Research Article

Morphological Characterization of Cacao Plants (*Theobroma cacao* L.) from Dharmasraya Regency of West Sumatra

Karakterisasi Morfologi Tanaman Kakao (Theobroma cacao L.) asal Kabupaten Dharmasraya Sumatera Barat

Ria Fitri Utama[1]*, Gustian[2], Siska Efendi[3]*

[1] Department of Agroecotechnology, Agriculture Faculty, Andalas University, Padang, Indonesia

[2] Department of Agrotechnology, Agriculture Faculty, Andalas University, Padang, Indonesia

[3] Department of Estate Crops Cultivation, Agriculture Faculty, Andalas University, Padang

*email: siskaefendi@agr.unand

Recived: September 2023
Accepted: December 2023
Published : December 2023

p-ISSN: 2723-7974
e-ISSN: 2723-7966
doi: 10.52045/jca.v4i1.562

Website: https://ojs.untika.ac.id/index.php/faperta

Abstract: Dharmasraya, a regency in West Sumatra Province, has traditionally focused on cultivating oil palm and rubber. However, due to a decline in prices for these commodities, there has been a shift towards cultivating cacao plants. Despite several years of cultivation, cacao production in Dharmasraya Regency remains low. This is attributed to unsuitable land and weather conditions, as well as the use of inferior plant material and uncertain origins of the cacao clone. To address these issues, a research study was conducted to assess the diversity and similarity of cacao plants in Dharmasraya Regency. The study focused on four locations within Sitiung Subdistrict: Siguntur, Sitiung, Gunung Medan, and Sungai Duo. A purposive sampling method was used to select the sample plants. The data was analyzed descriptively, and similarity analysis was performed using the NTSYS 2.02 software. The study identified seven different clones of cacao plants, each with distinct morphological characteristics in terms of leaves, flowers, fruits, and seeds. The phenotypic similarity analysis revealed a coefficient value ranging from 23% to 47%, indicating a moderate level of similarity, and a variability value ranging from 53% to 77%. It was found that qualitative traits exhibited a narrow range of variability, while quantitative traits displayed a broader range of phenotypic variability.

Keywords: Breeding, Clone, Exploration, Production, Varieties

Abstrak: Dharmasraya merupakan sebuah kabupaten di Provinsi Sumatera Barat, secara tradisional berfokus pada budidaya kelapa sawit dan karet. Namun, karena penurunan harga untuk komoditas ini, telah terjadi pergeseran ke arah budidaya tanaman kakao. Meskipun telah dibudidayakan selama beberapa tahun, produksi kakao di Kabupaten Dharmasraya masih rendah. Hal ini disebabkan oleh kondisi lahan dan cuaca yang tidak sesuai, serta penggunaan bahan tanaman yang kurang baik dan asal-usul klon kakao yang tidak jelas. Untuk mengatasi masalah ini, sebuah studi penelitian dilakukan untuk menilai keragaman dan kesamaan tanaman kakao di Kabupaten Dharmasraya. Penelitian ini difokuskan pada empat lokasi di Kecamatan Sitiung: Siguntur, Sitiung, Gunung Medan, dan Sungai Duo. Metode purposive sampling dilakukan untuk memilih tanaman sampel. Data dianalisis secara deskriptif, dan analisis kemiripan dilakukan dengan menggunakan perangkat lunak NTSYS 2.02. Penelitian ini mengidentifikasi tujuh klon tanaman kakao yang berbeda, masing-masing dengan karakteristik morfologi yang berbeda yakni daun, bunga, buah, dan biji. Analisis kemiripan fenotipik menunjukkan nilai koefisien yang berkisar antara 23% hingga 47%, yang mengindikasikan tingkat kemiripan yang moderat, dan nilai variabilitas berkisar antara 53% hingga 77%. Ditemukan bahwa sifat-sifat kualitatif menunjukkan kisaran variabilitas yang sempit, sedangkan sifat-sifat kuantitatif menunjukkan kisaran variabilitas fenotipik yang lebih luas.

Kata kunci: Eksplorasi, Klon, Pemuliaan, Produksi, Varietas

Citation:
Utama RF, Gustian, Efendi S. 2023. Morphological characterization of cacao plants (*Theobroma cacao* L.) from Dharmasraya Regency of West Sumatra. *Celebes Agricultural*. 4(1): 30-45. doi: 10.52045/jca.v4i1.562

INTRODUCTION

Cacao cultivation in community plantations faces various obstacles that lead to low production. Farmers face complex challenges encompassing social, economic, ecological, and technical aspects (Diana et al. 2020). Farmers face these challenges from the nursery, vegetative, and generative phases up to harvesting and post-harvest stages (Budiastuti et al. 2016). In the nursery phase, the challenge still encountered up to this point is the limited access to obtaining superior planting materials (Aryandi et al. 2021). This condition results in cacao being cultivated using planting materials from unclear sources. Most of these planting materials have the potential for low production. This condition often occurs in newly developing cacao cultivation areas, such as Dharmasraya Regency in West Sumatra Province (Rezki et al. 2022).

