

COCOA PLANTING MATERIALS OF MALAYSIAN COCOA BOARD

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Malaysian Cocoa J. 17: 101-109 (2025)

ABSTRACT – The development of cocoa planting materials program in Malaysian Cocoa Board has successfully introducing fifteen MCB clones i.e. MCBC 1, MCBC 2, MCBC 3, MCBC 4, MCBC 5, MCBC 6, MCBC 7, MCBC 8, MCBC 9, MCBC 10, MCBC 11, MCBC 12, MCBC 13, MCBC 14 and MCBC 15 with specific agronomic traits including high yielding, good pod and bean characteristics, tolerant to pest and diseases, high cocoa butter content, good and unique flavor and tolerant to extreme weather and environment. The MCB clones are part of fifty-four commercial clones recommended for planting throughout Malaysia consisting of PBC, KKM, QH, BAL and other clones. These clones have been categorized under four classes based on adaptability to a wide range of Malaysia agro-climatic conditions, good yield potential based on research and published data and other characteristics.

Keywords: Planting materials, clones, tolerant, flavour

INTRODUCTION

Cocoa (*Theobroma cacao* L.) is the third major commodity crop in Malaysia after oil palm and rubber (Johnsiul *et al.*, 2021, Johnsiul and Tamchek, 2023). The Malaysian Cocoa Board (MCB) has played a critical role in the advancement of Malaysia's cocoa industry through the development of high-performance cocoa planting materials (Ramba *et al.*, 2007). The selection of suitable and accurate cocoa planting materials will determine the yield and income obtained by cocoa growers. Two types of planting materials for cocoa growing are hybrids and clones. In Malaysia, cocoa growers are recommended to use cocoa clones because of their advantages compared to hybrid material, and for several reasons, especially in commercial cocoa farming where consistency, quality, and yield are critical (Yei Kheng *et al.*, 2021).

There are several benefits of using clonal materials. According to Johnsiul and Awang (2019), cocoa clones are genetically identical and they produce uniform trees in terms of growth, fruiting and maturity. Selection of high yield and quality cocoa clones would benefit cocoa growers by ensuring predictable pod yield, bean size and flavor quality. Most of the cocoa clones mature and produce pods earlier than hybrids which helps cocoa growers to get quicker returns on investment. Clonal materials have also been selected for resistance to specific pests and diseases, hence they can prevent total crop loss if an outbreak occurs. The

uniformity and predictability of clonal materials are important for the efficient use of land and the inputs given. This review paper aims to evaluate the current status of MCB cocoa clones and their contribution to the Malaysian cocoa sector.

DEVELOPMENT OF MCB COCOA CLONES

MCB focuses on the development of clonal planting materials in cocoa breeding research programs with several objectives, such as developing superior or improved cocoa clones with high yield, good pod and bean characteristics, high cocoa butter content, tolerance to major pests and diseases especially against to cocoa pod borer (CPB), vascular streak dieback (VSD) and black pod (BP) diseases, while having good and unique flavor beans, adaptation to a wide range of agro-climatic conditions and other desirable traits of economic importance (Ramba *et al.*, 2007, Japar *et al.*, 2020).

A comprehensive cocoa breeding program involves a whole steps of the cocoa breeding process including germplasm enhancement, hybridization, progeny trials, individual trees selection, clonal trials and multi-location field trials (Ramba *et al.*, 2007, Johnsiul and Awang, 2019). The selection of the potential cocoa clones in trial plots involved rigorous evaluation for yield potential, pest and disease

resistance, and adaptability to various environment conditions.

Since 2005, MCB has released fifteen (15) cocoa clones namely MCBC 1, MCBC 2, MCBC 3, MCBC 4, MCBC 5, MCBC 6, MCBC 7, MCBC 8, MCBC 9, MCBC 10, MCBC 11, MCBC 12, MCBC 13, MCBC 14 and MCBC 15 (Figure 1) for commercial planting in Malaysia, which is characterized by high yield, disease resistance, fine flavor traits and others (Ramba, *et al.*, 2013a, MCB, 2021). These clones are part of a broader collection of fifty-four (54) commercial cocoa clones recommended for cultivation throughout Malaysia including clones from Borneo Abaca Limited (BAL), Balong River Plantation (BR), Koperasi Pembangunan Desa (DESA), Klon Koko MARDI (KKM), Prang Besar Clone (PBC), Department of Agriculture Sabah Quoin Hill (QH) and SAFIMA Plantation-Red Pod (RP). These cocoa clones have been categorized into four classes (Table 1) based on five criteria such as adaptability to a wide-range of Malaysia agro-climatic conditions, good yield potential, good pod and bean characteristics, tolerance to major pests and diseases, high in cocoa butter content and good flavor (Ramba *et al.*, 2013b). These clones are tailored to suit Malaysia's diverse agro-climatic conditions, with the aim of enhancing productivity and bean quality in both local and international markets. Notably, all of these cocoa clones are officially registered as national plant varieties and four MCB cocoa clones (MCBC 6, MCBC 7, MCBC 8 and MCBC 9) were registered under plant variety protection (PVP) which is also known as plant breeders' rights under Malaysia's Department of Agriculture (DOA).

