Research Article

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Comparative studies on elite cocoa progenies in their initial years of growth

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Abstract

Hybridization work in cocoa conducted at Central Plantation Crops Research Institute during 1983-1997 has yielded many progenies of selected crosses. The field evaluation of those selected progenies carried out in discrete experiments under different environments and progeny trials resulted in certain best performing lines. They were evaluated for their performance in arecanut garden under uniform conditions in their initial years of growth. Assessment of growth and vigour of the hybrids with morphological observations, pod yield and bean characteristics was done to confirm the production potential of 21 selected elite progenies. The hybrids PII- 5, PII- 3, PIII-I-23 and PI-IV-478 were vigorous with sturdy stem and well spread canopies. Early bearing from second year of growth was observed in the hybrids PIII-II-89, PI-IV-478, PI-I-18 and PI-I-38. The hybrids PI-IV-478, PI-I-38, PIII-I-23, PIII-II-54 and PI-I-18 showed high pod yield potential with an annual yield of more than 50 pods per tree per year at the age of six years. Individual pod characteristics like size, husk to bean ratio, total pod weight recorded significant difference among hybrids. Bean parameters especially wet to dry bean ratio, shelling and recovery percentage and single dry bean weight were also studied to assess the suitability of the hybrids for the industries.

Keywords: clones, cocoa, hybrids, progenies

Introduction

Cocoa is gaining importance due to the projected demand of 30,000 MT of dry beans in the Indian chocolate industry during 2015 as against the production of 10,175 MT during 2005. This has necessitated identification of superior genotypes with high yielding potential to achieve higher productivity and sustainability in cocoa cultivation (Bhat *et al*., 1990). Selection of superior parents, their subsequent development into clones and exploitation of hybrid vigour through hybridization are considered as the easy approaches in perennial crops, especially in cocoa improvement (Nair *el al*., 1996; Vikraman Nair *et al*, 2002; Christian Cilas, 2003). Large number of crosses have been made throughout the cocoa producing countries and interpopulation heterosis, exceptional vigour, precocity and high yields have been demonstrated (Posnette, 1951; Bell and Rogers, 1956). The Central Plantation Crops Research Institute (CPCRI) has selected seven superior cross compatible parents, crossed them under different combinations and evaluated the progenies under progeny trials during 1983-1987. On the basis of individual tree selections, 21 elite progenies were selected from three progeny trials after 10-15 years of field evaluation. Though some elite progenies were identified, these earlier trials were conducted under several discrete experiments in different environments. Further, since a high proportion of individual trees have contributed to the high yield in any selected variety, to sustain the genetic gain obtained in breeding efforts, they should be vegetatively multiplied (Adomako and Adu-Ampomah, 2003). Thus, this comparative study on clones of elite progenies were taken up to assess and confirm their production potential under uniform local conditions.

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Materials and Methods

A total of 21 superior progenies of different cross combinations were selected from three progeny trials and planted in a comparative yield trial during 1999-2000 at a spacing 2.7 m x 2.7 m in an arecanut garden of same spacing. All these hybrids were evaluated for their height, girth, east west and north south spread of canopy, first branching height, number of branches, pruning weights, canopy volume and cropping efficiency. The canopy volume was calculated considering the canopy surface as cone shaped and using the formula πrl, whereas $r = EW + NS/4$ and $l = \sqrt{r^2 + h^2}$, h = canopy height. The yield to vigour ratio or the cropping efficiency was measured by dividing total pod weight per tree with trunk diameter or the girth (Lachenaud, 2003). The pod yield of individual trees in each hybrid during each harvest was compiled and given as pooled pod number for six years and average pod yield per tree per year. Pod characteristics such as individual pod weight (g), length (cm), breadth (cm), husk to bean ratio as well as ridge and furrow thickness (cm) were measured from five pods of each tree. Total pod weight per tree per year was compiled from number of pods and individual pod weight. Dry bean yield (DBY) per plant basis was derived from the mean of five years annual data. The number of pods required for recovery of one kilogram dry beans is the pod value which was used for compiling dry bean yield. Bean characteristics such as number of bold beans, percentage of flat beans and 50 beans wet weight were assessed. Beans were extracted, kept for fermentation, dried and observed for bean characteristics and other qualitative parameters like shelling (shell wt./ bean wt. x 100) and recovery (bean wt. without shell/ bean wt. x 100) percentages preferred by chocolate industry. Data were compiled under completely randomized design or individual single tree plot design with six trees per hybrid and analysed in WINSTAT software package.

