Research Article

doi:10.25081/jpc.2021.v49.i1.7055
Journal of Plantation Crops, 2020, 49(1): 7-13

Early performance of cocoa (*Theobroma cacao* L.) genotypes in arecanut under Assam condition of North East region of India

L.S. Singh*, Anok Uchoi, G.C. Acharya[1], S. Elain Apshara[2] and Alpana Das

ICAR- Central Plantation Crops Research Institute, Research Centre, Kahikuchi, Guwahati-781 017, Assam, India
[1]Central Horticultural Experiment Station, ICAR-Indian Institute of Horticultural Research, Bhubaneswar-751 019, Odisha, India
[2]ICAR- Central Plantation Crops Research Institute, Regional Station, Vittal-574 243, Karnataka, India

(Manuscript Received:15-09-2020, Revised: 12-01-2021, Accepted: 30-01-2021)

Abstract

Cocoa is an important plantation crop grown in southern parts of India. Though many cocoa varieties have been released for cultivation in different parts of India, there is no variety recommended for cultivation exclusively for India's North East region, especially Assam, where arecanut is grown as an important cash crop. Therefore the present investigation was undertaken to study the performance of 12 cocoa genotypes for its growth, pod yield and yield attributing traits for subsequent research programmes. The data for growth, pod yield and yield attributing traits were recorded three years after planting for five years (2015 to 2019), and the mean data were used for analysis. Genotype VTLC 11 significantly produced greater plant height (2.70 m), stem circumference (27.73 cm), height at jorquetting (36.16 cm) and canopy area (17.00 m^2). Mean average pod yield among the genotypes varied from 20.65 to 48.40 tree^{-1} year^{-1}. Genotype VTLC 19 produced significantly higher pod yield (48.40), number of fresh beans pod^{-1} (34.06), fresh bean weight pod^{-1} (229.65 g), dry bean weight pod^{-1} (119.32 g), single dry bean weight (1.20 g) and dry bean yield (1.76 kg). Considering the most economic traits of cocoa, VTLC 19 appears to be the most suitable genotype for commercial cultivation in the region.

Keywords: Bean, cocoa, genotypes, growth, pod, yield

Introduction

Cocoa (*Theobroma cacao* L.) is a commercial plantation crop mainly grown in the southern states of India. The cocoa bean is an important raw material for most of the chocolate industry. This crop is estimated to be grown in 82,940 ha with a production of 18,100 MT. In India, Kerala and Karnataka are major leading production states, followed by Andhra Pradesh. Indian chocolate industries and confectionaries require around 30,000 MT of cocoa beans every year (DCCD, 2019), and the demand is still growing. However, crop production could not meet the demand of the existing and emerging processing industry. To meet the industrial demand, there is a need to enhance crop production and productivity.

In India, the cocoa crop is mainly cultivated as a mixed crop in coconut and arecanut plantations. The crop can be introduced in other non-traditional areas where coconut and arecanut crops are being grown commercially. In Assam, arecanut is an important plantation crop grown in an estimated area of 81,000 ha with an annual production of 78,000 MT and productivity of 964 kg ha^{-1} (DASD, 2019). It is grown in almost all the districts, and 16 districts are having arecanut plantation of more than 2,000 ha each. A maximum area of 6,186 ha is reported in the Golaghat district; Kamrup Rural (4,264 ha) and Cachar (4,123 ha) are major arecanut growing

**Corresponding Author: singhleichombam@gmail.com*

regions, where arecanut is grown mainly as mono-crop. The cocoa crop being semi-shade loving, has the potential to introduce as a mixed crop in these arecanut plantations for extra income generation. This also enhances soil organic status through the fallen leaves of the cocoa crop. For enhancing yields and successful cocoa cultivation, selecting suitable genotype for different agro-climatic regions and adopting the right package of practices for the region are important. Selection and evaluation of superior plants, clonal propagation of selected plants and hybrid vigour exploitation are the best and easy approaches in cocoa improvement (Bhat *et al*., 1990; Christian, 2003).

