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MORPHOLOGICAL CHARACTERIZATION AND QUALITATIVE TRAIT DIVERSITY IN COWPEA (*Vigna Unguiculata* L. Walp.) GENOTYPES UNDER SUMMER CONDITIONS IN SOUTH GUJARAT

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ABSTRACT

Cowpea (*Vigna unguiculata* (L.) Walp.) is an important warm-season multipurpose legume valued for its nutritional quality, adaptability, and contribution to sustainable agriculture. Morphological characterization of germplasm is essential for the identification of distinct genotypes, assessment of phenotypic diversity, and selection of suitable parental lines for crop improvement programmes. The present investigation was undertaken to characterize the morphological diversity of thirty vegetable cowpea genotypes using qualitative descriptors under summer conditions. The experiment was conducted during the summer of 2024 at the Vegetable Research Farm, Regional Horticultural Research Station (RHRS), ASPEE College of Horticulture, Navsari Agricultural University, Navsari, Gujarat. Thirty genotypes, including twenty-nine diverse accessions and one standard check (Pusa Phalguni), were evaluated in a Randomized Complete Block Design with three replications under three sowing dates. Ten qualitative morphological traits were recorded following the standardized IPGRI/IITA cowpea descriptor guidelines. Substantial phenotypic variation was observed for all qualitative descriptors, indicating the presence of a broad genetic base among the evaluated genotypes. Plant growth habit varied from erect (26.7%) and semi-erect (23.3%) to bush (20.0%), pole type (20.0%), and horizontal (10.0%). Kidney-shaped seeds were predominant (43.3%), followed by elliptical (33.3%) and rhomboid (23.3%) seeds. Considerable variation was also recorded for climbing tendency, plant pigmentation, terminal leaflet shape, leaf colour, leaf texture, flower colour, pod curvature, and mature pod colour. Flower colour was equally represented by white, yellow, and purple types, while curved pods and green mature pods were the most frequent phenotypes. The observed diversity demonstrates the distinct morphological identity of the evaluated germplasm and highlights the usefulness of qualitative descriptors for varietal characterization. The wide range of morphological variation observed among the cowpea genotypes provides valuable genetic resources for germplasm conservation and characterization. Genotypes possessing desirable traits such as erect growth habit, non-climbing tendency, kidney-shaped seeds, and straight green pods may serve as promising parental lines for vegetable cowpea improvement programmes aimed at developing high-yielding and agronomically superior cultivars.

***Keywords* :** Germplasm accessions, morphological descriptors, qualitative traits, trait diversity, vegetable legume.

Introduction

Vegetables play a vital role in human health and nutritional security, supplying essential vitamins, minerals, dietary fibre, and antioxidants that help prevent micronutrient deficiencies and chronic non-communicable diseases. India ranks second in global vegetable production, contributing approximately 15.7% of world output (Dias, 2012). With accelerating population growth, urbanization, and climate change placing increasing pressure on food systems, the diversification of vegetable production to include nutritionally rich but underutilized species has become an urgent priority (Malo and Ghosh, 2020; Ofoedu *et al.*, 2021).

Among underutilized leguminous vegetables, cowpea (*Vigna unguiculata* (L.) Walp.) holds a position of unique importance. An ancient crop of probable African origin, cowpea is considered to have been domesticated in West Africa during the Neolithic period, with Ethiopia identified as the primary and Africa as the secondary centre of diversity (Vavilov, 1951; Steele, 1976). The crop belongs to the order Rosales, family Fabaceae, and genus *Vigna*. It is a diploid species with a somatic chromosome number of 2n = 22 (Darlington and Wylie, 1955). In India, cowpea is commonly known as *Lubia*, Black eye, *Roungi*, and Kaffir pea, and is grown primarily in the southern, western, and northeastern regions for its green pods as a vegetable and its dried grain as a pulse.

Vegetable cowpea is widely regarded as the "poor man's meat" owing to its high protein content and nutritional value. Green pods contain approximately 3.5% protein, 8.1% carbohydrates, 2.0% fibre, 0.09% minerals, and important vitamins A, B, and C per 100 g edible matter, along with significant quantities of iron and calcium (Smartt, 1976; Yadav, V.S. and R.D. Bhutani, 1988; Swaminathan, 1995). The crop also contributes to soil health through atmospheric nitrogen fixation via root nodules, making it a key component of sustainable, low-input farming systems (Boukar *et al.*, 2019; Ehlers and Hall, 1997).