Results and Discussion

Growth characteristics

Morphological observations taken are given in Table 1. The trees of the hybrid PII-7 grew to a height of 4.12 m followed by PII-6 (3.98 m) and the lowest height (2.55 m) was observed in trees of the hybrid PI-IV-478. The trunk circumference or girth of the stem differed significantly among the hybrids. The sturdiest stems were observed in the hybrids PII-5, PII-3, PIII-I-23 and PI-IV-478 with 43, 42.67, 39, 38.33 cm, respectively. Taller

Table 1. Growth habit of progenies at the age of six years

No.	Hybrid	Cross	Height (m)	Girth (cm)	EW (m)	NS (m)	HAFB (m)	Branches	Canopy volume (m^3)	Pruning wt. (kg)	Cropping efficiency
1	PI-I-18	NA-33 x ICS-89	3.68	35.43	4.38	3.90	0.64	4.33	23.95	12.53	0.56
2	PI-IV-440	NA-33 x ICS-89	3.30	26.43	3.97	4.20	0.50	3.33	22.47	14.47	0.39
3	PI-I-106	SCA-6 x IMC-67	3.83	34.67	4.17	3.67	0.78	3.00	23.08	13.73	0.31
4	PI-III-400	SCA-6 x IMC-67	3.35	25.23	3.60	3.33	0.43	2.00	22.83	9.67	0.34
5	PI-IV-478	NA-31 x ICS-89	2.55	38.33	2.60	3.07	0.42	3.00	12.29	15.73	0.66
6	PI-I-38	SCA-6 x ICS-6	3.35	32.33	4.22	3.47	0.33	4.00	21.66	12.33	0.88
7	PII-1	I-56 x II-67	2.97	31.00	3.57	3.37	0.76	3.00	15.57	7.37	0.11
8	PII-2	I-14 x I-56	2.76	30.33	3.07	3.48	0.40	3.33	14.81	11.20	0.06
9	PII-3	I-56 x III-35	2.98	42.67	3.43	3.13	0.35	3.00	16.09	11.67	0.25
10	PII-4	III-35 x IV-20	3.93	34.33	3.37	3.50	0.91	2.33	18.81	21.67	0.17
11	PII-5	I-14 x NC-42/94	3.03	43.00	3.45	3.57	0.83	2.33	16.32	16.00	0.24
12	PII-6	III-105 x NC-42/94	3.98	36.00	4.13	4.30	1.12	3.33	23.63	15.40	0.22
13	PII-7	I-56 x IV-20	4.12	29.93	4.27	3.77	0.31	2.67	27.70	19.47	0.18
14	PII-8	I-14 x IV-20	3.15	32.60	3.27	3.73	0.39	3.00	17.95	14.80	0.29
15	PIII-I-23	IMC-67 x ICS-6	3.38	39.00	3.45	3.62	0.36	3.67	19.55	10.60	0.42
16	PIII-III-20	IMC-67 x ICS-6	3.25	37.83	3.22	3.87	0.26	3.33	19.74	15.20	0.27
17	PIII-I-8	ICS-6 x SCA-6	3.97	35.00	4.15	4.20	0.26	3.33	27.94	11.53	0.35
18	PIII-III-13	Amel. x PA-7	3.75	35.00	3.68	3.72	0.49	3.00	21.97	14.00	0.32
19	PIII-II-89	PA-7 x NA-32	3.22	27.33	3.27	3.35	0.64	3.00	16.33	12.27	0.44
20	PIII-II-54	NA-31 x ICS-1	3.72	30.60	3.67	4.18	0.91	2.67	21.35	12.40	0.48
21	PIII-I-14	ICS-1 x SCA-12	3.88	36.33	3.57	4.18	0.80	3.33	22.41	15.73	0.43
		CV%	17.11	15.85	14.54	14.39	63.71	28.20	26.22	38.57	30.02
		SEd	0.48	4.40	0.43	0.43	0.29	0.71	4.35	4.32	0.09
		CD (P=0.05)	NS*	8.87	NS*	0.88	NS*	NS*	8.77	8.71	0.17

EW-East West, NS-North South, HAFB-Height at first branching, NS*- Non significant trees showed lesser stem girth and short trees had strong stems. For example the hybrid PI-IV-478 which recorded the lowest height of 2.55 m had a girth of 38.33 cm. Similar observations were reported from the Cocoa and Coconut Research Institute of Papua New Guinea (Efron *et al*., 2003). Their study showed that planting of small clones at higher density was economically beneficial than the big and medium clones.

