CLONAL EVALUATION OF COCOA HYBRIDS AND THEIR PARENTS

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Cocoa (Theobroma cacao L) became an integral part of palm based cropping systems in southern parts of India. Around 1895 and 388 thousand hectares area are available under coconut and arecanut respectively, which is to be explored for cultivation of cocoa as inter/ mixed crop. National Horticulture Mission identified cocoa as a potential plantation crop because of its profitable demand both in domestic and international chocolate markets, which necessitated identification of productive clones and hybrids for area expansion. On the research front, clonal selection programmes were initiated worldwide in the start of this century but later in most countries individual trees were selected from local landraces and used in hybridization programmes, without assessing them in clonal trials, which lead to confusing results. Current breeding strategy confirmed that production of cultivars as clones is relatively a feasible, suitable planting material to combine desirable traits, to sustain the genetic gain obtained from the breeding efforts and for early evaluation (Eskes and Lanaud, 2001; Adomako and Adu Ampomah, 2003; Lockwood, 2003) and so even in hybrid selection programs, clonal evaluation is recommended. With this background, this comparative study on clonal plants of both hybrids and their parents was conducted.

Materials and Methods

A total of 26 clones including 12 hybrids, 13 parental clones and 1 control variety were selected, multiplied as soft wood grafts and planted during 2000 at a distance of 2.7 m x 5.4 m in 2.7 m x 2.7 m spaced arecanut garden. All these clones were evaluated for their height, girth, first branching height, number of branches and canopy area. Considering the canopy as cone shaped, the canopy area was measured using the formula πrl, whereas $r = EW+NS/ 4$ and $l = Vr^2 + h^2$, h = canopy height and expressed in m^2. Number of pods yielded by individual trees of each clone during each harvest was compiled for seven years from 7 to 13 years after stabilisation of yield. Individual pod weight (g), number of bold beans/pod, fermented dry bean weight, shell and fat contents were measured. Fat was estimated by Soxlet apparatus with solvent extraction method. Data were compiled as completely randomized design with 6 trees per plot and analysed with SAS software package.

Results and Discussion

Growth characters

Morphological observations taken in twelve years old trees of 26 clones of hybrids and parents are given in Table 1. Among the parental clones, L 357 grown to a height of 4.17 rri and the lowest height (2.96 m) was observed in trees of the clone SCA 6. Both the tall and short trees were observed with parental clones. Girth of the stem differed significantly among the tested clones. All the hybrids recorded >40 cm stem girth whereas, 9 parental clones exhibited sturdy stems. In general, both hybrid and parental clones exhibited considerable vigour with strong stems. Efron et al., 2003 and Lachenaud, 2003 opined that the relationship between yield, vigour and yield efficiency are important in clonal evaluation trials planted at one density. In our experiment too high yielders were observed with high vigour and these hybrids recorded more vigour in their early years of growth as clones as well (Elain Apshara *et* al., 2008). Non significant results were observed with first branching heights, it might have because of the uniform and systematic pruning

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and training operations taken up with the grafted clones annually. But the canopy area and number of branches significantly differed among clones. The canopy area ranged from 10.2 m^2 to 22.9 m^2 in SCA 6 and IMC 67. It was said that optimal canopy area (15-20 m^2) should be maintained for optimal productivity especially in the grafted plants and under intercropping systems (Balasimha, 1988) and so the recommended levels of pruning were practiced.

Table 1. Growth characters of cocoa clones of hybrids and parents

S.No.	Clones	Height (m)	Girth (cm)	HAFB (m)	Branches no.	Canopy area (m^2)
1	NA 33 x ICS 89	3.83	42.0	1.08	10.2	16.3
2	SCA 6 x IMC 67	3.75	40.5	1.00	8.20	17.5
3	NA31xICS89	3.56	40.0	1.23	9.50	17.0
4	SCA 6 x ICS 6	3.61	40.2	1.16	10.2	16.0
5	JRAxNC42	4.08	43.7	1.29	10.3	16.4
6	JRA x L357	4.12	44.5	1.00	8.83	15.5
7	IMC 67 x ICS 6	3.48	40.8	1.03	7.17	13.3
8	ICS 6 x SCA 6	3.93	40.5	1.05	9.50	16.8
9	NA 31 x ICS 1	3.88	42.0	1.03	9.50	17.5
10	ICS 1x SCA 12	4.04	42.2	1.20	8.67	16.6
11	L364xNC29	3.77	41.7	0.95	8.33	18.2
12	L 364 x NC 42	3.64	40.8	0.96	9.17	17.0
13	NA31	3.41	38.8	0.92	7.00	14.9
14	NA33	3.25	38.3	1.02	7.67	14.1
15	ICS1	3.93	40.8	1.16	11.3	22.9
16	ICS 6	3.08	37.2	0.87	8.67	13.5
17	ICS 89	3.86	40.2	1.38	9.67	16.3
18	IMC 67	4.06	46.3	1.15	10.3	16.5
19	SCA 6	2.96	34.3	1.02	6.33	10.2
20	SCA 12	3.88	41.7	1.28	10.8	16.6
21	JRA	3.62	44.8	1.05	10.8	16.2
22	L357	4.17	45.3	1.15	13.2	21.0
23	L364	3.97	47.5	0.86	13.0	18.1
24	NC29	3.82	45.0	0.86	8.50	20.1
25	NC42	4.08	44.3	1.17	12.5	22.0
26	NC 45/53	3.49	38.3	0.95	9.50	16.4
	SEd	0.29	4.14	0.30	1.93	3.00
	CD5%	NS	8.12**	NS	3.78**	5.88**

