Revelation and Science
Special Issue: Plant Science 3 (1447H/2026) 56-70

Morphological Assessment of Genetic Variation in Eggplant (*Solanum melongena* L.) Cultivars

Syarifah Abharina Syed Syamsulharis, Halimaton Saadiah Othman*
Department of Plant Science, Kulliyyah of Science,
International Islamic University Malaysia (IIUM),
Jalan Sultan Ahmad Shah, Kuantan, Pahang, Malaysia.

ABSTRACT
Eggplant (*Solanum melongena* L.) is an economically and nutritionally important vegetable crop exhibiting wide morphological variation. This study assessed genetic diversity among 23 eggplant accessions using 38 morphological descriptors (24 quantitative and 14 qualitative) following IBPGR (1990) guidelines. Significant variation ($p < 0.05$) was observed for key agronomic traits, including fruit weight, fruit length, plant height, and leaf morphology. Cluster analysis (UPGMA) grouped the accessions into three distinct clusters, with Purple Ball and White Pearl emerging as contrasting cultivars. These findings highlight the importance of morphological characterisation in identifying genetic diversity, guiding breeding strategies, and supporting the improvement of eggplant cultivars for yield, adaptability, and consumer preferences.

Keywords: Eggplant, *Solanum Melongena*, Morphological Characterization, Genetic diversity, Cluster Analysis

Introduction

Eggplant (*Solanum melongena* L.), also known as aubergine or brinjal, is a member of the Solanaceae family and ranks as one of the most important solanaceous crops worldwide, after tomato, potato, pepper, and tobacco (Weese & Bohs, 2010). Globally, annual eggplant production surpasses 50 million tonnes, with Asia accounting for more than 90% of total cultivation, led by China, India, and Bangladesh (Mat Sulaiman et al., 2020). In addition to its economic significance, eggplant plays a vital role in household nutrition and livelihoods, particularly in developing countries where it serves as a staple vegetable.

Nutritionally, eggplant is a low-calorie food enriched with vitamins, dietary fiber, and minerals such as potassium, calcium, sodium, and iron (Michałojć & Buczkowska, 2008). It is particularly valued for its high antioxidant capacity, primarily due to phenolic acids and anthocyanins, such as nasunin, which confer health-promoting properties including protection against cardiovascular diseases, diabetes, and obesity (Marek et al., 2009; Cassidy et al., 2013; Khoo et al., 2017; Gürbüz et al., 2018). Beyond its nutritional value, eggplant has been traditionally used in folk medicine for treating ailments such as asthma, hypertension, and sore throat (Bhaskar & Kumar, 2015; Mahanta & Kalita, 2020). This combination of nutritional, medicinal, and culinary importance underpins the crop's wide adaptability and consumer demand.

One of the most remarkable features of eggplant is its wide morphological diversity, reflected in fruit size, shape, color, and prickliness (Sękara et al., 2007; Ali et al., 2011). This variation is important for consumer acceptance, as fruit appearance strongly influences market preference. For example, round purple fruits dominate in South Asia, whereas elongated light purple or green fruits are preferred in Southeast Asia (Taher et al., 2017). Such morphological diversity also provides a foundation for breeding programs, where genetic variability is critical for developing cultivars with improved yield, resistance to pests and diseases, and better adaptation to environmental stresses (Oladosu et al., 2021).

Despite its global significance, the genetic base of cultivated eggplant is considered narrow compared with other

**Corresponding author:*
Halimaton Saadiah Othman
Kulliyyah of Science,
International Islamic University Malaysia (IIUM)
Email: halimatonsaadiah@iium.edu.my

solanaceous crops (Knapp, 2013). The domestication process has reduced variation in traits such as fruit size and color, highlighting the need for systematic germplasm characterisation (Vorontsova & Knapp, 2012). While molecular markers provide valuable insights into genetic relationships,morphological characterisation remains an essential and cost-effective step in germplasm evaluation (Uddin et al., 2021; Musa et al., 2020). Morphological descriptors capture both qualitative and quantitative traits that directly relate to agronomic performance, thus offering practical information for breeders.

In Malaysia, eggplant is a popular vegetable cultivated in home gardens and commercial farms, yet production is insufficient to meet growing domestic demand (Jusoh & Mahmood, 2006). Imports from neighboring countries are common, and limited systematic research has been conducted to assess the available genetic resources. Without adequate characterisation of local and introduced accessions, opportunities to broaden the genetic base and improve existing cultivars remain underexploited. Therefore, this study was undertaken to assess the morphological diversity of 23 eggplant accessions using standard descriptors. By identifying contrasting and unique accessions, this work provides baseline information to support future eggplant breeding efforts in Malaysia.

Materials and Method

Plant Material Preparation

A total of 23 eggplant (*Solanum melongena* L.) accessions were used in this study (Table 1). Seeds were obtained from commercial seed suppliers and research sources. The experiment was carried out at the Glasshouse and Nursery Complex (GNC), Kulliyyah of Science, International Islamic University Malaysia (IIUM), Kuantan Campus, located at 3°46′N, 103°19′E. The region is characterized by a tropical monsoon climate, with temperatures ranging between 26 and 32 °C and consistently high humidity. The glasshouse provided semi-controlled conditions with natural light and regular watering, minimizing environmental variability that could otherwise influence trait expression.