The north south spread of the canopies showed significant difference, which ranged from 3.07 to 4.30 m while the east west spread was non significant. The first branching height and number of branches did not differ considerably between hybrids as the pruning and training measures taken up during early stages of growth might have contributed to the uniform architectures. The canopy volume showed a variation ranging from 12.29 m^3 in PI-I-478 to 27.94 m^3 spread in PIII-I-8. Weight of pruned branches ranged from a lowest of 7.37 kg in the hybrid PII-1 to the highest of 21.67 kg in PII-4. It has been reported that optimal canopy volume should be maintained for optimal productivity especially in the grafted plants (Balasimha, 1988). While maintaining these hybrids in the density of 2.7 m x 2.7 m the recommended levels of regular pruning (15-20 m^3 canopy) practices of CPCRI were followed. Trees of reduced size are much easier and less expensive to manage compared to larger trees (Atkinson, 2003) and so hybrids producing more pods with lesser and medium canopies were looked into in this experiment. The hybrids PI-IV-478, PI-I-38, PIII-I-23 and PIII-II-54 fell into this category with comparatively compact canopy.

Pod yield performance

Number of pods produced in a tree during each harvest was accounted and the pooled yield for six years as well as the annual mean pod yield over five years of growth are given in Tables 2 and 3. From the pooled data it was clear that the hybrids PI-IV-478, PI-I-38, PIII-I-23, PIII-II-54 and PI-I-18 were the potential high yielders and from the mean data it was confirmed that these hybrids yielded on an average more than 50 pods per tree per year. High yielding nature of these hybrids were observed by Bhat *et al.* (2000) in the earlier progeny trials also. The same hybrids were identified as precocious bearers as they recorded high pod yields in the second year of planting itself, which was confirmed from the yield data of the year 2002 (Table 2). Between the hybrids, number of pods per tree per year ranged from 1.33 (PII-2) to 90.33 (PI-IV-478) in the initial years of growth. Between the years, pod yield varied in all the hybrids as alternate bearing habit and unstabilised pod yield contributed to the same. 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.

Table 2. Pod yield of the progenies during initial years of growth

No.	Hybrid	Cross	No. of pods/ tree/ year				
			2002	2003	2004	2005	2006
1	PI-I-18	NA-33 x ICS-89	43.00	61.00	88.00	17.00	45.33
2	PI-IV-440	NA-33 x ICS-89	9.33	25.33	46.00	28.33	47.33
3	PI-I-106	SCA-6 x IMC-67	5.33	28.00	50.33	22.67	47.33
4	PI-III-400	SCA-6 x IMC-67	5.33	27.00	59.33	27.33	30.67
5	PI-IV-478	NA-31 x ICS-89	51.67	89.00	90.33	47.33	65.33
6	PI-I-38	SCA-6 x ICS-6	41.33	69.00	85.33	40.67	72.33
7	PII-1	I-56 x II-67	3.67	14.67	36.33	29.00	21.67
8	PII-2	I-14 x I-56	1.33	1.33	20.33	5.67	18.00
9	PII-3	I-56 x III-35	7.67	32.67	51.00	20.00	34.00
10	PII-4	III-35 x IV-20	2.67	23.00	35.33	19.00	27.00
11	PII-5	I-14 x NC-42/94	1.67	15.33	32.00	8.00	34.00
12	PII-6	III-105 x NC-42/94	6.33	16.67	44.33	30.33	26.33
13	PII-7	I-56 x IV-20	2.00	17.00	42.67	18.00	35.33
14	PII-8	I-14 x IV-20	2.33	26.00	42.67	39.67	52.67
15	PIII-I-23	IMC-67 x ICS-6	20.33	62.00	75.33	31.00	73.00
16	PIII-III-20	IMC-67 x ICS-6	30.67	42.67	42.00	26.33	46.00
17	PIII-I-8	ICS-6 x SCA-6	11.00	41.67	46.67	34.33	43.67
18	PIII-III-13	Amel. x PA-7	20.67	49.66	56.33	27.00	67.00
19	PIII-II-89	PA-7 x NA-32	53.67	74.66	35.67	37.00	53.67
20	PIII-II-54	NA-31 x ICS-1	15.66	43.67	70.33	50.00	76.00
21	PIII-I-14	ICS-1 x SCA-12	21.00	42.67	56.33	24.00	38.00
		CV%	14.57	19.80	20.03	19.41	11.72
		SEd	2.02	6.18	8.62	4.40	4.35
		CD (P=0.05)	4.08	12.48	17.39	8.88	8.77