The success of cacao cultivation requires the availability of superior cacao seeds and seedlings; thus, developing superior cacao cultivars or clones is essential to be carried out promptly (Prawoto et al. 2013). Until now, the cacao planting materials used have been F1 hybrid seeds, utilizing parents known for their potential yield and advantages in other characteristics, such as resistance to pests and diseases. Indonesian Center for Estate Crops Research and Development (ICECRD) reported that 23 superior cacao clones can be utilized for cacao development in Indonesia. Each clone has a production potential of 1-2.7 tons per hectare (Junaedi et al. 2016).

The goal of the cacao breeding program is to obtain superior planting materials that have high production and quality yields, as well as resistance to pests and diseases (Rubiyo 2013). Plant breeders need to have a collection of genetic resources (germplasm) to support breeding activities. Germplasm is the substance found within a group of living organisms and serves as a source of hereditary traits that can be utilized to develop superior cultivars. These collection materials are obtained from natural populations, wild species, and community plantations, as well as from the selection of several parents.

One of the prominent regions for cocoa production in Dharmasraya Regency is Sitiung, as indicated by research conducted by Putri et al. (2022). Furthermore, a study conducted by Rusmiati (2019) identified the presence of seven cocoa clones that originated from Dharmasraya. The success of a breeding program is greatly determined by the extent of genetic diversity present in the genetic sources being used. The higher the genetic diversity, the better the opportunity to obtain genetic sources for the traits that need improvement. Exploration and characterization are helpful as the materials to be used as parents for developing superior cacao plant varieties. Characterization involves identifying important economically valuable traits or characteristics that distinguish a specific genotype. Understanding the morphology of cacao plants is essential to cacao cultivation efforts. Understanding plant morphology is highly beneficial for the upcoming cultivation activities. Cultivation techniques can be adjusted to the plant's requirements by being familiar with plant morphology.

MATERIALS AND METHODS

The surveys was conducted at every cacao farm in 'Nagari' (the traditional administrative division) in Sitiung Subdistrict. The sampling criteria are plants that have entered the generative phase and have generated flowers and fruit (priority is given to sample plants over three years old). Data observation was carried out in qualitative and quantitative methods by observing the morphological characteristics of cacao plants. Observation of morphological traits was based on the Cacao Plant Characterization Guidebook (Zasari & Sitorus 2022) consists of the following:

1) Leaf morphology: leaf shape, leaf length (cm), leaf width (cm), leaf color, leaf tip, leaf surface, and leaf margin.
2) Flower morphology.
3) Fruit morphology: fruit shape, fruit length (cm), fruit width (cm), fruit color, fruit surface and fruit tip.
4) Seed morphology: seeds color and seeds weight (grams).

The observed leaves were located on the first branch, specifically the seventh leaf from the top. The leaf characteristics that are observed include:

1. Leaf shape was observed directly in the field. Leaf shape observation is conducted by visually assessing the shape of the leaves on the sample plant.
2. Leaf length was measured directly from the tip to the base of the leaf blade using a ruler.
3. Leaf width was measured from the most comprehensive edge of the leaf blade to the opposite side.
4. Leaf color was observed directly in the field.
5. The leaf surface was observed directly by touching the leaf surface.
6. Observing leaf tips directly on the sample leaves.
7. Leaf margins are observed directly by touching the leaf edges

Morphological flower characteristics

1. The color of cacao flowers can be observed directly.
2. The position of flowers was determined by visually observing the location of cacao flower growth.

Morphological fruit characteristics

1. The basal constriction of the fruit was observed by directly examining the obtained samples.
2. Fruit shape was observed directly on the obtained samples.
3. Fruit length was measured directly from the tip of the fruit to the base of the fruit stalk using a ruler.
4. Fruit diameter was determined by using a caliper.
5. Fruit skin color was determined by directly observing the skin of fully ripe physiological mature fruit.
6. Fruit weight was determined by weighing one fruit from the largest bunch. The selected fruit was chosen randomly. The weighed fruit is a ripe one and is measured using an analytical balance.
7. The fruit surface was determined by touching the entire surface of the fruit.
8. The shape of the fruit tip is obtained by observing the end part of the cacao fruit directly.

Morphological seed characteristics

1. The color of cacao beans is observed directly by opening the fruit skin to reveal the color of the cacao beans.
2. The weight of the beans is obtained by weighing the beans using an analytical balance. The beans selected for weighing are chosen randomly. Five beans are weighed from a single cacao pod, and then the average is calculated.

Morphology data were analyzed for phenotypic variability, similarity, and clustering. Phenotypic variability were analyzed using the following formula to assess the level of cacao diversity.

$$S^2 = \frac{\sum(Xi - \overline{X})^2}{\mathrm{n} - 1}$$

Notes:

S^2 : Diversity
X_i : Value of i-th observation
$\overline{X}$: Average value of observation
N : Number of observations

$$\mathrm{SD} = \sqrt{S^2}$$

Notes:

S^2 : Diversity
SD: Standard deviation

The criteria for examining the board and narrow phenotypic variability refer to Raden et al. (2017). Phenotypic variability is board if S2 ≥ 2 SD and narrow if S2 < 2 SD. Similarity and clustering were analyzed using the statistical program NTSYS 2.02. The resulting clustering is then interpreted to observe the level of diversity and the relationship between variants by examining the position of each variant using the UPGMA method.

