CADBURY-KAU CO-OPERATIVE COCOA RESEARCH PROJECT

Fourth Annual Report, 1990-'91

KERALA AGRICULTURAL UNIVERSITY

CONTENTS

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I. INTRODUCTION

The Cadbury - KAU Co-operative Cocoa Research Project started on 1.4.1987 was aimed at strengthening and continuing the ongoing work on genetic improvement, continuing the long-term experiments on crop management and taking up work on diseases. Ancillary studies on rooting of cuttings, top working and tissue culture were also taken up during the period. Of these ancillary studies, substantial progress was made in tissue culture research and a procedure for successful top working could be evolved. These two items of work were started since November, 1988.

Research highlights

1. A total of 24 clones were introduced as bud wood from the Quarantine Station of the University of Reading and successfully budded to be included in the germplasm collection.

2. With increasing age of hybrids, a steady improvement is observed in yield parameters.

3. The second stage of breeding was initiated by using 58 new plants of Germplasm I, II, III, IV and VI and of shade trial selected based on total yield upto 1989-'90, self-compatibility reaction and dry bean size.

4. Considerable progress could be achieved in the tissue culture of nodal explants from field grown trees. These could be successfully sprouted, shoots proliferated producing five to six leaves, rooting could be induced in these shoots and successfully planted out in pots.

5. One haploid plant could be recovered from the <u>in vitro</u> culture of flat bean embryos.

II PERSONNEL

The staff position was as follows:

Sl. No.	Post	Name of incumbent	Date of joining	Date of leaving
1.	Professor of Agronomy	Dr. R. Vikraman Nair	01.04.1987	--
2.	Associate Professor (Plant Breeding)	Dr.(Mrs.) V.K. Mallika	17.06.1987	--
3.	Associate Professor (Plant Pathology)	Dr. Koshy Abraham	01.06.1988	--
4.	Farm Assistant (Sr. Grade)	Mr. P.K. Haridas	01.04.1987	--
5.	Farm Assistant (Sr. Grade)	Mr. K.V. Natarajan	01.06.1989	--
6.	Office Assistant	Mr. K. Balakrishnan	04.06.1987	--
7.	Driver	Mr. K.V. Thankappan	--	18.10.1990
		Mr. P. Ramachandran	19.10.1990	22.12.1990
		Mr. K.M. Davy	22.12.1990	--

In addition to the above regular staff of the project, Mrs. Asha Sankar, Junior Assistant Professor, Department of Plantation Crops, College of Horticulture and Dr. N.K. Vijayakumar, Associate Professor, College of Forestry were associated with tissue culture work and Miss. Rekha and Mrs. Sindhu, Research Associate of an ICAR Ad-hoc scheme of the College of Horticulture were associated with tissue culture and breeding work of the project.

III TECHNICAL

A. CROP IMPROVEMENT

1. Germplasm collection

The germplasm collection consisting of six different sets of plants was maintained. A total of 30 types more were collected during the year. Six of these were collected as bud wood from farmers' fields from Konni of Pathanamthitta district and the remaining 24 from the Quarantine Station of the University of Reading, UK. Twenty five types collected as bud wood during 1988, budded and maintained were planted during May, 1990. With this, the total number of types field-planted so far as part of Germplasm VI comes to 159 and the total number collected to be included in this group to 194.

The details of the six sets of germplasm collections now available are given below.

Germplasm I

This is a group of plants arising from pods of 15 selected trees introduced from the Cocoa Research Institute of Ghana in 1978 and field-planted in 1979. Data on stem girth at 15 cm collected in December, 1990 and those on yield of pods from April, 1990 to March, 1991 are presented in Table 1 and Fig.1. The mean yield of types ranges from 13.3 in V_1 to 76.0 in V_{11} with an overall mean of 30.4. The mean yield of previous year was 44.2, the percentage decrease of the year being 31.2. The effect of climate is attributable to this decrease in yield which is noted in the general performance of cocoa in most of the other experiments also. With the objective of identifying superior plants from this germplasm collection, those with more than double the mean yield of the germplasm were selected. The list of such superior plants is given in Table 1 and the ranked list of such high-yielders in Table 2. The types with the largest number of four superior plants each were V_9 and V_4 followed by V_{10} with two plants. The highest yielding plant of the year is $V_{9.22}$ with an yield of 111 pods. Of the 14 plants identified as superior based on yield of the year, there was only one common to the list of

Table 1 Mean yield and girth of types of Germplasm I in the decreasing order of mean yield

Rank	Type No.	No. of plants	Yield (No. of pods)	Girth (cm)	Superior plants*
1	V_{11}	1	76.0	35.0	$V_{11.1}$(76)
2	V_8	4	59.8	38.7	$V_{8.12}$(83)
3	V_{10}	9	49.9	40.0	$V_{10.5}$(82), $V_{10.11}$(95)
4	V_9	15	48.4	43.2	$V_{9.14}$(90), $V_{9.22}$(111), $V_{9.8}$(86), $V_{9.12}$(72)
5	V_4	14	40.0	40.9	$V_{4.1}$(109), $V_{4.9}$(69), $V_{4.2}$(66), $V_{4.13}$(66)
6	V_7	7	38.9	39.9	$V_{7.5}$(64)
7	V_{15}	8	32.1	44.1	
8	V_6	16	28.8	37.1	
9	V_{12}	4	26.0	43.0	
10	V_2	15	24.7	41.4	$V_{2.9}$(63)
11	V_{13}	8	22.5	44.1	
12	V_5	11	20.5	35.4	$V5.13$(64)
13	V_{14}	17	17.3	40.8	
14	V_3	13	15.6	41.2	
15	V_1	8	13.3	34.3	
Total		149			
Mean			30.4		
Mean yield of 1989-90			44.2		

* Plants with more than double the overall mean yield are reckoned as superior. Figures in brackets indicate yield of plants.

Table 2 Ranking of superior plants of Germplasm I based on yield

Rank	Plant No.	Yield	Rank	Plant No.	Yield	Rank	Plant No.	Yield
1	$V_{9.22}$	111	6	$V_{10.5}$*	82	11	$V_{4.13}$	66
2	$V_{4.1}$	109	7	$V_{11.1}$	76	12	$V_{5.13}$	64
3	$V_{10.11}$	95	8	$V_{9.12}$	72	13	$V_{7.5}$	64
4	$V_{9.8}$	86	9	$V_{4.9}$	69	14	$V_{2.9}$	63
5	$V_{8.12}$	83	10	$V_{4.2}$	66			

* Found superior during previous year also.

Table 3 Ranking of superior plants of Germplasm I based on mean yield upto 1991 (1984-'91)

Rank	Plant No.	Yield of pods								
		84-85	85-86	86-87	87-88	88-89	89-90	90-91	Total	Mean
1	$V_{5.16}$	30	49	91	53	60	139	--	422	70.3
2	$V_{5.4}$	53	69	18	64	70	109	--	383	63.8
3	$V_{6.17}$	3	32	60	56	66	138	--	355	59.2
4	$V_{5.14}$	3	27	40	94	61	117	--	342	57.0
5	$V_{10.2}$	12	29	26	53	90	127	--	337	56.2
6	$V_{5.2}$	19	8	51	68	62	123	--	331	55.2
7	$V_{14.17}$	22	43	40	52	106	68	45	376	53.7
8	$V_{4.1}$	21	39	37	31	61	67	109	365	52.1
9	$V_{9.2}$	0	0	11	38	96	167	--	312	52.0
10	$V_{10.8}$	65	28	3	25	111	76	--	308	51.3
11	$V_{10.5}$	26	23	24	32	34	121	82	343	49.0
12	$V_{4.9}$	13	47	12	53	62	83	69	339	48.4
13	$V_{9.7}$	13	20	38	55	44	99	53	322	46.0

Contd.

Table 3 (Contd.)

Rank	Plant No.	Yield of pods								
		84-85	85-86	86-87	87-88	88-89	89-90	90-91	Total	Mean
14	$V_{10.11}$	28	22	17	44	46	66	95	318	45.4
15	$V_{8.6}$	37	0	16	0	68	81	114	316	45.1
16	$V_{4.2}$	29	8	23	57	54	77	66	314	44.9
17	$V_{8.12}$	0	26	3	44	81	74	83	311	44.4
18	$V_{13.6}$	13	16	68	50	50	94	19	310	44.3
19	$V_{4.17}$	14	16	16	68	50	98	46	308	44.0
20	$V_{6.15}$	0	3	3	83	72	90	57	308	44.0
21	$V_{9.22}$	15	2	9	2	85	80	111	304	43.4
22	$V_{7.4}$	20	29	18	51	36	86	60	300	42.9
23	$V_{10.13}$	15	43	41	37	69	39	50	294	42.0
24	$V_{15.4}$	13	20	45	48	58	69	34	287	41.0
25	$V_{4.13}$	8	38	14	63	46	51	66	286	40.9
26	$V_{2.7}$	3	23	25	38	76	74	42	281	40.1
27	$V_{4.14}$	13	28	30	60	49	73	27	280	40.0
28	$V_{5.11}$	31	65	34	49	36	40	24	279	39.9
29	$V_{4.5}$	38	62	49	50	42	24	9	274	39.1
30	$V_{5.1}$	13	58	56	64	26	39	18	274	39.1
31	$V_{9.17}$	48	0	6	16	61	71	55	257	36.7
32	$V_{9.4}$	1	20	45	61	43	47	37	254	36.3
33	$V_{2.4}$	5	19	41	46	35	67	38	251	35.9
34	$V_{4.7}$	7	93	39	48	18	29	7	241	34.4
35	$V_{6.14}$	0	4	23	23	59	70	58	237	33.9
36	$V_{9.24}$	14	17	0	3	55	102	44	235	33.6
37	$V_{2.9}$	4	15	11	34	56	48	63	231	33.0
38	$V_{4.15}$	7	6	19	51	39	66	43	231	33.0
39	$V_{9.8}$	31	15	15	9	32	39	86	227	32.4
40	$V_{10.1}$	16	19	20	33	62	16	59	225	32.1
41	$V_{10.12}$	5	16	19	30	63	37	49	219	31.3
42	$V_{14.23}$	13	25	26	70	25	26	23	208	29.7
43	$V_{5.13}$	1	11	35	24	13	33	64	181	25.9
44	$V_{9.12}$	0	2	7	28	26	43	72	178	25.4
45	$V_{1.4}$	0	4	9	49	21	69	23	175	25.0
46	$V_{7.5}$	12	17	13	4	20	41	64	171	24.4
47	$V_{11.1}$	2	5	7	4	34	28	76	156	22.3

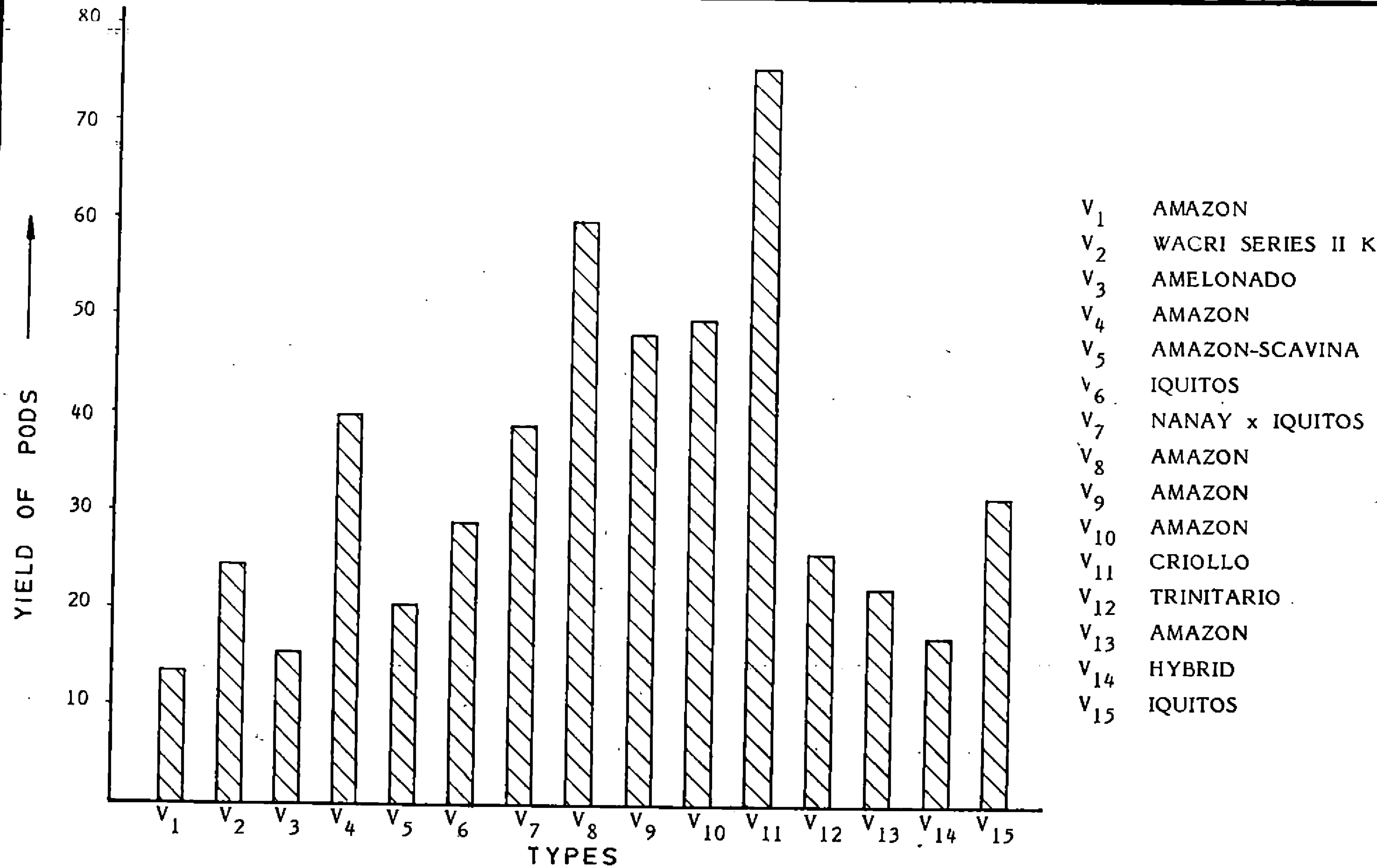

Fig - 1 MEAN YIELD OF TYPES OF GERMPLASM I (1990 - 91) superior plants of the previous year. As was done last year, the total pod yield of all the superior plants identified since 1987-88 were collected starting from 1984 when the experimental crop started yielding and these are presented in Table 3. The total number of such plants comes to 47 there being an addition of seven to the last year's total of 40. Data on the yield of the highest yielding eight plants could not be collected during the year as these were stripped of all the pods during December-January for assessment of their self-compatibility. The overall mean annual yield of the superior plants of this germplasm collection from the available data ranged from 22.3 to 70.3. The plant $V_{5.16}$ was the highest yielder followed by $V_{5.4}$, $V_{6.17}$, $V_{5.14}$ and $V_{10.2}$. With the objective of identifying plants for inclusion in the second stage of breeding, all the plants with overall mean yield of 50 pods upto last year were selected. The total number of such plants came to nine. The self-compatibility reactions of these nine plants were assessed through repeated selfing using controlled hand pollinations. Details of the number of hand pollinations done, self-compatibility positions assigned to these and the mean annual pod yield upto 1989-'90 are given in Tables 27&34Excepting two plants which were found to be self-compatible, all the remaining seven were tentatively included in the breeding programme pending further elimination based on unacceptable bean size. The selfed pods of the two self-compatible high-yielders are to be used for raising S_1 progenies with the final objective of achieving homozygosity through generations of selfing.

Germplasm II, III and IV

These collections, established in 1980 include seedling populations of 80 types collected from promising plants of various plantations of Kerala. Data on stem girth recorded in December, 1990 and yields of pods for the year are given in Table 4 and Fig.2. In Germplasm II, the overall mean yield of 126 plants of 26 types was 21.3 and the range in mean values was from 9.4 in GII-4 to 43.8 in GII-11. The overall mean of the previous year was 37.5, the extent of decrease being 43.2 per cent. As in Germplasm I, the effect of climate is attributable to the substantial decrease in mean yield of the year. Superior plants with more than double the overall mean yield were identified. There were a total of 18 such plants and the highest yielding plant of this

Table 4 Mean yield and girth of types of Germplasm II in the decreasing order of mean yield

Rank	Type No.	No. of plants	Yield (No. of pods)	Girth (cm)	Superior plants*
1	GII-11	4	43.8	46.5	11.4(81), 11.3(43)
2	GII-12	5	36.4	47.0	12.5(55), 12.4 (53)
3	GII-10	5	32.6	42.6	10.2(46)
4	GII-17	3	29.7	41.3	17.1(46)
5	GII-19	3	29.3	44.0	19.4(44)
6	GII-16	5	27.4	34.0	16.1(61)
7	GII-6	4	27.3	42.5	6.6(57)
8	GII-8	6	27.0	35.5	
9	GII-9	4	27.0	42.5	9.5(61)
10	GII-22	8	26.0	49.8	22.3(96), 22.4(50)
11	GII-21	5	23.6	43.8	21.2(69)
12	GII-26	3	23.3	36.7	26.1(44)
13	GII-7	3	21.7	41.3	
14	GII-25	6	20.7	34.5	25.7(52)
15	GII-20	5	20.6	40.8	20.2(56)
16	GII-24	7	20.3	39.4	24.6(56)
17	GII-15	4	18.3	37.0	
18	GII-1	4	18.0	41.8	
19	GII-18	2	18.0	40.0	
20	GII-13	4	17.5	35.8	
21	GII-23	7	13.6	43.0	23.2(55)
22	GII-14	5	12.0	31.2	
23	GII-5	6	10.8	37.3	
24	GII-3	6	10.2	37.3	
25	GII-2	6	9.8	38.7	
26	GII-4	5	9.4	37.8	
Total		126			
Mean			21.3		
Mean yield of 1989-90			37.5		

* Plants with more than double the overall mean yield are reckoned as superior. Figures in brackets indicate yield of plants.

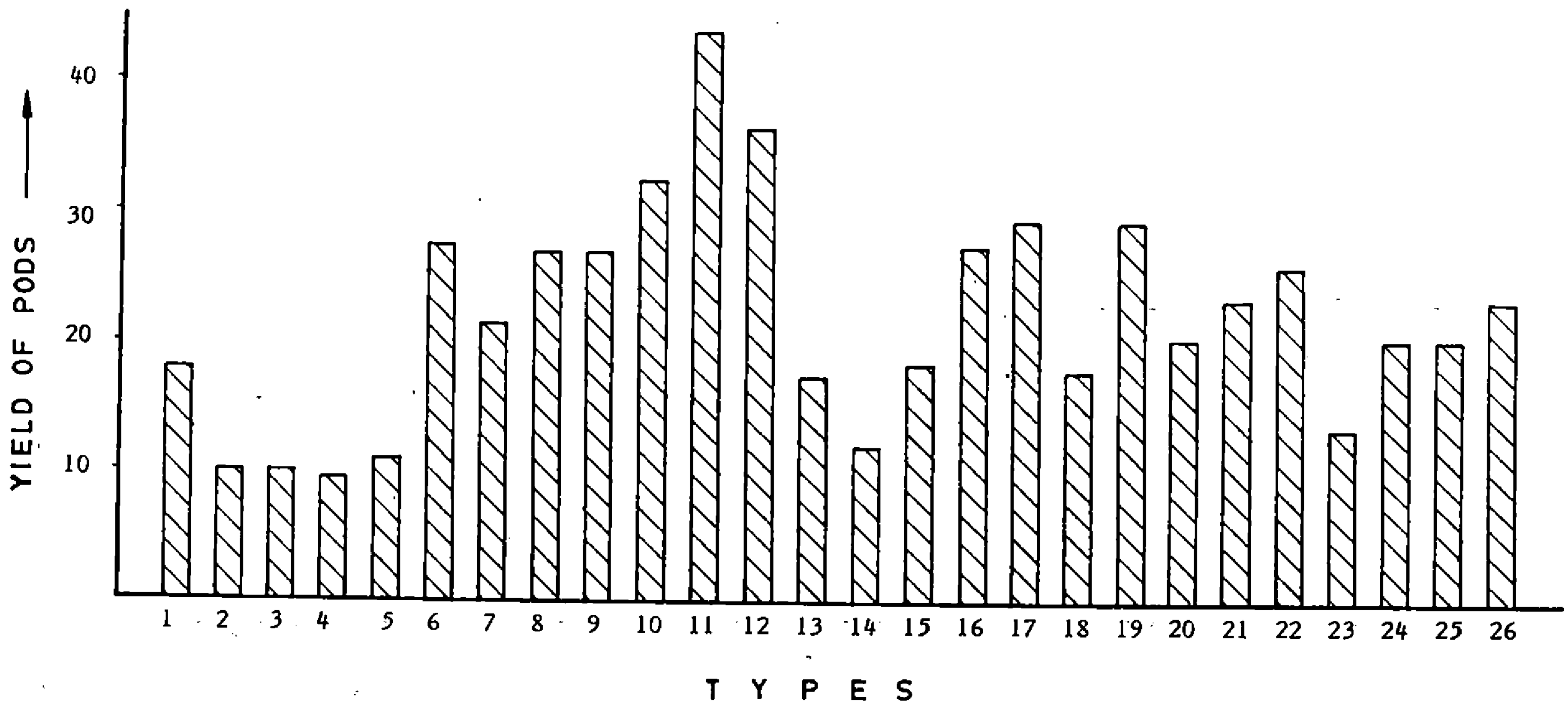

Fig - 2 MEAN YIELD OF TYPES OF GERMPLASM II (1990 - 91)

Table 5 Ranking of superior plants of Germplasm II based on yield

Rank	Plant No.	Yield	Rank	Plant No.	Yield	Rank	Plant No.	Yield
1	GII-22.3	96	7	GII-20.2	56	13	GII-22.4	50
2	GII-11.4*	81	8	GII-24.6	56	14	GII-10.2	46
3	GII-21.2*	69	9	GII-12.5	55	15	GII-17.1	46
4	GII-9.5	61	10	GII-23.2*	55	16	GII-19.4	44
5	GII-16.1	61	11	GII-12.4	53	17	GII-26.1	44
6	GII-6.6*	57	12	GII-25.7	52	18	GII-11.3	43

* Found superior during previous year also.

Table 6 Ranking of superior plants of Germplasm II based on mean yield upto 1991 (1984-1991)

Rank	Plant No.	Yield of pods								
		84-85	85-86	86-87	87-88	88-89	89-90	90-91	Total	Mean
1	GII-23.3	26	22	19	40	71	142	-	320	53.3
2	GII-18.2	3	15	37	50	87	126	-	318	53.0
3	GII-7.3	30	19	29	39	53	131	-	301	50.2
4	GII-16.3	2	17	31	21	70	144	-	285	47.5
5	GII-22.3	12	33	41	26	83	36	96	327	46.7
6	GII-14.3	2	4	7	29	138	95	-	275	45.8
7	GII-11.4	29	2	26	11	46	117	81	312	44.6
8	GII-7.2	15	13	24	66	56	82	-	256	42.7
9	GII-24.4	4	15	20	12	89	110	-	250	41.7
10	GII-12.5	0	6	29	23	101	64	55	278	39.7
11	GII-17.1	0	10	4	42	99	68	46	269	38.4
12	GII-7.4	31	14	55	23	78	45	21	267	38.1
13	GII-24.6	10	8	14	29	73	69	56	259	37.0
14	GII-8.4	11	41	19	33	46	57	31	238	34.0
15	GII-13.5	2	35	11	29	70	52	36	235	33.6
16	GII-23.2	7	11	11	1	50	100	55	235	33.6

Contd.

Table 6 (Contd.)

Rank	Plant No.	Yield of pods								
		84-85	85-86	86-87	87-88	88-89	89-90	90-91	Total	Mean
17	GII-6.6	0	0	2	7	74	94	57	234	33.4
18	GII-12.4	16	7	23	10	51	69	53	229	32.7
19	GII-6.4	9	4	22	31	53	61	30	210	30.0
20	GII-22.4	0	23	11	17	31	57	50	189	27.0
21	GII-19.6	17	21	27	41	40	25	15	186	26.6
22	GII-8.6	0	8	0	15	65	56	42	186	26.6
23	GII-21.2	18	12	2	0	6	75	69	182	26.0
24	GII-3.2	0	28	33	23	26	46	25	181	25.9
25	GII-10.1	9	2	17	0	53	63	34	178	25.4
26	GII-20.6	19	36	21	24	31	27	16	17.4	24.9
27	GII-19.4	3	0	0	9	49	67	44	172	24.6
28	GII-8.1	4	32	37	25	31	13	24	166	23.7
29	GII-8.2	7	31	34	37	16	16	21	162	23.1
30	GII-11.6	16	7	12	30	27	39	30	161	23.0
31	GII-18.5	0	0	5	4	32	85	35	161	23.0
32	GII-10.5	0	11	6	23	44	42	34	160	22.9
33	GII-9.1	12	17	22	6	52	32	17	158	22.6
34	GII-7.1	2	10	14	40	30	33	25	154	22.0
35	GII-10.2	1	0	3	7	38	54	46	149	21.3
36	GII-9.3	2	1	3	25	26	70	20	147	21.0
37	GII-20.2	0	0	0	2	33	48	56	139	19.9
38	GII-24.7	0	13	47	27	37	9	5	138	19.7
39	GII-3.4	0	9	0	21	45	36	17	128	18.3
40	GII-1.4	2	17	22	37	14	25	8	125	17.9
41	GII-2.4	23	11	42	23	22	33	4	125	17.9
42	GII-25.7	0	4	3	23	14	26	52	122	17.4
43	GII-5.2	11	18	20	25	9	21	17	121	17.3
44	GII-9.5	0	5	0	0	5	45	61	116	16.6
45	GII-26.1	0	6	0	3	17	36	44	106	15.1
46	GII-16.1	0	0	2	0	4	37	61	104	14.9
47	GII-13.3	0	7	11	31	17	28	8	102	14.6
48	GII-11.3	0	0	0	0	2	54	43	99	14.1

collection during the year was GII-22.3 with a pod yield of 96 (Table 5). Out of the 18 superior plants of the year, four were identified as superior last year also. As in Germplasm I, the total pod yield so far of all the superior plants identified since 1987-'88 was compiled for the period from 1984-'85 and the data are given in Table 6. The number of such plants comes to 48 and the range in mean yield for the period from 1984-'85 was from 14.1 to 53.3. There were 8 new additions to the list of superior plants during this year. The highest yielding five plants based on the total yield so far are GII-23.3, GII-18.2, GII-7.3, GII-16.3 and GII-22.3. The yield figures of seven high yielders could not be collected this year as these were used for hand pollination work for assessment of self-compatibility. Based on the results till last year, eight plants were selected as generally superior. The basis of selection in this Germplasm planted in 1980 was a mean annual yield of 40 pods. The selected plants are 23.3, 18.2, 7.3, 16.3, 14.3, 7.2, 24.4 and 7.4. These plants were studied further for their self-compatibility by repeated selfing starting from January, 1991. Details of hand pollinations done, number of selfed pods set and self compatibility positions are given in Table 34. Out of eight plants studied, five were found to be self-compatible and the remaining three, self-incompatible. The self-incompatible plants are 7.3, 16.3 and 23.3. Pending assessment of the pod and bean characters and elimination of types with dry bean weight of less than 1 g, all the three self-incompatible plants were included in the second stage of breeding starting with assessment of general combining ability.

The overall mean pod yield of Germplasm III was 24.8 and the range in mean yield from 14.5 to 47.8. This mean yield denotes a decrease of 20.9 per cent over the previous year's overall mean of 35.9. The type recording the highest yield this year is GIII-1 with a mean of 47.8 followed by GIII-4 with 43.8. Both these two types were already represented in the breeding programme through the plants, GIII-1.2 and GIII-4.1. There are 12 superior plants in this group and the highest yielder is GIII-11.2 with an yield of 92 pods. The number of plants appearing in the list of superior plants during both this year and previous year is only four. Data on the mean yield of types appear in Table 7 and Fig.3 and the ranked list of superior plants in Table 8.

Table 7 Mean yield and girth of types of Germplasm III in the decreasing order of mean yield

Rank	Type No.	No. of plants	Yield (No. of pods)	Girth (cm)	Superior plants
1	GIII-1	5	47.8	51.6	1.1(56), 1.5(55), 1.7(53)
2	GIII-4	4	43.8	43.8	4.1(69), 4.2(57)
3	GIII-11	6	37.7	42.8	11.2(92), 11.3(50)
4	GIII-2	5	36.4	48.0	2.1(61)
5	GIII-10	4	34.3	43.6	10.1(76), 10.7(55)
6	GIII-15	2	32.5	38.5	
7	GIII-18	7	26.0	39.7	
8	GIII-12	6	25.8	43.8	12.4(79)
9	GIII-9	5	25.2	42.0	9.3(63)
10	GIII-6	6	23.5	43.7	
11	GIII-14	4	22.8	42.8	
12	GIII-16	4	22.0	37.0	
13	GIII-5	5	21.2	47.0	
14	GIII-7	5	21.2	35.8	
15	GIII-17	5	19.8	38.2	
16	GIII-13	5	18.8	46.6	
17	GIII-8	6	15.2	36.3	
18	GIII-3	4	14.5	39.3	
Total		88			
Mean			24.8		
Mean yield of 1989-'90			35.9		

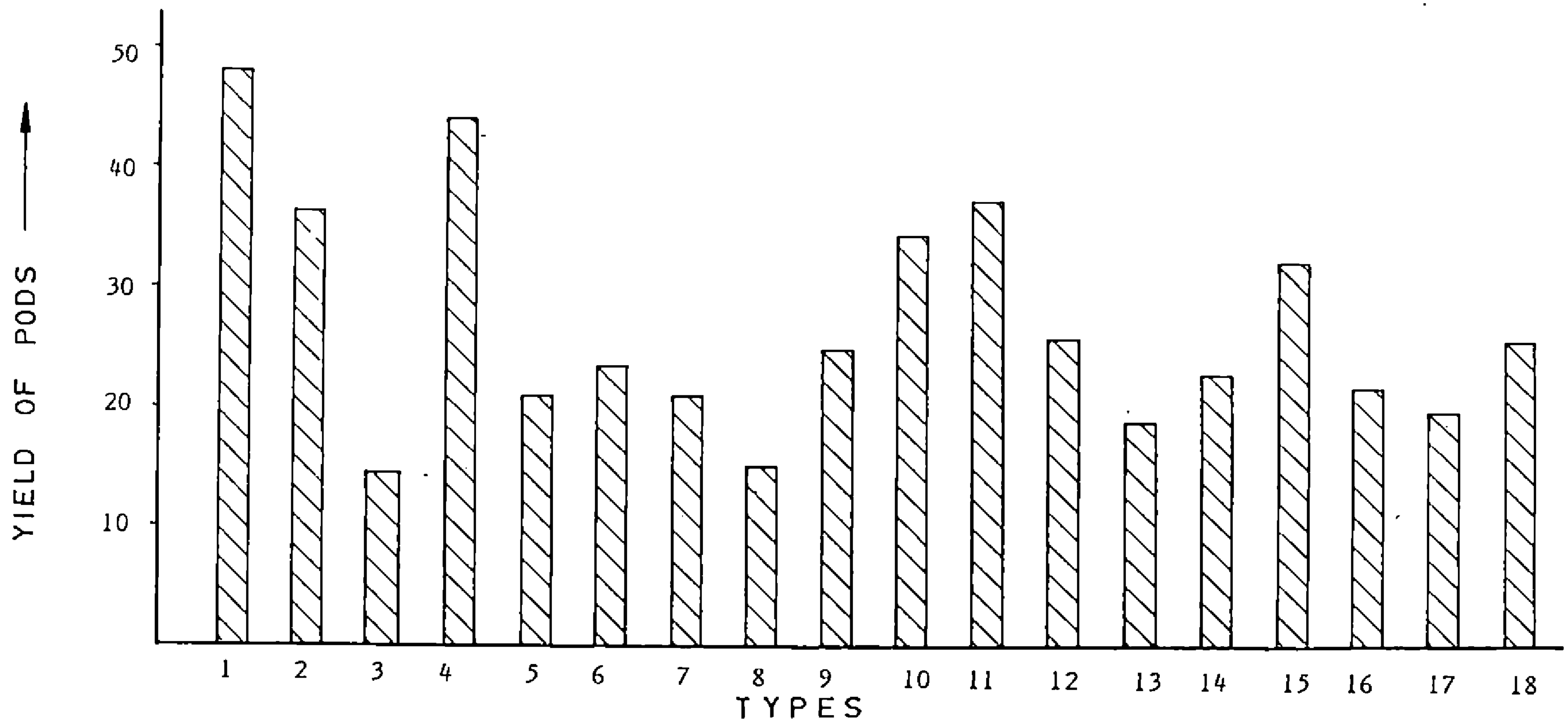

Fig-3 MEAN YIELD OF TYPES OF GERMPLASM III (1990-91)

Table 8 Ranking of superior plants of Germplasm III based on yield

Rank	Plant No.	Yield	Rank	Plant No.	Yield
1	11.2*	92.0	7	4.2	57
2	12.4*	79.0	8	1.1	56
3	10.1*	76.0	9	1.5	55
4	4.1*	69.0	10	10.7	55
5	9.3*	63.0	11	1.7	53
6	2.1	61.0	12	11.3	50

* Found superior during previous year also.