Though various varieties and hybrids of cocoa are developed for growing in different agro-climatic regions of the country, there are no reports of the performance of these varieties in north eastern parts of India. Therefore, to promote cocoa production and to develop suitable genotype, the present work was undertaken to evaluate some cocoa genotypes in the north eastern regions of India.

Materials and methods

The study was conducted for eight years (from 2012 to 2019) at the Research Centre of ICAR-Central Plantation Crops Research Institute (CPCRI), Kahikuchi, Guwahati, Assam State, India. It is situated at 20^0 18' N latitude and 91^0 78' E longitude and 50 m above the mean sea level (MSL). The mean maximum and minimum temperature vary from 15^0C to 32^0C and 8^0C to 22^0C. The research site enjoys a sub-tropical climate with an annual rainfall of about 1,500 mm. The soil of the experimental site is alluvial clay loam with a pH range of 4.8-5.5. The study comprised of softwood grafted cocoa genotypes (VTLCH 2, VTLCH 1, VTLCH 3, VTLCH 4, VTLCC 1, VTLC 61, VTLC 66, VTLC 11, VTLC 5, VTLC 19, VTLC 30, VTLC 1) eight years old, planted under arecanut spaced at 2.7 m x 5.4 m. Cocoa is planted in every alternate row of arecanut at the centre of four arecanut palms. Randomized block design (RBD) was followed for inference with three replications. Six trees per replication were taken for observations. Recommended crop management practices were followed for maintaining the good health of the crop. Special crop management, like pruning, was done yearly, once during September. Pruning includes removal of dead and diseased, crisscross branches and water shoots. Vegetative growth parameters *viz*., plant height, stem circumference (measured at the height of 30 cm from ground level) and canopy spread were recorded during September. Annual pod yield was compiled for five years, from 2015 to 2019. Height at jorquetting was recorded at the initial stage of producing fan branches. Canopy spread was recorded by measuring the widest portion of the tree spread in each direction (East-West and North-South), and canopy area was calculated using the formula ∏rl, where, r=E-W+N-S/4 and $l=\sqrt{r^2+h^2}$, h=canopy height. Individual pod characters were measured by averaging six pods harvested from each tree from April to May. Dry bean weight was estimated after drying the bean along with mucilage in the sun for twelve days. Data were statistically analyzed using MSTAT software.

Results and discussion

Vegetative growth characters

Vegetative growth characters *viz*., plant height, stem circumference, height at jorquetting, and canopy area of cocoa genotypes are presented in Table 1. Significant differences were observed among cocoa genotypes studied for plant height, stem circumference, height at jorquetting and canopy area. Plant height among the genotypes varied from 2.26 m to 2.70 m. Genotype VTLC 11 had maximum plant height (2.70 m) compared to other genotypes, while the minimum plant height was observed in genotype VTLC 61 (2.26 m). Genotype VTLC 11 was also found to produce the maximum stem circumference (27.73 cm), height at jorquetting (36.16 cm) and canopy area (17.00 m^2). Lesser and equal height at jorquetting was observed in two genotypes, VTLC 61 (16.0 cm) and VTLC 30 (16.0 cm). Greater canopy area in genotype VTLC 11 might have influenced the photosynthetic efficiency leading to better growth in the present study. At ICAR-Central Plantation Crops Research Institute, Regional Station, Vittal, Karnataka, (South India), same cocoa genotypes *viz*., VTLCH 1, VTLCH 2, VTLCH 3, VTLCH 4, VTLCC 1, VTLC 5, VTLC 7, VTLC 19, VTLC 30, VTLC 61, VTLC 1

Table 1. Growth performance of cocoa genotypes at Kahikuchi, Guwahati, Assam

Genotype	Height at jorquetting (cm)	Plant height (m)	Stem circumference (cm)	Canopy area (m^2)
VTLCH 2	19.00	2.35	20.81	9.91
VTLCH 1	20.20	2.47	21.87	9.81
VTLCH 3	27.00	2.40	24.38	9.92
VTLCH 4	21.25	2.41	21.08	9.62
VTLCC 1	24.20	2.42	24.03	9.33
VTLC 61	16.00	2.26	17.14	8.71
VTLC 66	16.75	2.56	22.80	10.40
VTLC 11	36.16	2.70	27.73	17.00
VTLC 5	20.20	2.57	23.74	15.24
VTLC 19	19.83	2.52	22.97	10.42
VTLC 30	16.00	2.38	22.32	8.95
VTLC 1	30.20	2.27	20.88	8.32
CV (%)	19.32	13.20	15.03	17.26
SEm (±)	0.93	0.05	0.65	0.93
CD (5%)	3.72	0.21	2.94	2.97

