

EVALUATION OF COCOA (*THEOBROMA CACAO* L.) HYBRIDS AND PARENTS FOR GROWTH AND YIELD CHARACTERS

K.S.Ananda, V.R.Bhat and D.Balasimha

Central Plantation Crops Research Institute,
Regional Station, Vittal, 574 243, D.K., Karnataka

ABSTRACT

An experiment was laid out with nine hybrids and seven parents of cocoa (*Theobroma cacao* Linn) to study the growth characters and yield performance. The planting of cocoa was done with a spacing of 2.7 x 5.4 m in a twelve year old areca garden of 2.7 x 2.7 m spacing at CPCRI Seed Farm, Kidu during 1991. The growth characters *viz.*, plant height, stem girth, spread of canopy, height at jorquette and number of branches were recorded from the second year of planting for five consecutive years. Significant differences were noticed among the hybrids and parents in respect of stem girth, height of the plant and spread of canopy. The hybrid II-67 x NC 29/66 recorded consistently good growth, followed by the cross II-67 x NC42/94. Maximum vigour with higher heterotic effects for the vegetative traits was observed in II-67 x NC29/66 and I-21 x NC29/66 crosses. The hybrid II-67 x NC29/66 registered highest pod value of 47.86 g and least pod index of 21.72 per cent. The cross II-67 x NC 42/94 and the parent II-67 also exhibited higher pod values and low pod indices. Yield traits *viz.*, number of pods per tree and dry bean weight also showed significant variation among the hybrids and parents. There was increasing trend in dry bean weight and production of pods over the years. The highest cumulative pod yield and dry bean weight was 191 pods per tree and 7.489 kg dry beans per tree, respectively in the cross II-67 x NC 29/66 for five years from fourth year after planting. Maximum heterosis for yield trait was seen in the hybrids II-67 x NC29/66 and II-67 x NC42/94. The clone II-67 was the common parent for both the high yielding hybrids identified in this study, suggesting its usefulness as the best combiner for exploiting heterosis for growth and yield traits. Hybrids II-67 x NC29/66 and II-67x NC42/94 are found to be most promising and the same could be exploited for commercial cultivation.

INTRODUCTION

Cocoa (*Theobroma cacao* L.) being an exotic introduction in Indian agriculture needs extensive crop improvement work through breeding and genetical studies. Though the present production of cocoa accounts to 7837 metric tonnes from an area of 14618 hectares the confectionaries in India meet their requirement of cocoa beans through import of beans from African countries. The cultivation of cocoa on a large scale started in India in the early 1970s and it is mainly grown as a mixed crop component in coconut and arecanut gardens especially in Kerala, Karnataka, Andhra Pradesh and Tamil Nadu. There is still a lot of scope for improving cocoa production. As such, there is no proven high yielding varieties/improved variety/hybrid in cocoa released for

increasing the production per unit area withstanding all the production pressures from biotic and abiotic factor components. The present investigation was undertaken to evaluate nine hybrids and seven parents for growth and yield performances as a mixed crop in arecanut gardens in order to identify hybrid/hybrid combination which posses high yield potential and also parents having best combining ability for exploiting heterosis for economically important traits.

MATERIALS AND METHODS

A field performance experiment was laid out with nine hybrids *viz.*, I-14 x NC29/66, I-14 x NC42/94, I-21 x NC23/43, I-21 x NC42/94, I-29 x NC23/43, I-29 x NC42/94, II-67 x NC29/66 & II-67 x NC42/99 and seven parents *viz.*, I-14

(Jorangan Red axil), I-21 (Amel x Na 33), I-29 (Amel x Na33), II-67 (Landas 364), NC23/43 (P3 x P), NC29/66 (P6 x P4) and NC42/94 (T86/2) of cocoa as a mixed crop in a twelve year old Sumangala areca garden in 1991 at the CPCRI Seed Farm, Kidu. The planting was done in a Randomised block design replicated thrice with a plot size of six. The spacing was 2.7 x 2.7 m for areca palms and 2.7 x 5.4 m for cocoa. For developing production of hybrid material in the existing experiment, four high yielding trees/clones namely I-14, I-21, I-29 and II-67 were selected as female parents maintained at CPCRI Regional Station, Vittal and they were crossed with three relatively drought tolerant pollen parents viz., NC23/43, NC29/66 and NC42/94 during 1990-91 flowering season. The trees selected for crossing were more than eighteen years old. The seedlings obtained from these crosses were planted in the field. Ten month old seedlings of both parents and hybrids were planted. The observation on growth characters such as stem height, plant height spread of canopy (North-south & East-west), height at jorquette and no.

