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Cocoa Production Capacity (*Theobroma cacao* L.): A Study of Branch, Flower Cushion, and Pod Production

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Abstract

Cocoa is an important global commodity and a source of income for millions of farmers in around the world. Nevertheless, yields is often still far from their potential. This study aims to evaluate the relationship between production space capacity and flower cushion status on pod production. The study was conducted at Kaliwining Experimental Station, Indonesian Coffee and Cocoa Research Institute, Jember, at an altitude of 45 m above sea level (a climate type D according to the Schmidt & Ferguson classification) and flat topography. The cocoa plant originated from top grafting seedlings with the age of six years. Design of experiment was randomized as a complete block design (RCBD) single factor consisting of seven clones as treatment with three replications. Each plot consisted of five sample plants. The parameter was observed involve branching type, branch surface area, flower cushion distance, flower cushion density, number of flower cushions, number of pods per flower cushion, number of pods per tree, and pod characteristics include pod length, pod girth, and pod weight. The results showed that all cocoa clones had production capacity with an average 490-635 flower cushions spread across the entire branch surface. The increase of pod weight was significantly influenced by length, girth, number of pods per flower cushion, and flower cushion distance.

Keywords: Cocoa clones, branch, flower cushion, cocoa pods

INTRODUCTION

Cocoa is an important global commodity and a source of income by the million's farmers in around the world (Vasquez-García *et al.*, 2022). Cocoa (*Theobroma cacao* L.) is a tropical tree classified in the Malvaceae family, growth under shade, and cultivated for its fruits, called pods, and its seeds are used to row material for chocolate and cosmetics industries (Alverson *et al.*, 1999; Wibaux *et al.*, 2024). Countries such as Côte d'Ivoire, Ghana, Indonesia, Ecuador and Cameroon contributed more than 70% of the world's cocoa supply (Mendoza-Meneses *et al.*, 2023).

Cocoa has good economic prospects, as domestic demand for cocoa continues to increase. However, cocoa production has not been able to meet domestic consumption requirements, as indicated by persistently high volume of imports, which reached approximately 340,000 tons (BPS, 2023). In many cases, cocoa production in smallholders is still far from its expected potential. One contributing factor is that production space is still not being fully utilized.

Cocoa is *cauliflorous* plant, which flowering and fruiting occurs throughout the trunk (*cauliflory*) and branches (*ramiflory*) (Young, 1994). The cocoa flower is arranged by 5 free white sepals, 5 free yellow petals, 10 stamens forming 2 circles with a steril outer circle (staminode), and white pistil (Smith 1992; Susilo 2015; Martinez *et al.*, 2017). The cocoa pod is elongated with a grooved surface, the color of pod is determined by the type of clone, and each pod contains 20-60 seeds with pulp (Doar´e *et al.*, 2020; Mendoza-Meneses *et al.*, 2023).

Branches are an as a place for important part that serve cocoa pod production. Cocoa flowers and pods develop on an organ called flower cushion, which is found on the entire surface of the branches (Wibaux *et al.*, 2025). Study on branch and flower cushions as main components of production space were still limited. Previous research has been focused on quality and methods of increasing yields without considering the potential of production space. The aim of this study was to evaluate the relationship between production space capacity and flower cushion status on pod production. The results were expected to provide information related to cocoa production capacity in various clones, which will be useful in future cocoa cultivation management and development.

MATERIAL AND METHODS

The study was conducted at Kaliwining Experimental Station, Indonesian Coffee and Cocoa Research Institute (ICCRI), Jember, at an altitude of 45 m above sea level (a climate type D according to the Schmidt & Ferguson classification) with Inceptisol soil and flat topography (Erwiyono, 2005; Sari & Susilo, 2015). The cocoa plant originated by top grafting seedling with the age of six years. Design of experiment was a randomized complete block design (RCBD) single factor consisting of seven clones as treatment with three replications. The treatment used to 7 cocoa clones that were established by Ministry of Agriculture of the Republic of Indonesia (Table 1) Each plot consisted of five sample plants.

Branching type was determined by the angel between opposite branches on the primary branch using protractor, according to classification by Setyawan *et al.*, (2021):

- Vertical (45-75^o)
- Intermediate (75-105^o), and
- Horizontal (105-180^o).