Table 1: *List of 23 eggplant accessions that were used in the study*

No.	Accessions name	Accessions code
1.	White Pearl	WP
2.	Mini ball	M.B
3.	Apple	Apple
4.	Terung Bulat	T.B
5.	White Ball	W.B
6.	Ulam Bulat	U.B
7.	Puteri	P3
8.	Purple Ball	Purple Ball
9.	Bulat Ungu	B.U
10.	Terung Bulat Putih	T.B.P
11.	Terung Putih Kedut	TPK
12.	Thai Giant	T.G
13.	Lezata F1	Lezata
14.	Terung Panjang Jaguh	TPJ
15.	Bride 323	Bride
16.	Icicle	Icicle
17.	Benang Panjang	Benang Panjang
18.	Ratih Hijau	R.H
19.	Monkey	Monkey
20.	Antaboga	Antaboga
21.	Hijau Gading	H.G
22.	Panjang Ungu	Pnjg ungu
23.	Prince	Prince

Seeds were first sown in germination trays containing a substrate mixture of peat moss and topsoil in a 2:1 ratio. After four weeks of growth, vigorous seedlings were transplanted into polybags measuring 40 × 40 cm, each filled with sterilized topsoil and organic compost in a 3:1 ratio. Plants were arranged at a spacing of 60 × 60 cm to allow for proper growth and air circulation.

Throughout the experimental period, standard agronomic practices, including manual weeding, irrigation, and pest management, were uniformly applied to all accessions to avoid confounding effects. The experimental design followed a Randomized Completely Block Design (RCBD) with three replications. Each replication contained three plants per accession, giving a total of nine plants for each accession. The RCBD was selected because it helps to reduce the impact of environmental heterogeneity within the glasshouse and improves the accuracy of statistical comparisons among treatments.

Morphological Evaluation

Morphological evaluation was performed using the descriptors recommended by the International Board for Plant Genetic Resources (IBPGR, 1990). In total, 38 traits were evaluated, of which 24 were quantitative and 14 were qualitative. The quantitative traits included measurements such as plant height, stem diameter, leaf blade length and width, leaf petiole length, number of primary branches, days to flowering, days to first harvest, flower diameter, pistil length, stamen length, fruit length and diameter, pedicel length, fruit weight, number of fruits per plant, and number of locules per fruit.

The qualitative traits recorded were plant growth habit, degree of leaf lobing, presence and density of prickles, corolla color, prickliness of flower buds, fruit shape, fruit curvature, skin color at mature stages, and fruit cross-sectional shape. Data for quantitative traits were measured using rulers, digital calipers, and an electronic balance, while qualitative traits were scored using descriptive categories or a 1–9 scale as specified in the IBPGR guidelines. Observations were recorded at three key stages of plant development: vegetative (45 days after transplanting), flowering (first anthesis), and maturity (harvest).

Statistical Analysis

The data collected from quantitative traits were subjected to analysis of variance (ANOVA) using SAS 9.4 software (SAS Institute Inc., Cary, NC, USA). When the F-test indicated significant differences among accessions at $p < 0.05$, Duncan's Multiple Range Test (DMRT) was applied to separate the means. Cluster analysis was performed using the Unweighted Pair Group Method with Arithmetic Mean (UPGMA) based on Euclidean distance coefficients to group the accessions according to similarity. A dendrogram was then constructed to illustrate the genetic relationships among the studied accessions.

Results

Qualitative Morphological Variation

The evaluation of 23 eggplant accessions revealed considerable variation across both qualitative and quantitative traits, indicating the presence of substantial morphological diversity within the germplasm. All accessions displayed an upright growth habit (Table 2) (Figure 1), which is typical of cultivated eggplants. However, significant variation was observed in leaf lobing, which ranged from very weak in accessions such as White Pearl and Apple to very strong in Purple Ball and Icicle (Table3). Corolla color also varied widely, with some accessions producing white flowers, as observed in White Pearl, while others such as Mini Ball and Bulat Ungu exhibited bluish-violet corollas (Table 4). Interestingly, the presence of prickles on flower buds was limited to only two accessions, Purple Ball and Bulat Ungu, distinguishing them from the rest of the collection (Table 4).

Fruit morphology exhibited the greatest diversity. Accessions differed not only in shape but also in pigmentation and external features. The fruits ranged from round, oval, elongated, and lobed shapes, and pigmentation varied from white and green to light purple and deep purple (Table 5). Differences in skin glossiness were also recorded, with some accessions producing glossy fruits while others were dull. These observations confirm the wide spectrum of morphological variation within cultivated eggplants and align with reports from earlier studies that highlighted fruit characteristics as key determinants of cultivar identity and consumer preference.

Quantitative Morphological Variation

The analysis of variance (ANOVA) revealed significant differences ($p < 0.05$) among accessions for all major quantitative traits, underscoring the diversity present in the collection. Purple Ball was particularly notable for its large leaf blade dimensions (359.19 cm^2), recording the highest mean values for both leaf length (19.62 cm) and width (18.28cm). In contrast, White Pearl consistently exhibited the lowest values across multiple vegetative traits, including stem diameter (2 cm) and leaf size (51.48 cm^2).

Variation was also evident in reproductive traits. Bulat Unggu produced the heaviest fruits (247.03g), reflecting its suitability as a high-yielding cultivar. On the other hand, Mini Ball (12.27g) and White Pearl (5.73g) produced the lightest fruits, consistent with their smaller overall plant architecture. The differences in days to flowering and fruit maturity further emphasized the diversity among accessions, with some cultivars flowering early (Puteri) and others showing delayed (Terung Panjang Putih) reproductive development. Such variation provides opportunities for selecting cultivars with desirable maturity periods tailored to specific production environments.

Cluster Analysis

Cluster analysis based on the Unweighted Pair Group Method with Arithmetic Mean (UPGMA) grouped the 23 accessions into three main clusters (Figure 2). Purple Ball and White Pearl formed distinct clusters of their own due to their contrasting morphological attributes, while the remaining accessions were distributed among an intermediate cluster. The distinct placement of Purple Ball and White Pearl highlight their genetic divergence, suggesting their potential as parental lines for hybridization. The grouping pattern observed in this study is consistent with findings from similar diversity studies conducted in Ethiopia and Bangladesh, where morphologically distinct accessions were identified as valuable breeding materials (Islam et al., 2018; Uddin et al., 2021; Musa et al., 2020).