RESULTS AND DISCUSSION

Subdistrict Sitiung is located at coordinates 101°31'59" - 101°43'30" E and 0°55'01" - 1°05'43" S. It lies at an elevation of 105 to 125 meters above sea level, covering an area of 1245.7 hectares. The subdistrict is comprised of four 'Nagari' (administrative divisions): Siguntur, Sitiung, Gunung Medan, and Sungai Duo, with respective areas of 503.2 ha, 322.7 ha, 306.5 ha, and 113.3 ha. Based on interviews with cacao plantation owners in Subdistrict Sitiung, it is known that cacao cultivation has been carried out for decades. The cacao trees are of ages 5, 10, and 15 years. The size of the plantations is approximately 40 Ч 20 square meters, with an average of around 30–50 trees. The plant spacing varies around 1 Ч 2 meters. Most of the cacao is grown in backyard plots and land behind houses. Cacao cultivation is conducted on a small scale.

Typically, farmers cultivate cacao from both seedlings and seeds. The sources of seedlings and seeds for cacao plants usually come from neighbors or nearby cacao plantation owners within the same 'Nagari.' Farmers harvest cacao when the pods are fully ripe, characterized by their yellow color. Cacao trees ready for harvest generally have an age of over three years. Commonly used fertilizers by farmers include Urea, KCl, and organic materials like cow and chicken manure. However, some smallholder cacao farmers do not apply fertilizers or adequately care for their plants. This lack of proper care results in suboptimal cacao production and declining yields.

Based on the observations conducted in Subdistrict Sitiung, only three out of the four 'nagari' were sampled, which are Nagari Siguntur, Sitiung, and Sungai Duo. In these three 'nagari', seven cacao plant variants were found. In Nagari Siguntur and Sungai Duo, three variants were identified, while Nagari Sitiung had one variant (Table 1).

Table 1. Sources of cacao varieties used in the studies

No	Sources	Clones
1	Siguntur	SG1 SG2 SG3
2	Sitiung	ST
3	Sungai Duo	SD1 SD2 SD3

Leaf Morphology

Leaf length and width

The longest leaf is found in variant SD1, measuring 42 cm, while the shortest is in variant ST1, measuring 17 cm. The widest leaf is in variant SD2, measuring 15 cm, and the narrowest is in variant ST1, measuring 8 cm (Table 2). The length and width of cacao leaves are generally around 30 cm and 10 cm, respectively (ICCRI 2004). This data implies that the length of the leaf in variant SD1 is longer than the regular leaf. On the other hand, the width of leaves found in all seven variants, ranging from 8-15 cm, is consistent with the standard leaf size.

Table 2. Variation in leaf morphology among seven cacao varieties

Varieties	Leaf shape	Leaf length	Leaf width	Leaf color	Leaf surface	Leaf tip	Leaf margin
SG1	elongated	30 cm	10 cm	dark green	smooth	pointed	slightly serrated

Varieties	Leaf shape	Leaf length	Leaf width	Leaf color	Leaf surface	Leaf tip	Leaf margin
							
SG2	elongated	32.5 cm	12 cm	dark green	rough	sharp	slightly serrated
							
SG3	elongated	24 cm	10,5 cm	dark green	rough	pointed	slightly serrated
							
ST1	elongated	17 cm	8 cm	dark green	rough	pointed	margined
							
SD1	elongated	42 cm	14,5 cm	dark green	rough	pointed	slightly serrated

Varieties	Leaf shape	Leaf length	Leaf width	Leaf color	Leaf surface	Leaf tip	Leaf margin
							
SD2 	elongated	37 cm	15 cm	dark green	rough	pointed	slightly serrated
SD3 	elongated	39 cm	11 cm	dark green	smooth	pointed	slightly serrated

One of the characteristics of cacao leaves is the presence of two articulations located at the base and the tip of the leaf stalk. These articulations allow the leaf to adjust to the direction of sunlight. The shape of the leaf blade is elongated with a pointed leaf tip and base. The arrangement of leaf veins is reticulate, and the veins are prominent on the lower surface of the leaf blade. The leaf margin is smooth, and the leaf tissue is thin yet durable, resembling parchment. The color of mature leaves is dark green and varies depending on the cultivar.

Leaf shape and tip

The leaf shape observation results indicate that the leaf shape is elongated. The leaf tip shape among the seven identified variants is pointed and sharp. Pointed leaf tip shape is found in variants SG1, SG3, ST1, SD1, SD2, and SD3, while sharp leaf tip shape is observed in variant SG2 (Table 2).

