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# MORPHOLOGICAL CHARACTERIZATION AND PHENETIC RELATIONSHIPS OF MADURA COWPEA (*VIGNA UNGUICULATA*) ACCESSIONS

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## SUMMARY

Cowpea (*Vigna unguiculata* L. Walp.), being a leguminous plant, has the second highest vegetable protein content after soybean. Cowpea development considerably supports food diversification and plays a vital role as a highly nutritious food source. The concerned study aimed to determine the variations in morphological traits and the morphological diversity among 18 local cowpea accessions. The collection of seed cowpea accessions came from four different Regencies, i.e., Sumenep (KT1, KT2, KT3, and KT4), Pamekasan (KT5, KT6, KT7, and KT8), Sampang (KT9, KT10, KT11, KT12, and KT13), and Bangkalan (KT14, KT15, KT16, KT17, and KT18), carrying out respective exploration activities per regency. The phenetic analysis, as executed in NTSys ver. 2.1, used simple matching similarity index and the unweighted pair group method with arithmetic average (UPGMA) method. The results revealed that accessions of 18 cowpeas showed variation for 12 morphological traits, including plant pigmentation, terminal leaflet shape, pod attachment, pod curvature, seed shape and color, and flower, eye, and pod colors. Based on the phenetic analysis of Madura cowpea accessions' morphology, the cowpea accessions showed similarity coefficients from 0.30 to 0.83, which further underwent division into two large groups. Accession KT11 displayed a separation from other accessions because of its significantly different traits of testa texture, pod eye color, and distinctive flower color.

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**Keywords:** Cowpea (*V. unguiculata* L.), Madura local accessions, morphological diversity, leaf and pod traits, similarity coefficient, Leguminaceae

**Key findings:** Madura cowpea (*V. unguiculata* L.) accessions revealed significant differences for 12 morphological traits, including plant pigmentation, terminal leaflet shape, pod attachment, pod curvature, seed shape and color, and flower, eye, and pod colors.

## INTRODUCTION

Indonesia's high population growth rate has led to a considerable increase in food demand (Khairati and Syahni, 2016). In addition to rice being a staple food (Putri and Hari, 2018), various communities also utilize soybeans (*Glycine max*) as a source of vegetable protein (Lestari *et al.,* 2021). However, in Indonesia, the soybean production is still scarce and unable to meet the population's needs, importing soybeans from other countries in large quantities. Thus, to overcome this problem, the community requires a food diversification program and should replace soybeans with other beans, including cowpeas (Aldillah *et al*., 2014).

Cowpea (*Vigna unguiculata*) is an annual herbaceous legume belonging to the genus *Vigna* and family Leguminaceae that can serve as an alternative to soybeans to support food security at large in Indonesia. Cowpea accessions are characteristic of an upright and creeping herbaceous structure, trifoliate leaves, nodular stems, pods, and seeds of varying shapes and colors (Trustinah, 1998). Cowpeas commonly have the highest protein content and other potential compounds; however, their utilization is still rare (Manole *et al*., 2024; Zolqadri *et al*., 2025). Cowpea tolerance for sandy soil and low rainfall has made it an important crop in the semiarid regions across Africa and Asia (Nogueira *et al*., 2023; Singh *et al*., 2023; Poudel *et al*., 2025).

Being the oldest leguminous crop, cowpeas, grown wild and cultivated, attained their first domestication in Cape Verde, Africa (Gómez, 2004; POWO, 2025). Its second domestication event probably occurred in Asia, before it spread into Europe and the Americas. These beans have the highest nutritional value and potential as a source of vegetable protein compared with other crop plants, such as *Jatropha* and rice (Setiawan *et al*., 2025). According to biochemical composition, cowpeas contain water content (11%–17%), ash content (3.13%–3.97%), fat content (0.58%–1.42%), protein (15.5%–20.76%), carbohydrate (58.46%–63.48%), and folic acid content (100.13–131.57 μg/mL) (Karuwal *et al.*, 2021). Moreover, cowpea is a source of vitamins and folic acid (Saini *et al*., 2016).

