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ARTICLE

MORPHOLOGICAL VARIATION AMONG ROBUSTA COFFEE (*Coffea canephora*) ACCESSIONS IN TEMANGGUNG AS A BASIS FOR SELECTION

[*Variasi Karakter Morfologi Beberapa Aksesi Kopi Robusta (Coffea canephora) di Temanggung sebagai Dasar Seleksi*]

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ABSRACT

Robusta coffee (*Coffea canephora*) is a strategic commodity that contributes significantly to farmers' livelihoods in Temanggung Regency, Central Java. This study aimed to evaluate the morphological variation among 56 robusta coffee accessions collected from 17 districts to support selection. A total of 30 morphological characters from leaves, stems, flowers, and fruits were evaluated following IPGRI (1996) and Coffee Industry Corporation (2016) descriptors. Morphological data were analyzed using the UPGMA method to construct a dendrogram and calculate similarity coefficients. The results revealed high morphological variation, particularly in apical stem color (reddish yellow to dark green), internode distance (2–10 cm), and ripe fruit color (yellowish green to dark red). Agronomically, short to medium internodes (2–5 cm) and monopodial stem growth were identified as desirable traits due to their association with higher productivity, compact canopy structure, and ease of management. Accessions PRK_2 and PRK_3 showed identical morphology (similarity coefficient 1.00), while TBR_1 and GMW_1 exhibited low similarity (<0.50), indicating significant genetic differentiation. The clustering pattern was not fully aligned with geographic origin, suggesting variations in planting material or local selection. In conclusion, morphological variation based on 30 characters demonstrates substantial genetic diversity for coffee breeding. Characters such as internode distance, fruit color, and stem growth type identified as key traits for production-oriented selection.

Keywords: accession, germplasm, morphology character, robusta, selection, Temanggung

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ABSTRAK

Kopi robusta (Coffea canephora) merupakan komoditas strategis yang berperan penting dalam meningkatkan kesejahteraan petani di Kabupaten Temanggung, Jawa Tengah. Penelitian ini bertujuan untuk mengevaluasi variasi karakter morfologi pada 56 aksesi kopi robusta yang dikoleksi dari 17 kecamatan sebagai dasar seleksi. Sebanyak 30 karakter morfologi pada organ daun, batang, bunga, dan buah diamati berdasarkan pedoman IPGRI (1996) dan Coffee Industry Corporation (2016). Data morfologi dianalisis menggunakan metode UPGMA untuk menyusun dendrogram dan menghitung koefisien kemiripan antaraksesi. Hasil penelitian menunjukkan adanya variasi morfologi yang tinggi, terutama pada warna batang apikal (kuning kemerahan hingga hijau tua), jarak antar buku batang (2–10 cm), dan warna buah matang (hijau kekuningan hingga merah tua). Secara agronomis, jarak internode yang pendek hingga sedang (2–5 cm) dan tipe pertumbuhan batang monopodial merupakan karakter yang menguntungkan karena berkaitan dengan produktivitas tinggi, tajuk yang kompak, dan kemudahan pemeliharaan. Aksesi PRK_2 dan PRK_3 memiliki koefisien kemiripan 1,00 yang menunjukkan kesamaan morfologi sempurna, sedangkan TBR_1 dan GMW_1 memiliki kemiripan <0,50 yang menunjukkan perbedaan genetik yang besar. Pola pengelompokan tidak sepenuhnya sesuai dengan asal geografis, yang mengindikasikan variasi bahan tanam atau seleksi lokal. Kesimpulannya, variasi morfologi berdasarkan 30 karakter menunjukkan keragaman genetik yang tinggi untuk pemuliaan kopi. Karakter seperti jarak internode, warna matang buah, dan tipe pertumbuhan batang merupakan karakter penting untuk seleksi yang berorientasi pada produksi.

***Kata kunci**: aksesi, plasma nutfah, robusta, seleksi, Temanggung*

INTRODUCTION

Coffee is one of Indonesia's leading plantation commodities, a potential non-oil and gas export, and a source of foreign exchange. Robusta coffee is a defensive commodity with strategic value to strengthen people's economies. Genetic factors, geographical, and climatic advantages are determining factors in the quality of coffee taste and aroma (Gumulya and Helmi, 2017). Based on data from the International Coffee Organization in 2025, exports of all types of coffee from Asia and Oceania in December 2024 decreased by 31.2%, the decrease was due to the declining domestic supply situation, due to biotic factors (plant genetics, age, pest attacks, and pathogens) and abiotic factors (nutrition, weather, and global climate change). Data from the Directorate General of Indonesian Plantations in 2023 shows that Indonesia is the 4th largest coffee exporting country in the world. The volume of Indonesian coffee exports from 2018 - 2022 increased by 56.291%, from 279,961 tons to 437,555 tons.

Temanggung coffee production is considered the largest in Central Java, accounting for 40% of the region's total. The demand for Temanggung coffee is increasing, both domestically and internationally. The total coffee exports from Temanggung are 200,000 tons per year, and Temanggung robusta coffee has contributed to 60% of Java Coffee exports to Europe, Asia, and America. The area of coffee plantations in Temanggung is only 12,800 ha, which is why Temanggung is still overwhelmed in meeting the demand for coffee (Septiani and Kawuryan, 2021). Robusta coffee is one of the commodities that has strategic value in efforts to empower the people's economy (Azmi and Handriatni, 2019). The large potential of Robusta coffee is expected to improve the welfare of coffee farmers by increasing and equalizing their income.

Plant breeding programs are designed over several cycles to systematically alter the genetic makeup of plants to achieve improved trait performance, to develop cultivars, and increase crop productivity (Voss-Fels *et al*., 2019). Plant breeding is based on the combination of plant traits required for the superior performance of new cultivars (Cooper *et al*., 2021). Through iterative cycles of breeding programs, breeders can utilize accessible genetic variation for traits, available through germplasm and genetic resources, to improve the genetics of various traits on crop cultivars (Hickey *et al*., 2019). Optimizing/improvement in genetic and phenotypic value among population due to selection, are important for decide parents that have the desirable traits in plant breeding, especially attributed to inherited genetics. Decisions and accuracy of selection are fundamental in breeding program (Rutkoski, 2019).

Information on diversity and classification can show the level and relationship between cultivars, as a basis for selection or parents in hybridization (Nandariyah *et al*., 2021) Plant breeding

is a dynamic and sustainable activity, its dynamic is reflected in the challenges and natural conditions of the environment that tend to change, and sustainable because it always adapts to environmental developments and human needs (Koryati *et al*., 2022). Characterization of plant morphology is needed for identification purposes at the phenotype level, and changes that occur due to environmental factors (Indraloka and Rahayu, 2022). The purpose of this study was to observe genetic diversity through the morphological characteristics of robusta coffee plants in the Temanggung area as an effort to conserve germplasm in the selection considerations of parents in robusta coffee plant breeding. Therefore, evaluating the morphological diversity among Robusta coffee accessions in Temanggung is essential to provide fundamental information for genetic resource management, selection of superior parental lines, and the development of sustainable breeding and conservation programs.

MATERIALS AND METHODS

Research site

The research was conducted on agricultural land located in Bansari, Bansari District, Temanggung Regency, Central Java. The research began on August 10, 2023, and morphological observations began on September 23, 2024. All observations were completed on December 1, 2024.

Research Tools and Materials

The tools used in this study include pruning shears, shovels, watering cans, plastic bags, rulers, magnifying glasses, protractors, cameras with macro lenses, and stationery sets. The materials used in this study include robusta coffee accessions (in the form of stem cuttings), planting media (soil, cocopeat, and compost), plant growth regulators/root stimulants (Clonex™), liquid organic fertilizers (NatureGen™), and planter bags (50 litre size).