Table 1: Criteria classes of Malaysia cocoa clones

Category	Criteria
Class I	Suitable for planting throughout Malaysia with good yield potential (>2.5 ton/ha/year) and tolerant to major pest and diseases. Clones (6): MCBC 1, MCBC 8, MCBC 10, KKM 22, PBC 123 and QH 1003.
Class II	Suitable for planting in selective areas (inland soil) with good yield potential (>2.5 ton/ha/year), moderately tolerant to major diseases and possess good pod and bean quality (pod value <25, beans number per pod >35 and average dry bean weight >1.0g). Clones (18): MCBC 9, MCBC 11, MCBC 12, MCBC 13, MCBC 14, MCBC 15, BR 25, KKM 1, KKM 4, KKM 5, KKM 19, KKM 25, PBC 112, PBC 137, PBC 139, PBC 221, QH 22 and RP 1.

Class III	Suitable for planting in some locations (volcanic soil type), possess good pod and bean characteristics while moderately tolerant to major diseases. Clones (19): MCBC 2, MCBC 4, MCBC 6, MCBC 7, KKM 2, KKM 6, KKM 15, KKM 17, KKM 26, KKM 27, KKM 28, PBC 159, PBC 179, QH 37, QH 326, QH 1176, DESA 1, BAL 209 and BAL 244.
Class IV	Susceptible to major diseases, weak plant characteristics (droopy and poor growth) and moderate in pod and bean quality (average dry bean weight of <1.0g and high pod value). Clones (11): MCBC 3, MCBC 5, KKM 3, PBC 130, PBC 131, PBC 140, QH 186, QH 240, QH 441, QH 968 and QH 1287.

Source: Ramba *et al.* (2013b).