Table 9 Ranking of superior plants of Germplasm III based on mean yield upto 1991 (1984-'1991)

Rank	Type No.	Yield of pods								
		84-85	85-86	86-87	87-88	88-89	89-90	90-91	Total	Mean
1	GIII-8.6	1	6	43	34	107	65	-	256	42.7
2	GIII-9.3	6	11	31	32	48	105	63	296	42.3
3	GIII-4.2	0	27	29	33	49	63	57	258	36.9
4	GIII-7.1	5	16	34	47	65	56	34	257	36.7
5	GIII-11.3	0	9	67	39	69	22	50	256	36.6
6	GIII-4.1	11	0	10	23	41	83	69	237	33.9
7	GIII-6.3	0	0	7	14	46	123	38	228	32.6
8	GIII-10.1	0	1	6	2	33	105	76	223	31.9
9	GIII-12.4	0	1	7	24	30	81	79	222	31.7
10	GIII-11.5	0	9	32	22	53	66	37	219	31.3
11	GIII-11.2	0	6	1	0	12	88	92	199	28.4
12	GIII-2.1	0	2	31	26	10	58	61	188	26.9

Contd.

Table 9 (Contd.)

Rank	Type No.	Yield of pods 84-85	85-86	86-87	87-88	88-89	89-90	90-91	Total	Mean
13	GIII-2.2	2	18	12	33	48	41	33	187	26.7
14	GIII-1.5	0	0	0	43	25	60	55	183	26.1
15	GIII-18.5	0	8	38	21	47	40	28	182	26.0
16	GIII-2.4	3	14	11	23	41	64	24	180	25.7
17	GIII-1.2	4	2	13	11	34	77	37	178	25.4
18	GIII-18.7	0	3	5	17	62	64	22	173	24.7
19	GIII-1.7	0	14	20	27	21	36	53	171	24.4
20	GIII-4.6	3	17	18	21	42	53	14	168	24.0
21	GIII-8.4	0	15	25	25	53	33	11	162	23.1
22	GIII-10.7	0	0	12	21	29	44	55	161	23.0
23	GIII-1.1	0	0	0	9	26	62	56	153	21.9
24	GIII-12.3	1	2	20	48	59	5	0	135	19.3
25	GIII-3.1	0	1	1	8	44	33	43	130	18.6
26	GIII-7.7	0	9	14	26	22	27	15	113	16.1

Table 10 Mean yield and girth of types of Germplasm IV in the decreasing order of mean yield

Rank	Type No.	No. of plants	Yield (No. of pods)	Girth (cm)	Superior plants
1	GIV-1	4	62.8	44.3	1.4(78), 1.7(142)
2	GIV-36	6	62.5	42.5	36.5(75), 36.7(90), 36.9(125)
3	GIV-33	4	48.8	43.5	33.4(58), 33.9(114)
4	GIV-2	8	41.0	44.0	2.5(84), 2.7(63), 2.9(53)
5	GIV-32	5	40.8	43.6	32.8(67), 32.9(86)
6	GIV-6	7	35.6	42.4	6.3(61), 6.8(66)
7	GIV-3	7	30.6	40.4	3.9(98)
8	GIV-27	5	29.6	38.6	27.6(57), 27.8(75)
9	GIV-35	3	28.3	44.0	

Contd.

Table 10 (Contd.)

Rank	Type No.	No. of plants	Yield (No. of pods)	Girth (cm)	Superior plants
10	GIV-5	9	27.8	41.0	5.5(73), 5.7(65)
11	GIV-4	5	27.2	43.3	
12	GIV-8	6	26.5	53.3	8.2(79)
13	GIV-11	8	22.6	39.0	
14	GIV-31	5	22.4	35.3	31.7(50)
15	GIV-12	8	22.1	37.6	12.9(50)
16	GIV-17	4	22.0	38.0	
17	GIV-7	5	21.8	41.6	7.8(64)
18	GIV-19	6	21.7	36.8	
19	GIV-13	9	21.2	34.9	13.1(108)
20	GIV-18	4	21.0	37.3	
21	GIV-16	4	20.5	39.3	
22	GIV-15	6	20.3	34.5	
23	GIV-25	7	18.9	34.4	
24	GIV-14	7	18.7	46.0	
25	GIV-30	6	18.5	38.5	
26	GIV-29	4	17.5	40.3	29.9(57)
27	GIV-34	5	17.4	37.8	
28	GIV-24	4	16.8	31.0	
29	GIV-22	7	16.0	35.6	
30	GIV-26	3	14.3	38.0	
31	GIV-28	6	13.3	35.8	
32	GIV-9	5	12.8	36.6	
33	GIV-20	6	11.8	37.0	
34	GIV-10	7	10.1	39.3	
35	GIV-23	7	8.9	34.3	
36	GIV-21	3	5.7	32.0	
Total		205			
Mean			24.3		
Mean yield of 1989-'90			32.9		

Table 11 Ranking of superior plants of Germplasm IV based on yield

Rank	Plant No.	Yield	Rank	Plant No.	Yield	Rank	Plant No.	Yield
1	GIV-1.7*	142	9	GIV-8.2	79	17	GIV-7.8	64
2	GIV-36.9*	125	10	GIV-1.4*	78	18	GIV-2.7*	63
3	GIV-33.9*	114	11	GIV-27.8	75	19	GIV-6.3	61
4	GIV-13.1*	108	12	GIV-36.5	75	20	GIV-33.4	58
5	GIV-3.9	98	13	GIV-5.5	73	21	GIV-27.6	57
6	GIV-36.7*	90	14	GIV-32.8	67	22	GIV-29.9*	57
7	GIV-32.9*	86	15	GIV-6.8	66	23	GIV-12.9*	50
8	GIV-2.5*	84	16	GIV-5.7*	65	24	GIV-31.7	50

* Found superior during previous year also.

Table 12 Ranking of superior plants of Germplasm IV based on mean yield upto 1991 (1984-1991)

Rank	Plant No.	Yield of pods 84-85	85-86	86-87	87-88	88-89	89-90	90-91	Total	Mean
1	GIV-35.7	0	17	23	105	141	182	--	468	78.0
2	GIV-13.1	16	9	120	9	80	100	108	442	63.1
3	GIV-14.2	4	18	49	32	137	67	--	307	51.2
4	GIV-1.7	2	14	18	31	44	106	142	357	51.0
5	GIV-33.9	3	11	4	27	56	122	114	337	48.1
6	GIV-36.6	0	14	20	31	88	115	--	268	44.7
7	GIV-36.7	0	28	39	45	37	69	90	308	44.0
8	GIV-1.2	5	10	31	19	98	98	--	261	43.5
9	GIV-2.5	11	0	1	23	34	148	84	301	43.0
10	GIV-36.9	0	0	5	8	72	91	125	301	43.0
11	GIV-4.5	0	1	29	26	61	138	--	255	42.5
12	GIV-10.9	0	15	32	33	82	91	--	253	42.2
13	GIV-1.4	0	0	33	33	75	76	78	295	42.1

Contd.

Table 12 (Contd.)

Rank	Plant No.	Yield of pods							Total	Mean
		84-85	85-86	86-87	87-88	88-89	89-90	90-91		
14	GIV-3.9	10	21	15	11	78	62	98	295	42.1
15	GIV-12.9	0	3	19	29	69	112	50	282	40.3
16	GIV-2.7	9	13	16	22	64	93	63	280	40.0
17	GIV-13.5	4	42	41	54	34	41	38	254	36.3
18	GIV-2.9	2	1	21	27	60	81	53	245	35.0
19	GIV-10.7	2	11	25	35	90	50	20	233	33.3
20	GIV-16.5	0	2	34	12	61	73	48	230	32.9
21	GIV-31.7	0	7	25	15	71	54	50	222	31.7
22	GIV-32.9	4	6	19	9	26	69	86	219	31.3
23	GIV-32.8	0	0	16	16	64	48	67	211	30.1
24	GIV-29.9	0	6	5	12	62	67	57	209	29.9
25	GIV-5.7	2	8	10	8	34	81	65	208	29.7
26	GIV-27.8	0	5	3	32	33	58	75	206	29.4
27	GIV-36.8	2	3	13	12	58	69	38	195	27.9
28	GIV-27.6	0	8	10	14	49	55	57	193	27.6
29	GIV-30.8	9	21	14	12	64	55	17	192	27.4
30	GIV-14.9	0	1	0	4	68	77	42	192	27.4
31	GIV-35.5	9	7	21	27	41	46	39	190	27.1
32	GIV-8.2	0	0	4	3	48	54	79	188	26.9
33	GIV-5.5	0	0	12	16	21	64	73	186	26.6
34	GIV-4.2	3	16	20	25	35	39	46	184	26.3
35	GIV-36.5	0	0	4	9	41	54	75	183	26.1
36	GIV-7.8	1	0	9	7	55	40	64	176	25.1
37	GIV-33.4	0	1	24	6	75	10	58	174	24.9
38	GIV-5.8	0	7	9	10	50	53	43	172	24.6
39	GIV-14.1	7	14	19	23	27	44	38	172	24.6
40	GIV-4.9	6	3	1	4	32	85	35	166	23.7
41	GIV-6.7	1	12	3	5	62	45	38	166	23.7
42	GIV-30.6	0	20	4	11	47	39	38	159	22.7

Contd.

Table 12 (Contd.)

Rank	Plant No.	Yield of pods							Total	Mean
		84-85	85-86	86-87	87-88	88-89	89-90	90-91		
43	GIV-25.9	7	5	12	20	22	44	45	155	22.1
44	GIV-7.3	11	18	0	70	23	29	1	152	21.7
45	GIV-13.3	4	14	17	20	38	38	9	140	20.0
46	GIV-34.3	0	2	5	13	57	36	23	136	19.4
47	GIV-19.9	3	7	13	40	18	22	32	135	19.3
48	GIV-30.5	0	14	0	5	56	39	20	134	19.1
49	GIV-12.5	2	22	28	19	21	28	9	129	18.4
50	GIV-16.4	1	15	36	28	15	34	3	126	18.0
51	GIV-6.3	0	0	0	6	13	43	61	123	17.6
52	GIV-6.8	0	4	4	4	8	35	66	121	17.3
53	GIV-24.5	0	1	1	19	22	29	41	113	16.1
54	GIV-13.8	0	0	5	22	33	35	15	110	15.7
55	GIV-5.6	0	0	0	7	18	66	18	109	15.6
56	GIV-9.2	2	18	22	25	10	BS	BS	77	15.4
57	GIV-26.8	0	24	31	19	5	15	10	104	14.9
58	GIV-9.1	0	0	16	5	56	8	8	103	14.7
59	GIV-34.4	0	0	3	4	49	13	6	75	10.7
60	GIV-3.5	0	6	2	0	4	34	11	57	8.1
61	GIV-4.6	0	10	12	20	4	2	0	48	6.9

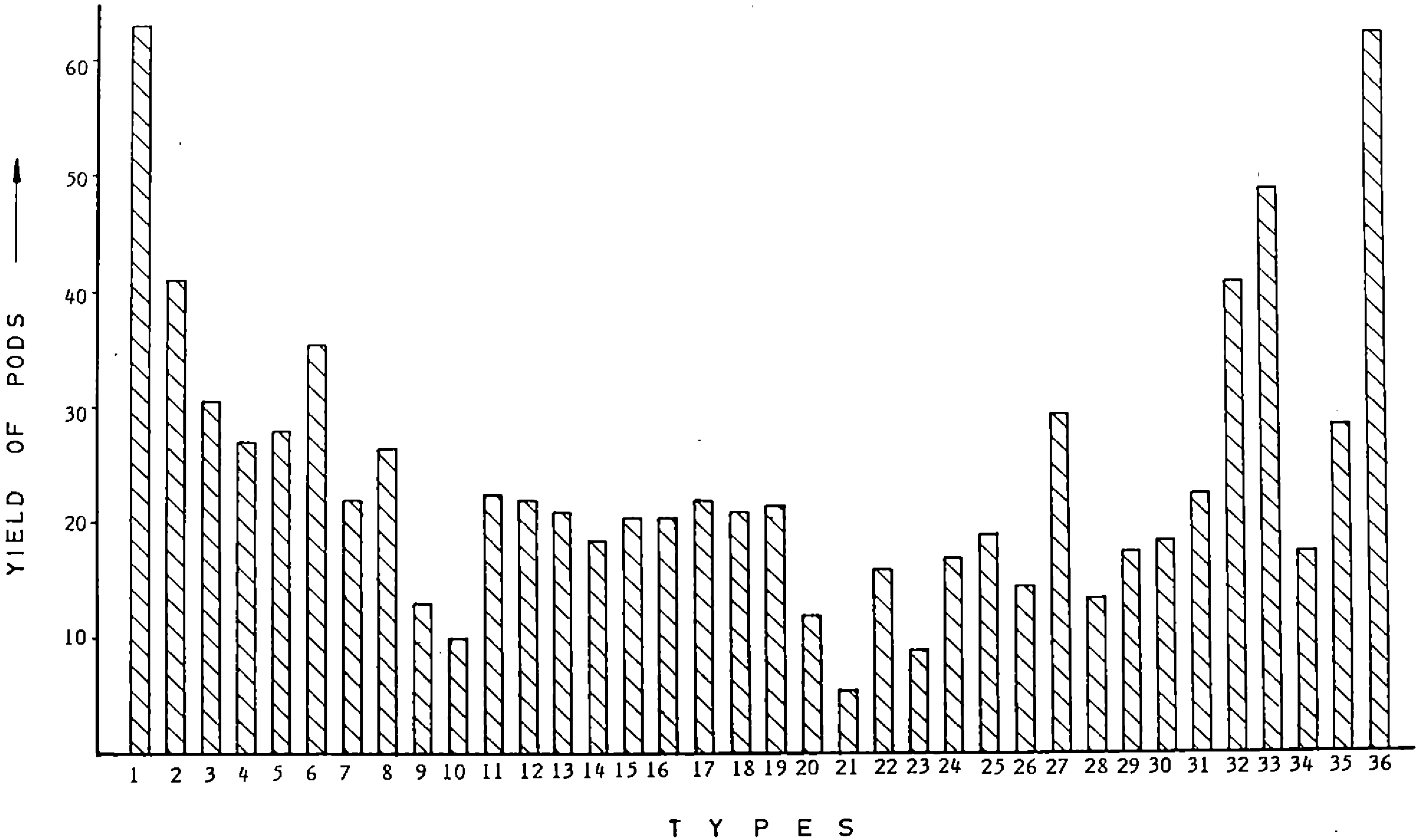

Fig-4 MEAN YIELD OF TYPES OF GERMPLASM IV (1990-91)

Yield data of plants identified as superior so far were compiled and these are given in Table 9. There were two new additions to the list of superior plants this year. Based on the procedure followed for Germplasm I and II, one plant was identified as generally superior and the basis of selection was an yield of over 40 pods. This plant is GIII 8.6 which was later found to be self-compatible. As such, no new plant was included in the new breeding programme.

In Germplasm IV, the range in mean yield was from 5.7 in GIV-21 to 62.8 in GIV-1 with an overall mean of 24.3. The corresponding overall mean of the previous year was 32.9, the extent of decrease in yield being 26.1 per cent. A total of 24 superior plants appeared in this population of 205 plants whose data could be collected. The highest yielder of the year was GIV-1.7 and its yield was 142 pods. Twelve out of the 24 superior plants were identified as superior last year also. As in the case of the other three sets of germplasm collections, data on yield of all the plants identified as superior during the last four years were compiled for the period from 1984-'85 and these are given in Table 12. The total number of such plants comes to 61, a net addition of five new plants to this group of superior plants during this year. The plant GIV-9.9 identified as superior based on data upto last year was deleted from the list this year as this plant died. The plants newly added to the group are GIV-5.5, GIV-6.3, GIV-6.8, GIV-27.8 and GIV-36.5. Yield data from six high-yielding plants could not be collected during the year as these were used for self-compatibility studies. Highest yielding plants of this germplasm collection based on data upto last year were also subject to further studies on self-compatibility reaction. The total number of plants selected as high-yielding was seven and the basis of selection was an yield of over 40 pods. Two out of these seven were found to be self-compatible. Details of the number of pollinations done and the self-compatibility positions appear in Table 34. The five self-incompatible plants were used for assessment of their general combining ability.

Germplasm V

he collection originally included budded plants of 50 types from promising plants of unknown parentage. These were field-planted in 1981 with a total population of 185. There are many gaps in the area and the present population of surviving plants is 53 belonging to 28 types. Data on the yield of these plants is given in Table 13. The range in mean yield of types is from 0 in GV-32 to 81 in GV-3. Unlike what it is in rest of the germplasm collections, there was an increase in mean yield from last year's mean of 23.9 to 29.9. It may be recalled that contrary to the general increase in yield last year over 1988-'89 in nearly all the rest of the experimental area, it was a decrease that was noted in this germplasm collection. There are a total of seven superior plants with more than double the mean yield. Three of these are common with the list of last year. As was done last year, the yields of all the plants identified as superior during the last four years were compiled and the list of such plants ranked based on total yield obtained from the first bearing is given in Table 15. The total number of such plants is 13 and the range in mean yield for the six-year period, 16.9 to 35.9. The highest yielding plants based on the compiled data are 3.2, 1.6, 2.1, 1.3 and 2.6. As the same types were collected and included in Germplasm VI, no plant from Germplam V was included in the breeding programme.

Germplasm VI

This collection of vegetatively propagated types was originally established in 1983 with a total of 126 types collected from CPCRI Regional Station, Vittal, Cadbury Farm, Thamarassery, RARS, Pilicode and CPCRI Sub-station, Kannara and was expected to include nearly all the cocoa types introduced into the country from time to time. Following the original field-planting of these 126 types in 1983, there had been some losses and the total number that survived was only 91. A fresh collection of 26 out of these missing 35 types was made in 1988 from Vittal, Kannara and Pilicode and these were planted in August. New budded types were added to this germplasm collection mainly of plants from farmers' fields with reported superiority in yield performance. The total number field-established so far comes to 159.

Collection of bud wood was continued during the year and in addition to that from farmers' fields, a total of 24 clones were introduced from the Quarantine Station of the University of Reading during December, 1990. The list of types introduced is given in Table 16. All these were successfully budded and are being maintained in isolation for watching for freedom from diseases. These are proposed

Table 13 **Mean yield of types of Germplasm V in the decreasing order of mean yield**

Rank	Type No.	No. of plants	Yield (No. of pods)	Superior plants*
1	GV-3	2	81.0	3.2(81)
2	GV-16	1	64.0	16.8(64)
3	GV-1	6	63.0	1.3(86), 1.5(71), 1.6(65)
4	GV-2	3	54.0	2.1(75), 2.6(68)
5	GV-17	1	48.0	
6	GV-29	1	44.0	
7	GV-28	1	43.0	
8	GV-34	1	41.0	
9	GV-19	2	36.0	
10	GV-13	2	34.5	
11	GV-37	1	34.0	
12	GV-9	1	30.0	
13	GV-25	1	28.0	
14	GV-12	1	26.0	
15	GV-33	2	26.0	
16	GV-21	3	20.0	
17	GV-14	2	19.0	
18	GV-8	3	14.0	
19	GV-22	3	13.7	
20	GV-7	3	12.3	
21	GV-26	1	12.0	
22	GV-11	1	11.0	
23	GV-31	2	5.5	
24	GV-5	1	5.0	
25	GV-24	2	1.5	
26	GV-23	4	1.3	
27	GV-4	1	1.0	
28	GV-32	1	0.0	
Total		53		
Mean			29.9	
Mean yield of 1989-'90			23.9	

* Plants with more than double the overall mean yield are reckoned as superior. Figures in brackets indicate yield of plants

Table 14 Ranking of superior plants of Germplasm V based on yield

Rank	Plant No.	Yield	Rank	Plant No.	Yield	Rank	Plant No.	Yield
1	GV-1.3	86	4	GV-1.5	71	7	GV-16.8*	64
2	GV-3.2	81	5	GV-2.6	68			
3	GV-2.1*	75	6	GV-1.6*	65			

* Found superior during previous year also

Table 15 Ranking of superior plants of Germplasm V based on total yield upto 1990 (1984-1991)

Rank	Plant No.	Yield of pods							Total	Mean
		84-85	85-86	86-87	87-88	88-89	89-90	90-91		
1	GV-3.2	0	0	4	1	55	34	157	251	35.9
2	GV-1.6	13	7	34	9	55	55	65	238	34.0
3	GV-2.1	0	4	3	0	96	45	75	223	31.9
4	GV-1.3	0	5	5	0	71	45	86	212	30.3
5	GV-2.6	0	0	13	0	60	47	68	188	26.9
6	GV-1.5	3	8	6	27	39	34	71	188	26.9
7	GV-13.4	0	2	4	2	82	55	41	186	26.6
8	GV-16.8	0	0	3	19	33	58	64	177	25.3
9	GV-28.3	0	0	5	9	61	54	43	172	24.6
10	GV-1.4	0	4	17	0	28	54	56	159	22.7
11	GV-1.2	1	0	20	0	28	52	50	151	21.6
12	GV-17.2	0	0	0	0	50	37	48	135	19.3
13	GV-31.4	0	0	8	0	66	34	10	118	16.9

Table 16 List of types introduced from University of Reading

Sl. No.	Type	Sl.No.	Type	Sl.No.	Type
1	AMAZ 3-2	9	EQX 78	17	MAN 15-60
2	AMAZ 6-3	10	ICS 16	18	PA 7
3	AMAZ 15	11	ICS 100	19	PA 56
4	BE 3	12	IMC 20	20	SC 1
5	BE 10	13	LAF 1	21	TJ 1
6	CC 11	14	LCT EEN 127	22	UF 227
7	EQX Z	15	LCT EEN 162-1010	23	UF 667
8	EQX 69	16	MAN 15-2	24	UF 676

Table 17 Mean yield of types of Germplasm VI in the decreasing order of mean yield

Rank	Type No.	Parentage	No. of plants	Mean yield
1	44	Landas 357 (s)	4	75.8
2	24	$W_{5/15}$ ($T_{63/884}$) (s)	2	71.5
3	15	NA (s)	1	71.0
4	54	SIAL 93 (b)	2	67.0
5	14	C 78 (s)	4	66.3
6	7	P_3 x P_4 (s)	4	52.0
7	50	ICS 6 (c)	5	50.0
8	25	$T_{7/12}$ (s)	3	47.0
9	85	Landas 18 (s)	1	46.0
10	17	NA (s)	1	45.0
11	59	ICS 6 (b)	2	44.0
12	10	CF 176 x $T_{19/5}$) (s)	4	43.8

Contd.

Table 17 (Contd.)

Rank	Type No.	Parentage	No. of plants	Mean yield
13	19	$W_{6/56}$ ($T_{63/970}$) (s)	5	42.4
14	6	C 44 (s)	3	42.3
15	9	P_3 x P_1 (s)	3	42.0
16	22	P_{12} x P_2 (s)	5	41.2
17	33	Amel x Na 33 (s)	3	40.3
18	31	P_7 x P_6 (s)	2	38.5
19	61	C 6 (s)	5	38.4
20	49	SCA 6 (s)	2	37.5
21	79	Landas 5 (s)	4	37.0
22	40	Jerangau Amel x Na 33 (s)	4	36.0
23	34	Amel x Na 32 (s)	3	34.0
24	94	Landas 36 (s)	2	33.5
25	2	C 42 (s)	5	33.4
26	56	EET 272 (b)	5	33.4
27	45	Landas 361 (s)	5	33.0
28	43	Jerangau Amel x Pa 7 (s)	4	32.5
29	21	$T_{65/7}$ (s)	3	32.0
30	29	P_6 x P_6 (s)	2	28.5
31	82	Landas 14 (s)	2	28.0
32	3	$T_{17/11}$ (s)	3	27.0
33	35	PA_7 x Na 32 (s)	5	26.0
34	67	P_{5c} (b)	2	26.0
35	16	P_6 x P_4 (s)	2	25.0
36	13	$T_{30/10}$ x Na 32 (s)	5	25.0
37	37	Landas 365 (s)	5	24.8
38	28	P_{10} x P_1 (s)	2	24.0
39	52	Na 31 (c)	4	23.8
40	30	$T_{85/5}$ x Na 32 (s)	2	23.5
41	51	IMC 67 (c)	5	23.2
42	23	P_9 x P_4 (s)	1	23.0
43	55	IMC 10 (b)	4	22.5
44	80	Landas 8 (s)	4	22.3

Contd.

Table 17 (Contd.)

Rank	Type No.	Parentage	No. of plants	Mean yielc
45	46	Na 33 (s)	3	21.3
46	4	C 76 (s)	2	21.0
47	86	Landas 19 (s)	5	20.8
48	36	Landas 364 (s)	4	20.5
49	27	P_9 x P_7 (s)	1	19.0
50	53	MOQ 413 (b)	2	19.0
51	39	Landas 356 (s)	2	18.5
52	68	P_{7c} (b)	4	17.5
53	11	C 79 (s)	3	16.0
54	8	P_4 x P_1 (s)	3	14.7
55	26	P_1 x P_7 (s)	1	14.0
56	60	Na 33 (b)	4	13.0
57	48	ICS 6 (s)	5	10.4
58	83	Landas 16 (s)	2	9.0
59	42	Jerangau PA 7 x Na 32 (s)	4	8.3
60	20	$T_{86/2}$ (s)	4	7.8
61	122	Jerangau 57 (s)	4	7.3
62	64	C 3 (s)	1	7.0
63	100	Landas 50 (s)	3	6.3
64	118	Jerangau 13 (s)	4	5.0
65	75	ICS 45 x ICS 60 (s)	2	4.5
66	126	SCA 6 (b)	1	4.0
67	71	Na 58 (b)	2	3.5
68	114	Jerangau 8 (s)	3	3.3
69	38	Landas 358 (s)	3	3.0
70	77	J 195 x ICS 45 (s)	3	3.0
71	73	I 594 x ICS 45 (s)	4	2.0
72	116	Jerangau 11 (s)	4	2.0
73	32	Jerangau Red axil (s)	1	1.0
74	74	ICS 45 x ICS 39 (s)	2	1.0
75	87	Landas 21 (s)	1	1.0

Table 17 (Contd.)

Rank	Type No.	Parentage	No. of plants	Mean yield
76	108	Landas 89 (s)	2	1.0
77	115	Jerangau 9 (s)	5	1.0
78	112	Jerangau 6 (s)	5	0.6
79	113	Jerangau 7 (s)	3	0.3
80	76	J 195 x ICS 60 (s)	1	0.0
81	89	Landas 24 (s)	5	0.0
82	96	Landas 40 (s)	1	0.0
83	101	Landas 52 (s)	3	0.0
84	109	Jerangau 2 (s)	4	0.0
85	111	Jerangau 5 (s)	2	0.0
86	125	ICS 95 (b)	1	0.0
Mean of mean yield				23.1
Mean yield of 1989-'90				19.2

s - seedling b - budded plant c - cutting NA - Not available

Table 18 **Ranking of *superior types of Germplasm VI based on mean yield upto 1991 (1989-1991)**

Rank	Type No.	Mean yield 1989-90	Mean yield 1990-91	Mean
1	44	70.3	75.8	73.1
2	24	50.5	71.5	61.0
3	7	56.8	52.0	54.4
4	54	38.0	67.0	52.5
5	50	52.0	50.0	51.0
6	14	33.0	66.3	49.7
7	15	27.0	71.0	49.0
8	25	48.3	47.0	47.7

* Types with more than double the overall mean yield are reckoned as superior

to be planted during May-June, 1991. With this, the total number collected to be included in this germplasm collection comes to 194.

A substantial number of plants of this collection which were planted in 1983 had come to bearing since 1988 and data on their yield were collected this year also. These are presented in Table 17 and Fig.5. The range in mean yield was from 0 to 75.8, the highest yielding type being GVI - 44 (Landas 357). Seven types of this group are yet to yield. Out of the 99 types available from the original planting of 1983, data from 5 types could not be collected during the year as these were used for controlled hand pollination. Among the remaining 86 types whose yield data could be collected seven did not yield at all. Three of the 79 yielding types had pod yield between 70 and 80, two between 60 and 70, two between 50 and 60, 10 between 40 and 50, 12 in the range from 30 and 40, 19 from 20 to 30 and nine from 10 to 20. The largest number of 22 types had yield of less than 10. A comparison with the data of the previous year indicates that, in general, there was an increase in the number of types of the higher-yiedling groups. This is to be expected as this planting is only seven years old and is yet to reach the stage of yield stabilisation. Graphical presentation of the frequency distribution of yield of this and previous years is given in Fig.6. The overall mean yield of this group was also higher this year as compared to the mean of last year, the extent of increase being 20 per cent. This increase must be treated as impressive as it is a decrease in yield to the tune of 20 to 50 per cent that was noted this year in nearly all the rest of experimental plants that had come to yield stabilisation. Based on the procedure of selecting plants with more than double the overall mean yield of the group, eight plants were selected as superior. The accession numbers of these in the decreasing order of yield are 44, 24, 7, 54, 50, 14, 15 and 25. The yield figures of these plants during this and the previous years and the mean yield values are given in Table 18.

