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Performance of S_1 Inbreds of Cocoa (*Theobroma cacao* L.) Genotypes

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ABSTRACT

The evaluation of 57 inbreds belonging to nine genotypes of S_1 generation showed considerable variability with respect to growth, pod, bean, economic and biochemical characters. In the process of development of inbreds, the S_1 inbred have not attained sufficient homozygosity showing high degree of variability. The maximum variability was observed for pod weight, wet bean pod weight per pod and fat content. Hence, selfing of inbreds for at least 6-7 generation is essential to get sufficient homozygosity in the inbreds to produce a highly heterozygous hybrid.

Keywords Performance, Inbreds, Cocoa, Genotype, Homozygosity.

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INTRODUCTION

Cocoa (*Theobroma cacao* L.) is the third important beverage crop next to tea and coffee. The processed seeds are used for the production of cocoa powder and cocoa butter. Cocoa butter is of great importance because of its use in the chocolate, cosmetic, confectionaries, perfumeries, pharmaceuticals industris. It is native species of tropical Amazon rain forest of South America (Cheesman 1944, Motamayor *et al.* 2002).

Olmecs used the name “kakawa” and it was believed that, they were the first to grow cocoa as a domestic crop (Coe and Coe 1996). The term cocoa has been derived from the word ‘cacahoatl’ which was earlier used by the Aztec Indians. According

to Aztec mythology, God 'quetzacoatl' whom they called as 'xocolatl' brought the cocoa to the earth. It is popularly known as 'The Food of Gods' because of its divine origin. Also the term chocolate was derived from the word 'xocolatl' (Mossu 1992).

Cocoa was originally placed under the family Sterculiaceae. Based on the recent phylogenetic studies on combined analysis of plastid atpB and rbcL DNA sequences, morphological, anatomical, palynological and chemical characteristics included it into broadly defined Malvaceae family (Judd and Manchester 1997, Alverson *et al.* 1999).

In India cocoa is grown over an area of 82,940 ha with annual production of 18,920 mt. The productivity of cocoa in India, is 580 kg/ha (DCCD 2017). Cocoa is predominantly grown in mixed stands in rubber and backyards of the humid tropics of Kerala, in Tamil Nadu, it is grown as an intercrop in the coconut and arecanut in Karnataka.

Hence, there is scope for improving the productivity of cocoa in India. Use of cocoa hybrid and their cultivation is the vital method for increasing the productivity. All the hybrids in a cross do not show the same level of superiority due to the use of heterozygous parents in the breeding program (Rosemary 1998). For developing high yielding hybrid, highly homozygous inbred lines are the pre requisite. Cocoa Research Center (CRC), Kerala Agricultural University, Thrissur has started the development of inbred lines, and achieved till fifth generation inbred. In the present study, the performance of S_1 inbreds is discussed.

MATERIALS AND METHODS

Nine genotypes of S_1 generations planted at CRC, farm, Vellanikkara are evaluated for pod, bean and biochemical characters. Five mature pods of uniform size and maturity were harvested from each inbred for recording the observations by following standard procedure. The economic characters were estimated as Pod value (g) = Single dry bean weight x Number of beans per pod (Toxopeus and Jacob 1970), Pod index (PI) =1000g ÷ pod value (g) (Morera *et al.* 1991), Efficiency index (EI) =(Pod weight (g))/(Pod value (g)) (Jacob and Atanda 1971) and Dry matter recovery (%) = (Dry bean weight (g))/(Wet bean weight (g)) x 100. The fat and poly phenol are estimated. Fat was estimated by petroleum ether (40-60^{o}C) extraction method using. Soxhlet apparatus and expressed in percentage (Sadasivam and Manickam 1996). The total phenols in the extract then estimated by Folin-Ciocalteu reagent method developed by Malik and Singh (1980). The data were analyzed using WASP.

RESULTS AND DISCUSSION

Growth observations

The morphological characterization was done using descriptors developed by Bekele and Butler (2000). The details of plant height and girth in S_1 inbreds of

Table 1. Growth and pod characters of S_1 inbreds of cocoa.

