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प्रान्तीय क्षेत्र, विट्टल

CENTRAL PLANTATION CROPS RESEARCH INSTITUTE
(Indian Council of Agricultural Research)
REGIONAL STATION - VITTAL - 574 243, KARNATAKA, INDIA

No.F.9(4)/01-T. Dated: 26.7.2001

The Scientist-in-Charge
PMT Cell
CPCRI, Kasaragod

Sub: Forwarding of RPF III – reg.

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Sir,

I am herewith forwarding six copies of the RPF III entitled "Evolving high yielding varieties by selection and hybridization in cocoa (Theobroma cacao L.)", received from Dr Vivek R Bhat, Sr. Scientist (Horticulture), for further necessary action.

Yours faithfully,

(D Balasimha)
HEAD

Cocoa file
HDCI pl.
like & approve
27/07/01

Encl: a/a
ve/rpf

(5b

RPF III

FINAL REPORT

1Institute Code No..:Gen. II (299) 2.ICAR Code No.: PI-84/22-ICI-F30/ 2110

3. Name & Address of Research Institute/ Centre: Central Plantation Crops Research Institute Regional Station Vittal, Dakshina Kannada , Karnataka - 574 243

4 Project Title.. Evolving high yielding varieties by selectionand hybridization in cocoa (*Theobroma cacao* L.)

5. Name & Designation of Principal Investigator : Vivek R. Bhat — Sr Scientist (Hort.)

6.Name (s) and Designation of the Associate(s) and Establishment (s) on which borne:

(a) Whole time

Principal investigator		Associates
1984	P.M. Kumaran	B.S.Chaudhary
1985	P.M.Kumaran	R.V.Nair
1986	R.V.Nair	—
1987	R.V.Nai	P.M.Kumaran
1988	B.S.Chaudhary,	R.V.Nair, R.Dhanpal
1989	B.C. Viraktamath	B.S.Chaudhary
1990	B.C.Viraktamath	K.S.Ananda
1991	B.C. Viraktamath	K.S.Ananda
1992	K.S.Ananda	——
1993	K.S.Ananda	——
1994	K.S.Ananda	V.R.Bhat
1995	K.Sujatha	V.R.Bhat, K.S. Ananda
1996	K.S.Sujatha	V.R.Bhat, K.S.Ananda
1997	V.R.Bhat,	K.S.Ananda
1998	V.R.Bhat	M. Elangoan
1999	V.R.Bhat	M. Elangoan

7.Location of Research Project with complete address: (Division/ Section/ Sub-centre)
CPCRI RS Vittal - Division of Crop Improvement

8.Date of start; 1984 9. Date of termination: 2000

10.a) Objectives (Not more than 150 words)

- to evolve hybrid progenies thro' crossing between selected compatible lines of cocoa and evolve clones of high yielding cacao.
- to field evaluate these hybrid progenies and the clones using the ideal clone as check lines in progeny trials
- to assess the inheritance of desired traits like drought tolerance and black pod disease tolerance in the hybrids involving tolerant clones.
- to identify the best cacao with high yielding potential with moderate canopy volume so as to befit them in areca intercropping system.

b) Practical Utility (Not more than 100 words)

- The practical utility of the projct while conceiving the project has been better cocoa clones/ varieties with desired traits like high yield with moderate canopy volume so as to avoid any competition between cocoa and main crop -arecanut. This project has aimed at evolving hybrid progenies with high value of heterosis / hybrid vigour.These would yield clones for further multi-locational trial and releasing the best clones with wider adaptability and stability for commercial cultivation by the farmers.

11. Technical Programme:

(Indicate briefly plan of procedure, technique, instruments, and special materials, organism, special environments etc.,)

- Crossing thro' hand pollination technique between compatible cocoa selected mother plants and raising those hybrid seedlings in the nursery- field planting along with the clones of their parental lines and a premium clone as check line in discrete 4 progeny trials of well designed RBD. In total 40 hybrids were tried along three F3 progenies and another trial with clones of selected Nigerian cocoa were tried in a separate trial at Vittal. Measured and observed for their growth and yield attributes like..girth, branches, height at first branching , canopy volume and dry bean yield, pod yield and quality parameters ,drought tolerance etc. For rest of the time for almost 8-10 years The data on stable yield were pooled and analyzed subjected to stability test, and final conclusion were derived w. r. t. their field evaluation performance in relation to their canopy volume.