Notwithstanding its agronomic flexibility and nutritional quality, the average yield of cowpea in India remains far below potential, at only 500-700 kg ha^{-1} against a potential of more than 2,000 kg ha^{-1} under optimal conditions (Singh and Tarawali, 1997). The yield gap is attributable to limited exploitable genetic diversity, non-synchronous flowering, low pod set, susceptibility to pests and diseases, and insufficient availability of varieties suited to intensive cultivation systems. A well-structured breeding programme grounded in a thorough understanding of genetic variability, trait heritability, and genotype performance is therefore prerequisite to meaningful improvement (Singh, 2005). Morphological and biochemical characterization, being rapid, cost-effective, and universally applicable approaches, form the foundation of such programmes by documenting phenotypic diversity and facilitating genotype identification (Mafakheri *et al.*, 2017).

Qualitative morphological traits governed primarily by major genes and exhibiting minimal genotype × environment interaction are particularly reliable for germplasm characterization, varietal documentation, and hybrid purity testing (Patel *et al.*, 2022; Oo *et al.*, 2022). Despite the availability of diverse cowpea germplasm in Indian gene banks, comprehensive morphological characterization of accessions specifically for vegetable use has been sporadic. This study was therefore designed to evaluate thirty cowpea genotypes assembled from diverse agro-ecological regions of India for ten qualitative morphological descriptors under summer conditions. Specifically, the objectives were: (i) to characterize the genotypes for qualitative morphological traits using IPGRI/IITA descriptors; (ii) to determine the extent of morphological diversity among genotypes; and (iii) to identify genotypes with desirable plant architecture and pod traits for use as parents in vegetable cowpea improvement programmes.

Materials and Methods

Experimental Site and Agro-climatic Conditions

The experiment was conducted during summer 2024 at the Vegetable Research Farm, Regional Horticultural Research Station (RHRS), ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India (20°57′ N, 72°54′ E; altitude 11.98 m above MSL). The experimental station lies within the South Gujarat Heavy Rainfall Agro-climatic Zone (AES-III), characterized by a tropical climate receiving an average annual rainfall of approximately 1,800 mm, predominantly between early June and late September. Meteorological data including maximum and minimum temperature, relative humidity, sunshine hours, and rainfall were recorded from the Agro-meteorological Observatory, N.M. College of Agriculture, NAU, Navsari for the period February-July 2024.

Soil Characteristics

The experimental soil belongs to the order Inceptisols (sub-order Ochrepts; great soil group Vertic Ustochrepts) under the Jalalpore soil series of South Gujarat, locally known as black cotton soil. The soil was deep black, well-drained, with good water-holding capacity and reasonably suitable for cowpea cultivation.

Experimental Material and Design

Thirty cowpea genotypes comprising twenty-nine diverse lines sourced from Anand Agricultural University (AAU), Navsari Agricultural University (NAU), the All India Coordinated Research Project on Vegetable Crops (AICRP-VC), and the National Bureau of Plant Genetic Resources (NBPGR, New Delhi) and one standard check (Pusa Phalguni, IARI, New Delhi) were evaluated. Details of the genotypes are presented in Table-1. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications under three sowing dates (15 February, 28 February and 15 March 2024), providing three environments for performance evaluation. Plant spacing was maintained at 45 cm × 30 cm. Five randomly selected plants per plot per replication, excluding border plants, were tagged for observations.

Cultural Practices and Crop Management

The experimental field was prepared by thorough ploughing, harrowing, and levelling. Well-decomposed farmyard manure (FYM) at 20 t ha^{-1} was incorporated during field preparation. Nitrogen at 20 kg ha^{-1} as urea and phosphorus at 40 kg ha^{-1} as single super phosphate (SSP) were applied as basal doses. Gap filling was carried out at 10 days after sowing (DAS). Flood irrigation was applied immediately after sowing, with subsequent irrigations based on soil moisture and weather conditions. Three hand weedings were performed throughout the crop period to maintain weed-free conditions.