Plant No.	Genotype	Plant height (cm)	Girth (cm)	Pod weight (g)	Pod length (cm)	Pod breadth (cm)	Ridge thickness (cm)	Furrow thickness (cm)	No. of beans/ pod	Flat bean/ pod
4.2	H 7.3	200	53	390.00	14.20	7.22	1.54	1.18	36.40	0.80
4.3	H 7.3	218	28	272.00	12.14	7.02	1.62	0.72	39.60	1.80
4.4	H 7.3	210	61	346.00	15.30	7.54	1.14	0.74	39.60	1.40
4.5	H 7.3	197	51	262.00	13.50	7.18	0.82	0.62	40.20	1.00
4.6	H 7.3	520	58	388.00	15.20	8.12	1.22	0.98	40.40	1.40
4.7	H 7.3	410	51	378.00	15.00	6.92	1.04	0.82	43.80	1.00
4.8	H 7.3	229	45	304.00	12.82	6.80	1.22	0.66	23.60	0.60
4.9	H 7.3	220	36	104.00	8.10	6.30	1.14	0.80	22.80	1.40
4.10	H 7.3	420	37	300.00	13.90	7.10	1.42	1.00	47.40	1.20
4.11	H 7.3	426	52	336.00	12.04	7.86	0.98	0.72	40.00	6.20
4.12	H 7.3	410	63	488.00	15.46	8.28	1.02	0.86	43.40	0.40
4.13	H 7.3	220	78	215.00	13.80	7.44	1.20	0.80	30.00	0.60

Table 1. Continued.

Plant No.	Genotype	Plant height (cm)	Girth (cm)	Pod weight (g)	Pod length (cm)	Pod breadth (cm)	Ridge thckness (cm)	Furrow thickness (cm)	No. of beans/ pod	Flat bean/ pod
4.14	H 7.3	235	53	296.00	12.20	7.30	1.50	0.90	35.60	0.20
4.15	H 7.3	232	62	278.00	13.12	6.72	1.34	0.76	35.60	0.80
4.16	H 7.3	515	53	268.00	12.72	7.44	0.88	0.68	36.20	2.20
4.17	H 7.3	205	49	356.00	14.98	7.20	1.06	0.88	43.40	0.40
4.18	H 7.3	205	60	164.00	10.28	5.76	1.24	1.08	27.60	1.60
6.1	H1 1.2	206	44	256.00	10.74	6.80	1.00	0.68	42.20	0.20
6.2	H1 1.2	250	47	296.00	14.00	7.20	0.78	0.34	35.80	0.20
6.3	H1 1.2	236	52	246.00	11.74	6.06	0.72	0.48	36.00	0.40
6.4	H1 1.2	145	45	320.00	12.94	7.14	1.02	0.72	42.20	0.80
12.1	G VI 135	110	56	288.00	13.20	7.00	1.72	0.94	38.60	0.40
122	G VI 135	360	72.0	218.00	10.84	6.66	1.50	0.90	31.80	1.20
12.3	G VI 135	510	68	300.00	12.12	7.44	1.72	0.84	32.00	1.20
12.4	G VI 135	385	73	362.00	13.90	8.10	1.64	1.16	42.60	1.80
12.5	G VI 135	415	74	280.00	12.50	6.80	1.18	0.80	40.20	1.20
12.6	G VI 135	480	69	264.00	12.60	5.90	1.20	0.82	34.00	0.60
12.7	G VI 135	345	71	220.00	10.30	7.10	1.28	0.80	34.80	0.80
12.8	G VI 135	510	47	332.00	11.50	7.36	1.28	0.82	44.20	1.20
14.1	G VI 141	330	73	444.00	14.20	7.00	1.42	1.14	35.60	1.00
14.2	G VI 141	150	36	318.00	15.66	6.96	1.42	0.96	26.60	2.00
16.1	P II 13.12	440	44	402.00	16.30	8.36	1.56	0.66	45.60	1.00
16.2	P II 13.12	720	52	254.00	11.12	7.74	1.32	1.16	31.80	5.00
16.3	P II 13.12	780	46	256.00	10.70	7.26	1.14	0.76	35.00	1.20
18.1	G VI 256.5	550	37	149.00	10.74	5.76	1.00	0.84	18.40	0.20
18.2	G VI 256.5	620	51	268.00	15.30	7.20	0.98	0.76	39.00	0.80
18.3	G VI 256.5	720	35	342.00	16.50	7.50	1.04	0.66	44.20	0.60
18.4	G VI 256.5	715	31	272.00	16.50	6.90	1.24	0.76	33.80	1.20
18.5	G VI 256.5	550	42	246.00	14.76	7.30	1.34	0.82	32.40	0.60
18.6	G VI 256.5	650	37	198.00	13.08	6.30	2.54	0.62	37.20	2.80
19.1	P II 4.8	470	34	254.00	10.90	7.30	1.12	0.86	29.60	1.40
19.2	P II 4.8	780	54	314.00	15.60	6.96	1.82	1.46	31.40	1.80
19.3	P II 4.8	720	33	414.00	17.34	7.94	1.22	0.82	40.60	1.60
19.4	P II 4.8	610	34	318.00	15.50	7.56	1.80	0.88	36.60	1.20
21.1	P II 13.8	540	44	428.00	12.76	8.76	2.06	1.82	34.40	2.80
21.2	P II 13.8	530	34	532.00	14.80	7.10	2.30	1.44	34.00	1.40
21.3	P II 13.8	555	36	316.00	13.90	8.90	1.98	1.48	30.00	1.40
22.1	P II 13.8	360	30	252.00	12.58	6.32	1.26	0.92	27.20	1.40
23.1	P II 12.9	730	49	518.00	14.80	7.70	1.16	0.84	38.60	3.00
23.2	P II 12.9	610	46	190.00	9.72	6.14	2.26	1.94	19.00	1.60
23.3	P II 12.9	740	38	316.00	14.12	7.86	1.62	0.74	32.60	1.80
23.4	P II 12.9	740	46	292.00	13.30	7.34	1.80	0.76	30.40	1.40
23.5	P II 12.9	530	26	240.00	10.46	6.10	1.56	0.92	15.20	5.20
				CV	19.46	8.74	39	15.92	13.73	15.52
				C D (0.05)	77.09	0.78	0.66	0.18	5.97	1.79