12. Summary of the project :

In total forty hybrids and four F3 progenies of CRYN Synthetics had been tried in four discrete Progeny trials spread over Regional Station Vittal and Seed Farm Kidu along with a clonal trial on Nigerian Selected Clones at Vittal. The conclusions on all these five sets of trials have been compiled in the following fashion:

Progeny Trial I

All the parents are of proven record both in terms of bean yield potential and also in terms of tolerance to stresses like drought, open cultivation and black pod. The experiment on these lines was laid out in a Randomised Block Design with 5 replications and following five compatible combinations as treatments: Na33 x ICS 89, Na33 x ICS 89, SCA6 x IMC 67, Na31 x ICS89, SCA6 x ICS6, Na31 x ICS95

This experiment was started with an objective of finding a superior hybrid combination among the tried five combinations in terms of bean yield. It was initiated during 1983 with the planting of progeny seedlings by 1st of September 1983. Five hybrids comprised five treatments replicated five times with an initial plot size of 12 plants per experimental unit with an adopted spacing of 2.7 m x 2.7m (double the recommended population) in an areca garden in B 3.4 block running to an area of 4046 sq. meter. Later the population was thinned to halve and then onwards the plot size was maintained at 6 plants / experimental unit. Border plants were of bulk Forastero type. Growth parameters and pod and bean have been measured for since 1984 onwards and the final evaluation report is placed here.The hybrids performed on par when evaluated on annual yield basis while; they showed differential performance when analysed on pooled basis. Six year stabilized bean data yield were considered while comparing performance of hybrids on pooled basis.

Progenies belonging to Na 33x ICS 89 excelled in bearing heavy bean yield (1.005 kg/plant/annum) with a maximum degree of consistency expressed through an acceptable value of standard deviation (0.313), a least value of CV (31.14%) and a best range of stable yield i.e. 0.692-1.318 kg. Hence Na 33x ICS 89 hybrid can be very well accepted as a potential high yielding hybrid.

PROGENY TRIAL-II:

A trial was begun to evaluate seventeen hybrids (seedling progenies) of cocoa along with their parental lines (seven clones) and a check line (I-14 seedlings) in a randomised complete block design comprising of 25 treatments replicated thrice with a plot size of eight. The trial was initiated in 1984-85 and the planting of all the three blocks at CPCRI Regional Station, Vittal was completed in the later part of 1985. The details of the experiment are depicted in the following table.

The observations on growth as well as yield parameters have been recorded since 1987. An effort is made hereby to draw conclusions about the progenies under trial by taking into account the performance of the lines over the six years (1992-97) The data were analysed on pooled basis and their annual performance since beginning were also considered for deriving any conclusion on these lines. Growth parameters like canopy volume, plant height, girth at the bottom, height at jorquette and weight of prunings has been observed for in addition to the main parameter of dry bean yield. The pod and bean characters also have been recorded along with their pod values. Though the I-14 x IV-20 hybrid progenies showed all the promising features to be the best out of 17 crosses involved in the trial in the early bearing stage of the crop it failed to retain its consistency later once the crop attained stability in their yield. However, it has recorded on par with all other seven better performing lines of which I-56 x II-67 bore the maximum dry bean yield compared to all other hybrids and parental lines. Based on the performance of hybrids involved in the trial with respect to the growth and yield attributes, the following eight hybrids have been noted to be better performing lines.

I-56 x II-67, I-14 x I-56, I-56 x III-35, III-35 x IV-20, I-14 x NC 42/94, III-105 x NC 42/94, I-56 x IV-20, I-14 x IV-20

All these hybrids gave a stabilised yield of more than 1.300 kg of dry beans per plant per annum. Progenies belonging to I-56 x II-67 hybrid line bore 1.481 kg of dry beans per plant which showed a gain of 74.2 per cent yield over that of check line that produced only 0.739 kg. The maximum heterosis value of 56.6 per cent was seen with III-35 x IV-20 hybrid followed by I-56 x IV-20 (46.4%), I-56 x III-35 (46.3%) and I-56 x II-67 (39.6%).