Observation on pod was conducted every month from January to June 2025. Observation was conducted at each branch category:

Table 1. List of 7 cocoa clones that used to research and their characteristics

Accession number *	Clones	Origin*	Characteristics*
KW 30	ICCRI 03	DR 2 x Sca	Pod is rounded, and the young one is light red
KW 617	ICCRI 09	TSH x Sulawesi 1	Pod is elliptical, and the young one is dark red
M45	MCC 02	Exploration in South Sulawesi	Pod is rounded and elliptical, and the young one is dark red
KW 516	Monika 1	Exploration in North Sumatera	Pod is elliptical, and the young one is light green
KW 562	Monika 2	Exploration in North Sumatera	Pod is oblong, and the young one is dark green
KW 162	Sulawesi 1	Exploration in Sulawesi area	Pod is oblong, and the young one is dark red
KW 163	Sulawesi 2	Exploration in Sulawesi area	Pod is elliptical, and the young one is light red

*)Susilo *et al.*, 2020; Al-Afandi *et al.*, 2023; Kepmentan 2024.

- Small (girth = 5-15 cm)
- Medium (girth = 15-25 cm), and
- Large (girth > 15 cm).

Each branch was taken 30 cm as a sample to observe the flower cushio. The parameter was observed involve branching type, branch surface area, flower cushion distance, flower cushion density, number of flower cushions, number of pods per flower cushion, number of pods per tree, and pod characteristics include pod length, pod girth, and pod weight.

RESULT AND DISCUSSION

Performance of Cocoa

The cocoa plant originated by top grafting seedling had a short main stem and relatively low productive branches (Figure 1). This was most advantageous due to facilitating maintenance and harvesting activities (Ainum *et al.*, 2024). Top grafting was known to accelerate early production by reducing the juvenile phase (Daouda *et al.*, 2018; N'zi *et al.*, 2023).

Branching type was determined by the magnitude of the angel of the primary branch or branch that immediately growth from the main stem (Setyawan *et al.*, 2021). The results of observations showed that each clone had a significant difference. Monika 2, Sulawesi 1, and Sulawesi 2 were classified as clones that had a vertical branching architecture type. ICCRI 09, MCC 02, and Monika 1 were classified as clones that had a intermediate branching type with degree of angle range 75-105^{o}. ICCRI 03 had a degree of angle more than 105^{o}, so that it classified as a horizontal branching type (Table 2). Genetics was a major factor that contribute in determining the architecture of cocoa (Cai *et al.*, 2016).

Branching type was predicted to influence the width of the cocoa canopy. The vertical branching type could forms a slimmer canopy