Leaf surface, leaf margin, and leaf color

The observed leaf surface shapes are smooth and rough. A smooth leaf surface is found in variants SG1 and SD3, while a rough leaf surface is observed in variants SG2, SG3, ST1, SD1, and SD2. The seven identified variants' leaf margins and color are slightly serrated and dark green, respectively (Table 2).

Flower Morphology

The flower color of cacao observed in the field includes egg yolk yellow, pink, and white (Figure 1). Cacao flowers with yellow egg yolk are found in variants SG1, SG2, and SD2, while pink cacao flowers are observed in variants SG3, ST1, and SD3. Additionally, white cacao flowers are present in variant SD1. The positioning of cacao flowers is consistent across the seven variants located at the branch junction. Cacao plants are cauliflorous, meaning the flowers grow and develop from the leaf axils on the stems and branches. The location where these flowers grow gradually enlarges and thickens over time, forming what is commonly known as the flower cushion (Lukito, 2010).

Fruit Morphology

Fruit shape and color

The observed cacao fruit shapes in the field include oblong, round, and elongated round. The oblong fruit shape is found in variants SG2, SG3, SD1, SD2, and SD3, while the round shape is observed in variant SG1 (Table 3). The elongated round shape is present in variant ST1. The ripe cacao fruit colors are yellow, orange, and reddish yellow. Yellow fruit color is found in variants SG1, SG2, SD1, and SD2, orange in variant ST1, and reddish yellow in variants SG3 and SD3.

Figure 1. Cacao plant flower colors: a) egg yolk yellow, b) pink, c) white

Fruit tip shape and basal constriction

The observed cacao fruit tip shapes include twisted, pointed, and blunt. The twisted tip shape is found in variants SG2 and SD2, pointed tip shape is in variant SG3. Blunt tip shapes are observed in variants SG1, ST1, SD1, and SD3. Basal constriction in the fruit is categorized as strong, moderate, and weak. Strong basal constriction is present in variants SG3 and SD2, moderate constriction in variants SG1, ST1, SD1, and SD3, and weak constriction in variant SG2 (Table 3).

The color of cacao fruit is highly diverse, but only two colors exist. When young, the fruit is green or slightly whitish-green; when ripe, it turns yellow. Some fruits were red when young and turned orange when ripe. The fruit ripens after six months. At that time, its size varies from 10 to 30 cm in length, depending on the cultivar and environmental factors during fruit development (Lukito 2010).

Fruit surface

Three cacao fruit surfaces are rough, rough with serrations, and smooth. The rough surface is found in variants SG1, SG2, SG3, ST1, and SD1. The rough surface with serrations is found in variant SD2, while the smooth surface is found in variant SD3. The cacao fruit tip shapes in the field include twisted, pointed, and blunt. The twisted tip shape is found in variants SG2 and SD2, the pointed tip shape in variant SG3, and the blunt tip shape in variants SG1, ST1, SD1, and SD3.

The length, diameter, and weight of the fruit

The longest fruits are found in variants SG1 and SG3, measuring 19 cm, while the shortest are in variant ST1, measuring 11 cm. The largest fruit diameter is in variant SG1, measuring 10.5 cm, while the smallest is in variant ST1, measuring 7 cm. The highest fruit weight recorded is 850 grams, found in variant SG1.

Table 3. Variation in fruit morphology among seven cacao varieties

Varieties	Fruit shape	Fruit length	Fruit width	Fruit weighs	Fruit color	Fruit surface	Fruit tip
		----- cm -----		--- g ---			
SG1 	round	19	10.5	850	yellow	rough	blunt
SG2 	round	17	9.5	750	yellow	rough	twists
SG3 	elongated	19	8.9	700	reddish-yellow	rough	pointed

Varieties	Fruit shape	Fruit length	Fruit width	Fruit weighs	Fruit color	Fruit surface	Fruit tip
		----- cm	-----	--- g ---			
ST1 	elongated	11	7 cm	200	orange	rough	blunt
SD1 	elongated	16	9.8	600	yellow	rough	blunt
SD2 	elongated	16	9.8	500	yellow	serrated	twisted
SD3 	oblong	12	8.3	400	reddish-yellow	smooth	blunt

Seeds Morphology

Seed color and weight

The cacao seeds in the seven variants exhibit dark red and dark purple colors. The heaviest cacao seeds are found in the SD1 variant, weighing 3.37 grams (Table 4). Cacao seeds are arranged in five rows encircling the fruit axis. Their quantity varies, ranging from 20 to 50 seeds per fruit. When cut transversely, it can be observed that the seeds are composed of two cotyledons that fold against each other, with their base attached to the embryo axis. The cotyledon color is white for the Criollo type and purple for the Forastero type. Cacao seeds are enveloped by the fruit's flesh (pulp), which is white with a sweet and sour taste, and is suspected to contain substances that inhibit germination. Inside the fruit's flesh is a seed coat (testa) that encloses two cotyledons and the embryonic process. Cacao seeds do not have dormancy. Despite the fruit's flesh containing germination-inhibiting substances, sometimes seeds germinate within fruits that were harvested late due to the flesh having dried up (ICCRI 2004).

