in meter. The girth is measured in the tree trunk at 15 cm height above ground level. The first branching height is measured from ground level to the level of the trunk initiating branches. The canopy volume was calculated using the formula πrl, whereas $r = EW + NS/4$ and $l = \sqrt{r^2 + h^2}$, h = canopy height. The prunings weights were taken during the annual pruning operation.

The pod yield of individual trees was compiled for eight years from 2000- 2007 from fifth year of bearing upto twelfth year. Pod characteristics such as individual pod weight (g), length (cm), breadth (cm), ridge and

*Author for correspondence: elain_apshara@yahoo.co.in

furrow thickness (cm), number of beans per pod were measured from five pods of each clone. From ten year old trees these pods were harvested during the main harvest season of June- July months. Total pod weight per tree per year was compiled from number of pods and individual pod weight. Beans were extracted, kept for fermentation, dried and observed for bean characteristics like single bean dry weight (SBW), shelling percentage (shell wt./ bean wt. x 100) and fat content as per industry standards. Fat was estimated by petroleum ether extraction method using Soxhlet apparatus and expressed in percentage. Data were analysed using WINSTAT program.

Results and Discussion

Growth characters

Morphological observations taken from six year old trees of 44 clones are given in Table 1. The plant height differed significantly among trees of all the clones. The trees of NC-12 showed short stature with a height of 1.31 m whereas, the trees of NC-23 have grown to a height of 4.55 m. Few taller trees were observed in eight other clones with more than 3 m height. The trunk circumference or girth of the stem differed significantly among the clones. The clone NC-36 recorded a lowest girth of 10.13 cm whereas the sturdiest stem was observed in the clone NC-63 with 36.25 cm. It was observed that the stem girth increased correspondingly with plant height, which indicated the vigour of the plant. In cocoa, a positive relationship between girth and yield is established (Enriquez, 1981; Paulin *et al.,* 1993). Longworth and Freeman (1963) suggested to consider yield along with trunk diameter for better efficiency in selection and most of the clones in this study exhibited stronger stems. The first branching height showed significant difference among the clones which recorded a lowest of 0.42 m in the clones NC-36 and NC-49 and a highest of 1.10 m in the clone NC-26.

The east west and north south spread of the canopies which contributed to the canopy volume showed significant difference value for canopy spread, which ranged from 0.88 m (NC-12 and NC-36) to 3.16 m (NC-26) and 0.80 m (NC-12) to 3.17 m (NC-23) respectively. A small canopy with 1.06 m^3 spread was observed in the clone NC-12 whereas a voluminous canopy (20.40 m^3) was observed in the clone NC-23. It has been reported that optimal canopy volume should be maintained for optimal productivity especially in the grafted plants (Balasimha, 1988). It was also suggested that trees of reduced size are much easier and less expensive to manage compared to larger trees (Atkinson, 2003). The