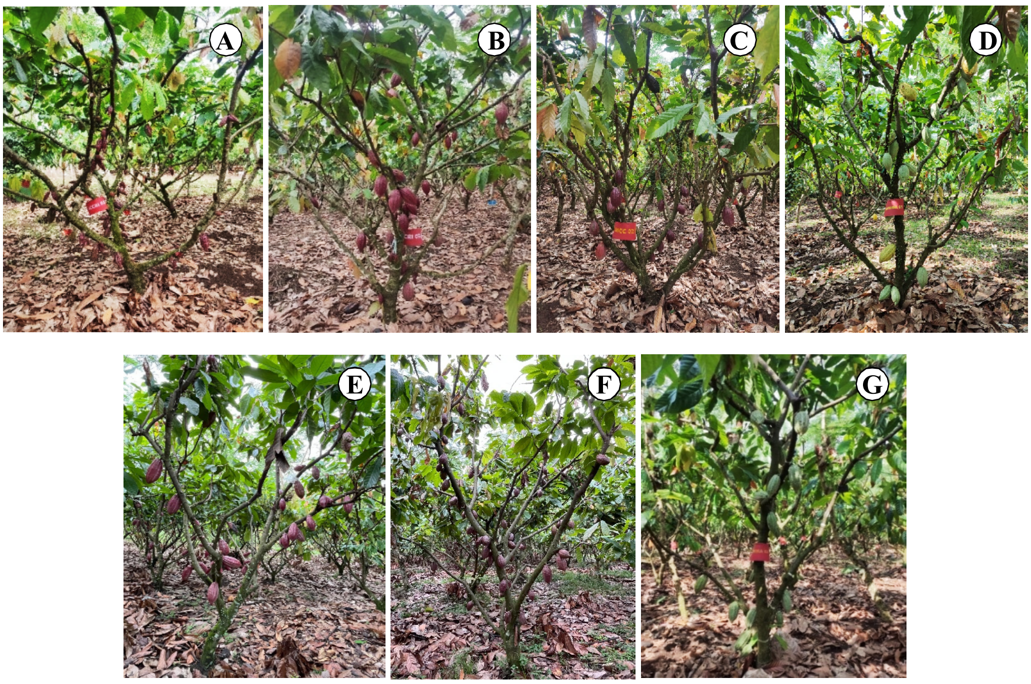

Figure 1. Performance of cocoa clones; A). ICCRI 03, B). ICCRI 09, C). MCC 02, D). Monika 1, E). Monika 2, F). Sulawesi 1, and G). Sulawesi 2

Table 2. Classification of branching type on 7 cocoa clones

Clones	Branch angle (°)	Branching type
ICCRI 03	108.47 a	Horizontal
ICCRI 09	75.25 b	Intermediate
MCC 02	76.43 b	Intermediate
Monika 1	80.63 b	Intermediate
Monika 2	74.00 b	Vertical
Sulawesi 1	57.72 c	Vertical
Sulawesi 2	73.10 bc	Vertical

Note: Number with the same letter within column are not significantly different according to HSD-Tukey test ($p < 0.05$). *)Setyawan *et al.*, 2021.

than the intermediate and horizontal type, so that the space of growth required tends to be smaller and potentially to increase the population per hectare through planting distance arrangements (Setyawan *et al.*, 2021). In addition, cocoa clones with canopy that was not too wide (standard 3 m x 3 m) allows sunlight penetration, thereby creating optimal microclimate conditions for cocoa growth and development (Zakariyya, 2016).

Production Space Capacity

Branches were major component that contributing in determining cocoa production. Branch surface area was an indication potential space production, due to the fact that flowering and fruiting accurs on the entire branches (Swanson *et al.*, 2008; Meneses-Buitrago *et al.*, 2019). It was predicted that an increase in branch widht will result in higher number of flower cushions. The results of observations showed that no significant differences on the seven clones in branch surface area and number of flower cushions.

Flower cushion was a spot on the stem where the flower grows, originally from the site of a leaf stalk (Hancock & Flowler, 1994). As the flowers develop continuously in the same position, it gradually becomes thickened (Wibaux *et al.*, 2025). There were no significant difference in the distance between flower cusions on each clone, with an average distance of 5.6 cm (Table 3). According to Martono (2016), it was known that the distance of flower cushions was around 5 to 10 cm.

The number of flower cushions per tree was no significant difference on each clone. According to the results of observations, its were estimated that there were around 490-635 flower cushions per tree (Table 3). Wibaux *et al.* (2025) reported that cocoa was originated by top grafting has about 490-635 flower cushions per tree. The number of flower cushions is not constant, it can change due to pruning management factors (Uchoi *et al.*, 2018). The flower cushions were scattered across every branch category, with the most scattered on the small branches. It was suspected that the small branches had a greater number compared to the large or medium branches (Table 4).

The flower cushions on the cocoa trunk and branches were arranged in a specific formation. The formations of the flower cushions follow the pattern of the leaves (Figure 2). The pattern of leaves was different on trunk and branches (Hallé *et al.*, 1978). The arrangement of leaves on the trunk forms a spiral pattern with a formula of 3/8, while on the branches the arrangement of leaves forms two rows with a formula of 1/2 (Hall, 1914). In top grafted cocoa, production was focused only on plagiotropic branches, so that the flower cushions were arranged in two rows or *alternate distichous phyllotaxy* (Wibaux *et al.*, 2025).