The beans of I-56 x II-67 had a size of 1.00 gram in terms of dry weight basis. The pod value for this particular hybrid was 23.8. The minimum pod value was noticed with the progenies of I-56 x NC 42/94 (17.9). All the types of pods were observed in the progenies tried under this trial. The most bigger pods were noted with those of II-67 x IV-20 and was nearing 690g each in size. The husk colour, its texture, thickness over ridges and furrows varied over a wide range among the progenies.

The progenies differed significantly only in respect of girth at the bottom and weight of prunings while there was no significant variation among the progenies with regard to the other growth parameters like height of the plant, height at first branching and Canopy volume. Plants of I-56 x II-67 produced 19.01 kg of prunings that differed significantly from that of highest vigorous plants.

Progeny Trial III:

An experiment on evaluating the progenies of hybrid combinations as suggested by GAR Wood and Dr VJ Jacob was initiated with crossing work at Lalbagh, Bangalore during July, August & September 1986-1987. This yielded nine hybrid pods, which were sown in polybags. These along with F3 progenies of 4 Malaysian hybrids (Pa 7 x Na 32, Amelonado x Pa 7, Amelonado x Na 32 and Amelonado x Na 33) were planted under Areca nut (at Vittal) and under coconut (at Kasaragod) in a Randomised Block Design with 3 replications and 8 plants/plot with a spacing of 5.4m x 5.4m in a quincunx system. The selfed progenies of Pa 7 x Na 32 plants were used as check plants. Experiment was laid out in 6500 square meter area of B 3.5 and B 4.3 Blocks. Hybrid progenies along with the F3 Amazon (that are known to be CRYN Synthetics) have been observed annually for their growth and yield measurement and their final six years stable yield data have been utilized in deriving the pooled analysis and inference. The same have been used in inferring about their consistency of their bean yield bearing and has been expressed in terms of standard deviation, CV (%) and range for their stable yield.

Hybrid progenies along with the F3 Amazon (that are known to be CRYN Synthetics) have been observed annually for their growth and yield measurements for analysing on pooled basis their final six-year stable yield data have been utilized in interpreting the pooled analysis and in deriving the inferences. The same have been used in inferring about their consistency of their bean yield bearing and has been expressed in terms of standard deviation, CV (%) and range for their stable yield.

Series of tables revealing their growth and yield parameters have been compiled here. Progenies of ICS 6x Sca 6 have shown superiority over other hybrid and F3 progenies in almost all the years excepting in the year of 1993-94 and 1996-97. However, the performance of these progenies in the initial two years was on par and did not differ significant. But on pooled basis the progenies of ICS 6x Sca 6 showed significantly better performance followed by those of Amelonado x Na 33. Pod and bean studies have been conducted with reference to all the treatment combination. Taking into all these observations a selection of the superior plants from the best performing progenies is exercised and this yielded eight best potential yielders.

Hybrid progenies of ICS 6 x Sca 6 and F3 progenies of Amel. x Na 33 excelled on pooled basis in terms of their bean yield potential while, three more hybrid progenies also performed significantly better than the check plants. Rest all showed poor performance. However, from consistency point of view the progenies of ICS 6 x Sca 6, ICS 6 x Sca 12 and IMC 67 x ICS 6 may be considered as good lines since the other two high yielders have had high values of CV (%) and Std. Deviation along with wider ranges for their means.

Nigerian Clones:

. Eight high yielding trees of the Nigerian origin (NC 102, NC 119, NC 73, NC 63, NC 13, NC 116, NC 53 and NC 8) were selected during 1985 and multiplied clonally (side grafting was the method adopted) for clonal evaluation. Experiment was laid out in an RBD with eight Nigerian clones representing eight treatments along with two checks represented by I-14 seedlings and I -14 clones in-order to compare the performance of Nigerian clones both in terms of their potential high yield as well as to make a way for comparison of performance of seedlings Vs clones. Thirty-six clones of each of the 10 treatments were planted in three replicated blocks in a quincunx system comprising 12 plants (plot size) with a spacing of 5.4mx5.4m. Forastero bulk plant has been used for border planting in the orchard running for 6706 square meter in the C2.2 block. The final concluding remarks have been filed here after observing the analysed various annual growth and yield parameters. The final verdicts have been based on the pooled analysis of past six years stable yield and stability indices indicated by standard deviation, CV and Range for stable yield.