A total of 12 types of this germplasm collection were used for the first stage of breeding even before these came to bearing. Selection for this purpose was made based on the reported superior combining abilities of these. All these were also derived through vegetative multiplication from the original plants. Further selection based on their performane was not so far done as these plants had not come to reasonable bearing. Now that data on yield had become available, though only for a year upto March 1990, further selection of plants was made for inclusion in the second stage of breeding. The limit in

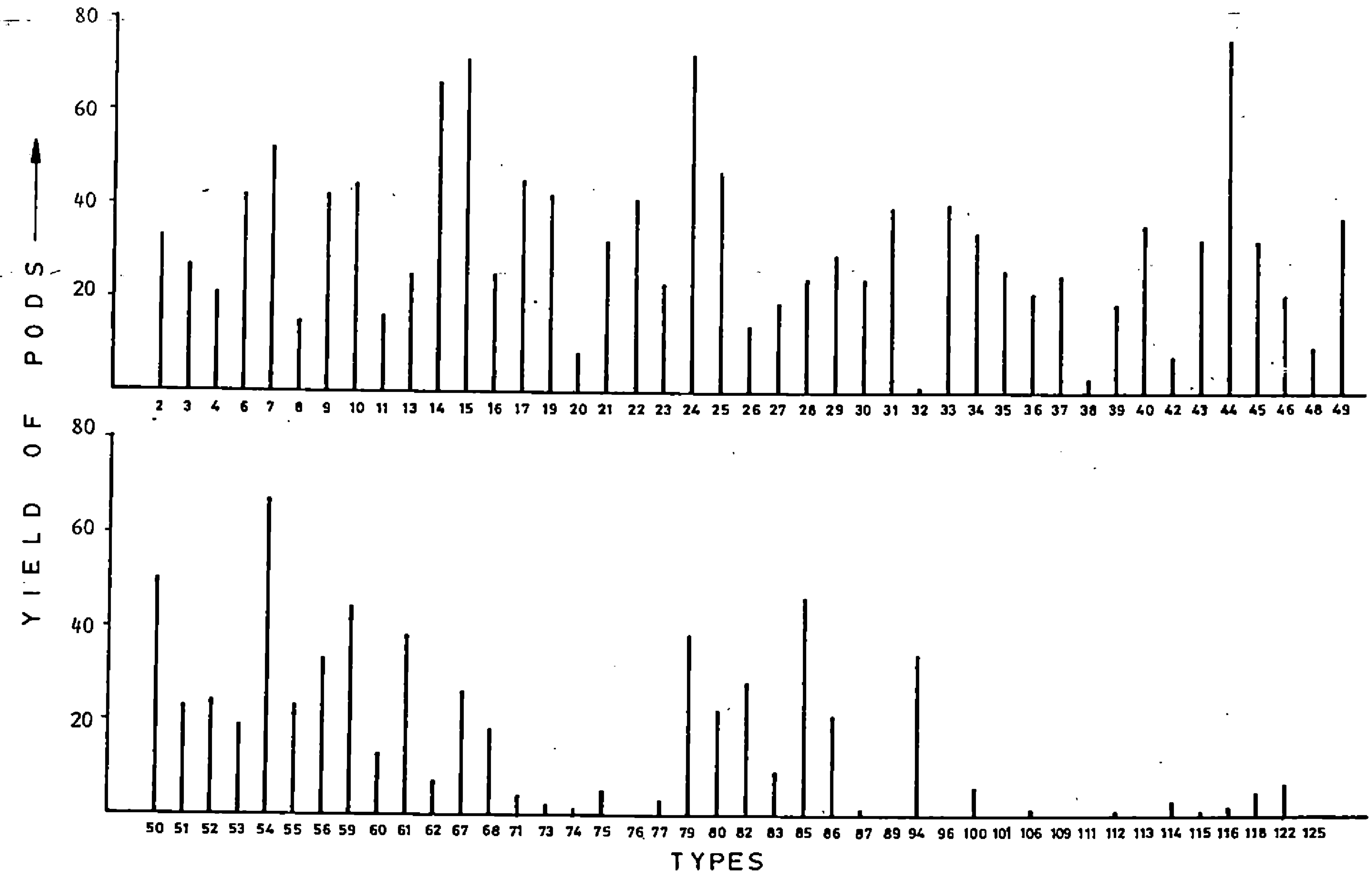

Fig- 5 MEAN YIELD OF TYPES OF GERMPLASM VI (1990-91)

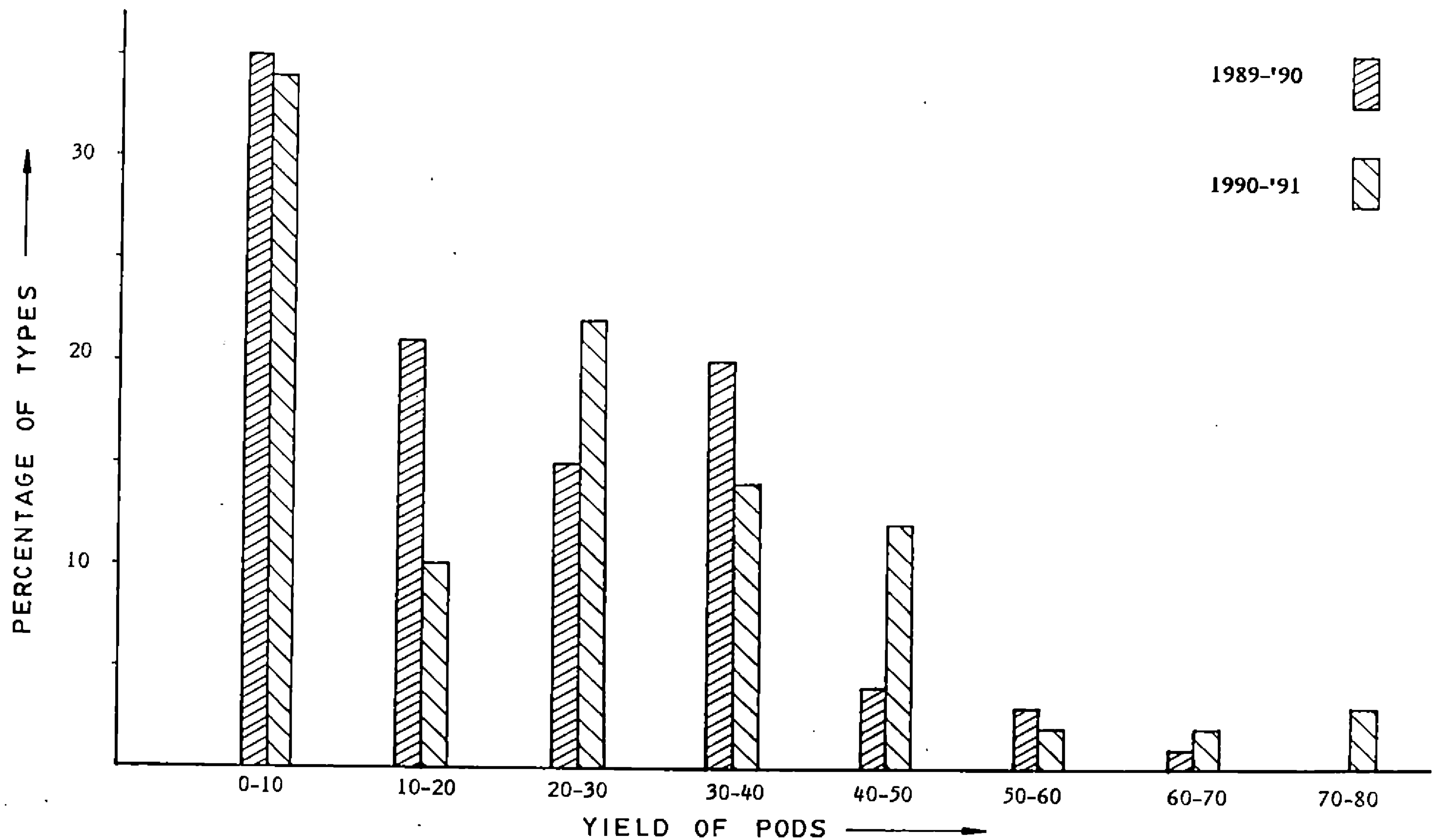

Fig-6 FREQUENCY DISTRIBUTION OF TYPES OF GERMPLASM VI yield was arbitrarily fixed as 30 pods and a total of 22 types were selected. The pod and bean characters of some of these were already assessed earlier. Similarly, self-compatibility reactions of some types were also assessed earlier. Those types whose self-compatibility was not assessed were studied this year through controlled hand pollinations. Details of the types selected, their pod yield, pod and bean characters, self-compatibility positions and the characters that remain to be assessed are given in Table 19.

2. Breeding

Cocoa breeding programme aims at evolving high-yielding types utilising the available genetic diversity in the country. This long-term programme, taken up in phases since 1984 involved selection high-yielding self-incompatible parents, production of hybrids of these through controlled hand pollinations, screening them initially based on seedling vigour and final selection based on field performance. A total of 121 crosses were, thus, made, 29 were selected based on seedling vigour over a period of four years and these were planted as a replicated progeny trial during 1988-'89. The hybrids selected based on seedling vigour during the first three years were also planted as an unreplicated observational trial along with a row of seedlings from open-pollinated pods and budded parents of these hybrids. These were planted during 1986, 1987 and 1988, respectively and the hybrids designated as Series I, II and III hybrids. Development of inbred lines through continued selfing as well as production of haploids from flat beans were also taken up later. During this year, the second stage of breeding was initiated utilising all the selected parent plants of the first stage and the newly selected parent plants. The programme consists of assessing the general combining ability of the parents using the plant $V_{5/9}$ of Germplasm I as the common parent and using seedling vigour as the criterion. Assessment of specific combining ability again based on seedling vigour and identification of best combiners based on field performance are to follow.

The items of work taken up during the year were the following:

(i) Assessment of the performance of Series I, Series II and Series III hybrids and their parents.

Table 19 Characters of types of Germplasm VI initially selected for the second stage of breeding based on yield

Sl. No.	Type No.	Mean yield	Self-compatibility position	Mean bean dry weight (g)	Wet bean weight g/pod
1	44	73.1	SC	1.0	103.6
2	24	61.0	SI^{+}	NA	NA
3	7	54.4	SI^{++}	0.9	NA
4	54	52.5	SI^{++}	1.0	109.3
5	50	51.0	SI^{+}	1.6	172.1
6	14	49.7	SC	0.5	NA
7	15	49.0	NA	NA	NA
8	25	47.7	SI^{++}	1.2	146.1
9	9	44.2	SC	1.0	98.8
10	22	40.5	SI^{+}	1.0	106.6
11	10	39.4	NA	1.0	110.0
12	19	38.7	SI^{++}	0.9	NA
13	56	37.3	SI^{++}	1.0	125.3
14	6	36.5	SI^{++}	0.7	NA
15	2	36.0	SI^{++}	1.1	104.3
16	33	32.9	SC	NA	NA
17	17	32.0	SI^{++}	NA	NA
18	35	30.7	SI^{++}	0.7	NA
19	29	30.6	SC	1.1	102.6
20	51	30.1	SI^{++}	1.5	193.8
21	34	30.0	NA	0.9	NA
22	23	30.0	SC	1.1	143.3

SC - Self-compatible, SI^{+} - Self-incompatible with early pod wilt

SI^{++} - Self-incompatible with no signs of swelling of ovary, NA - Not assessed

(ii) Assessment of the growth of hybrids of the progeny trial.

(iii) Production of hybrids for gap-filling the progeny trial.

(iv) Development of inbreds

(v) Recovery of haploid plants from flat beans.

(vi) Selection of new parents and assessment of bean characters and self-compatibility reaction.

(i) Assessment of the performance of Series I, Series II and Series III hybrids and their parents

These hybrids were produced as part of the first stage of the breeding programme and two sets of crosses were produced. The first set involved the threé selected plants of Mannuthy as commom parents and these were to be crossed with all the other 24 selected parents. Out of these possible 72 crosses, five could not be made during the period from 1984-'85 to 1986-'87. The list of the crosses and the periods during which these were made were given in the Third Annual Report (1989-'90). The second set had the five parents of Germplasm I against 11 of Germplasm VI. The actual number of crosses made out of the possible 55 was 52. Details of these also appear in the Third Annual Report. Out of the total of 119 crosses made in the two sets, 24 were made during 1984-'85, 61 in 1985-'86 and 24 in 1986-'87 and the remaining 10 in 1987-'88. Two more crosses were made using other parents making the total number to 121. The hybrids selected based on seedling vigour from among the crosses of 1984-85 were planted during 1986 as part of an observational trial along with a row of plants from open-pollinated bulk pods and budded parents of all these selected crosses. These hybrids are designated as Series I hybrids. Series II hybrids arise from hand pollinations of 1985-'86 and Series III from pollinations of 1986-'87. These were also planted along with bulk seedlings and budded parents. Series I and II hybrids and their parents had started yielding since last year and data on their yield along with those on growth parameters were collected. Details of the results are given below.

Series I hybrids and parents

There are a total of seven hybrids in this group. A row of bulk seedlings and cloned parents were planted along with these hybrids in 1986. The maximum populations of hybrids and bulk were maintained as 15 and that of parents, 10. Data on stem girth and yield were collected from hybrids and bulk and those of yield from parents. These data on growth character of hybrids and bulk were statistically analysed separately treating the design as completely randomised with variable replications and the plot size as a single plant. These are presented in Table 20 and Fig.7 along with data on yield of last year and the mean yield of the two-year period. In girth and yield of the hybrids and in the yield of parents during the year, differences were not significant. This is in contrast to the yield trends of last year when the differences were statistically significant. The major reason for this appears to be the much better performance of hybrids/types with very poor yield last year. Comparing between hybrids and parents, however, differences were conspicuous and significant with superior performance of hybrids as compared to the vegetatively multiplied parents. The general yield level of the year was nearly comparable to that of last year excepting for the impressive recovery of the poor yielders.

The pods harvested from the hybrids and parents were used for studying the pod and bean characters. Pods for the purpose were collected during the period from January, 1990 to March 1991. The pod characters studied included pod weight, length and width, number of seeds per pod, wet bean weight per pod and pericarp thickness at ridge and furrow. Bean characters include length, width and thickness in addition to oven-dry weight of peeled bean. The same observations were also recorded last year during the same period. Mean values of all the characters of each plant observed during 1989-'90 and 1990-'91 are presented in the Table 21.

In order to assess the performance of the hybrids the annual increment/decrement in pod and bean characters was worked out as percentage over the mean values for the last year. An increase in pod weight was observed in all the seven hybrids with 8.4% in H 6 to 64.3% in H 2. In all the hybrids there was a remarkable increase in the wet bean weight ranging from 4.6 per cent in H 7 to 26.1 in H 2. Regarding the number of beans/pod the

Table 20 Mean girth and yield of Series I hybrids and their parents

Hybrid/ parent	Cross/parent	No. of plants	Girth (cm)	Yield of pods		Mean
				1989-90	1990-91	
H_1	$V_{5/9}$ x 54	3	29.3	20.3	18.3	19.3
H_2	$V_{10/3}$ x 54	8	29.2	12.9	15.5	14.2
H_3	$V_{15/5}$ x 54	5	34.6	15.4	15.2	15.3
H_4	$V_{15/5}$ x 55	5	28.6	4.0	18.6	11.3
H_5	$V_{10/3}$ x 61	9	30.1	16.4	15.1	15.8
H_6	$V_{10/3}$ x 64	9	29.7	13.2	24.3	18.8
H_7	$V_{5/9}$ x 68	10	32.7	28.4	21.9	25.2
B	Bulk	10	29.8	6.9	12.6	9.8
F test			NS	Sig.	NS	
P_1	$V_{5/9}$	6	—	6.6	5.0	5.8
P_2	$V_{10/3}$	5	—	4.4	4.8	4.6
P_3	$V_{15/5}$	9	—	2.8	4.9	3.9
P_4	54	4	--	5.6	7.5	6.6
P_5	55	7	--	0.4	5.0	2.7
P_6	61	9	--	1.0	10.1	5.6
P_7	64	9	—	0.8	6.1	3.5
P_8	68	8	—	0.4	7.1	3.8
F test				Sig.	NS	

Ranking of hybrids and bulk based on girth

H_3 H_7 H_5 B H_6 H_1 H_2 H_4

Ranking of hybrids and bulk based on yield of 1990-'91

H_6 H_7 H_4 H_1 H_2 H_3 H_5 B

Ranking of parents based on yield of 1990-'91

P_6 P_4 P_8 P_7 P_1 P_5 P_3 P_2

Ranking of hybrids and parents based on yield of 1990-'91

H_6 H_7 H_4 H_1 H_2 H_3 H_5 B P_6 P_4 P_8 P_7 P_1 P_5 P_3 P_2

Table 21 Pod and bean characters of hybrids of 1986

Hybrid No.	Number of pods studied		Pod length (cm)		Pod width (cm)		Pod weight (g)		Wet bean weight per pod (g)		Number of beans/pod	
	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91
$H_{1.2}$	5	9	11.1	12.2	6.5	6.8	214.0	235.0	70.0	85.0	37.8	40.7
$H_{1.3}$	1	2	12.0	14.5	6.0	8.5	220.0	380.0	95.0	80.0	40.0	46.5
$H_{1.4}$	-	2	-	26.5	-	7.3	-	220.0	-	77.5	-	39.0
$H_{1.6}$	-	1	-	19.0	-	8.5	-	460.0	-	110.0	-	46.0
Mean			11.6	18.1	6.3	7.8	217.0	323.8	82.5	88.1	38.9	43.1
Percentage increase				56.0%		23.8%		49.2%		6.8%		10.8%
$H_{2.3}$	-	2	-	14.0	-	8.3	-	335.0	-	95.0	-	44.0
$H_{2.4}$	12	7	12.3	14.8	5.6	7.1	205.0	301.4	53.8	71.4	37.6	40.0
$H_{2.5}$	-	18	-	12.2	-	7.2	-	257.2	-	85.8	-	41.1
$H_{2.6}$	1	-	12.0	-	6.0	-	220.0	-	95.0	-	40.0	-
$H_{2.7}$	-	4	-	16.6	-	6.9	-	496.3	-	127.5	-	45.8
$H_{2.11}$	-	8	-	14.8	-	8.1	-	355.6	-	89.4	-	43.3
Mean			12.2	14.5	5.8	7.5	212.5	349.1	74.4	93.8	38.8	42.8
Percentage increase				18.9%		29.3%		64.3%		26.1%		10.3%
$H_{3.1}$	9	3	11.9	12.2	6.9	7.3	291.7	301.7	88.9	86.7	41.1	36.0
$H_{3.2}$	1	11	12.5	13.2	7.5	7.9	375.0	370.9	115.0	108.6	45.0	40.0
$H_{3.3}$	-	1	-	15.0	-	9.5	-	480.0	-	140.0	-	47.0
$H_{3.4}$	3	5	12.5	12.9	7.0	7.7	300.0	333.0	95.0	112.0	47.0	45.2
Mean			12.3	13.3	7.1	8.1	322.2	371.4	99.6	111.8	44.4	42.1
Percentage increase				8.1%		14.1%		15.3%		12.3%		- 5.2%
$H_{4.3}$	1	1	14.0	15.5	7.5	8.0	410.0	515.0	140.0	155.0	58.0	51.0
$H_{4.4}$	-	3	-	15.7	-	9.0	-	510.0	-	141.7	-	45.6
$H_{4.6}$	-	4	-	15.6	-	9.1	-	552.5	-	165.0	-	39.3
$H_{4.7}$	-	7	-	14.6	-	7.9	-	435.0	-	130.7	-	46.1
$H_{4.10}$	-	5	-	15.0	-	8.6	-	455.0	-	148.0	-	49.6
Mean			14.0	15.3	7.5	8.5	410.0	493.5	140.0	148.1	58.0	46.3
Percentage increase				9.3%		13.3%		20.4%		5.8%		-20.2%
$H_{5.1}$	-	1	-	17.5	-	7.0	-	350.0	-	95.0	-	40.0
$H_{5.2}$	4	-	14.4	-	6.6	-	282.5	-	87.5	-	35.0	-
$H_{5.3}$	11	6	17.5	18.3	6.4	7.5	326.8	412.0	82.3	103.0	41.6	43.4
$H_{5.4}$	7	3	13.7	14.7	7.1	6.8	251.4	263.3	80.0	83.3	38.0	35.7
$H_{5.5}$	-	5	-	14.9	-	7.3	-	282.0	-	95.0	-	44.0
$H_{5.6}$	-	4	-	16.3	-	8.4	-	456.3	-	107.5	-	39.5
$H_{5.7}$	-	2	-	16.0	-	8.0	-	257.6	-	122.5	-	47.5
$H_{5.8}$	1	4	13.5	14.3	6.0	7.1	240.0	325.0	65.0	72.5	44.0	32.8
$H_{5.10}$	-	18	-	15.8	-	6.9	-	311.4	-	96.4	-	39.6
$H_{5.12}$	-	3	-	14.3	-	6.7	-	300.0	-	115.0	-	49.3
Mean			14.8	15.8	6.5	7.3	275.2	339.7	78.7	98.9	39.7	41.4
Percentage increase				6.8%		12.3%		23.4%		25.7%		4.3%

Table 21 (Contd.)

Hybrid No.	Dry weight of a single bean (g)		Seed length (mms)		Seed width (mms).		Seed thickness (mms)		Pericarp thickness (mms)	
	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91
$H_{1.2}$	0.7	0.7	20.2	19.1	12.0	10.7	6.3	6.3	7.8	5.6
$H_{1.3}$	0.8	0.8	19.4	21.4	11.6	12.4	6.6	6.2	6.0	7.8
$H_{1.4}$	-	0.7	-	19.1	-	10.9	-	6.3	-	6.8
$H_{1.6}$	-	1.0	-	20.4	-	11.8	-	6.8	-	9.5
Mean	0.8	0.8	19.8	20.0	11.8	11.5	6.5	6.4	6.9	7.4
Percentage increase		0%		1.0%		-2.5%		-1.5%		7.2%
$H_{2.3}$	-	0.8	-	20.3	-	11.3	-	5.9	-	8.8
$H_{2.4}$	0.6	0.8	17.0	17.6	10.9	10.9	6.7	7.4	9.0	9.7
$H_{2.5}$	-	0.8	-	19.7	-	11.8	-	6.2	-	7.8
$H_{2.6}$	0.8	-	19.4	-	11.6	-	6.6	-	6.0	-
$H_{2.7}$	-	0.9	-	22.2	-	12.0	-	6.5	-	9.9
$H_{2.11}$	-	0.7	-	18.4	-	10.6	-	5.9	-	9.2
Mean	0.7	0.8	18.2	19.6	11.3	11.3	6.7	6.4	7.5	9.1
Percentage increase		14.3%		7.7%		0%		-4.5%		21.3%
$H_{3.1}$	0.8	0.8	21.4	22.1	11.3	11.7	5.9	6.4	9.5	8.4
$H_{3.2}$	1.0	1.2	24.0	24.5	14.0	12.9	6.2	6.9	10.0	9.2
$H_{3.3}$	-	1.2	-	23.6	-	13.2	-	6.8	-	9.0
$H_{3.4}$	0.8	0.9	21.7	21.5	12.8	12.2	5.8	5.8	9.0	9.2
Mean	0.9	1.0	22.4	22.9	12.7	12.5	5.9	6.5	9.5	9.0
Percentage increase		11.1%		2.2%		-1.6%		10.2%		5.3%
$H_{4.3}$	0.7	1.0	21.6	24.6	12.4	13.8	5.4	6.0	8.0	10.0
$H_{4.4}$	-	1.3	-	24.8	-	13.9	-	8.1	-	9.8
$H_{4.6}$	-	1.3	-	27.1	-	13.4	-	6.9	-	10.2
$H_{4.7}$	-	1.0	-	22.0	-	11.7	-	7.1	-	7.3
$H_{4.10}$	-	1.2	-	21.2	-	13.0	-	7.3	-	9.0
Mean	0.7	1.2	21.6	23.9	12.4	13.2	5.4	7.1	8.0	9.3
Percentage increase		71.4%.		10.7%		6.5%		31.5%		16.3%
$H_{5.1}$	-	0.8	-	18.4	-	9.6	-	8.0	-	8.5
$H_{5.2}$	0.8	-	20.4	-	11.8	-	7.7	-	7.7	-
$H_{5.3}$	0.7	0.8	17.5	18.4	10.6	12.6	6.9	7.2	9.0	8.9
$H_{5.4}$	0.7	0.8	19.5	18.1	11.9	10.6	6.3	7.3	7.8	6.5
$H_{5.5}$	-	0.6	-	19.4	-	10.1	-	5.6	-	7.1
$H_{5.6}$	-	0.8	-	21.9	-	11.9	-	6.7	-	8.7
$H_{5.7}$	-	0.8	-	18.6	-	12.2	-	6.4	-	7.5
$H_{5.8}$	0.5	0.8	19.8	20.1	9.6	9.6	5.8	7.1	7.8	8.5
$H_{5.10}$	-	0.8	-	17.9	-	10.6	-	7.7	-	7.3
$H_{5.12}$	-	0.7	-	20.2	-	11.4	-	6.4	-	6.9
Mean	0.7	0.8	19.3	19.2	11.0	11.0	6.7	6.9	8.1	7.8
Perentage increase		14.3%		-0.5%		0%		3.0%		-3.7%

Table 2i (Contd.)

Hybrid No.	Number of pods studied		Pod length (cm)		Pod width (cm)		Pod weight (g)		Wet bean weight per pod (g)		Number of beans/ pod	
	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91
$H_{6.2}$	2	19	16.0	15.2	7.8	7.6	355.0	372.1	62.5	51.6	23.0	34.3
$H_{6.3}$	-	6	-	13.3	-	8.0	-	351.7	-	100.8	-	42.7
$H_{6.5}$	3	15	16.7	16.6	7.3	7.5	435.0	396.0	101.6	93.7	40.3	40.7
$H_{6.6}$	1	3	14.0	15.8	7.0	7.8	320.0	433.3	80.0	93.3	41.0	30.3
$H_{6.7}$	-	11	-	13.8	-	6.9	-	299.5	-	94.5	-	42.8
$H_{6.8}$	2	17	16.5	17.9	6.3	8.0	337.5	480.6	90.0	115.6	37.5	41.6
$H_{6.9}$	-	5	-	17.1	-	7.4	-	358.0	-	98.0	-	41.4
$H_{6.10}$	1	14	12.0	12.6	7.5	7.9	295.0	329.3	105.0	98.1	44.0	36.2
Mean			15.0	15.3	7.2	7.6	348.5	377.6	87.8	93.2	37.2	38.8
Percentage increase				2.0%		5.6%		8.4%		6.2%		4.3%
$H_{7.1}$	-	7	-	15.4	-	7.6	-	370.7	-	84.9	-	36.7
$H_{7.2}$	17	8	15.6	15.5	8.2	7.4	314.7	370.0	100.9	113.5	44.0	41.5
$H_{7.3}$	8	17	13.3	13.7	7.2	6.6	227.3	270.6	71.3	88.8	39.4	44.9
$H_{7.4}$	6	3	13.7	15.0	7.0	6.8	239.2	310.0	77.5	83.3	40.0	35.7
$H_{7.5}$	2	-	15.0	-	7.8	-	285.0	-	105.0	-	44.5	-
$H_{7.6}$	5	-	14.0	-	8.0	-	275.0	-	101.0	-	44.3	-
$H_{7.7}$	-	3	-	14.7	-	6.7	-	303.3	-	98.3	-	41.3
$H_{7.8}$	-	13	-	13.2	-	6.8	-	268.8	-	94.2	-	43.6
$H_{7.9}$	2	3	13.3	14.3	7.5	7.8	262.5	358.3	80.0	115.0	40.5	46.0
$H_{7.10}$	5	-	15.1	-	7.8	-	321.0	-	111.0	-	47.8	-
Mean			14.3	14.5	7.6	7.1	275.0	321.7	92.2	96.4	43.0	41.4
Percentage increase				1.4%				17.0%		4.6%		-3.7%
Bulk	18	18	12.7	14.8	7.3	8.1	271.1	437.8	69.1	92.0	37.8	37.2
Percentage increase				16.5%		11.0%		61.5%		33.1%		-1.6%
P_1	5	3	14.1	13.3	7.7	7.2	360.0	248.3	113.0	96.7	40.2	42.7
P_2	8	3	15.0	14.8	8.2	8.2	370.0	378.3	104.3	85.0	46.0	35.7
P_3	11	2	13.4	14.0	8.2	8.0	363.2	430.0	99.1	105.0	42.4	39.0
P_4	4	-	13.5	-	8.3	-	331.2	-	98.7	-	40.2	-
P_5	-	9	-	17.1	-	9.7	-	624.1	-	180.6	-	53.1
P_6	5	7	17.8	18.9	6.2	7.7	378.0	391.4	105.0	120.0	42.2	46.0
P_7	1	1	12.0	13.5	6.5	8.0	225.0	310.0	55.0	80.0	41.0	38.0

Table 21 (Contd.)

Hybrid No.	Dry weight of a single bean (g)		Seed length (mm)		Seed width (mm)		Seed thickness (mm)		Pericarp thickness (mm)	
	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91
$H_{6.2}$	1.0	1.0	21.5	21.9	11.7	11.4	8.5	7.7	11.5	10.9
$H_{6.3}$	-	0.8	-	22.2	-	11.3	-	6.6	-	9.6
$H_{6.5}$	0.8	0.8	20.1	18.1	11.0	10.4	7.5	7.6	9.0	8.6
$H_{6.6}$	0.7	1.0	20.0	20.3	11.2	11.0	7.4	7.6	8.5	9.7
$H_{6.7}$	-	0.8	-	18.9	-	10.6	-	6.6	-	7.6
$H_{6.8}$	0.8	1.1	21.2	20.8	10.6	10.8	7.6	7.6	8.0	9.0
$H_{6.9}$	-	0.9	-	20.5	-	10.8	-	7.7	-	9.7
$H_{6.10}$	0.7	0.9	20.2	22.1	11.0	11.5	6.4	6.2	7.5	8.2
Mean	0.8	0.9	20.6	20.6	11.1	11.0	7.5	7.2	8.9	9.2
Percentage increase		12.5%		0%						3.4%
$H_{7.1}$	-	0.8	-	19.3	-	9.7	-	6.7	-	8.5
$H_{7.2}$	0.8	0.8	19.0	19.4	10.4	10.2	6.7	6.7	8.4	7.3
$H_{7.3}$	0.6	0.7	17.3	18.5	10.1	10.3	5.9	6.3	7.9	6.3
$H_{7.4}$	0.5	0.7	18.4	19.8	9.1	9.4	6.0	7.2	7.8	6.9
$H_{7.5}$	0.8	-	20.2	-	9.4	-	6.6	-	7.3	-
$H_{7.6}$	0.6	-	19.9	-	10.4	-	6.0	-	7.5	-
$H_{7.7}$	-	0.9	-	20.3	-	11.4	-	6.5	-	5.0
$H_{7.8}$	-	0.7	-	19.2	-	10.6	-	6.1	-	6.6
$H_{7.9}$	0.7	0.8	17.4	19.6	10.3	10.8	6.7	6.1	8.5	8.7
$H_{7.10}$	0.8	-	19.6	-	10.8	-	6.0	-	8.7	-
Mean	0.7	0.8	18.8	19.4	10.1	10.3	6.3	6.5	8.0	7.0
Percentage increase		14.3%		3.2%		2%		3.2%		-
Bulk	0.8	0.9	20.3	21.6	11.6	11.1	7.8	7.9	8.6	11.1
Percentage increase		12.5%		6.4%		-4.3%		-1.3%		29.1%
P_1	0.8	0.6	21.1	19.4	11.5	10.6	7.0	8.5	8.6	6.0
P_2	0.8	0.9	18.8	19.6	11.8	11.5	7.1	7.0	9.4	9.9
P_3	0.9	1.1	21.3	21.6	12.7	12.0	6.8	7.0	10.1	8.5
P_4	0.9	-	22.1	-	13.1	-	6.7	-	10.9	-
P_5	-	1.0	-	24.0	-	12.3	-	6.4	-	11.5
P_6	0.9	0.8	20.1	20.7	11.6	11.4	8.0	7.8	9.2	9.1
P_7	0.6	0.7	18.8	21.8	31.2	12.0	5.6	5.4	7.5	7.5

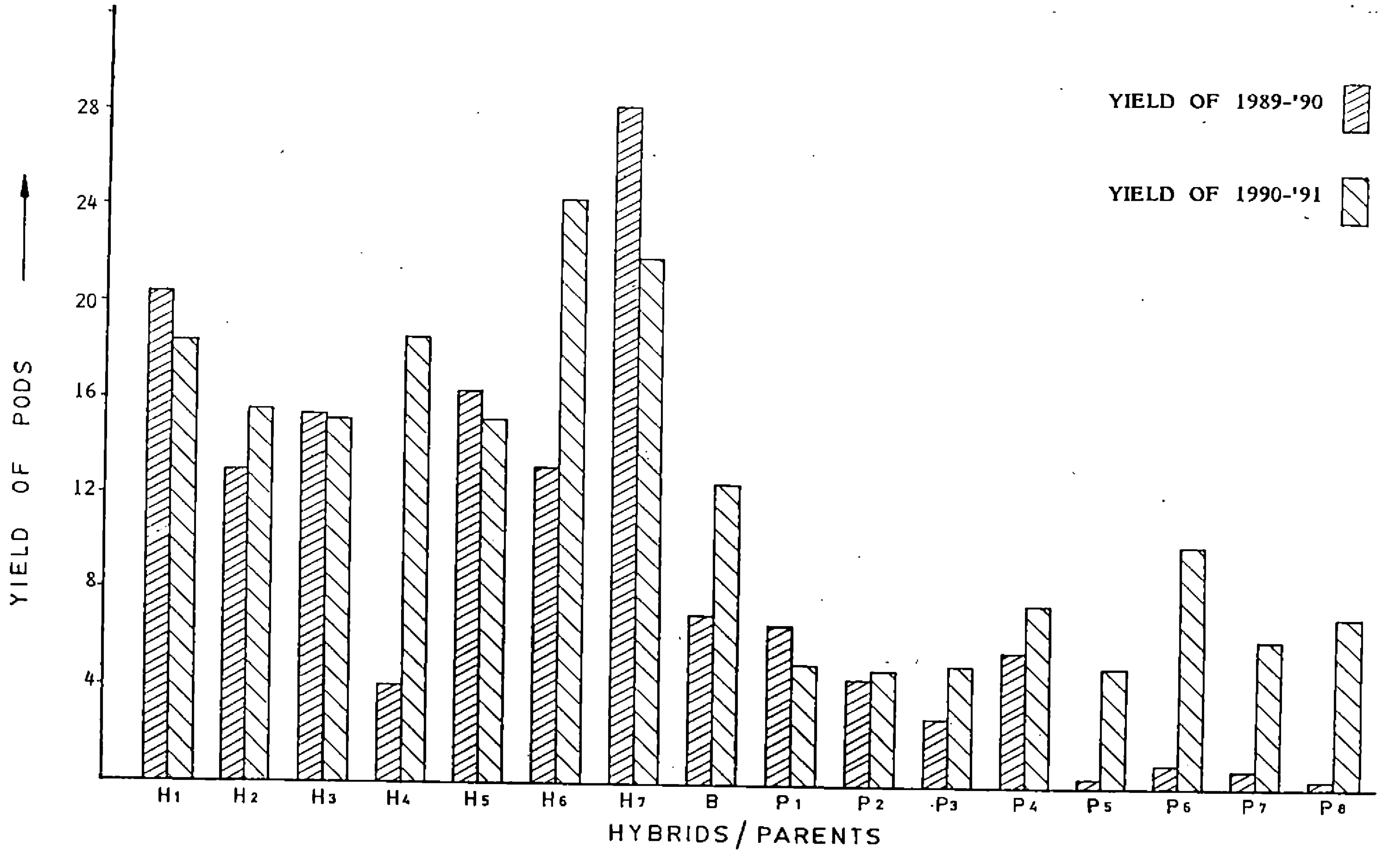

Fig-7 MEAN YIELD OF SERIES I HYBRIDS AND PARENTS values ranged from -20.2% in H 4 to +10.8% in H 1. The peeled bean dry weight showed a steady increase in most of the hybrids while in a few, the weight remained the same. The percentage increase ranged from 11.1 in H 3 to 71.4 in H 4. The hybrid H 4 which showed a decrease in seed number compensated it by showing a remarkable increase in dry weight. Similar trend was observed in other hybrids also which showed a decrease in seed number during the period.