and VTLC 66 evaluated for growth characters showed that genotype VTLC 10 produced greater plant height, girth and canopy area ten years after planting (Apshara, 2017). The difference in growth characters among cocoa genotypes at Kahikuchi, Assam and Vittal, Karnataka, might be attributed to various factors such as environment, soil moisture, availability of nutrients and genetic factor of the tree, as reported earlier by various workers (Apshara *et al*., 2009; Aikpokpodion *et al*., 2011; Thondaiman *et al*., 2013; Bhalerao *et al*., 2018).

Pod yield of cocoa genotypes

Table 2 shows the pod yield performance of different cocoa genotypes during different years. In the 4th year after planting, the cocoa pod yield among the genotypes varied from 7.86 to 17.65 pods tree^{-1} year^{-1}. Genotype VTLC 5 produced greater pod yield tree^{-1} year^{-1} (17.65), which was statistically at par with genotypes VTLC 19 (15.00), VTLCH 2 (14.17) and VTLC 30 (13.33). The least pod yield was recorded in genotype VTLC 1 (7.86) pods tree^{-1} year^{-1}. However, during the 5th, 6th, 7th and 8th years after planting, genotype VTLC 19 produced significantly higher pod yield tree^{-1} year^{-1}than other genotypes, with an average pod yield of 48.40 pods tree^{-1} year^{-1}. A gradual increase in pod yield was also observed in all the genotypes studied. At ICAR-Central Plantation Crops Research Institute, Regional Station, Vittal, Karnataka, South India, Apshara (2017) observed an average pod yield of the same twelve genotypes, varying from 32.7 to 45.8 pods tree^{-1} year^{-1}. Greater pod yield was recorded in

Table 2. Pod yield performance of cocoa genotypes at Kahikuchi, Guwahati, Assam

Genotype	Number of pods tree^{-1} year^{-1}					
	2015 (4th year)	2016 (5th year)	2017 (6th year)	2018 (7th year)	2019 (8th year)	Mean
VTLCH 2	14.17	26.07	33.67	47.83	58.54	36.16
VTLCH 1	8.26	13.34	26.40	45.20	49.68	28.57
VTLCH 3	9.33	11.33	29.83	41.15	51.32	28.60
VTLCH 4	10.67	17.74	27.66	35.35	42.16	26.71
VTLCC 1	12.32	19.94	29.80	40.00	53.24	31.06
VTLC 61	9.52	12.28	13.00	38.02	42.43	23.05
VTLC 66	11.15	15.00	38.75	45.71	54.67	33.05
VTLC 11	9.13	14.76	29.50	54.00	62.13	33.90
VTLC 5	17.65	23.48	38.60	48.75	56.32	36.96
VTLC 19	15.00	39.80	57.60	60.32	69.28	48.40
VTLC 30	13.33	22.94	37.24	44.33	46.00	32.76
VTLC 1	7.86	10.17	16.50	30.46	38.34	20.65
CV (%)	12.43	11.23	12.25	11.86	14.32	14.51
SEm (±)	0.92	1.36	0.75	1.15	2.23	1.28
CD (5%)	4.05	6.00	3.31	5.07	6.38	4.96

genotype VTLC 5 (45.8), while genotype VTLC 19 produced 38.3 pods tree^{-1} year^{-1} after ten years of planting under Vittal agro-climatic condition. Variation in pod yield performance with same cocoa varieties (CCRP 1, CCRP 2, CCRP 3, CCRP 4, CCRP 5, CCRP 6, CCRP 7, CCRP 8, CCRP 9 and CCRP 10) was also reported from Kerala Agricultural University (Sujith and Minimol, 2016) and Tamil Nadu Agricultural University (Sumitha *et al*., 2018).