Nigerian collection, NC 45/53 had the highest yield per plant per annum (0.930-1.726 kg) with a lower value for coefficients of variation. This is followed by NC 38/119 taking into account its stability value (CV% = 21.32) and yield range of 0.904-1.394 kg. Clones differed significantly with regard to most of the canopy measurements. There occurred significant differences in the clones in respect to their pod weight and pod values. Correlation studies have indicated the strong and positive relation between stem girth and canopy volume, while, pod value of each accession was negatively correlated with 1000 seed weight. The stability in the yield potential of NC 45/53 and NC 38/119 could be confirmed by looking through the parameters like lower CV values coupled with higher yield range observed with these particular clones. Though NC 38/119 clone showed the best stability index with least CV value (21.32%), NC 45/53 gained an additional quality of being self-compatible in addition to having had the highest yield range of 0.930-1.726 kg per clone. The former clone has been self incompatible and cross compatible and thus in need of some other compatible clones while planting in the main field where as, the latter clone (NC 45) being self compatible can produce crop in the garden with no pre-requisite of other clones in the vicinity. Hence these two clones could be regarded as the better performing clones with a stable and higher bean yield.

Progeny Trial IV:

Nine hybrids along with their seven parental lines field planted during 1991-92 at CPCRI Seed Farm, Kidu were evaluated for their performance and hybrid vigour for over eight years and concluded on analysing their stable yield data for five years. The hybrids evaluated were: I-14 x NC 29/66, I-14 x NC 42/94, I-21 x NC 23/43, I-21 x NC 42/94, I-29 x NC 23/ 43, I-29 x NC 42/ 94, II-67 x NC 29/ 66 and II-67 x NC 42/94. The design adopted was Randomised Block Design with three replication and a plot size of 6 clones.

Observations were recorded on all the growth and yield attributes from the second year of planting. Pod and bean studies were also included for quality assessment of the involved hybrids. The data recorded on pod and beans characters were subjected to statistical analysis, which revealed highly significant variations among the hybrids and parents in respect of all the characters studied. The hybrid II-67 x NC 29/66 has registered highest pod value of 47.86 g followed by II-67 x NC 42/94(41.25).

The yield data recorded from 1993-94 to 1997-98 for five consecutive years was subjected to statistical analysis which revealed significant differences among the varieties and hybrids in respect of number of pod produced / tree/ year and dry bean weight/ tree/ year.

On the pooled analysis the hybrid II-67 x NC 29/66 was found to be most promising followed by the cross II-67 x NC 42/ 94. Maximum heterosis / hybrid vigour for growth characters as well as yield component traits was also observed in the above quoted hybrids.

Table 1.Consistency measurements

Hybrids	Mean (a)	Std. Deviation (b)	CV (%)	Range for the stable Yield	
				(a-b)	(a+b)
Na33xICS 89	1.005	0.313	31.14	0.692	1.318
SCA6x IMC 67	0.965	0.308	31.91	0.657	1.273
Na31xICS89	0.787	0.306	38.88	0.481	1.093
SCA6xICS6	0.934	0.407	43.58	0.527	1.341
Na31xICS95	0.731	0.228	31.19	0.503	0.959