Series II hybrids and parents

There are 12 selected hybrids, 13 budded parents and a row of bulk in this group. The maximum population was kept as 15 in all these. These hybrids were produced by hand pollination in 1985-'86 and were planted in 1987. The experimental plants started bearing last year. Data on stem girth of hybrids and bulk and those on yield of all the plants including parents were collected. The data were analysed using the same procedure as in Series I and are presented in Table 22 and Fig.8 along with the yield figures of the first year of bearing. Unlike the Series I hybrids, differences between hybrids, between parents and between parents and hybrids were statistically significant in this group though the trend in yield was different from that of last year. Among the hybrids, H_1 ($V_{15/5}$ x 64) and H_2 (13/12 x $V_{5/9}$) recorded the highest yield figures and among the parents, P_9 (GVI-54) and P_5 ($V_{5/9}$). Open-pollinated bulk gave a relatively low mean yield of 12.4 though it was not the lowest. Out of the total 13 seedling types, this was ranked the seventh unlike in Series I group where it came as the last. As was the case in Series I, budded parents gave much lower yields than hybrids, the range in mean figures being from 1.9 in P_{12} (GVI-61) to 9.7 in P_9 (GVI-54). The same results were obtained last year also. This inferiority of cloned parents must be taken only as early trends which are expected to change in favour of the parents in due course. Comparing the general yield level of this year and that of the last, there was an impressive increase during this year in both the hybrids and parents.

As in Series I hybrids, observations on the pod and bean characters of the hybrids and parents were taken during the last quarter of 1989-'90 and 1990-'91. Mean values of all the pod and bean characaters of each plant were

Table 22 Mean girth and yield of Series II hybrids and their parents

Hybrid/ Parent	Cross/Parent	No. of plants	Girth (cm)	Yield of pods		Mean
				1989-'90	1990-'91	
H_1	$V_{15/5}$ x 64	15	27.3	14.7	19.5	17.1
H_2	13/12 x $V_{5/9}$	14	28.0	11.9	18.4	15.2
H_3	16/9 x 20/4	14	27.3	6.9	10.6	8.8
H_4	16/9 x 19/5	14	27.8	7.6	10.3	8.9
H_5	$V_{10/3}$ x 56	6	26.7	4.7	12.7	8.7
H_6	$V_{5/9}$ x 61	12	25.3	5.8	14.3	10.1
H_7	$V_{5/9}$ x 55	15	23.2	7.6	13.6	10.6
H_8	16/9 x $V_{4/8}$	15	25.3	3.1	7.9	5.5
H_9	16/9 x 55	13	26.5	3.8	7.9	5.9
H_{10}	9/16 x 20/4	15	25.7	2.1	10.3	6.2
H_{11}	16/9 x 56	15	28.6	1.0	10.4	5.7
H_{12}	$V_{4/8}$ x 54	14	25.5	3.9	12.6	8.3
B	Bulk	12	27.2	1.1	12.4	6.8
F test			Sig.	Sig.	Sig.	
P_1	9/16	14	--	1.6	2.6	2.1
P_2	13/12	14	--	0.6	2.4	1.5
P_3	16/9	15	--	2.7	4.6	3.7
P_4	$V_{4/8}$	11	--	0.7	2.3	1.5
P_5	$V_{5/9}$	14	--	10.7	9.1	9.9
P_6	$V_{10/3}$	15	--	3.1	8.1	5.6
P_7	20/4	13	--	3.8	7.5	5.7
P_8	19/5	11	--	1.4	3.8	2.6
P_9	54	13	--	3.2	9.7	6.5
P_{10}	55	9	--	1.3	5.8	3.6
P_{11}	56	14	--	0.3	2.5	1.4
P_{12}	61	15	--	0.2	1.9	1.1
P_{13}	64	12	--	2.2	2.7	2.5
F test				Sig.	Sig.	

Contd.

Ranking of hybrids and bulk based on girth

H_{11} H_2 H_4 H_3 H_1 B H_5 H_9 H_{10} H_{12} H_6 H_8 H_7

Ranking of hybrids and bulk based on yield of 1990-'91

H_1 H_2 H_6 H_7 H_5 H_{12} B H_3 H_{11} H_{10} H_4 H_9 H_8

Ranking of parents based on yield of 1990-'91

P_9 P_5 P_6 P_7 P_{10} P_3 P_8 P_{13} P_1 P_{11} P_2 P_4 P_{12}

Ranking of parents and hybrids based on yield of 1990-'91

H_1 H_2 H_6 H_7 H_5 H_{12} B H_3 H_{11} H_{10} H_4 P_9 P_5 P_6 H_9 H_8 P_7 P_{10} P_3 P_8 P_{13} P_1 P_{11} P_2 P_4 P_{12}

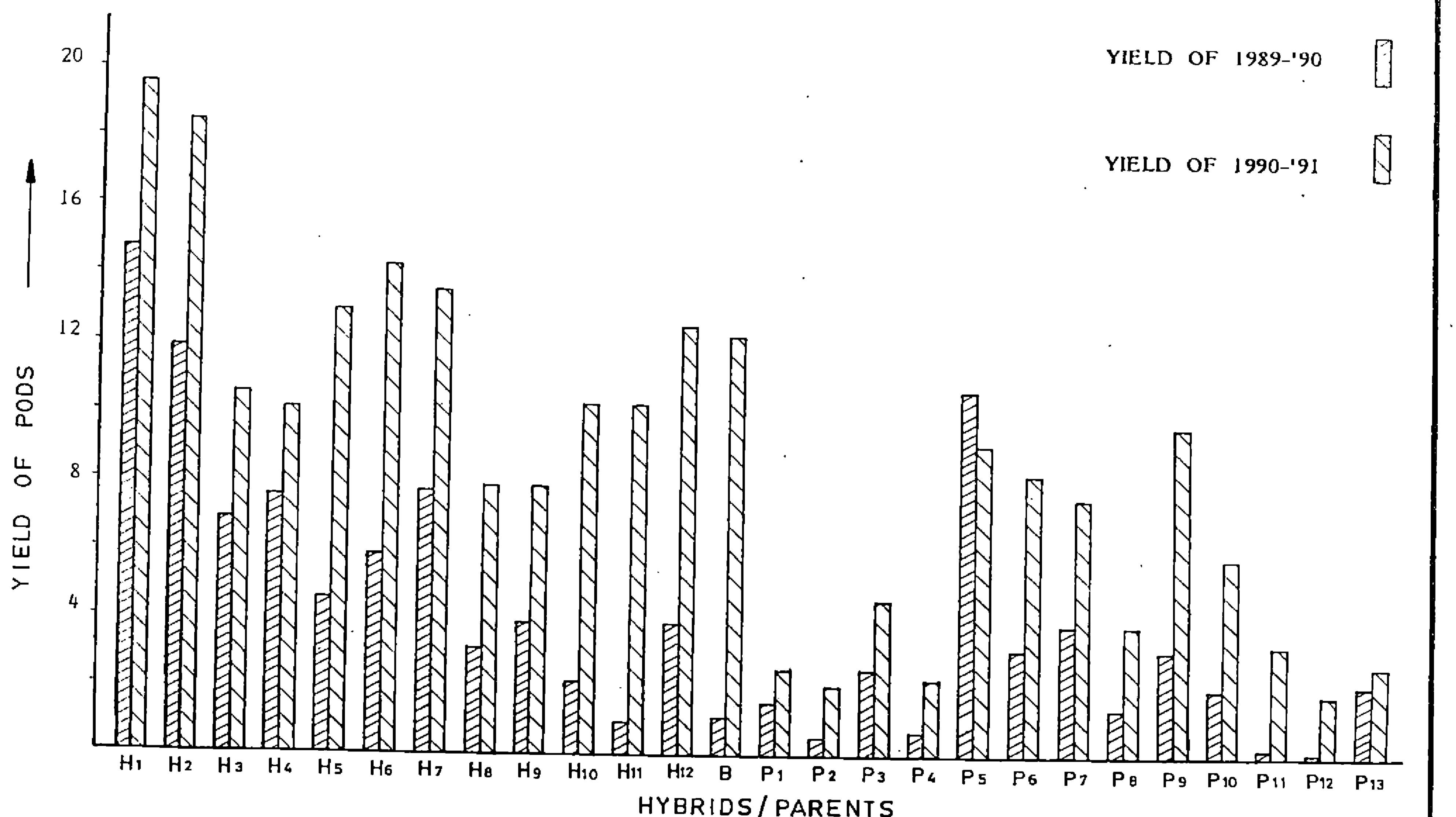

Fig-8 MEAN YIELD OF SERIES II HYBRIDS AND PARENTS

Table 23 Pod and bean characters of hybrids of 1987

Hybrid No.	Number of pods studied		Pod length (cm)		Pod width (cm)		Pod weight (g)		Wet bean weight per pod (g)		Number of beans/pod	
	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91
$H_{1.1}$	2	-	14.0	-	6.8	-	300.0	-	100.0	-	45.0	-
$H_{1.2}$	2	9	14.5	12.2	8.5	6.8	265.0	235.0	82.5	85.0	43.0	40.7
$H_{1.3}$	-	1	-	16.0	-	7.0	-	260.0	-	55.0	-	33.0
$H_{1.4}$	12	3	10.8	12.0	7.3	7.2	176.7	210.0	43.8	51.7	35.2	43.7
$H_{1.5}$	1	1	14.0	15.0	7.0	7.5	235.0	300.0	70.0	80.0	49.0	38.0
$H_{1.6}$	14	1	18.4	19.5	7.8	8.0	383.2	390.0	78.2	80.0	40.7	43.0
$H_{1.7}$	8	7	14.1	14.4	7.5	7.6	260.6	299.3	88.1	94.3	43.7	39.6
$H_{1.8}$	1	-	13.0	-	7.0	-	310.0	-	90.0	-	42.0	-
$H_{1.9}$	-	3	-	12.3	-	7.7	-	263.3	-	83.2	-	38.7
$H_{1.10}$	-	10	-	12.9	-	8.3	-	311.5	-	89.0	-	36.4
$H_{1.11}$	9	2	11.8	14.0	7.2	8.0	237.8	342.5	58.3	80.0	41.7	30.0
$H_{1.12}$	6	8	10.0	12.0	5.4	7.1	139.0	202.5	45.0	51.6	42.8	38.0
$H_{1.13}$	1	-	15.0	-	7.0	-	275.0	-	70.0	-	46.0	-
$H_{1.14}$	5	3	13.7	12.2	7.8	6.2	213.0	150.0	68.0	55.0	43.8	45.0
$H_{1.15}$	-	2	-	15.3	-	8.3	-	372.5	-	80.0	-	39.0
Mean			13.6	14.0	7.2	8.2	254.1	278.1	72.2	80.4	43.0	38.8
Percentage increase				2.9%		13.9%		9.5%		11.4%		-9.8%
$H_{2.1}$	3	8	12.3	15.0	6.0	7.7	213.3	327.5	66.7	100.0	40.7	38.0
$H_{2.2}$	11	3	14.9	14.3	8.3	7.8	328.2	290.0	82.0	70.0	40.5	33.3
$H_{2.3}$	6	8	11.9	11.5	6.9	6.8	212.5	213.1	60.8	65.0	36.7	38.8
$H_{2.4}$	1	-	15.5	-	8.5	-	385.0	-	110.0	-	47.0	-
$H_{2.5}$	3	2	14.0	16.0	7.2	8.5	266.7	377.5	86.7	110.0	44.7	46.0
$H_{2.6}$	14	1	13.6	16.0	7.6	9.5	297.7	555.0	74.3	140.0	35.8	35.0
$H_{2.8}$	3	1	14.5	19.0	6.8	8.0	243.3	375.0	53.3	80.0	37.9	40.0
$H_{2.9}$	6	5	14.7	14.5	8.4	8.1	268.3	339.0	59.2	73.0	32.2	33.8
$H_{2.10}$	6	3	11.4	12.8	7.8	7.8	223.3	331.7	70.8	110.0	40.8	43.0
$H_{2.11}$	18	5	10.8	12.3	7.2	7.8	170.0	292.0	39.1	47.0	22.6	18.6
$H_{2.12}$	-	1	-	11.5	-	6.5	-	185.0	-	35.0	-	12.0
$H_{2.13}$	-	7	-	14.1	-	7.4	-	285.7	-	84.3	-	37.1
$H_{2.14}$	2	-	12.5	-	6.5	-	200.0	-	47.5	-	30.0	-
$H_{2.15}$	3	2	10.7	13.3	6.3	8.5	138.3	295.0	46.7	80.0	33.3	43.5
Mean			13.1	14.2	7.3	7.9	245.6	322.2	66.4	82.9	36.9	34.9
Percentage increase				8.4%		8.2%		31.2%		24.9%		-5.4%
$H_{3.1}$	3	9	11.2	14.6	5.7	7.0	153.3	286.1	51.7	83.3	42.3	39.2
$H_{3.2}$	-	2	-	17.5	-	7.0	-	365.0	-	115.0	-	39.0
$H_{3.3}$	7	-	17.2	-	7.5	-	350.7	-	93.5	-	46.8	-
$H_{3.4}$	6	-	15.5	-	8.7	-	425.8	-	95.8	-	41.5	-

Table 23 (Contd.)

Hybrid No.	Dry weight of a single bean (g)		Seed length (mm)		Seed width (mm)		Seed thickness (mm)		Pericarp thickness (mm)	
	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91
$H_{1.1}$	0.8	-	20.6	-	11.1	-	6.6	-	7.3	-
$H_{1.2}$	0.7	0.7	17.6	19.1	9.8	10.7	6.0	6.3	7.5	5.6
$H_{1.3}$	-	0.7	-	19.0	-	9.8	-	7.2	-	9.0
$H_{1.4}$	0.3	0.4	14.6	15.7	8.5	8.6	4.5	4.2	8.8	7.0
$H_{1.5}$	0.6	0.5	17.6	17.0	9.8	9.6	5.4	6.6	6.5	8.0
$H_{1.6}$	0.7	0.8	20.1	22.0	9.4	9.6	6.4	7.0	9.9	10.0
$H_{1.7}$	0.7	0.8	20.8	21.9	10.8	11.1	5.8	6.7	6.3	6.5
$H_{1.8}$	0.6	-	19.4	-	11.0	-	6.4	-	9.0	-
$H_{1.9}$	-	0.8	-	18.2	-	9.6	-	6.8	-	7.2
$H_{1.10}$	-	0.8	-	21.3	-	12.1	-	5.7	-	7.5
$H_{1.11}$	0.5	0.8	17.6	17.9	9.3	9.4	5.4	6.9	7.7	9.5
$H_{1.12}$	0.3	0.6	15.6	18.1	9.2	11.1	4.2	6.2	4.2	4.9
$H_{1.13}$	0.5	-	16.2	-	9.2	-	5.6	-	8.0	-
$H_{1.14}$	0.5	0.5	18.2	18.6	9.5	9.8	5.6	5.0	7.8	4.9
$H_{1.15}$	-	0.5	-	16.4	-	9.2	-	5.8	-	8.8
Mean	0.6	0.7	18.0	18.8	9.8	10.1	5.6	6.8	7.5	7.4
Percentage increase		16.7%		4.4%		3.1%		21.4%		-1.3%
$H_{2.1}$	0.5	0.9	17.8	19.9	10.8	11.2	6.2	7.3	6.2	6.7
$H_{2.2}$	0.5	0.8	17.7	19.7	10.3	10.8	6.5	6.4	10.1	9.3
$H_{2.3}$	0.5	0.7	16.4	17.7	10.0	10.1	6.7	5.8	7.5	6.9
$H_{2.4}$	0.7	-	20.4	-	10.6	-	6.2	-	8.5	-
$H_{2.5}$	0.7	0.8	18.8	20.0	10.4	10.9	6.6	7.0	6.7	6.3
$H_{2.6}$	0.8	0.9	17.6	21.6	11.0	11.4	6.9	7.4	9.6	9.0
$H_{2.8}$	0.5	0.7	18.0	16.8	10.0	10.2	5.4	6.6	8.3	9.0
$H_{2.9}$	0.7	0.8	16.3	18.4	9.7	10.5	7.2	7.6	7.3	8.6
$H_{2.10}$	0.5	0.8	16.4	19.8	11.2	11.6	6.2	6.1	7.4	6.5
$H_{2.11}$	0.6	0.8	17.8	18.7	9.9	10.7	6.3	7.8	8.8	9.9
$H_{2.12}$	-	0.7	-	17.6	-	10.6	-	8.2	-	11.5
$H_{2.13}$	-	0.7	-	18.7	-	10.5	-	7.1	-	6.9
$H_{2.14}$	0.6	-	17.2	-	10.0	-	6.4	-	7.8	-
$H_{2.15}$	0.5	0.8	17.0	20.4	9.4	11.2	5.4	5.6	4.2	6.3
Mean	0.6	0.8	17.6	19.1	10.3	10.8	6.3	6.9	7.8	8.1
Percentage increase		33.3%		8.5%		4.9%		9.5%		3.9%
$H_{3.1}$	0.5	0.9	15.6	18.2	10.2	11.7	4.4	7.4	6.0	6.6
$H_{3.2}$	-	0.9	-	19.7	-	10.9	-	6.5	-	7.3
$H_{3.3}$	0.8	-	20.6	-	10.6	-	7.1	-	8.8	-
$H_{3.4}$	0.9	-	19.0	-	12.0	-	8.5	-	10.8	-

Table 23 (Contd.)

Hybrid No.	Number of pods studied		Pod length (cm)		Pod width (cm)		Pod weight (g)		Wet bean weight per pod (g)		Number of beans/ pod	
	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91
$H_{3.5}$	5	-	16.1	-	7.2	-	309.0	-	88.0	-	38.0	-
$H_{3.7}$	11	3	13.5	14.5	7.8	7.8	273.6	345.0	67.2	61.2	27.9	22.3
$H_{3.8}$	3	5	16.8	17.6	8.0	8.3	491.6	489.0	78.3	107.0	24.6	41.8
$H_{3.9}$	5	5	15.0	14.4	7.4	8.1	[illegible]	355.0	82.0	101.0	39.0	43.6
$H_{3.10}$	6	-	15.7	-	6.8	-	326.7	-	102.5	-	44.0	-
$H_{3.11}$	-	12	-	18.3	-	7.2	-	370.0	-	87.5	-	42.5
$H_{3.12}$	-	2	-	18.8	-	8.0	-	435.0	-	120.0	-	45.0
$H_{3.13}$	1	2	13.0	13.5	6.5	7.0	220.0	277.5	85.0	100.0	30.0	37.0
$H_{3.14}$	4	1	14.3	15.0	7.5	8.5	296.2	385.0	80.0	90.0	38.0	38.0
$H_{3.15}$	-	1	-	15.0	-	8.0	-	400.0	-	90.0	-	45.0
Mean			14.8	15.9	7.3	7.8	319.1	370.8	82.4	95.5	37.2	39.3
Percentage increase				7.4%		6.8%		16.2%		15.9%		5.6%
$H_{4.1}$	-	4	-	15.0	-	7.1	-	267.5	-	85.5	-	37.8
$H_{4.2}$	2	-	13.3	-	6.0	-	195.0	-	55.0	-	33.5	-
$H_{4.3}$	1	-	17.0	-	7.0	-	415.0	-	115.0	-	46.0	-
$H_{4.5}$	10	2	15.7	18.8	8.0	9.3	406.5	675.0	94.0	107.5	41.0	38.5
$H_{4.6}$	-	1	-	18.0	-	8.0	-	425.0	-	105.0	-	43.0
$H_{4.7}$	5	1	17.2	20.0	9.5	10.0	471.0	830.0	102.0	-	42.2	-
$H_{4.8}$	4	4	17.5	17.6	8.9	8.0	461.3	495.0	100.0	97.0	42.5	37.0
$H_{4.9}$	2	-	14.2	-	8.0	-	385.0	-	97.5	-	36.0	-
$H_{4.10}$	-	6	-	16.8	-	8.7	-	416.7	-	99.2	-	33.0
$H_{4.11}$	5	1	14.6	18.5	6.9	9.5	348.0	615.0	80.0	130.0	38.3	42.0
$H_{4.12}$	6	1	18.0	18.5	8.1	8.0	459.1	460.0	122.5	135.0	39.0	47.0
$H_{4.13}$	6	15	16.6	16.2	8.3	7.2	350.0	315.0	105.8	98.3	42.0	40.9
Mean			16.0	17.7	7.7	8.4	387.9	499.9	96.9	106.8	40.1	39.9
Percentage increase				10.6%		9.1%		28.9%		10.2%		0.5%
$H_{5.2}$	-	1	-	15.0	-	7.5	-	520.0	-	110.0	-	56.0
$H_{5.3}$	6	18	20.7	16.4	8.5	7.7	461.7	397.2	121.7	97.5	48.3	44.2
$H_{5.4}$	5	5	13.9	14.5	7.6	8.4	344.0	416.0	142.0	135.0	54.0	44.0
$H_{5.6}$	-	2	-	18.3	-	8.5	-	492.5	-	122.5	-	44.0
$H_{5.7}$	8	4	15.4	16.0	7.6	8.4	360.6	392.5	115.0	120.0	46.6	42.8
Mean			16.6	16.0	7.9	8.1	388.8	443.6	126.2	117.0	49.6	46.2
Percentage increase				-3.6%		2.5%		14.1%		-7.3%		-6.9%
$H_{6.1}$	1	5	14.5	12.4	7.5	6.1	235.0	172.0	70.0	54.0	31.0	34.6
$H_{6.2}$	-	4	-	16.8	-	7.5	-	331.3	-	130.0	-	45.0
$H_{6.4}$	8	-	14.1	-	6.6	-	212.5	-	65.6	-	39.3	-
$H_{6.5}$	2	4	13.5	14.1	6.5	6.9	215.0	285.0	85.0	96.3	39.0	40.3

Table 23 (Contd.)

Hybrid No.	Dry weight of a single bean (g)		Seed length (mm)		Seed width (mm)		Seed thickness (mm)		Pericarp thickness (mm)	
	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91
$H_{3.5}$	0.8	-	18.2	-	11.7	-	7.7	-	9.2	-
$H_{3.7}$	0.8	1.0	20.4	21.8	10.7	10.9	7.2	8.0	9.8	9.9
$H_{3.8}$	1.2	0.8	21.4	19.2	11.7	10.5	9.5	7.6	14.2	9.5
$H_{3.9}$	0.8	0.9	19.8	20.3	10.7	11.5	6.7	6.6	10.3	9.2
$H_{3.10}$	0.9	-	19.5	-	11.6	-	7.7	-	8.6	-
$H_{3.11}$	-	0.8	-	19.6	-	10.9	-	7.3	-	8.4
$H_{3.12}$	-	1.0	-	20.0	-	10.4	-	7.6	-	10.0
$H_{3.13}$	-	1.1	-	22.2	-	14.0	-	7.2	6.5	6.0
$H_{3.14}$	0.7	0.8	18.7	19.8	11.4	10.6	6.5	7.0	10.1	9.5
$H_{3.15}$	-	0.8	-	-	-	-	-	-	-	7.5
Mean	0.8	0.9	19.2	20.1	11.2	11.3	7.3	7.2	9.4	9.3
Percentage increase		12.5%		4.7%		0.9%		-1.4%		1.1%
$H_{4.1}$	-	0.9	-	20.8	--	10.9	-	7.2	-	5.9
$H_{4.2}$	0.5	-	18.4	-	10.8	-	6.4	-	6.0	-
$H_{4.3}$	1.0	-	20.2	-	11.6	-	7.6	-	9.0	-
$H_{4.5}$	1.1	0.9	20.4	22.7	10.9	11.2	7.2	8.7	11.5	12.5
$H_{4.6}$	-	0.9	-	19.2	-	11.2	-	7.0	-	10.0
$H_{4.7}$	0.9	-	20.2	-	11.6	-	7.8	-	12.2	-
$H_{4.8}$	0.9	1.0	20.3	20.0	12.2	12.2	8.0	7.4	11.7	9.0
$H_{4.9}$	1.0	-	21.6	-	11.9	-	7.9	-	7.3	-
$H_{4.10}$	-	1.1	-	21.5	-	12.0	-	8.7	-	10.5
$H_{4.11}$	0.3	1.1	21.6	22.2	11.0	10.4	6.6	7.2	9.7	14.0
$H_{4.12}$	1.1	1.1	21.4	22.2	11.6	12.4	8.0	8.4	10.7	8.0
$H_{4.13}$	1.0	0.9	21.1	19.1	12.4	11.4	7.6	7.1	7.9	6.1
Mean	0.8	1.0	20.6	21.0	11.6	11.5	7.5	7.7	9.9	9.5
Percentage increase		25.0%		1.9%		0.9%		2.7%		-4.0%
$H_{5.2}$	-	0.7	-	21.8	-	12.0	-	5.6	-	7.0
$H_{5.3}$	0.7	0.7	19.4	18.2	10.4	9.6	7.0	6.6	11.3	9.8
$H_{5.4}$	0.7	1.0	21.0	21.1	12.2	12.1	5.8	6.9	7.1	7.3
$H_{5.6}$	-	1.0	-	21.6	-	11.4	-	6.6	-	9.5
$H_{5.7}$	0.8	1.0	20.8	20.2	11.9	11.2	6.4	6.8	8.8	8.4
Mean	0.7	0.9	20.4	20.6	11.5	11.3	6.4	6.5	9.1	8.4
Percentage increase		28.6%		1.0%		-1.7%		1.6%		-7.7%
$H_{6.1}$	0.8	0.5	19.4	17.5	10.8	9.3	6.4	6.1	8.0	5.2
$H_{6.2}$	-	0.9	-	22.0	-	11.0	-	6.8	-	5.1
$H_{6.4}$	0.5	-	17.2	-	9.8	-	5.8	-	6.2	-
$H_{6.5}$	0.5	0.8	17.0	18.5	9.9	10.6	6.3	6.6	5.8	6.2

Table 23 (Contd.)

Hybrid No.	Number of pods studied		Pod length (cm)		Pod width (cm)		Pod weight (g)		Wet bean weight per pod (g)		Number of beans/ pod	
	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91
$H_{6.6}$	1	-	17.0	-	8.0	-	295.0	-	90.0	-	43.0	-
$H_{6.8}$	8	-	15.6	-	8.1	-	302.5	-	84.4	-	39.0	-
$H_{6.9}$	2	-	12.5	-	7.0	-	175.0	-	60.0	-	36.5	-
$H_{6.10}$	-	3	-	17.0	-	8.0	-	285.0	-	118.3	-	38.7
$H_{6.14}$	6	1	15.4	18.0	7.1	7.0	275.0	380.0	91.6	120.0	41.3	43.0
$H_{6.15}$	-	4	-	15.0	-	6.8	-	257.5	-	75.0	-	42.8
Mean			14.7	15.6	7.3	7.1	244.3	285.1	78.1	98.9	38.4	40.7
Percentage increase				6.1%		-2.7%		16.7%		26.6%		6.1%
$H_{7.1}$	-	6	-	15.6	-	7.3	-	328.3	-	93.2	-	45.8
$H_{7.3}$	-	1	-	17.0	-	8.0	-	470.0	-	180.0	-	58.0
$H_{7.4}$	-	6	-	15.9	-	8.0	-	452.5	-	151.7	-	54.7
$H_{7.5}$	5	2	13.7	15.3	7.5	8.3	397.0	437.7	128.0	135.0	45.8	48.5
$H_{7.6}$	1	9	12.5	13.9	7.0	7.8	235.0	309.4	95.0	108.3	48.0	40.2
$H_{7.7}$	9	-	15.0	-	8.4	-	310.5	-	113.8	-	49.7	-
$H_{7.8}$	4	-	16.0	-	12.5	-	387.5	-	102.5	-	48.7	-
$H_{7.9}$	5	7	13.4	14.8	8.1	8.9	306.2	415.7	91.8	108.3	43.5	44.2
$H_{7.10}$	9	12	14.8	15.9	7.7	8.4	346.6	477.5	143.3	170.4	49.6	45.5
$H_{7.11}$	-	2	-	17.8	-	9.3	-	647.5	-	177.5	-	53.0
$H_{7.12}$	10	10	14.1	15.7	8.1	8.6	260.0	433.5	95.0	135.6	51.0	52.2
$H_{7.13}$	3	4	16.0	15.4	8.6	9.1	496.6	483.8	173.3	136.7	56.7	53.3
$H_{7.14}$	1	1	13.5	16.5	7.5	8.0	280.0	415.0	95.0	165.0	41.0	58.0
Mean			14.3	15.8	8.4	8.3	335.5	442.8	115.3	142.0	48.2	50.3
Percentage increase				10.5%		1.2%		32.0%		23.2%		4.4%
$H_{8.1}$	4	10	13.7	14.6	7.3	7.3	226.2	264.0	72.5	78.0	44.0	46.5
$H_{8.3}$	-	1	-	17.0	-	8.0	-	470.0	-	120.0	-	46.0
$H_{8.4}$	1	-	16.5	-	7.0	-	375.0	-	95.0	-	50.0	-
$H_{8.6}$	2	-	17.7	-	8.3	-	367.5	-	90.0	-	46.5	-
$H_{8.9}$	-	4	-	12.9	-	7.4	-	366.3	-	93.8	-	42.0
$H_{8.13}$	3	-	16.2	-	8.0	-	408.3	-	126.7	-	50.3	-
$H_{8.15}$	-	1	-	20.0	-	8.5	-	420.0	-	160.0	-	56.0
Mean			15.8	16.1	7.7	7.8	344.3	380.1	96.1	113.0	47.7	47.6
Percentage increase				2.1%		1.3%		10.4%		17.6%		0.2%
$H_{9.1}$	3	2	16.3	16.0	8.8	8.8	380.0	422.5	118.3	127.5	51.6	47.1
$H_{9.3}$	3	5	15.1	13.4	8.1	7.7	358.3	319.0	108.3	68.0	49.6	31.4
$H_{9.4}$	-	3	-	11.8	-	7.5	-	265.0	-	70.0	-	34.7
$P_{9.5}$	1	2	16.5	17.3	8.0	9.3	455.0	480.0	125.0	140.0	52.0	55.0
$P_{9.7}$	3	-	17.0	-	8.8	-	406.6	-	128.3	-	55.6	-

Table 23 (Contd.)