Pod and bean characters of cocoa genotypes

The genotypes differed significantly for the various pod and bean characters studied. Genotype VTLCH 4 produce greater individual pod weight (407.46 g) followed by VTLC 11 (376.41 g), which was found to be statistically at par with genotypes VTLCH 2 (370.98 g), VTLC 19 (362.09 g), VTLC 61 (352.48 g) and VTLC 66 (350.00 g). With regard to pod length and pod circumference, genotype VTLC 11 was found to produce greater pod length (18.20 cm). However, pod circumference was found to be significantly higher in genotype VTLCH 4 (25.34 cm). Pod circumference for the rest of the genotypes varied from 24.73 cm to 20.31 cm. A similar finding with respect to the length and breadth of pods as influenced by the size and weight of pods has been reported (Apshara, 2017). In the present study, genotypes VTLCH 4 (407.46 g), VTLC 11 (376.41 g), VTLCH 2 (370.98 g), VTLC 19 (362.09 g), VTLC 61 (352.48 g) and VTLC 66 (350 g) recorded pod weight above 350 g, which is an important criterion required for the selection of pod (Apshara, 2010). The ridge and furrow thickness of cocoa pods varied from 1.67 cm to 1.14 cm and 1.24 cm to 0.90 cm, respectively. Genotype VTLCH 4 (1.67 cm) was found to have greater ridge thickness, followed by VTLC 11 (1.55 cm). Variability of pod traits such as pod length, girth, weight and pod wall thickness of 21 superior progenies of different cross combination in cocoa were reported (Apshara *et al*., 2008). The results are in agreement with those reported by Subramanian and Balasimha (1981) and Mallika *et al*. (1996).

Bean traits of cocoa genotypes have been presented in Table 3. A significantly higher number of fresh beans pod^{-1} was observed in genotype VTLC 19 (34.06), followed by genotype VTLC 11 (32.07) and VTLC 66 (30.38). The least number of fresh beans pod^{-1} was recorded in genotype VTLC 1 (22.09). Similar findings on the variation of the number of beans pod^{-1} among different cocoa genotypes of different genetic origin were reported (Enriquez and Soria, 1968; Lachenaud and Oliver, 2005). In the present study, pods with more than 30 beans were observed in four genotypes *viz*., VTLCH 4 (30.33), VTLC 66 (30.38), VTLC 11 (32.07) and VTLC 19 (34.06). Though genotype VTLCH 2 produced fewer beans pod^{-1} (< 30), considering the single dry bean weight, this genotype can be potential for the region. In the present study, less number of beans (< 35) was found in most of the genotypes, which was found to be an ideal criterion required for seed selection (Peter, 2002). The number of beans pod^{-1} is not an important indicator for good traits because more number of beans with small bean size is not recommended (Engles, 1982). This is because; it results in low-fat content (Enriquez and Soria, 1966; Rubeena, 2015). Higher husk: bean ratio was recorded in genotype VTLC 66 (5.82), which was statistically at par with genotype VTLC 30 (5.77) and VTLC 1 (5.63). Husk thickness had a significant role in deciding pod weight (Rubeena, 2015). Husk thickness of pods should be more than one cm as per the selection criteria (Apshara, 2010). In the present study, most of the genotypes also posses husk thickness value higher than one cm, which is a desirable trait for selecting mother trees. Fresh bean weight pod^{-1} among the genotypes varied from 229.65 g to 149.70 g. Genotype VTLC 19 had a greater fresh bean weight (229.65 g) compared to other genotypes. Lesser husk to bean ratio (3.55) in this genotype might have contributed to more bean weight than other genotypes. Dry bean weight pod^{-1} varied from 58.66 g to 119.32 g. Genotype VTLC 19 was also found to produce higher dry bean weight pod^{-1} (119.32 g). A single dry bean weight of above 1.0 g was observed in two genotypes, VTLC 19 (1.20 g) and VTLC 61 (1.01 g). The weight of a single dry bean (>1) is an important selection criterion to meet the international standard (GoI, 1997) and also for deciding yield in cocoa since the potential yield in cocoa is contributed mostly by pod weight, bean size and single dry bean weight. (Toxopeus and