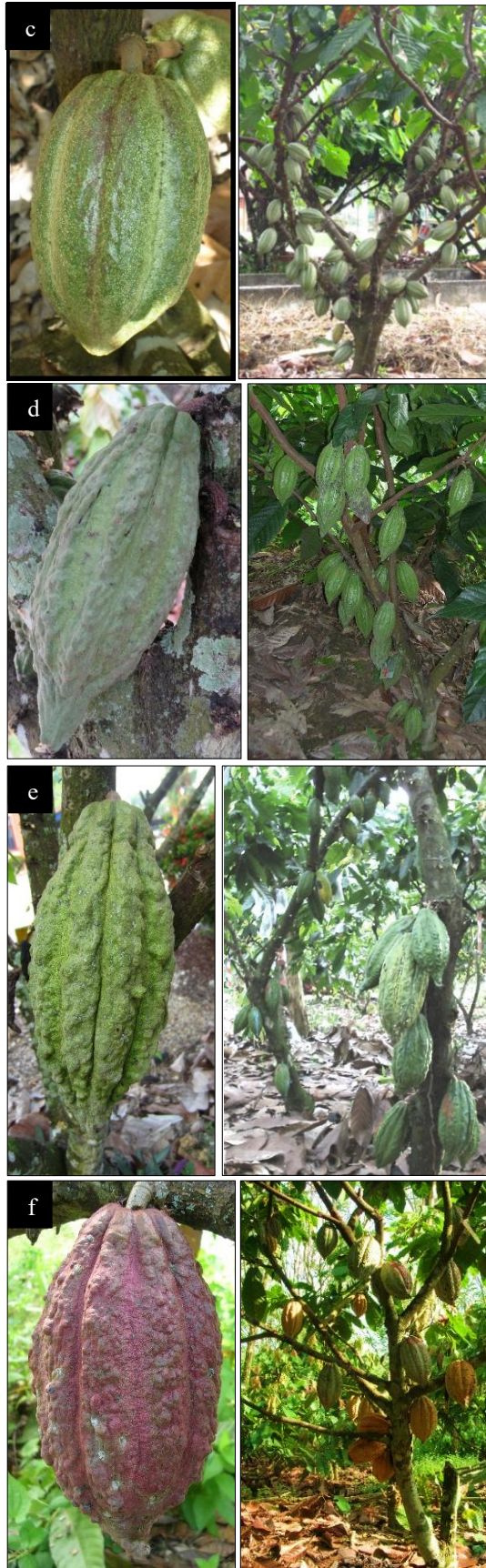




Figure 1: MCB cocoa clones (a) MCBC 1 (b) MCBC 2 (c) MCBC 3 (d) MCBC 4 (e) MCBC 5 (f) MCBC 6 (g) MCBC 7 (h) MCBC 8 (i) MCBC 9 (j) MCBC 10 (k) MCBC 11 (l) MCBC 12 (m) MCBC 13 (n) MCBC 14 and (o) MCBC 15

AGRONOMIC PERFORMANCE

Agronomic traits of MCB clones have been extensively studied. High yield and quality planting materials are very important for cocoa crops because of the high demand for cocoa beans worldwide. The selection and evaluation of high yielding clones with good bean quality (Ramba *et al.*, 2007) were implemented at research stations and at various locations throughout Malaysia. Both characteristics are crucial for cocoa beans production as the beans are widely used as a source of chocolate and cocoa based products.

Each Malaysian cocoa clone has unique and distinctive characteristics. Referring to Table 2 (Ramba *et al.*, 2013b), the productivity of MCB clones is in the range of 1.32-5.74 tonnes/hectare/year or 44-109 pods/tree/year. MCBC 5 has the potential of producing 5.74 tonnes/hectare/year with a planting density of 1000 trees per hectare. The pod index of MCB cocoa clones ranges between 17.1 to 37 pods, average size of dried beans between 0.8 to 1.5g, bean number per pod of 33 to 46 beans and most of them are self-incompatible. Hence, mixed planting is necessary to encourage pollination activities. MCBC 1, MCBC 8 and MCBC 10 (class I clones) exhibited the best yield performance, bean quality and disease resistance among others. These superior traits, particularly in terms of yield and resistance to disease would suit these clones for planting in a wider range of environmental conditions in Malaysia. The implementation of the 4P concept in cocoa crop management including sanitation, manuring, pruning and harvesting would lead to a better yield (Osman, 2020).

Table 2: Technical information of MCB cocoa clones

Clone	Potential Dry Bean Yield (kg/tree/yr)**	Pod Yield Per Tree Per Year	Pod Value*	Average Dry Bean Weight (g)	Bean Number Per Pod	Cocoa Butter Content (%)	Compatibility
MCBC 1	3.59	69	19.2	1.30	39	56.0	Self-incompatible
MCBC 2	2.92	51	17.5	1.50	38	56.0	Self-incompatible
MCBC 3	3.14	60	19.1	1.37	38	59.0	Self-incompatible
MCBC 4	2.77	58	20.9	1.33	35	55.0	Self-incompatible
MCBC 5	5.74	109	19.0	1.41	37	55.0	Self-incompatible
MCBC 6	3.46	75	21.7	1.38	37	55.2	Self-incompatible
MCBC 7	2.60	50	19.2	1.22	46	55.4	Self-incompatible
MCBC 8	3.51	60	17.1	1.50	40	54.7	Self-compatible
MCBC 9	3.76	91	24.1	1.29	33	51.3	Self-incompatible
MCBC 10	4.63	92	22.1	1.18	35	54.7	Self-incompatible
MCBC 11	4.62	76	18.3	1.38	43	54.4	Self-incompatible
MCBC 12	3.03	63	23.1	1.08	43	58.9	Self-incompatible
MCBC 13	3.70	70	21.1	1.23	39	56.5	Self-incompatible
MCBC 14	3.67	66	20.0	1.14	35	56.2	Self-incompatible
MCBC 15	1.32	44	37.0	0.80	36	51.4	Self-incompatible

*Pod value refers to number of cocoa pods required to produce 1 kg of dry beans.

**Based on 1000 trees per hectare

Source: Ramba *et al.*, (2013a), Ramba *et al.* (2013b), MCB (2021)

Table 3 below shows the comparative analysis of MCB cocoa clones with other Malaysian cocoa clones. The MCB cocoa clones indicated larger bean size with good yield potential, pod value and cocoa butter content compared to other local clones (Ramba *et al.*, 2016).