Observations Recorded

Ten qualitative morphological descriptors were recorded following the standardized IPGRI/IITA cowpea descriptor protocols. The traits and their respective scoring classes were as follows: (i) **plant growth habit**– erect, semi-erect, bush, horizontal, or pole type; (ii) **seed shape** – kidney, elliptical, or rhomboid; (iii) **climbing tendency** – none, slight, or pronounced; (iv) **plant pigmentation** – absent or present, determined by visual assessment of stem and petiole colouration; (v) **terminal leaflet shape** – hastate, sub-hastate, sub-globose, or globose; (vi) **leaf colour** – green or dark green; (vii) **leaf texture** – glabrous or pubescent; (viii) **flower colour** – white, yellow, or purple; (ix) **pod curvature** – straight, curved, or horseshoe; and (x) **mature pod colour** – green or dark green.

Statistical Analysis

Analysis of variance was performed as per the model described by Panse, V.G. and P.V. Sukhatme (1961). Genotypic and phenotypic coefficients of variation (GCV, PCV) were estimated following Burton, G.W. and D.E. DeVane (1953). Heritability in broad sense and expected genetic advance were computed as per Johnson, H.W. *et al.* (1955). Genotypic and phenotypic correlation coefficients were estimated following Al-Jibouri, H. *et al.* (1958), and path coefficient analysis was conducted following the methods of Dewey, D.R. and K. Lu (1959) and Wright, S. (1921). Genetic divergence was assessed using Mahalanobis's D^2 statistics, with clustering by Tocher's method as described by Rao, C.R. (1952). Stability analysis was performed using the Eberhart, S.T. and W.A. Russell (1966) model.

Table 1 : Details of the 30 cowpea [*Vigna unguiculata* (L.) Walp.] genotypes used in the present study

Sr. No.	Genotype	Source Institute	Place of Collection
1	GVC-9	Anand Agricultural University	Anand, Gujarat
2	GC-5	Anand Agricultural University	Anand, Gujarat
3	AVCP-1	Anand Agricultural University	Anand, Gujarat
4	GDVC-2	Anand Agricultural University	Anand, Gujarat
5	NCK-15-01	Navsari Agricultural University	Navsari, Gujarat
6	NCK-15-05	Navsari Agricultural University	Navsari, Gujarat
7	NCK-15-08	Navsari Agricultural University	Navsari, Gujarat
8	2019/COPBVAR-2	AICRP on Vegetable Crops	Multi-location, India
9	2019/COPBVAR-3	AICRP on Vegetable Crops	Multi-location, India
10	2019/COPBVAR-5	AICRP on Vegetable Crops	Multi-location, India
11	2019/COPBVAR-6	AICRP on Vegetable Crops	Multi-location, India
12	2021/COPBVAR-2	AICRP on Vegetable Crops	Multi-location, India
13	2021/COPBVAR-5	AICRP on Vegetable Crops	Multi-location, India
14	NC-5	NBPGR, New Delhi	National gene bank, India
15	NC-16	NBPGR, New Delhi	National gene bank, India

16	NC-28	NBPGR, New Delhi	National gene bank, India
17	NC-47	NBPGR, New Delhi	National gene bank, India
18	NC-52	NBPGR, New Delhi	National gene bank, India
19	NC-57	NBPGR, New Delhi	National gene bank, India
20	NC-81	NBPGR, New Delhi	National gene bank, India
21	NC-88	NBPGR, New Delhi	National gene bank, India
22	NC-90	NBPGR, New Delhi	National gene bank, India
23	NC-119	NBPGR, New Delhi	National gene bank, India
24	NC-121	NBPGR, New Delhi	National gene bank, India
25	NC-142	NBPGR, New Delhi	National gene bank, India
26	NC-161	NBPGR, New Delhi	National gene bank, India
27	NC-187	NBPGR, New Delhi	National gene bank, India
28	NC-196	NBPGR, New Delhi	National gene bank, India
29	NC-198	NBPGR, New Delhi	National gene bank, India
30	Pusa Phalguni (Check)	IARI, New Delhi	New Delhi, India

Results and Discussion

Ten qualitative morphological traits were recorded across thirty cowpea genotypes to characterize the phenotypic diversity of the germplasm panel. The results, summarized in Table-2, reveal wide variation across all descriptor classes, confirming the genetic heterogeneity of the assembled collection. The frequency distribution of plant growth habit is presented separately in Table-3.