Jacob, 1970; Yapp and Phua, 1987). The dry bean yield of twelve genotypes varied from 0.31 kg to 1.76 kg. Higher dry bean yield was recorded in genotype VTLC 19 (1.76 kg), followed by VTLCH 2 (0.85 kg) and VTLC 11 (0.64 kg). However, in a study conducted at ICAR-Central Plantation Crops Research Institute, Regional Station, Vittal, Karnataka, South India, dry bean yield of twelve same cocoa genotype varied from 1.07 to 1.88 kg. The mean dry bean yield of eight-year-old cocoa was comparatively lower than the dry bean yield at Regional Station, Vittal, Karnataka, South India. This might be due to the difference in the age of the tree studied. Variation in the dry bean yield of cocoa clones has been worked out by many researchers (Adomako and Adu-Ampomah 2003; Iwaro *et al*., 2003; Assemat *et al*., 2005; Bekele and Bidaisee, 2006; Maharaj *et al*., 2011). Yield in cocoa is the product of the number of pods tree^{-1} and the weight of dry beans pod^{-1}. The dry bean weight pod^{-1} depends upon the number of bean in pods which is decided by the size of pods. In the present study, VTLC 19, followed by VTLC 5, VTLCH 2 and VTLC 11, were found to have a higher number of pods and dry bean yield tree^{-1}.

Correlation among growth characters and pod yield of cocoa genotypes

Correlation coefficients among various vegetative growth parameters and pod yield were calculated using the mean values (Table 4). Plant height, stem circumference, canopy spread (East-West and North-South) and canopy area were significant and positively correlated with the pod yield except for the initial height at jorquetting. The highest correlation (0.97) was observed between the canopy area and canopy spread (North-South). Mallika *et al*. (1996) reported the importance of these traits in the yield improvement of cocoa.

From the present study, it was found that genotype VTLC 19 recorded a higher pod yield of 48.40 pods tree^{-1} year^{-1} in an optimal canopy of 10.42 m^2, with 34 beans pod^{-1} and 1.20 g single dry bean weight yielded 1.76 kg dry beans at the age of eight years under arecanut in Assam condition. Further, genotypes VTLCH 2, VTLC 5 and VTLC 11 were also found to be potential for the region with respect to pod yield and dry bean yield. However, long-term observations are needed for these genotypes on yield stability, potentiality, quality and recommendation for commercial cultivation in Assam.

Table 3. Pod and bean characters of cocoa genotypes at Kahikuchi, Guwahati, Assam

Genotype	Pod weight (g)	Pod length (cm)	Pod circumference (cm)	Ridge (cm)	Furrow (cm)	No. of fresh beans pod^{-1}	Husk: bean ratio	Fresh bean weight (g)	Dry bean weight (g)	SBW* (g)	DBY* (kg)
VTLCH 2	370.98	16.00	22.98	1.39	1.14	29.34	4.07	225.82	89.32	0.96	0.85
VTLCH 1	272.04	15.92	22.02	1.14	0.90	28.78	4.25	149.70	88.33	0.94	0.63
VTLCH 3	263.27	16.96	20.31	1.15	0.93	25.45	5.06	165.39	81.67	0.81	0.47
VTLCH 4	407.46	17.18	25.34	1.67	1.20	30.33	4.94	160.62	72.66	0.72	0.50
VTLCC 1	311.47	16.57	23.65	1.31	0.92	29.27	5.35	171.45	75.32	0.75	0.56
VTLC 61	352.48	16.63	24.73	1.27	1.05	26.35	3.65	217.68	99.67	1.01	0.48
VTLC 66	350.00	17.67	23.32	1.32	1.11	30.38	5.82	185.52	58.66	0.58	0.49
VTLC 11	376.41	18.20	23.53	1.55	1.24	32.07	4.23	211.68	74.67	0.75	0.64
VTLC 5	290.08	15.52	22.72	1.23	0.97	25.34	4.09	203.31	77.33	0.77	0.62
VTLC 19	362.09	16.70	23.91	1.38	1.08	34.06	3.55	229.65	119.32	1.20	1.76
VTLC 30	312.20	15.61	22.60	1.41	1.15	23.15	5.77	186.90	100.00	0.91	0.62
VTLC 1	264.51	15.48	22.85	1.52	1.16	22.09	5.63	210.42	67.53	0.85	0.31
CV (%)	13.94	5.08	4.07	10.25	15.23	13.27	33.20	18.47	17.23	8.16	18.15
SEm (±)	6.62	0.14	0.25	0.04	0.02	0.44	0.06	3.24	1.02	0.02	0.03
CD (5%)	29.19	0.61	1.10	0.17	0.08	1.94	0.26	14.29	4.50	0.08	0.13