Table 4. Variation in seeds morphology among seven cacao varieties

Varieties	Seeds Color	Seeds Weight
		---- g ----
SG1 	dark red	2,06
SG2 	dark red	1,95
SG3 	dark purple	2,14
ST1 	dark purple	1,14

Varieties	Seeds Color	Seeds Weight
		---- g ----
SD1 	dark red	3,37
SD2 	dark red	1,90
SD3 	dark purple	2,25

Phenotypic Variability

The phenotypic variability of cacao plants in the Sitiung District shows broad and narrow phenotypic variability. Traits with broad variability include flower color, fruit shape, fruit skin color, fruit surface, basal constriction, fruit tip shape, leaf length, leaf width, fruit length, fruit diameter, fruit weight, and seed color (Table 5). Broad phenotypic variability values imply that the appearance of these phenotypic traits is largely influenced by environmental factors (plant height and yield components). A comprehensive genetic variability value will also result in broad phenotypic variability if the interaction with the environment is sufficiently high. Genetic variability occurs due to the influence of genes and different interactions within a population and its environment.

Narrow phenotypic variability includes leaf shape, color, surface, tip, margin, flower position, and seed weight. Narrow phenotypic variability in observed morphological traits cannot serve as a basis for selection in plant breeding activities, as selection is successful or effective when the plant population to be selected from has wide variability. Narrow phenotypic variability can be expanded through hybridization, introduction of new germplasm, and mutation (Tedianto 2012).

Swasti (2007) stated that variability among plant traits can be classified into qualitative character variability, which refers to traits easily distinguishable into specific categories (color, shape, texture). Qualitative traits are influenced by genetics, making their qualitative attributes helpful in distinguishing between cultivars. Quantitative character variability pertains to traits that gradually vary from one extreme to another and are not easily classifiable into distinct categories like qualitative traits. Environmental factors heavily influence these traits (for example, plant height and yield components).

Table 5. Phenotypic variability data of cacao characteristics

Characteristics	S^2	SD	Criteria
Leaf shape	0.00	0.00	Narrow
Leaf color	0.00	0.00	Narrow
Leaf surface	0.95	0.97	Narrow
Leaf tip	0.57	0.75	Narrow
Leaf margin	0.00	0.00	Narrow
Flower color	2.28	1.51	Broad
Flower position	0.00	0.00	Narrow
Fruit shape	2.48	1.57	Broad
Fruit skin color	3.61	1.90	Broad
Fruit surface	2.47	1.57	Broad
Seed color	1.14	1.07	Broad
Basal constriction	1.90	1.38	Broad
Fruit tip shape	3.61	1.90	Broad
Leaf length (cm)	73.2	8.55	Broad
Leaf width (cm)	6.20	2.49	Broad
Fruit length (cm)	10.6	3.26	Broad
Fruit diameter (cm)	1.36	1.16	Broad
Weight of fruit (grams)	49880.9	223.34	Broad
Seed weight (grams)	0.43	0.66	Narrow

*Note: S^2= Variance, SD= Standard deviation

Similarity analysis

Qualitative and Quantitative Data

Similarity analysis is conducted based on qualitative and quantitative traits. Similarity among seven variants of local cacao plants in the Sitiung Subdistrict is analyzed using the Numerical Taxonomy and Multivariate Analysis System (NTSYS) version 2.02. The coefficient values will depict the level of similarity among the compared variants. In the dendrogram, larger coefficient values indicate a closer level of similarity between the compared variants, while smaller coefficient values reveal lesser similarity (Figure 2). The degree of similarity for each compared variant can be determined based on the coefficient of similarity. Observations of qualitative and quantitative traits allow for identifying the similarity level among each cacao variant in the Sitiung Subdistrict.

The results of the similarity analysis conducted on seven variants of local cacao plants in the Sitiung Subdistrict have coefficient values ranging from 23% to 47%, with a variability value of 53% to 77%. Based on the coefficient values obtained, the similarity is considered low, as the coefficient of similarity is ≤ 0.6 or 60%. The phenotypic traits resulted in two groups, namely Group I and Group II. Group I further comprises two subgroups, namely Subgroup IA and Subgroup IB. Group II also has two subgroups, Subgroup IIA and Subgroup IIB (Table 6). In Group I, specifically Subgroup IA, variants SG1 and SD1 are grouped with a coefficient of 47%, while Subgroup IB consists of variants SG2 and SD2 with a coefficient of 41%. As for Group II, Subgroup IIA includes variants SG3 and SD3 grouped at a coefficient of 41%, and Subgroup IIB contains one variant, coded as ST1, with a coefficient of 37%. This data indicates that based on the dendrogram of qualitative and quantitative traits, the level of similarity is low, as the similarity coefficient is ≤ 0.6, or 60%. Swasti (2007) explains that similarity analysis uses morphological characteristics to determine the proximity of similarity relationships among plants. Morphological traits can be employed to recognize and illustrate species similarity. Species with close similarity exhibit numerous similarities among one another.

