Research Article

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Evaluation of cocoa plus trees (*Theobroma cacao* L.) for high yield in Coimbatore plantations

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Abstract

A survey was conducted in cocoa growing areas of Coimbatore district of Tamil Nadu for identifying the high yielding plus trees to increase the production and productivity of cocoa in Tamil Nadu. Thirty five high yielding plus trees were screened from farmer's field and yield characters were recorded. Maximum flowering was observed in Tc (Vedapatti) 62 while the pod set percentage was high in Tc (Vedapatti) 2. Pod weight, single dry bean weight and dry bean weight per pod was maximum in Tc (Vedapatti) 99 while Tc (Vedapatti) 72 recorded higher number of beans pod^{-1} and dry bean yield tree^{-1}. This study shows the variability among the plus trees and the identified well performing plus trees can be used in breeding programs to get sustainable yield in cocoa.

Keywords: Cocoa, Coimbatore, high yield, plus trees, variability

Introduction

Cocoa (*Theobroma cacao*. L) belongs to the family Malvaceae and has its geographical origin in the Amazon basins of South America (Motamayor *et al.,* 2002). Cocoa is predominantly grown in tropical areas of Central and South America, Asia and Africa (Marita *et al.,* 2001). Cocoa beans are important raw materials for chocolate industry and cocoa products are also used in cosmetics, beverages, jellies, ice creams and juices. In India, cocoa is being cultivated largely in the states of Kerala, Karnataka, Andhra Pradesh and Tamil Nadu with an area of 26,969 hectares and total production of 16,050 MT. Tamil Nadu ranks first in area under cocoa cultivation whereas Andhra Pradesh leads in production and Kerala in productivity (785 kg ha^{-1}) (DCCD, 2017). The study was carried out in the existing open pollinated cocoa plantations in Coimbatore to identify high yielding cocoa varieties suitable for this agro-climate with an objective to improve the productivity of cocoa in Tamil Nadu.

Materials and methods

A survey was conducted during 2017 in cocoa fields situated at Thondamuthur and Vedapatti region of Coimbatore district. A total of 124 plus trees were identified, out of which 111 plus trees (TC 1 to TC 111) were from Vedapatti and the rest were from Thondamuthur (TC 112 to TC 124).

Evaluation of 124 plus trees of cocoa for its yield and yield contributing traits resulted in selection of best performing 35 plus trees.

The following observations were recorded in the selected 35 plus trees number of flowers tree^{-1} was calculated as a product of number of flower cushions tree^{-1} and number of flowers cushion^{-1} and expressed in numbers. The number of pods in each plus tree was counted and expressed in numbers. Matured pods were harvested randomly from the selected plus tree during the peak harvest season and the weight of each pod was noted and average pod weight was calculated. Pod set percentage was also

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calculated and expressed in percentage. The total number of beans pod^{-1}, dry bean weight pod^{-1}, single dry bean weight and dry bean weight tree^{-1} were also calculated. Coefficient of variation, standard deviation and correlation coefficient was analyzed using SPSS (Nei, 1978).

Results and discussion

Flower and pod character

Flower and pod characters observed are given in Table 1. Among the 35 plus trees evaluated, Tc (Vedapatti) 61 recorded the maximum number of flowers tree^{-1} (8880) and the minimum was observed in Tc (Vedapatti) 2 (436). The average number of flowers tree^{-1} was 1593. Standard deviation and coefficient of variation was 1455.9 and 91.4 per cent, respectively. The number of pods tree^{-1} was maximum in Tc (Vedapatti) 110 which registered 84 pods tree^{-1} and Tc (Vedapatti) 55 recorded minimum numbers of pods tree^{-1} (20). Average number of pods tree^{-1} was 38.8. Standard deviation and coefficient of variation was 13.9 and 35.9 per cent, respectively. Pod weight showed significant variation in 35 plus trees and it ranged from 178.3 g in Tc (Vedapatti) 111 and 570 g in Tc (Vedapatti) 99. Pod set percentage ranged from 0.25 to 6.38. Though number of flowers observed was high in Tc (Vedapatti) 61 pod set percentage recorded was low and the yield was also low.