Samples Source

Robusta coffee accessions used in this study were taken from 17 of the total 20 sub-districts in Temanggung Regency, including Tembarak/TBR (1 accession), Tlogomulyo/TLG (3 accessions), Kranggan/KRG (3 accessions), Pringsurat/PGS (3 accessions), Temanggung/TMG (4 accessions), Bulu/BLU (1 accession), Bansari/BNS (3 accessions), Parakan/PRK (3 accessions), Kedu/KDU (3 accessions), Kaloran/KLO (3 accessions), Kandangan/KDG (3 accessions), Candiroto/CDR (4 accessions), Jumo/JMO (3 accessions), Gemawang/GMW (6 accessions), Wonoboyo/WNB (5 accessions), Tretep/TRP (4 accessions), and Bejen/BJN (4 accessions). Not all sub-districts in Temanggung cultivate robusta coffee; the number of accessions taken depends on the number of coffee populations and the production of commodities in each sub-district.

Method

The research is based on descriptive analysis directly conducted on the object of observation, in the form of coffee accessions, so that the object of research is a source of the data. The data on the diversity of robusta coffee accessions obtained through morphological characterization serve as a database to study morphological variation and provide a basis for selection. The stages of this research are as follows :

1. Conduct field surveys and observations to obtain accession candidates
2. Collect samples for propagation material
3. Perform sample cultivation and maintenance during growth
4. Morphological observation of coffee accessions
5. Data Analysis

Observations were conducted on 30 morphological characters, including 13 leaf, 7 stem, 5 flower, and 5 fruit characters, following the descriptors provided by IPGRI (1996) and the Coffee Industry Corporation (2016). The list of observed morphological characters is presented in the table below.

Table 1. The observed morphological characters table of robusta coffee (*Tabel karakter morfologi kopi robusta yang diamati*)

No.	Plants organs (*Organ tanaman*)	Character (*Karakter*)	Character Group (*Grup Karakter*)
1.	Leaf (*Daun*)	Apical leaf color (*Warna daun apikal*)	(1) yellow, (2) reddish yellow, (3) pink, (4) red, (5) light green, and (6) green (*(1) kuning, (2) kuning kemerahan, (3) merah muda, (4) merah, (5) hijau muda, dan (6) hijau*)
		Leaf color (*Warna daun*)	(1) light green, (2) dark green, (3) yellowish green, and (4) yellow (*(1) hijau muda, (2) hijau tua, (3) hijau kekuningan, dan (4) kuning*)
		Leaf trichomes (*Trikoma daun*)	(1) trichomes present and (2) no trichomes (*(1) ada dan (2) tidak*)
		Leaf shape (*Bentuk daun*)	(1) lancet, (2) oval lancet, (3) ellipses, (4) oval, (5) breech egg round, and (6) spoon shape (*(1) lanset, (2) lanset oval, (3) jorong, (4) lonjong, (5) bundar telur sungsang, dan (6) sudip*)
		Leaf arrangement (*Duduk daun*)	(1) opposite, (2) alternate, (3) decussate, and (4) distichous
		Leaf stalk color (*Warna tangkai daun*)	(1) yellow, (2) yellowish green, (3) light green, (4) dark green, and (5) pink (*(1) kuning, (2) hijau kekuningan, (3) hijau muda, (4) hijau tua, dan (5) merah muda*)
		Leaf venation (*Bentuk tulang daun*)	(1) pinnate, (2) arcuate, (3) cross venulate, (4) reticulate, and (5) dichotomous
		Leaf vein color (*Warna tulang daun*)	(1) white, (2) yellow, (3) yellowish green, (4) light green, and (5) dark green (*(1) putih, (2) kuning, (3) hijau kekuningan, (4) hijau muda, dan (5) hijau tua*)
		Leaf tip shape (*Bentuk ujung daun*)	(1) pointed, (2) blunt, (3) round, and (4) jagged (*(1) runcing, (2) tumpul, (3) bulat, dan (4) bergerigi*)
		Leaf margin (*Bentuk tepi daun*)	(1) undulate, (2) sinuate, (3) serrate, (4) dentale, and (5) scalloped
		Leaf stalk inclination (*Kemiringan tangkai daun*)	(1) parallel, (2) 90º, (3) tilted upwards, and (4) angled upwards (*(1) sejajar, (2) 90º, (3) miring ke atas, dan (4) miring ke bawah*)
		Apical stem color (*Warna batang apikal*)	(1) yellow, (2) reddish red, (3) brown, (4) red, (5) light green, (6) green, and (7) dark green

No.	Plants organs (*Organ tanaman*)	Character (*Karakter*)	Character Group (*Grup Karakter*)
			(*(1) kuning, (2) kuning kemerahan, (3) coklat, (4) merah, (5) hijau muda, (6) hijau, dan (7) hijau tua*)
		Leaf border shape (*Bentuk garis tepi daun*)	(1) straight or inline, (2) wavy, and (3) curly (*(1) lurus atau segaris, (2) bergelombang, dan (3) keriting*)
2.	Stem (*Batang*)	Stem epidermis color (*Warna epidermis batang*)	(1) milky white, (2) light brown, (3) dark brown, and (4) blackish brown (*(1) putih susu, (2) coklat muda, (3) coklat pekat, dan (4) coklat kehitaman*)
		Stem color (*warna batang*)	(1) milky white, (2) brownish white, (3) light brown, (4) dark brown, (5) blackish brown, and (6) green (*(1) putih susu, (2) putih kecoklatan, (3) coklat muda, (4) coklat pekat, (5) coklat kehitaman, dan (6) hijau*)
		Stem texture (*tekstur batang*)	(1) rough, (2) medium, and (3) smooth (*(1) kasar, (2) sedang, dan (3) halus*)
		Internode distance (*Jarak antar buku*)	(1) 2-4 cm, (2) 4-6 cm, (3) 6-8 cm, (4) 8-10 cm, and (5) more than 10 cm (*(1) 2-4 cm, (2) 4-6 cm, (3) 6-8 cm, (4) 8-10 cm, dan (5) lebih dari 10 cm*)
		Stem growth type (*Tipe pertumbuhan batang*)	(1) monopodial, (2) simpodial, (3) dikotom, (4) ferticillate, and (5) tetratichous
		Legitimate shoot color (*Warna tunas legitim*)	(1) light green, (2) green, (3) dark green, and (4) yellowish brown (*(1) hijau muda, (2) hijau, (3) hijau tua, dan (4) coklat kekuningan*)
		Legitimate axis angle (*Sudut sumbu legitim*)	(1) 10-30º, (2) 30-50º, and (3) 60-80º
3.	Flower (*Bunga*)	Pollen form/shape (*Bentuk benang sari*)	(1) spheroidal, (2) subprolate, (3) ellipsoidal, and (4) ekstensipulus (*(1) bulat, (2) oval, (3) elips, dan (4) berlekuk*)
		Petal color (*Warna kelopak*)	(1) white, (2) yellowish white, (3) greyish white, and (4) brown (*(1) putih, (2) putih kekuningan, (3) putih keabu-abuan, dan (4) coklat*)
		Pistil color (*Warna putik*)	(1) white, (2) yellowish white, and (3) greenish white (*(1) putih, (2) putih kekuningan, dan (3) putih kehijauan*)
		Domatia position (*Posisi domatia*)	(1) axillary domatia dan (2) abaxial domatia (*(1) domatia aksila (dekat pangkal tangkai daun), (2) domatia abaksial (di bagian bawah tangkai daun)*)