Table 2: *Percentage ranges of variation in morphological plant growth.*

Plant growth habit	Accessions
Prostrate	0%
Intermediate	0%
Upright	100%

Table 3: *Morphological variations in leaf traits of eggplant accessions.*

Accessions	Leaf blade lobing	Leaf blade colors	Petiole color	Leaf hairs
WP	Very weak	Light green	Green	Few
M.B	Weak	Green	Greenish violet	Many
Apple	Very weak	Green	Violet	Many
TB	Weak	Green	Violet	Intermediate
WB	Very weak	Light green	Green	Many
UB	Intermediate	Light green	Green	Intermediate
P3	Strong	Light green	Green	Very many
Purple Ball	Very strong	Dark green	Dark violet	Very many
BU	Weak	Green	Green	Intermediate
TBP	Very weak	Green	Violet	Intermediate
TPK	Strong	Green	Dark violet	Intermediate
TG	Intermediate	Green	Greenish violet	Very many
Lezata	Strong	Green	Violet	Intermediate
TPJ	Very strong	Green	Violet	Intermediate
Bride	Very weak	Green	Greenish violet	Few
Icicle	Very strong	Dark green	Dark violet	Very many
BP	Intermediate	Green	Dark violet	Intermediate
R.H	Weak	Green	Green	Intermediate
Monkey	Strong	Green	Green	Intermediate
Antaboga	Weak	Light green	Greenish violet	Many
HG	Strong	Green	Green	Intermediate
PU	Weak	Green	Green	Few
Prince	Intermediate	Green	Greenish violet	Few

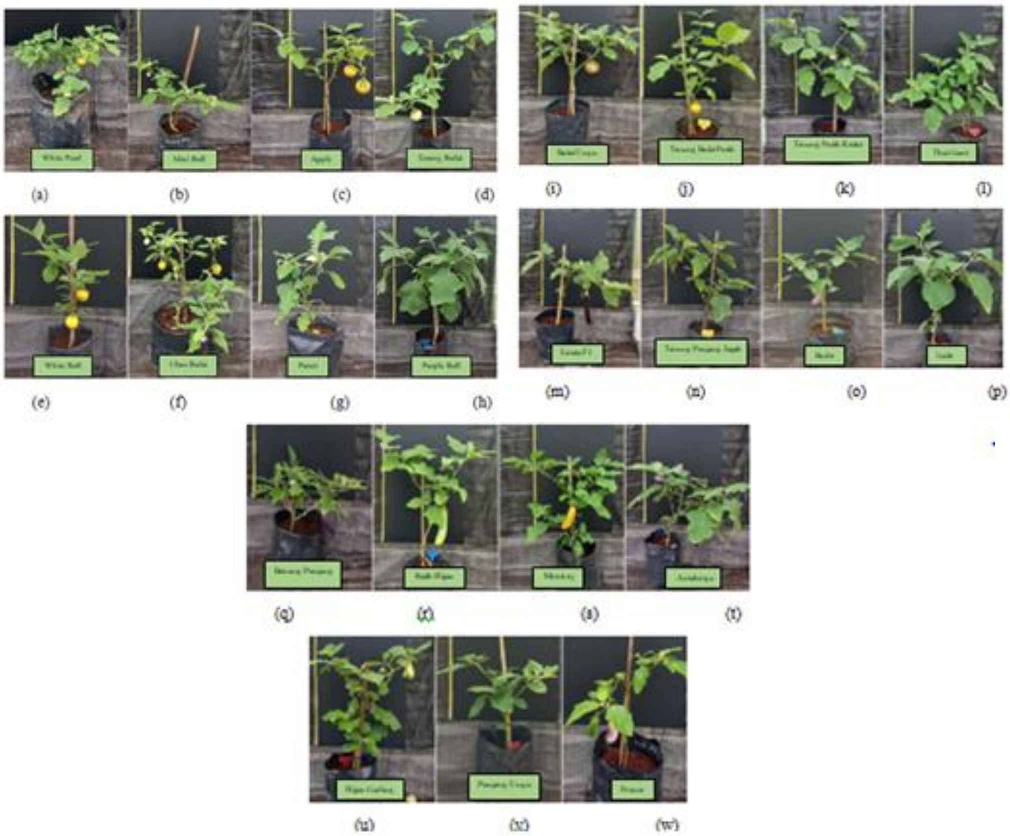


Figure 1: *Plant stands for all eggplant accessions.*

Table 4: *Morphological variations in flower traits of 23 eggplant accessions.*

Accessions	Corolla colour	Flowering habit	Flower bud spine	Pistil length
WP	White	Cluster	Absent	Both
MB	Bluish violet	Cluster	Absent	Long
Apple	Light violet	Solitary	Absent	Long
TB	Bluish violet	Solitary	Absent	Both
WB	Pale violet	Solitary	Absent	Long
UB	Pale violet	Cluster	Absent	Both
P3	Pale violet	Cluster	Absent	Long
Purple Ball	Light violet	Solitary	Present	Long
BU	Bluish violet	Solitary	Present	Long
TBP	Light violet	Solitary	Absent	Long
TPK	Greenish white	Solitary	Absent	Long
TG	Pale violet	Solitary	Absent	Long
Lezata	Pale violet	Cluster	Absent	Long
TPJ	Light violet	Solitary	Absent	Long
Bride	Pale violet	Solitary	Absent	Long
Icicle	Bluish violet	Cluster	Absent	Both
BP	Pale violet	Cluster	Absent	Short
RH	Light violet	Solitary	Absent	Long
Monkey	Pale violet	Solitary	Absent	Both
Antaboga	Light violet	Solitary	Absent	Long
HG	Pale violet	Cluster	Absent	Long
PU	Pale violet	Cluster	Absent	Long
Prince	Bluish violet	Solitary	Absent	Long