Cocoa is highly heterogeneous crop so the variability among the pod and also flower characters are wide. A study conducted to evaluate 21 cross combinations of cocoa showed variability for pod weight and yield related traits (Apshara *et al.*, 2008). In this present study, the quantitative flower and pod characters like, number of flowers tree^{-1}, number of pods tree^{-1}, pod weight and pod set percentage registered greater diversity among 35 plus trees. Knowledge of available variability in a crop species provide a guide for the utilization and conservation of useful variation (Aikpokpodion, 2010). In this study, 35 plus trees showing significant variation in bean and fruit traits indicated that, these variations form the on-farm collection, and it is a valuable reservoir of genetic diversity. The positive traits in the plus trees can be utilized as planting material during farm expansion to get sustainable yield (Aikpokpodion, 2010).

Table 1. Yield contributing characters (flower and pod characters) of cocoa surveyed from 35 plus trees in Coimbatore district

Sl. No.	Plus trees	Number of flowers tree^{-1}	Pod set (%)	Number of pods tree^{-1}	Pod weight (g)
1.	Tc (Vedapatti) 1	2688	2.2	58	376.7
2.	Tc (Vedapatti) 2	436	6.2	27	311.7
3.	Tc (Vedapatti) 9	828	3.9	27	416.7
4.	Tc (Vedapatti) 15	1492	2.9	43	319.7
5.	Tc (Vedapatti) 18	852	3.4	29	308.7
6.	Tc (Vedapatti) 29	4077	1.0	39	401.7
7.	Tc (Vedapatti) 31	1496	1.9	29	542.3
8.	Tc (Vedapatti) 33	1112	2.3	26	363.0
9.	Tc (Vedapatti) 37	1268	2.1	27	399.7
10.	Tc (Vedapatti) 40	1020	4.3	44	345.7
11.	Tc (Vedapatti) 41	990	2.8	28	372.7
12.	Tc (Vedapatti) 42	654	3.4	22	450.0
13.	Tc (Vedapatti) 45	780	3.1	24	355.3
14.	Tc (Vedapatti) 48	1052	2.6	27	325.0
15.	Tc (Vedapatti) 55	1020	2.0	20	431.0
16.	Tc (Vedapatti) 61	8880	0.3	25	409.3
17.	Tc (Vedapatti) 63	1191	3.2	38	334.3
18.	Tc (Vedapatti) 64	1895	2.4	46	513.7
19.	Tc (Vedapatti) 66	1467	4.1	60	375.7
20.	Tc (Vedapatti) 67	1965	2.7	52	297.3
21.	Tc (Vedapatti) 68	1435	3.1	44	436.0
22.	Tc (Vedapatti) 72	2576	2.0	52	478.3
23.	Tc (Vedapatti) 75	729	3.6	26	378.0
24.	Tc (Vedapatti) 76	1540	2.6	40	551.3
25.	Tc (Vedapatti) 78	1425	3.4	48	391.3
26.	Tc (Vedapatti) 85	1812	1.9	35	348.0
27.	Tc (Vedapatti) 86	912	4.2	38	262.0
28.	Tc (Vedapatti) 88	1722	3.4	58	398.7
29.	Tc (Vedapatti) 90	892	4.5	40	346.0
30.	Tc (Vedapatti) 91	1052	5.2	55	392.3
31.	Tc (Vedapatti) 94	1032	4.4	45	292.3
32.	Tc (Vedapatti) 99	892	2.7	24	570.0
33.	Tc (Vedapatti) 110	2310	3.6	84	430.0
34.	Tc (Vedapatti) 111	1698	2.5	43	178.3
35.	Tc (Thondamuthur) 121	549	6.4	35	364.7
Mean		**1593**	**3.1**	**38.8**	**384.8**
Maximum		**8880.0**	**84.0**	**6.4**	**570.0**
Minimum		**436.0**	**20.0**	**0.3**	**178.3**
SD		**1455.9**	**13.9**	**1.3**	**81.8**
CV (%)		**91.4**	**35.9**	**40.6**	**21.3**

Bean characters

Bean characters for 35 plus trees are given in Table 2. Among the 35 plus trees, number of beans pod^{-1} showed wide variation ranging from 29.0 to 52.0. Number of beans pod^{-1} was high in Tc (Vedapatti) 72 and the less number of beans pod^{-1} was recorded in Tc (Vedapatti) 111. The mean