Table 1. Growth characters of Nigerian cocoa collections

No.	Clone	Plant height (m)	Girth (cm)	Ht. at first branching (m)	East West (m)	North South (m)	Canopy volume (m^3)	Prunes weight (kg)
1	NC-2	1.89	16.38	0.53	1.87	2.39	5.81	2.44
2	NC-3	2.54	19.13	0.56	2.46	2.29	8.29	3.78
3	NC-5	1.75	16.63	0.56	1.51	1.39	3.19	2.69
4	NC-6	1.92	20.00	0.79	1.93	2.39	5.14	2.75
5	NC-7	2.76	24.25	0.89	2.31	2.21	7.72	3.49
6	NC-8	1.87	15.13	0.63	1.47	1.43	3.28	4.19
7	NC-9	2.76	24.25	0.88	2.31	2.21	7.65	3.88
8	NC-10	2.12	14.25	0.69	1.51	1.61	3.64	2.35
9	NC-12	1.31	10.38	0.62	0.88	0.80	1.06	2.08
10	NC-13	3.04	24.38	0.83	2.81	2.94	11.78	7.75
11	NC-14	1.98	16.88	0.51	1.56	1.53	4.05	2.29
12	NC-15	2.24	20.50	0.64	2.00	2.41	6.45	2.74
13	NC-20	3.09	25.13	0.81	2.83	2.86	11.34	6.25
14	NC-23	4.55	26.63	0.66	3.13	3.17	20.40	7.88
15	NC-24	2.68	24.00	0.62	2.36	2.39	8.72	4.28
16	NC-25	2.61	23.88	0.58	2.73	2.50	9.69	4.19
17	NC-26	3.06	26.63	1.10	3.16	3.09	12.26	7.50
18	NC-27	2.83	25.13	0.71	2.54	2.50	9.39	5.13
19	NC-29	2.00	18.75	0.66	2.58	2.43	7.15	3.46
20	NC-30	2.74	25.00	0.73	2.41	2.43	8.45	6.50
21	NC-31	2.07	16.88	0.75	1.70	1.84	4.15	1.80
22	NC-32	2.23	20.25	0.54	1.93	1.81	5.35	2.98
23	NC-34	2.61	19.38	0.57	1.66	2.01	6.39	3.13
24	NC-35	2.47	21.25	0.58	2.43	2.03	7.47	3.40
25	NC-36	1.50	10.13	0.42	0.88	1.04	1.76	1.25
26	NC-37	3.20	33.00	0.87	2.58	3.00	11.81	7.63
27	NC-38	1.99	14.50	0.67	1.53	1.57	3.56	3.04
28	NC-39	2.56	17.75	0.49	1.60	2.16	6.67	3.75
29	NC-41	2.30	24.25	0.66	2.18	2.06	6.45	3.06
30	NC-42	2.31	21.63	0.70	1.51	1.83	4.77	5.38
31	NC-43	2.41	24.63	0.85	2.31	2.59	7.66	6.88
32	NC-45	3.77	30.75	0.74	2.63	2.88	14.20	3.25
33	NC-46	2.00	22.75	0.77	2.03	2.29	5.54	3.75
34	NC-48	2.36	21.88	0.57	2.03	2.31	7.16	3.00
35	NC-49	2.23	17.75	0.42	1.89	1.78	5.84	3.25
36	NC-50	2.94	22.13	0.99	2.61	2.66	9.74	5.25
37	NC-51	2.69	24.25	0.70	2.51	2.46	9.11	2.81
38	NC-52	2.75	26.25	0.53	3.11	2.78	12.24	4.38
39	NC-53	3.13	27.63	0.85	2.72	2.46	10.66	7.50
40	NC-55	2.54	22.63	0.72	2.34	2.39	8.06	3.69
41	NC-56	2.69	24.00	0.68	1.85	2.06	6.93	4.56
42	NC-57	4.24	27.38	0.70	2.68	3.06	17.25	8.25
43	NC-63	3.79	36.25	0.71	2.54	2.69	13.76	3.00
44	NC-64	1.84	20.75	0.62	2.29	2.18	5.83	3.95
	CV%	59.93	22.91	42.12	27.77	26.79	2.64	55.92
	SED	0.78	2.51	0.14	0.30	0.30	0.10	1.17
CD (P=0.05)		1.53	4.95	0.28	0.60	0.59	0.21	2.31

clones, NC-37, NC-26, NC-50, NC-20, NC-51, NC-27 and NC-25 had comparatively compact canopies and they have recorded higher pod yields (Table 2). Weight of pruned branches ranged from a lowest of 1.25 kg in the clone NC-36 to the highest of 8.25 kg in NC-57 which has helped in maintaining an optimal canopy under mixed cropping system (Thomas and Balasimha, 1992).