Total pod weight per tree per year is given in Table 3 and it differed significantly among the hybrids and it ranged from a minimum of 1.74 kg in PII-2 to a maximum of 33.13 kg in PI-I-38. The number of pods and individual pod weights mainly contributed to the total pod weight. The harvest efficiency of a hybrid was the cumulative of number of pods, potential total pod weight and average of single pod weight (Lachenaud, 2003). In this study the higher number of pods per tree per year increased the pod weights per tree per year. The pods of hybrid PII-1 weighed less (155.87 g) and pods of the hybrid PI-I-38 weighed more (537.7 g). Heavier pods measuring more than 400 g were harvested from the hybrids viz., PII-5, PIII-I-14, PI-I-38 and PI-II-400 (Table 4).

Generally single pod weights are determined by the size of the pods, which are measured on the basis of pod length and breadth. High heritable values were recorded for fruit length (55 %), fruit diameter (63 %) and total weight of fruits (57 %) by earlier workers like Glendinning (1963) and Soria *et al.* (1974) in hybrid

Table 3. Pod yield performance of progenies

No.	Hybrid	Cross	Pooled pod no.	Mean pod no.	Pod wt./ tree (kg)	Pod value	DBY (kg/ tree)
1	PI-I-18	NA-33 x ICS-89	763	50.87	19.90	12.84	1.73
2	PI-IV-440	NA-33 x ICS-89	520	34.67	10.20	15.89	1.08
3	PI-I-106	SCA-6 x IMC-67	461	30.73	10.38	15.11	1.06
4	PI-III-400	SCA-6 x IMC-67	449	29.93	11.05	13.92	0.86
5	PI-IV-478	NA-31 x ICS-89	1031	68.73	16.35	21.59	1.57
6	PI-I-38	SCA-6 x ICS-6	926	61.73	33.13	21.24	2.64
7	PII-1	I-56 x II-67	316	21.07	3.31	32.55	0.67
8	PII-2	I-14 x I-56	140	9.33	1.74	26.92	0.22
9	PII-3	I-56 x III-35	436	29.07	7.51	19.49	0.92
10	PII-4	III-35 x IV-20	321	21.40	7.53	14.91	0.83
11	PII-5	I-14 x NC42/94	273	18.20	8.22	11.15	0.57
12	PII-6	III-105 x NC42/94	372	24.80	9.24	13.88	0.84
13	PII-7	I-56 x IV-20	345	23.00	7.49	16.37	0.64
14	PII-8	I-14 x IV-20	490	32.67	8.73	19.39	0.89
15	PIII-I-23	IMC-67 x ICS-6	785	52.33	13.73	20.32	1.75
16	PIII-III-20	IMC-67 x ICS-6	563	37.53	10.71	18.08	1.39
17	PIII-I-8	ICS-6 x SCA-6	532	35.47	12.42	15.05	1.33
18	PIII-III-13	Amel. x PA-7	662	44.13	11.26	20.01	1.12
19	PIII-II-89	PA-7 x NA-32	712	47.47	11.88	20.25	1.50
20	PIII-II-54	NA-31 x ICS-1	767	51.13	14.51	17.65	1.76
21	PIII-I-14	ICS-1 x SCA-12	546	36.40	15.59	11.74	1.06