Cowpea seeds contain carbohydrates, proteins, fats, water (Gerrano *et al*., 2019), and polyphenols with the highest antioxidant properties (Lim *et al.,* 2021). With its diverse metabolite content, cowpeas have the considerable potential for sustainable growth and development. Additionally, cowpeas can adapt to dry and semi-arid environments. Cowpea cultivation greatly supports food diversification and can provide a highly nutritious food source (Bete *et al.,* 2020). Furthermore, they have a wide distribution in Indonesia, such as in Java, Sumatra, East Nusa Tenggara, Maluku, and Sulawesi. Geographical differences contribute to the diversity of cowpea's morphological characteristics. Morphological characterization is an important approach for understanding the cowpea diversity.

Reports on cowpea seed diversity stated its existence in several regions in Indonesia, including East Nusa Tenggara (Mau *et al*., 2023, 2025), Maluku (Karuwal *et al*., 2017; 2021), Samosir (Simanjuntak, 2019), Jeneponto (Hanifa and Hidayah, 2017), and Yogyakarta (Sayekti *et al*., 2012). However, in Madura, Indonesia, the study on cowpea diversity is yet to occur. Therefore, this research aimed to determine the variation in morphological characteristics and diversity among the local Madura cowpea accessions. These information on cowpea diversity will help in obtaining accessions with superior characteristics. Furthermore, this diversity is essential for trait-based selection, providing the necessary genetic basis for crop improvement and the systematic development of high-potential local varieties.

## MATERIALS AND METHODS

### Genetic material and procedure

The experimental research commenced on 18 Madura cowpea (*V. unguiculata* L.) accessions in October-December 2023 in a net house built on farmers' land in District Socah, Bangkalan Regency, Madura, Indonesia. The cowpea accessions collected came from four different regencies, respectively carrying out the exploration activities there–Sumenep (KT1, KT2, KT3, and KT4), Pamekasan (KT5, KT6, KT7, and KT8), Sampang (KT9, KT10, KT11, KT12, and KT13), and Bangkalan (KT14, KT15, KT16, KT17, and KT18). Researchers collected samples from landraces (Sumenep), farmers' varieties (Bangkalan), or wild types (Sampang and Pamekasan). Morphological observations proceeded on 12 characters of cowpea referring to IBPGR (International Board for Plant Genetic Resources, 1983) (Table 1).

### Data analysis

Morphological data analysis was descriptive (Fendiyanto *et al.*, 2021), and for similarity (Fendiyanto *et al.*, 2023), the study used the Simple Matching (SM) coefficient and the Unweighted Pair Group Method with Arithmetic Average (UPGMA) methods using the NTSys version 2.1 program. The color of plant organs (e.g., leaves, stems, and fruits) entailed determination using the Munsell Color Chart. Conducting observations continued under natural daylight conditions to ensure consistent color perception. Each plant sample reached visual comparison with the closest matching color chip in the Munsell system, with the corresponding hue, value, and chroma recorded. The same evaluator performed all observations to minimize observer bias. Then, the recorded color data underwent tabulation before using as qualitative descriptors in the analysis.

## RESULTS AND DISCUSSION

### Morphological variations

Based on the evaluation of 18 Madura cowpea (*V. unguiculata*) accessions, the observations revealed morphological diversity for the variables, viz., plant pigmentation, terminal leaflet shape, pod attachment, pod curvature, seed shape and color, and flower, eye, and pod colors. Therefore, according to Karuwal *et al.* (2021), Maluku cowpea accessions generally vary in seed shape, color, texture, and distinctive seed pattern.

Cowpeas have various leaf blade shapes, including globose, subglobose, sub-hastate, and hastate. The most common cowpea leaf shape is hastate that almost looked like a spearhead**.** The sub-hastate shape of the leaf blade was evident in cowpea accessions KT4 and KT15; the globose form resulted only in accession KT9; and the subglobose form emerged in accessions KT2, KT10, KT11, and KT18. Past studies also revealed cowpea leaf shapes vary, namely, hastate and subglobose (Pottorff *et al*., 2012). However, most cowpea accessions from Jeneponto have their own ovate leaf shapes (Hanifa and Hidayah, 2017). The Madura cowpea accessions also have diverse leaf colors, including pale green, intermediate green, and dark green. However, the most common leaf colors were the pale and intermediate green, except for accessions KT1, KT17, and KT18 (Figure 1). About the diversity of plant hairiness, all the cowpea accessions have glabrarescent morphology, except for the accession KT13. Polnaya (2008) also reported the different shapes and colors of cowpea accession leaves on Lakor Island, such as rhomboid, ovate, and delta, with light green, green, and dark green leaf shades, and a slightly rough and smooth leaf texture.