Pod yield performance

Number of pods obtained from a tree during each harvest were accounted from fifth year of bearing upto twelfth year i.e. from 2000 to 2007 (Table 2) along with pooled and mean yield over eight years. A gradual increase in the pod yield was observed from 2000 to 2007 among the clones. Initial yield at five years ranged from a minimum of 2.8 (NC-12) to a maximum of 43.6 (NC-37) and at the age of twelve years the pod yield ranged from 14.5 (NC-14) to 63.8 (NC-37). The clones NC-37, NC-23, NC-26, NC-50, NC-20 and NC-51 gave the high yield with an average of more than 45 pods per tree per year. In the earlier evaluation trials few of the above clones have yielded more pods per tree per year (Nair and Bhat, 1996). The same clones were also identified as precocious bearers as they recorded high pod yields in their initial years of growth. The yield data further showed evidence that the clones, which has yielded lesser pods in the initial years continued to yield less whereas, the clones yielded more pods continued to give more pods. And so the precocity in bearing behaviour can help in predicting the performance of clones in the later years. However, Mallika *et al*. (1996) and Sounigo *et al.* (2003) stressed that data from additional years of harvesting would be necessary before deciding the stability of pod yields and to overcome the poor efficiency in selection of individual trees. The pooled data showed a minimum of 64.3 (NC-12) pods and a maximum of 495.4 (NC-37) pods over eight years. The high yielders throughout the growth period expressed stable and regular bearing behaviour.

Total pod weight per tree per year is given in Table 2 which ranged from a minimum of 2.5 kg in NC-12 to a maximum of 29.2 kg in NC-37 between clones. It is said that the harvest efficiency was the cumulative of number of pods, potential total pod weight and average of single pod weight (Lachenaud, 2003). He also recommended juvenile and adult vegetative vigour, periodic and cumulative yield and yield x vigour ratio are the important factors in clonal evaluation trials. In this experiment it was observed that the clones recorded with thicker trunks (>20 cm girth) showed a positive impact on the harvest efficiency with more number of pods and pod weights.