Table 3. Comparative analysis of MCB cocoa clones with other Malaysian cocoa clones

CLONE	PYT	DBY (kg/ha/yr)**	PV	ADBW (g)	BNP	BUTTER CONTENT (%)	CPC (%)
KKM 1	68.4	3930	17.4	1.06	51	56	34.0
MCBC 9	90.7	3760	24.1	1.29	33	51	33.5
MCBC 1	68.9	3590	19.2	1.30	39	56	34.3
MCBC 8	59.9	3510	17.1	1.50	40	55	33.1
QH 22	75.1	3510	21.4	1.15	42	55	28.3
BR 25	67.3	2690	25.0	1.00	40	45	40.5
PBC 123	58.7	2550	23.0	1.04	42	53	33.8
KKM 25	72.5	2440	29.7	1.30	24	52	39.0
KKM 22	58.1	2420	24.0	1.09	38	57	31.0
PBC 139	43.4	2250	19.3	1.18	44	57	25.3
KKM 4	51.0	2040	25.0	1.06	38	54	36.0
QH 1003	50.5	2030	24.9	1.36	31	53	31.9

KKM 5	43.8	2020	21.7	1.07	42	49	42.0
PBC 112	38.3	1530	25.0	1.01	38	56	27.0

*PYT-pod yield per tree, DBY-dry bean yield, PV-pod value, ADBW-average dry bean weight, BNP-bean number per pod, CPC-cocoa powder content

**Based on 1111 trees per hectare

Source: Ramba *et al.*, (2016)

Cocoa crop have also been challenged by their minimal resistance to major pests and diseases. Most of the Malaysian cocoa clones are tolerant to vascular streak dieback (VSD) and black pod diseases infection and are moderately tolerant to cocoa pod borer (CPB) infestation. Kasran (1999) reported that MCBC 1 is highly tolerant to VSD disease infection while Ramba *et al.* (2016) revealed that MCBC10 is tolerant to VSD and black pod diseases. Currently, the pests and diseases can be controlled by integration with host plant resistant materials, biological control and pod sleeving methods, in addition to chemical control. Study by Maisin (2020) indicated that CPB problem could be overcome by adopting integrated pest management (IPM) in the field whereas Bakar and Awang (2020) reported that cocoa pod sleeving is one of the best methods for managing CPB in the large scale areas.

Most of Malaysian cocoa clones have a high percentage of cocoa butter content, which makes them more desirable in the cocoa trade since cocoa butter attracts a significant part of the income derived from the sale of cocoa. According to Ramba *et al.* (2013b), MCB clones contained cocoa butter content ranging from 51.3-59.0% (Table 2).

Cocoa trees are very sensitive to climate change and can affect the productivity and quality of the beans. Lahive *et al.* (2019) reported that the significant yield reduction in cacao was due to water limitation but there is evident that sensitivity to water limitation varies with genotypic variation. Prolonged dry periods for more than three months and flooding in some lowland cocoa growing regions (Bertolde *et al.* 2012) would cause substantial negative effects on tree growth and yield and, also the dry and damp conditions can lead to an increase in disease incidence. Several MCBC clones in the MCB collection have shown promising resilience under prolonged dry conditions and have also adapted well to regions with high annual rainfall. Osman *et al.* (2017) reported that MCBC 1, MCBC 4, MCBC 5, MCBC 6, MCBC 8, MCBC 9 and MCBC 10 were tolerant to drought conditions. MCBC 1, MCBC 3, MCBC 4, MCBC 5, MCBC 6, MCBC 8 and MCBC 9 are tolerant to water stress.

According to Muda *et al.* (2021), seeds of MCB cocoa clones can be an alternative rootstock in nurseries. Clones such as MCBC 7 can produce a good quality seedlings in terms of growth and development, while Mat Yazik *et al.* (2008) reported that MCBC 2 and MCBC 5 are suitable for rootstocks due to low infection by white root disease pathogen.

BEAN QUALITY AND FLAVOUR PROFILE

Bean quality is a critical factor in the marketability of cocoa. In cocoa crops, the flavour profiles of cocoa beans play the main role in measuring cocoa quality which leads to premium and higher price. According to Afoakwa *et al.* (2013), raw cocoa beans containing astringent, unpleasant taste and flavour must be fermented, dried, and roasted in order to obtain the cocoa flavour characteristics and taste. Many factors affect the flavour of cocoa beans such as cocoa origin, genotype, location and environmental conditions of the planted crop (i.e. soil condition as well as climate during pod maturation), post-harvest treatments (fermentation, drying), factory processes (roasting, conching) and etc. (Othman *et al.*, 2006, Afoakwa *et al.*, 2008, Sukha *et al.*, 2014, Kongor *et al.*, 2016).