The flower color of local Madura cowpea accessions was white in accession KT11 and purple in the nine accessions—KT1, KT3, KT4, KT5, KT7, KT9, KT10, KT14 and KT18. The remaining eight accessions have mauve-pink flower colors (Figure 1). Polnaya (2008) reported that flower colors in cowpea

**Table 1.** Qualitative morphology scoring data of the cowpea accessions.

| No. | Character | Description |
|---|---|---|
| 1 | Plant Pigmentation | 0 None<br>1 Very slight<br>3 Moderate at the base and tips of petioles 5 Intermediate<br>7 Extensive<br>9 Solid |
| 2 | Terminal Leaflet Shape | 1 Globose<br>2 Sub–globose<br>3 Sub–hastate<br>4 Hastate |
| 3 | Plant Hairiness | 3 Glabrescent<br>5 Short appressed hairs<br>7 Pubescent to hirsute |
| 4 | Pod Attachment to Peduncle | 3 Pendant<br>5 30°–90° down from erect<br>7 Erect |
| 5 | Immature Pot Pigmentation | 1 Pigmented tip<br>2 Pigmented sutures<br>3 Pigmented valves, green sutures<br>4 Splashes of pigment<br>5 Uniformly pigmented<br>6 Other (specify in the notes descriptor, 11) |
| 6 | Pod Curvature | 0 Straight<br>3 Slightly curved<br>5 Curved<br>7 Coiled |
| 7 | Seed Shape | 1 Kidney<br>2 Ovoid<br>3 Crowder<br>4 Globose |
| 8 | Testa Texture | 1 Smooth<br>3 Smooth to rough<br>5 Rough (fine reticulation)<br>7 Rough to wrinkled<br>9 Wrinkled (coarse folds on the testa) |
| 9 | Eye Color | 0 Eye absent (white, cream)<br>1 Brown splash or gray<br>2 Tan Brown<br>3 Red<br>4 Green<br>5 Blue to black<br>6 Blue to black spots or mottle<br>7 Speckled (even distribution of fine speckling)<br>8 Mottled (dark brown pigment typically Absent around hilum)<br>9 Mottled and speckled (Victor)<br>Other (specify in the Notes descriptor, |
| 10 | Flower Color | 1 White<br>2 Violet<br>3 Mauve–pink |
| 11 | Leaf Color | 1 Coriaceous<br>2 Intermediate<br>3 Membranous |
| 12 | Pod Color | 1 Pale tan or straw<br>2 Dark tan<br>3 Dark brown<br>4 Black or dark purple<br>5 Other (specify in the Notes descriptor, 11) |