Table 2. Pod yield performance of Nigerian cocoa collections over eight years

No.	Clone	No. of pods 2000	2001	2002	2003	2004	2005	2006	2007	Pooled	Mean	Pod wt. (kg)
1	NC-2	9.9	11.9	21.4	26.3	36.5	45.0	34.8	39.5	225.2	28.1	8.4
2	NC-3	6.4	21.3	22.5	31.0	49.0	36.4	40.4	42.5	249.4	31.2	17.7
3	NC-5	6.5	11.5	18.5	20.1	21.9	23.0	20.5	24.6	146.6	18.3	9.6
4	NC-6	5.6	13.4	17.8	23.4	24.5	30.4	29.3	37.4	181.7	22.7	9.8
5	NC-7	10.3	17.0	22.4	24.4	26.8	30.3	32.6	35.5	199.2	24.9	8.0
6	NC-8	6.1	10.0	14.5	18.4	21.3	24.0	27.3	33.8	155.3	19.4	6.7
7	NC-9	9.1	13.4	19.4	23.5	25.3	28.4	35.5	43.1	197.7	24.7	12.6
8	NC-10	13.5	23.3	29.5	33.6	40.5	39.4	42.6	45.9	268.3	33.5	12.4
9	NC-12	2.8	4.3	6.5	7.1	8.1	9.4	10.4	15.8	64.3	8.0	2.5
10	NC-13	14.0	17.1	21.0	26.5	29.6	34.0	36.9	38.3	217.4	27.2	9.7
11	NC-14	2.9	3.6	5.5	8.8	9.6	10.8	12.5	14.5	68.2	8.5	4.6
12	NC-15	14.3	22.6	28.9	39.3	44.0	47.8	55.1	52.3	304.2	38.0	26.0
13	NC-20	36.1	39.5	40.3	43.3	47.3	48.0	52.5	53.9	360.8	45.1	21.8
14	NC-23	37.9	48.9	49.5	50.9	56.6	56.3	65.6	60.5	426.2	53.3	24.8
15	NC-24	15.1	19.1	24.8	27.6	35.8	33.5	36.3	43.6	235.8	29.5	16.7
16	NC-25	28.5	35.4	40.5	44.0	45.8	45.5	48.5	56.3	344.4	43.0	24.5
17	NC-26	31.6	42.6	44.0	47.1	54.6	57.3	60.8	56.8	394.8	49.3	19.3
18	NC-27	31.8	31.0	38.9	41.8	48.4	50.0	56.0	53.8	351.6	43.9	20.3
19	NC-29	14.1	18.3	27.3	32.4	36.6	37.3	39.4	40.8	246.0	30.8	11.6
20	NC-30	29.6	34.0	38.9	42.8	43.8	46.3	43.1	44.4	322.8	40.3	18.2
21	NC-31	13.9	23.1	25.9	29.5	32.4	39.5	35.8	40.8	240.8	30.1	12.4
22	NC-32	10.6	14.9	21.3	27.0	31.4	35.0	36.9	39.4	216.4	27.1	13.2
23	NC-34	17.9	21.6	27.1	29.5	35.1	38.9	40.5	41.0	251.7	31.5	16.7
24	NC-35	6.8	10.9	25.6	22.5	29.4	28.3	26.8	31.9	182.1	22.8	14.8
25	NC-36	3.6	6.9	6.4	12.4	20.8	23.8	24.8	29.0	127.5	14.1	5.7
26	NC-37	43.6	47.0	55.6	63.8	68.0	77.1	76.5	63.8	495.4	61.9	29.2
27	NC-38	7.1	12.3	14.5	15.9	21.3	19.5	21.5	19.1	131.1	16.4	3.9
28	NC-39	16.9	22.1	25.3	30.8	37.0	35.9	40.5	42.3	250.7	8.0	6.0
29	NC-41	7.6	10.1	12.1	13.0	15.5	12.3	17.0	20.3	107.9	13.5	5.7
30	NC-42	7.4	12.0	15.8	17.3	17.1	17.8	20.1	22.6	130.0	16.3	10.2
31	NC-43	15.4	18.4	18.5	25.9	30.0	29.3	39.8	36.4	213.5	26.7	9.0
32	NC-45	9.3	14.1	21.5	29.4	37.0	38.0	31.5	41.0	221.8	27.7	8.0
33	NC-46	15.9	17.1	22.6	28.9	33.4	32.3	30.8	34.6	215.5	26.9	9.7
34	NC-48	20.9	25.6	33.1	36.0	36.3	37.9	41.8	47.6	231.5	34.9	19.2
35	NC-49	18.5	23.6	33.6	37.5	38.8	39.5	38.8	43.4	273.6	34.2	10.7
36	NC-50	38.8	45.0	49.3	46.4	47.5	52.1	55.3	53.3	387.6	48.4	18.0
37	NC-51	30.4	34.4	42.6	45.8	49.8	47.0	52.4	51.5	353.8	44.2	16.5
38	NC-52	27.4	32.3	38.3	45.8	43.4	46.3	47.0	45.0	325.3	40.7	21.7
39	NC-53	24.1	28.5	31.9	37.8	41.5	41.3	38.4	42.1	285.5	35.7	21.7
40	NC-55	24.4	27.3	33.3	38.3	37.4	41.5	45.5	46.8	294.3	36.8	21.3
41	NC-56	20.1	26.5	27.9	28.9	30.0	30.8	30.9	36.3	231.3	28.9	18.1
42	NC-57	23.6	27.5	33.9	38.1	42.8	42.6	44.5	45.6	298.7	37.3	24.1
43	NC-63	14.4	18.9	24.9	24.1	29.3	37.3	33.8	37.8	220.3	27.5	8.9
44	NC-64	10.8	16.0	19.1	22.9	22.3	22.9	22.6	25.1	161.7	20.2	6.3
	Mean	17.2	22.1	27.1	30.9	34.8	36.3	38.0	40.2			
	CV%	60.1	54.8	49.0	45.8	44.5	45.6	44.6	33.4			
	SED	5.2	6.1	6.6	7.1	7.7	8.3	8.5	6.7			
	CD (P=0.05)	10.1	11.9	13.1	13.9	15.2	16.3	16.7	13.2			