Plant Growth Habit

The thirty genotypes exhibited five distinct growth habits: erect (8 genotypes; 26.7%), semi-erect (7; 23.3%), bush (6; 20.0%), horizontal (3; 10.0%), and pole type (6; 20.0%) (Table-3). The coexistence of determinate (erect and bush) and indeterminate (pole type) forms within the same germplasm panel indicates considerable architectural diversity. Determinate types with erect or bush habits are preferred for high-density cultivation and ease of harvest, while indeterminate pole-type genotypes may be advantageous in intercropping systems for their prolonged pod-production period. Toyin (2019) similarly documented erect, semi-erect, and trailing growth forms in Indian cowpea accessions, attributing differences to genetic variation in apical dominance and phytohormonal regulation. Ezzat *et al.* (2019) further noted that most modern cultivars selected for vegetable use tend toward compact, erect growth to facilitate crop management.

Seed Shape

Three distinct seed shapes were observed: kidney (13; 43.3%), elliptical (10; 33.3%), and rhomboid (7; 23.3%). Kidney-shaped seeds predominated, consistent with their documented consumer preference in South Asian fresh markets. Seed shape is determined by the morphology of the seed coat and cotyledons and serves as an important qualitative marker for variety identification and market differentiation. Zafeiriou *et al.* (2023) reported comparable seed morphological variation including kidney, rhomboid, and globose forms among Greek cowpea landraces, attributing such diversity to local adaptation and historical selection pressure. The rhomboid-seeded accessions in the present panel, predominantly NBPGR-maintained lines, reflect the preservation of ancestral morphological traits within the gene bank collection.

Climbing Tendency

Climbing tendency was absent in 10 genotypes (33.3%), slight in 13 (43.3%), and pronounced in 7 (23.3%). Genotypes with pole-type or horizontal growth habits predictably exhibited greater climbing propensity. From a practical standpoint, genotypes with absent or slight climbing tendency are more amenable to stake-free, direct-sown cultivation systems, thereby reducing production costs. Ezzat *et al.* (2019) confirmed that climbing propensity in cowpea is a genetically controlled trait, with pronounced climbers exhibiting higher vegetative biomass but requiring additional support structures. The preponderance of non-climbing or slightly climbing genotypes in the present panel reflects the pre-selection of germplasm lines suited to vegetable cowpea production environments.

Plant Pigmentation

Pigmentation of the stem and petiole was present in 16 genotypes (53.3%) and absent in 14 (46.7%). Anthocyanin pigmentation in cowpea stems is governed by regulatory genes in the flavonoid biosynthesis pathway and represents a visually distinctive marker useful in hybrid identification and field rouging. Deshpande *et al.* (2018) identified pigmentation intensity as a highly variable qualitative trait among Nigerian cowpea lines and proposed its utility for field-level genotype differentiation. The near-equal distribution of pigmented and non-pigmented genotypes in the present panel reflects the broad genetic base of the assembled collection.

Terminal Leaflet Shape

Four categories of terminal leaflet shape were recorded: hastate (10; 33.3%), sub-hastate (8; 26.7%), sub-globose (8; 26.7%), and globose (4; 13.3%). Leaflet morphology is governed by allelic variation at major loci and exhibits moderate heritability, making it a reliable descriptor for morphological characterization. Mafakheri *et al.* (2017) reported comparable variation in terminal leaflet shapes among cowpea germplasm from India, confirming that this trait serves effectively as a tool for morphological fingerprinting, particularly in the absence of molecular markers.

Leaf Colour

Leaf colour was green in 18 genotypes (60.0%) and dark green in 12 (40.0%). Leaf colour is determined by the concentration and proportions of chlorophylls and carotenoids in the mesophyll. Dark green foliage is generally associated with higher chlorophyll content per unit leaf area and greater photosynthetic efficiency. Gomes *et al.* (2021) reported leaf colour as a moderately heritable trait in cowpea landraces from Mozambique and suggested its potential utility for early phenotypic selection for photosynthetic vigour.

Leaf Texture

Leaf texture was glabrous in 16 genotypes (53.3%) and pubescent in 14 (46.7%). Leaf pubescence is a constitutive physical defence mechanism that impedes the movement and settlement of small arthropods including aphids and thrips. Oo *et al.* (2022) demonstrated that pubescent cowpea genotypes exhibited measurably greater resistance to aphid infestation compared to glabrous types, attributing this to both the mechanical barrier effect of trichomes and the deterrent effect of surface terpene exudates. The balanced distribution of glabrous and pubescent types in the present panel provides an opportunity to assess the relationship between leaf texture and field pest incidence.