Table 3. Production space capacity of cocoa clones

Clones	BSA (cm^2)	FCD (cm)	NFC	NPFC	NPT
ICCRI 03	17746.73 a	4.82 a	543.14 a	1.73 a	12.89 a
ICCRI 09	17875.54 a	5.38 a	538.97 a	1.23 b	23.93 a
MCC 02	20135.40 a	5.49 a	635.10 a	1.22 b	21.45 a
Monika 1	18810.41 a	5.33 a	507.45 a	1.34 b	21.35 a
Monika 2	16150.47 a	5.39 a	491.27 a	1.28 b	19.07 a
Sulawesi 1	17411.16 a	5.60 a	504.99 a	1.30 b	22.90 a
Sulawesi 2	19347.06 a	4.74 a	619.68 a	1.76 a	28.68 a
Average	17411.16	5.60	504.99	1.30	21.47

Note: Number with the same letter within column are not significantly different according to HSD-Tukey test (p < 0.05). *)Setyawan *et al.*, 2021. BSA = branch surface area, FCD = flower cushion distance, NFC = number of flower cushion, NPFC = number of pods per flower cushion, NPT = Number of pods per tree.

Table 4. Distribution of flower cushions on each branch category

Clones	Branch category			Total
	Small	Medium	Large	
ICCRI 03	379.13	115.18	48.83	543.14 a
ICCRI 09	407.39	110.46	21.12	538.97 a
MCC 02	489.30	121.36	24.44	635.10 a
Monika 1	368.46	103.48	35.51	507.45 a
Monika 2	331.71	104.73	54.82	491.27 a
Sulawesi 1	362.42	108.29	34.28	504.99 a
Sulawesi 2	436.13	119.15	63.95	619.68 a
Average	396.36 a	111.81 b	40.42 c	595.35

Note: Number with the same letter within column and row are not significantly different according to HSD-Tukey test (p < 0.05). Branch category according to girth: small (5-15 cm), medium (15-25 cm) and large (>25 cm).

Figure 2. Formation of flower cuhions on plagiotropic branches

Flower cushion density was measured by the number of flower cushion per unit area of branch in 100 cm^2. There were significant difference among branches and among clones; however, no significant interaction was observed between branch and clone (Table 5). The average flower cushion density on small, medium, and large branches was 3.68/100 cm^2, 2.32/100 cm^2, and1.53/100 cm^2 respectively. The small branches showed the highest density, presumably due to the shorter distance between rows of flower cushions, which results in a denser appearance.

In general, only 1-2 pods that was produced on flower cushion (Thifany *et al.*, 2020). The results of observations showed there were significant differences between clones in their ability to produce pod per flower cushion. Genetic effects were clearly observed in determining pod number. Sulawesi 2 and ICCRI 03 were known had a potential to produce more pod on flower cushion than ICCRI 09, MCC 02, Monika 1, Monika 2, dan Sulawesi 1 (Table 3). In some cases, Sulawesi 2 and ICCRI 03 can produce more than 2 pods on flower cushion (Figure 3).

Cocoa Pod Performance

The number of pods produced per flower cushion was assumed to influence pod characteristics. The results showed that there were significant differences between clones in the variables of pod length, girth, and weight. The Sulawesi 2 and ICCRI 03, which had the potential to produce more than one pod per flower cushion, had relatively smaller pod dimensions than the other clones (Table 6). This indicates that the more pods produced in a flower cushion, the smaller the size of the pods. Glendinning (1963)

Table 5. Flower cushion density on each branch category

Clones	Branch category (number/100 cm^2)			Avg. of branch
	Small	Medium	Large	
ICCRI 03	3.67	2.51	1.76	2.65 ab
ICCRI 09	4.00	2.49	1.52	2.67 ab
MCC 02	3.77	2.25	1.35	2.46 ab
Monika 1	3.19	2.16	1.48	2.27 b
Monika 2	3.32	2.10	1.63	2.35 ab
Sulawesi 1	3.68	2.27	1.34	2.43 ab
Sulawesi 2	4,11	2.46	1.63	2.73 a
Avg. of clones	3.68 a	2.32 b	1.53 c	(-)

Note: Number with the same letter within column and row are not significantly different according to HSD-Tukey test (p < 0.05). Branch category according to girth: small (5-15 cm), medium (15-25 cm) and large (>25 cm).

Figure 2. Number of pods per flower cushion: one pod on MCC 02 (A) and Monika 1 (B) and multiple pods on Sulawesi 2 (C) and ICCRI 03 (D).

found that pod size tends to be negatively correlated with the number of pods. In other words, cocoa with smaller pods will produce more pods to maximize production capacity.