Table 3. Pod and bean characteristics of Nigerian cocoa collections

Clone	1 Pod weight (g)	Pod length (cm)	Pod breadth (cm)	Ridge (cm)	Furrow (cm)	Beans no.	Beans Wet wt./ pod (g)	Dry bean wt./ pod (g)	SBW (g)	DBY (kg)	Shelling %	Fat (%)
NC-2	300.0	18.0	8.8	0.97	0.60	39.0	86.26	35.4	0.93	1.03	20.13	49.17
NC-3	566.7	18.7	9.5	1.40	1.10	41.0	86.67	31.5	0.77	0.98	19.80	40.67
NC-5	523.3	22.7	12.0	1.13	0.87	45.0	131.7	40.6	0.90	0.74	17.80	41.67
NC-6	433.3	19.2	8.4	1.40	1.00	42.0	91.67	29.5	0.70	0.67	21.53	39.00
NC-7	320.0	17.0	8.3	1.23	0.93	40.0	103.3	38.5	0.97	0.96	18.50	51.67
NC-8	345.0	16.7	8.4	1.20	0.70	40.0	87.16	37.3	0.93	0.78	16.77	50.33
NC-9	509.9	23.9	11.0	1.47	1.10	38.7	87.0	39.5	1.02	0.96	16.73	38.80
NC-10	370.0	20.8	11.2	0.93	0.57	49.3	99.99	47.8	0.97	1.60	17.60	42.00
NC-12	315.8	13.2	8.0	0.93	0.77	34.3	109.4	30.1	0.88	0.24	17.30	44.13
NC-13	355.8	16.5	8.4	1.20	0.80	41.0	92.60	33.5	0.82	0.89	18.20	41.00
NC-14	536.7	20.8	9.6	1.27	0.93	45.3	118.3	37.7	0.83	0.33	19.20	43.00
NC-15	683.3	23.3	10.5	2.10	1.43	26.3	84.56	23.8	0.91	0.91	18.11	46.03
NC-20	483.4	20.3	9.3	1.40	0.70	43.0	110.3	44.4	1.00	1.93	11.24	54.45
NC-23	465.3	19.6	12.9	1.40	0.87	42.3	121.3	47.4	1.12	2.53	11.50	51.32
NC-24	566.7	17.4	8.4	1.40	1.13	47.0	145.0	56.5	1.20	1.67	16.28	40.43
NC-25	569.7	22.2	11.2	1.67	1.03	40.3	111.3	49.9	1.24	2.16	13.07	53.20
NC-26	390.2	20.2	10.5	1.33	0.67	43.0	108.5	50.2	1.17	2.48	12.62	51.11
NC-27	461.6	22.0	11.7	1.63	0.93	43.7	97.05	46.8	1.07	2.06	12.45	51.60
NC-29	376.7	19.0	9.9	1.33	1.03	32.3	93.34	30.9	0.96	0.95	20.70	48.67
NC-30	451.4	23.7	12.0	1.40	0.93	43.7	118.7	48.6	1.11	1.93	13.33	54.97
NC-31	412.7	21.4	10.8	1.10	0.77	40.7	93.90	41.2	1.01	1.24	16.93	52.67
NC-32	486.7	21.8	10.9	1.43	1.07	40.7	77.41	36.6	0.90	0.99	20.56	46.00