cocoa are presented in Table 1. The maximum plant height of 780 cm was recorded in inbred P II 4.8 (Plant number 19.1) and P II 13.12 (Plant number 16.2) followed by 750 cm in S_1 inbred P II 12.9 (Plant number 23.3) and the least plant height of 110 was observed in S_1 inbred H 1.2 (Plant number 6.4). The maximum collar girth of 78 cm was observed in S_1 inbred H 7.3 (Plant number 1.12) followed by 74 cm girth in G VI 135 (Plant number 12.6) and the least collar girth of 30 cm was observed in P II 13.8 (Plant number 21.3).

Pod characters of S_1 inbreds of cocoa

The mean pod weight varied between 104 g and 532

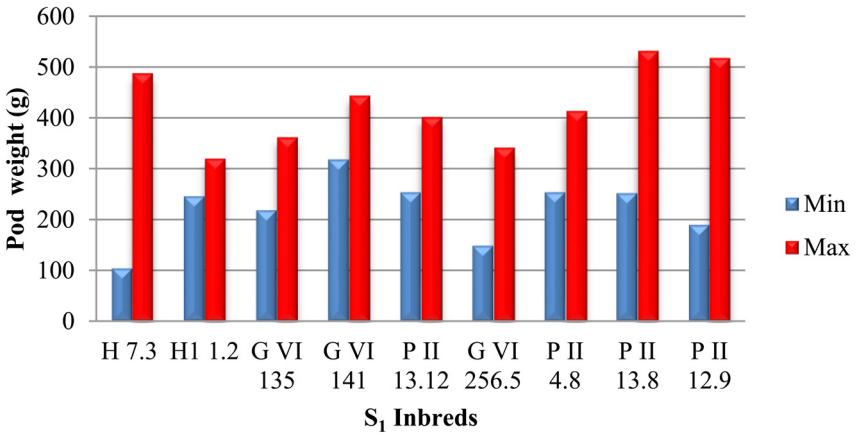

Fig. 1. Pod weight of S_1 inbreds.