HAFB- Height at first branching

Pod yield

Number of pods produced in a tree during each harvests were accounted and the annual mean pod yields were compiled for seven years of growth and given in Table 2. From the mean data it was confirmed that 6 progenies and only 1 parental clone yielded on an average more than 50 pods/ tree/ year. High yielding and precocious nature of these hybrids was observed by Bhat *et al.*, (1998) in the earlier progeny trials as well as in the clonal evaluation trial in the initial years of growth (Elain Apshara *et al.*, 2008). From the mean pod yields it was observed that the clonal progenies of SCA 6 x ICS 6, NA 33 x ICS 89 and NA 31 x ICS 1 yielded high with 68.1, 66.9 and 62.3 pods/ tree/ year respectively. Though the parents involved in these hybrids exhibited low pod yield, the hybrid combination expressed high yielding behaviour. The cumulative factors, number of pods, total pod weight and average single pod weight contribute to the harvest efficiency of a hybrid (Lachenaud, 2003). In our trial, individual pod weights were taken and it was observed that the pods of parental clones weighed both the lowest of 274 g (SCA 12) and the highest of 646 g (L 364) and all the hybrids had >350 g fresh pod weight.

Table 2. Pod yield performance of cocoa clones of hybrids and parents

S.No.	Clones	Years							Mean
		7	8	9	10	11	12	13	
1	NA 33 x ICS 89	37.0	45.5	66.0	63.0	88.0	81.6	87.4	66.9
2	SCA 6 x IMC 67	31.2	47.0	60.1	44.9	48.4	65.3	46.5	49.1
3	NA 31 x ICS 89	47.6	65.3	42.8	41.2	41.3	75.2	51.5	52.1
4	SCA 6 x ICS 6	40.5	52.5	64.4	77.1	74.7	84.3	83.5	68.1
5	JRA x NC 42	28.0	34.2	51.7	41.8	43.4	77.1	58.8	47.9
6	JRA x L 357	39.6	52.7	35.8	37.6	43.0	86.2	54.9	50.0
7	IMC 67 x ICS 6	31.1	73.1	34.5	33.8	35.3	77.6	55.5	48.7
8	ICS 6 x SCA 6	34.4	43.5	53.6	31.8	49.5	75.6	81.2	52.8
9	NA31 xlCS1	50.2	56.1	55.0	57.8	63.6	70.6	82.7	62.3
10	ICS 1x SCA 12	24.2	38.4	53.6	38.1	42.6	57.7	31.2	40.9
11	L 364 x NC 29	31.1	32.7	33.6	37.7	35.1	49.1	65.3	40.7
12	L 364 x NC 42	26.8	26.7	23.9	30.2	36.7	46.8	55.8	35.3
13	NA31	26.0	28.2	24.8	26.1	38.1	36.0	32.5	30.2
14	NA33	14.3	26.0	28.9	30.7	40.7	39.4	33.7	30.5
15	ICS1	16.0	24.8	18.3	26.0	43.8	46.7	54.7	32.9
16	ICS 6	25.7	30.6	35.0	32.2	36.4	43.2	40.7	34.8
17	ICS 89	18.8	26.2	26.9	30.5	49.8	46.7	67.1	38.0
18	IMC 67	31.4	33.5	35.4	45.8	59.1	63.4	66.8	47.9
19	SCA 6	26.1	26.7	33.4	31.7	34.3	41.5	42.8	33.8
20	SCA 12	18.1	28.3	29.9	40.3	56.3	52.1	58.1	40.4
21	JRA	34.7	40.9	51.6	51.9	69.2	54.8	52.1	50.7
22	L357	30.7	41.4	45.6	40.8	43.9	41.2	46.8	41.5
23	L364	33.6	41.6	47.6	55.5	55.4	48.1	46.8	46.9
24	NC29	27.6	32.6	36.7	37.0	39.4	40.9	37.5	36.0
25	NC42	25.9	27.3	27.2	37.8	30.2	32.7	33.3	30.6
26	NC 45/53	38.8	40.2	41.5	40.0	30.5	48.5	68.5	44.0
	SEd	4.82	6.88	6.50	4.31	8.32	11.9	10.5	
	CD5%	9.54**	13.6**	12.9**	8.52**	16.5**	23.6**	20.7**	