*SBW-Single dry bean weight *DBY-Dry bean yield

Table 4. Correlation among growth characters and pod yield of cocoa genotypes

	Plant height	Stem circumference	East-West	North-South	Canopy area	Height at jorquetting
Stem circumference	0.89 **					
East-West	0.76 **	0.78 **				
North-South	0.90 **	0.86 **	0.89 **			
Canopy area	0.92 **	0.88 **	0.93 **	0.97 **		
Height at jorquetting	0.39	0.57 *	0.55	0.40	0.51	
Yield	0.47 **	0.23 **	0.34 **	0.49 **	0.43 **	-0.25

*Significant at 0.05 level (2 tailed), **Significant at 0.01 level (2 tailed)

References

Adomako, B. and Adu-Ampomah, Y. 2003. Bean characteristics of progenies of upper Amazon cacao in Ghana. *Tropical Agriculture* (Trinidad) **80**: 41-47.

Aikpokpodion, P.O., Badaru, K., Raji, L.O. and Eskes, A.B. 2011. Selection of new cocoa (*Theobroma cacao* L.) varieties in on-station and on-farm trials in Nigeria. In: Final Report of the CFC/ICCO/Bioversity international project on "cocoa productivity and quality improvement: a participatory approach 2004-2010".

Assemat, S., Lachenaud, P., Ribeyre, F., Davrieux, F., Pradon, J. L. and Cros, E. 2005. Bean quality traits and sensory evaluation of wild Guianan cocoa populations (*Theobroma cacao* L.). *Genetic Research and Crop Evolution* **52**(7): 911-917.

Bekele, F. L. and Bidaisee, G. G. 2006. Characterization of germplasm in the International Cocoa Genebank, Trinidad. In: *Global Approaches to Cocoa Germplasm Utilization and Conservation*. Final report of the CFC/ICCO/IPGRI project on "Cocoa Germplasm Utilization and Conservation: a Global Approach" (1998-2004). CFC, Amsterdam, The Netherland/ICCO, London, UK/IPGRI, Rome, Italy.

Bhalerao, P. P., Maheswarappa, H. P., Sumitha, S. and Apshara, S.E. 2018. Performance of Cocoa clones as intercrop in coconut gardens under south Gujarat condition. *International Journal of Innovative Horticulture* **7**(2): 120-122.

Bhat, K. S., Bhagawan, S. and Nair, R. V. 1990. Identification of high yielding trees in cacao (*Theobroma cacao* L.). *Indian Journal of Agricultural Sciences* **60**: 641-642.

Christian, C. 2003. How to improve the efficiency of individual cocoa tree selection in progeny trial. In: *Abstracts of International Workshop of Cocoa Breeding for Improved Production Systems*. INGENIC, Miklin Hotel. Accra, Ghana, 19-21 October, p. 3.

DASD, (2019). Arecanut area, production and productivity in India. https://www.dasd.gov.in.

DCCD, (2019). Production scenario of cocoa. https://dccd.gov.in.

Apshara, S.E. 2017. Comparative study on clonal and seedling progenies of selected cocoa genotypes. *Indian Journal of Horticulture* **74**(2):168-172.

Apshara, S.E., Bhat, V. R. and Nair, R. V. 2008. Comparative studies on elite cocoa progenies in their initial years of growth. *Journal of Plantation Crops* **36**(1): 38-44.