Table 2. Yield contributing characters (bean characters) of cocoa surveyed from 35 plus trees in Coimbatore district

Sl. No.	Plus trees	Number of beans pod^{-1}	Single dry bean weight (g)	Dry bean weight pod^{-1} (g)	Estimated dry bean yield tree^{-1}
1.	Tc (Vedapatti) 1	36.3	0.93	33.7	1953.4
2.	Tc (Vedapatti) 2	29.7	0.64	18.9	509.2
3.	Tc (Vedapatti) 9	38.3	0.86	33.1	893.7
4.	Tc (Vedapatti) 15	42.3	0.55	23.4	1006.2
5.	Tc (Vedapatti) 18	39.7	0.87	34.6	1002.5
6.	Tc (Vedapatti) 29	38.0	1.23	46.7	1822.9
7.	Tc (Vedapatti) 31	43.0	0.73	31.5	912.3
8.	Tc (Vedapatti) 33	35.7	0.82	29.1	756.3
9.	Tc (Vedapatti) 37	42.0	0.81	34.1	920.2
10.	Tc (Vedapatti) 40	46.0	0.70	32.3	1419.4
11.	Tc (Vedapatti) 41	46.7	1.07	49.9	1396.6
12.	Tc (Vedapatti) 42	39.3	1.19	46.8	1029.8
13.	Tc (Vedapatti) 45	38.0	0.69	26.4	632.6
14.	Tc (Vedapatti) 48	32.3	0.66	21.4	578.1
15.	Tc (Vedapatti) 55	38.0	0.96	36.3	726.0
16.	Tc (Vedapatti) 61	32.7	0.94	30.8	770.3
17.	Tc (Vedapatti) 63	33.7	1.37	46.1	1752.2
18.	Tc (Vedapatti) 64	43.3	0.60	25.9	1193.2
19.	Tc (Vedapatti) 66	40.0	1.12	44.8	2686.2
20.	Tc (Vedapatti) 67	36.0	0.88	31.5	1639.0
21.	Tc (Vedapatti) 68	36.7	0.78	28.6	1258.4
22.	Tc (Vedapatti) 72	52.0	1.05	54.3	2825.7
23.	Tc (Vedapatti) 75	29.3	0.99	29.1	757.4
24.	Tc (Vedapatti) 76	45.3	1.08	49.1	1965.2
25.	Tc (Vedapatti) 78	45.3	0.97	44.0	2111.0
26.	Tc (Vedapatti) 85	37.3	1.12	41.7	1458.8
27.	Tc (Vedapatti) 86	29.7	0.90	26.7	1013.5
28.	Tc (Vedapatti) 88	42.3	0.78	32.8	1904.1
29.	Tc (Vedapatti) 90	37.3	0.99	37.0	1478.0
30.	Tc (Vedapatti) 91	35.3	1.14	40.4	2221.5
31.	Tc (Vedapatti) 94	44.3	0.81	36.0	1621.4
32.	Tc (Vedapatti) 99	40.3	1.42	57.4	1377.8
33.	Tc (Vedapatti) 110	42.0	0.78	32.9	2760.2
34.	Tc (Vedapatti) 111	29.0	0.99	28.8	1238.8
35.	Tc (Thondamuthur)121	40.0	0.86	34.4	1203.3
Mean		**38.8**	**0.92**	**35.7**	**1394.2**
Maximum		**52.0**	**1.4**	**57.4**	**2825.7**
Minimum		**29.0**	**0.6**	**18.9**	**509.2**
SD		**5.4**	**0.2**	**9.3**	**623.2**
CV(%)		**14.0**	**22.5**	**26.1**	**44.7**

number of beans pod^{-1} was 38.8. Among the plus trees, the highest single dry bean weight of 1.42 g recorded in Tc (Vedapatti) 99 and the lowest was recorded in Tc (Vedapatti) 15 (0.6 g). Dry bean weight pod^{-1} recorded in Tc (Vedapatti) 99 was maximum with 57.4 g and minimum (18.9 g) in Tc (Vedapatti) 2. Estimated dry bean yield tree^{-1} varied between 509.2 g and 2825.7 g in the 35 plus trees. Tc (Vedapatti) 72 recorded higher dry bean yield tree^{-1}, while Tc (Vedapatti) 2 recorded the lower dry bean yield tree^{-1}. The mean dry bean yield tree^{-1} was recorded about 1394.1 g. Standard deviation and coefficient of variation was 623.2 and 44.7 per cent, respectively.