g among the S_1 generation of different genotypes. The mean pod weight recorded among the S_1 inbreds was 303.02 g. The pod weight in H 7.3 ranged from 104 g in plant number 4.9 to 488 g in plant number 4.12. The pod weight in G VI 135 ranged from 218 g in plant number 23.6 to 362 g in plant number 23.14. The pod weight varied significantly in G VI 141 genotype and it ranged between 318 g to 444 g in plant number 14.2 and 14.1 respectively (Table 1). The pod weight varied significantly in inbred P II 13.12 from 254 g in plant number 16.2 to 402 g in plant number 16.1.The pod weight in G VI 256.5 varied significantly and it ranged from 149 g in plant number 18.1 to 342 g in plant number 18.3 (Fig. 1). The pod weight in P II 4.8 ranged from 254 g in plant number 19.1 to 414 g in plan number 19.3. Whereas, it varied from 252 g in plant number 22.1 to 532 g in plant number 21.2 in genotype PII 13.8. The pod weight ranged significantly in P II 12.9 genotype, the pod weight ranged from 190 g in plant number 23.2 to 518 g in plant number 23.1.

The wide variation in pod weight was observed among the S_1 progeny of same parent indicating the high amount of segregation and heterozygous nature of the parent (Minimol *et al.* 2015). The mean pod length varied between 8.1 cm and 17.34 cm among the S_1 generation of different genotypes. The mean pod length recorded among the S_1 inbreds was 13.24 cm. The pod breadth ranged from 5.76 cm in plant number 4.18 to 8.90 cm in plant number 21.3. Like pod length individuals in S_1 generation of G VI 141 also did not exhibited significant difference in pod breadth. Ridge thickness varied significantly among the genotypes in

Table 2. Bean characters of S_1 inbreds of cocoa.

Plant No.	Genotype	Wet bean weight per pod (g)	Dry bean weight per pod (g)	Single bean weight (g)	Bean length (mm)	Bean breadth (mm)	Bean thickness (mm)
4.2	H 7.3	91.48	28.63	0.79	17.14	11.45	7.50
4.3	H 7.3	64.42	29.05	0.73	16.57	11.41	7.54
4.4	H 7.3	166.36	42.96	1.09	22.04	12.50	6.52
4.5	H 7.3	84.16	31.01	0.78	22.28	13.31	7.05
4.6	H 7.3	97.58	41.33	1.02	19.67	11.38	6.77
4.7	H 7.3	89.80	37.63	0.86	20.23	11.07	6.47
4.8	H 7.3	58.40	22.79	0.97	13.46	10.49	7.45

Table 2. Continued.