Table 2. Bean yield increment and heterosis values of hybrids

Hybrid/parent	Bean yield (kg/pl/annum)	Percent increase	Heterosis over MP value
I-14 x NC 42/94	1.389	65	32.5
I-14 x IV 20	1.331	59.2	31.1
I-14 x I-56	1.465	72.6	33.5
I - 14 x III - 35	1.137	39.8	7.5
I-14 x III - 105	1.069	33	-5
I-56 x NC 42/94	0.996	25.7	3.7
I-56 x IV - 20	1.358	61.9	46.4
I-56 x II-67	1.481	74.2	39.6
I-56 x III- 35	1.418	67.9	46.3
I-56 x III - 105	0.968	22.9	-6.7
II-67 x NC 42/94	0.977	23.8	-3.7
II-67 x IV - 20	0.991	25.2	1.2
III-35 x NC 42/94	1.096	35.7	19
III-35 x IV - 20	1.391	65.2	56.6
III-105 x NC42/94	1.368	62.9	38.4
III-105 x IV - 20	1.204	46.5	26
III-105 x I-56	0.903	16.4	-5.5
I – 14	1.185	44.6	
I – 56	1.009	27	
II – 67	1.113	37.4	
III – 35	0.93	19.1	
III – 105	1.065	32.6	
IV – 20	0.846	10.7	
NC 42/94	0.912	17.3	
I - 56 (Check)	0.739		
CV (%)	35.32		
SEM ±	0.094		
CD at P = 0.05	0.263		

Table 3. Dry bean yield on annual and pooled basis

Hybrids/ F3 progenies	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	pooled
ICS1 x Sca 6	0.661	0.938	1.360	1.335	0.785	0.634	0.952
ICS1 x Sca 12	0.699	0.731	1.210	1.136	0.407	0.710	0.815
Na 31 x ICS 1	0.524	1.091	1.407	1.072	0.489	0.627	0.868
ICS 6 x Sca 6	1.018	1.139	1.335	1.649	1.060	0.669	1.145
ICS 6 x Sca 12	0.711	1.093	1.159	1.276	0.786	0.687	0.952
ICS 6 x Na 33	0.485	0.897	1.149	1.419	0.564	0.563	0.846
IMC 67 x ICS 6	0.721	0.961	1.183	1.143	0.918	0.721	0.941
Na 31 x ICS 6	0.450	1.072	1.229	1.347	0.672	0.444	0.869
ICS89 x Sca 6	0.443	0.957	1.309	1.106	0.671	0.645	0.855
Pa7 x Na 32	0.499	0.830	1.189	1.185	0.472	0.405	0.763
Amelonado x Pa 7	0.345	1.097	1.407	0.978	0.447	0.673	0.824
Amelonado xNa32	0.510	0.979	1.114	0.958	0.543	0.897	0.834
Amelonado xNa33	0.622	1.731	1.895	1.150	0.486	0.609	1.082
Bulk Forastero (check)	0.509	0.958	1.465	1.014	0.854	0.622	0.904
CV(%)	41.10	27.21	17.95	30.77	31.39	38.90	29.69
S Em ±	0.139	0.162	0.136	0.213	0.119	0.143	0.063

Table 4. Annual dry bean yield (Kg/plant) from 1991-92 to 1996-97

Nigerian clone	1991-92	1992-93	1993-94	1994-95	1995-96	1996-1997	pooled	Percent gain over clonal check
NC 39/102	0.572	0.876	1.148	1.010	0.613	0.851	0.845	-21.10
NC 38/119	1.054	0.998	1.293	1.500	0.809	1.237	1.149	09.30
NC 26/73	0.950	1.033	1.271	1.515	0.544	0.923	1.040	-01.60
NC 29/63	0.971	1.037	1.225	1.182	0.644	1.299	1.060	00.40
NC 34/113	0.535	0.862	1.061	0.786	0.563	1.012	0.803	-25.30
NC 40/116	0.664	0.811	0.973	1.619	0.651	1.004	0.954	-10.20
NC 45/53	0.963	1.072	1.205	1.807	1.063	1.855	1.328	27.20
NC 55/8	0.452	1.048	1.39	0.615	0.479	0.949	0.780	-27.60
I-14 clone	0.671	1.298	1.258	1.194	0.716	1.203	1.056	--------
I-14 seedling	0.799	1.432	1.201	1.669	0.784	1.358	1.208	--------
CV (%)	39.57	34.54	15.44	26.01	27.60	34.69	30.10	
SEM ±	0.174	0.209	0.105	0.194	0.109	0.234	0.07	
CD	NS	NS	NS	0.57	NS	NS	0.203	