of branches produced were recorded annually from second year of planting i.e., from 1992 onwards for five consecutive years upto 1996-97. Pod value (Atanda and Jacob 1973) and pod index (Paulin and Eskes, 1995) for the hybrids and parents were worked out on individual basis. Pod value is the dry bean weight/pod and it gives a direct indication of actual yield of individual variety. Pod index determines the number of pods required for making one kg of dry beans. The yield parameters viz., no. of pods produced/tree and dry bean weight (g)/tree were recorded starting from 1993-94 to 1997-98 for five consecutive years. The data on growth and yield component traits were subjected to statistical analyses and compared the performance of hybrids and parents. Also heterosis for the F1 hybrids were worked out based on mid parental values using the formula $(F1 \text{ value} - MP \times 100 / MP \text{ value})$, where MP value is the average of Male and Female parents), for the morphological as well as yield traits in to order measure the quantum of vigour among the hybrids and combining ability of parents.

Table 1. Growth performance of cocoa hybrids and parents (2nd year of planting)

Hybrids/parents	Girth (cm)	Total Height			Height at Canopy		No. of branches
		(m)	Jorquette (m)	NS	EW		
I-14XNC29/66	3.61	2.84	2.02	1.77	1.64	2.02	
I-14XNC42/94	3.56	2.75	1.82	1.50	1.41	2.83	
I-21XNC23/43	3.34	2.45	1.60	1.70	1.61	2.86	
I-21XNC29/66	3.52	2.57	1.64	1.45	1.52	2.87	
I-21XNC42/94	3.21	2.30	1.12	1.05	1.00	2.08	
I-29XNC23/43	3.12	2.37	0.70	0.48	0.53	0.67	
I-29XNC42/94	3.01	2.19	1.24	0.85	0.78	2.00	
II-67XNC29/66	4.47	3.96	1.78	1.67	1.67	3.87	
II-67XNC42/94	3.84	2.83	1.95	1.67	1.41	2.19	
I-14	2.34	2.63	1.20	0.80	0.70	0.50	
I-21	2.48	1.73	0.67	0.67	0.68	1.67	
I-29	2.27	1.74	0.85	0.50	0.60	0.56	
II-67	1.79	1.42	1.25	0.50	0.48	1.67	
NC23/43	2.31	1.69	0.42	0.48	0.40	0.45	
NC29/66	2.34	1.72	0.32	0.23	0.25	1.00	
NC42/94	2.35	2.04	0.55	0.47	0.26	1.00	
GM	2.97**	2.28**	1.25*	0.86*	0.83*	1.79*	
CV (%)	13.78	11.90	62.62	62.67	64.42	67.46	
CD(P=0.05)	0.68	0.45	1.10	0.90	0.88	2.02	

Table 2. Growth performance of cocoa hybrids and parents (6th year of planting)