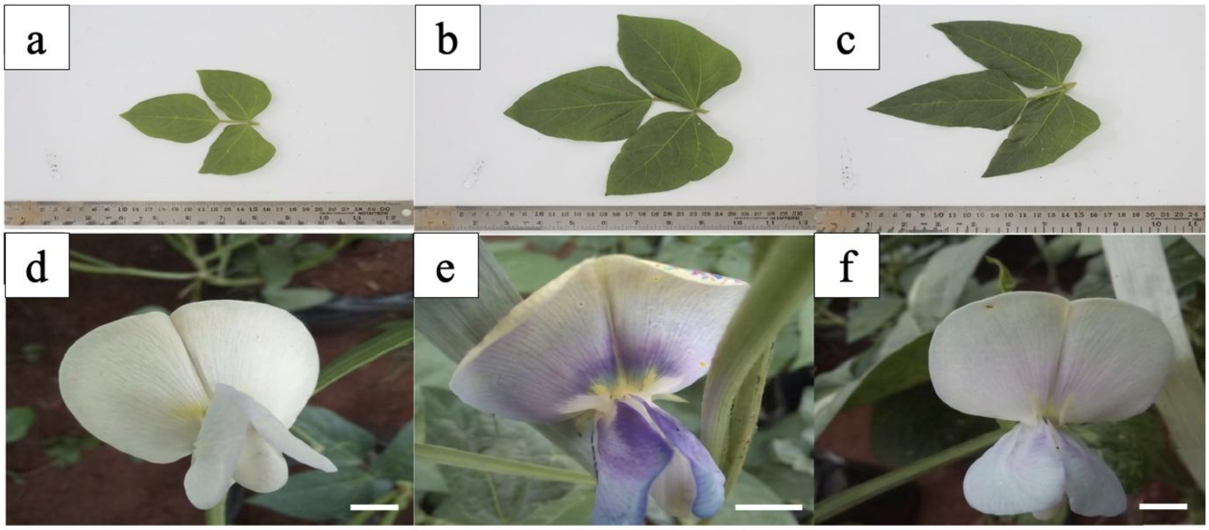


**Figure 1.** Shape and color of cowpea leaves, a) sub-globose, pale green, b) sub-hastate, intermediate green, c) hastate, dark green; flower color: d) white, e) violet, and f) mauve-pink. Bar represents 1 cm.

accessions on Lakor Island have whitish purple, purplish white, and pink shades, while cowpeas from Jeneponto have purple flowers (Hanifa and Hidayah, 2017). Cowpea flowers comprising 4–6 flower units arranged alternately in acropetal succession. Flower formation begins on the lowest flower stalk and continues sequentially to the next higher stalk (Fachrudin, 2000).

Splicing pods is the morphological diversity observed during pods maturity. The splicing characters of the stem pod include pendant, 30°–90° down from erect, and erect. The cowpea accessions, KT1, KT2, KT3, KT4, KT8, KT9, and KT18, have the character of connecting pendant pods. Furthermore, the accession of KT5, KT6, KT7, KT10, KT11, KT14, KT16, and KT17 have the character that was 30°–90° down from the erect. However, accessions KT12, KT13, and KT15 revealed erect features (Figure 2). The cowpea pods' position varies, with some having short stems (the pods located inside the plant) and some having long stems (the pods visible above the plant and the pods standing upright or facing downwards) (Trustinah, 1998).

Diversity in fruit pigmentation before ripening depends on the presence and absence of color pigment in the fruit, both at the tip of the pod, at the edges or cut seams, and pod valves. In the studied cowpea accessions, several accessions showed pigments at the end of the pod, such as in accessions KT1, KT2, KT11, KT14, KT5, and KT16. However, all other accessions have no pigment in their pods (Figure 2). Pigmentation in the young pods of the Jeneponto cowpea accessions showed solid color, and some even had no pigment (Hanifa and Hidayah, 2017).

Pod curvature can be either straight or curved, as and when ripe. Among the studied cowpea accessions, several accessions had straight pods, such as KT15 and KT16. The accession KT2 appeared with curved pods, while all other cowpea accessions had slightly curved pods (Figure 2). Hanifa and Hidayah (2017) reported that the pod curve was slight in the cowpea accessions from Jeneponto.

In cowpea, pod color varies and depends on the accessions. Madura cowpea accession pods showed diverse colors, including light brown, straw, and dark brown (Figure 2). However, the dominant pod color was the light brown and straw in the local Madurese cowpea accessions. Cowpea pods were light green and green when young and become cream, brown, and black at maturity (Trustinah, 1998). According to Trustinah