Flower Colour

Flower colour was equally distributed among white (10; 33.3%), yellow (10; 33.3%), and purple (10; 33.3%) classes. Flower colour in cowpea is governed by structural genes in the anthocyanin and flavonoid pathways and is considered a stable, highly heritable descriptor useful for variety registration and hybrid purity testing. Patel *et al.* (2022) documented variation in flower colour among Indian cowpea genotypes and correlated it with differential expression of genes encoding chalcone synthase in the anthocyanin pathway. The equal distribution across the three colour classes confirms the diverse genetic background of the assembled germplasm.

Pod Curvature

Pod curvature was recorded as straight in 9 genotypes (30.0%), curved in 14 (46.7%), and horseshoe-shaped in 7 (23.3%). Straight pods are generally preferred by fresh market consumers and processors, whereas curved or horseshoe-shaped pods are associated with indeterminate pole-type growth habits. Patel *et al.* (2022) reported significant variation in pod curvature among Indian cowpea germplasm, underscoring its importance as a qualitative character in morphological studies. The predominance of curved pods among NBPGR accessions in the present panel likely reflects the diversity in growth habit and pod developmental genetics retained within the gene bank collection.

Mature Pod Colour

At physiological maturity, pod colour was green in 16 genotypes (53.3%) and dark green in 14 (46.7%). Green pods command premium prices in fresh vegetable markets across India. Pod colour at maturity is influenced by chlorophyll retention capacity and its rate of degradation during pod senescence, traits partly under genetic control and partly responsive to temperature and humidity during pod filling. Toyin (2019) reported similar variation in mature pod colour in Indian cowpea lines, ranging from pale green to dark green depending on genotype and agro-climatic origin. The near-equal split between green and dark green pods in the present panel provides adequate diversity for market-quality-oriented selection.

Table 2 : Qualitative morphological characterization of 30 cowpea genotypes

Qualitative Trait	Class Distribution (No. of Genotypes)	Predominant Class (%)
Plant growth habit	Erect (8), Semi-erect (7), Bush (6), Horizontal (3), Pole type (6)	26.7% erect; 20.0% pole type
Seed shape	Kidney (13), Elliptical (10), Rhomboid (7)	43.3% kidney shaped
Climbing tendency	None (10), Slight (13), Pronounced (7)	43.3% slight tendency

Plant pigmentation	Present (16), Absent (14)	53.3% pigmented
Terminal leaflet shape	Hastate (10), Sub-hastate (8), Sub-globose (8), Globose (4)	33.3% hastate
Leaf colour	Green (18), Dark green (12)	60.0% green
Leaf texture	Glabrous (16), Pubescent (14)	53.3% glabrous
Flower colour	White (10), Yellow (10), Purple (10)	Equal distribution (33.3% each)
Pod curvature	Straight (9), Curved (14), Horseshoe (7)	46.7% curved
Mature pod colour	Green (16), Dark green (14)	53.3% green

Table 3 : Frequency distribution of plant growth habit among 30 cowpea genotypes

Plant Growth Habit	No. of Genotypes	Frequency (%)
Erect	8	26.7
Semi-erect	7	23.3
Bush	6	20.0
Horizontal	3	10.0
Pole type	6	20.0
Total	30	100.0

Conclusion

The present investigation revealed substantial morphological diversity among thirty cowpea genotypes evaluated under summer conditions at Navsari, Gujarat. All ten qualitative descriptors plant growth habit, seed shape, climbing tendency, plant pigmentation, terminal leaflet shape, leaf colour, leaf texture, flower colour, pod curvature, and mature pod colour exhibited meaningful variation, confirming the genetic heterogeneity of the assembled germplasm panel. NBPGR-maintained accessions demonstrated the widest range of morphological variation, underscoring their potential as valuable sources of novel alleles for vegetable cowpea improvement. Genotypes with erect or semi-erect growth habits, kidney-shaped seeds, straight green pods, and non-climbing tendencies represent desirable ideotypes for intensive vegetable production systems. The morphological characterization data generated provide a systematic reference for germplasm documentation, varietal identification, and rational selection of parents for hybridization programmes. Further integration of quantitative trait analysis, biochemical characterization, and molecular marker profiling with the present morphological data would yield a comprehensive understanding of genetic architecture and facilitate accelerated development of improved cowpea varieties for nutritional security and sustainable agriculture.

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