Hybrid No.	Dry weight of a single bean (g)		Seed length (mm)		Seed width (mm)		Seed thickness (mm)		Pericarp thickness (mm)	
	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91
$H_{6.6}$	0.7	-	18.0	-	10.6	-	6.0	-	7.0	-
$H_{6.8}$	0.6	-	18.5	-	9.9	-	6.4	-	8.7	-
$H_{6.9}$	0.4	-	17.2	-	10.5	-	5.3	-	7.8	-
$H_{6.10}$	-	0.9	-	18.5	-	9.8	-	7.5	-	8.4
$H_{6.14}$	0.7	0.9	17.9	19.0	10.9	10.4	6.8	7.2	5.7	7.5
$H_{6.15}$	-	0.6	-	18.0	-	9.8	-	6.1	-	6.5
Mean	0.6	0.8	17.7	18.9	10.3	10.2	6.1	6.7	7.0	6.5
Percentage increase		39.3%		6.8%		0.9%		9.8%		-7.1%
$H_{7.1}$	-	0.9	-	20.9	-	12.8	-	6.8	-	6.8
$H_{7.3}$	-	1.0	-	22.0	-	12.0	-	6.4	-	6.0
$H_{7.4}$	-	0.9	-	12.6	-	11.4	-	6.4	-	6.6
$H_{7.5}$	0.8	0.8	22.1	19.9	12.4	11.1	6.5	5.9	9.0	7.0
$H_{7.6}$	0.5	0.8	19.0	20.7	10.2	11.1	5.8	7.1	7.0	7.0
$H_{7.7}$	0.6	-	20.4	-	10.5	-	6.0	-	6.9	-
$H_{7.8}$	0.6	-	19.9	-	10.8	-	5.1	-	10.6	-
$H_{7.9}$	0.6	0.8	19.7	20.0	10.4	10.1	6.0	6.7	7.6	7.9
$H_{7.10}$	0.8	1.0	19.8	21.9	12.0	12.8	6.2	7.4	6.5	7.1
$H_{7.11}$	-	1.1	-	23.6	-	13.0	-	7.0	-	10.8
$H_{7.12}$	0.5	0.8	16.7	19.5	9.4	9.8	5.4	6.8	7.9	8.5
$H_{7.13}$	0.8	0.9	21.9	21.8	11.4	11.7	6.5	6.4	9.0	8.3
$H_{7.14}$	0.6	0.8	20.2	21.8	10.6	12.2	6.2	5.8	7.5	6.5
Mean	0.6	0.9	20.0	21.3	10.9	11.6	6.0	6.6	8.0	7.5
Percentage increase		50.0%		6.5%		6.4%		10.0%		-6.3%
$H_{8.1}$	0.6	0.9	17.0	16.3	10.6	10.6	6.2	7.2	7.3	6.0
$H_{8.3}$	-	0.9	-	19.2	-	11.0	-	8.2	-	8.5
$H_{8.4}$	0.7	-	18.6	-	11.2	-	6.8	-	9.0	-
$H_{8.6}$	0.8	-	19.6	-	9.8	-	6.8	-	9.3	-
$H_{8.9}$	-	0.8	-	18.9	-	10.3	-	5.8	-	8.8
$H_{8.13}$	0.7	-	21.1	-	12.0	-	6.3	-	9.2	-
$H_{8.15}$	-	0.9	-	18.6	-	10.8	-	7.0	-	8.0
Mean	0.7	0.9	19.1	18.3	10.9	10.7	6.5	7.1	8.7	7.8
Percentage increase		28.6%		-4.2%		-1.8%		9.2%		-10.1%
$H_{9.1}$	1.0	0.9	20.2	21.2	10.8	11.0	6.4	6.8	9.2	8.0
$H_{9.3}$	0.8	0.9	20.2	21.6	11.7	11.7	6.2	6.5	7.9	7.7
$H_{9.4}$	-	0.8	-	18.5	-	11.3	-	7.1	-	8.5
$P_{9.5}$	0.9	0.9	22.4	22.8	13.4	12.6	6.0	5.8	11.0	8.8
$P_{9.7}$	0.8	-	22.6	-	11.0	-	6.2	-	9.6	-

Table 23 (Contd.)

Hybrid No.	Number of pods studied		Pod length (cm)		Pod width (cm)		Pod weight (g)		Wet bean weight per pod (g)		Numbers of beans/ pod	
	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91
$H_{9.8}$	-	4	-	16.6	-	8.1	-	467.5	-	125.0	-	41.5
$H_{9.10}$	3	1	17.2	18.0	8.5	8.5	391.7	535.0	111.6	-	45.0	-
$H_{9.11}$	8	8	15.6	15.4	7.8	7.7	311.8	342.5	85.6	100.0	50.6	50.8
$H_{9.12}$	-	4	-	17.3	-	8.5	-	450.0	-	106.3	-	43.0
$H_{9.13}$	1	2	19.5	18.5	8.0	8.0	530.0	545.0	170.0	167.5	61.0	56.0
$H_{9.14}$	-	1	-	16.5	-	8.5	-	450.0	-	140.0	-	54.0
$H_{9.15}$	2	-	14.3	-	7.3	-	387.5	-	137.5	-	51.5	-
Mean			16.4	16.1	8.2	8.3	402.6	427.7	123.1	116.0	52.1	45.9
Percentage increase				-1.8%		1.2%		6.2%		-5.7%		-11.8%
$H_{10.1}$	1	2	15.0	20.5	6.0	7.3	235.0	460.0	50.0	112.5	19.0	42.0
$H_{10.4}$	-	1	-	15.0	-	8.0	-	400.0	-	130.0	-	42.0
$H_{10.5}$	1	2	15.0	15.0	7.5	8.3	370.0	392.5	100.0	110.0	44.0	45.0
$H_{10.6}$	5	8	15.5	13.5	8.1	7.4	285.0	285.6	83.0	71.2	37.4	34.0
$H_{10.7}$	-	4	-	15.8	-	7.6	-	393.8	-	115.0	-	41.3
$H_{10.8}$	-	2	-	16.8	-	7.8	-	380.0	-	82.5	-	34.5
$H_{10.9}$	-	1	-	16.0	-	9.5	-	555.0	-	150.0	-	51.0
$H_{10.10}$	1	1	16.0	15.0	8.5	7.5	310.0	375.0	90.0	130.0	39.0	47.0
$H_{10.11}$	3	4	16.5	18.1	6.7	8.1	358.3	512.5	83.3	111.7	38.7	37.3
$H_{10.12}$	7	3	15.3	15.8	8.1	7.7	323.5	348.3	115.0	105.0	46.1	36.0
$H_{10.13}$	-	2	-	19.3	-	8.0	-	514.0	-	122.5	-	45.5
$H_{10.14}$	5	-	14.1	-	7.3	-	315.0	-	95.0	-	42.0	-
$H_{10.15}$	-	1	-	15.5	-	10.0	-	570.0	-	105.0	-	40.0
Mean			15.3	16.4	7.5	8.1	313.8	432.2	88.0	112.1	38.0	42.1
Percentage increase				7.2%		8.0%		37.7%		27.4%		10.9%
$H_{11.2}$	-	2	-	16.5	-	7.8	-	460.0	-	150.0	-	54.0
$H_{11.3}$	-	4	-	15.6	-	8.3	-	386.3	-	117.5	-	46.3
$H_{11.4}$	2	-	19.5	-	7.5	-	440.0	-	107.5	-	51.5	-
$H_{11.5}$	1	2	17.0	18.0	8.5	8.3	495.0	530.0	170.0	180.0	57.0	57.5
$H_{11.8}$	-	3	-	15.8	-	7.7	-	395.0	-	111.7	-	43.3
$H_{11.9}$	7	18.	17.0	17.0	7.6	7.5	395.7	390.6	96.4	87.2	46.0	45.6
$H_{11.10}$	3	7	16.3	14.8	8.2	8.3	438.3	389.3	125.0	114.2	48.3	45.3
$H_{11.14}$	-	6	-	16.0	-	7.5	-	327.5	-	93.3	-	46.7
$H_{11.15}$	-	2	-	16.0	-	7.3	-	347.5	-	95.0	-	47.0
Mean			17.5	16.2	8.0	7.8	442.3	403.3	124.7	118.6	50.7	48.2
Percentage increase				-7.4%		-2.5%		-8.8%		-4.9%		-4.9%
$H_{12.1}$	-	6	-	14.7	-	7.3	-	332.5	-	70.8	-	41.2
$H_{12.2}$	-	1	-	15.0	-	8.0	-	450.0	-	115.0	-	46.0

Table 23 (Contd.)

Hybrid No.	Dry weight of a single bean (g)		Seed length (mm)		Seed width (mm)		Seed thickness (mm)		Pericarp thickness (mm)	
	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91
$H_{9.8}$	-	1.0	-	21.7	-	11.9	-	7.7	-	8.9
$H_{9.10}$	0.8	-	20.6	-	11.6	-	5.4	-	9.3	-
$H_{9.11}$	0.7	0.8	19.2	21.0	10.4	11.1	5.9	6.1	8.2	6.8
$H_{9.12}$	-	0.9	-	22.3	-	10.5	-	7.9	-	8.4
$H_{9.13}$	1.2	1.2	23.8	-	13.2	-	8.8	-	10.5	7.5
$H_{9.14}$	-	0.9	-	23.4	-	13.0	-	7.0	-	9.7
$H_{9.15}$	1.0	-	22.2	-	12.6	-	6.6	-	8.8	-
Mean	0.9	0.9	21.4	21.6	11.8	11.6	6.4	6.9	9.3	8.3
Percentage increase		0%		0.9%		-1.7%		7.8%		-10.8%
$H_{10.1}$	0.9	0.9	20.0	19.5	10.6	11.2	8.4	7.9	8.5	9.5
$H_{10.4}$	-	1.1	-	23.4	-	13.2	-	7.2	-	7.0
$H_{10.5}$	0.9	1.1	21.8	22.0	13.4	12.4	8.0	7.6	11.0	8.8
$H_{10.6}$	0.8	0.7	19.4	20.1	11.6	12.3	7.2	6.5	8.7	7.7
$H_{10.7}$	-	1.1	-	20.1	-	12.3	-	7.7	-	9.6
$H_{10.8}$	-	0.8	-	18.9	-	10.7	-	7.8	-	9.8
$H_{10.9}$	-	1.0	-	22.0	-	13.2	-	7.0	-	10.5
$H_{10.10}$	0.9	1.0	18.8	20.2	11.4	12.4	7.2	7.8	8.5	6.5
$H_{10.11}$	0.8	1.1	19.3	19.2	11.0	10.6	7.8	7.8	10.8	8.8
$H_{10.12}$	[illegible]	1.2	20.9	21.0	12.8	12.9	7.4	7.8	8.2	7.7
$H_{10.13}$	-	0.9	-	21.0	-	10.3	-	7.2	-	10.0
$H_{10.14}$	0.9	-	20.3	-	12.5	-	7.3	-	9.1	-
$H_{10.15}$	-	1.0	-	-	-	-	-	-	-	12.5
Mean	0.9	1.0	20.1	20.7	11.9	12.0	7.6	7.5	9.3	9.0
Percentage increase		11.1%		3.0%		0.8%		-1.3%		-3.2%
$H_{11.2}$	-	0.8	-	22.6	-	10.9	-	6.2	-	6.8
$H_{11.3}$	-	0.8	-	20.2	-	10.9	-	7.2	-	6.0
$H_{11.4}$	0.7	-	19.7	-	9.8	-	7.3	-	11.3	-
$H_{11.5}$	0.9	1.0	22.6	19.7	11.2	11.5	7.4	6.6	7.5	9.3
$H_{11.8}$	-	0.8	-	19.6	-	10.3	-	6.5	-	7.0
$H_{11.9}$	0.8	0.7	20.9	18.9	10.3	10.2	6.6	6.8	10.9	9.5
$H_{11.10}$	1.0	1.0	22.5	22.9	11.7	11.7	6.9	5.7	9.6	7.3
$H_{11.14}$	-	0.8	-	22.2	-	11.4	-	6.4	-	8.4
$H_{11.15}$	-	0.8	-	18.8	-	11.2	-	7.4	-	7.8
Mean	0.9	0.8	21.4	20.6	10.8	11.0	7.1	6.6	9.8	7.8
Percentage increase		-11.1%		-3.7%		2.9%		-7.0%		-20.4%
$H_{12.1}$	-	0.7	-	17.9	-	11.1	-	5.5	-	9.6
$H_{12.2}$	-	0.9	-	20.4	-	12.2	-	6.4	-	9.5

Table 23 (Contd.)

Hybrid No.	Number of pods studied		Pod length (cm)		Pod width (cm)		Pod weight (g)		Wet bean weight per pod (g)		Numbers of beans/ pod	
	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91
$H_{12.3}$	-	2	-	17.3	-	8.0	-	492.5	-	132.5	-	46.0
$H_{12.4}$	4	6	13.9	15.7	6.1	7.5	228.8	411.7	71.3	82.0	47.3	31.2
$H_{12.5}$	3	-	13.0	-	6.8	-	293.3	-	105.0	-	39.0	-
$H_{12.6}$	1	-	12.0	-	6.5	-	225.0	-	70.0	-	36.0	-
$H_{12.7}$	14	2	12.5	13.3	6.3	7.0	215.7	265.0	75.4	85.0	41.2	32.5
$H_{12.8}$	9.	2	14.1	14.5	8.2	7.5	305.0	365.0	89.4	95.0	35.8	37.0
$H_{12.10}$	4	-	13.6	-	8.4	-	456.3	-	117.5	-	42.8	-
$H_{12.14}$	-	1	-	15.0	-	7.5	-	280.0	-	95.0	-	45.0
Mean			13.2	15.1	7.1	7.5	287.4	371.0	88.1	96.5	40.4	39.8
Percentage increase				14.4%		5.6%		29.1%		9.5%		-1.5%
Bulk	[illegible]	18	16.5	16.2	7.8	8.1	409.3	413.1	125.0	108.9	48.1	43.9
Percentage increase				-1.8%		16.7%		0.9%		-12.9%		-8.7%
P_1	13	3	14.2	16.7	6.8	7.5	236.5	325.0	52.9	61.7	24.6	24.7
P_2	5	6	13.7	15.3	8.6	9.1	400.0	512.5	91.0	106.3	46.2	40.8
P_3	18	2	16.3	16.3	7.8	7.8	372.2	365.0	95.5	72.5	43.9	31.0
P_4	1	-	17.5	-	8.5	-	400.0	-	105.0	-	45.0	-
P_5	18	10	13.5	14.0	7.6	8.1	268.6	339.0	85.2	117.1	35.7	43.3
P_6	12	12	14.1	15.3	7.3	8.3	320.0	405.8	85.0	98.6	39.9	42.6
P_7	18	9	16.8	16.6	8.6	8.4	443.6	497.8	111.3	113.8	39.8	32.7
P_8	5	3	15.5	16.5	8.3	7.7	439.0	406.7	118.0	108.3	36.0	40.7
P_9	18	4	11.8	13.4	7.2	8.3	270.2	363.8	77.2	88.8	33.9	34.0
P_{10}	6	11	15.4	17.4	8.3	9.4	479.1	622.7	148.3	192.1	56.7	59.1
P_{11}	3	4	14.2	18.1	7.2	8.6	326.7	506.3	85.0	125.0	31.7	51.0
P_{13}	13	-	12.9	-	7.1	-	309.6	-	84.6	-	42.9	-

Table 23 (Contd.)

Hybrid No.	Dry weight of a single bean (g)		Seed length (mm)		Seed width (mm)		Seed thickness (mm)		Pericarp thickness (mm)	
	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91	1989-90	1990-91
$H_{12.3}$	-	1.0	-	20.8	-	12.4	-	6.6	-	9.0
$H_{12.4}$	0.4	0.9	17.6	20.2	9.4	11.3	6.4	7.7	9.2	10.3
$H_{12.5}$	0.7	-	21.6	-	13.2	-	7.0	-	9.2	-
$H_{12.6}$	0.5	-	20.2	-	10.4	-	5.4	-	9.5	-
$H_{12.7}$	0.6	0.8	17.2	19.3	10.7	11.5	6.1	7.5	7.3	5.8
$H_{12.8}$	0.8	0.9	19.4	20.8	12.4	13.4	7.4	7.0	10.5	9.3
$H_{12.10}$	1.0	-	23.0	-	13.0	-	7.2	-	13.2	-
$H_{12.14}$	-	0.9	-	18.4	-	11.2	-	6.6	-	7.0
Mean	0.7	0.9	19.8	19.7	11.5	11.9	6.6	6.8	9.8	8.6
Percentage increase		28.6%		-0.5%		3.5%		3.0%		-12.2%
Bulk	0.9	0.9	19.8	20.5	12.5	11.4	7.3	7.4	9.6	8.6
Percentage increase		0.0%		3.5%		-8.8%		1.4%		-10.4%
P_1	0.7	1.0	20.0	21.1	11.1	11.2	7.9	7.9	9.2	11.3
P_2	0.7	0.8	19.1	20.7	11.0	11.2	6.4	6.8	10.8	10.4
P_3	0.8	0.9	19.6	20.4	11.1	10.6	7.2	7.7	9.7	6.8
P_4	0.7	-	17.4	-	11.8	-	8.8	-	12.5	-
P_5	0.7	0.7	18.8	19.0	10.7	10.5	6.7	6.7	8.0	6.8
P_6	0.7	0.8	19.4	19.0	11.1	11.1	6.9	7.1	9.2	8.5
P_7	0.9	1.2	19.8	21.5	11.9	12.3	7.7	9.0	11.5	10.9
P_8	1.1	1.1	21.3	21.3	12.3	12.5	7.7	7.8	10.1	8.7
P_9	0.8	1.0	21.2	21.7	12.3	11.8	6.0	7.6	9.8	9.9
P_{10}	0.9	1.0	22.1	23.1	11.8	11.9	6.4	6.5	10.2	11.9
P_{11}	-	0.8	19.2	20.0	11.0	11.2	5.2	6.7	7.8	10.7
P_{13}	0.6	-	19.9	-	11.6	-	6.0	-	9.8	-

worked out and are presented in Table 23. As in Series I hybrids, the percentage increase/decrease in the various parameters was worked out in order to have an assessment of the extent of improvement in these factors with increasing age of the hybrids.

Change in the pod weight values expressed as percentages over last year's value ranged from -8.8 in H_{11} to +37.7 in H_{10}. For wet bean weight also, the values showed a similar trend ranging from -7.3% in H_5 to 27.4% in H_{10}. The hybrid H_{10} showed the maximum increase in the values of pod weight, wet bean weight and number of beans (10.9%). With regard to pod weight as well as dry bean weight, a considerable decrease was noticed in the hybrid H_{11} when compared to the previous year. However, a remarkable increase (50%) in dry weight of beans was observed in the hybrid H_7 belonging to the cross $V_{5/9}$ x 55. This hybrid planted in the progeny trial was also observed to be precocious in flowering.

Based on the desirable attributes like vigour in growth, precocity and promising yield attributes, one of the parents of this hybrid $V_{5/9}$ is already selected as a tester parent in the second stage of breeding programme.

Series III hybrids and parents

These hybrids were produced through hand pollination done in 1986-'87, selected based on seedling vigour in 1987-'88 and field-planted in 1988. The total number of crosses was 24 and the number selected, five. These were also planted along with a row of open-pollinated bulk seedlings and eight parents and the maximum number of plants was kept as 15 in all the cases. Observations on stem girth of hybrids and those on plant height and canopy spread of parents were taken in December, 1990 and data on these are given in Table 24. Statistical analysis was done taking the design as randomised block with variable replications and the plot size as a single plant. The differences between hybrids were statistically significant with H_4 ($V_{4/8}$ x 52) recording the highest girth figures and H_3 ($V_{4/8}$ x 64) the lowest. The open-pollinated bulk came in between and was ranked the fourth. In

Table 24 Mean stem girth of hybrids and open pollinated plants of Series III (Hand pollinated 1986-87, Field planted - 1988) and height and canopy spread of parents

Hybrid/ Parent	Cross/Parent	No. of plants	Height (cm)	Girth (cm)	Spread (cm)
Hybrids					
H_1	9/16 x 53	15	--	18.2	--
H_2	16/9 x 64	15	--	18.1	--
H_3	$V_{4/8}$ x 64	13	--	17.7	--
H_4	$V_{4/8}$ x 52	15	--	21.7	--
H_5	$V_{10/3}$ x 68	14	--	20.0	--
B	Bulk	15	--	18.2	--
F test				Sig.	
Parents					
P_1	9/16	14	194.3	--	212.3
P_2	16/9	15	171.3	--	222.8
P_3	$V_{4/8}$	15	185.0	--	234.0
P_4	$V_{10/3}$	14	107.5	--	130.7
P_5	GVI - 52	15	146.3	--	114.2
P_6	GVI - 53	14	67.9	--	48.0
P_7	GVI - 64	15	101.0	--	105.8
P_8	GVI - 68	15	64.0	--	44.0
F test			Sig.		Sig.

Ranking of hybrids and bulk based on girth

H_4 H_5 H_1 B H_2 H_3

Ranking of parents based on height

P_1 P_3 P_2 P_5 P_4 P_6 P_8

Ranking of parents based on spread

P_3 P_2 P_1 P_4 P_5 P_7 P_6 P_8

Table 25 Pod and bean characters of hybrids of 1988

Hybrid No.	No. of pods studied	Pod length (cm)	Pod width (cm)	Pod weight (cm)	Wet bean weight/ pod (g)	No. of beans/ pod	Dry weight of single bean (g)	Seed length (mm)	Seed width (mm)	Seed thickness (mm)	Pericarp thickness (mm)
$H_{1.3}$	1	15.5	7.0	280.0	90.0	39.0	0.8	19.6	11.2	7.0	9.0
$H_{1.6}$	5	18.8	7.7	391.0	127.0	44.8	1.0	22.7	11.5	7.6	6.9
Mean		17.2	7.4	335.5	108.5	41.9	0.9	21.2	11.4	7.3	8.0
$H_{2.2}$	2	14.3	7.3	275.0	70.0	44.5	0.8	20.0	10.2	6.2	7.0
$H_{2.3}$	3	16.0	8.2	378.3	106.7	48.3	0.7	20.1	10.7	6.1	8.3
$H_{2.4}$	2	16.5	7.8	287.5	80.0	47.5	0.6	20.2	10.0	5.8	9.0
$H_{2.6}$	1	16.0	8.0	380.0	90.0	45.0	0.7	20.4	10.4	6.4	8.5
$H_{2.7}$	1	13.0	7.0	250.0	65.0	42.0	0.5	17.4	9.8	5.4	8.0
$H_{2.8}$	1	16.5	7.0	310.0	65.0	41.0	0.6	18.2	9.2	6.4	9.5
$H_{2.12}$	2	13.5	6.8	192.5	60.0	34.5	0.6	-	-	-	7.8
Mean		15.1	7.4	296.2	76.7	43.3	0.6	16.1	10.1	6.1	8.3
$H_{3.5}$	2	14.3	7.3	327.5	115.0	43.0	0.9	21.2	11.6	7.0	8.0
$H_{3.10}$	1	14.0	8.0	310.0	90.0	47.0	0.7	19.2	10.4	6.2	7.0
$H_{3.11}$	14	13.4	6.7	275.0	69.6	35.9	0.8	19.1	10.5	5.9	9.6
Mean		13.9	7.3	304.2	9.15	42.0	0.8	19.8	10.8	6.4	8.2
$H_{4.3}$	4	18.0	7.8	412.5	102.5	45.8	0.8	20.3	11.8	7.2	7.7
$H_{4.4}$	8	15.2	6.8	279.4	90.0	45.4	0.8	18.8	10.4	6.9	7.4
$H_{4.6}$	1	16.0	7.0	300.0	80.0	44.0	0.6	17.2	10.0	6.0	10.5
$H_{4.7}$	1	14.0	6.0	150.0	50.0	40.0	0.5	16.2	9.4	5.2	5.0
$H_{4.8}$	1	12.0	7.0	220.0	70.0	39.0	0.7	18.8	10.0	6.8	6.5
$H_{4.11}$	3	14.7	7.0	238.3	66.7	39.0	0.8	18.0	9.6	5.8	8.0
$H_{4.13}$	4	16.0	7.9	361.3	102.5	39.0	0.8	21.3	10.3	7.4	9.5
$H_{4.14}$	2	16.5	8.0	360.0	92.5	46.5	0.8	20.2	11.0	6.6	7.8
Mean		15.3	7.2	290.2	81.8	42.3	0.7	18.9	10.3	6.5	7.8
$H_{5.3}$	1	13.0	7.0	300.0	105.0	39.0	0.9	23.4	13.6	6.8	6.5
$H_{5.4}$	1	17.0	7.0	405.0	110.0	52.0	0.8	17.2	10.4	6.6	5.0
$H_{5.6}$	1	14.0	7.0	235.0	60.0	38.0	0.6	18.6	10.6	6.2	7.0
$H_{5.7}$	3	16.0	6.5	233.3	68.3	44.7	0.5	18.6	10.0	5.2	4.5
$H_{5.11}$	2	16.5	8.0	380.0	122.5	53.0	0.8	20.0	10.9	6.3	8.0
$H_{5.13}$	3	16.7	8.0	381.7	131.7	56.3	0.9	21.8	10.6	6.1	8.9
$H_{5.14}$	2	15.5	8.0	330.0	102.5	55.0	0.7	22.6	11.6	6.4	8.3
Mean		15.5	7.4	323.6	100.0	48.3	0.7	20.3	11.1	6.2	6.9
Bulk	2	17.1	8.0	375.0	92.5	35.5	0.9	20.8	11.2	7.0	9.3
P_1	1	16.0	7.0	360.0	90.0	45.0	0.8	19.2	10.2	6.4	9.5
P_2	12	15.9	7.4	334.2	85.0	42.4	0.7	19.5	10.4	6.7	9.1
P_3	1	14.5	7.0	260.0	75.0	45.0	0.6	15.2	9.6	6.8	8.0

height and canopy spread of parents also, the differences were significant with P_1 (9/16), P_2 (16/9) and P_3 ($V_{4/8}$) being generally superior.

A few of the hybrids and parents have started yielding during the year. Yield data are not furnished as many of the plants are yet to yield. However, pod and bean characters of these plants were recorded as already done in Series I and II hybrids and parents during January to March 1991. The data are presented in Table 25. In most of these plants, the values were observed to be below average as the trees are hardly three years old. However, these data may serve as a fruitful base data for comparison in the coming years.

(ii) Assessment of the growth of hybrids of the progeny trial

The hybrids selected as superior based on seedling vigour during the four-year period from 1984-'85 to 1987-'88 were field-planted during the period starting from November, 1988 as a replicated progeny trial. Details of the number of crosses made and number selected during each year were given in the Third Annual Report, 1989-'90. The total number of crosses included in this progeny trial is 29 and these were planted along with a set of seedlings arising from open-pollinated pods. The design is randomised block, number of replications five and the number of plants per plot, six. Two of these five replications were planted under intense shade of existing rubber and three in an area without shade trees and under the temporary shade of banana. Planting was started in 1988 but only 21 hybrids and the bulk seedlings could be planted during that year. The remaining hybrids were planted during 1989. There were quite a few gaps which were filled from time to time. Gap filling became necessary especially in the three replications provided with banana shade only. The crop under the shade of rubber appeared to grow much better and faster and a few plants had already started yielding. Without such a shading and with accompaniment of banana only, crop growth was much poorer. The necessity and advantage of having good shading for the early establishment period of cocoa was apparent. Data on stem girth and plant height were collected during December, 1990. Data on these related to replications I and II

Table 26 **Mean height and girth of plants of progeny trial**

Hybrid	Cross	Number of plants	Girth (cm)	Height (cm)
H_1	20/4 x 9/16	12	15.6	146.8
H_2	20/4 x 16/9	12	15.5	116.5
H_3	19/5 x 16/9	11	16.2	132.6
H_4	$V_{10/3}$ x 54	12	17.6	125.9
H_5	$V_{10/3}$ x 56	12	16.3	119.4
H_6	$V_{10/3}$ x 61	12	15.7	108.9
H_7	$V_{5/9}$ x 54	12	14.9	143.4
H_8	$V_{5/9}$ x 55	12	17.0	126.1
H_9	$V_{5/9}$ x 61	12	9.5	117.8
H_{10}	$V_{4/8}$ x 16/9	12	14.2	114.8
H_{11}	$V_{4/8}$ x 54	12	14.0	118.0
H_{12}	$V_{15/5}$ x 55	12	13.6	102.8
H_{13}	$V_{15/5}$ x 54	12	13.8	112.7
H_{14}	13/2 x $V_{5/9}$	12	14.2	117.0
H_{15}	16/9 x 56	12	15.7	126.5
H_{16}	$V_{15/5}$ x 56	12	14.7	131.5
H_{17}	$V_{15/5}$ x 59	12	7.9	80.2
H_{18}	$V_{9/6}$ x 68	12	14.1	121.6
H_{19}	$V_{9/6}$ x 51	12	14.3	120.3
H_{20}	$V_{9/6}$ x 61	12	16.3	118.9
H_{21}	$V_{9/6}$ x 55	11	14.6	109.7
H_{22}	51 x 126	11	8.4	94.4
H_{23}	59 x 126	12	12.0	107.5
H_{24}	$V_{5/9}$ x 68	10	9.9	115.6
H_{25}	$V_{5/9}$ x 64	11	10.4	95.9
H_{26}	$V_{10/3}$ x 68	10	11.3	109.9
H_{27}	$V_{10/3}$ x 64	12	11.2	87.0
H_{28}	$V_{4/8}$ x 68	12	9.3	100.0
H_{29}	59 x 16/9	12	11.3	86.8
B	Bulk	12	14.4	114.7

Contd.

Table 26 (Contd.)