evaluation trials. So these traits were recorded for our elite progenies which, showed significant variabilities (Table 4). Longer pods (19.95 and 19.71 cm) were observed in the hybrids PI-II-400 and PI-I-38 and wide, bold pods were observed in PII-5 (8.29) and PI-I-38 (8.13). The pods of the hybrid PI-I-38 are the biggest as they recorded more pod weight, length and breadth. The lesser weighing pods of PII-1 have showed lesser pod length and breadth. The ridge and furrow thickness was also measured, which is an important trait in screening of clones for cocoa pod borer resistance in recent years. The ridge thickness varied from 0.71 (PII-1) to 1.39 cm (PIII-I-14) and furrow thickness ranged from 0.43 (PII-1) to 0.93 cm (PII-6). It indicates the thin skinned or lighter husked fruits, compactness or the filling of beans inside the pods. In this experiment, pods of PII-1 had thin pericarps. Husk and bean weights were also measured separately to work out the percentage of filling which showed remarkable differences. The husk to bean ratio was very less in PII-1 (1.71) and PIII-II-89 (1.90) whereas, it was on the higher side in PI-II-400 and PII-6. It was observed that heavier pods had more of husk portion than the bean, which is an undesirable feature. Among the hybrids evaluated, 61 per cent of them showed satisfactory pod filling.

Table 4. Pod characteristics of progenies

No.	Hybrid	Cross	Pod weight (g)	Pod length (cm)	Pod breadth (cm)	Ridge (cm)	Furrow (cm)	Husk weight (g)	Bean weight (g)	Husk: Bean
1	PI-I-18	NA-33 x ICS-89	390.67	15.59	7.72	1.14	0.70	279.40	112.10	2.49
2	PI-IV-440	NA-33 x ICS-89	323.07	14.97	7.16	1.07	0.66	226.67	96.20	2.36
3	PI-I-106	SCA-6 x IMC-67	353.93	15.67	7.57	1.05	0.81	245.80	88.20	2.79
4	PI-III-400	SCA-6 x IMC-67	410.83	19.95	7.70	1.21	0.84	379.90	81.88	4.64
5	PI-IV-478	NA-31 x ICS-89	238.47	16.35	5.65	0.99	0.69	173.47	59.33	2.92
6	PI-I-38	SCA-6 x ICS-6	537.70	19.71	8.13	1.36	0.87	408.80	123.51	3.32
7	PII-1	I-56 x II-67	155.87	12.87	5.87	0.71	0.43	98.43	57.43	1.71
8	PII-2	I-14 x I-56	270.77	14.35	6.41	0.95	0.65	187.27	83.10	2.25
9	PII-3	I-56 x III-35	257.42	14.43	6.71	0.93	0.55	180.08	70.83	2.54
10	PII-4	III-35 x IV-20	352.57	14.45	7.78	0.90	0.63	246.53	111.78	2.20
11	PII-5	I-14 x NC42/94	503.87	16.67	8.29	1.38	0.71	355.30	148.17	2.40
12	PII-6	III-105 x NC42/94	366.13	15.34	7.67	1.31	0.93	286.07	73.73	3.88
13	PII-7	I-56 x IV-20	312.73	15.12	7.22	1.17	0.77	240.20	71.08	3.38
14	PII-8	I-14 x IV-20	272.03	13.79	6.97	1.01	0.81	198.82	69.82	2.85
15	PIII-I-23	IMC-67 x ICS-6	261.89	14.51	6.90	1.01	0.62	193.71	66.20	2.93
16	PIII-III-20	IMC-67 x ICS-6	282.87	14.82	7.02	0.95	0.66	196.59	69.80	2.82
17	PIII-I-8	ICS-6 x SCA-6	346.87	15.57	7.41	1.01	0.59	235.40	113.80	2.07
18	PIII-III-13	Amel. x PA-7	266.67	13.99	7.05	0.99	0.59	188.33	65.87	2.86
19	PIII-II-89	PA-7 x NA-32	276.67	14.87	6.59	0.94	0.62	167.10	87.88	1.90
20	PIII-II-54	NA-31 x ICS-1	301.33	14.28	6.99	1.13	0.79	213.48	70.78	3.02
21	PIII-I-14	ICS-1 x SCA-12	429.33	13.59	7.99	1.39	0.86	329.93	95.43	3.46
		CV%	20.35	9.94	6.85	16.98	19.24	19.28	24.84	
		SEd	54.68	1.24	0.40	0.15	0.11	37.72	17.54	
		CD(P=0.05)	110.36	2.50	0.81	0.30	0.22	76.13	35.39	