The development of cocoa pods from tiny pod to ripe pod usually takes 5-6 months. Pod development happens slowly during the early 40 days, then very rapidly until day 75, then it slows down again, followed by embryo development and fat accumulation in the beans (Yusianto & Firmanto, 2015). There were variations in the shape, surface texture, and color of pods depending on the type of clone. They were usually oval and elongated. When cocoa ripens, most pods change color on the skin (Biehl *et al.*, 1989). Generally, cocoa with green pods will turn yellow when ripe, while cocoa with red pods will turn orange when ripe (Hancock & Flowler, 1994). The color of the cocoa pod skin is influenced by pigment content such as anthocyanins, flavonols, and chlorophyll (Tee *et al.*, 2021)

The results of observations showed that the ICCRI 09, Sulawesi 1, Sulawesi 2, and MCC 02 had red young pod skins that turned orange or yellowish red when ripe, while the Monika 1 and Monika 2 had green young pod skins that turned yellow when ripe. ICCRI 03 has mottled green and red pods, which turn yellow or yellow-orange when ripe (Figure 4).

Relationship Between Variables

The results of the correlation analysis showed that there was a strong and significant relationship between branch surface area and the number of flower cushions (r = 0.740**). This indicates that an increase in branch surface area tends to be followed by an increase in the number of flower cushions. A greater number of flower cushions was predicted to increase production capacity.

The branch surface area and the number of flower cushions on each clone had no

Table 6. Pod performance on cocoa clones

Clones	Pod length (cm)	Pod girth (cm)	Pod weight (g)
ICCRI 03	18.33 ef	24.91 b	432.39 c
ICCRI 09	21.57 bc	30.77 a	742.03 ab
MCC 02	19.89 de	29.84 a	681.15 ab
Monika 1	22.53 ab	31.14 a	791.50 a
Monika 2	23.22 a	29.58 a	732.62 ab
Sulawesi 1	20.80 cd	26.94 b	624.46 b
Sulawesi 2	18.03 f	25.28 b	435.11 c
Average	20.62	28.35	634.18

Note: Number with the same letter within column are not significantly different according to HSD-Tukey test ($p < 0.05$).

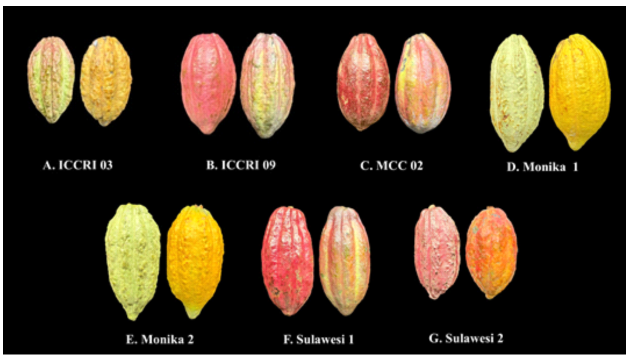

Figure 4. Performance of young and ripe pods on 7 clones

significant relationship with the number of pods produced (Table 7). It was suspected that not all flower cushions were actively producing. Previous studies have reported that only about 34-45% of flower suchions actively produced flowers and less than 10% of flower cushions were able to produce pods (Thifany *et al.*, 2020; Wibaux *et al.*, 2025).

The flowering of cocoa was influenced by various factors such as nutrition, hormones, shade, and microclimate conditions, especially rainfall, temperature, and sunlight intensity (Chailakhyan & Krikorian, 1975; Wibaux *et al.*, 2025). However, only some of the flowers were able to develop. It was found that less than 5% of the flowers were successfully fertilized and only 10% of the buds have the potential to develop into cocoa pods (Falque *et al.*, 1995).

Pod weight a significant positive correlation with flower cushion distance (r = 0.450*), pod length (r = 0.910**), and pod girth (r = 0.953**), as well as had a negative correlation with the number of pods per cushion (r = -0.744**). These results indicate that an increase in pod weight tends to be followed by an increase in flower cushion distance, pod length, and pod girth. Flower cushion distance that is not too close together provides optimal space for cocoa pod development. The number of pods per cushion had the potential to reduce pod weight, which is suspected to be related to assimilation competition bertween pods within a single cushion.