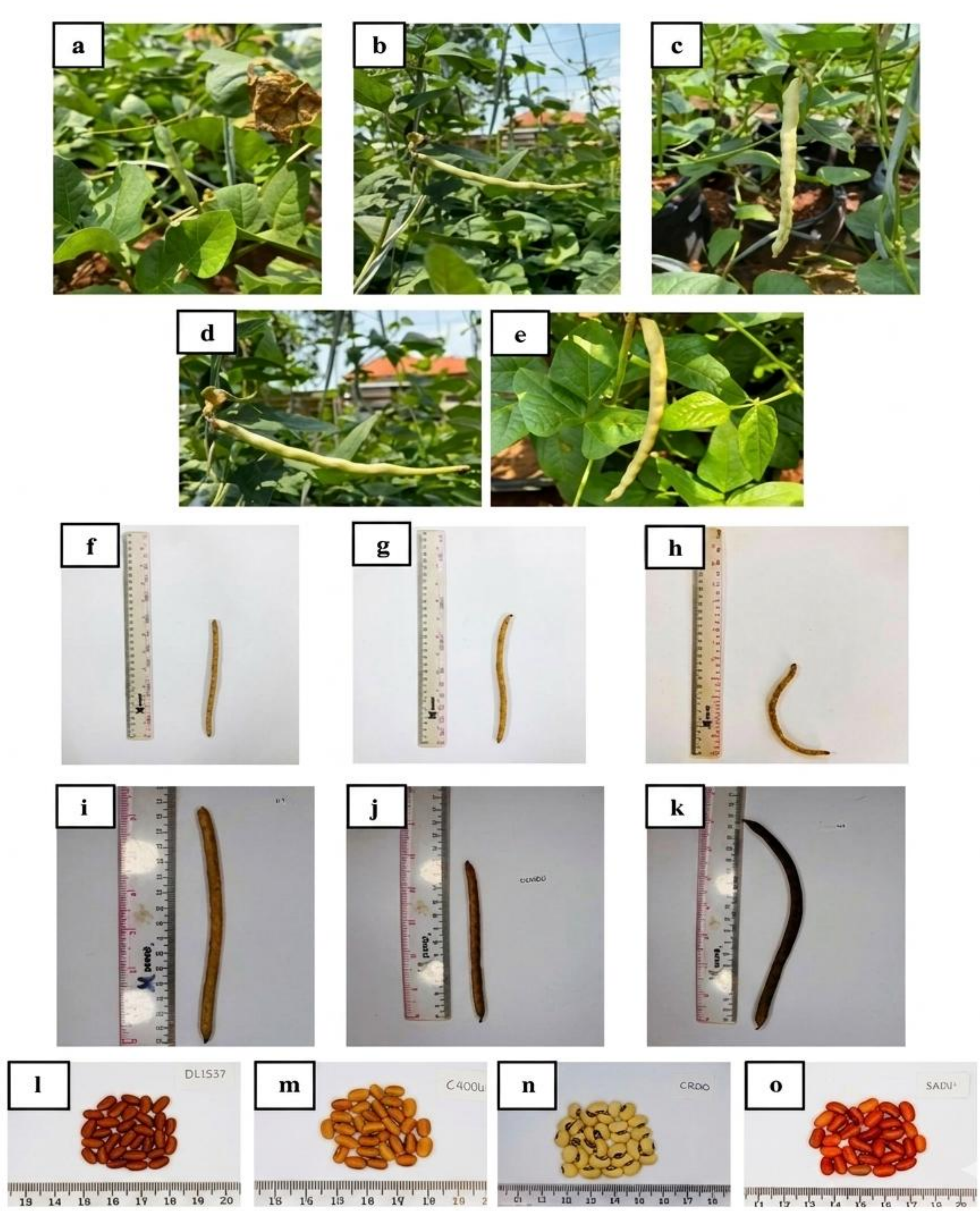


**Figure 2.** Pod attachment to peduncle: a) pendant, b) 30°–90° down from erect, c) erect; immature pot pigmentation: d) pigmented tip, e) none; pod curvature: f) straight, g) slightly curved, h) curved; pod color: i) pale tan or straw, j) dark tan, k) dark brown; and seed shape: l) kidney, m) ovoid, n) globose, and o) rhomboid. Bar represents 1 cm.