Table 5. Performance of progenies of IV- hybrids

Hybrids	dry bean weight (kg/plant /annum) pooled data
I- 14 x NC 29/66	0.654
I-14 x NC 42/94	0.558
I-21 x NC 23/43	0.747
I-21 x NC 29/66	0.978
I-21 x NC 42/.94	0.441
I-29 x NC 23/43	0.600
I-29 x NC 42/94	0.437
II_67 x NC 29/66	1.552
II-67 x NC 42/94	1.245
I-14	0.813
I-21	0.459
I-29	0.497
II-67	0.654
NC 23/43	0.392
NC 29/66	0.340
NC 42/94	0.682
CV(%)	25.02
S Em ±	44.61
CD (P=0.05)	0.141

13. Progress of work in relation to the time targeted for completion of work and reasons for non-achievement of targets, if any.

14. Publication :

(a) Research Papers: Eleven

ANANDA, K.S., BHAT V. R. AND BALASIMHA, D., 2000. Evaluation of cocoa hybrids (Theobroma cacao L.) for growth and yield characters. PLACROSYM XIV – Abstract : 32p.

ANIL KUMAR, V., NIRALA, V., BALASIMHA, D., ANANDA, K.S., BHAT V. R. AND PARTHASARTHY, V.A., 2000. Half -sib analysis in cocoa hybrids. PLACROSYM XIV – Abstract :15p.

ANIL KUMAR, V., BALASIMHA, D. AND ANANDA, K.S., 2000. Photosynthetic characteristics in Cocoa hybrids and parents. National Sem. Recent Adv. Plant Biol., held during 3rd -5th Feb., 2000, CPCRI Kasargod.

BALASIMHA, D., ANIL KUMAR, V., AND ANANDA, K.S., 1999. Pod and bean characteristics of cocoa hybrids during early years of bearing. J. Plantation crops **27** : 99-103.

BALASIMHA, D., ANIL KUMAR, V., VIRAKTHAMATH B.C. and ANANDA, K.S., 1999. Leaf water potential and stomatal resistance in cocoa hybrids and parents. Plantation Recherche & Developpment , **6**(2) : 116-18.

BHAT, V. R., 1999. Cocoa-germplasm characterization, conservation and utilization- a chapter in the *proceedings of Summer school on crop improvement of plantation crops* that was held during 08th to 28th June , 1999 at CPCRI Kasaragod

BHAT, V.R., BALASIMHA, D. AND ANANDA, K.S. 2000. Crop improvement in cocoa at CPCRI - presented in a National Sem. Cocoa held on 9th & 10th June, 2000 at Thrissur Kerala.

BHAT,V.R., NAIR, R.V. AND ANANDA, K.S. 2001. Performance of Elite Nigerian clones. *Journal of Plantation Crops* –(in print)

BHAT,V. R., SUJATHA, K., NAIR, R.V., ANANDA, K.S. AND VIRAKTHMATH, B. C.1998. High yielding cocoa (*Theobroma cacao* L.) hybrids. *Recent Adv. Plantation Crops Research* –Papers presented in *the Proceedings of the Thirteenth Symposium on Plantation Crops (PLACROSYM XIII)* held during 16th to 18th December, 1998 at Coimbatore. Ed.: **N. Muralidharan and R. Raj Kumar** :

NAIR, M.K. AND BHAT, V.R., 1995. Status of cocoa research and future needs. *Indian Cocoa, Arecanut & Spices Journal* **14** :116-119

NAIR,R.V., ANANDA,K.S. AND BHAT, V.R., 1996. Improvement breeding in cocoa.. *Proc. Of Seminar on Crop Breeding in Kerala* held at *Dept. of Botany, Univ. of Kerala, Kariavattom*, 25th January, 1996. Page 97-101.

(b) Popular articles

(c) Reports

15. Details (Nos. etc.) of Field/ Laboratory Note Books and their final location:

The field note books (8) and yield registers (6) connected to all the first experiments have been maintained in the Horticulture Section of Vittal regional station while those of the Progeny IV trial have been maintained at Seed Farm Kidu.

16. Signature of Principal Investigator

17. Signature of Head of Division/ Section/ Station

18. Signature of Director