Table 5: *Morphological variations in fruit traits of 23 eggplant accessions.*

Accessions	Fruit curvature	Fruit cross-section	Fruit shape	Fruit apex shape	Fruit colour at maturity	Fruit colour distribution	Fruit position	Fruit length/ width ratio
WP	None	Circular, no grooves	¼	Rounded	White	Uniform	Pendant	Broader than long
MB	None	Circular, no grooves	¼	Rounded	Light purple	Uniform	Pendant	Broader than long
Apple	None	Few grooves	¼	Rounded	Green	Uniform	Pendant	Broader than long
TB	None	Circular, no grooves	¼	Depressed	Green	Uniform	Pendant	Broader than long
WB	None	Elliptic, no grooves	¼	Rounded	White	Uniform	Pendant	Broader than long
UB	None	Elliptic, no grooves	¼	Rounded	White	Uniform	Pendant	Broader than long
P3	-	-	-	-	Dark purple	Uniform	Pendant	Broader than long
Purple Ball	None	Circular, no grooves	¼	Rounded	Dark purple	Mottled	Pendant	Broader than long
BU	None	Circular, no grooves	¼	Rounded	Light purple	Mottled	Pendant	Broader than long
TBP	None	Few grooves	¼	Depressed	White	Uniform	Pendant	As long as broad
TPK	None	Many grooves	¼	Depressed	White	Uniform	Pendant	Broader than long
TG	None	Elliptic, no grooves	½	Rounded	Green	Uniform	Pendant	Twice as long as broad
Lezata	None	Elliptic, no grooves	¾	Rounded	Dark purple	Uniform	Pendant	Several times as long as broad
TPJ	Slightly curved	Elliptic, no grooves	½	Rounded	Dark purple	Mottled	Pendant	Three times as long as broad
Bride	Slightly curved	Elliptic, no grooves	¾	Rounded	Light purple	Mottled	Pendant	Three times as long as broad
Icicle	Slightly curved	Elliptic, no grooves	¾	Rounded	White	Uniform	Pendant	Several times as long

Table 6: *Evaluation of morphological traits among all accessions: values represent averages over all the observations for quantitative traits for plant traits.*

Accessions	Plant height (cm)	Plant breadth (cm)	Number primary branches	Stem Diameter (cm)
WP	22.30^{k}	41.80^{j}	2.00^{a}	2.00^{f}
M.B	43.00^{ij}	62.50^{def}	2.00^{a}	3.70^{abc}
Apple	60.20^{cdefg}	67.00^{bcde}	2.00^{a}	3.20^{cde}
TB	53.30^{defghi}	52.30^{fghij}j	2.00^{a}	2.60^{ef}
WB	50.30^{efghij}	47.40^{hij}	2.00^{a}	3.10^{cde}
UB	$57.40^{cdefghi}$	49.30^{ghij}	2.00^{a}	3.00^{cde}
P3	58.00^{cdefgh}	49.50^{ghij}	2.00^{a}	3.80^{abc}
Purple Ball	72.30^{abc}	60.10^{efg}	2.00^{a}	1.20^{g}
BU	68.30^{abcd}	78.00^{ab}	2.00^{a}	4.23^{a}
TBP	61.70^{bcdef}	63.70^{def}	2.00^{a}	3.10^{cde}
TPK	81.70^{a}	88.80^{a}	2.00^{a}	3.00^{cde}
TG	64.00^{bcde}	78.00^{ab}	2.00^{a}	2.50^{f}
Lezata	69.30^{abc}	73.70^{bcd}	2.00^{a}	2.60^{ef}
TPJ	46.50^{ghij}	46.00^{ij}	2.00^{a}	2.00^{hi}
Bride	52.80^{defghi}	65.80^{bcde}	2.00^{a}	3.40^{bcd}
Icicle	63.80^{bcde}	88.20^{a}	2.00^{a}	3.73^{abcd}
BP	37.00^{j}	40.70^{j}	2.00^{a}	2.70^{def}
R.H	74.60^{ab}	52.30^{gfhe}	2.00^{a}	3.63^{abc}
Monkey	58.30^{hedgf}	76.00^{bc}	2.00^{a}	3.30^{bcde}
Antaboga	61.00^{bcdefg}	64.00^{cdef}	2.00^{a}	3.50^{abc}
HG	62.00^{bcdef}	61.00^{efg}	2.00^{a}	4.00^{ab}
PU	44.30^{hij}	47.40^{jhi}	2.00^{a}	3.40^{bcd}
Prince	47.67^{fghij}	58.90^{efgh}	2.00^{a}	3.10^{cde}

Note: The average value in a column followed by the same letter is not significantly different ($p \leq 0.05$) according to Tukey's Honestly Significant Difference test.

Table 7: Evaluation of morphological traits among all accessions: values represent averages over all the observations for quantitative traits for leaf traits.

Accessions	Petiole length (cm)	Leaf blade length (cm)	Leaf blade width (cm)	Leaf Index (cm^2)
WP	1.80^{ef}	9.03^{j}	5.70^{j}	51.48^{g}
MB	1.33^{f}	9.63^{ij}	5.87^{i}	56.59^{g}
Apple	2.60^{def}	15.37^{d}	9.93^{def}	152.87^{de}
TB	1.93^{ef}	14.10^{defg}	9.37^{efg}	134.05^{efg}
WB	3.00^{def}	12.00^{ghi}	8.00fghi	96.00^{fgh}
UB	1.6^{ef}	11.13^{hij}	6.60^{hi}	75.37^{gh}
P3	3.10^{def}	14.77^{def}	9.30^{efg}	137.55^{def}
Purple Ball	7.95^{a}	19.62^{a}	18.28^{a}	359.19^{a}
BU	6.47^{abc}	15.93^{cd}	14.37^{bc}	230.05^{bc}
TBP	1.87^{ef}	14.13^{defg}	9.47^{efg}	136.75^{efg}
TPK	3.70^{cdef}	19.33^{a}	13.40^{bc}	258.42^{b}
TG	2.53^{def}	12.17^{fghi}	7.73^{fghi}	93.81^{fgh}
Lezata	3.53^{cdef}	16.63^{bcd}	10.67^{de}	176.67^{cd}
TPJ	4.73^{bcde}	18.17^{bcd}	15.23^{b}	277.68^{b}
Bride	5.37^{abcd}	15.00^{de}	8.90^{efgh}	133.54^{efg}
Icicle	7.00Z^{ab}	19.17^{ab}	14.13^{bc}	280.37^{b}
BP	2.73^{def}	10.87^{hij}	5.77^{i}	62.87^{gh}
RH	3.97^{bcdef}	15.90^{cd}	12.07^{cd}	191.10^{cd}
Monkey	2.53^{def}	14.17^{defg}	10.00^{def}	142.05^{de}
Antaboga	3.27^{cdef}	16.60^{bcd}	13.73^{bc}	227.90^{bc}
HG	2.23^{def}	10.27^{hij}	6.93^{ghi}	71.32^{fg}
PU	4.17^{bcdef}	14.80^{def}	9.70^{def}	144.98^{de}
Prince	2.97^{def}	12.43^{efgh}	8.13^{efghi}	101.19^{fgh}