NC-34	530.0	23.7	12.2	1.33	0.70	43.3	110.0	39.7	0.92	1.25	18.42	38.29
NC-35	650.0	22.7	12.0	1.30	1.07	43.3	99.93	38.7	0.89	0.87	16.38	49.67
NC-36	405.0	19.0	9.5	1.40	0.97	40.0	106.8	36.7	0.92	0.66	16.67	52.53
NC-37	472.2	23.0	13.0	1.13	0.93	42.7	107.8	44.0	1.03	2.45	10.99	51.00
NC-38	240.7	16.5	8.5	1.07	0.57	36.7	75.56	28.4	0.77	0.47	18.11	37.67
NC-39	745.4	24.3	12.4	1.60	1.10	49.3	134.3	50.0	1.01	1.44	18.19	46.04
NC-41	420.6	14.4	8.2	1.40	1.20	41.7	94.58	29.8	0.72	0.49	14.33	38.67
NC-42	629.3	17.0	8.8	1.90	1.50	43.3	118.2	34.0	0.78	0.54	15.52	47.60
NC-43	337.3	15.9	8.0	1.10	0.83	46.3	94.23	37.7	0.81	0.92	13.71	45.60
NC-45	289.8	14.4	6.8	1.17	0.60	32.3	69.83	40.0	0.96	0.73	16.00	51.53
NC-46	361.7	14.0	6.7	1.17	0.80	42.0	115.3	35.8	0.85	0.96	14.88	47.00
NC-48	549.5	22.5	11.7	1.37	1.03	43.3	129.5	46.5	1.07	1.55	14.67	50.67
NC-49	313.5	17.2	8.6	1.30	0.87	31.3	84.2	26.7	0.85	0.93	17.66	48.33
NC-50	371.5	18.7	11.8	1.30	0.73	33.3	70.01	32.8	1.00	1.45	12.68	50.63
NC-51	373.3	17.3	9.5	1.13	0.77	43.3	85.89	43.7	1.00	1.83	13.91	50.11
NC-52	533.8	22.0	11.3	1.50	0.87	49.7	128.4	54.7	1.10	2.26	12.74	51.67
NC-53	608.3	20.7	10.8	1.87	1.33	41.0	132.2	52.4	1.29	1.93	14.56	53.30
NC-55	578.9	22.0	12.0	1.50	1.23	39.3	116.3	36.8	0.93	1.32	15.33	51.17
NC-56	625.4	22.8	11.8	1.83	1.07	43.7	124.5	48.4	1.11	1.42	10.65	52.50
NC-57	644.9	21.8	11.1	1.70	1.07	40.3	131.2	50.3	1.25	1.88	11.93	54.57
NC-63	321.6	14.1	7.6	1.17	0.83	41.3	101.1	48.4	1.17	1.10	10.10	55.27
NC-64	312.2	14.6	8.3	1.17	0.97	44.0	85.53	38.6	0.88	0.79	16.08	48.83
CV%	10.78	6.21	11.7	9.91	15.7	9.16	17.1	11.3	8.49	16.02	7.05	4.45
SED	40.48	0.99	0.96	0.11	0.12	3.08	14.5	3.7	0.07	0.16	0.91	1.74
CD (P=0.05)	80.45	1.96	1.90	0.22	0.24	6.12	28.2	7.4	0.13	0.33	1.80	3.45