In cocoa, relationship between vegetative characters and yield is positive (Enriquez, 1981; Paulin *et al.,* 1993). Longworth and Freeman (1963) suggested to consider yield along with trunk diameter for better efficiency in selection. Bhat *et al.* (2000) observed strong and positive correlation between bean yield and stem girth in earlier progeny trials with same hybrids. Efron *et al.* (2003a) opined that the relationship between yield, vigour and yield efficiency are important in clonal evaluation trials planted at one density. So in this experiment, the cropping efficiency was worked out with stem girth and total pod weight (Table 1). The hybrids PI-I-38, PI-IV-478 and PI-I-18 had high harvest efficiencies of 0.88, 0.66 and 0.56, respectively. These hybrids also produced more pods 68.73, 61.73 and 50.87, respectively. As the juvenile and adult vegetative vigour, periodic and cumulative yield and yield x vigour ratio are the important factors in cocoa hybrid/ clonal evaluation trials (Lachenaud, 2003), these evaluations should be continued in the later years of growth.

Bean characteristics

While counting the total number of beans, the number of bold and flat beans were also taken into account since they are said to be representing the apparent fertility of the hybrid as well as the number of aborted ovules (Lachenaud, 2005). The total number of beans observed were considerably good in all the hybrids, which varied from 34.13 to 47.60. There have been reports on differences in the number of beans among cocoa groups and populations (Allen, 1988) and the studies on Trinitario and Forastero Amelonado types by Lachenaud *et al.* (1998) showed that their average normal beans per pod was between 33.3 to 42.1 and most of our hybrids also showed the same trend (Table 5). Number of flat beans recorded significant difference between pods of different hybrids and it ranged from 0.87 (PIII-III-20) to 3.33 (PII-1). Further correlations should be studied between number of ovules and number of beans and the influence of changing environments on development of beans, which is the economic part of cocoa.

The annual dry bean yield per tree ranged from a lowest of 0.22 to a highest of 2.64 in the hybrids tested. Twelve hybrids out of 21 showed high yield efficiencies of more than 1 kg dry bean per tree per year (Table 3). In the qualitative studies, wet weight of 50 beans were recorded and it ranged from 45.33 g (PII-1) to 145 g in PIII-I-8 and it exhibited wide variation between

Table 5. Bean characteristics of progenies

No.	Hybrid	Beans no.	Bold beans	Flat beans	50 beans wet wt. (g)	50 beans dry wt. (g)	Wet: Dry	Shelling (%)	Recovery (%)	1 dry bean wt. (g)	Bean length (cm)	Bean width (cm)	Bean dia. (cm)
1	PI-I-18	42.83	41.40	1.87	131.67	41.34	3.22	21.44	82.54	0.82	2.15	1.10	0.58
2	PI-IV-440	40.67	40.27	1.00	117.33	38.88	3.01	23.89	80.72	0.78	2.03	1.09	0.55
3	PI-I-106	39.27	38.87	1.00	113.00	44.58	2.59	15.53	87.05	0.89	2.07	1.17	0.60
4	PI-III-400	44.17	43.17	1.50	92.33	30.74	3.03	19.03	84.05	0.66	1.99	0.94	0.61
5	PI-IV-478	34.13	32.55	1.00	75.33	27.18	2.78	19.92	83.42	0.90	1.99	1.04	0.65
6	PI-I-38	45.92	45.45	1.22	132.77	47.09	2.81	22.42	84.85	0.94	2.23	1.19	0.64
7	PII-1	44.60	41.73	3.33	45.33	16.76	2.73	22.85	80.78	0.76	2.00	1.04	0.63
8	PII-2	37.27	35.47	2.00	82.35	30.23	2.73	21.82	85.78	0.67	1.85	0.98	0.62
9	PII-3	38.25	35.83	2.53	101.67	44.19	2.32	13.23	88.45	0.89	1.95	1.14	0.61
10	PII-4	42.80	41.97	1.33	125.33	55.80	2.25	15.10	87.28	0.92	1.90	1.18	0.62
11	PII-5	43.53	42.47	1.17	107.03	28.27	3.81	20.51	83.87	0.74	1.92	1.23	0.69
12	PII-6	40.47	38.33	3.00	91.67	44.08	2.08	14.28	87.61	0.88	2.02	1.25	0.67
13	PII-7	37.02	36.33	1.44	91.00	31.89	3.01	16.99	85.65	0.76	1.99	1.17	0.62
14	PII-8	41.38	40.73	1.00	84.00	33.25	2.60	18.89	84.51	0.67	1.87	1.23	0.53
15	PIII-I-23	37.67	36.79	1.27	89.00	31.57	2.90	17.11	85.87	0.91	1.85	0.96	0.61
16	PIII-III-20	47.60	40.27	0.87	107.00	45.96	2.34	19.66	83.81	0.92	2.12	1.26	0.58
17	PIII-I-8	38.13	36.80	1.83	145.00	53.88	2.68	13.21	88.36	1.02	2.33	1.31	0.71
18	PIII-III-13	35.33	34.47	1.67	89.67	36.87	2.44	19.55	83.80	0.74	2.00	1.07	0.58
19	PIII-II-89	45.98	44.63	1.28	94.67	35.37	2.67	20.46	83.07	0.81	1.89	1.00	0.65
20	PIII-II-54	39.67	38.97	1.33	86.33	34.87	2.49	14.10	87.68	0.88	1.93	1.20	0.61
21	PIII-I-14	39.27	38.33	1.11	120.67	36.88	3.30	17.34	85.70	0.86	1.98	1.20	0.69
	CV%	14.46	11.97	52.64	14.31	17.04	14.54	25.67	4.05	14.81	9.26	9.34	12.60
	SEd	4.81	3.84	0.67	11.80	5.23	0.33	3.85	2.80	0.10	0.15	0.09	0.06
	CD(P=0.05)	NS	NS	1.35	23.83	10.56	0.66	NS	NS	0.20	NS	0.17	NS