Plant No.	Genotype	Wet bean weight per pod (g)	Dry bean weight per pod (g)	Single bean weight (g)	Bean length (mm)	Bean breadth (mm)	Bean thickness (mm)
4.9	H 7.3	63.00	17.14	0.75	11.22	9.25	6.07
4.10	H 7.3	168.00	37.35	0.79	13.26	10.18	7.68
4.11	H 7.3	96.92	37.99	0.93	18.47	12.64	5.67
4.12	H 7.3	115.82	51.62	1.19	18.58	11.48	6.64
4.13	H 7.3	61.34	23.12	0.77	18.50	10.25	6.49
4.14	H 7.3	75.08	24.72	0.71	16.44	10.69	7.62
4.15	H 7.3	80.48	31.76	0.89	18.55	12.09	6.55
4.16	H 7.3	69.18	34.51	0.95	19.82	10.57	7.10
4.17	H 7.3	90.56	37.06	0.86	17.66	11.14	6.73
4.18	H 7.3	111.80	20.89	0.76	18.99	10.35	7.26
6.1	H1 1.2	81.24	32.05	0.76	17.19	11.42	5.48
6.2	H1 1.2	100.00	29.15	0.82	17.40	10.39	7.19
6.3	H1 1.2	87.76	24.43	0.68	15.12	10.61	6.59
6.4	H1 1.2	81.32	29.41	0.68	17.34	11.45	6.67
12.1	G VI 135	67.44	29.02	0.75	17.37	10.45	6.84
122	G VI 135	45.10	20.89	0.64	16.97	10.94	6.69
12.3	G VI 135	64.48	24.37	0.76	16.07	10.99	6.35
12.4	G VI 135	86.46	32.02	0.75	16.61	11.01	7.61
12.5	G VI 135	110.00	28.98	0.72	16.20	10.48	7.11
12.6	G VI 135	106.00	26.21	0.77	16.38	10.54	6.89
12.7	G VI 135	81.40	25.63	0.74	17.19	10.35	6.14
12.8	G VI 135	87.10	30.99	0.70	16.99	11.32	6.31
14.1	G VI 141	92.74	27.11	0.76	17.60	11.27	7.20
14.2	G VI 141	54.84	19.84	0.75	16.96	10.71	7.57
16.1	P II 13.12	85.22	36.20	0.79	18.77	12.23	8.55
16.2	P II 13.12	59.30	21.03	0.66	17.64	11.64	6.40
16.3	P II 13.12	88.00	26.47	0.76	17.18	11.23	6.39
18.1	G VI 256.5	81.00	12.23	0.67	13.37	9.28	6.41
18.2	G VI 256.5	64.24	26.72	0.69	21.22	10.49	8.26
18.3	G VI 256.5	108.22	32.90	0.74	19.35	11.24	6.31
18.4	G VI 256.5	106.00	27.22	0.81	19.39	11.31	6.27
18.5	G VI 256.5	90.00	24.99	0.77	16.35	9.26	6.37
18.6	G VI 256.5	47.74	21.10	0.57	18.82	9.42	5.88
19.1	P II 4.8	85.40	20.28	0.69	17.17	11.71	6.48
19.2	P II 4.8	135.00	24.55	0.78	15.31	12.34	6.22
19.3	P II 4.8	94.84	32.99	0.82	13.50	9.50	6.50
19.4	P II 4.8	97.00	28.01	0.76	18.35	10.91	8.51
21.1	P II 13.8	158.00	29.58	0.86	16.76	11.33	6.79
21.2	P II 13.8	224.00	29.59	0.87	19.52	11.46	6.90
21.3	P II 13.8	144.00	28.95	0.97	20.86	12.74	7.38
22.1	P II 13.8	78.80	22.09	0.81	17.92	12.51	7.50
23.1	P II 12.9	101.08	44.07	1.14	21.23	13.12	6.72
23.2	P II 12.9	38.80	14.48	0.76	20.84	11.42	8.06
23.3	P II 12.9	51.20	25.96	0.80	19.17	10.58	6.53
23.4	P II 12.9	50.80	25.16	0.83	19.99	11.56	5.90
23.5	P II 12.9	31.26	9.58	0.63	14.87	9.96	6.44
	CV.	219.36	16.70	8.58	3.70	4.74	6.39
	CD.(0.05)	23.502	5.836	0.085	0.81	0.652	0.542

S_1 generation. The ridge thickness ranged from 0.72 cm in plant number 6.4 to 2.54 cm in plant number 18.6. Even though ridge thickness did not show much variation, the furrow thickness ranged from 0.34 cm

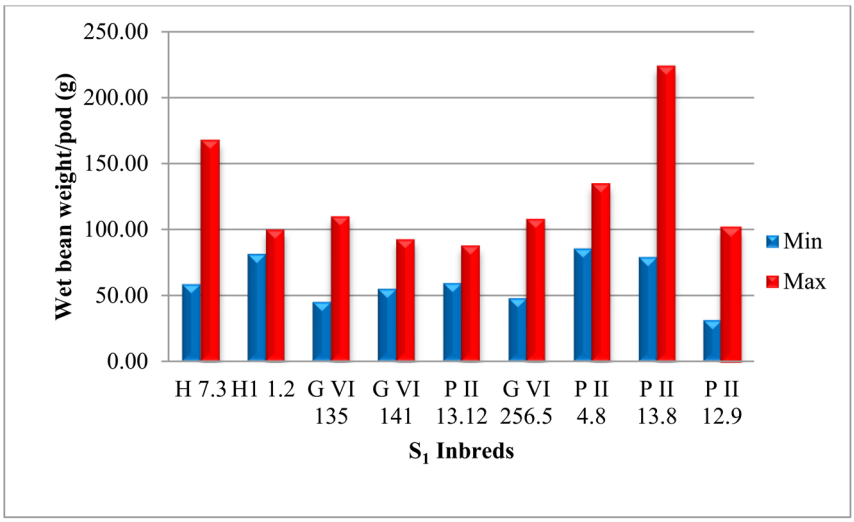

Fig. 2. Wet bean weight per pod of S_1 inbreds.