Ranking of hybrids and bulk based on girth

H_4 H_8 H_5 H_{20} H_3 H_{15} H_6 H_1 H_2 H_7 H_{16} H_{21} B H_{19} H_{10} H_{14} H_{18} H_{11} H_{13} H_{12} H_{23} H_{26} H_{29} H_{27} H_{25} H_{24} H_9 H_{28} H_{22} H_{17}

Ranking of hybrids and bulk based on height

H_1 H_7 H_3 H_{16} H_{15} H_8 H_4 H_{18} H_{19} H_5 H_{20} H_{11} H_9 H_{14} H_2 H_{24} H_{10} B H_{13} H_{26} H_{21} H_6 H_{23} H_{12} H_{28} H_{25} H_{22} H_{27} H_{29} H_{17}

only were processed as a uniform experimental crop could be established only in these two replications planted under the shade of rubber. The results obtained (Table 26) showed a superiority of hybrids H_1, H_3, H_4, H_7, H_8, H_{15} and H_{16} both in height and girth. Similarly, a general inferiority was also observed for hybrids H_{17}, H_{22}, H_{25}, H_{28}, H_{29} etc. in both the growth parameters. Most of the plants of this trial have started flowering and the first ripened pod was harvested from the plant 10.14 ($V_{5/9}$ x 55) on 2.11.1990. This hybrid (H_8) is also observed to be vigorous in growth. The parent $V_{5/9}$ of this hybrid is already selected as a tester parent in the second stage breeding programme because of its very high specific combining ability based on seedling observations.

(iii) Production of hybrids for gap filling the progeny trial

The following hybrids were produced during the period from September to December, 1990 through controlled hand pollination. These were produced for gap filling the progeny trial.

(i)	$V_{5/9}$ x 54	(ii)	$V_{5/9}$ x 55
(iii)	$V_{5/9}$ x 61	(iv)	$V_{5/9}$ x 64
(v)	$V_{5/9}$ x 68	(vi)	$V_{10/3}$ x 61
(vii)	$V_{10/3}$ x 64	(viii)	$V_{10/3}$ x 68
(ix)	$V_{15/5}$ x 54	(x)	$V_{15/5}$ x 56
(xi)	16/9 x 55	(xii)	$V_{4/8}$ x 64
(xiii)	$V_{4/8}$ x 68	(xiv)	$V_{4/8}$ x 16/9
(xv)	20/4 x 9/16	(xvi)	19/5 x 16/9
(xvii)	$V_{9/6}$ x 51	(xviii)	$V_{9/6}$ x 55
(xix)	$V_{9/6}$ x 61		

(iv) Development of inbreds

This item of work was taken up to finally produce homozygous inbreds of high-yielding self-compatible plants. This is expected to take five to seven generations of selfing. The first set of selfed pods of plants 12/21 and

18/7 of Mannuthy, $V_{3/16}$ of Germplasm I and 7/4 of Germplasm II was produced during 1987 and seedlings arising from these planted under three sets of conditions - one in large pots, another in the nursery area and yet another in the field. The first two sets were raised under special conditions to induce faster growth and early flowering. There were three plants each in pots and seven in the nursery area. A sizeable number of these plants came to flowering this year and these were used for selfing to produce second generation selfed pods. Many of these plants were found to be self-incompatible and selfed pods could be produced from progenies of only two parents, $V_{3/16}$ of Germplasm I and 7/4 of Germplasm II. Details of pollinations done, pods set and self-compatibility positions are given in Table 27.

The set of inbreds planted in the field in June 1989 had three selfed plants each of the four parents and three budded parent plants. Such a simultaneous planting of parents and progenies was done to have an assessment of the extent of inbreeding depression. All the selfed plants flowered during this year. The growth rate of budded parent plants, in general, was poor as is commonly observed in all budded plants in the early years of growth compared to the seedlings. Observations on height and girth of these seedlings and budded plants were recorded in December 1990 and data in these are presented in Table 28.

(v) Recovery of haploid plants from flat beans

With the objective of producing haploid plants, flat beans collected from bulk seeds at the time of bean extraction were sown in potting mixture in containers as well as in culture media under sterile conditions. Since the germination of flat beans under *in vivo* conditions was found to be very poor, only *in vitro* germination was attempted during the current year. Details of these are given elsewhere.

(vi) Selection of new parents and assessment of bean characters and self-compatibility reaction

Selection of high-yielding plants for the second stage of breeding was made from among the plants available in Germplasm I, II, III, IV and VI and

Table 27 Pollinations done, pods set and self-compatibility positions of S_1 plants of self-compatible high yielders

Sl.No.	Parent plant	No. of flowers pollinated	No. of pods developed	Self-compatibility position
1	7/4.1	18	0	SI^{++}
2	7/4.2	57	0	SI^{+}
3	7/4.3	44	0	SI^{++}
4	7/4.4	21	0	SI^{++}
5	7/4.5	44	0	SI^{+}
6	7/4.6	42	0	SI^{++}
7	7/4.7	33	4*	--
8	7/4.8	28	0	SI^{++}
9	7/4.9	33	3	SC
10	7/4.10	11	0	SI^{++}
11	$V_{3/16.1}$	11	0	SI^{++}
12	$V_{3/16.2}$	17	3	SC
13	$V_{3/16.3}$	7	0	SI^{++}
14	$V_{3/16.4}$	9	0	SI^{++}
15	$V_{3/16.5}$	9	0	SI^{+}
16	$V_{3/16 6}$	22	1	SC
17	$V_{3/16.7}$	8	2	SC
18	$V_{3/16.8}$	9	0	SI^{+}
19	18/7.1	22	3*	--
20	18/7.2	24	5*	--
21	18/7.3	28	7*	--
22	18/7.4	4	1*	--
23	18/7.5	12	0	SI^{+}
24	18/7.6	41	0	SI^{++}
25	18/7 7	28	0	SI^{++}
26	18/7.8	23	3*	--
27	18/7.10	13	2	SC
28	12/21.1	29	0	SI^{++}
29	12/21.2	18	0	SI^{++}
30	12/21.3	50	0	SI^{++}
31	12/21.7	5	0	SI^{++}

* Pods developed for four to eight weeks and then wilted. May be self-compatible. SI^{+} - Self-compatible with early swelling of ovary followed by wilting. SI^{++} - Self-incompatible with no signs of pod swelling.

Table 28 Mean height and girth of budded self-compatible parent plants and their selfed (S_1) progenies

	Number of plants	Height (cm)	Girth (cm)
Parents			
$M_{12/21}$	3	141.7	14.3
$M_{18/7}$	3	105.0	13.7
GI $V_{3/16}$	3	90.0	12.0
GII 7/4	3	165.0	15.7
S_1 progeny			
$M_{12/21}$	3	213.3	16.7
$M_{18/7}$	3	188.3	17.7
GI $V_{3/16}$	3	123.3	13.7
GII 7/4	3	175.0	17.0

Table 29 High-yielding plants of Germplasm I selected for the second stage of breeding and their mean yields

Sl.No.	Plant No.	Yield
1	$V_{5.16}$	70.3
2	$V_{5.4}$	63.8
3	$V_{6.17}$	59.2
4	$V_{5.14}$	57.0
5	$V_{10.2}$	56.2
6	$V_{5.2}$	55.2
7	$V_{14.17}$	55.2
8	$V_{9.2}$	52.0
9	$V_{10.8}$	51.3

from shade trial area based on the yield from 1984 to March, 1990. Plants already selected in 1984 as high yielders for the first stage of breeding could not be included for this assessment as these plants were used for hand pollination work during most of the period and data on yield could not be collected from them. The basis of selection from each of the collections is given below.

Germplasm I - Plants were selected from this group based on the yield for the six-year period from 1984-'85 to 1989-'90. Data appear in the Third Annual Report. All the plants with annual mean yield of over 50 pods for this period were selected as high yielders. The list of plants selected and their mean yields are given in Table 29. The total number of plants selected comes to nine.

Germplasm II, III and IV - The basis of selection from these groups was the mean yield for the six-year period from 1984-'85 to 1989-'90 (Third Annual Report) and the limit fixed was 40 pods. The list of plants selected and their mean yield figures are given in Table 30. The total number of plants selected from these three groups comes to 16.

Germplasm V - None of the plants of this group had yields of over 30 pods. As such, no plant was selected from this group.

Germplasm VI - For selection of types from this group, yields of 1988-'89 and 1989-'90 were used as the basis and the limit was fixed as 30 pods. The number of types selected came to 22 and the list of such plants along with their mean yield for the two-year period are given in Table 31.

Shade trial area - The basis of selection from this group of over 1000 plants arising from ordinary seedlings planted originally in 1979 was the mean yield for the six-year period from 1984-'85 to 1989-'90. The limit was fixed as 90 pods. The list of plants thus selected is given in Table 32. The total number of such plants came to six. Nearly all the selected plants were found to be from the deshaded area of the shade trial and one of the reasons for the high yield of these plants was attributed to be the shade-free condition. As such, a further selection from the shaded area was made basing the selection on a mean yiled

Table 30 High-yielding plants of Germplasm II, III and IV and their mean yields

Sl. No.	Plant No.	Yield
G II		
1	23.3	53.3
2	18.2	53.0
3	7.3	50.2
4	16.3	47.5
5	14.3	45.8
6	7.2	42.7
7	24.4	41.7
8	7.4	41.0
G III		
1	8.6	42.7
G IV		
1	35.7	78.0
2	13.1	55.7
3	14.2	51.2
4	36.6	44.7
5	1.2	43.5
6	4.5	42.5
7	10.9	42.2

Table 31 High-yielding types of Germplasm VI and their mean yields

Sl. No.	Type No.	Yield	Sl. No.	Type No.	Yield
1	44	73.1	12	19	38.7
2	24	61.0	13	56	37.3
3	7	54.4	14	6	36.5
4	54	52.5	15	2	36.0
5	50	51.0	16	33	32.9
6	14	49.7	17	17	32.0
7	15	49.0	18	35	30.7
8	25	47.7	19	29	30.6
9	9	44.2	20	51	30.1
10	22	40.5	21	34	30.0
11	10	39.4	22	23	30.0

Table 32 High-yielding plants of the shade trial originally selected and their mean yields

Sl. No.	Plant No.	Yield
1	44.1	133.7
2	51.1	99.5
3	49.7	96.7
4	50.12	91.2
5	45.5	91.0
6	39.1	90.3

of 50 pods. Details of plants thus selected are given in Table 33. The number of plants additionally selected from the shade trial area came to eight.

Assessment of self-compatibility position of the selected high-yielders was done using selfing through hand pollination during the period from January 1991. The positions of some types of Germplasm VI were assessed already in the earlier years. Such an assessment was made with the objective of eliminating the types/plants which are self-compatible. Further elimination based on bean size also is necessary, the limit being 1 g. Data on this in some types of Germplasm VI were already available. Details of the number of pollinations done in each case to assess self-compatibility, the position assigned and the available information on pod and bean characters are given in Tables 34 and 35.

Final selection of new parents from among the selected high-yielders was made by further elimination of plants/types with dry bean size of less than 1 g and those that are self-compatible. All the remaining types and plants which were either assessed as self-incompatible with acceptable bean size or were yet to be assessed for these two characters were tentatively selected for the second stage of breeding starting with assessment of general combining ability using the common parent, GI-$V_{5/9}$. All the crosses involving those parents whose bean size will be found to be lower than 1 g and which will be assessed as self-compatible will be eliminated later. All the parents of the first stage of breeding are also to be included along with the new parents for the study on general combining ability. The final list of parents selected for the new breeding programme along with the plant characters that remain to be assessed is given in Table 36.

3. Comparative assessment of the performance of self-incompatible parental clones

In order to assess the comparative performance of parent plants selected for the breeding work under comparable conditions, this replicated field trial was taken up. Planting was done in June 1989. Budding was the mode of propagation. The number of plants per plot was kept as six and the number of replications was three. All the parent plants used in the breeding programme were included in this trial and the total number comes to 26. Observations on

Table 33 High-yielding plants of the shaded area of the shade trial and their mean yields

Sl. No.	Plant No.	Yield
1	38.1	82.7
2	27.16	64.2
3	40.7	62.4
4	31.11	62.4
5	33.12	61.7
6	39.9	57.5
7	28.3	55.8
8	24.1	50.3

Table 34 Assessment of self-compatibility position and pod and bean characters of high-yielders initially selected for the second stage of breeding

Sl. No.	Plant/ Type No.	Number of pollination	No. of pods set	Self-compatibility position	Mean bean dry weight (g)	Wet bean weight (g/pod)
GP I						
1	5.2	107	--	SI^{++}	--	--
2	5.4	89	--	SI^{++}	--	--
3	5.14	30	--	SI^{++}	--	--
4	5.16	65	--	SI^{++}	--	--
5	6.17	98	1	SC	--	--
6	9.2	103	3	SC	--	--
7	10.2	27	--	SI^{++}	--	--
8	10.8	84	--	SI^{++}	--	--
9	14.17	45	--	SI^{+}	--	--

Contd.

Table 34 (Contd.)

Sl. No.	Plant/ Type No.	Number of pollinations	No. of pods set	Self-compatibility position	Mean bean dry weight (g)	Wet bean weight (g/pod)
GP II						
10	7.2	43	6	SC	--	--
11	7.3	88	--	SI^{++}	--	--
12	7.4	100	10	SC	--	--
13	14.3	38	3	SC	--	--
14	16.3	52	--	SI^{++}	--	--
15	18.2	42	2	SC	--	--
16	23.3	104	--	SI^{++}	--	--
17	24.4	43	5	SC	--	--
GP III						
18	8.6	107	12	SC	--	--
GP IV						
19	1.2	14	4	SC	--	--
20	4.5	71	--	SI^{++}	--	--
21	10.9	54	--	SI^{++}	--	--
22	13.1	32	--	SI^{+}	--	--
23	14.2	100	--	SI^{++}	--	--
24	35.7	116	4	SC		
25	36.6	83	--	SI^{+}		
GI VI						
26	2	40	--	SI^{++}	1.1	104.3
27	6	73	--	SI^{++}	0.7	--
28	7	100	--	SI^{++}	0.9	--
29	9	124	4	SC	1.0	98.8
30	10	7	--	NA	1.0	110.0
31	14	47	1	SC	0.5	--
32	15	--	--	NA	--	--

Contd.

Table 34 (Contd.)

Sl. No.	Plant/ Type No.	Number of pollinations	No. of pods set	Self-compatibility position	Mean bean dry weight (g)	Wet bean weight (g/pod)
33	17	28	--	SI^{++}	--	--
34	19	56	--	SI^{++}	0.9	--
35	22	65	--	SI^{+}	1.0	106.6
36	23	168	7	SC	1.1	143.3
37	24	76	--	SI^{+}	--	--
38	25	116	--	SI^{++}	1.2	146.1
39	29	151	6	SC	1.1	102.6
40	33	19	5	SC	--	--
41	34	--	--	NA	0.9	--
42	35	108	--	SI^{++}	0.7	--
43	44	24	5	SC	1.0	103.6
44	50	176	--	SI^{+}	1.6	172.1
45	51	84	--	SI^{++}	1.5	193.8
46	54	22	--	SI^{++}	1.0	109.3
47	56	111	--	SI^{+}	1.0	125.3
Shade						
48	24.1	56	2	SC	--	--
49	27.16	17	--	NA	--	--
50	28.3	89	--	SI^{++}	--	--
51	31.11	13	--	NA	--	--
52	33.12	53	23	SC	--	--
53	38.1	67	6	SC	--	--
54	39.1	36	2	SC	--	--
55	39.9	107	2	SC	--	--
56	40.7	86	8	SC	--	--
57	44.1	117	3	SC	--	--
58	45.5	9	2	SC	--	--
59	49.7	50	--	SI^{++}	--	--
60	50.12	99	--	SI^{++}	--	--
61	51.1	56	--	SI^{++}	--	--

SC - Self-compatible SI^{+} - Self-incompatible with early swelling of ovary followed by wilting SI^{++} - Self-incompatible with no signs of swelling of ovary NA - Self-compatibility position not assigned

Table 35 Pod and bean character of selected parents (Stage II)

Plant No.	No. of pods studied	MEAN			
		Pod weight (g)	Wet bean weight (g)	Bean No.	Dry weight of single bean (g)
GI - $V_{5/2}$	2	415.0	102.5	47.5	0.8
GI - $V_{5/4}$	1	250.0	85.0	40.0	0.6*
GI - $V_{5/14}$	1	265.0	95.0	43.0	0.7*
GI - $V_{6/17}$	10	365.0	102.0	38.1	0.8
GI - $V_{9/2}$	12	439.2	99.2	33.8	1.0
GI - $V_{10/2}$	17	404.1	113.8	42.9	1.1
GI - $V_{10/8}$	12	394.6	97.1	39.8	0.8
GII - 7/2	7	300.7	90.0	48.9	0.7
GII - 7/3	4	280.0	67.5	38.5	0.5**
GII - 14/3	2	410.0	115.0	41.0	0.8
GII - 16/3	1	400.0	100.0	33.0	0.9
GII - 18/2	17	251.3	87.1	43.5	0.7**
GII - 23/3	7	492.1	92.9	38.6	1.0
GII - 24/4	9	361.1	73.3	33.0	0.9
GIV - 1/2	13	423.8	105.8	41.6	0.9
GIV - 4/5	2	362.5	120.0	42.5	1.0
GIV - 10/9	17	507.6	122.6	37.8	1.2
GIV - 13/1	18	298.1	72.8	40.2	0.6**
GIV - 14/2	4	408.8	97.5	47.3	0.7
GIV - 35/7	17	425.6	100.6	44.6	0.8
GIV - 36/6	17	321.8	95.6	39.6	1.0
24/1 shade	9	441.7	127.2	47.0	1.0
27/16 shade	5	404.0	122.0	40.6	0.8
33/12 shade	13	230.8	65.8	37.5	0.7**
38/1 shade	17	289.4	102.6	43.2	0.8
39/1 shade	9	229.4	72.2	41.6	0.6**
39/9 shade	7	287.9	86.4	39.7	0.9
40/7 shade	10	464.5	78.5	27.8	1.0
44/1 shade	11	403.6	129.1	41.6	1.1
45/5 shade	11	365.5	119.5	39.7	0.9
49/7 shade	4	348.8	82.5	39.5	0.7**
50/12 shade	5	371.0	88.0	27.8	1.2
51/1 shade	2	385.0	72.5	32.5	0.8

* More pods required to be studied before elimination

** Plants with low bean weight and to be eliminated

Table 36 Final list of plants selected as parents for the second stage of breeding

Sl.No.	Plant No.		Characters to be assessed	Sl. No.	Plant No.		Characters to be assessed
1	M	9.16	—	28	GIV	18.5	—
2	"	13.12	--	29	"	32.5	--
3	"	16.9	—	30	"	36.6	BS
4	GI	4.8	--	31	GVI	2	--
5	"	5.2	BS	32	"	10	CP
6	"	5.4	BS	33	"	15	BS & CP
7	"	5.14	BS	34	"	17	BS
8	"	5.16	BS	35	"	22	--
9	"	9.6	—	36	"	24	BS
10	"	10.2	BS	37	"	25	—
11	"	10.3	--	38	"	50	—
12	"	10.8	BS	39	"	51	—
13	"	14.17	BS	40	"	54	—
14	"	15.5	--	41	"	55	--
15	GII	7.3	BS	42	"	56	—
16	"	12.3	--	43	"	59	—
17	"	16.3	BS	44	"	60	—
18	"	19.5	--	45	"	61	--
19	"	20.4	—	46	"	64	—
20	"	23.3	BS	47	"	68	--
21	GIII	1.2	--	48	Shade	27.16	BS & CP
22	"	4.1	—	49	"	28.3	BS
23	GIV	2.5	—	50	"	28.3	BS
24	"	4.5	BS	50	"	31.11	BS & CP
25	"	10.9	BS	51	"	49.7	BS
26	"	13.1	BS	52	"	50.12	BS
27	"	14.2	BS	53	"	51.1	BS

BS - Bean size CP - Compatibility position height and spread of plants were taken in December 1990 and the data on these are presented in the Table 37.

The results indicate a superiority of the parent P_{11} (GII-20/4) both in height and spread though this type was not significantly different from a few other parents. This superior trend is also exhibited by hybrids including this parent in the progeny trial planted during the same period. But it is too early to predict their performance since the plants are hardly two years old.

4. Multilocational testing of parental clones

With the objective of having a rough assessment of the multilocational performance of parental clones, budded plants from the selected self-incompatible parents were planted at various locations in the State. Two of the other objectives are that (i) these will act as polyclonal seed gardens, the seeds from which will be necessarily hybrids of high yielders and theoretically superior to open-pollinated bulk seedlings and (ii) those planted in areas with vascular streak die-back will provide information on clonal differences in susceptibility to this disease. A total of thirteen such clonal plantings were taken up so far and the total number of plants involved is 1903. Eight of these plots are in farmers' fields and five in farms of the University and the Central State Farm, Aralom. Details are given in Table 38. One of the seven types (GVI-44) planted in a farmers' field (S.No.6) was later found to be self-compatible. The seed garden at Konni (S.No.7) was planted with high yielders of the shade trial pending assessment of their incompatibility positions. Self-compatibility positions of a few of these plants were studied during the year and two of them (S 44/1) and S 45/5) were found to be self-compatible. Others are yet to be assessed for their compatibility reactions. In the three new gardens planted during this year at Panniyoor, Vellayani and Muvattupuzha only high yielding self-incompatible selected parents were used for planting.

Table 37 Height and spread of parental clones of the comparative yield trial

Clone No.	Parent	Height (cm)	Spread (cm)
P_1	$M_{9/16}$	131.1	119.7
P_2	$M_{16/9}$	134.5	93.5
P_3	$M_{13/12}$	86.2	61.7
P_4	$V_{4/8}$	130.6	120.6
P_5	$V_{5/9}$	134.7	98.8
P_6	$V_{9/6}$	101.7	92.4
P_7	$V_{10/3}$	108.8	91.3
P_8	$V_{15/5}$	123.6	103.4
P_9	GII-2/3	128.3	89.5
P_{10}	GII-19/5	113.6	116.7
P_{11}	GII-20/4	149.7	162.1
P_{12}	GIII-1/2	93.8	79.0
P_{13}	GIII-4/1	125.3	130.9
P_{14}	GIV-2/5	103.5	76.5
P_{15}	GIV-18/5	112.8	108.2
P_{16}	GIV-32/5	106.7	112.2
P_{17}	GVI-50	130.4	99.9
P_{18}	GVI-51	115.0	85.9
P_{19}	GVI-54	112.3	88.1
P_{20}	GVI-55	92.8	55.4
P_{21}	GVI-56	116.0	86.2
P_{22}	GVI-59	148.6	112.2
P_{23}	GVI-60	122.2	75.2
P_{24}	GVI-61	121.6	113.5
P_{25}	GVI-64	102.5	95.5
P_{26}	GVI-68	117.2	79.7

Ranking of parental clones based on height

P_{11} P_{22} P_5 P_2 P_1 P_4 P_{17} P_9 P_{13} P_8 P_{23} P_{24} P_{26} P_{21} P_{18} P_{10} P_{15} P_{19} P_7 P_{16} P_{14} P_{25} P_6 P_{12} P_{20} P_3

P_{11} P_{13} P_4 P_1 P_{10} P_{24} P_{16} P_{22} P_{15} P_8 P_{17} P_5 P_{25} P_2 P_6 P_7 P_9 P_{19} P_{21} P_{18} P_{26} P_{12} P_{14} P_{23} P_3 P_{20}

Table 38 Details of multilocational clonal gardens

Sl. No.	Location	Date of planting	No. of parents	No. of plants
1	Regional Agricultural Research Station, Kumarakom	22.5.88	8	96
2	Farm of Mr. Babu Thomas, Chirathadam, Kuravilangad, Kottayam Dist.	16.8.88	8	60
3	Farm of Mr. M.P. Chacko, Retd. Headmaster, Manakkad, Vazhithala P.O. (685 584), Idukki Dist.	18.8.88	8	55
4	Central State Farm, Aralam, Cannanore Dist.	.9.88	8	400
5	Farm of Mr. Babu Thomas, Chirathadam, Kuraviiangad, Kottayam Dist. (Location II)	27.5.89	8	107
6	Farm of Mr. N.I. Ulahannan, Nedungattu Veedu, Kavakkad, P.O. (Via) Kalloorkkad,Moovattupuzha	.8.89	7	35
7	Farm of Mr. K.J. Baby, Rubber Merchant, C/o Studio Johnson, Konni	19.8.89	9	90
8	Intructional Farm, Kerala Agricultural University, Vellanikkara	3.9.89	12	120
9	Farm of Dr. S.R. Achuthanandan, Santhi Nursing Home, Kodungallor - 680 664, Trichur Dist.	19 12.89	21	217
10	Farm of Prof. K.J. Kurian, Poovathumkal House, Thudanganad, Thodupuzha	8.6.90	25	255
11	Pepper Research Station, Panniyur	25.6.90	13	123
12	Agricultural College, Vellayani	30 6 90	21	195
13	Farm of Mr. Paul Maliyakal, Maliyakal, Kodalikkad, P.O. (Via) Vazhakkulam, Muvattupuzha			
	TOTAL			1903

B. CROP MANAGEMENT

1. Studies to determine the response of cocoa to shade and irrigation

This observational trial planted in 1979 was originally aimed at assessing the growth and yield trends of cocoa at various levels of shade. The experimental cocoa plants of over 1000 were planted in an existing rubber garden and were raised under the rubber canopy till 1984, when the plot was divided into four to provide varying levels of shade. Shade manipulation was done by graded thinning of rubber; one of the plots being left without any thinning and yet another with all the rubber removed. The remaining two plots received half and three-fourth thinning. Measurements made with lux meter in 1984 in the unthinned portion of the experimental area indicated that the percentage light infiltration was around 25. It was, therefore, assumed that shade levels in the remaining three plots would be about 50, 25 and 0. Measurements of light infiltration made during February, 1990 simultaneously with line quantum sensor under shade and quantum sensor in the open indicated the position to be much different, the percentage light infiltration values being around 8 (6-12), 34 (30-41) and 26 (16-34) in the unthinned, half-thinned and three-fourth thinned plots. These measurements were made from four locations in the unthinned plot and from three each in the other two plots and measurement at each location was for the period from 9 am to 4 pm with value integration for every five minutes. Eventhough measured shade levels were lower in the plot three-fourth thinned than in the half-thinned, these are designated as high and medium shade, respectively.

During 1988, the experimental plots were subdivided and one each under each shade level was continued without irrigation and another set brought under sprinkler irrigation. Data on girth of stem collected during December, 1990 and those on yield of pods from April, 1990 to March, 1991 are given in Tables 39 and 40 . With increasing illumination, there was increase in stem girth under both irrigatged and unirrigated conditions. The only exception to this appears to be the slight decrease with increasing illumination in the open beyond low shade in the irrigated set. Unlike what it was during last year, the effect of irrigation on this growth attribute was apparent there being higher gain in girth under irrigated conditions. Such a trend of advantage in

Table 39 Effects of shade and irrigation on stem girth of cocoa

Shade levels	Irrigated			Unirrigated			Mean girth of 1990-91
	1989-90	1990-91	Per cent increase	1989-90	1990-91	Per cent decrease	
High shade	33.6	37.7	12.2	31.8	36.9	16.0	37.3
Medium shade	36.6	41.1	12.3	35.4	38.5	8.8	39.8
Low shade	36.3	47.4	30.6	37.2	40.7	9.4	44.1
No shade	43.0	45.3	5.3	42.2	44.7	5.9	45.0
Mean	37.4	42.9	14.7	36.7	40.2	9.5	

Table 40 Effects of shade and irrigation on yield of cocoa

Shade levels	Irrigated			Unirrigated			Mean yield of 1990-91
	1989-90	1990-91	Per cent decrease	1989-90	1990-91	Per cent decrease	
High shade	23.1	11.7	49.4	6.9	4.2	39.1	8.0
Medium shade	43.4	29.5	32.0	18.4	7.4	59.8	18.5
Low shade	62.3	40.3	35.3	28.2	27.9	1.1	34.1
No shade	54.1	44.2	18.3	57.8	51.2	11.4	47.7
Mean	45.7	31.4	31.3	27.8	22.7	18.3	

growth by irrigation was not noted last year and it was then interpreted that it could be because of the short span available since starting irrigation for this growth character to express itself. In yield, the trend was comparable to what it was last year and the major conclusions are the following:

(i) With increasing levels of illumination, there was consistent and conspicuous increase in yield. The magnitude of increase was, however, much more in the unirrigated set than in the irrigated. Comparing between the high shade and no shade situations, the extent of yield increase is over 12 times in unirrigated cocoa whereas the comparable value for the irrigated crop is only 3.8.

(ii) Irrigation resulted in an increase in yield, the extent of increase in overall mean being 38.3 per cent. The extent of advantage, however, varied with illumination level, the gain being noted only in the crop provided with shade. In the deshaded set, the mean yield was in fact, more in the unirrigated plot, the difference being larger than what it was last year. Such a trend is contrary to what was expected. While it is true that one of the reasons for the higher yield in the unirrigated plot could be the incidental inclusion of higner yielding plants, this does not appear to adequately explain the consistent and conspicuous trend. It is, however, too early to draw conclusions on this aspect as it is only the second year since irrigation was provided.

As was done during the last three years, superior plants with yield of more than 100 pods were identified during this year also. The list of such plants in the order of decreasing yield is given in Table 41. The total number of such plants in this population of over 1000 plants comes to 32 and the highest yielding plant is 52.1 with an yield of 202. The highest yielder of last year, 38.1 does not appear in the list since the plant was selected for the second stage breeding programmes. As in the case of Germplasm I to V, the yield of all the plants identified as superior during the last three years was compiled for the seven year period starting from 1984-'85. The list of these plants ranked on the basis of overall mean yield for the seven year period is given in Table 42. The range in annual mean was from 26.3 to 133.7, plant 44.1 being the highest yielder. The difference in yield between this plant and the next highest yielder was large. The highest yielding five plants of this

Table 41 Ranking of superior plants of shade trial

Rank	Plant No.	Yield	Rank	Plant No.	Yield	Rank	Plant No.	Yield
1	52.1	202	12	51.7	125	23	40.3	109
2	53.19	176	13	51.22	124	24	50.5	109
3	43.13	157	14	52.12	120	25	49.11	108
4	43.9	155	15	48.6	118	26	43.4	105
5	41.10	153	16	49.13	117	27	49.19	104
6	47.20	150	17	32.7	116	28	47.9	103
7	46.10	143	18	53.12	114	29	45.15	102
8	47.4	138	19	29.5	112	30	27.4	101
9	50.8	134	20	51.16	112	31	44.15	101
10	46.9	131	21	45.9	111	32	51.18	101
11	50.19	129	22	52.17	111			

Table 42 **Ranking of superior plants of the shade trial and their yields for the seven year period from 1984-85 to 1989-90**

Rank	Tree No.	Number of pods/plant								
		'84-85	'85-86	'86-87	'87-88	'88-89	'89-90	'90-91	Total	Mean
1	44/1	23	30	96	151	285	217	--	802	133.7
2	51/1	2	0	85	81	182	247	--	597	99.5
3	49/7	17	9	51	118	216	169	--	580	96.7
4	50/12	37	15	89	94	96	216	--	547	91.2
5	45/5	11	3	60	128	152	192	--	546	91.0
6	39/1	10	30	67	122	152	161	--	542	90.3
7	45/9	10	11	73	14	133	239	111	591	84.4
8	49/13	0	13	54	80	216	106	117	586	83.7
9	38/1	2	8	35	80	88	283	--	496	82.7
10	43/4	7	24	91	63	134	153	105	577	82.4
11	47/20	2	28	55	81	120	133	150	569	81.3

Contd.

Table 42 (Contd.)