The stepwise regression analysis was used to determine the variables that had a significant direct effect on the result (Nasri *et al.*, 2014).). In this case, pod weight was the main component of cocoa yield. There were two variables that had a direct effect on pod weight, namely pod length and pod girth. The regression equation obtained was Y = -1004.746** + 35.597 LP** + 30.534 PI** (R^2 = 0.970**). The value of R^2 = 0.970 indicates that these two variales were able to influence production by 97%. According to the regression equation results, it was found that pod weight increased when pod length and pod girth increased. All these results can be used as a basis for increasing production through cultivation management and cocoa development activities in the future.

CONCLUSION

Cocoa had a production capacity with an average of 490-635 flower cushions spread across the entire surface of the branch. The increase of pod weight was significantly influenced by the pod length, pod girth, number of pods per flower cushion, and flower cushion distance.

Table 7. Correlation between branch surface area, flower cushion, and pod

	BSA	FCD	NFC	NPFC	NTP	PL	PG	PW
BSA	1							
FCD	-0.280 ns	1						
NFC	0.740 **	-0.443 *	1					
NPFC	0.004 ns	-0.678 **	-0.030 ns	1				
NPT	0.017 ns	0.073 ns	0.066 ns	-0,134 ns	1			
PL	-0.037 ns	0.449 *	-0.255 ns	-0,635 **	-0.119 ns	1		
PG	0.185 ns	0.413 ns	0.083 ns	-0.725 **	0.074 ns	0.798 **	1	
PW	0.148 ns	0.450 *	-0.014 ns	-0.744 **	-0.023 ns	0.910 **	0.953 **	1

Notes: ns = non-significant, * = significant at P < 0.05, ** = significant at P <0.01; BSA = branch surface area, FCD = flower cushion distance, NFC = number of flower cushion, NPFC = number of pods per flower cushion, NPT = number of pods per tree, PL = pod length, PG = pod girth, and PW = pod weight.

Table 8. Stepwise regression analysis

Model	Regression coefficients	t_{values}	Sig.
Intercept	-1004.746	-14.837 **	0.000
PG	35.597	9.300 **	0.000
PL	30.534	6.104 **	0.000

a. Dependent Variable: pod weight (PW)
b. Predictors: (Constant), pod girth (PG), pod length (PL)

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REFERENCES

Ainum, N.; A. Laapo and C. Christoporus (2024). Respon petani terhadap teknik sambung pucuk kakao (Studi kasus di Kecamatan Lore Utara Kabupaten Poso) Sulawesi Tengah. *Agroland: Jurnal Ilmu-ilmu Pertanian*, 31(3), 281-291. https://jurnal.faperta.untad.ac.id/index.php/agrolandnasional/article/view/2225.

Alverson, W.S.; B.A. Whitlock; R. Nyfeller; C. Bayer & D.A. Baum (1999). Phylogeny of the core Malvales: Evidence from ndhF sequence data. *American Journal of Botany*, 86, 1474–1486. https://doi.org/10.2307/2656928.

Biehl, B.; B. Meyer; G. Crone & L. Pollmann (1989). Chemical and physical changes in the pulp during ripening & post harvest storage of cocoa pods. *Journal of the Science of Food & Agriculture*, 48(2), 189-208. https://doi.org/10.1002/jsfa.2740480207Digital Object Identifier (DOI).

BPS (2023). Statistik Kakao Indonesia: Volume 8, 2024. BPS-Statistik Indonesia, Jakarta. https://www.bps.go.id/id/publication/2024/11/29/ed255af0c9059f288fb7e1de/statistik-kakao-indonesia-2023.html.

Cai, G.; Q. Yang; H. Chen; Q. Yang; C. Zhang; C. Fan & Y. Zhou (2016). Genetic dissection of plant architecture and yield–related traits in *Brassica napus*. *Scientific Reports,* 6, 1–16. https://www. nature.com/articles/srep21625.

Chailakhyan, M.K. & A.D. Krikorian (1975). Forty years of research on the hormonal basis of plant development—some personal reflections. *The Botanical Review,* 41(1), 1-29. https://link. springer.com/article/10.1007/BF02860835.