Bhat *et al.* (2000) and Efron *et al.* (2003) corroborated these results.

Pod and bean characters

Among the 44 clones tested the weight of pods ranged from 240.7 g (NC-38) to 745.4 g (NC-39). Heavier pods measuring more than 500 g were harvested from 16 other clones. Significant variabilities were observed for all fruit characters (Table 3) which was in accordance with the results of other evaluation trials by Glendinning (1963) and Soria *et al.* (1974) who confirmed the difference in pod and bean characteristics between clones of different genetic origin. Longer pods (24.3 cm) were observed in the clone NC-39 and wider pods were observed in NC-37 (13.0 cm). Smaller pods with 13.2 cm length and 6.7 cm breadth were observed in the clones NC-12 and NC-46, respectively. The ridge and furrow thickness were measured in pods to study the thickness of husk. This character is considered as an important trait in screening clones for black pod and cocoa pod borer resistance. The ridge thickness varied from 0.93 (NC-10 and NC-12) to 2.10 cm (NC-15) and furrow thickness ranged from 0.57 (NC-10 and NC-38) to 1.50 cm (NC-42). In this experiment, pods of NC-10 had thin husk, whereas, NC-42 had thicker ones.

Number of beans inside pods showed large variability ranging from 26.3 beans (NC-15) to 49.7 beans (NC-52). In this trial pods with more than 40 beans were observed in 34 clones. The wet weight of beans per pod ranged from 69.83 g in NC-45 to 145 g in NC-24. The corresponding dry bean weight per pod was also recorded for all clones which ranged from 23.8 g in NC-15 to 56.5 gram in NC-24. The clone NC-6 had the lightest beans (0.70 g) and NC-53 had heaviest beans with 1.29 g. 17 clones recorded single bean weights of more than 1 gram. The proportion of wet to dry bean weight per pod and single dry bean weight contributed to the dry bean yield of the clones. Dry bean yield was the lowest in NC-12 (0.24 kg) whereas; it was the highest (2.53 kg) in NC-23. In total, 22 clones yielded more than 1 kg dry bean yields per tree per year. Enriquez and Soria (1968) studied the variability in bean size, shell percent and number of beans per pod in cocoa clones of different genetic origin and found significant differences. Those variabilities were observed in bean count, size and shell percent of our clones also. Shelling percentages were worked out which recorded a minimum of 10.10 per cent in NC-63 and a maximum of 21.53 per cent in NC-6. Fat contents were estimated in the dry beans of all the clones and 21 clones recorded more than 50 per cent fat. Beans of the clone NC-38 was estimated with a lowest fat content of 37.67 and highest fat percentage (55.27) was estimated in NC-63. As a single dry bean weight of 1 g and above, shelling percentage of 10-15 percent and fat content more than 50 per cent are considered as desirable characters for industries the clones NC-37, NC-23, NC-26, NC-50, NC-20, NC-51, NC-27 and NC-25 were considered as best clones.

Correlation studies

Correlation of pod yield with vegetative characters was worked out to study the cropping efficiency. Highly significant and positive correlations were obtained for the growth characters height, girth, height at first branching, east west and north south spread of canopy, pruning weights and canopy volume (Table 4.). Mallika *et al.* (1996) suggested that these traits can be possibly considered in the yield improvement of cocoa in selecting good clones.

Table 4. Correlation between pod yield and other attributes

S. No.	Characters	Correlation coefficient
1	Plant height	0.46(**)
2	Girth	0.18(**)
3	Height at first branching	0.40(**)
4	East West spread	0.50(**)
5	North South spread	0.47(**)
6	Canopy volume	0.40(**)
7	Prunes wt	0.45(**)

**significant at 1% level

Conclusion

Evaluation of 44 Nigerian clones for their growth and yield performance led to identification of vigorous, precocious and high yielders. The clones NC-37, NC-23, NC-26, NC-50, NC-20, NC-51, NC-27 and NC-25 were identified as early and heavy bearers with tree vigour, medium canopy, more number of pods, pod weight and dry bean yield per tree per year. They were regular bearers throughout their growth period. Based on their single dry bean weight, shelling percentage and fat content, they were also found as suitable for industry. They can be multiplied and suggested for cultivation in a wider scale to get maximum productivity and sustainability in cocoa cultivation.

References

Atkinson, C. J. 2003. Enhancing harvest index in temperate fruit tree crops through the use of dwarfing rootstocks. In: *Housing workshop on cocoa breeding for improved production systems,* INGENIC, Miklin Hotel, Accra, Ghana, 19-21 October 2003, p.5, no.13.