in plant number 6.2 to 0.72 cm in plant number 6.4 of H 1 1.2. The number of beans per pod ranged from 15.2 in plant number 23.5 to 47.4 in plant number 4.10. Similar studies were conducted by Adewale *et al.* (2010) and reported that the bean characters exhibited maximum diversity in exotic germplasm. Enriquez and Soria *et al.* (1974) , Pound (1932) revealed that dry or wet weight of bean is considered to be yield expressing characters and similar finding were reported with respect to number of flat beans per pod in the inbreds of cocoa which ranged between 0 and 9 in cocoa inbred studies (Minimol *et al.* 2015).

Bean characters of S_1 inbreds of cocoa

The details of bean characters of S_1 inbred of cocoa are presented in Table 2. Important bean characters mm, 9.25 to 13.31 mm, 5.48 to 8.55 mm respectively. The variation in wet bean weight per pod is presented in Fig. 2. The wet bean weight per pod among the plants of S_1 generation of H 7.3 genotype varied significantly, the wet bean weight per pod ranged from 58.40 g in plant number 4.8 to 168 g in plant number 4.10. The wet bean weight per pod varied significantly and it ranged from 81.24 g in plant number 6.1 to 100g in 6.2 in H1 1.2. The wet bean weight per pod ranged significantly in G VI 135 and it from 45.10 g to 110 g in plant number 12.2 and 12.5 respectively.

The wet bean weight per pod ranged between 54.84 g to 92.74 g in plant number 14.2 and 14.1 respectively in G VI 141. The wet bean weight per pod varied significantly in P II 13.12. The wet bean weight per pod varied from 59.30 g in plant number 16.2 to 88 g in plant number 16.3 (Fig. 2). The maximum (108.22 g) and minimum (47.74 g) wet bean weight per pod was observed in plant number 18.3 and 18.6 of GVI 256.5 respectively. Significant variation for wet bean weight per pod was observed in P II 4.8. The maximum (135 g) and minimum (85.40 g) wet bean weight per pod was observed in plant number 19.2 and 19.1 respectively. The wet bean weight per pod was ranged from 78.8 g in plant number 22.1 to 224 g in plant number 21.2 of PII 13.8 inbred. Significant variation was observed for wet bean weight per pod in P II 12.9. The wet bean weight per pod ranged from 31.26 g in plant number 23.5 to 101.80 g in plant number 23.1.

The variation in dry bean weight per pod is presented in Fig 3. The dry bean weight per pod among the plants of S_1 generation of H 7.3 genotype varied significantly, the dry bean weight per pod ranged from 17.14 to 51.62 in plant number 4.9 and 4.12 respectively. The economic characters such as pod yield, pod value, efficiency index, conversion index, dry bean weight per pod and

dry matter recovery showed significant difference among the inbreds and are summarized in Table 3.

Economic characters of S_1 inbreds of cocoa

Pod value is the dry bean obtained per pod. The pod value ranged from 9.58 to 51.61. The maximum pod value was obtained in H 7.3 (Plant number 4.12) and the least in P II12.9 (Plant number 23.5). Pod index is the number of pods required to produce kg dried beans. The pod index should be minimum as per the selection criterion. It was observed minimum (23.94)

Table 3. Economic and biochemical characters of S_1 inbreds of cocoa.