Hybrids/Clones	Girth (cm)	Total height (m)	Canopy (NS) (m)	Canopy (EW) (m)	No of branches	Height at Jorquette (m)
I-14XNC29/66	13.52	5.66	4.52	4.50	3.32	2.23
I-14XNC42/94	12.73	5.07	4.68	4.43	3.00	1.93
I-21XNC23/43	13.76	5.01	4.39	4.22	3.11	1.93
I-21XNC29/66	13.66	5.32	4.82	4.51	2.84	1.87
I-21XNC42/94	12.49	4.43	4.55	4.41	2.94	1.71
I-29XNC23/43	13.36	4.73	4.41	4.40	2.69	1.60
I-29XNC42/94	11.76	4.59	4.15	4.28	2.67	1.74
II-67XNC29/66	14.97	6.04	4.98	5.69	2.89	1.98
II-67XNC42/94	13.54	5.55	4.76	4.94	3.28	2.09
I-14	11.36	4.45	4.14	4.38	3.22	1.58
I-21	10.20	3.94	3.63	3.67	2.77	1.54
I-29	9.69	3.89	3.45	3.53	2.89	1.27
II-67	10.28	4.04	3.80	3.86	2.64	1.47
NC23/43	10.31	4.70	4.14	4.27	2.94	1.38
NC29/66	9.29	4.03	3.35	3.63	2.75	1.32
NC42/94	12.53	5.02	4.52	4.65	2.61	1.52
GM	12.09**	4.78**	4.27**	4.35**	2.91*	1.70*
CV %	11.45	11.81	11.30	11.02	18.89	13.50
CD (P=0.05)	2.31	0.94	0.81	0.80	0.92	0.38

RESULTS AND DISCUSSIONS

There were significant differences among the hybrids and parents in respect of stem girth and height of the plant among the morphological traits studied during the second year of planting (Table 1). Hybrid II-67 x NC 29/66 had higher stem girth and plant height followed by the cross II-67 x NC 42/94, while the lowest of and height was observed in the parent II-67. After sixth year of planting, the hybrids and parents varied significantly for the characters, stem girth, total height and spread of canopy (Table 2). The hybrid II-67 x NC 29/66 continued to show maximum growth with thickest girth tallest height and widest canopy size both NS and EW direction as compared to other hybrids and parents. Though there was no significant difference among parents and hybrids for the characters, number of branches, hybrids I-14 x NC29/66 and I-14xNC42/94 showed higher branching tendency. The yield in cocoa always depends on morphological traits like stem girth, total height and spread of canopy. A strong and positive correlation was observed between bean yield and stem girth; the major contributor towards the

establishment and production of crop (Bhat *et al.*, 2000). Stem girth at collar regarded as the major repository of starch reserve (Balasimha & Nair 1989). Earlier studies indicated that significant correlations between morphological and yield traits in cocoa and increased canopy area had increased bean yield during the early age of the plants (Balasimha 1988). Hence, in the present study, high bean yield in crosses was influenced by vigorous growth of the trees. Over all, significantly higher growth performance was noticed in II-67x NC 29/66 and II-67 x NC42/94 crosses.

Heterosis for the hybrids was worked out by taking the mid parental values (Table 3). The hybrid II-67 x NC29/66 showed maximum vigour with higher heterotic effects of 34.60%(girth), 33.19% (plant height) and spread of canopy (NS = 27.71% and EW = 34.09%) followed by the cross I-21 x NC 29/66 for the characters plant girth, total height, spreading of canopy (NS and EW). The hybrid II-67 x NC 42/94 recorded maximum vigour in respect of number of bunches produced. The maximum for the height at jourquette was noticed in the combination I-14 x

Table 3. Heterosis for growth characters in cocoa hybrids

Hybrids/Clones	Girth (cm)	Total height (m)	Canopy (NS) (m)	Canopy (EW) (m)	No of branches	Height at Jorquette (m)
I-14XNC29/66	23.63	25.09	17.03	11.11	09.94	34.67
I-14XNC42/94	06.13	05.52	07.48	-2.03	02.67	19.69
I-21XNC23/43	25.14	20.36	11.39	05.92	13.18	24.35
I-21XNC29/66	28.62	25.00	24.37	19.07	-0.70	23.53
I-21XNC42/94	08.98	-5.00	10.33	05.67	08.50	10.53
I-29XNC23/43	25.15	09.30	13.83	06.04	-8.55	16.88
I-29XNC42/94	05.53	02.83	03.86	04.44	-4.87	20.11
II-67XNC29/66	34.60	33.19	27.71	34.09	02.42	29.80
II-67XNC42/94	15.77	18.38	12.61	13.77	19.82	28.71

NC29/66 followed by the hybrid II-67 x NC 29/66 (29.80%). The decreased/negative heterosis was observed in I-29 x NC 42/94 for the character stem girth and height at jorquette I-14 x NC 42/94 for EW spread of canopy and I-29 x NC 23/43 for the trait II-67 x NC 29/66 and I-21 x NC29/66 for the vegetative characters should have come from the parent NC29/66. High heterotic effects especially for the characters height, stem girth, number of branches and spread of canopy are preferred since these characters determine ultimately the yield of cocoa.