Rank	Tree No.	Number of pods/plant								
		'84-85	'85-86	'86-87	'87-88	'88-89	'89-90	'90-91	Total	Mean
12	50/8	0	14	45	149	92	133	134	567	81.0
13	47/4	8	0	18	67	210	184	—	486	81.0
14	45/2	8	20	31	92	184	132	90	557	79.9
15	51/22	0	0	64	95	135	132	124	550	78.6
16	50/9	0	36	46	41	167	181	60	531	75.9
17	53/12	0	0	46	75	142	149	114	526	75.1
18	43/13	0	0	41	63	76	187	157	524	74.9
19	42/18	0	8	42	94	117	182	78	521	74.4
20	46/9	2	37	52	85	111	99	131	517	73.9
21	46/6	0	32	49	56	154	119	97	507	72.4
22	49/11	3	16	55	72	143	106	108	503	71.9
23	45/11	15	10	86	82	145	137	28	503	71.9
24	50/19	16	25	76	53	104	92	129	495	70.7
25	48/6	16	42	46	67	86	114	118	489	69.9
26	51/18	8	14	61	84	112	108	101	488	69.7
27	53/19	13	49	46	21	80	98	176	483	69.0
28	48/12	0	4	51	84	148	126	69	482	68.9
29	46/10	0	4	38	54	115	125	143	479	68.4
30	50/5	2	14	57	35	122	118	109	457	65.3
31	51/7	4	0	44	36	118	126	125	453	64.7
32	27/16	0	17	63	56	152	97	--	385	64.2
33	42/1	1	1	43	29	110	116	99	449	64.1
34	46/18	5	48	48	103	123	61	55	443	63.3
35	50/15	0	6	25	53	123	152	84	443	63.3
36	40/7	12	1	85	66	87	123	—	374	62.4
37	31/11	9	17	76	61	107	104	--	374	62.4
38	43/9	0	12	8	52	110	97	155	434	62.0
39	45/15	0	0	57	16	100	157	102	432	61.7
40	33/12	0	0	55	51	129	135	—	370	61.7
41	27/1	0	1	1	27	46	112	187	429	61.3

Contd.

Table 42 (Contd.)

Rank	Tree No.	Number of pods/plant								
		'84-85	'85-86	'86-87	'87-88	'88-89	'89-90	'90-91	Total	Mean
42	50/16	18	15	61	42	84	130	79	429	61.3
43	43/2	2	14	53	85	114	74	84	426	60.9
44	49/19	0	38	42	55	120	60	104	419	59.9
45	51/13	1	20	40	32	152	97	77	419	59.9
46	51/10	12	0	74	58	115	66	89	414	59.1
47	50/17	1	25	38	85	115	84	59	407	58.1
48	32/7	0	5	17	14	156	98	116	406	58.0
49	39/9	19	32	34	58	93	109	--	345	57.5
50	43/3	2	7	5	82	87	147	65	395	56.4
51	25/2	13	25	66	119	53	73	45	394	56.3
52	28/3	3	8	57	56	66	145	--	335	55.8
53	51/14	10	34	49	40	92	102	48	375	53.6
54	40/3	0	3	18	5	57	183	109	375	53.6
55	42/16	0	10	16	70	73	131	73	373	53.3
56	47/9	0	25	17	67	103	53	103	368	52.6
57	52/17	0	38	8	7	93	110	111	367	52.4
58	47/7	0	0	31	62	134	80	59	366	52.3
59	29/5	0	3	19	48	126	55	112	363	51.9
60	47/16	1	4	29	33	111	86	95	359	51.3
61	33/4	0	4	15	9	107	144	78	357	51.0
62	24/1	22	38	6	57	71	108	--	302	50.3
63	52/13	6	21	28	43	113	87	50	348	49.7
64	49/5	4	6	56	22	74	101	84	347	49.6
65	22/3	3	17	68	12	116	48	49	313	44.7
66	48/21	0	1	2	34	103	107	64	311	44.4
67	18/11	1	1	53	103	69	52	28	307	43.9
68	51/11	0	9	10	23	118	71	66	297	42.4
69	48/10	0	0	17	61	124	59	34	295	42.1
70	37/8	0	2	9	57	73	101	52	294	42.0
71	37/3	3	25	26	37	72	109	10	282	40.3

Contd.

Table 42 (Contd.)

Rank	Tree No.	Number of pods/plant								
		'84-85	'85-86	'86-87	'87-88	'88-89	'89-90	'90-91	Total	Mean
72	46/2	0	7	5	9	56	128	77	282	40.3
73	51/3	8	0	2	20	106	74	72	282	40.3
74	41/10	0	16	7	24	40	42	153	282	40.3
75	32/4	0	1	18	18	62	108	67	274	39.1
76	22/1	2	2	26	26	113	57	29	255	36.4
77	50/4	0	0	8	38	84	107	15	252	36.0
78	44/16	3	3	44	36	8	100	52	246	35.1
79	43/10	4	10	41	6	32	102	48	243	34.7
80	44/22	0	17	22	19	46	116	9	229	32.7
81	27/4	0	0	6	13	20	78	101	218	31.1
82	44/5	2	2	3	1	22	133	46	209	29.9
83	44/15	1	0	2	7	39	40	101	190	27.1
84	53/18	0	0	12	0	20	101	51	184	26.3

group are 44.1, 51.1, 49.7, 50.12, 45.5 and 39.1. The yield of these plants for the current year could not be recorded as they were included in this year's breeding programme.

2. Trials on training and pruning of cocoa

This replicated field experiment started in 1981 involves regulating the jorquette height and number of tiers. It has seven treatments with the first tier formed at 1-1.5 m, 1.5-2 m and 2-2.5 m with one or two tiers along with unpruned control. The experimental plants were pruned for regulating the jorquette height as required. Data on pod yield were collected and these are presented in Table 43 and Fig.9 along with those of previous years starting from 1985-86 when the experimental crop started yielding. The trend of results of this year are consistent with those of the previous three years with the treatment differences being statistically at par and contrary to the trend of the first two years of bearing when there was a distinct and statistically significant superiority of the unpruned plants. The disadvantage of the pruned set in the first two years is attributable to the disturbance given to the plants to shape them to treatment specifications. Though the differences in the subsequent years were not significant, control of no pruning recorded the highest mean yield upto 1989-'90. This trend also disappeared this year with two treatments receiving pruning giving higher mean yield. The final conclusion based on the yield so far is to be that pruning done to restrict growth of cocoa to a single stem and to one or two tiers will not adversely affect productivity. However, in the early years of bearing an advantage of the unpruned set is likely to be noted.

3. NPK fertilizer experiment on budded plants

This field experiment started in 1983 has a total of 27 treatment combinations of three levels each of N, P_2O_5 and K_2O. The design is confounded factorial in RBD with three replications. Clonal material was used for the study in order to eliminate plant to plant variability and there were three plants per plot. The levels of nutrients tried are the following.

N - 0, 100 and 200 g N/plant/year
P - 0, 40 and 80 g P_2O_5/plant/year
K - 0, 140 and 280 g K_2O /plant/year

Table 43 Effect of methods of pruning on the yield of cocoa

Sl. No.	Treatments	Yield of pods					
		1985-'86	1986-'87	1987-'88	1988-'89	1989-'90	1990-'91
1	Single tier at 1-1.5 m	1.5	3.4	3.4	12.9	24.3	14.4
2	Single tier at 1.5-2 m	1.4	4.6	4.5	11.0	27.7	16.8
3	Single tier at 2-2.5 m	0.3	1.4	5.5	7.4	22.1	14.8
4	Second tier over 1-1.5 m	0.0	2.7	4.2	14.4	27.4	23.9
5	Second tier over 1.5-2 m	0.8	2.1	6.5	15.0	34.0	23.8
6	Second tier over 2-2.5 m	0.5	2.1	4.5	7.6	22.0	13.7
7	Control (without pruning)	3.9	8.1	8.3	20.1	37.7	20.2
	SEm ±	0.6	0.9	1.6	2.9	6.0	3.5
	CD (0.05)	1.2	2.6	NS	NS	NS	NS

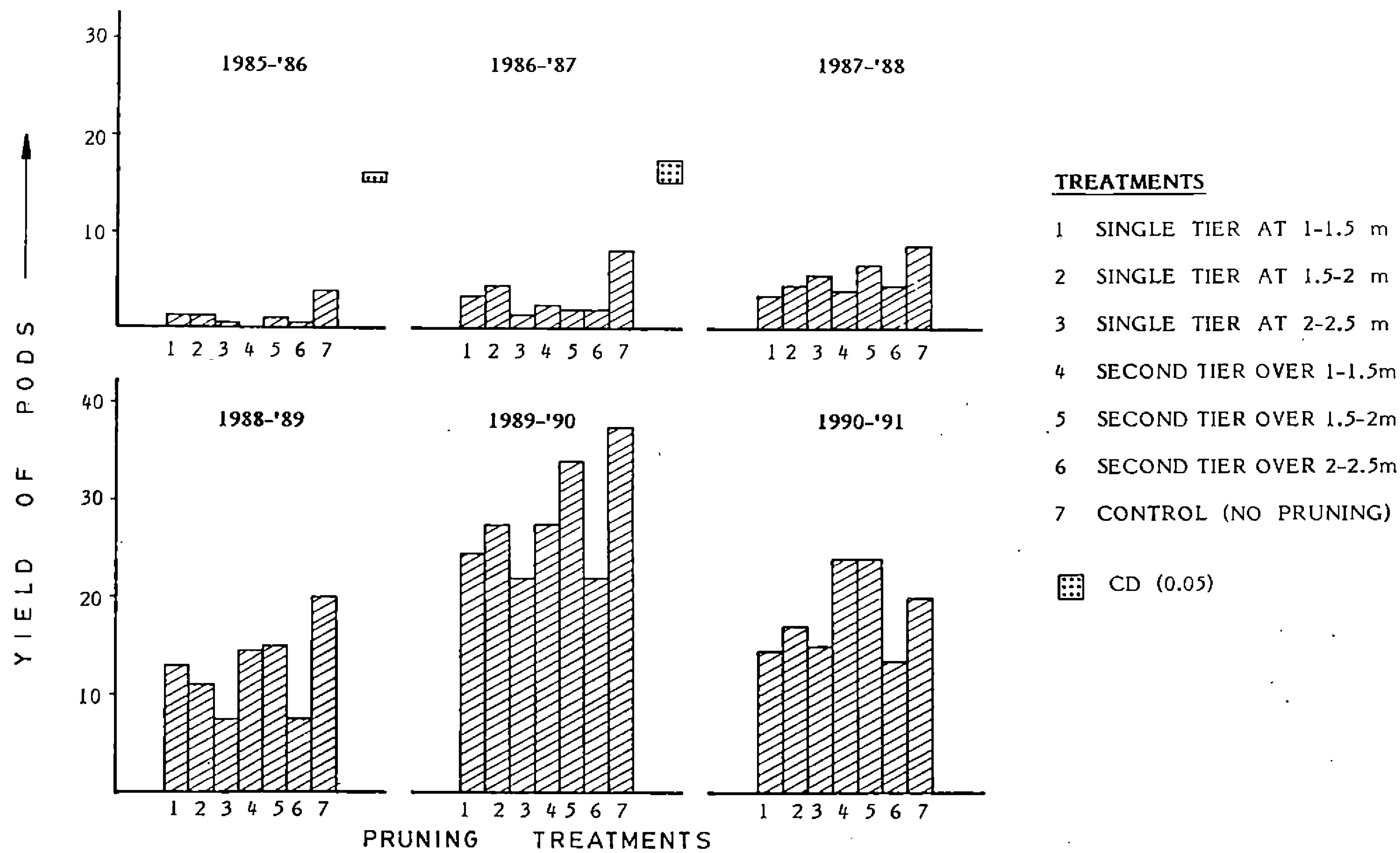

Fig-9 EFFECT OF PRUNING ON THE YIELD OF COCOA

One-third the fertiliser was applied in May-June and the remaining in September-October. During the first year of planting, the crop received one-third the above fertilizer dose, it received two-third during the second year and full dose from third year onwards. Observations on canopy spread upto 1987 and of yield upto 1987-88 indicated that there were consistent and significant advantages due to nitrogen application but not to the remaining two nutrients (Table 44). However, these advantages tended to disappear with advancing age. Similarly, there were visual symptoms of nitrogen dificiency in plants receiving no nitrogen fertilizer in the early years which also disappeared later. This disappearance of deficiency symptoms and of significant differences were attributed to root overlapping and contribution of nutrients through falling leaves from adjacent plants. To avoid root overlapping, trenches to a depth of 50 cm were dug around each experimental plot during 1988. Experience since then has indicated that while this must have prevented root overlapping to an extent, error due to contribution by leaf litter must have increased as trenches got naturally filled with falling leaves. Data on the yield since 1989-'90 showed statistical significance due to nitrogen but not to the other two nutrients. The same trend continued this year also there being a progressive increase with increasing levels of applied nitrogen upto 200 g/plant (Table 44 and Fig.10). The differences between the two successive levels of nitrogen were also statistically significant. Differences between levels of phosphorus were significant though there was no consistent trend of increase or decrease. Between levels of potassium, the differences were not significant. As in the case of most of the other experimental area, there was a decrease in the overall mean yield of this experimental crop also, the extent of it as compared to the overall mean of last year being 29 per cent.

Table 44 Effect of fertiliser levels on the growth and yield of cocoa

	Canopy spread (cm)					Yield of pods			
	Dec., '83	Dec., '84	Dec., '85	Dec., '86	Dec., '87	1987-'88	1988-'89	1989-'90	1990-'91
Nitrogen (g N/tree/year)									
0	55	129	228	292	245	7.2	29.9	36.4	25.4
100	70	164	267	325	261	8.7	22.5	39.8	32.0
200	72	159	256	315	240	10.6	26.9	47.5	40.4
SEm±	—	7	5	8	38	1.0	3.3	3.1	2.5
CD (0.05)	—	14	9	16	NS	2.7	NS	6.2	5.1
Phosphorus (g P_2O_5/tree/year)									
0	66	147	242	319	244	9.1	23.6	43.5	35.5
40	68	159	268	310	254	8.6	26.5	37.5	26.4
80	67	146	245	304	248	8.7	29.9	42.7	33.4
SEm±	—	7	5	8	38	1.0	3.3	3.1	2.5
CD (0.05)	—	NS	NS	16	NS	NS	NS	NS	5.1
Potassium (g K_2O/tree/year)									
0	67	153	250	315	244	8.3	25.2	41.5	29.4
140	65	148	235	309	254	8.8	27.4	42.7	34.6
280	69	151	238	308	249	9.4	27.4	39.5	31.2
SEm±	—	7	5	8	38	1.0	3.3	3.1	2.5
CD (0.05)	—	NS	NS	16	NS	NS	NS	NS	NS

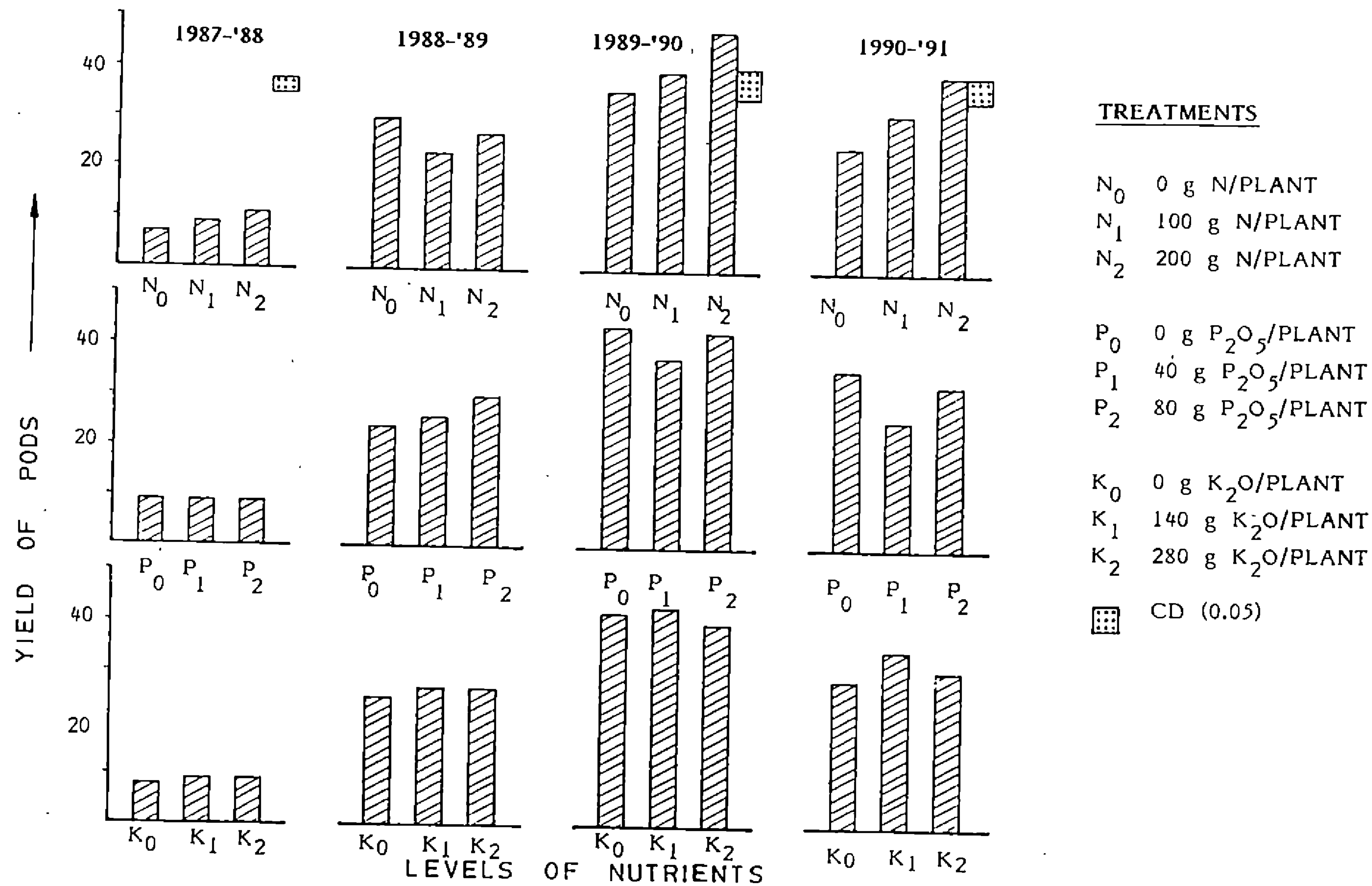

Fig-10 EFFECT OF LEVELS OF NUTRIENTS ON THE YIELD OF COCOA

C. CROP PROTECTION

1. Survey of cocoa diseases in Kerala

This study is aimed at finding out the extent of occurrence of various diseases of cocoa in different cocoa growing tracts of the state. During the period of report, disease survey was carried out in Kodalikkad and Kavakkad areas of Ernakulam district and also in certain areas of Idukki. In addition to this a study was made on the incidence of various diseases in the seed gardens at Thottuva, Vazhithala, Kavakkad and Konni. Details of diseases observed are given below.

(i) Vascular streak die-back disease

The fungal pathogen Oncobasidium theobromae causes this disease. Characteristic symptoms of the disease like yellowing of the middle leaf of the twigs with green islands, defoliation, brown marks on the scars of the fallen leaves, axillary bud growth and vascular discolouration of the infected twigs and fructification of fungi on fallen leaf scars under high humid conditions were noticed. During the period, this disease was noticed in all the areas under survey.

(ii) White thread blight

The pathogen, Marasmius scandans manifests externally on the bark. In severe cases of infection, the leaves detach themselves from the twigs and hang by the net work of mycelial strands of the pathogen. Prevalence of the disease was noticed in the Kadalikkad area of Ernakulam district.

(iii) Pod rot disease

Pod rot caused by Colletotrichum gloeosporioides was noticed invariably in all cocoa gardens surveyed, with varying intensities.

(iv) Leaf spot disease

Prevalence of leaf spot symptoms due to Colletotrichum gloeosporioides was noticed in all gardens surveyed. Leaf blight of young seedlings caused by

Phytophthora palmivora was noticed in our nursery at Vellanikkara. This disease was a serious problem in the soft wood grafting of cocoa attempted during the year.

(v) Shot hole disease

This disease which caused 'shot hole' symptoms on leaves was noticed at Kavakkad area of Ernakulam district. Though the etiology of the disease is not known, a fungi belonging to Pestalotia sp. could be isolated from the affected tissue.

(vi) Wilt disease of cocoa

Wilt disease suspected to be caused by Ceratocystis sp. was noticed in some areas of Idukki district.

(vii) Zinc deficiency symptoms

Characteristic zinc deficiency symptoms were noticed in the cocoa type $V_{4/8}$ planted in the seed garden II at Thottuva. As a control measure, some of the affected plants were sprayed with 0.5 per cent zinc sulphate and a few were left as control. The symptoms were not observed in the new flushes of both sprayed as well as unsprayed plants, indicating that the deficiency may get corrected naturally and does not require any remedial measures.

2. Studies on vascular streak die-back disease (VSD)

(i) Screening of cocoa types for susceptibility to VSD

This study is aimed at finding out whether any of the cocoa types selected for the ongoing breeding programme possesses any resistance reaction against vascular streak die-back disease. Observations on the extent of incidence of VSD were recorded from cocoa types planted in the three seed gardens; one at Vazhithala and two at Thottuva and the data are presented in Table 45. All the plants included in the seed garden at Vazhithala were found to be highly susceptible to the disease. All the types in the seed garden I at Thottuva were infected while in the seed garden II two types ($M_{16/9}$ and $V_{5/9}$) escaped infection and in the remaining types only upto 30 per cent plants were infected.

Table 45 Extent of infection of cocoa types with VSD in seed gardens in farmers' fields

Sl. No.	Cocoa type	Percentage of infection					
		Vazhithala		Thottuva I		Thottuva II	
		1989-90	1990-91	1989-90	1990-91	1989-90	1990-91
1	$M_{9/16}$	0.0	85.7	12.5	50.0	7.7	30.0
2	$M_{16/9}$	0.0	85.7	12.5	50.0	0.0	0.0
3	$V_{4/8}$	28.6	100.0	0.0	87.5	0.0	23.1
4	$V_{5/9}$	0.0	85.7	0.0	42.9	0.0	0.0
5	$V_{10/3}$	0.0	85.7	0.0	25.0	0.0	20.0
6	$V_{15/5}$	0.0	71.4	12.5	62.5	8.3	22.2
7	GII 19/5	0.0	100.0	0.0	37.5	0.0	18.2
8	GII 20/4	28.6	100.0	12.5	62.5	0.0	9.1

The escape of infection in these plants may be due to the late planting done in this garden compared to the other two.

(ii) Studies on transmission of VSD

Attempts were made to transmit VSD infection to disease-free seedlings by using live infected tissues. The following methods were employed.

1. Patch budding, using buds from infected twigs.
2. Side grafting using infected scions.
3. Insertion of portion of leaf scar containing fruiting body of the fungus into the stem.
4. Insertion of stem portions containing vascular tissues from infected plants into the host.
5. Patch budding with buds from axils of infected leaves.

The different methods of transmission were attempted during October 1990 and the plants were kept in isolation. None of the above mentioned methods was found to be effective in causing infection in the host plants since the infected vegetative tissues used as inoculam sources dried off within a short period. So the studies are to be continued further in order to draw a final conclusion on this.

3. Studies on fungal contaminants in the in vitro culture of cocoa

Systemic fungal infection continues to be a serious problem in the in vitro culture of cocoa. Regardless of the procedure used to sterilize the explants from field, the percentage of infection is always above 70. Attempts were made to identify the different fungi as well as to study their intensity of infection in the culture tubes during the period from January to March 1991. The identity of the fungi associated with cocoa tissue culture was established based on morphological characters and seventeen different fungi were identified. The different types of fungi isolated as well as their extent of infection are furnished in the Table 46. More than five per cent of the infection was caused by the fungi Aspergillus sp., Colletotrichum gloeosporioides, Penicillium sp., non-sporulating hyaline septate fungi, non-sporulating hyaline coenocytic fungi and

Table 46 Common fungal contaminants in the cocoa tissue culture media

Sl. No.	Type of fungus	Percentage occurrence
1	*Alternaria* Sp.	2.9
2	*Aspergillus* Sp.	6.1
3	*Aspergillus niger*	5.3
4	*Botrytis* Sp.	0.8
5	*Chaetomium* Sp.	0.5
6	*Colletotrichum gloeosporioides*	10.5
7	*Curvularia* Sp.	2.4
8	*Cylindrocladium* Sp.	0.3
9	*Helminthosporium* Sp.	0.8
10	*Penicillium* Sp.	5.5
11	*Pestalotia* Sp.	0.3
12	*Rhizopus* Sp.	1.8
13	Yeast	0.3
14	Non sporulating, dark brown septate mycelial fungi	21.8
15	Non sporulating, dark brown, coenocytic fungi	3.2
16	Non sporulating, hyaline septate mycelial fungi	11.6
17	Non sporulating hyaline coenocytic fungi	6.7

the maximum of 21.8 per cent by non-sporulating dark brown septate fungi. Fungi like Aspergillus sp., Penicillium sp., and Rhizopus sp. are common lab contaminants and can easily be controlled by proper surface sterilization and by following aseptic conditions in the lab.

D. ANCILLARY STUDIES

The two items of work taken up during the year are on tissue culture and top working.

1. Tissue culture

Work on tissue culture was taken up since 1988 and the lines of work were the following.

(i) Micropropagation
(ii) Somatic embryogenesis
(iii) Anther culture
(iv) Culture of flat bean embryos
(v) Culture of embryonic axes

(i) Micropropagation

Steps involved in this include producing proliferated shoots from axillary or terminal buds, production of multiple shoots, rooting of proliferated shoots and planting out.

1. Producing proliferated shoots

The systemic contamination of field explants could be controlled to a considerable extent by prior fungicidal treatment of the mother plants. The fungicides used were the contact fungicide, Dithane M 45 and the systemic one, Bavistin. The periodicity of fungicidal spray was twice weekly. Except during rainy season, about sixty per cent of the explants could be saved by prior fungicidal treatment of the mother plants.

A positive correlation was observed between size of the explant and response in culture. Hence stem segments were cut into nodal explant sections leaving the lower internode at its greatest length, without limiting to 1 cm as reported earlier. Retention of part of the lamina was also found to favour bud sprout. Freshly prepared chlorine water was found to be the most effective surface sterilant especially because of its lower toxicity and residual effects. Before excision of explants, the trimmed shoots were washed in tap water containing a few drops of the surfactant, Teepol. This treatment along with a swab of the dried shoots with cotton dipped in 70% ethanol helped to minimise the surface contamination to a considerable extent.

Bud swelling usually occurred five to eight days after culturing. This was usually followed by the shedding of the original leaf bit which was to be removed from the culture tube to avoid secondary infection. Bud development and leaf expansion were observed in many of the culture tubes following this (Plate 5). A number of media additives have been found to favour bud proliferation when added to the basal woody plant medium. Use of the following two media was found to be equally effective in inducing the initial bud break followed by expansion of one or two leaves.

1. WPM + IAA 0.05 ppm + Kinetin 1 ppm + $Ag\ NO_3$ 5 ppm.
2. WPM + IAA 0.05 ppm + 2 ip 0.5/1 ppm + $Ag\ NO_3$ 5 ppm.

MS medium was also effective eventhough response was better in WPM.

Addition of organic supplements like peptone @ 100 mg l^{-1}, ascorbic acid @ 100 mg l^{-1}, mixture of aminoacids (leucine 0.4, L - arginine 0.4, L - lysine 0.4, glycine 2.0 and L-tryptophan 0.2 mg l^{-1}) singly or in combination to the above two hasic media favoured sustained growth of shoots up to the expansion of three to four leaves (Plate 6).

A major problem in cocoa tissue culture has been the profuse callusing of the various explants in most of the media tested. The predominance of callus usually inhibited the continued growth of the sprouted buds. A remarkable observation made during the current year was the suppression of callus by the addition of silver nitrate @ 5 mg l^{-1} to the medium. This chemical not only suppressed the callus, but also favoured sustained growth of the shoots.

By following the above pre-treatments, sterilization, media additives etc. about 300 explants could be induced to produce proliferated shoots during the period under report. These could also survive two to three subcultures eventhough the rate of growth was very slow.

The details of the various media tried along with varying concentrations of the diverse additives used are given in Table 47.

2. Induction and production of multiple shoots

Induction of bud break and production of small leafy shoots could be easily achieved from nodal explants of cocoa from field grown trees in the different media mentioned earlier. Attempts were made to induce multiple shoot production by incorporating different concentrations of 2 ip, the phenolic compound phloroglucinol and also the cytokinin derivative, adenine sulphate. Only two shoots could be produced from single pre-existing axillary meristem by the above treatments (Plate 7). In these too, consistent results could not be obtained. Addition of 2 ip and phloroglucinol to the media led to heavy callusing in most cases which prevented further shoot proliferation. But this problem was overcome by the incorporation of Ag NO_3 @ 5 mg l^{-1}. Among the different cytokinins tried, maximum stimulation of axillary buds was observed with 2 ip. A range of concentrations were tried from 0.5 to 5 ppm but lower concentrations appeared more suitable. A synergistic effect between the phenolic compound phloroglucinol and the cytokinin 2 ip was also evident in sustaining proliferation of induced shoots.

Cultures consisting as many as six axillary shoots could be produced from nodal segments collected from <u>in vitro</u> raised seedlings. This was possible by initial culture in MS medium containing 2 ip 5 ppm and IAA 0.1 ppm and subsequent transfer to same medium containing a lower concentration of 2 ppm 2 ip after a fortnight (Plate 8). However, this rapid proliferation could not be sustained in the subsequent subcultures. Callusing was the major problem when the stem segments from these shoots were cultured in a horizontal position in an attempt to induce rapid multiplicatioin. Even from <u>in vitro</u> raised shoots, consistent results could not be obtained in induction of multiple shoots even in the same media.

3. Rooting and planting out

As reported earlier, rooting of cocoa shoots derived from <u>in vitro</u> seedling could be easily attained by a short duration pulse treatment of IBA 1000 ppm in alcohol. Plantlets rooted in this way could also be hardened

Table 47 Effect of different media and hormone supplements on micropropagation

Sl. No.	Media composition	Explants source	Number of explants			
			Inoculated.	Lost by contamination	Sprouted	Dead
1.	½ MS	Field	4	3	--	1
2.	½ MS (Co-cultured with mature seeds)	In vitro*	37	35	--	2
3.	MS liquid medium	Field	23	3	--	20
4.	MS + Coconut water 15%	Field	48	32	--	16
5.	MS + Coconut water 15% + NAA 0.1	Field	48	44	--	4
6.	MS + BA 0.44	Field	53	42	2	9
7.	MS + BA 0.5 + NAA 0.5	Field	24	24	--	--
8.	MS + BA 1 + NAA 1	Field	24	23	--	1
9.	MS + BA 1 + IBA 0.1	Field	15	7	--	8
10.	MS + BA 1 + IBA 0.1 + GA_3 0.1	Field	8	8	--	--
11.	MS + BA 1 + IBA 0.1 + GA_3 0.2	Field	8	4	--	4
12.	MS + BA 1 + IBA 0.1 + GA_3 0.3	Field	8	--	--	8
13.	MS + BA 1 + IBA 0.1 + GA_3 0.4	Field	8	--	--	8
14.	MS + BA 1 + IBA 0.1 + GA_3 0.5	Field	8	--	--	8
15.	MS + BA 1.33 + Kinetin 0.93 + Calcium pantothenate 0.2 μM + Biotin 0.5 μM	Field	24	23	--	1
16.	MS + BA 2	Field	93	38	--	55
17.	MS + BA 2 + NAA 0.1	Field	44	20	--	24

Contd.

Table 47 (Contd.)