No.	Plants organs (*Organ tanaman*)	Character (*Karakter*)	Character Group (*Grup Karakter*)
		Position of stamen and pistil (*Posisi benang sari dan putik*)	(1) short stamen with long pistil, (2) long stamen with short pistil, and (3) stamen and pistil equal in length (*(1) stamen pendek dengan pistil panjang, (2) stamen panjang dengan pistil pendek, dan (3) stamen dan pistil sama panjang*)
4.	Fruit (*Buah*)	Ripe fruit color (*Warna matang buah*)	(1) yellowish green, (2) yellow, (3) reddish yellow, (4) pink, (5) red, and (6) dark red (*(1) hijau kekuningan, (2) kuning, (3) kuning kemerahan, (4) merah muda, (5) merah, dan (6) merah tua*)
		Peeled seed shape (*Bentuk biji kupas*)	(1) one pointy end, (2) boxed, (3) both blunt ends (like an imperfect circle), and (4) both ends are pointed (*(1) salah satu ujung runcing, (2) mengkotak, (3) kedua ujung tumpul (seperti lingkaran tidak sempurna), dan (4) kedua ujung runcing*)
		Center gap of seed (*Celah tengah biji*)	(1) letter ”C”, (2) letter ”S”, (3) letter ”I” with one pointed end, and (4) letter ”I” with all pointed ends (*(1) huruf ”C”, (2) huruf ”S”, (3) huruf ”I’ dengan salah satu ujung runcing, dan (4) huruf ”I” dengan semua ujung runcing*)
		Parchment color (*Warna parchment*)	(1) clear, (2) milky white, (3) off-white or grey, (4) yellowish white, and (5) yellow (*(1) bening, (2) putih susu, (3) putih pucat atau abu-abu, (4) putih kekuningan, dan (5) kuning*)
		Peeled seed color (*Warna biji kupas*)	(1) white, (2) yellowish white, (3) off-white or grey, (4) greenish white, (5) green, and (6) yellow (*(1) putih, (2) putih kekuningan, (3) putih pucat atau abu-abu, (4) putih kehijauan, (5) hijau, dan (6) kuning*)

Data Analysis

The data obtained were used to identify preliminary indications of genetic diversity based on morphological variations in leaves, stems, flowers, and fruits. The data were presented in the form of a morphological character table, a similarity matrix, and a UPGMA dendrogram to analyze the degree of kinship and similarity among Robusta coffee accessions. All analyses were performed using the NTSYS-PC version 2.2 software with the SimQual function.

RESULTS

The Robusta coffee accessions were evaluated based on several morphological characters observed in the leaves, stems, flowers, and fruits. Among these traits, two morphological characters, apical stem color and ripe fruit colors, showed the highest degree of variation across accessions collected from various sub-districts in Temanggung Regency (Figures 1 and 2). In addition, internode distance showed moderate variation. In contrast, floral characters demonstrated relatively low diversity, as illustrated in Figure 3.

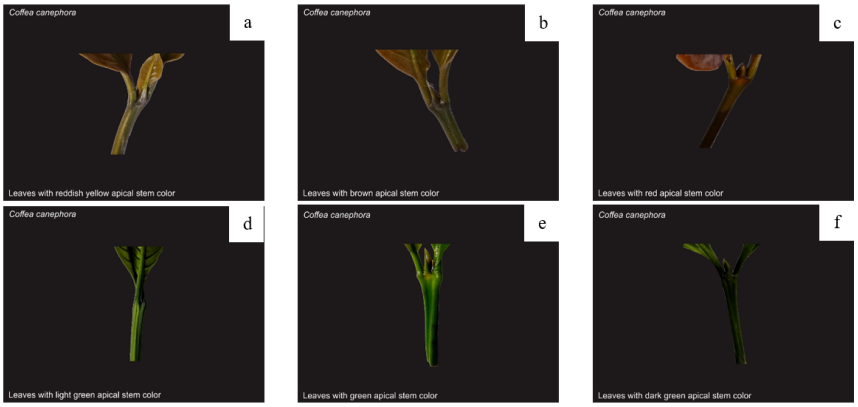

Figure 1. Diversity of apical stem color characters of Robusta coffee accessions, a: reddish yellow, b: brown, c: red, d: light green, e: green, and f: dark green. (*Keragaman karakter warna batang apikal aksesi kopi Robusta, a: kuning kemerahan, b: coklat, c: merah, d: hijau muda, e: hijau, dan f: hijau tua*).

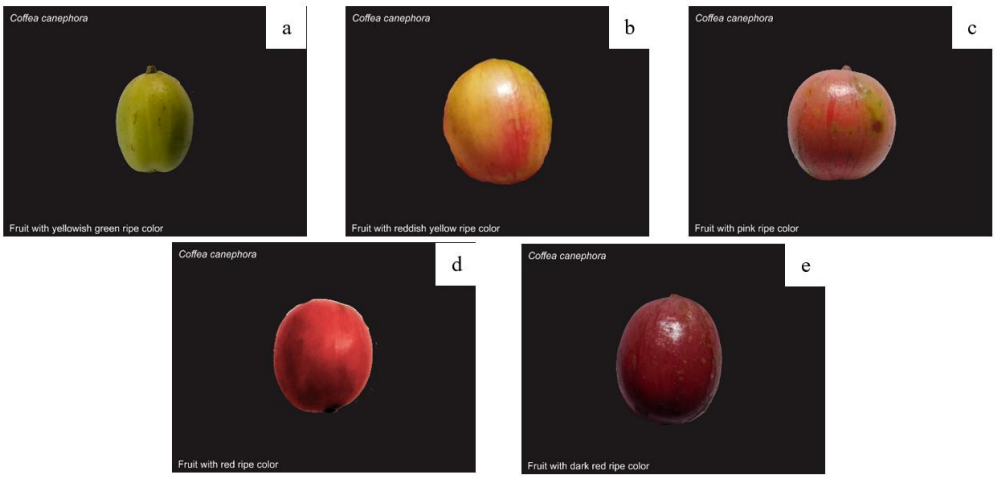

Figure 2. Diversity of ripe fruit color characters of Robusta coffee accessions, a: yellowish green, b: reddish yellow, c: pink, d: red, and e: dark red. (*Keragaman karakter warna matang buah aksesi kopi Robusta, a: hijau kekuningan, b: kuning kemerahan, c: merah muda, d: merah, dan e: merah tua*).

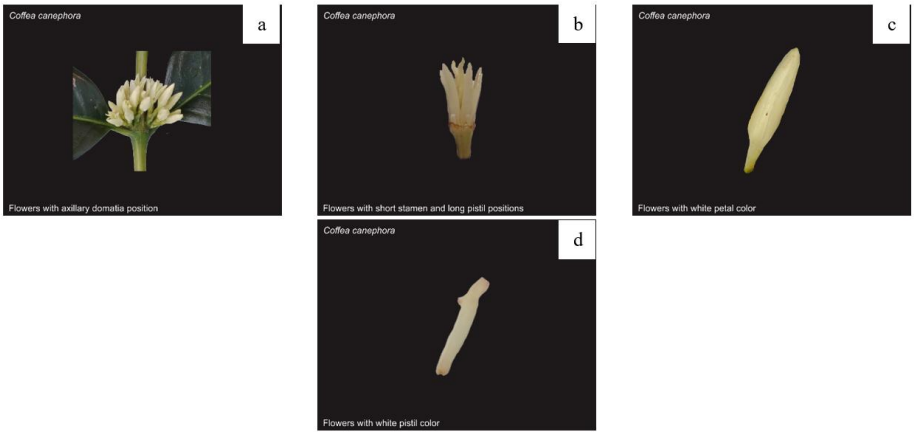

Figure 3. Low diversity characters in flower parts of Robusta coffee accessions, a: position of axillary domatia, b: position of short stamen and long pistil, c: white petal color, and d: white pistil color. (*Keragaman karakter pada organ bunga aksesi kopi Robusta, a: posisi domatia aksila, b: posisi stamen pendek dan pistil panjang, c: warna kelopak putih, dan d: warna putik putih*).

The differences in morphological characters in Robusta coffee accessions observed from various sub-districts in Temanggung Regency are more detailed in Table 2 below.

Table 2. Morphological characters of 56 Robusta coffee accessions (*Karakter morfologi 56 aksesi kopi Robusta*).