Table 4. Pod value and pod index of cocoa hybrids and parents

Hybrid/parent	Pod value	Pod index
I-14XNC29/66	31.88	31.51
I-14XNC42/94	30.93	32.35
I-21XNC23/43	35.31	28.37
I-21XNC29/66	39.42	25.91
I-21XNC42/94	27.48	36.66
I-29XNC23/43	29.54	33.92
I-29XNC42/94	24.10	41.74
II-67XNC29/66	47.86	21.72
II-67XNC42/94	41.25	24.74
I-14	35.86	28.05
I-21	26.21	39.38
I-29	28.62	35.02
II-67	39.90	25.24
NC23/43	24.88	40.32
NC29/66	19.73	53.92
NC42/94	34.09	29.58
Mean	28.97*	32.57*
CV (%)	21.8	15.60
CD(P=0.05)	3.90	4.26

Highly significant variations in pod value and pod index were noticed among the hybrids and parents (Table 4). The cross II-67 x NC 29/66 registered highest pod value followed by the hybrid II-67 x NC42/94 among the hybrids and parents. The parent II-67 also showed high pod value followed by the parent I-14. The pod value is the dry bean weight per pod and it gives a direct indication of actual yield of that individual variety. The lowest pod values was observed in I-29 x NC42/94 and in the parent NC29/66 and contributes towards less commercial yield. Similar trend was also noticed among the hybrids and parents in respect of pod index. The desirable least pod index was noticed in the cross II-67 x NC 29/66 and the next best II-67 x NC 42/94. The mother parent II-67 might have contributed to highest pod value and lowest pod index observed in the cross II-67 x NC 29/66. Mallika *et al.* (1996) reported that the pod/bean characteristics increased over the years in terms of pod width, length weight, bean weight, length and bean thickness.

The year-wise mean yield along with cumulative yield for the characters, number of pods produced/tree and dry bean weight (g)/tree for the five consecutive years from 1993-94 to 1997-98 was recorded (Table 5). The statistical analysis revealed that highly significant variations existed among these yield traits among the parents and hybrids. Hybrids exhibited superiority over parents in terms of overall mean production of pods/tree and dry bean yield/tree/year.

Highest mean number of 38.21 pods produced/tree/year and cumulative of 191.05

Table 5. Heterosis for no. of pods per tree in cocoa hybrids

Hybrids/ Clones	No. of pods /tree/year					
	93-94	94-95	95-96	96-97	97-98	Mean
I-14XNC29/66	-29.50	9.82	36.80	30.37	34.37	2.91
I-14XNC42/94	17.86	-22.6	-17.38	36.81	34.88	-20.63
I-21XNC23/43	63.76	20.04	47.64	32.97	28.16	24.58
I-21XNC29/66	59.78	21.19	49.58	33.3	30.71	27.04
I-21XNC42/94	-1.97	-28.03	3.98	27.45	31.28	-14.91
I-29XNC23/43	23.8	16.67	36.32	29.07	28.56	17.68
I-29XNC42/94	-16.03	-3.77	2.04	26.95	31.68	-4.18
II-67XNC29/66	65.29	54.89	62.18	52.2	30.24	49.74
II-67XNC42/94	69.46	43.0	50.01	14.18	30.8	40.69

pods produced/tree were recorded in trees belonging to the cross II-67 x NC 29/66 followed by the cross II-67 x NC42/94 with a mean of 34.31 pods/tree and cumulative of 171.55 pods/tree. These two crosses consistently yielded more compared to other crosses/parents over the five cropping years. Among the parents I-14 and NC42/94 produced highest cumulative number of 120.95 and 112.95 pods/tree, respectively. Similar trend in yield was also observed by Bhat *et al.* (2000).