Bean characters

Number of bold beans represents the apparent fertility of the hybrid (Lachenaud *et al.*, 2005) and it was counted which showed significant difference between clones and varied from a minimum of 36.8 to 48.6 beans/ pod. Pods of all clones had >35 beans. Beans of 1.0 gram and above is preferred by the processing units and in this study the single dry bean weights ranged from 0.72 to 1.22. Among the progenies, 9 hybrids exhibited >1 g single dry bean weight and among the parents only 2 clones recorded >1 g single dry bean weight. The dry bean yield per clone was computed from the mean pod yield, number of beans and single dry bean weight. It ranged from 0.91 to 3.22 kg/ tree. Compared to the parental clones, the hybrid clones yielded high. Majority of the clones showed high yield efficiencies of more than 2 kg dry beans/ tree. Shelling and nib recovery percentages, which are important in the confectioner's point of view were calculated which varied from 11.1 to 25 and 78.8 to 88.7% respectively. Fat estimated from dry beans varied from 40.5 to 55%. Beans of more than 1 gram showed more than 50% fat contents. Based on vigour, optimal canopy, mean pod yield over 7 years, single dry bean weight, number of beans, dry bean yield, shelling and fat contents the best performers were selected.

Table 3. Pod and Bean characters of cocoa clones of hybrids and parents

Sl. No.	Clones	Pod wt. (g)	No.of beans	SBW (g)	DBY (kg)	Shell (kg)	Nib recovery %	Fat %
1	NA 33 x ICS 89	490	43.4	1.11	3.22	11.1	88.0	52.0
2	SCA6xlMC67	476	40.8	1.00	2.00	12.5	88.5	51.0
3	NA 31 x ICS 89	494	41.8	0.96	2.09	16.0	87.0	50.0
4	SCA6xlCS6	506	40.8	1.13	3.14	15.0	88.0	55.0
5	JRAxNC42	502	44.4	0.96	2.04	15.8	87.1	51.5
6	JRAxL357	432	43.6	1.08	2.35	14.5	88.2	53.4
7	IMC 67 x ICS 6	398	42.0	0.99	2.02	16.2	87.8	50.0
8	ICS 6 x SCA 6	374	48.0	1.00	2.53	16.6	85.8	51.0
9	NA 31 x ICS 1	420	41.2	1.05	2.70	15.2	87.5	46.0
10	ICS 1x SCA 12	598	43.4	0.95	1.69	16.0	85.6	49.8
11	L 364 x NC 29	447	40.1	1.05	1.71	15.2	87.3	50.5
12	L 364 x NC 42	441	40.4	1.07	1.53	14.3	87.7	51.2
13	NA31	406	42.6	0.76	0.98	21.2	83.1	40.6
14	NA33	346	39.2	0.76	0.91	23.0	81.0	40.5
15	ICS1	566	38.6	0.87	1.10	25.0	83.0	46.0
16	ICS 6	374	42.0	0.81	1.18	19.4	85.8	42.5
17	ICS 89	468	37.0	0.90	1.27	16.5	85.7	48.8
18	IMC 67	414	43.6	1.01	2.11	14.8	89.0	50.2
19	SCA 6	335	38.5	0.87	1.13	16.0	87.5	46.6
20	SCA 12	274	36.8	0.72	1.07	18.9	84.5	42.3
21	JRA	458	42.0	1.22	2.60	14.6	87.9	56.2
22	L357	518	42.0	0.87	1.52	19.0	83.8	43.3
23	L364	646	41.2	0.85	1.64	22.0	80.8	47.5
24	NC29	370	41.2	0.96	1.42	17.0	85.8	50.2
25	NC42	448	42.0	0.85	1.09	17.5	82.7	48.6
26	NC 45/53	336	39.2	0.98	1.69	20.0	85.8	44.0

Conclusion

Comparative study of 26 clones including hybrids and parents for growth and yield parameters led to identification of high yielders with quality beans. Clonal progenies of hybrids, SCA 6 x ICS 6, NA 33 x ICS 89 and NA 31 x ICS 1 and parents JRA and IMC 67 were identified as stable and heavy bearers with optimal canopy in the intercropping system, with favourable dry bean yields and quality beans. The clones of the above said hybrids established their potential both as seedling progenies and clonal progenies and these will be further tested under Coconut canopy and in different locations for their potenial.

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