NS - Not significant

progenies. These 50 beans were fermented, dried, processed and observed for other characteristics such as wet: dry bean ratio, shelling and recovery percentage and bean size with regard to length, width and diameter. The dry weight of 50 beans ranged from 16.76 to 55.80 g and it also showed similar variations as for wet bean weight. The wet to dry bean weight ratio ranged from a lowest of 2.08 in PII-6 to a highest of 3.81 in PII-5. The hybrid evaluation trials conducted at Ghana and Ivory Coast showed high heritable values for bean traits such as number of beans, wet and dry bean weights (Ramirez and Enriquez, 1988) which, necessitated this evaluation in our hybrids too. Shelling and recovery percentages, which are important from the confectioner's point of view hasn't differed statistically between hybrids but varied from 13.23 to 23.89 and 80.78 to 88.45 per cent, respectively. All the hybrids were on par with each other and showed good shelling and recovery percentages. Beans of 1 g and above are preferred by the processing units and in this study the single dry bean weight ranged from 0.673 to 1.017. The hybrids PIII-I-8, PIII-III-20, PIII-I-23, PI-I-38 and PII-4 showed considerably higher single dry bean weight nearing unity. In formulating selection indices the bean traits, dry weight, length and thickness have proved their usefulness and genetic worth (Rose Mary *et al.,* 2002) and are considered as pointer towards selection of superior genotypes in the early years of bearing. Considering this individual length, width and diameter of beans were taken in this study (Table 5) and it was observed that bean width showed considerable difference and longer and wider beans weighed more.

Conclusion

Comparative study of 21 elite hybrids for growth and yield parameters in the early years of growth has lead to identification of vigorous, precocious and high yielders. Trees of the hybrids PII-5, PII-3, PIII-I-23, PI-IV-478 and PIII-III-20 of cross combinations I-14 x NC-42/94, I-56 x III-35, IMC-67 x ICS-6 and NA-31 x ICS-89 had high vigour. Hybrids PI-I-38, PI-I-18, PIII-I-8, PI-IV-478, PIII-II-54 and PIII-III-20 of cross combinations SCA-6 x ICS-6, NA-33 x ICS-89, ICS-6 x SCA-6, NA-31 x ICS-89 and IMC-67 x ICS-6 were identified as early and high bearers with maximum number of pods, single dry bean weight of 1 g, dry beans yield with optimal canopy volume. Further evaluation on growth and yield performance, stability of pod yields in the later years will enable us to confirm the credentials of these selected elite hybrids.

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