Morphology (*Morfologi*)	**Accessions** (*Aksesi)*																																
	TBR	**TLG**			**KRG**			**PGS**			**TMG**				**BLU**		**BNS**			**PRK**			**KDU**			**KLO**			**KDG**			**CDR**
	1	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**1**		**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**
Apical leaf color (*Warna daun apikal*)	6	5	5	1	6	5	7	5	6	6	6	5	6	5	4		5	5	5	2	5	5	6	5	6	5	6	5	5	6	6	5
Leaf color (*Warna daun*)	3	2	2	2	3	1	2	1	1	2	2	2	2	2	2		1	2	2	2	1	1	1	1	1	1	1	1	1	1	1	2
Leaf trichomes (*Trikoma daun*)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Leaf shape (*Bentuk daun*)	4	4	4	4	4	4	4	4	4	4	3	4	3	4	6		4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Leaf arrangement (*Duduk daun*)	2	1	1	1	3	3	3	4	4	4	1	1	1	1	1		1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	1
Leaf stalk color (*Warna tangkai daun*)	3	4	4	4	3	3	3	3	3	3	4	4	3	4	4		4	4	4	4	4	4	4	3	3	4	3	3	3	4	4	4
Leaf venation (*Bentuk tulang daun*)	1	1	1	1	1	1	1	1	1	1	1	3	1	3	1		1	1	1	1	1	1	3	3	1	3	3	3	3	3	3	3
Leaf vein color (*Warna tulang daun*)	3	4	4	4	4	4	4	3	3	3	3	4	3	4	4		3	3	3	3	3	3	4	4	3	3	3	3	4	4	3	4
Leaf tip shape (*Bentuk ujung daun*)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Leaf margin (*Bentuk tepi daun*)	2	4	4	1	3	3	3	3	1	3	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Leaf stalk inclination (*Kemiringan tangkai daun*)	4	3	3	1	3	3	3	3	3	3	1	1	4	3	3		3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	3
Apical stem color (*Warna batang apikal*)	5	6	6	6	6	6	6	6	6	5	6	6	6	5	6		6	6	6	5	6	6	6	6	6	5	6	6	6	6	6	5
Leaf border shape (*Bentuk garis tepi daun*)	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Stem epidermis color (*Warna epidermis batang*)	2	1	2	2	2	1	4	2	3	2	2	2	2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3

Morphology (*Morfologi*)	**Accessions** (*Aksesi*)																																
	TBR	**TLG**			**KRG**			**PGS**			**TMG**				**BLU**	**BNS**			**PRK**			**KDU**			**KLO**			**KDG**			**CDR**
	1	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**1**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**
Stem color (*warna batang*)	2	2	3	3	2	2	4	2	2	2	2	3	2	2	2	2	2	2	2	2	2	3	2	3	2	2	3	2	3	3	3
Stem texture (*tekstur batang*)	3	1	1	1	2	2	2	3	3	3	2	1	3	1	1	2	1	2	1	2	2	1	1	1	2	2	2	3	2	2	1
Internode distance (*Jarak antar buku*)	3	2	2	2	3	2	3	3	3	4	2	3	3	3	3	2	3	2	2	3	3	2	2	2	3	3	3	3	3	3	2
Stem growth type (*Tipe pertumbuhan batang*)	4	2	2	2	2	2	2	2	2	2	3	2	3	2	2	2	2	2	3	3	3	2	1	2	2	2	2	2	2	2	2
Legitimate shoot color (*Warna tunas legitim*)	1	3	3	3	1	1	1	2	2	1	2	3	1	1	2	1	1	3	2	1	1	2	2	2	2	2	2	1	2	2	3
Legitimate axis angle (*Sudut sumbu legitim*)	2	3	3	3	3	3	2	2	2	2	2	1	2	2	2	2	3	3	2	3	3	2	2	2	2	2	3	2	2	3	3
Pollen form/shape (*Bentuk benang sari*)	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	3	3	3	2	3	2	3	3	3	3
Petal color (*Warna kelopak*)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pistil color (*Warna putik*)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Domatia position (*Posisi domatia*)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Position of stamen and pistil (*Posisi benang sari dan putik*)	2	2	2	2	1	1	3	1	1	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1
Ripe fruit color (*Warna matang buah*)	5	5	6	5	4	4	4	4	4	5	6	5	6	6	4	3	3	3	3	3	3	3	2	3	3	3	2	3	3	3	3
Peeled seed shape (*Bentuk biji kupas*)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	5	5	5	3	3	3	5	3	5	3
Center gap of seed (*Celah tengah biji*)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Parchment color (*Warna parchment*)	4	4	3	4	4	4	4	4	5	4	4	4	4	4	3	4	4	4	4	4	4	3	3	3	3	3	3	4	4	4	3
Peeled seed color (*Warna biji kupas*)	3	3	3	4	6	6	6	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	3	4	4	2

Morphology (*Morfologi*)	**Accessions** (*Aksesi)*																								
	CDR			**JMO**			**GMW**						**WNB**					**TRP**				**BJN**			
	2	**3**	**4**	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Apical leaf color (*Warna daun apikal*)	6	5	6	1	2	5	5	5	5	2	5	5	6	5	6	6	6	2	2	5	5	5	5	5	5
Leaf color (*Warna daun*)	2	2	2	1	1	1	2	2	2	2	2	2	2	2	2	2	2	1	2	2	1	2	1	2	2
Leaf trichomes (*Trikoma daun*)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Leaf shape (*Bentuk daun*)	4	4	4	4	4	6	4	4	4	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4
Leaf arrangement (*Duduk daun*)	1	1	1	1	1	1	1	1	1	1	1	1	3	3	1	1	1	3	3	3	1	1	1	1	1
Leaf stalk color (*Warna tangkai daun*)	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4	4	4	3	1	4	4	4	4	4
Leaf venation (*Bentuk tulang daun*)	3	1	3	2	3	2	2	2	2	3	3	3	2	3	3	1	3	1	1	1	1	1	2	3	3
Leaf vein color (*Warna tulang daun*)	4	4	4	2	4	4	4	2	4	4	4	4	4	4	4	4	4	3	3	2	3	3	2	4	4
Leaf tip shape (*Bentuk ujung daun*)	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Leaf margin (*Bentuk tepi daun*)	1	4	1	1	1	4	1	4	1	1	1	1	2	2	2	4	4	2	2	2	4	4	4	1	1
Leaf stalk inclination (*Kemiringan tangkai daun*)	1	3	1	3	1	3	3	3	3	3	1	3	3	3	3	3	1	1	1	3	3	3	3	1	1
Apical stem color (*Warna batang apikal*)	6	6	6	1	6	6	5	5	5	6	5	6	5	5	6	6	6	2	2	1	1	5	5	6	5
Leaf border shape (*Bentuk garis tepi daun*)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2
Stem epidermis color (*Warna epidermis batang*)	3	2	2	2	2	3	1	1	1	2	2	2	2	2	3	2	2	1	1	1	1	2	2	2	2
Stem color (*warna batang*)	3	2	3	2	1	3	3	3	3	3	3	3	2	2	3	3	3	1	1	1	2	1	2	1	3
Stem texture	1	1	1	2	2	1	1	1	1	2	2	2	1	2	1	1	1	1	2	2	2	1	1	1	1

Morphology (*Morfologi*)	**Accessions** (*Aksesi)*																								
	CDR			**JMO**			**GMW**						**WNB**						**TRP**				**BJN**		
	2	**3**	**4**	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
(*tekstur batang*)																									
Internode distance (*Jarak antar buku*)	3	2	3	2	3	3	2	2	3	2	2	2	2	2	3	2	3	3	2	3	4	4	4	3	2
Stem growth type (*Tipe pertumbuhan batang*)	2	2	2	3	1	3	3	3	3	3	3	3	2	2	2	2	2	3	2	2	3	3	1	2	3
Legitimate shoot color (*Warna tunas legitim*)	3	3	3	1	2	1	1	2	2	2	1	2	2	3	3	3	3	1	1	1	3	1	2	2	2
Legitimate axis angle (*Sudut sumbu legitim*)	2	3	3	3	2	2	2	2	2	3	3	3	3	2	3	2	2	2	2	2	2	1	3	2	2
Pollen form/shape (*Bentuk benang sari*)	3	3	3	3	3	3	3	2	3	2	3	3	2	2	2	2	2	2	2	2	2	2	2	2	3
Petal color (*Warna kelopak*)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pistil color (*Warna putik*)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Domatia position (*Posisi domatia*)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Position of stamen and pistil (*Posisi benang sari dan putik*)	2	2	1	1	1	1	1	1	2	2	2	2	2	1	1	2	1	1	1	2	2	2	1	1	3
Ripe fruit color (*Warna matang buah*)	6	6	6	6	6	4	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	5	5	6	5
Peeled seed shape (*Bentuk biji kupas*)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Center gap of seed (*Celah tengah biji*)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Parchment color (*Warna parchment*)	2	3	3	2	2	2	3	3	3	3	4	3	4	4	3	3	3	4	4	4	3	3	3	3	3
Peeled seed color (*Warna biji kupas*)	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	3	3	3