In this study, out of 35 plus trees 10 plus trees had single dry bean weight of more than 1 g which is minimum single dry bean weight required in international market (Wood and Lass, 1985). Aikpokpodion (2010) reported that during component analysis for 17 morphological traits in cocoa, bean traits contributed to 24.5 per cent of variation as against 43.6 per cent of total variation observed. Maharaj *et al*. (2011) suggested that cotyledon weight should be given more importance than number of beans pod^{-1} for selection of cultivars and separation of best clone from a group of population. The dry bean is the economic part of cocoa. Selection focused on genotypes with higher dry bean weight enhances production of cocoa. In cocoa, pods with higher number and weight of the bean after fermentation are preferred characters while selecting a particular genotype from base population. In this study, the wider variation for number of beans pod^{-1}, single dry bean weight, dry bean weight pod^{-1} and dry bean yield tree^{-1} are mainly due to the genetic factors with the influence of environment and nutrient status. These results agreed with the findings of many investigators in cocoa (Mallika *et al.,* 1996; Apshara *et al.,* 2009; Thondaiman *et al.,* 2013).

Correlation

Correlation analysis was carried out with yield and yield contributing traits and furnished in Table 3. Correlation coefficient analysis reveals the common relationship between the different plant characters which contribute to the particular trait (Robinson *et al.,* 1949). In the present study, number of flowers tree^{-1} showed positive correlation with pod weight, number of pods tree^{-1}, single dry bean weight, dry bean weight pod^{-1} and dry bean yield tree^{-1}. Number of flowers per tree is an important criteria for yield of plant, positive correlation between number of flowers tree^{-1} and dry bean yield observed in this study

Table 3. Correlation analysis for yield contributing characters of selected 35 plus trees of cocoa from Coimbatore district.

Correlation analysis	Number of flowers tree^{-1}	Pod set percentage	Pod weight	Number of pods tree^{-1}	Number of beans pod^{-1}	Single dry bean weight	Dry bean weight pod^{-1}	Estimated dry bean yield tree^{-1}
Number of flowers tree^{-1}	1							
Pod set percentage	-0.612**	1						
Pod weight	0.105	0.172	1					
Number of pods tree^{-1}	0.120	-0.295	-0.049	1				
Number of beans pod^{-1}	-0.062	-0.095	0.263	0.503**	1			
Single dry bean weight	0.084	-0.151	-0.063	0.199	-0.046	1		
Dry bean weight pod^{-1}	0.033	-0.174	0.064	0.454**	0.497**	0.838**	1	
Estimated dry bean yield tree^{-1}	0.116	0.058	0.83**	0.184	0.474**	0.386*	0.581**	1

****Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level**

was also proved by Thondaiman *et al.,* 2013. Pod set percentage in cocoa is very low (0.5-5%), even though there is profuse flowering (Aneja *et al.,* 1999). Similarly, the pod set percentage showed a highly significant negative correlation with number of flowers tree^{-1}, whereas it showed a positive correlation with pod weight and dry bean yield tree^{-1}. Pod weight showed positive correlation with number of beans pod^{-1} and dry bean weight pod^{-1}. It was found that pod weight showed a decreasing trend with increase in number of pods tree^{-1} based on the nutrient status of the plant. These results coincides with the findings of Latchman *et al.* (2000). Number of pods tree^{-1} showed a highly significant positive correlation with number of beans pod^{-1} and dry bean weight pod^{-1}. In this study, there was a negative correlation between number of beans pod^{-1} and single dry bean weight whereas it showed highly significant positive correlation with dry bean weight pod^{-1} and dry bean yield tree^{-1}. Single dry bean weight pod^{-1} showed a significant positive correlation with dry bean weight pod^{-1} and dry bean yield pod^{-1}.

Conclusion

Cultivated populations are products of recombination and show variability among them. Selection from these populations from farmer's field can be further used in the breeding programme of cocoa to improve the yield for enhancing the productivity of cocoa in Tamil Nadu.

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