The hybrid vigour for the character number of pods/tree for all the crosses was estimated. The maximum heterotic effects was observed in the cross II-67 x NC29/66. It was followed by the cross II-67 x NC42/94. Hybrids I-21 x NC23/43, I-21 x NC29/66 and also I-29xNC23/43 exhibited better heterotic effects. Heterosis manifested in these hybrids may be a reason for increased number of pods production (Attanda and Taxopeus 1969).

There were significant variations in dry bean yield over the years among hybrids and parents and there was increasing trend in yield/tree over five years. The maximum cumulative dry bean yield of 7488.9 g/tree over the five years period was observed in the cross II-67 x NC29/66 with an average of 1497.8 g/tree/year. The performance of the cross II-67 x NC42/94 also found to be promising with cumulative yield of 6226.8 g/tree with a mean of 1245.4 g/tree/year. The high yielding mother parent II-67 has been the common parent for the above high yielding combination, might have contributed significantly towards the dry bean yield. The maximum

potential yield of 2122.2 g/tree and 1975.1 g/tree was noticed in 1996-97 and 97-98 seasons, respectively in the combination II-67 x NC29/66. Crosses I-21 x NC29/66 and I-21 x NC23/43 were also found to be superior for this character by yielding 977.7 and 947.0 g dry bean yield per tree/year, respectively. Among the parents, I-14 and NC 42/94 exhibited an average yield of 812.0 and 681.5 g dry beans/palm/year.

Hybrid vigour estimated for dry bean yield based on mid-parental values for the hybrids. Over the five years period, the cross II-67 x NC 29/66 increased its vigour for the trait dry bean yield by 70.09, 71.73, 76.16, 72.02 and 80.90 percentages for the consecutive five years, respectively with a mean of 74.18 per cent vigour. Heterosis was also found to be more in crosses I-21 x NC 29/66 (61.40%) , II-67 x NC 42/94(48.76%) and I-21 x NC 23/43 (47.85%). For this trait too, the parent II-67 has significantly contributed by combining well with NC 29/66 and NC 42/94. Also, the parent I-21 proved as a better combiner with NC 29/66 for the character dry bean yield resulting in increased vigour/yield.. Crosses I-29 x NC 42/94 and I-14 x NC42/94 showed low heterotic effects of -34.79% and -33.85%, respectively. In the present study, superiority of hybrids over the parents in respect of growth and yield traits has been established. Similar results were also obtained from the earlier studies by many workers (Cherian *et al.*, 1996; Mallika *et al.* 1996 and Bhat, *et al.*, 2000).

Based on the growth parameters and dry bean yield over five years period, the hybrid II-67 x NC 29/66 has been identified as the most

promising type followed by the cross II-67 x NC 42/94. Maximum heterosis/increased vigour for both morphological and yield component traits was also observed in same hybrid combinations. The parent II-67 has been the common parent for the two high yielding hybrids suggesting its usefulness as the best combiner for exploiting heterosis for economically important traits of cocoa. High yielding hybrids identified in the present study can be exploited directly for commercial cultivation.

REFERENCES

- Atanda, O.E. and Jacob, V.J. 1973. *Ghana Journal of Science*, **13**:72-77.
- Attanda, A.O. and Toxopeus, H. 1969. In: Proceedings of III International Cocoa Research Conference, Cocoa Research Institute, Ghana. pp.545-557
- Balasimha, D. 1988. *Journal of Plantation Crops*, **18** (Suppl.): 65-71.
- Balasimha, D. and Nair, B.P. 1989. *Journal of Plantation Crops*, **17**:57-58.
- Bhat, V.R., Sujatha, K., Ananda, K.S., Nair, R.V. and Virakthamath, B.C. 2000. In: *Recent Advances in Plantation Crops Research*. (N. Muralidharan and R.Rajkumar eds.), pp. 105-109
- Cherian, H., Vijaya Kumar, N.K. and Nair, R.V. 1996. *Journal of Plantation Crops*, **24**: 43-49.
- Mallika, V.K., Rekha, C., Rekha, K., Swapna, M. and Nair, R.V. 1996. *Journal of Plantation Crops*, **24**:363-369.
- Paulin, D. and Eskes, A.B. 1995. *Cocoa breeding strategies*, **2**:14-18.