Based on the morphological characteristics of 56 Robusta coffee accessions from Temanggung Regency, a striking diversity was observed, especially in the color of the apical stem and ripe fruit. The color of the apical stem varies from reddish yellow to dark green, while the color of ripe fruit ranges from yellowish green to dark red. Leaf organs show variations in leaf color, edge shape, and leaf position, although some characters, such as the shape of the tip and leaf veins, are relatively uniform. Stem color and stem surface texture also show clear differentiation between accessions. Meanwhile, flower characters tend to be uniform, especially in the color of the petals and pistils. Fruit characters, such as the shape of peeled seeds and parchment color, also show differences between accessions. In general, these results indicate that morphology can serve as an indicator of genetic diversity among Temanggung Robusta coffee accessions**.**

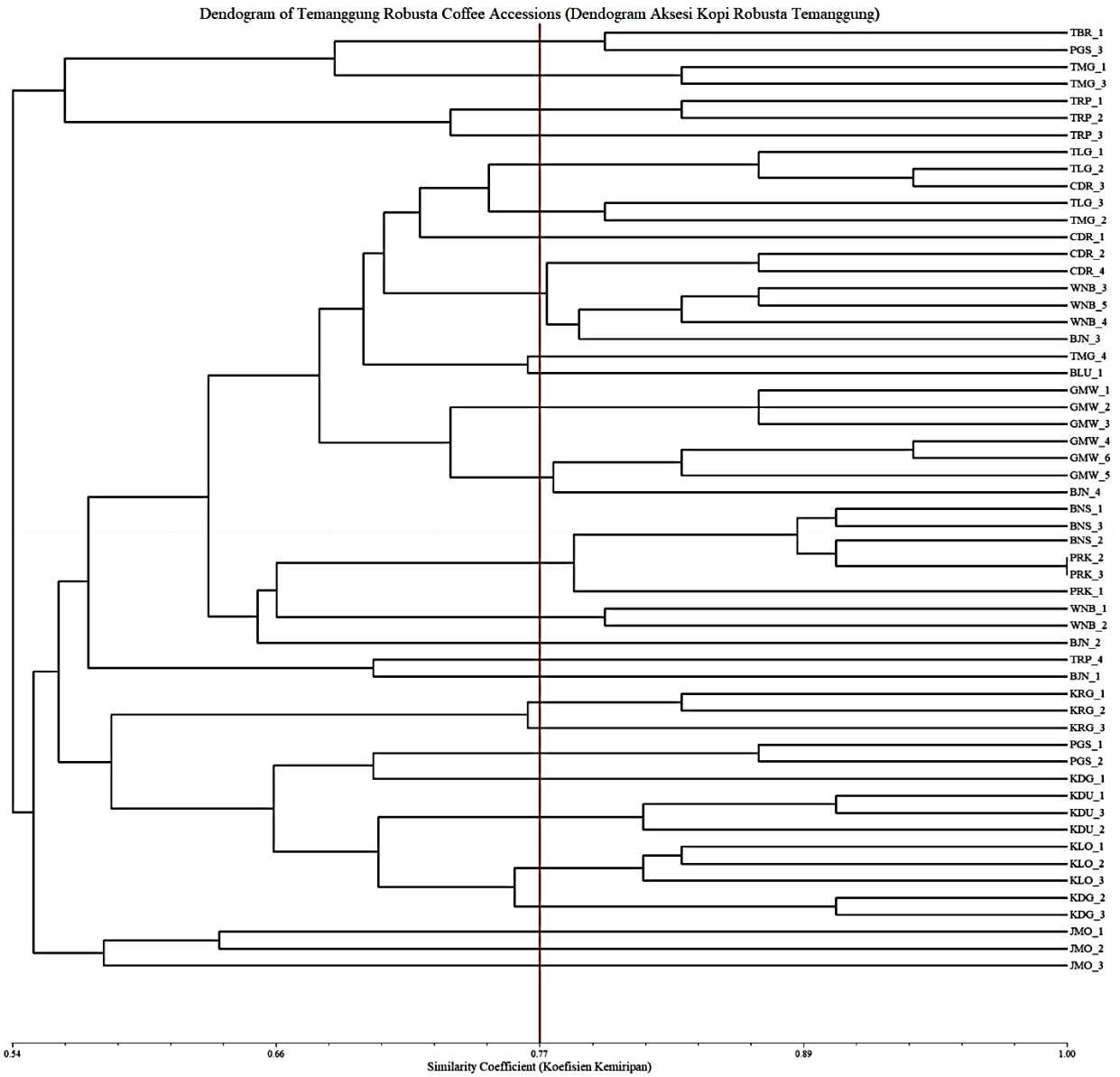

Figure 4. Dendogram of 56 Robusta coffee accessions based on morphology characters. (*Dendogram 56 aksesi kopi Robusta berdasarkan karakter morfologi*).

The results of the dendrogram analysis of 56 Robusta coffee accessions from 17 sub-districts in Temanggung Regency showed that there was considerable genetic variation in morphological characters. The dendrogram compiled using the UPGMA method and morphological characters of leaves, stems, flowers, and fruits showed the formation of several groups of accessions with varying levels of similarity. Accessions PRK_2 and PRK_3 from Parakan District have a similarity coefficient of 1.00, indicating that they have identical morphological characters. This indicates the possibility that both come from the same parent plant or that they are the result of vegetative propagation from a similar source. In addition, several other accession pairs, such as CDR_1 and CDR_2, TRP_1 and TRP_2, and WNB_2 and WNB_3, also show high similarity coefficient values (>0.90), indicating a close phenotypic relationship. On the other hand, there are pairs of accessions with low similarity (<0.50), such as TBR_1 and GMW_1, which reflect significant morphological differences, either due to genetic factors or local environmental influences. Overall, the dendrogram clustering pattern shows that variations in apical stem color and ripe fruit color are dominant factors in group separation. This information is important as a basis for selection to select the superior parents for Robusta coffee breeding programs in the Temanggung area.