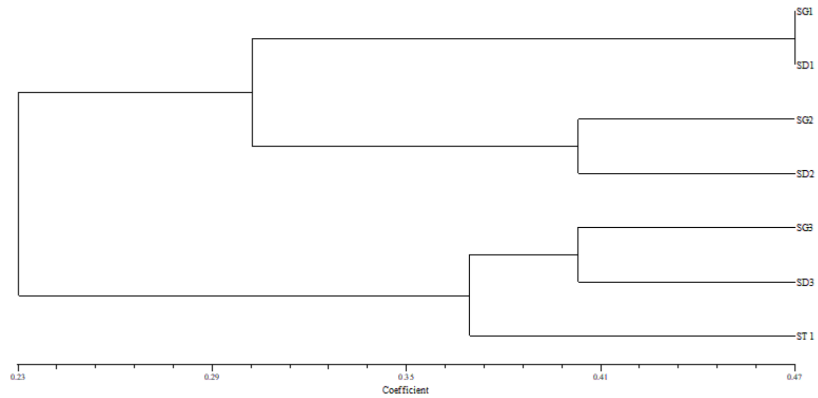

Figure 2. Dendrogram of seven cacao varieties based on qualitative and quantitative traits

Table 6. Clustering of seven varieties of local cacao plants based on the dendrogram results of qualitative and quantitative traits

Main Group	Subgroup	Variants
I	IA	SG1, SD1
	IB	SG2, SD2
II	IIA	SG3, SD3
	IIB	ST1

Qualitative Similarity Analysis

From the observations based on qualitative traits, the level of similarity for each variant of local cacao plants in the Sitiung Subdistrict can be determined. The results of the similarity analysis of 7 variants based on qualitative traits can be seen in Figure 3. The results of the similarity analysis conducted on the seven variants of local cacao plants for qualitative traits are presented in Figure 3. The coefficient values range from 34% to 67%, indicating that qualitative traits have a moderate level of similarity, with variability values ranging from 33% to 66%. Qualitative traits resulted in 2 main groups, Group I, and Group II. Group I has two subgroups, Subgroup IA and Subgroup IB. There are also two subgroups within Group IIA and Subgroup IIB. In Group I, specifically Subgroup IA, variants with the codes SG1 and SD1 are grouped. Subgroup IB consists of variants SG2 and SD2, which are also grouped with a coefficient of 67%, indicating a moderate level of similarity. Variants SG1 and SD1's qualitative traits show similarities in leaf shape, leaf color, leaf tip, leaf margin, flower position, fruit shape, fruit surface, seed color, basal constriction, and fruit tip shape. Meanwhile, variants with codes SG2 and SD2 share similar traits such as leaf shape, leaf color, leaf surface, flower position, fruit skin color, seed color, and fruit tip shape.

In Group II, Subgroup IIA consists of 2 variants with codes SG3 and ST1, grouped with a coefficient of 55%. Subgroup IIB includes one variant with code SD3, having a coefficient value of 44%, indicating a moderate level of similarity. Variants SG3 and ST1's qualitative traits show similarities in leaf shape, leaf color, leaf margin, flower position, fruit surface, fruit color, seed color, and fruit tip shape. The inheritance of qualitative traits is easily distinguishable, as each variant possesses distinct population patterns. On the other hand, certain groups are challenging to categorize. These groups represent transitional zones between the two inheritance systems and encompass intermediate forms inherited due to environmental interaction influences, allowing some genotypes to be expressed in their phenotypic forms (Sholtis & Weiss 2005).

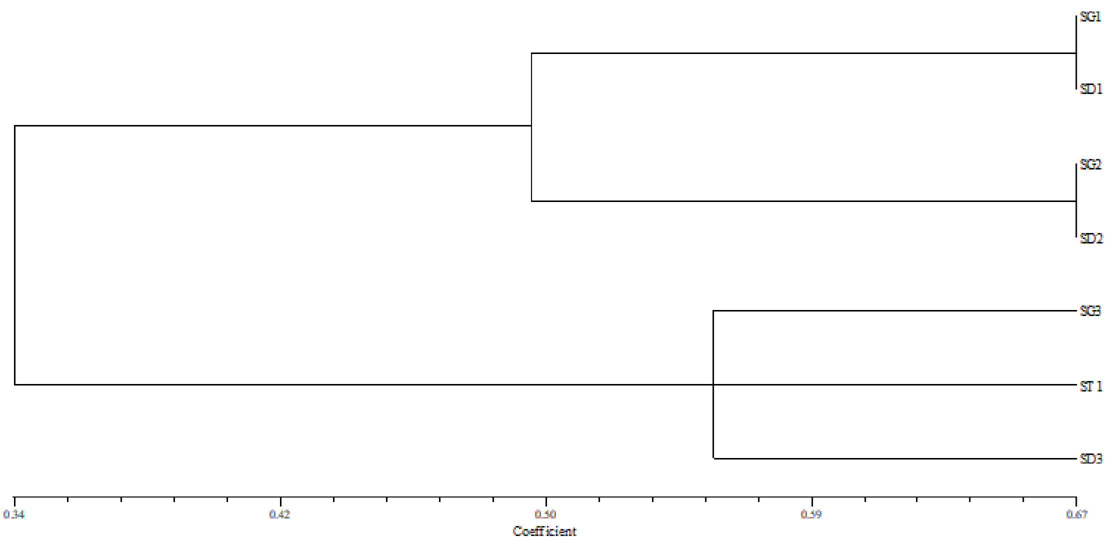

Figure 3. Dendrogram of seven clones of local cacao plants based on qualitative traits