Studies have shown that fermentation duration and clonal variety significantly influence flavor profiles. For example, MCBC 2 fermented for five days exhibited the most intense cocoa flavor with lower bitterness and astringency levels, making it favourable for premium chocolate production (Zolkopli. *et al.*, 2021). Therefore, it is suggested that through the correct and perfect pre and post-harvest treatments (pod storage, fermentation and drying), cocoa beans quality especially in flavour could be improved. Current research by MCB (2021) on flavor profile of MCB cocoa clones' revealed four MCB clones namely MCBC 9 (cocoa and floral note), MCBC 12 (cocoa, fresh fruit and floral notes), MCBC 14 (cocoa and nutty notes) and MCBC 15 (cocoa, nutty and fresh fruit notes) as fine flavor cocoa clones of Malaysia meanwhile Nanyan *et al.* (2023) reported that

cocoa beans of MCBC 12 and MCBC 15 have flowery special notes.

Most of Malaysian cocoa beans are of the Trinitario variety which is known to produce fine-flavoured cocoa. As a small cocoa bean-producing country, Malaysian cocoa beans have been recognized as one of the best or fine flavour cocoa in the world (Tee *et al.*, 2021) through the Cocoa of Excellence (COE) Programme and International Cocoa Awards (ICA). This prestige programme aims to recognize and promote the diversity of cocoa flavours from the producing countries around the world to produce high quality cocoa beans.

GENETIC STUDY

Studies on cocoa genomes have shown significant progress over the last decade. Cocoa genome sequencing studies have revealed the connections between genes and traits of interest (Neela *et al.*, 2015). This discovery has facilitated scientists and breeders in speeding up the development of superior cocoa clones in terms of pest and disease resistance, yield and flavour improvement and, other traits of economic interest.

Genetic studies of cocoa clones in MCB have been conducted for clonal identification, screening of desirable traits and other objectives. Molecular markers such as microsatellite markers (SSR's) have been applied in investigating relationships between clones using phylogenetic analysis (Johnsiul and Ramba, 2016). DNA fingerprints of more than 500 cocoa germplasm collections, including MCB cocoa clones were generated using 15 SSR primers specific to cocoa. Johnsiul and Awang (2019) reported that class I clones show a high diversity and can be utilized as genetic materials in cocoa breeding programmes.

The genetic uniformity of cocoa clones can be evaluated morphologically and using molecular markers (Johnsiul and Awang, 2019). Maintaining genetic uniformity during clonal propagation is vital for a consistent performance. Assessments using SSR markers revealed that while clone MCBC 8 maintained genetic uniformity, others showed genetic variations, possibly due to mislabeling or propagation errors (Johnsiul and Awang, 2019). They also reported that crossing MCBC 1 with MCBC 8 is predicted to produce higher probability of positive heterosis on yield as both commercial clones have the highest yield that contributing traits in Class I (Japar *et al.*, 2020).

CONCLUSIONS

The efforts of the Malaysian Cocoa Board to develop superior and refining cocoa clones have significantly contributed to the sustainability and competitiveness of Malaysia's cocoa industry. The MCB series of cocoa clones are mainly emphasis on productivity, pests and diseases tolerance especially on cocoa pod borer, vascular streak dieback and black pod diseases, and also the quality of flavor. These clones have been used throughout Malaysia for the productivity and quality of the cocoa beans. Through continued research and adoption of the latest and advanced technology, MCB ensures the provision of high-quality and market-preferred cocoa clones to cocoa growers, bolstering Malaysia's position in the global cocoa market. The future research directions are to develop superior cocoa planting materials with minimal input requirement and tolerance to extreme weather and climate change.

ACKNOWLEDGMENTS

The authors would like to thank the Director General of MCB for his permission to present this paper. Appreciation is extended to the Deputy Director-General (Research & Development) and the Director of Cocoa Upstream Technology Division for their guidance, constructive suggestions and comments. Thanks are also extended to the staffs of the planting material development section and those who were directly or indirectly involved in this project. This study was supported by the Ministry of Finance, 12th Malaysia Plan, 'Projek Pembangunan Bahan Tanaman Fine or Flavour Cocoa (FFC) dan Koko Organik di Semenanjung Malaysia' (P20001001230009) and Malaysian Cocoa Board.

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