Table 3. Similarity matrix based on morphological markers (*Matriks kemiripan berdasarkan penanda morfologi*).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	1.00																						
2	0.53	1.00																					
3	0.47	0.87	1.00																				
4	0.50	0.80	0.80	1.00																			
5	0.60	0.57	0.53	0.53	100																		
6	0.50	0.70	0.60	0.57	0.83	1.00																	
7	0.53	0.57	0.53	0.53	0.77	0.77	1.00																
8	0.67	0.60	0.57	0.50	0.70	0.73	0.67	1.00															
9	0.63	0.53	0.50	0.47	0.63	0.63	0.60	0.87	1.00														
10	0.80	0.63	0.57	0.57	0.63	0.60	0.63	0.77	0.70	1.00													
11	0.60	0.63	0.63	0.67	0.50	0.50	0.50	0.60	0.60	0.63	1.00												
12	0.50	0.73	0.73	0.80	0.47	0.47	0.50	0.53	0.47	0.53	0.60	1.00											
13	0.77	0.57	0.57	0.57	0.57	0.50	0.57	0.67	0.67	0.73	0.83	0.57	1.00										
14	0.63	0.73	0.73	0.67	0.57	0.57	0.60	0.63	0.57	0.70	0.67	0.76	0.70	1.00									
15	0.53	0.70	0.73	0.67	0.57	0.53	0.60	0.67	0.67	0.60	0.70	0.67	0.67	0.76	1.00								
16	0.57	0.67	0.63	0.60	0.67	0.70	0.57	0.73	0.67	0.63	0.70	0.57	0.63	0.70	0.63	1.00							
17	0.57	0.73	0.70	0.67	0.70	0.63	0.57	0.70	0.63	0.63	0.63	0.67	0.67	0.76	0.70	0.87	1.00						
18	0.50	0.77	0.73	0.70	0.67	0.67	0.53	0.67	0.60	0.60	0.70	0.63	0.60	0.67	0.63	0.90	0.90	1.00					
19	057	0.63	0.60	0.60	0.53	0.50	0.47	0.63	0.60	0.63	0.73	0.53	0.63	0.70	0.67	0.80	0.80	0.80	1.00				
20	0.57	0.63	0.60	0.57	0.70	0.67	0.53	0.70	0.63	0.57	0.67	0.57	0.67	0.67	0.60	0.90	0.90	0.87	0.77	1.00			
21	0.57	0.63	0.60	0.57	0.70	0.67	0.53	0.70	0.63	0.57	0.67	0.57	0.67	0.67	0.60	0.90	0.90	0.87	0.77	1.00	1.00		
22	0.40	0.57	0.67	0.67	0.50	0.53	0.47	0.57	0.60	0.47	0.57	0.60	0.47	0.63	0.67	0.67	0.60	0.60	0.63	0.57	0.57	1.00	
23	0.43	0.57	0.60	0.57	0.50	0.60	0.47	0.63	0.60	0.47	0.53	0.53	0.50	0.63	0.63	0.63	0.57	0.57	0.60	0.57	0.57	0.83	1.00
24	0.50	0.53	0.63	0.63	0.53	0.57	0.50	0.67	0.70	0.57	0.60	0.50	0.57	0.53	0.63	0.70	0.63	0.63	0.67	0.60	0.60	0.90	0.80
25	0.53	0.50	0.53	0.50	0.57	0.53	0.60	0.73	0.60	0.57	0.57	0.53	0.50	0.70	0.63	0.73	0.67	0.67	0.67	0.70	0.70	0.67	0.63
26	0.57	0.47	0.50	0.50	0.67	0.63	0.53	0.67	0.77	0.60	0.60	0.50	0.60	0.60	0.63	0.70	0.63	0.63	0.60	0.67	0.67	0.76	0.73
27	0.43	0.47	0.57	0.53	0.67	0.63	0.60	0.73	0.63	0.47	0.47	0.53	0.47	0.53	0.53	0.67	0.67	0.67	0.53	0.70	0.70	0.67	0.70
28	0.60	0.53	0.50	0.50	0.63	0.67	0.60	0.63	0.67	0.60	0.50	0.60	0.63	0.70	0.57	0.70	0.67	0.60	0.53	0.67	0.67	0.67	0.70
29	0.50	0.50	0.53	0.63	0.63	0.60	0.50	0.60	0.63	0.50	0.60	0.63	0.53	0.63	0.60	0.67	0.60	0.60	0.57	0.63	0.63	0.80	0.63
30	0.47	0.47	0.50	0.60	0.60	0.57	0.47	0.47	0.60	0.47	0.57	0.57	0.50	0.53	0.50	0.63	0.63	0.63	0.53	0.67	0.67	0.76	0.60
31	0.37	0.70	0.77	0.70	0.47	0.57	0.53	0.47	0.50	0.47	0.47	0.67	0.40	0.70	0.60	0.60	0.67	0.70	0.63	0.57	0.57	0.73	0.63
32	0.47	0.63	0.70	0.73	0.47	0.43	0.53	0.57	0.57	0.50	0.63	0.77	0.60	0.73	0.67	0.50	0.57	0.53	0.50	0.47	0.47	0.67	0.53
33	0.47	0.87	0.93	0.76	0.57	0.63	0.50	0.50	0.50	0.57	0.63	0.67	0.57	0.73	0.73	0.63	0,70	0.73	0.60	0.60	0.60	0.63	0.63
34	0.43	0.63	0.77	0.76	0.57	0.50	0.40	0.47	0.53	0.47	0.60	0.77	0.57	0.70	0.67	0.53	0.67	0.63	0.53	0.57	0.57	0.73	0.60

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
35	0.40	0.50	0.53	0.53	0.50	0.57	0.40	0.47	0.47	0.43	0.57	0.40	0.50	0.57	0.47	0.63	0.57	0.60	0.57	0.67	0.67	0.53	0.53
36	0.43	0.47	0.53	0.57	0.50	0.50	0.50	0.57	0.57	0.40	0.63	0.60	0.53	0.63	0.60	0.60	0.53	0.53	0.57	0.60	0.60	0.67	0.67
37	0.43	0.53	0.57	0.47	0.53	0.60	0.57	0.60	0.60	0.43	0.43	0.50	0.53	0.57	0.60	0.53	0.53	0.43	0.47	0.57	0.57	0.57	0.60
38	0.47	0.67	0.73	0.60	0.43	0.57	0.50	0.50	0.50	0.53	0.60	0.60	0.57	0.77	0.63	0.63	0.63	0.60	0.70	0.60	0.60	0.67	0.63
39	0.40	0.63	0.70	0.50	0.40	0.47	0.40	0.50	0.47	0.47	0.57	0.50	0.47	0.63	0.57	0.60	0.60	0.60	0.73	0.57	0.57	0.60	0.57
40	0.47	0.63	0.70	0.57	0.43	0.43	0.47	0.50	0.50	0.50	0.60	0.63	0.57	0.77	0.70	0.57	0.63	0.57	0.70	0.60	0.60	0.60	0.57
41	0.40	0.63	0.77	0.67	0.53	0.50	0.47	0.47	0.47	0.47	0.70	0.63	0.57	0.67	0.67	0.63	0.63	0.70	0.70	0.67	0.67	0.67	0.60
42	0.53	0.67	0.73	0.73	0.50	0.57	0.50	0.47	0.40	0.57	0.73	0.73	0.63	0.80	0.57	0.63	0.63	0.67	0.63	0.67	0.67	0.57	0.53
43	0.43	0.70	0.83	0.70	0.50	0.57	0.50	0.53	0.50	0.50	0.73	0.70	0.60	0.73	0.70	0.63	0.63	0.70	0.63	0.67	0.67	0.70	0.67
44	0.57	0.70	0.70	0.63	0.63	0.57	0.50	0.53	0.50	0.63	0.63	0.57	0.53	0.73	0.63	0.60	0.67	0.67	0.70	0.57	0.57	0.57	0.50
45	0.53	0.67	0.67	0.57	0.63	0.63	0.57	0.60	0.50	0.60	0.60	0.60	0.50	0.77	0.57	0.73	0.67	0.77	0.70	0.63	0.63	0.57	0.57
46	0.43	0.67	0.77	0.63	0.60	0.50	0.50	0.50	0.57	0.47	0.50	0.67	0.50	0.67	0.63	0.57	0.70	0.67	0.57	0.60	0.60	0.67	0.53
47	0.43	0.70	0.83	0.67	0.57	0.50	0.50	0.53	0.53	0.53	0.67	0.60	0.60	0.63	0.70	0.67	0.67	0.70	0.67	0.57	0.57	0.70	0.57
48	0.47	0.63	0.77	0.67	0.57	0.43	0.50	0.53	0.53	0.50	0.60	0.73	0.57	0.70	0.67	0.60	0.67	0.63	0.60	0.57	0.57	0.70	0.57
49	0.57	0.50	0.47	0.47	0.53	0.53	0.50	0.57	0.53	0.50	0.57	0.47	0.57	0.57	0.47	0.63	0.63	0.53	0.67	0.67	0.67	0.43	0.40
50	0.57	0.53	0.50	0.50	0.60	0.63	0.60	0.57	0.53	0.60	0.60	0.43	0.57	0.53	0.43	0.67	0.60	0.63	0.63	0.57	0.57	0.40	0.40
51	0.57	0.60	0.57	0.47	0.60	0.60	0.63	0.57	0.50	0.60	0.53	0.50	0.57	0.67	0.53	0.63	0.63	0.60	0.53	0.60	0.60	0.37	0.37
52	0.47	0.63	0.63	0.50	0.47	0.53	0.43	0.53	0.50	0.53	0.60	0.43	0.53	0.57	0.53	0.67	0.57	0.63	0.60	0.67	0.67	0.50	0.53
53	0.50	0.60	0.63	0.57	0.43	0.40	0.40	0.43	0.37	0.60	0.50	0.60	0.50	0.60	0.53	0.57	0.63	0.57	0.63	0.60	0.60	0.47	0.47
54	0.47	0.63	0.63	0.50	0.50	0.50	0.33	0.57	0.50	0.53	0.47	0.50	0.40	0.60	0.57	0.63	0.67	0.63	0.67	0.67	0.67	0.57	0.63
55	0.43	0.60	0.70	0.63	0.53	0.47	0.50	0.60	0.57	0.47	0.63	0.73	0.57	0.77	0.73	0.67	0.73	0.67	0.67	0.63	0.63	0.70	0.67
56	0.50	0.63	0.70	0.70	0.37	0.43	0.47	0.50	0.47	0.53	0.67	0.73	0.53	0.73	0.67	0.57	0.57	0.57	0.70	0.53	0.53	0.70	0.67