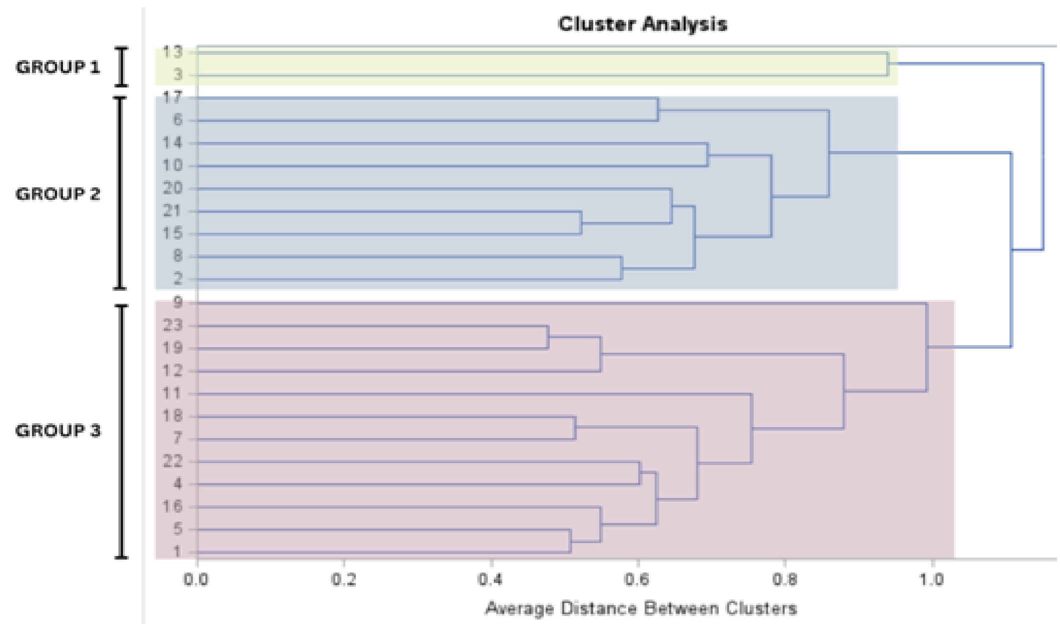
Note: The average value in a column followed by the same letter is not significantly different ($p\leq 0.05$) according to Tukey's Honestly Significant Difference test.

Table 8: *Evaluation of morphological traits among all accessions: values represent averages over all the observations for quantitative traits for fruit traits.*