Sl. No.	Genotype	Pod value	Pod index	Efficiency index	Dry matter recovery	Fat content (%)	Phenol (%)
4.2	H 7.3	28.63	28.92	13.69	31.63	54.33	2.52
4.3	H 7.3	29.05	33.15	9.56	45.59	52.33	2.51
4.4	H 7.3	42.96	26.51	8.07	29.87	52.13	2.46
4.5	H 7.3	31.01	32.66	8.87	36.70	51.83	2.16
4.6	H 7.3	41.33	26.51	9.49	42.42	40.87	2.18
4.7	H 7.3	37.63	25.35	10.05	42.19	53.23	2.34
4.8	H 7.3	22.79	39.16	13.56	39.20	53.30	2.24
4.9	H 7.3	17.14	63.05	6.24	27.21	60.87	2.37
4.10	H 7.3	37.35	30.57	8.06	22.82	57.50	3.47
4.11	H 7.3	37.99	25.78	8.32	42.16	54.83	3.25
4.12	H 7.3	51.62	23.94	9.78	44.85	50.87	2.86
4.13	H 7.3	23.12	39.04	9.44	37.66	50.07	2.94
4.14	H 7.3	24.72	52.34	12.52	34.00	48.40	2.28
4.15	H 7.3	31.76	35.61	9.44	40.19	46.07	2.59
4.16	H 7.3	34.51	30.80	7.73	49.94	41.97	2.26
4.17	H 7.3	37.06	26.69	9.66	41.25	53.13	2.89
4.18	H 7.3	20.89	42.30	8.15	18.84	56.20	3.37
6.1	H1 1.2	32.05	38.06	8.01	39.74	55.33	2.94
6.2	H1 1.2	29.15	33.26	10.32	29.32	54.70	2.96
6.3	H1 1.2	24.43	41.00	10.08	27.85	55.17	2.19
6.4	H1 1.2	29.41	41.44	12.34	38.69	53.33	2.20
12.1	G VI 135	29.02	33.14	9.95	43.22	41.63	1.85
122	G VI 135	20.89	55.41	12.84	45.15	38.63	1.84
12.3	G VI 135	24.37	42.81	12.46	38.02	48.60	1.89
12.4	G VI 135	32.02	33.41	11.31	37.10	49.87	2.77
12.5	G VI 135	28.98	33.60	9.76	26.42	55.30	2.70
12.6	G VI 135	26.21	38.01	10.03	24.77	55.40	2.68
12.7	G VI 135	25.63	38.85	8.60	31.69	55.23	2.68
12.8	G VI 135	30.99	33.42	10.88	35.87	55.20	2.68
14.1	G VI 141	27.11	35.63	16.53	29.69	48.73	2.47
14.2	G VI 141	19.84	49.31	16.36	36.66	58.23	3.60
16.1	P II 13.12	36.20	32.30	11.21	42.44	34.43	3.35
16.2	P II 13.12	21.03	44.90	12.00	35.49	56.80	3.57
16.3	P II 13.12	26.47	39.20	9.71	30.16	54.67	3.48
18.1	G VI 256.5	12.23	81.35	13.06	15.20	55.47	3.35
18.2	G VI 256.5	26.72	43.17	10.07	42.95	58.50	3.28
18.3	G VI 256.5	32.90	30.71	10.39	30.99	58.30	3.28
18.4	G VI 256.5	27.22	37.60	10.12	25.92	58.50	3.29
18.5	G VI 256.5	24.99	38.96	9.91	27.81	58.53	3.23
18.6	G VI 256.5	21.10	47.28	9.37	44.60	58.67	3.06
19.1	P II 4.8	20.28	48.83	12.55	23.76	54.33	2.04
19.2	P II 4.8	24.55	43.51	12.74	19.57	45.17	2.01
19.3	P II 4.8	32.99	31.44	12.66	36.11	45.90	2.02
19.4	P II 4.8	28.01	35.83	11.48	28.85	61.23	2.92

Table 3. Continued.

Sl. No.	Genotype	Pod value	Pod index	Efficiency index	Dry matter recovery	Fat content (%)	Phenol (%)
21.1	P II 13.8	29.58	33.99	14.55	18.91	61.43	1.47
21.2	P II 13.8	29.59	33.49	18.01	13.41	60.10	1.72
21.3	P II 13.8	28.95	40.32	11.79	21.00	62.93	2.41
22.1	P II 13.8	22.09	42.34	11.34	28.12	45.20	2.13
23.1	P II 12.9	44.07	26.72	11.76	43.88	64.93	2.16
23.2	P II 12.9	14.48	64.37	13.59	37.23	61.57	2.13
23.3	P II 12.9	25.96	43.69	12.28	50.71	54.53	2.23
23.4	P II 12.9	25.16	40.11	11.67	49.62	36.70	2.13
23.5	P II 12.9	9.58	95.14	25.97	31.25	1.254	0.646
	CV	16.70	31.39	26.54	17.84	1.077	0.027
	CD (0.05)	5.836	15.458	3.716	7.547		