Quantitative Similarity Analysis

From the observations based on quantitative traits, the level of similarity for each variant of local cacao plants in the Sitiung Subdistrict can be determined. The results of the similarity analysis of seven variants based on quantitative traits can be seen in Figure 4. The results of the similarity analysis conducted on the seven variants of local cacao plants for quantitative traits are presented in Figure 4. The coefficient values range from 0% to 33%, indicating that quantitative traits have a low level of similarity, with variability values ranging from 67% to 100%. Quantitative traits resulted in two main groups.

The analysis results can be observed in Figure 4, where the main Group I, specifically Subgroup IA, consists of 2 variants that are grouped with a coefficient of 33%, coded as SG1 and SG3. Subgroup IB, including variants ST1 and SD1, was grouped with a coefficient of 17%. Subgroup IC, comprising variants SD2 and SD3, has a coefficient value of 8%, while main Group IIA, with the variant SG2, has a coefficient value of 0%, each indicating a low level of similarity (Table 7). According to Illahi (2020), taxonomic distance refers to coefficient values that quantitatively represent the level of dissimilarity between compared samples. The larger the dissimilarity value, the lower the degree of similarity between individuals (varying).

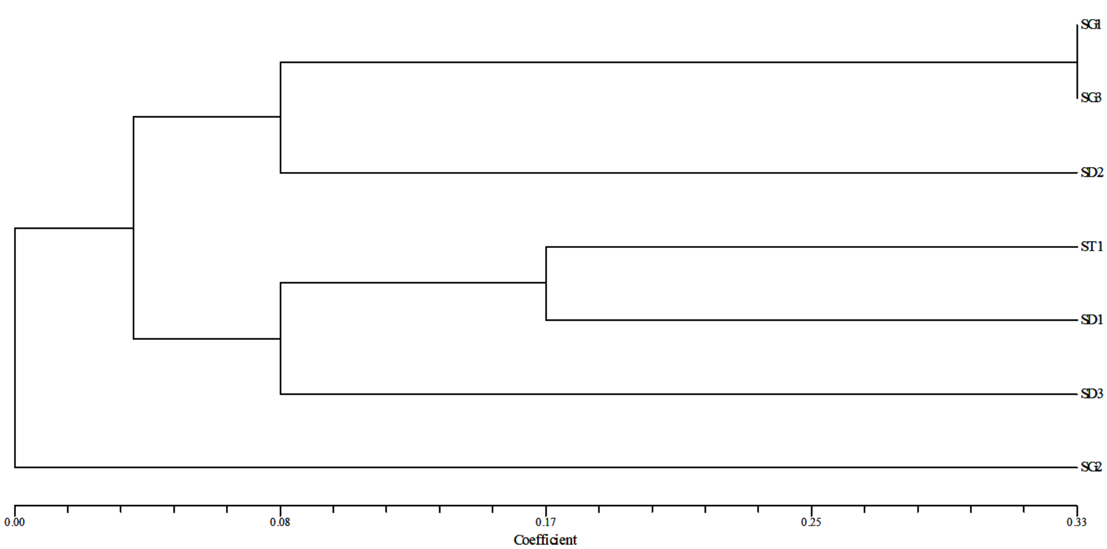

Figure 4. Dendrogram of seven varieties of local cacao plants based on quantitative traits

Table 7. Clustering of seven varieties of local cacao plants based on the results of the quantitative dendrogram

Main Group	Subgroup	Variants
I	IA	SG1, SG3
	IB	ST1, SD1
	IC	SD2, SD3
II	IIA	SG2

Fauza et al. (2015) state that the larger the similarity coefficient, the greater the level of similarity between the compared plants. Conversely, the smaller the similarity coefficient, the lower the level of similarity between those plants. This means that the larger the similarity value, the closer the relationship degree; conversely the smaller the similarity value, the farther the relationship. In plant breeding, having distant plant relatives in hybrid assembly results in high heterosis, and a significant amount of recombination due to segregation occurs.

CONCLUSIONS

Seven cacao variants were discovered in smallholder cacao plantations in the Sitiung District, specifically in the Nagari Siguntur, Sitiung, and Sungai Duo areas. The smallholder cacao plants in the Sitiung District consist of seven variants with variant codes: SG1, SG2, SG2, ST1, SD1, SD2, and SD3. The phenotypic variability of these seven smallholder cacao plant variants, in terms of quantitative and qualitative characteristics, exhibits a wide range of values. Phenotypic similarity analysis in the Sitiung District reveals significant genetic diversity, with coefficient values ranging from 23% to 47% and variability values between 53% and 77%.