Accession	FL (cm)	FG (cm)	FW (cm)	FCL (%)	FPL (cm)	NLF (No)	TNF	NFB	AFW (g)	DFH
WP	2.23^{k}	7.21^{j}	2.47^{gh}	60.12^{b}	2.00^{h}	2.00^{a}	14.00^{b}	3.00^{b}	5.73^{i}	126.00^{fg}
MB	2.87^{k}	8.67^{ij}	2.73^{gh}	53.89^{b}	2.07^{h}	2.00^{a}	15.00^{a}	3.00^{b}	12.27^{ij}	128.00^{fg}
Apple	5.40^{ij}	15.4^{cd}	4.50^{def}	39.98^{cd}	2.47^{gh}	2.00^{a}	3.00^{f}	1.00^{d}	47.33^{gh}	145.00^{ef}
TB	5.63^{ij}	15.07^{cde}	5.73^{bc}	40.27^{cd}	3.27^{efg}	2.00^{a}	2.00^{g}	1.00^{d}	56.97^{fgh}	167.00^{de}
WB	6.53^{hij}	15.2^{cde}	5.20^{bcd}	43.42^{c}	3^{fgh}	2.00^{a}	10.00^{c}	2.00^{c}	61.67^{fg}	150.00^{ef}
UB	4.27^{jk}	12.37^{fgh}	4.50^{def}	34.00^{cdefg}	2.3^{gh}	1.00^{b}	10.00^{c}	3.00^{b}	30.00^{hij}	142.00^{ef}
Purple Ball	9.00^{fg}	22.80^{b}	10.00^{a}	39.56^{cde}	4.33^{de}	2.00^{a}	5.00^{d}	1.00^{d}	156.10^{b}	206.00^{abc}
B.U	8.50^{fgh}	27.00^{a}	10.17^{a}	39.22^{cde}	4.3^{de}	2.00^{a}	5.00^{d}	1.00^{d}	247.03^{a}	197.00^{cd}
T.B.P	6.50^{hij}	17.00^{c}	6.50^{b}	38.46^{cde}	3.3^{efg}	2.00^{a}	3.00^{f}	1.00^{d}	43.20^{ghi}	132.00^{fg}
TPK	7.17^{ghi}	24.23^{a}	9.33^{a}	71.33^{a}	5.13^{abcd}	1.00^{b}	3.00^{f}	1.00^{d}	149.03^{b}	183.00^{cd}
T.G	8.50^{fgh}	10.50^{ghi}	4.50^{def}	28.00^{efgh}	4.3^{de}	2.00^{a}	2.00^{g}	1.00^{d}	30.00^{hij}	234.00^{a}
Lezata	17.70^{bc}	8.70^{ij}	3.50^{fg}	23.16^{fghij}	5.6^{abcd}	2.00^{a}	4.00^{e}	1.00^{d}	67.50^{efg}	220.00^{ab}
TPJ	17.50^{c}	12.1^{fgh}	5.50^{bcd}	36.00^{cdefg}	6.10^{ab}	2.00^{a}	1.00^{h}	1.00^{d}	86.40^{def}	200.00^{bc}
Bride	18.25^{bc}	12.8^{efg}	5.25^{bcd}	8.93^{j}	3.50^{efg}	2.00^{a}	2.00^{g}	1.00^{d}	115.15^{cd}	99.50^{g}
Icicle	15.00^{e}	11.87^{fgh}	4.07^{def}	21.10^{hi}	4.03^{def}	2.00^{a}	3.00^{f}	1.00^{d}	97.30^{de}	189.00^{cd}
B.P	24.20^{a}	7.20^{i}	2.30^{h}	14.46^{ij}	3.50^{efg}	2.00^{a}	5.00^{d}	3.00^{b}	50.00^{gh}	136.00^{ef}
R.H	17.50^{c}	12.30^{fgh}	5.20^{bcd}	25.71^{fghi}	5.10^{bcd}	2.00^{a}	3.00^{f}	1.00^{d}	144.50^{bc}	215.00^{abc}
Monkey	16.53^{cd}	13.20^{fgh}	5.87^{bc}	24.10^{ghi}	3.97^{def}	2.00^{a}	3.00^{f}	1.00^{d}	116.80^{cd}	204.00^{abc}
Antaboga	16.5^{cd}	13.40^{def}	6.00^{bc}	30.30^{defgh}	6.30^{a}	2.00^{a}	1.00^{h}	1.00^{d}	110.00^{d}	230.00^{ab}
H.G	14.5^{e}	11.20^{fgh}	5.50^{bcd}	20.70^{hi}	5.00^{bcd}	2.00^{a}	3.00^{f}	3.00^{b}	56.60^{fgh}	230.00^{ab}
P.U	20.00^{b}	10.00^{hi}	5.00^{bcd}	24.00^{ghi}	6.00^{abcd}	2.00^{a}	2.00^{g}	1.00^{d}	65.50^{fg}	186.00^{cd}
Prince	10.50^{f}	14.77^{cde}	6.17^{b}	31.13^{defgh}	4.73^{cd}	2.00^{a}	2.00^{g}	1.00^{d}	98.57^{de}	138.00^{cd}

Note: fruit length (FL), fruit girth (FG), fruit width (FW), relative fruit calyx length (FCL), fruit pedicel length (FPL), number of locules per fruit (NLF), total number of fruit (TNF), number of fruits per branch (NFB), average fruit weight (AFW), and days first fruit to harvest (DFH).
Note: The average value in a column followed by the same letter is not significantly different ($p \leq 0.05$) according to Tukey's Honestly Significant Difference test.

Figure 2: *UPGMA dendrogram constructed from morphological data showing a genetic relationship among 23 eggplant accessions. Note: 1. Terung Panjang Jaguh. 2. Icicle. 3.Puteri. 4. White pearl. 5. Terung Putih Kedut. 6. Prince. 7. Lezata. 8. Apple. 9. Bride. 10.Ulam Bulat. 11. Benang Panjang. 12. Ratih Hijau. 13. Purple Ball. 14. Bulat Ungu. 15. Terung Bulat Putih. 16. Monkey. 17. Terung Bulat. 18. Thai Giant. 19. Miniball. 20.White ball. 21. Antaboga. 22. Hijau Gading. 23. Panjang Ungu.*



Discussion

The present study revealed considerable morphological variation among the 23 eggplant accessions, particularly in fruit and vegetative traits. Such variation underscores the existence of genetic diversity within cultivated eggplant germplasm, a finding consistent with earlier reports from different regions (Ali et al., 2011; Uddin et al., 2021; Musa et al., 2020). Morphological diversity is essential not only for taxonomic classification but also for identifying promising cultivars and parental lines for breeding programs aimed at improving yield, quality, and adaptability.

Qualitative Traits and Their Breeding Importance

All accessions exhibited an upright growth habit, which is advantageous for field management and fruit harvesting. Previous studies reported more variability in growth habit, including prostrate and intermediate forms (Islam et al., 2018; Uddin et al., 2021). The absence of these forms in the current collection may be related to selection pressure favoring compact and erect plants, which are often more desirable in cultivation.

Leaf traits such as lobing, coloration, and trichome density showed high variability and contributed substantially to genetic differentiation among accessions. In particular, Purple Ball and Icicle exhibited strongly lobed leaves, while White Pearl and Bride had weak lobes. Similar variability in leaf lobing has been reported in African and Asian eggplant landraces (Oyelana et al., 2009). The predominance of green leaf blades contrasts with reports of higher dark green frequency in other environments (Mungai et al., 2016), suggesting possible environmental influences on pigmentation. Variation in trichome density, with high density in Icicle and Purple Ball, supports the role of this trait in defense against insect herbivory (Ehleringer & Mooney, 1978).

Flower characteristics also discriminated accessions effectively. Corolla color ranged from bluish violet to white, with pale violet predominating, similar to previous studies (Kowalska, 2008). The predominance of solitary flowers (61%) aligns with findings by Boddepalli et al. (2016), although cluster-bearing accessions may contribute to higher fruit set. Pistil length variation was notable, with long pistils dominant across accessions, which is favorable since long-styled flowers are generally associated with higher fruit yield and seed set (Kowalska, 2013).