	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
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24	1.00																						
25	0.63	1.00																					
26	0.80	0.83	1.00																				
27	0.70	0.80	0.83	1.00																			
28	0.63	0.63	0.73	0.63	1.00																		
29	0.70	0.73	0.83	0.73	0.77	1.00																	
30	0.73	0.70	0.80	0.77	0.73	0.90	1.00																
31	0.63	0.60	0.57	0.60	0.53	0.60	0.57	1.00															
32	0.57	0.53	0.57	0.50	0.53	0.67	0.57	0.73	1.00														
33	0.60	0.57	0.53	0.53	0.50	0.50	0.47	0.77	0.70	1.00													
34	0.63	0.53	0.63	0.63	0.57	0.70	0.67	0.80	0.87	0.77	1.00												

	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
35	0.50	0.50	0.53	0.50	0.47	0.50	0.50	0.57	0.50	0.60	0.57	1.00											
36	0.57	0.60	0.67	0.60	0.60	0.73	0.63	0.57	0.73	0.57	0.73	0.63	1.00										
37	0.57	0.43	0.53	0.53	0.57	0.53	0.43	0.60	0.63	0.57	0.57	0.57	0.60	1.00									
38	0.60	0.53	0.50	0.50	0.53	0.53	0.43	0.77	0.63	0.67	0.67	0.63	0.57	0.67	1.00								
39	0.57	0.57	0.47	0.53	0.40	0.47	0.40	0.67	0.53	0.63	0.57	0.57	0.50	0.60	0.87	1.00							
40	0.53	0.67	0.50	0.57	0.47	0.53	0.43	0.67	0.67	0.63	0.63	0.50	0.57	0.60	0.87	0.87	1.00						
41	0.57	0.63	0.57	0.67	0.47	0.60	0.57	0.67	0.63	0.70	0.70	0.60	0.67	0.47	0.70	0.70	0.77	1.00					
42	0.47	0.57	0.47	0.53	0.57	0.60	0.57	0.70	0.67	0.67	0.70	0.63	0.63	0.50	0.77	0.63	0.70	0.80	1.00				
43	0.60	0.63	0.60	0.67	0.53	0.63	0.60	0.73	0.67	0.77	0.73	0.63	0.67	0.53	0.77	0.70	0.77	0.93	0.87	1.00			
44	0.50	0.63	0.53	0.53	0.50	0.57	0.53	0.60	0.57	0.70	0.60	0.53	0.47	0.40	0.63	0.67	0.70	0.70	0.67	0.67	1.00		
45	0.47	0.70	0.60	0.60	0.63	0.63	0.53	0.67	0.57	0.67	0.60	0.53	0.57	0.43	0.67	0.67	0.63	0.67	0.70	0.67	0.80	1.00	
46	0.57	0.53	0.57	0.63	0.50	0.60	0.57	0.77	0.77	0.70	0.83	0.47	0.57	0.57	0.67	0.67	0.70	0.73	0.60	0.70	0.70	0.70	1.00
47	0.67	0.50	0.53	0.53	0.47	0.57	0.47	0.67	0.67	0.77	0.73	0.47	0.53	0.57	0.70	0.73	0.67	0.70	0.57	0.67	0.67	0.70	0.80
48	0.60	0.57	0.60	0.60	0.57	0.67	0.57	0.67	0.80	0.70	0.87	0.43	0.67	0.57	0.67	0.70	0.70	0.70	0.63	0.67	0.63	0.70	0.87
49	0.47	0.53	0.50	0.50	0.53	0.53	0.50	0.40	0.50	0.43	0.50	0.47	0.60	0.50	0.60	0.60	0.60	0.50	0.53	0.43	0.57	0.60	0.57
50	0.50	0.50	0.53	0.53	0.53	0.50	0.47	0.43	0.47	0.47	0.47	0.43	0.53	0.40	0.57	0.57	0.50	0.53	0.57	0.47	0.60	0.70	0.53
51	0.40	0.60	0.50	0.53	0.53	0.50	0.43	0.43	0.50	0.53	0.43	0.47	0.47	0.43	0.57	0.60	0.63	0.53	0.57	0.53	0.63	0.70	0.57
52	0.53	0.70	0.57	0.57	0.40	0.47	0.43	0.50	0.50	0.67	0.47	0.57	0.50	0.50	0.60	0.67	0.67	0.60	0.53	0.60	0.50	0.60	0.53
53	0.50	0.60	0.43	0.50	0.33	0.37	0.37	0.53	0.43	0.63	0.47	0.43	0.40	0.47	0.60	0.63	0.63	0.57	0.57	0.57	0.53	0.50	0.50
54	0.53	0.63	0.53	0.60	0.47	0.47	0.47	0.60	0.40	0.63	0.53	0.60	0.53	0.53	0.63	0.77	0.67	0.60	0.53	0.60	0.67	0.60	0.60
55	0.60	0.67	0.63	0.67	0.63	0.67	0.57	0.67	0.73	0.67	0.80	0.47	0.77	0.53	0.70	0.70	0.77	0.73	0.67	0.73	0.63	0.70	0.77
56	0.60	0.60	0.53	0.53	0.53	0.60	0.50	0.73	0.67	0.63	0.70	0.50	0.63	0.53	0.80	0.73	0.77	0.73	0.80	0.80	0.60	0.63	0.60

	47	48	49	50	51	52	53	54	55	56
47	1.00									
48	0.87	1.00								
49	0.53	0.60	1.00							
50	0.57	0.57	0.83	1.00						
51	0.53	0.53	0.70	0.77	1.00					
52	0.60	0.57	0.60	0.53	0.63	1.00				
53	0.57	0.53	0.53	0.47	0.53	0.70	1.00			
54	0.60	0.60	0.50	0.40	0.47	0.63	0.67	1.00		
55	0.73	0.87	0.63	0.60	0.60	0.53	0.57	0.63	1.00	
56	0.63	0.70	0.50	0.47	0.43	0.50	0.60	0.63	0.77	1.00

Note: Similarity coefficient with the color "n" there is no morphological difference in the observed variables. (*Koefisien kemiripan dengan warna "n" tidak ada perbedaan secara morfologi pada variabel yang diamati*).

DISCUSSION

Field research was conducted in 17 sub-districts in Temanggung Regency, Central Java. This inventory produced morphological characteristic data from 56 robusta coffee accessions in the entire observation area. Each sub-district has 1 to 6 representative accessions, with the fewest in the Tembarak District (1 accession) and the most in the Gemawang District (6). Accessions within the same region tend to show high morphological similarity. Not all areas in Temanggung Regency cultivate coffee; several also cultivate Arabica coffee. The number of accessions taken is also based on how dominant Robusta coffee cultivation is in the area.

In this study, after obtaining planting material in the form of stem cuttings, planting was carried out at the same location under a set of environmental conditions as homogeneous as possible. This aims to suppress the influence of environmental factors so that the genetic diversity expressed in the morphology of Robusta coffee can be identified properly, without interaction with environmental factors, making it a translocation method. The method of planting plant populations from various sources based on location by translocation can be used to highlight phenotypic differences with minimal environmental influence (Dhayani and Abeli, 2022).