REFERENCES

Aryandi NA, Anwar A, Efendi S & Suhendra D. 2021. Pengaruh coating gel lidah buaya terhadap viabilitas dan vigor benih kakao. *Jurnal Pertanian*, *12*(2):55–65. https://doi.org/https://doi.org/10.30997/jp.v12i2.4234

Budiastuti S, Purnomo D, Nyoto S Widono S & Yunindanova MB. 2016. Cocoa cultivation on suboptimal land. *Journal of Natural Sciences Research*, *6*(20): 13–17. https://www.iiste.org/Journals/index.php/JNSR/article/view/33780

Diana P, Efendi S & Akhir N. 2020. Pengaruh beberapa dosis abu janjang kelapa sawit terhadap pertumbuhan bibit kakao (*Theobroma cacao* L.). *Ziraa'Ah Majalah Ilmiah*, *45*(1):69–79. http://dx.doi.org/10.31602/zmip.v45i1.2601

Fauza H, Ferita I, Putri N, E, Nelly N & Rusman B. 2015. Studi awal penampilan fenotipik plasma nutfah jengkol (*Pithecollobium jiringa*) di Padang, Sumatera Barat. *Seminar Nasional Masyarakat Biodiversitas Indonesia*, *1*:23–30. https://doi.org/10.13057/psnmbi/m010104

Illahi AK. 2020. Keragaman fenotipe dan kemiripan morfologis Hanjeli (*Coix lacryma-jobi* L.) di Kabupaten Lima Puluh Kota. *Jurnal Ilmu-Ilmu Pertanian Indonesia*, *22*(2):129–135. https://doi.org/10.31186/jipi.22.2.129-135

ICCRI [Indonesian Coffee and Cacao Research Institute]. 2004. *Panduan Lengkap Budidaya Kakao*. AgroMedia Pustaka.

Junaedi TS, Darwisah B & Yana RN. 2016. Identifikasi klon unggul kakao di Desa Tarengge Kecamatan Wotu Kabupaten Luwu Timur. *Agrokompleks*, *16*(1):23–26. https://doi.org/10.51978/japp.v16i1.174

Lukito A. 2010. *Buku pintar budi daya kakao/Pusat Penelitian Kopi dan Kakao Indonesia*. AgroMedia Pustaka.

Prawoto AA, Pujiyanto, Panggabean TR & Wahyudi T. 2013. *Panduan Lengkap Kakao : Manajemen Agribisnis Dari Hulu Hingga Hilir*. Penebar Swadaya.

Putri RE, Gustian & Suhendra D. 2022. Quantitative characteristics and variability of cocoa (*Theobroma cacao*) in Koto Salak district, Dharmasraya regency. *Jurnal Riset Perkebunan*, *3*(2): 101–109. https://doi.org/10.25077/JRP.3.2.101-109.2022

Raden I, Nugroho CC & Syahrani. 2017. Identification and characterization of morphological diversity of Lemba (*Curculigo latifolia*) in East Kalimantan, Indonesia. *Biodiversitas*, *18*(4): 1367–1376. https://doi.org/10.13057/biodiv/d180412

Rezki D, Efendi S & Herviyanti. 2022. Pengaruh kompos, bahan humat dari batubara tidak produktif dan pupuk buatan terhadap bibit Kakao (*Theobroma cacao*) pada Oxisol. *Jurnal Riset Perkebunan*, *3*(1):38–47. https://doi.org/10.25077/jrp.3.1.38-47.2022

Rubiyo. 2013. Inovasi teknologi perbaikan bahan tanam kakao di Indonesia. *Buletin RISTRI*, *4*(3):199–214.

Rusmiati M. 2019. *Eksplorasi dan karakterisasi tanaman kakao (Theobroma cacao L.) rakyat di Kecamatan Sungai Rumbai kabupaten Dharmasraya*. [Skripsi]. Padang(ID):Universitas Andalas. http://scholar.unand.ac.id/46467/

Sholtis S & Weiss KM. 2005. Phenogenetics: genotypes, phenotypes, and variation. In Hallgrímsson B & Hall BK (Eds.) *Variation*. Cambridge (UK): Academic Press. https://doi.org/10.1016/B978-0-12-088777-4.50023-5

Swasti E. 2007. *Pengantar Pemuliaan Tanaman*. Fakultas Pertanian Unand.

Tedianto. 2012. *Karakteristik Labu Kuning Berdasarkan Penanda Morfologi dan Kandungan Protein, Karbohidrat, Lemak pada Berbagai Ketinggian Tempat*. Surakarta(ID):Universitas Sebelas Maret.

Zasari M & Sitorus R. 2022. Eksplorasi-karakterisasi morfologi tanaman kakao lokal di Pulau Bangka. *AGROSAINSTEK: Jurnal Ilmu Dan Teknologi Pertanian*, *6*(1):23–33. https://doi.org/10.33019/agrosainstek.v6i1.356