Fruit traits were among the most variable and highly informative descriptors. The observed diversity in curvature, apex shape, color, and size confirms previous reports that fruit morphology is a key differentiator of eggplant genotypes (Rosa-Martínez et al., 2022). Accessions such as Bulat Ungu and Purple Ball produced large, heavy fruits, whereas White Pearl and Mini Ball yielded compact, small fruits suitable for niche markets. The high frequency of uniform coloration (65%) suggests that stable fruit pigmentation is common among these accessions, although mottled forms may still be useful for specialty breeding

The wide variation in qualitative traits, especially fruit shape, size, and pigmentation, reflects the influence of both genetic and environmental factors on trait expression. Similar observations have been reported by Sękara et al. (2007) and Taher et al. (2017), who noted that fruit morphology is among the most diverse traits in eggplant. In this study, Purple Ball and Icicle showed strong leaf lobing, while White Pearl and Apple displayed very weak lobing. Since leaf morphology has been linked to photosynthetic efficiency and plant adaptability (Oboh et al., 2005), such variability could be explored in breeding programs targeting improved biomass accumulation and stress resilience.

Fruit pigmentation also showed substantial diversity, ranging from white and green to dark purple. Anthocyanin-rich purple fruits, such as those of Mini Ball and Bulat Ungu, are particularly desirable due to their antioxidant content and associated health benefits (Lo Scalzo et al., 2016; Gürbüz et al., 2018). Breeding programs could thus capitalize on both consumer-preferred colors and nutritionally superior varieties. The limited occurrence of prickliness in flower buds, observed only in Purple Ball and Bulat Ungu, is also noteworthy. While prickles may deter pests (Younas et al., 2022), they are often undesirable for harvesting and handling. This suggests that the presence or absence of prickles may be a useful selection criterion depending on production and market requirements.

Quantitative Traits and Agronomic Potential

Significant differences were observed among accessions for quantitative traits such as plant height, leaf size, fruit weight, and days to flowering. These findings indicate the potential for selecting high-yielding cultivars. Thai Giant, which produced the heaviest fruits, represents a promising candidate for yield improvement, consistent with reports by Moncada et al. (2013) that fruit size is a strong determinant of market value. Conversely, accessions such as Mini Ball and White Pearl produced smaller fruits, which may have niche value in specialty or ornamental markets.

Variation in flowering and maturity times also highlights opportunities for developing cultivars suited to specific agro-ecological zones. Early-flowering accessions can be advantageous in regions with short growing seasons, while late-flowering types may be beneficial in areas with extended cultivation cycles (Nguyen et al., 2022). Thus, the diversity observed in reproductive traits provides flexibility for breeders to meet diverse production needs.

Genetic Relationships

Cluster analysis further confirmed the genetic diversity among accessions by grouping them into three major clusters. The distinct placement of Purple Ball and White Pearl highlights their morphological divergence, making them promising candidates for hybridization. Similar patterns have been observed in other studies, where highly divergent accessions were successfully utilized in breeding programs to generate hybrids with enhanced heterosis and yield potential (Islam et al., 2018; Musa et al., 2020). The clustering of intermediate accessions suggests shared genetic backgrounds, which could be exploited for developing stable and uniform cultivars.

Implications for Breeding

The diversity documented in this study has important implications for breeding. First, the identification of contrasting accessions such as Purple Ball and White Pearl offers breeders opportunities to develop hybrids with desirable combinations of traits. For instance, the large leaf area of Purple Ball may contribute to vigorous growth, while the early maturity of White Pearl could shorten crop cycles. Second, the observed variation in fruit traits provides avenues for developing cultivars targeting different consumer preferences, from large-fruited Thai Giant types to small-fruited specialty varieties like Mini Ball.

Overall, the findings emphasize the significance of morphological characterisation as a low-cost and effective approach for assessing genetic diversity in eggplant. When combined with molecular markers, this approach can strengthen the identification of promising parental lines for future breeding programs.

Conclusion

The morphological characterisation of 23 eggplant (Solanum melongena L.) accessions revealed significant diversity across both qualitative and quantitative traits, demonstrating the broad genetic variability available within cultivated germplasm. Differences in fruit morphology, including size, shape, and pigmentation, emerged as the most pronounced sources of variation, while vegetative traits such as leaf blade dimensions and stem diameter also contributed meaningfully to overall diversity. These findings confirm that eggplant remains a morphologically diverse crop, despite reports of a relatively narrow genetic base due to domestication and selection pressures.

Acknowledgements
The authors would like to thank Kulliyyah of Science, International Islamic University Malaysia for the equipment and facilities provided to conduct the research.

References
Ali, Z., Xu, Z. L., Zhang, D. Y., He, X. L., Bahadur, S., Yi, J. X.,& Yu, X. Q. (2011). Molecular diversity analysis of eggplant (Solanum melongena) genetic resources. *Genetics and Molecular Research, 10*(2), 1141–1155. https://doi.org/10.4238/vol10-2gmr1118.

Bhaskar, B., & Kumar, P. (2015). Pharmacognostical review of *Solanum melongena* Linn. *Journal of Pharmacognosy and Phytochemistry, 3*(6), 117–119.

Boddepalli, V. N., Patel, M. C., Yadav, S. K., & Gami, R. A. (2016). Studies on flowering behaviour in brinjal (*Solanum melongena* L.). *International Journal of Agriculture Sciences, 8*(65), 3642–3644.

Cassidy, A., Bertoia, M., Chiuve, S., Flint, A., Forman, J., & Rimm, E. B. (2013). Habitual intake of anthocyanins and flavanones and risk of cardiovascular disease in men. *American Journal of Clinical Nutrition, 97*(1), 141–148.

Ehleringer, J., & Mooney, H. A. (1978). Leaf hairs: Effects on physiological activity and adaptive value to a desert shrub. *Oecologia, 37*(2), 183–200.

Gürbüz, N., Uluişik, S., Frary, A., Frary, A., & Doğanlar, S. (2018). Health benefits and bioactive compounds of eggplant. *Food Chemistry, 268,* 602–610.