Apshara, S.E., Bhat, V. R., Ananda, K. S., Nair, R. V. and Suma, D. 2009. Evaluation and identification of high yielding trees in Nigerian cocoa germplasm. *Journal of Plantation Crops* **37**(2): 111-116.

Apshara, S.E. 2010. Cocoa planting material production. *Technical Bulletin No.66*, Published by Thomas, G.V., ICAR-Central Plantation Crops Research Institute.

Engles, J.M.M. 1982. A systematic description of cocoa clones. III. Relationships between characteristics and some consequences for the cacao breeding. *Euphytica* **32**: 719-733.

Enriquez, G. and Soria, J.V. 1966. Estudio de la variabile de varies characteristicas delar mazereas de cocoa (*Theobroma cacao* L.). *Fitotecnia Latino-Americana* **3**(1): 99-118.

Enriquez, G. and Soria, J. V. 1968. The variability of certain bean characteristics of cacao (*Theobroma cacao* L.). *Euphytica* **17**: 114-120.

GoI (Government of India). 1997. Cocoa beans grading and marketing rules. AGMARK standards. *Gazette of India Part II* **3**:1.

Iwaro, A. D., Bekele, F. L. and Butler, D. R., 2003. Evaluation and utilization of cacao (*Theobroma cacao* L.) germplasm at the International Cocoa Genebank, Trinidad. *Euphytica* **130**: 207-221.

Lachenaud, P. and Oliver, G. 2005. Variability and selection for morphological bean traits in wild cocoa trees (*Theobroma cacao* L.) from French Guiana. *Genetic Research and Crop Evolution* **52**(3): 225-231.

Maharaj, K. P., Maharaj, F., Bekele, D., Ramnath, G. G., Bidaisee, I., Bekele, C. and Presad, K. 2011. Trinidad selected hybrids: an investigation of the phenotypic and agro-economic traits of 20 selected cacao cultivars. *Tropical Agriculture* (Trinidad) **88**(4): 175-185.

Mallika, V. K., Rekha, C., Rekha, K., Swapna, M. and Nair, R. V. 1996. Evaluation of pod and bean characters of cocoa hybrids in early years of bearing. *Journal of Plantation Crops* **24**: 363-369.

Peter, K. V. (2002). *Plantation Crops*. National Book Trust, India, A-5 Green Parks, New Delhi-110016, pp. 94-123.

Rubeena, M. 2015. Analysis of bean characters in cocoa (*Theobroma cacao* L.) hybrids bred for bold beans. *M.Sc. Thesis*, KAU, Vellanikkara, Kerala, India. pp. 67.

Subramanian, N. and Balasimha, D. 1981. Variability in pod and bean characters in some cocoa hybrids. Genetics, plant breeding and horticulture. In: Proceedings of the fourth annual symposium on plantation crops, *PLACROSYM IV*, Mysore, 3-5 December, pp. 168-174.

Sujith, S.S. and Minimol, J.S. 2016. Kerala Agricultural University Released cocoa varieties. *Advances in Life Sciences* **5**(16): 6258-6261.

Sumitha, S., Balakrishnan, S., Sobha, N., Kumar, M., Jeyakumar, P. and Jegadeeswari, V. 2018. Growth and yield performance of cocoa (*Theobroma cacao* L.) varieties under Tamil Nadu condition. *Journal of Pharmacognosy and Phytochemistry* **7**(5): 591-594.

Thondaiman, V., Rajaman, K., Senthil, N., Shoba, N. and Joel, A. J. 2013. Variability studies and identification of high yielding plus trees of cocoa (*Theobroma cacao* L.) in Tamil Nadu. *African Journal of Agricultural Research* **8**(26): 3444-3453.

Toxopeus, H. and Jacob, V.J. 1970. Studies on pod and bean values of *Theobroma cacao* L. in Nigeria. II. Number of beans per pod, with special reference to the natural pollination process. *Netherland Journal of Agricultural Science* **18**: 188-194.

Yapp, J.H.H. and Phua, P.K. 1987. Inter-Upper Amazon cocoa hybrids of Sabah-series III Progeny Trial. Seminar on current palm kernel utilization and recent advances in cocoa cultivation *Proceedings of the Society of Agricultural Scientist*, Sabah.