Sl. No.	Media composition	Explants sources	Number of explants: Inoculated	Lost by contamination	Sprouted	Dead
18.	MS + BA 2 + IBA 0.1	Field	15	4	-	11
19.	MS + BA 2 + IAA 0.1 + GA_3 2	Field	48	28	-	20
20.	MS + BA 2 + IAA 0.2	Field	89	45	2	42
21.	MS + BA 2 + NAA 0.2	Field	69	49	-	20
22.	MS + BA 2.2	Field	55	40	3	12
23.	MS + BA 2.2 + Kinetin 0.93 + Calcium pantothenate 0.2 µM + Biotin 0.5 µM	Field	24	21	-	3
24.	MS + BA 3 + IBA 0.1	Field	16	2	-	14
25.	MS + BA 4 + IBA 0.1	Field	14	5	-	9
26.	MS + BA 4 + NAA 0.2	Field	45	29	-	16
27.	MS + BA 4 + NAA 0.25	Field	46	2	-	44
28.	MS + BA 4.4 + IBA 0.5	Field	52	13	1	38
29.	MS + BA 4.4 + Kinetin 0.93 + Calcium pantothenate 0.2 µM + Biotin 0.5 µM	Field	24	22	-	2
30.	MS + BA 5 + NAA 0.1 + GA_3 0.1	Field	49	16	-	33
31.	MS + BA 5 + NAA 0.2	Field	12	11	-	1
-	MS + BA 5 + NAA 0.2	In vitro*	13	2	6	5
32.	MS + BA 5 + NAA 0.2 + $AdSO_4$ 40	In vitro*	23	1	2	20
33.	MS + BA 5 + NAA 0.2 + Casein hydrolysate 500	Field	14	10	-	4
	MS + BA 5 + NAA 0.2 + Casein hydrolysate 500	In vitro*	13	4	3	6
34.	MS + BA 5 + Adenine sulphate 160 + Sodium dihydrogen orthophosphate 170	Field	45	37	-	8
35.	MS + BA 7.5 + NAA 0.2	In vitro*	26	--	4	22
36.	MS + 2ip 1.5 + Glyphosate 0.17	Field	98	26	29	43

Contd.

Table 47 (Contd.)

Sl. No.	Media composition	Explants source	Number of explants			
			Inoculated	Lost by contamination	Sprouted	Dead
37.	MS + 2ip 2	Field	9	2	2	5
	MS + 2ip 2	In vitro*	202	137	49	16
38.	MS + 2ip 2 + IAA 0.1	Field	35	15	2	18
	MS + 2ip 2 + IAA 0.1	In vitro*	293	137	45	109
39.	MS + 2ip 2 + IAA 0.1 + GA_3 1	In vitro*	246	110	4	132
40.	MS + 2ip 2 + IAA 0.1 + GA_3 2 + PG 126	In vitro*	38	29	2	7
41.	MS + 2ip 2 + IBA 0.1 + GA_3 2 + PG 126	In vitro*	48	20	-	28
42.	MS + 2ip 5 + IAA 0.1	Field	17	6	-	11
	MS + 2ip 5 + IAA 0.1	In vitro*	32	15	4	13
43.	MS + Kinetin 0.5 + IAA 0.5	Field	47	41	1	5
	MS + Kinetin 0.5 + IAA 0.5	In vitro*	50	27	1	22
44.	MS + Kinetin 1 + IAA 0.1	Field	18	5	1	12
	MS + Kinetin 1 + IAA 0.1	In vitro*	198	71	26	101
45.	MS + Kinetin 1 + IAA 0.1 + GA_3 1	In vitro*	48	26	2	20
46.	MS + Kinetin 1 + IAA 0.2	Field	50	15	17	18
47.	MS + Kinetin 1 + IAA 0.5 + $AgNO_3$ 5	Field	91	37	35	19
48.	MS + Kinetin 2 + IAA 0.1	In vitro*	5	2	-	3
49.	MS + Kinetin 2 + IAA 0.1 + GA_3 2 + PG 162	In vitro*	25	10	-	15
50.	MS + Kinetin 2 + IBA 0.1	Field	53	46	-	7
51.	MS + Kinetin 2 + IBA 0.1 + GA_3 2 + PG 126	In vitro*	25	11	-	14
52.	MS + Kinetin 2 + IBA 0.1 + GA_3 2 + PG 162	Field	30	18	1	11
53.	MS + Kinetin 2 + IAA 0.2	Field	44	28	-	16

Contd.

Table 47 (Contd.)

Sl. No.	Media composition	Explant source	Number of explants			
			Inoculated	Lost by contamination	Sprouted	Dead
54.	MS + Kinetin 2 + 2,4-D 0.1	Field	54	32	-	22
55.	MS + Kinetin 8.6 + 2,4-D 0.05	Field	24	23	-	1
56.	MS + Glyphosate 0.17	Field	81	33	15	33
	MS + Glyphosate 0.17	In vitro*	40	14	24	2
57.	MS + Glyphosate 0.34	Field	46	19	10	17
58.	MS + Glyphosate 8.5	Field	18	15	1	2
59.	MS + Glyphosate 17	Field	20	16	1	3
60.	MS + Glyphosate 25.5	Field	20	14	-	6
61.	MS + Glyphosate 34	Field	19	13	-	6
62.	WPM	Field	172	113	-	59
	WPM	In vitro*	48	34	-	14
63.	Modified WPM [Substituted with $(NH_4)_2SO_4$]	Field	42	33	-	9
	Modified WPM [Substituted with $(NH_4)_2SO_4$]	In vitro*	12	9	-	3
64.	WPM + Coconut water 15%	Field	63	46	-	17
	WPM + Coconut water 15%	In vitro*	39	22	9	8
65.	WPM + GA_3 0.35	Field	22	18	-	4
66.	WPM + GA_3 0.9	Field	23	23	-	-
67.	WPM + 2,4-D 2	Field	27	27	-	-
68.	WPM + 2,4-D 5	Field	28	27	-	1
69.	WPM + 2,4-D 6	Field	12	11	-	1
70.	WPM + 2,4-D 7	Field	12	12	-	-
71.	WPM + 2,4-D 9	Field	12	12	-	-

Contd.

Table 47 (Contd.)

Sl. No.	Media composition	Explant source	Number of explants: Inoculated	Lost by contamination	Sprouted	Dead
72.	WPM + 2,4-D 10	Field	12	11	-	1
73.	WPM + IBA 1	Field	40	34	-	6
74.	WPM + IBA 1 + GA_3 2 + PG 162	Field	47	16	1	30
75.	WPM + IBA 5	Field	20	16	-	4
76.	WPM + IBA 7	Field	22	20	-	2
77.	WPM + IBA 10	Field	21	18	-	3
78.	WPM + NAA 0.5 μM	Field	20	-	-	20
79.	WPM + NAA 2.5 μM	Field	20	3	3	14
80.	WPM + NAA 5 μM	Field	20	3	-	17
81.	WPM + NAA 10 μM	Field	20	6	-	14
82.	WPM + BA 0.5 μM	Field	20	10	1	9
83.	WPM + BA 0.5 μM + NAA 0.5 μM	Field	20	7	6	7
84.	WPM + BA 0.5 μM + NAA 2.5 μM	Field	20	6	-	14
85.	WPM + BA 0.5 μM + NAA 5 μM	Field	20	9	-	11
86.	WPM + BA 0.5 μM + NAA 10 μM	Field	20	6	-	14
87.	WPM + BA 2.5 μM	Field	34	4	2	28
	WPM + BA 2.5 μM	In vitro*	6	-	4	2
88.	WPM + BA 2.5 μM + NAA 0.5 μM	Field	51	10	2	39
	WPM + BA 2.5 μM + NAA 0.5 μM	In vitro*	6	-	4	2
89.	WPM + BA 2.5 μM + NAA 2.5 μM	Field	17	6	-	11
	WPM + BA 2.5 μM + NAA 2.5 μM	In vitro*	3	-	1	2
90.	WPM + BA 2.5 μM + NAA 5 μM	Field	17	6	1	10
	WPM + BA 2.5 μM + NAA 5 μM	In vitro*	3	2	-	1

Contd.

Table 47 (Contd.)

Sl. No.	Media composition	Explant source	Number of explants: Inoculated	Lost by contamination	Sprouted	Dead
91.	WPM + BA 2.5 μM + NAA 10 μM	Field	16	5	1	10
	WPM + BA 2.5 μM + NAA 10 μM	In vitro*	3	-	-	3
92.	WPM + BA 5 μM	Field	20	1	1	18
93.	WPM + BA 5 μM + NAA 0.5 μM	Field	20	2		18
94.	WPM + BA 5 μM + NAA 2.5 μM	Field	20	1	1	18
95.	WPM + BA 5 μM + NAA 5 μM	Field	20	2	2	16
96.	WPM + BA 5 μM + NAA 10 μM	Field	19	-	-	19
97.	WPM + BA 10 μM	Field	20	5	1	14
98.	WPM + BA 10 μM + NAA 0.5 μM	Field	15	1	-	14
99.	WPM + BA 10 μM + NAA 2.5 μM	Field	15	12	-	3
100.	WPM + BA 10 μM + NAA 5 μM	Field	15	13	-	2
101.	WPM + BA μM + NAA 10 μM	Field	15	9	-	6
102.	WPM + BA 0.5 μM + IAA 0.05 μM	Field	24	4	1	19
103.	WPM + BA 0.75 μM + IAA 0.05 μM	Field	24	5	3	16
104.	WPM + BA 0.3	Field	29	24	-	5
	WPM + BA 0.3	In vitro*	27	14	10	3
105.	WPM + BA 0.4	Field	24	17	1	6
106.	WPM + BA 0.75	Field	24	7	1	16
107.	WPM + BA 1 + IAA 0.1 + Amino acids + $AgNO_3$ 5	Field	82	32	45	5
108.	WPM + BA 1 + Amino acids + $AgNO_3$ 5	Field	93	5	31	57
109.	WPM + BA 1 + IAA 0.5 + Amino acids	Field	24	4	1	19
110.	WPM + BA 1.5	Field	23	11	2	10

Contd.

Table 47 (Contd.)

Sl. No.	Media composition	Explant source	Number of explants: Inoculated	Lost by contamination	Sprouted	Dead
111.	WPM + BA 2	Field	115	37	2	76
112.	WPM + BA 2 + IBA 0.02	Field	20	14	1	5
113.	WPM + BA 2 + IBA 0.05	Field	20	8	5	7
114.	WPM + BA 2 + IBA 0.07	Field	20	10	6	4
115.	WPM + BA 2 + IBA 0.1	Field	20	9	2	9
116.	WPM + BA 2 + IBA 0.1 + PG 162	Field	27	25	-	2
117.	WPM + BA 2 + IAA 0.1	In vitro*	180	53	15	112
118.	WPM + BA 2 + IAA 0.1 + Amino acids + $AgNO_3$ 5	Field	88	13	21	54
119.	WPM + BA 4 + NAA 0.2	Field	94	56	1	37
120.	WPM + BA 5 + Casein hydrolysate 500	In vitro*	10	7	-	3
121.	WPM + BA 5 + NAA 0.1	Field	49	31	-	18
122.	WPM + BA 5 + NAA 0.2	Field	10	9	-	1
	WPM + BA 5 + NAA 0.2	In vitro*	12	11	-	1
123.	WPM + BA 5 + NAA 0.2 + Casein hydrolysate 500	Field	17	15	-	2
124.	WPM + BA 5 + NAA 0.2 + $AdSO_4$ 40	In vitro*	32	24	4	4
125.	WPM + BA 5 + IAA 0.2	Field	24	22	-	2
126.	WPM + BA 5 + Kinetin 2.5	Field	23	20	-	3
127.	WPM + BA 7.5 + NAA 0.2	In vitro*	24	21	-	3
128.	WPM + BA 10	Field	18	16	-	2
129.	WPM + BA 10 + Coconut water 15%	Field	23	16	-	6
130.	WPM + 2ip 0.5 + Amino acids + Coconut water 10%	Field	95	63	13	19
131.	WPM + 2ip 0.5 + Amino acids + Ascorbic acid 100 mg + Coconut water 10%	Field	91	65	11	15
132.	WPM + 2ip 0.5 + Amino acids + $AgNO_3$ 5 + PG 125	Field	89	36	50	3

Contd.

Table 47 (Contd.)

Sl. No.	Media composition	Explant source	Number of explants: Inoculated	Lost by contamination	Sprouted	Dead
133.	WPM + 2ip 1	Field	52	46	4	2
	WPM + 2ip 1	In vitro*	98	38	31	29
134.	WPM + 2ip 1 + IAA 0.1	Field	52	42	5	5
	WPM + 2ip 1 + IAA 0.1	In vitro*	102	55	13	34
135.	WPM + 2ip 1 + Amino acids + $AgNO_3$ 5 + PG 125	Field	180	77	96	7
136.	WPM + 2ip 1 + Amino acids + IAA 0.1 + Ascorbic acid 100 mg + $AgNO_3$ 5 + PG 125	Field	68	15	8	45
137.	WPM + 2ip 1.5 + Amino acids	Field	69	25	9	35
138.	Liquid WPM + 2ip 2	In vitro*	61	20	25	16
139.	WPM + 2ip 2	Field	257	193	12	52
	WPM + 2ip 2	In vitro*	334	90	101	143
140.	WPM + 2ip 2 + Coconut water 10%	Field	29	18	3	8
	WPM + 2ip 2 + Coconut water 10%	In vitro*	17	13	2	2
141.	WPM + 2ip 2 + GA_3 1	In vitro*	50	22	-	28
142.	WPM + 2ip 2 + IAA 0.1	Field	20	18	-	2
	WPM + 2ip 2 + IAA 0.1	in vitro*	248	138	22	88
143.	WPM + 2ip 2 + IAA 0.1 + GA_3 1	Field	40	30	-	10
	WPM + 2ip 2 + IAA 0.1 + GA_3 1	In vitro*	448	307	10	131
144.	WPM + 2ip 2 + IBA 0.1 + GA_3 2 + PG 126	In vitro*	49	24	1	24
145.	WPM + 2ip 2 + IBA 0.1 + GA_3 2 + PG 162	In vitro*	40	15	-	25
146.	WPM + 2ip 2 + IBA 0.5 + GA_3 2 + PG 162	In vitro*	49	32	-	17
147.	Liquid WPM + 2ip 2 + Amino acids	In vitro*	18	6	4	8

Contd.

Table 47 (Contd.)

Sl. No.	Media composition	Explant source	Number of explants: Inoculated	Lost by contamination	Sprouted	Dead
148.	WPM + 2ip 2 + Amino acids	Field	82	51	6	25
	WPM + 2ip 2 + Amino acids	In vitro*	56	52	-	4
149.	WPM + 2ip 2 + Amino acids + $AgNO_3$ 5	Field	42	2	6	34
	WPM + 2ip 2 + Amino acids + $AgNO_3$ 5	In vitro*	17	7	6	4
150.	WPM + 2ip 2 + Amino acids + Coconut water 10%	Field	29	19	5	5
	WPM + 2ip 2 + Amino acids + Coconut water 10%	In vitro*	18	12	4	2
151.	WPM + 2ip 2 + Amino acids + Ascorbic acid 100 mg	Field	44	34	1	9
	WPM + 2ip 2 + Amino acids + Ascorbic acid 100 mg	In vitro*	48	20	20	8
152.	WPM + 2ip 2 + Amino acids + Ascorbic acid 100 mg + Coconut water 10%	Field	50	15	22	13
	WPM + 2ip 2 + Amino acids + Ascorbic acid 100 mg + Coconut water 10%	In vitro*	44	10	24	10
153.	WPM + 2ip 2 + Amino acids + Ascorbic acid 100 mg + IAA 0.1	Field	15	10	-	5
	WPM + 2ip 2 + Amino acids + Ascorbic acid 100 mg + IAA 0.1	In vitro*	50	17	18	15
154.	WPM + 2ip 3 + IAA 0.1	Field	48	43	1	4
155.	WPM + 2ip 3 + IAA 0.1 + Amino acids + Ascorbic acid 100 mg	Field	91	25	7	59
156.	WPM + 2ip 5	Field	65	50	1	14
	WPM + 2ip 5	In vitro*	91	58	9	24
157.	WPM + 2ip 5 + IAA 0.1	Field	48	15	2	31
158.	WPM + Kinetin 1	In vitro*	240	151	42	47
159.	WPM + Kinetin 1 + GA_3 0.35	Field	21	19	-	2
	WPM + Kinetin 1 + GA_3 0.35	In vitro*	22	19	-	3
160.	WPM + Kinetin 1 + GA_3 0.9	Field	20	16	-	4

Contd.

Table 47 (Contd.)

Sl. No.	Media composition	Explant source	Number of explants			
			Inoculated	Lost by contamination	Sprouted	Dead
161.	WPM + Kinetin 1 + IAA 0.1	Field	1524	1221	102	201
	WPM + Kinetin 1 + IAA 0.1	In vitro*	1182	594	245	343
162.	WPM + Kinetin 1 + IAA 0.1 + GA_3 1	In vitro*	232	123	3	106
163.	WPM + Kinetin 1 + IAA 0.1 + PG 162	Field	70	41	-	29
	WPM + Kinetin 1 + IAA 0.1 + PG 162	In vitro*	51	10	3	38
164.	WPM + Kinetin 1 + IAA 0.05 + Amino acids	Field	71	18	14	39
	WPM + Kinetin 1 + IAA 0.05 + Amino acids	In vitro*	15	4	10	1
165.	WPM + Kinetin 1 + IAA 0.1 + Amino acids	Field	48	36	8	4
166.	WPM + Kinetin 1 + IAA 0.1 + Amino acids + $AgNO_3$ 5	Field	251	184	51	16
	WPM + Kinetin 1 + IAA 0.1 + Amino acids + $AgNO_3$ 5	In vitro*	73	32	37	4
167.	WPM + Kinetin 1 + IAA 0.1 + Amino acids + $AgNO_3$ 5 + PG 125	Field	90	13	6	71
168.	WPM + Kinetin 1 + IAA 0.1 + Amino acids + Ascorbic acid 100 mg + $AgNO_3$ 5 + Glyphosate 0.17	Field	84	9	71	4
169.	WPM + Kinetin 1 + IAA 0.1 + Amino acids + Ascorbic acid 100 mg + $AgNO_3$ 5 + Glyphosate 0.75	Field	92	24	33	35
170.	WPM + Kinetin 1 + IAA 0.1 + 5% leaf extract	Field	17	13	-	4
171.	WPM + Kinetin 1 + IAA 0.1 + 10% leaf extract	Field	17	16		1
172.	WPM + Kinetin 1 + IAA 0.1 + 30% leaf extract	Field	17	12	-	5
	WPM + Kinetin 1 + IAA 0.1 + 30% leaf extract	In vitro*	17	5	2	10
173.	WPM + Kinetin 1 + IAA 0.1 + 2.5% seed extract	Field	8	-	-	8
	WPM + Kinetin 1 + IAA 0.1 + 2.5% seed extract	In vitro*	18	2	3	13
174.	WPM + Kinetin 1 + IAA 0.1 + 5% seed extract	Field	8	-	-	8
	WPM + Kinetin 1 + IAA 0.1 + 5% seed extract	In vitro*	17	5	3	9

Contd.

Table 47 (Contd.)

Sl. No.	Media composition	Explant source	Number of explants: Inoculated	Lost by contamination	Sprouted	Dead
175.	WPM + Kinetin 1 + Amino acids + Ascorbic acid 100 mg + $AgNO_3$ 5	Field	87	14	72	1
176.	WPM + Kinetin 1 + Glyphosate 0.17	Field	57	33	5	19
	WPM + Kinetin 1 + Glyphosate 0.17	In vitro*	8	6	2	-
177.	WPM + Kinetin 1 + Ad SO_4 80	Field	48	18	10	20
178.	WPM + Kinetin 1 + Ad SO_4 80 + Amino acids + Glyphosate 1	Field	110	101	8	1
179.	WPM + Kinetin 2	Field	22	21	-	1
	WPM + Kinetin 2	In vitro*	21	19	-	2
180.	WPM + Kinetin 2 + GA_3 0.35	Field	20	20	-	-
	WPM + Kinetin 2 + GA_3 0.35	In vitro*	2	-	-	2
181.	WPM + Kinetin 2 + GA_3 0.9	Field	21	19	-	2
	WPM + Kinetin 2 + GA_3 0.9	In vitro*	3	-	-	3
182.	WPM + Kinetin 2 + IAA 0.1	In vitro*	25	4	-	21
183.	WPM + Kinetin 2 + IBA 0.1 + GA_3 2 + PG 162	In vitro*	48	27	2	19
184.	WPM + Kinetin 2.5 + IBA 5	Field	20	18	-	2
185.	WPM + Kinetin 4	Field	21	21	-	-
	WPM + Kinetin 4	In vitro*	3	1	-	2
186.	WPM + Kinetin 4 + GA_3 0.35	Field	23	23	-	-
	WPM + Kinetin 4 + GA_3 0.35	In vitro*	4	2	-	2
187.	WPM + Kinetin 4 + GA_3 0.9	Field	21	20	-	1
	WPM + Kinetin 4 + GA_3 0.9	In vitro*	2	-	-	2
188.	WPM + Kinetin 5 + IAA 0.5	Field	24	1	-	23

Contd.

Table 47 (Contd.)

Sl. No.	Media composition	Explant source	Number of explants: Inoculated	Lost by contamination	Sprouted	Dead
189.	WPM + Kinetin 6	Field	48	36	-	12
	WPM + Kinetin 6	In vitro*	25	24	-	1
190.	WPM + Kinetin 6 + GA_3 0.35	Field	23	23	-	-
	WPM + Kinetin 6 + GA_3 0.35	In vitro*	3	1	-	2
191.	WPM + Kinetin 6 + GA_3 0.9	Field	22	20	-	2
	WPM + Kinetin 6 + GA_3 0.9	In vitro*	2	2	-	-
192.	WPM + Kinetin 8	Field	22	21	-	1
	WPM + Kinetin 8	In vitro*	2	-	-	2
193.	WPM + Kinetin 8 + GA_3 0.35	Field	21	20	-	1
	WPM + Kinetin 8 + GA_3 0.35	In vitro*	4	2	-	2
194.	WPM + Kinetin 8 + GA_3 0.9	Field	21	16	1	4
	WPM + Kinetin 8 + GA_3 0.9	In vitro*	4	1	-	3
195.	WPM + Kinetin 10	Field	23	23	-	-
	WPM + Kinetin 10	In vitro*	1	-	-	1
196.	WPM + Kinetin 10 + GA_3 0.35	Field	23	22	-	1
197.	WPM + Glyphosate 1 + $AgNO_3$ 5 + PG 125	Field	74	22	38	14
198.	WPM + Amino acids	Field	224	194	18	12
	WPM + Amino acids	in vitro*	183	112	35	36
199.	WPM + Amino acids + Glyphosate 0.17	Field	93	75	11	7
	WPM + Amino acids + Glyphosate 0.17	In vitro*	15	12	-	3
200.	WPM + Amino acids + $AgNO_3$ 5	Field	170	37	117	16
	WPM + Amino acids + $AgNO_3$ 5	In vitro*	26	19	4	3

Contd.

Table 47 (Contd.)

Sl. No.	Media composition	Explant source	Number of explants: Inoculated	Lost by contamination	Sprouted	Dead
201.	WPM + Amino acids + $AgNO_3$ 10	Field	24	10	6	8
	WPM + Amino acids + $AgNO_3$ 10	In vitro*	21	9	8	4
202.	WPM + Amino acids + Ascorbic acid 100 mg + Charcoal 0.15% +	Field	121	107	4	10
	WPM + Amino acids + Ascorbic acid 100 mg + Charcoal 0.15%	In vitro*	73	57	4	12
203.	WPM + Amino acids + Ascorbic acid 100 mg + Charcoal 0.15% + $AgNO_3$ 5	Field	78	29	45	4
	WPM + Amino acids + Ascorbic acid 100 mg + Charcoal 0.15% + $AgNO_3$ 5	In vitro*	31	10	20	1
204.	WPM + Amino acids + GA_3 1 + Glyphosate 0.17 + $AgNO_3$ 5 + PG 125	Field	79	24	1	54
	WPM + Amino acids + GA_3 1 + Glyphosate 0.17 + $AgNO_3$ 5 + PG 125	In vitro*	25	14	10	1
205.	WPM + Amino acids + GA_3 1 + Glyphosate 1 + $AgNO_3$ 5	Field	101	37	47	17
206.	WPM + Amino acids + GA_3 1 + Glyphosate 1 + $AgNO_3$ 5 + PG 125	Field	91	31	33	27
207.	SH medium + BA 5 + NAA 0.2	In vitro*	25	19	-	6
208.	SH medium + BA 5 + NAA 0.2 + Ad SO_4 40	In vitro*	25	14	-	11
209.	SH medium + BA 5 + NAA 0.2 + Casein hydrolysate 500	In vitro*	23	11	-	12
210.	SH medium + BA 7.5 + NAA 0.2	In vitro*	27	25	2	-
211.	SH medium + Kinetin 1 + IAA 0.1	Field	13	11	-	2
	SH medium + Kinetin 1 + IAA 0.1	In vitro*	8	8	-	-
212.	SH medium + Kinetin 2 + IAA 0.1	In vitro*	25	13	10	2
	Total When not specified concentration are in ppm.		**15545**	**8681**	**2149**	**4715**

* In vitro : Explants collected from sterile seedlings

and planted out without difficulty. The plantlets already planted out in the field during May 1990 are coming up and are comparable to seedlings of the same age in growth and morphology (Plate 13). A sterilised mixture of 'soil-rite' and soil appeared to be the best potting mixture for the immediate plat-out of the plantlets and the usual potting mixture was ideal for further transplanting in larger pots.

Induction of roots in shoots derived from field explants was not so easy as in vitro shoots. The quick dip of IBA 1000 ppm failed to induce roots. The medium recommended by Flynn et al. (1990) for inducing rooting also did not work in our lab. Increasing the concentration of IBA from 3 mg l^{-1} to 5 mg l^{-1} in the above medium also did not produce any positive results. However, rooting could be achieved in a few of these shoots by the short duration pulse treatment in IBA at a higher concentration of 5000 ppm. The roots produced by this treatment appeared to be more vigorous than those from other methods of rooting. Stray cases of rooting were also observed in shoot proliferation medium containing 2 ip and in the shoot induction medium of Flynn et al. during prolonged culture. Plant out of rooted shoot proliferated from field explants was also successful (Plate 11).

(ii) Somatic embryogenesis

No work was done by the staff of the project during the period as the work was assigned to a post-graduate student.

(iii) Anther culture

Only two sets of anther culture were done during the period. The anthers at tetrad stage were inoculated in Nitsch medium containing 0.5 ppm kinetin and 10 per cent coconut water with or without 0.5 per cent activated charcoal. The culture tubes were incubated in light, diffuse light and dark. Fresh flower buds as well as those given a cold treatment (5-10°C) for varying periods were used for dissection of anthers. Out of the 48 tubes inoculated, callusing was observed in one of the tubes after six weeks. This was having Nitsch salts + 10 per cent coconut water & 0.5 ppm kinetin without activated charcoal in the medium. Anthers for these studies were derived from fresh flower buds and the tubes were incubated under diffuse light. Further regeneration from callus was not attempted.

Further work was not done on tis aspect as it was allotted to a post graduate student.

(iv) Culture of flat bean embryos

Flat beans were collected from ripe pods at the time of seed extraction and embryos were extracted from fresh beans and cultured. Half MS medium containing 4% sucrose - the same medium used for mature embryo culture - was also used for culture of flat bean embryos. Most of the flat bean embryos germinated and grew as normal seedlings. Out of about 400 flat bean embryos cultured and germinated during the period under report only one germinated producing a typical haploid plant (Plate 14). This plantlet had the unique phenotype of a haploid. Growth of this plant is slow and it produced very small irregular leaves. The erect leaves are supported by short, erect petioles that are quite distinct from the decumbent leaf of the diploid. The leaf has a distinct puckered aspect of the lamina due to a series of invaginations. The plant is to be diploidized using colchicine solution after ascertaining the ploidy number using the leaf tip squash method.

(v) Culture of embryonic axis

No work on this was done during the year.

2. Top working

Standardisation of conditions for top working cocoa was the objective of this field trial started since November, 1988 using trees originally planted in 1979. As was observed earlier, the procedure of snapping the stem back was successful in inducing growth of chupons. Budding on these chupon shoots also was successful. The plants top worked by this procedure continued to make better growth than freshly budded plants. During this year, top working was continued with a row of plants snapped back every month. Success of top working continued to be total. An account of top working done so far and the success of each is given in Table 48. The total number of plants successfully top worked by the different methods so far comes to 123 and the number of newly budded plants planted in the gaps to 37. Each row of plants with a

Table 4 8 Comparison of methods and time of top working

Plant used for bud collection	No. top worked	Method and time	No. Successful	Percentage Success	Remarks
GVI - 50	5	Cut at jorquette - Nov., '88	1	20	--
GVI - 51	6	Cut at jorquette - Nov., '88	2	33	--
GVI - 54	6	Cut at 30 cm - Nov., '88	3	50	--
GVI - 55	8	Cut at 30 cm - Nov., '88	4	50	--
GVI - 56	8	Cut at 30 cm - June, '89	4	50	--
GVI - 59	8	Cut at 30 cm - June, '89	6	75	--
GVI - 60	6	Snapped - Oct., '89	6	100	--
GVI - 64	6	Snapped - Dec., '89	6	100	--
GVI - 68	6	Budded on hard bark	3	-	Three to be budded
M - 9/16	6	Snapped - Jan., '90	6	100	--
M - 16/9	6	Snapped - Feb., '90	6	100	--
$V_{4/8}$	8	Snapped - March, '90	8	100	--
$V_{5/9}$	8	Snapped - April, '90	8	100	--
$V_{10/3}$	8	Snapped - May, '90	8	100	--
$V_{15/5}$	7	Snapped - June, '90	7	100	--
GII - 12/3	7	Snapped - July, '90	7	100	--
GII - 19/5	3	Snapped - Aug., '90	3	100	--
GII - 20/4	6	Snapped - Sept., '90	6	100	--
GIII - 1/2	7	Snapped - Oct., '90	7	100	--
GIII - 4/1	8	Girdled to half circle - Oct., '90	7	-	One to be top worked
GIV - 2/5	6	Snapped - Dec., '90	6	100	--
GIV - 18/5	6	Girdled to two half circles - Dec., '90	2	-	Four to be top worked
GIV - 32/5	8	Snapped - Jan., '91	7	-	One to be top worked
			123		

maximum number of eight has one high-yielding self-incompatible parent plant of the breeding programme used for budding or top working. The total number of types so far top worked with comes to 23 and in due course, this experimental area is expected to provide comparison of the performance of the selected parent plants when top worked. Comparison with normal budding and fresh planting also is expected from this.

Plate 1 A hybrid cocoa plant of the progeny trial full of pods in the third year of planting, under the shade of banana

Plate 2 View of the hybrid progeny trial, replications I and II planted under the shade of existing rubber trees, in the second year of growth

Plate 3 View of the comparative yield trial of parental clones in their second year of growth

Plate 4 Inbred (S_2) of the plant GII 7/4 (left) compared with a hybrid cocoa plant of the same age

Plate 5 Nodal explant showing bud development and leaf expansion 4-5 weeks after culturing

Plate 6 A series of culture tubes showing shoot proliferation one to two months after culturing


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Plate 7 Two vigorous shoots produced simultaneously from a single pre-existing axillary meristem in a nodal explant from field

Plate 8 Multiple shoots produced from nodal segment of an axenic seedling

Plate 9 Roots produced following pulse treatment with 5000 ppm IBA in ½ MS medium containing 0.5 per cent activated charcoal

Plate 10 Roots produced following pulse treatment with 5000 ppm IBA in ½ MS medium containing 1 per cent activated charcoal

Plate 11 Rooted plantlet from field explant planted out in soil - soil rite (1:2) medium

Plate 12 Three month old plantlet derived from shoot tip of an axenic seedling planted out in soil - soil rite (1:2) medium

Plate 13 One year old tissue culture plant planted out in the field

Plate 14 Haploid plant recovered from flat bean embryo culture one month after plant out


TISSUE CULTURE
PLANT
MAY 1990

Plate 15 An old cocoa tree, rejuvenated by top working, in the second year of growth with a single scion

Plate 16 A bearing top worked tree with three vigorous scions in the second year of growth