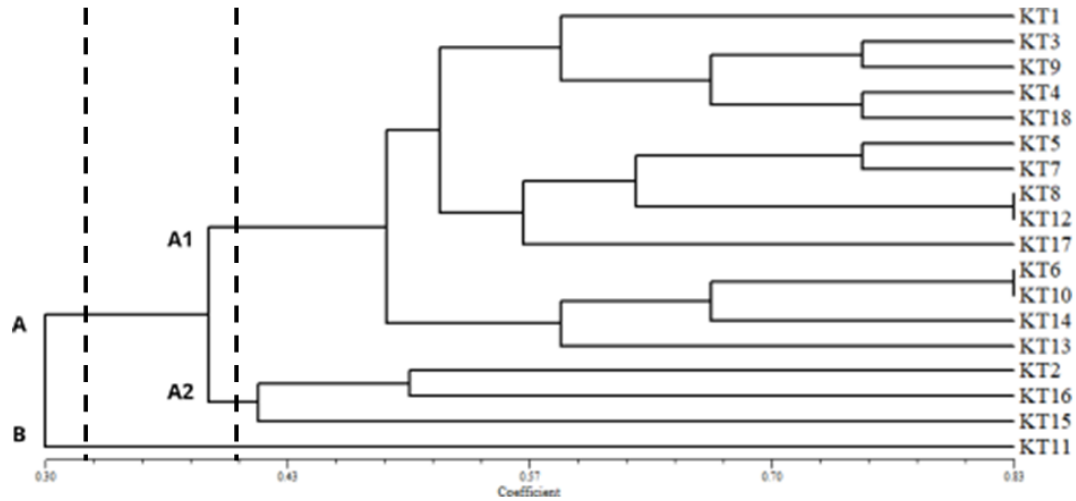


**Figure 3.** Dendrogram of 18 Madura cowpea accessions based on morphological traits using the UPGMA method.

(2016), the cowpea accession pods vary in size, shape, color, and texture.

The seed shapes of the local Madurese cowpea accessions also vary, including kidney-shaped, ovoid, globose, and rhomboid. The kidney-shaped form was evident in the cowpea accessions KT2, KT4, KT5, KT7, KT8, KT12, KT16, and KT17, while the ovoid seed shape resulted in the accessions KT1, KT6, K10, KT13, KT14, and KT15. The globose seed shape appeared in the accessions KT11 and KT18, and the rhomboid seed shape was only distinct in accession KT3. In the East Nusa Tenggara Province, Indonesia, the cowpea seed shape differs, including ellipse, kidney-shaped, square, crowder, and globe (Setyowati*,* 2016), whereas the seed shapes of cowpeas in the Maluku accessions were rhomboid and kidney-shaped (Karuwal *et al*., 2021).

Cowpea accessions considerably varied in seed color. In this study, the observed seed colors were white, yellowish-brown, and gray-brown (Figure 2). Karuwal *et al*. (2021) reported that the seed colors of Maluku cowpea accessions were batik, red, white, brown, black, red striped, yellowish-brown, and gray-brown. Previous studies enunciated that black was the dominant seed color, followed by red and white (Setyowati*,* 2016). The eye color of the seeds also contrasts, ranging from splashed brown and gray, to brownish brown, red, green, and mottled. Eye color of Maluku cowpea accessions showed white, red, black, gray, and brown (Karuwal *et al*., 2021). The majority of the Madura cowpea accessions have a smooth texture, except the accession KT11 that has a wrinkled texture. These results were greatly analogous to the past research which reported that Maluku cowpea accessions have a smooth texture (Karuwal *et al.*, 2021).

**Cluster analysis**

Cluster analysis based on 12 morphological characters divided the Madura cowpea accessions into two large groups with similarity coefficients ranging from 0.30 to 0.83. Groups A and B did not cluster based on sampling locations, rather converged based on morphological traits. In group A, the cowpea accessions converged based on the characteristic of glabrescent plant hairiness, while group B based on differences in the characteristics of wrinkled testa texture, blue-to-black eye color, and white flower color (Figure 3).

At the similarity coefficient of 40%, group A attained further division into two groups. Group A1 converged based on the characteristic of slightly curved pod curvature, and group A2 converged based on the characteristics of plant hairiness, straight pod curvature, immature pod pigmentation, testa texture, and flower and pod colors. Susantidiana *et al.* (2009) also stated that the greater similarity among the accessions showed the accessions have a close kinship relationship.

The dendrogram revealed each cowpea accession was morphologically diverse (Figure 3). The results showed the local Madura cowpea accessions disclosed the highest morphological diversity. Study findings were in line with the statement of Afitu *el al*. (2016), who reported the advantages of local cultivars by having greater diversity and the ability to adapt to diverse environmental conditions, with low but stable production.

## CONCLUSIONS

The Madura cowpea (*V. unguiculata*) accessions proved diverse for 12 morphological characters, including plant pigmentation, terminal leaflet shape, pod attachment, pod curvature, seed shape and color, and flower, eye, and pod colors. Based on phenetic analysis, the morphology of Madura cowpeas further split into two major groups, with a similarity coefficient of 0.30 to 0.83. Cowpea accession KT11 showed obvious separation from other accessions because of its distinctive characteristics of testa texture, pod eye color, and flower color.

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