IBPGR. (1990). *Descriptors for eggplant.* International Board for Plant Genetic Resources.

Islam, M. A., Saha, S. R., & Rahman, M. M. (2018). Genetic diversity analysis of eggplant (*Solanum melongena* L.) genotypes. *Bangladesh Journal of Agricultural Research, 43*(2), 277–290.

Jusoh, M., & Mahmood, N. (2006). Status of eggplant production in Malaysia. *Acta Horticulturae, 710,* 199–204.

Khoo, H. E., Azlan, A., Tang, S. T., & Lim, S. M. (2017). Anthocyanidins and anthocyanins: Colored pigments as food, pharmaceutical ingredients, and the potential health benefits. *Food & Nutrition Research, 61*(1), 1361779.

Knapp, S. (2013). A revision of the *Solanum torvum* complex (Solanaceae). *PhytoKeys, 31,* 1–120.

Kowalska, G. (2008). Flowering biology of eggplant and procedures intensifying fruit set—Review. *Acta Scientiarum Polonorum Hortorum Cultus, 7*(4), 63–76.

Kowalska, G. (2013). Influence of flower morphology on the fruit setting of eggplant (*Solanum melongena* L.). *Acta Scientiarum Polonorum Hortorum Cultus, 12*(2), 117–127.

Lo Scalzo, R., Fibiani, M., Francese, G., D'Alessandro, A., Rotino, G. L., Conte, P., & Mennella, G. (2016). Cooking influence on physico-chemical fruit characteristics of eggplant (*Solanum melongena* L.). *Food Chemistry, 194,* 835–842.

Mahanta, P., & Kalita, J. (2020). Ethnomedicinal, phytochemical and pharmacological aspects of *Solanum melongena* L.: A review. *Journal of Pharmacognosy and Phytochemistry, 9*(4), 975–981.

Marek, J., Matuszak, I., & Kosson, R. (2009). Antioxidant capacity of selected eggplant (*Solanum melongena* L.) cultivars. *Vegetable Crops Research Bulletin, 71,* 99–106.

Mat Sulaiman, N. N., Othman, R., & Ismail, M. R. (2020). Trends in eggplant (*Solanum melongena* L.) research in Asia. *Journal of Tropical Agriculture and Food Science, 48*(1), 19–30.

Michałojć, Z., & Buczkowska, H. (2008). Content of macroelements in eggplant fruits depending on nitrogen fertilization. *Acta Scientiarum Polonorum Hortorum Cultus, 7*(2), 25–33.

Moncada, A., Miceli, A., Sabatino, L., & D'Anna, F. (2013). Effect of grafting on yield and quality of eggplant (*Solanum melongena* L.). *Scientia Horticulturae, 149,* 108–114.

Mungai, N. W., Wachira, F. N., Kahangi, E. M., & Wakhungu, J. (2016). Morphological characterization of African eggplant (*Solanum aethiopicum* L.) landraces in Kenya. *Journal of Plant Breeding and Crop Science, 8*(8), 111–120. https://doi.org/10.5897/JPBCS2016.0585

Musa, M., Shimelis, H., Amelework, B., & Mengistu, F. (2020). Genetic diversity of eggplant (*Solanum melongena* L.) collections in Ethiopia as revealed by morphological traits. *Plant Genetic Resources, 18*(3), 186–195.

Nguyen, P. H., Nguyen, T. T. H., & Tran, D. X. (2022). Evaluation of agronomic traits in eggplant (*Solanum melongena* L.) cultivars under different environmental conditions. *Journal of Crop Science and Biotechnology, 25*(1), 15–25.

Oboh, G., Ekperigin, M. M., & Kazeem, M. I. (2005). Nutritional and phytochemical composition of eggplant (*Solanum* species). *Food Chemistry, 92*(4), 601–607.

Oladosu, Y., Rafii, M. Y., Abdullah, N., Hussin, G., Ramli, A., Rahim, H. A., … & Kareem, I. (2021). Genetic diversity studies in crop improvement programs: Advances and prospects. *Plants, 10*(6), 1360.

Oyelana, O. A., Ugborogho, R. E., & Ajani, O. O. (2009). Morphological variation in Solanum aethiopicum (Solanaceae) groups in parts of South Western Nigeria. *Botanical Research International, 2*(1), 7–16.

Rosa-Martínez, E., Prohens, J., Gramazio, P., Herraiz, F. J., Plazas, M., & Vilanova, S. (2022). Diversity in fruit morphology and its genetic basis in eggplant (*Solanum melongena* L.). *Frontiers in Plant Science, 13,* 878145.

Sękara, A., Cebula, S., & Kunicki, E. (2007). Cultivated eggplants—Origin, breeding objectives and genetic resources: A review. *Folia Horticulturae, 19*(2), 97–114.

Taher, D., Solberg, S. Ø., Prohens, J., Chou, Y. Y., Rakha, M., & Wu, T. H. (2017). World vegetable center eggplant collection: Origin, composition, seed dissemination and utilization in breeding. *Frontiers in Plant Science, 8,* 1484.

Uddin, M. N., Sultana, S., & Hossain, M. M. (2021). Morphological characterization and genetic diversity of eggplant (*Solanum melongena* L.) germplasm. *Bangladesh Journal of Botany, 50*(2), 233–241.

Vorontsova, M. S., & Knapp, S. (2012). A new species of spiny *Solanum* (Solanaceae) from Africa. *PhytoKeys, 18,* 1–11. Weese, T. L., & Bohs, L. (2010). Eggplant origins: Out of Africa, into the Orient. *Taxon, 59*(1), 49–56.

Younas, M., Zeb, Q., Ali, H., Ali, S., & Shah, A. (2022). Morphological diversity and prickliness in eggplant (*Solanum melongena* L.) germplasm: Implications for breeding. *Journal of Agricultural Science, 14*(3), 52–63.

Article History
Received: 17 October 2025
Accepted: 28 January 2026