Balasimha, D. 1988. A whole plant structure: Function model for cocoa. *J. Plantn. Crops* **18** (supplement): 65-71.

Balasubramanian, P.P. 2002. Development and Marketing. pp. 161-168. In: *Cocoa* (Ed.) Balasimha, D. CPCRI, Kasaragod.

Bhat, K.S. and Bavappa, K.V.A. 1972. Cocoa under coconuts. pp. 116-121. In: *Proc. of Conf. Intcorp. Socie. Planters*, Kuala Lumpur, Malaysia, 1971.

Bhat, K.S., Bhagawan, S. and Nair, R.V. 1990. Identification of high yielding trees in cacao *(Theobroma cacao L.). Indian J. Agric. Sci.* **60**: 641- 642.

Bhat, V.R., Sujatha, K., Ananda, K.S., Nair, R.V. and Virakthmath, B.C. 2000. Evaluation of cocoa hybrids. pp. 105-109. In: *PLACROSYM XIII* December 16-18, Coimbatore.

Efron, Y., Epaina, P. and Marfu, J. 2003. Breeding strategies to improve cocoa production in Papua New Guinea. p.1, no. 2. In: *Internl. workshop on cocoa breeding for improved production systems*, INGENIC, Miklin Hotel, Accra, Ghana, 19-21 October 2003.

Enriquez, G.A. 1981. Early selection for vigour of hybrid seedlings. In: *Proc.8th Internl. Cocoa Res. Conf.* pp. 535-539.

Enriquez, G. and Soria, J.W. 1968. The variability of certain bean characteristics of cacao (*Theobroma cacao* L). *Euphytica* **17**: 114-120.

Glendinning, D.R. 1963. The inheritance of bean size, pod size and number of beans per pod in cocoa with a note on bean shape. *Euphytica* **12**: 311-322.

Lachenaud, P. 2003. Genetic effects of inter-tree competition in mixed cocoa stands on yield, vigour and cropping efficiency. 2003. p.5, no. 12. In: *International workshop on cocoa breeding for improved production systems*, INGENIC, Miklin Hotel, Accra, Ghana, 19-21 October 2003.

Longworth, J.F. and Freeman, G.H. 1963. The use of trunk girth as a calibrating variate for field experiments on cocoa trees. *J. Hort. Sci*. **38**: 61-67.

Mallika, V.K., Rekha, C., Rekha, K., Swapna, M. and Nair, R.V. 1996. Evaluation of pod and bean characters of cocoa hybrids in early years of bearing. *J. Plantn. Crops* **24**: 363-369.

Nair, M.K and Bhat, V.R. 1996. Status of cocoa research and future needs. *Indian Cocoa, Arecanut and Spices J.* **19**(4): 116-119.

Paulin, D., Mossu, G., Lachenaud, P. and Cilas, C. 1993. Cocoa breeding in Coted' Ivoire performance analysis of sixty-two hybrids in four localities. *Café Cacao The*. **37**: 3020.

Shama Bhat, K, S. Bhagavan and R.V. Nair. 1990. Identification of high yielding trees in cocoa (*Theobroma cacao* L). *Indian J. of Agric. Sci.* **60**(9): 641-2.

Soria, V.J, Ocampo, F. and Paez, G. 1974. Parental influence of several cocoa clones on the yield performance of their progenies. *Turrialba* **24**: 58-65.

Sounigo, O., Goran, J.N., Paulin, D., Clement, D. and Eskes, A.B. 2003. Individual tree variation and selection: experience from Cote d'Ivore. p. 2, no. 6. In: *International workshop on cocoa breeding for improved production systems*, INGENIC, Miklin Hotel, Accra, Ghana, 19-21 October 2003.

Thomas, G. and Balasimha, D. 1992. Canopy architecture, photosynthesis and yield of cocoa trees. *Café Cacao The* **36**: 103-108.