in H7.3 (86) (plant number 4.12). The least pod index of 39.08 in the in fifth generation was reported by Minimol *et al.* 2015. The maximum pod index (95.14) was observed in P II 12.9 indicating it non suitable for future selection of this inbred for this particular criterion. Efficiency index is an indication of the pod weight required to produce one gram dry bean. Efficiency Index should be minimum for selection of germplasm. Dry Matter Recovery (%) is the ratio of dry bean weight to wet bean weight. High dry matter recovery is a good criterion for selection from the germplasm. The maximum values (50.71 %) were observed for the P II 12.9 (Plant number 23.2), minimum values (13.41 %) in P II 13.8 (Plant number 21.2).

Biochemical characters of S_1 inbreds of cocoa

Cocoa beans are the major economic parts which contain the cocoa butter used for making chocolate. The quality of chocolate mainly depends upon the biochemical constituents present in the bean. Fat is responsible for softness, aroma and flavor and polyphenols for color of chocolate. In the present study the fat and poly phenols estimated are summarized in Table 3.

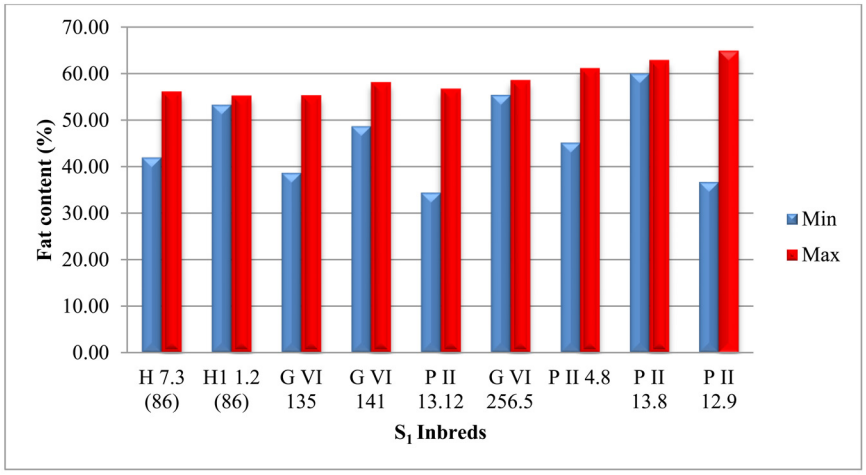

Fig. 3. Fat content of S_1 inbreds.

The fat content ranged from 38.63 in genotype P II 13.12 (Plant number12.3) to maximum of 64.93 pe PII 12.9 (Plant number 16.1). The fat content ranged from 54.33 in plant number 19.1 to 45.17 in plant number 19.4 in P II 4.8. The fat content varied significantly among the plants of P II 13.8 and the minimum fat content (60.10) was observed in plant number 21.2 and maximum fat content (62.93) in plant number 22.3. Significant variation was observed fat content of P II 12.9 and it ranged from 36.70 in plant number 23.5 to 54.53 in plant number 23.4 respectively (Fig. 3). Fat estimation in cocoa was also estimated previously by Ajmal (2016) in cocoa hybrids and Veeresh (2018) in 30 exotic germplasm. In the present study, 73% of S_1 inbreds recorded more than 50 % fat. High fat content of cocoa beans is major attribute responsible for flavor and aroma of chocolate (Mossu 1992). So the inbreds showing high fat content can be selected for further breeding program. According to Kim and Keeny 1984, poly phenols comprise 12 -18 % of the total bean weight is responsible for color of the chocolate. In the present study poly phenols ranged between 1.47 to 3.6 % among the inbreds. The maximum poly phenols (3.6 %) are observed in G VI 141 (Plant number 14.2) followed by P II 13.12 (3.57%). The least poly phenol content estimated in P II 13.8 inbred (Plant number 21.1).

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