Daouda, K.K.; J.C. N'zi; J. Kahia; L. Diby; J.L. Kouassi; K. Bene & C. Kouame (2018). Comparison of grafting techniques & their effects on some growth parameters of ten elite cocoa clones (*Theobroma cacao* L.). *Africa Journal of Agricultural Researce*, 13(41), 2249-2255. https://doi.org/10.5897/AJAR 2015.9847.

Doare F.; F. Ribeyre & C. Cilas (2020). Genetic and environmental links between traits of cocoa beans and pods clarify the phenotyping processes to be implemented. *Scientific Reports*, 10(1), 1-6. https://www.nature.com/articles/s41598-020-66969-9.

Erwiyono, R. (2005). Soil moisture and turgidity of selected Robusta coffee clones on alluvial plain with seasonal rainfall pattern. *Pelita Perkebunan*, 21, 113—130. https://doi.org/10.22302/iccri.jur.pelitaperkebunan.v21i2.19.

Falque, M.; A. Vincent; B.E. Vaissiere & A.B. Eskes (1995). Effect of pollination intensity on fruit and seed set in cacao

(*Theobroma cacao* L.). Sex. *Plant Reprod*, 8, 354–360. https://link. springer.com/article/10.1007/BF00243203.

Glendinning, D.R. (1963). The inheritance of bean size, pod size and number of beans per pod in cocoa with a note on bean shape. *Euphytica*, 12, 311-322. https://link.springer.com/article/10.1007/BF00027467.

Hall, C.J.J.V. (1914). Cocoa. Macmillan & Co. ST. Martin Streets, London.

Hallé, F.; R.A. Oldeman & P.B. Tomlinson (1978). Tropical trees and forests: An anrchitectural analysis. Springer-Verlag, Berlin Heidelberg, New York. https://oook.info/Plantae/Halle.pdf .

Hancock, B.L. & M.S. Fowler (1994). Cocoa bean production and transport. *Industrial chocolate manufacture and use*, pp. 8-24. Boston, MA: Springer US. https://link.springer.com/chapter/10.1007/978-1-4615-2111-2_2.

Kepmentan (2024). Keputusan Menteri Pertanian Republik Indonesia Nomor: 88/Kpts/KB.010/12/2024 Tentang Pelepasan Klon Unggul Monika 01 Sebagai Varietas Unggul Kakao (pp. 1-4).

Martono, B. (2016). Karakteristik morfologi dan kegiatan plasma nutfah. *Bunga Rampai: Inovasi Teknologi Bioindustri Kakao*, 1(1), 15-28. https://repository.pertanian.go.id/server/api/core/bitstreams/d57ca1ec-4186-4741-9007-659b4ca5fa07/content.

Martý´nez, I.B.; M.V.d.l. Cruz; M.R. Nelson & P. Bertin (2017). Morphological characterization of traditional cacao (*Theobroma cacao* L.) plants in Cuba. *Genet Resour Crop Evol*, 64, 73–99. https://link.springer.com/article/10.1007/s10722-015-0333-4.

Meneses-Buitrago, D.H.; M.M.B. Benavides; L.F.G. Gil & H.S.R. Zambrano (2019). Evaluation of irrigation and pruning on the phenology & yield of *Theobroma cacao* L. *Agronomía Mesoamericana,* 30(3), 681–693. http://dx.doi.org/10.15517/am.v30i3.36307.

Nasri, R.; A. Kashani; F. Paknejad; S. Vazan & M. Barary (2014). Correlation, path analysis and stepwise regression in yield and yield component in wheat (*Triticum aestivum* L.) under the temperate climate of Ilam province, Iran. *Indian Journal of Fundamental & Applied Life Science*s, 4(4), 188-189. https://www.cabidigitallibrary.org/doi/full/10.5555/20153026531.

N'zi, J.C.; K. Issouf; A.A.M. Kacou; K. Siaka; & K. Christophe (2023). Successful grafting elite cocoa clones (*Theobroma cacao* L.) as a function of the age of rootstock. *Heliyon*, 9(8), e18732. https://pmc.ncbi.nlm.nih.gov/articles/PMC10407737/.

Setyawan, B.; I.A. Sari; F. Ihsan; H. Panua & A.W. Susilo (2021). Branching angles of several cocoa genotypes and their effect on determining optimum plant spacing. *Pelita Perkebunan,* 37(3), 177–183. https://ccrjournal.com/index.php/ccrj/article/view/473.