The results of the study showed that there was substantial morphological variation among 56 Robusta coffee accessions from Temanggung Regency, especially in the apical stem and ripe fruit colors. This variation reflects significant genetic differences that could be used in coffee plant conservation and breeding. Characters such as apical stem color, which varies from reddish yellow to dark green, and ripe fruit color, which ranges from yellowish green to dark red, are important indicators in distinguishing one accession from another. This is in accordance with the research of Taibi *et al*. (2019) that plant morphological characters are influenced by genetic and environmental factors and can be used as a basis for phenotypic identification in efforts to select and germplasm conservation.

Kinship analysis using a dendrogram shows that some accessions are very closely related, such as PRK_2 and PRK_3, which have a similarity coefficient of 1.00. This indicates that both are likely to come from the same genetic source or from the same plant but planted in different locations. On the other hand, there are also groups of accessions with low similarity that show high genetic diversity. Accessions with low similarity have strategic value as genetic sources in the assembly of new varieties, especially to increase plant adaptability and productivity (Hickey *et al*., 2019).

The identified morphological diversity can serve as a basis for initial selection in breeding programs, especially to identify cross-pollination parents with broad genetic differences. According to Voss-Fels *et al*. (2019), broad genetic variation is an important prerequisite for improving agronomic traits through plant breeding. In addition, the results of this study support long-term conservation efforts for Robusta coffee germplasm, both in situ and ex situ, especially in the management of collection gardens and genetic banks.

The similarity coefficient is calculated from the distribution of morphological character data, which is then presented as a dendrogram. The results are shown in the dendrogram (Figure 4), where the level of similarity between all accessions ranges from 54% to 100%. It can be observed that the genetic diversity of Temanggung Robusta coffee, based on the accessions observed, has a moderate level of diversity but is wide, as it is less than 50% (Kurnia *et al*., 2023). However, several accessions with strong characteristics have the potential to be a source of genetic diversity for robusta coffee.

In detail, if we review it based on the dendrogram obtained, we can see that there are accessions that are far apart in the dendrogram, such as TBR_1 (Tembarak) and JMO_3 (Jumo), which indicate large differences in morphological characters and, indirectly, the potential for significant genetic differences. This reflects the importance of the diversity of genetic resources in the Temanggung area. Accessions from several areas, such as Gemawang (GMW) and Bejen (BJN), appear to be distributed across multiple clusters, suggesting genetic heterogeneity within a sub-district. This could be due to the influence of microenvironment, farmer selection, or diverse seedling origins. This fairly complex cluster separation pattern indicates that the genetic diversity of Robusta coffee in Temanggung is moderate to high and does not entirely depend on geographic origin. This

supports the importance of comprehensive and selective conservation of germplasm, because each accession has its own genetic potential that can be utilized in breeding programs.

According to Prastowo and Arimarsetiowati (2019), the diversity observed may be influenced by environmental growth conditions and genetic distribution, driven by agronomic factors. In areas with close geographic proximity, there will tend to be identical climate patterns. This will affect how plant morphology is expressed to adapt to their growing environment, although also considering that all areas in the tropical zone tend to have similar and consistent climate characteristics (Rivai, 2023). The climate identity of a regional cluster will influence the morphological characteristics based on the agronomic side. Apart from the existence of deliberate genetic differences, such as the breeding process and polyploidy induction, according to Taylor *et al*. (2009), exposure to the environmental conditions described previously for a long time and even allowing abiotic stress to occur can cause mutations in plants so that they experience spontaneous and random genetic changes, which will affect plant morphology. These changes will be able to become even more diverse because Robusta coffee performs cross-pollination (Duque and Blair, 2022), which is different from Arabica, which is self-pollinating (Manrique and Thimann, 2002). Cross-pollination will cause a combination of genetic material so that diversity is created. This is also reinforced by the fact that most of the production of robusta coffee seeds is through seeds, and sometimes farmers even produce their own seeds.

Genetic diversity is a valuable resource for developing varieties and for collection purposes (Hoban *et al*., 2021). Through the genetic diversity of Robusta coffee accessions, which is indicated through variations in morphological characters, which strikingare quite diverse, it can be used for the collection of core accessions, the collection of cross parents with high genetic differences, and a valuable database to avoid genetic duplication in both breeding and conservation. In the research conducted, several morphological characteristics can also be observed, which characterize agronomic advantages, such as the distance between stem segments and the type of stem growth. Agronomically, a short to medium internode spacing of 2–5 cm is considered most beneficial. Short internodes allow more nodes to form per stem, increasing the number of lateral branch growth points and the potential for more flower and fruit clusters. This can lead to higher productivity per plant. In addition, plants with short internodes tend to have a more compact, dense crown, making them easier to prune, spray, and maintain overall. Plants also become more robust and resistant to falling over due to wind or fruit load (Wingten, 2004). However, if the distance between segments is too long (>6 cm), it will reduce the number of nodes per stem, resulting in a sparse plant crown, and make harvesting and management difficult (Matta *et al*., 2007).

Agronomically, the most profitable type of Robusta coffee stem growth is monopodial with a straight main stem and balanced primary branches. This structure forms a neat crown, facilitates pruning, spraying, and harvesting, and supports good light penetration and air circulation. Plants with stable stem growth are also more resistant to lodging and efficient in utilizing planting space. Conversely, irregular growth types can complicate plantation management and reduce productivity (Wingten, 2004). Examples of accessions with short interstem segments are CDR_1, JMO_1, WNB_1, WNB_2, and BJN_4. While examples of accession with a monopodial natural growth type include KDU_2, JMO_2, and BJN_2. Indirectly, it explains that the genetic diversity of coffee accessions can provide important genetic traits for several purposes, not only for conservation. Therefore, maintaining the diversity and conservation of Temanggung Robusta coffee germplasm is important.

The considerable morphological variation observed among the 56 Robusta coffee accessions from Temanggung provides critical insights into the extent of genetic diversity present within the local germplasm. Variations in apical stem color, internode distance, and ripe fruit color are not only indicative of underlying genetic differentiation but also represent key agronomic traits linked to plant vigor, canopy architecture, and yield potential. Accessions exhibiting short to medium internode spacing and monopodial stem growth are particularly valuable, as these traits contribute to compact plant structure, enhanced light interception, and increased flower and fruit density factors that directly support higher productivity and ease of cultivation. The differentiation observed among accessions

with low similarity coefficients (<0.50) further suggests a broad genetic base that can be strategically exploited to develop new hybrids with superior performance and resilience. Consequently, the morphological characterization data generated in this study provides a scientific foundation for the identification, selection, and conservation of elite Robusta coffee accessions, ensuring the sustainable utilization of genetic resources in future breeding and germplasm improvement programs.

CONCLUSION

This study showed that there was quite wide morphological diversity among 56 Robusta coffee accessions from 17 sub-districts in Temanggung Regency. The most varied morphological characters were observed in the apical stem and ripe fruit color, which are important indicators for identifying accessions. Relationship analysis using dendrograms revealed several main groups with varying levels of similarity, indicating that genetic diversity among accessions was not entirely influenced by geographical proximity. Accessions PRK_2 and PRK_3 had the highest similarity (1.00), while several other accessions showed striking differences. Several accessions also showed favorable agronomic characters, such as short internode distance, varying ripe fruit color, and monopodial stem growth, which can serve as a basis for selecting for superior varieties. These results confirm that morphological characterization is an effective approach in identifying genetic potential for the conservation and management of local Robusta coffee genetic resources.

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AUTHOR CONTRIBUTIONS

AHA: conducting research planning, take care of some permits, processing data, collect accessions, maintain accession, collecting data in the field, and writing draft articles; BA: collecting accessions, collecting data in the field, and writing articles; BAFR: collecting accessions, collecting data in the field, and writing articles; ANO: collecting accessions, collecting data in the field, inputting data into tabulations, and writing articles; EI: collecting accessions, collecting data in the field, and writing articles.

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