Smith, N.J.H. (1992). Tropical forests and their crops. Comstock, Ithaca, NY. 568 pp.

Susilo, A.W. (2015). Botani, Keragaman Genetik dan Pengolahan Plasma Nutfah. Dalam Kakao: Sejarah, Boatani, Proses Produksi, Pengolahan, dan Perdagangan. UGM Press, Yogyakarta, hal: 19–35.

Susilo, A.W.; I.A. Sari & B. Setyawan (2020). Yield performance of promosing cocoa clones (*Theobroma cacao* L.) in dry climate conditions. *Pelita Perkebunan,* 31(1), 20-31. https://doi.org/10.22302/iccri.jur.pelitaperkebunan.v36i1.372.

Swanson, J.D.; J.E. Carlson & M.J. Guiltinan (2008). Comparative flower development in *Theobroma cacao* based on temporal morphological indicators. *International Journal of Plant Sciences,* 169(9), 1187-1199. https://www.journals.uchicago.edu/doi/abs/10.1086/591986.

Tan, G.Y. (1990). Combining ability analysis of yield & its component in cocoa. *J. Amer. Soc. Hort. Sci.,* 115(3), 509-512. https:/

/journals.ashs.org/view/journals/jashs/115/3/article-p509.xml.

Tee, Y.K.; K. Bariah; B.H. Zainudin; K.C.S. Yap; & N.G. Ong (2021). Impacts of cocoa pod maturity at harvest and bean fermentation period on the production of chocolate with potential health benefits. *Journal of the Science of Food and Agriculture*, 102(4), 1576-1585. https://doi.org/10.1002/jsfa.11494.

Thifany, A.J.; E. Santoso & N. Khumaida (2020). Faktor-faktor yang memengaruhi produksi dan efektivitas panen pada kakao mulia. *J. Agron,* 48(2), 187-195. https://dx.doi.org/10.24831/jai.v48i2.30565.

Uchoi, A.; N. Shoba; S. Balakrishnan; N.O. Gopal & D. Uma (2018). Impact of canopy management on flowering and yield attributes of cocoa (*Theobroma cacao* L.) under tropical condition of Tamil Nadu. *International Journal of Chemical Studies*, 6(5), 629-633. https://www.researchgate.net/profile/Anok-Uchoi/publication/397785478.

Vasquez-García, J.; J.C. Santos-Pelaez; R. Malqui-Ramos; C.N. Vigo; W.C. Alvarado & L.G. Bobadilla (2022). Agromorphological characterization of cacao (*Theobroma cacao* L.) accessions from the germplasm bank of the National Institute of Agrarian Innovation, Peru. *Heliyon,* 8(10), e10888. https://doi.org/10.1016/j.heliyon.2022.e10888.

Wibaux, T.; F. Normand; R. Vezy; J.B. Durand & P.E. Lauri (2024). Does seasonal flowering and fruiting patterns of cacao only depend on climati factors? The case study of mixed genotype populations in Coteˆd'Ivoire. *Scientia Horticulturae*, 337(113529), 1-15. https://doi.org/10.1016/j.scienta. 2024.113529.

Wibaux, T.; P.É. Lauri; A.A. M'Bo Kacou; O. Pondo Kouakou & R. Vezy (2025). A spatial perspective on flowering in cauliflorous cacao: Architecture defines flower cushion location, not its early activity. *Annals of Botany*, 136(2), 309-323. https://doi.org/10.1093/aob/mcaf107.

Young, A.M. (1994). The Chocolate Tree: A Natural History of Cacao. Smithsonian Institution Press, Washington & London.

Yusianto & H. Firmanto (2015). Panen dan Pascapanen. *Dalam* Kakao: Sejarah, Boatani, Proses Produksi, Pengolahan, dan Perdagangan. UGM Press, Yogyakarta, hal. 502-546.

Zakariyya, F. (2016). Menimbang indeks luas daun sebagai variabel penting pertumbuhan kakao. *Warta Pusat Penelitian Kopi dan Kakao Indonesia,* 28(3), 8-12. https://warta.iccri.net/wp-content/uploads/2023/06/2.

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