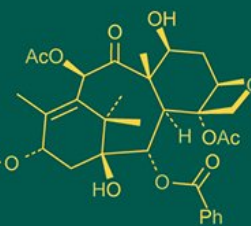
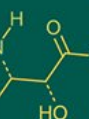
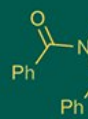


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Genetic variability and divergence analysis for yield and its contributing traits in cowpea (*Vigna Unguiculata* (L.) Walp) Genotypes under Western Uttar Pradesh conditions

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Abstract

The present investigation was conducted to assess the genetic variability, association and genetic divergence among cowpea (*Vigna unguiculata* (L.) Walp.) genotypes under the agro-climatic conditions of Western Uttar Pradesh. The experiment was conducted during Zaid 2025 at the Horticulture Research Centre, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, using 25 cowpea genotypes in a randomized block design with three replications. Significant differences were observed among genotypes for all the morphological and yield-related traits, indicating substantial genetic variability. Green pod yield per plant ranged from 153.10 to 393.88 g, with IC-536723 recording the highest yield. Plant height exhibited the highest GCV (36.59%) and PCV (37.19%). High heritability coupled with high genetic advance was observed for plant height, number of pods per plant, number of seeds per plant, dry weight of leaves and green pod yield, indicating good prospects for selection. Green pod yield showed significant positive association with number of branches, pods per plant, pod length, seeds per pod, seeds per plant, single pod weight and dry weight of leaves. Mahalanobis D² analysis grouped the genotypes into three clusters, with maximum inter-cluster distance between Cluster II and Cluster III (5.340). Cluster II showed superior mean performance for most yield-contributing traits. Days to maturity contributed the maximum (12.38%) to genetic divergence, followed by days to 50% flowering (11.03%) and pod length (10.32%). The study identified IC-536723 as a promising genotype and Clusters II and III as useful divergent groups for future cowpea improvement programmes.

Keywords: Cowpea, genetic variability, heritability, genetic advance, correlation, genetic divergence, mahalanobis D², cluster analysis, green pod yield, germplasm

Introduction

Cowpea (*Vigna unguiculata* (L.) Walp.) is an important food legume cultivated extensively in tropical and subtropical regions and is valued for its nutritional, economic and environmental benefits. It is a rich source of protein, vitamins and minerals and is also well adapted to drought, heat and low-fertility conditions, making it an important crop for sustainable agriculture and food security. The productivity and adaptability of cowpea largely depend on the genetic variability available within the crop. Considerable variation exists for important morphological and agronomic traits such as plant growth habit, plant height, branching, flowering time, pod length, number of pods per plant, seed characteristics and yield. Such variability provides an important resource for selecting superior genotypes and developing improved cultivars. Morphological characterization is a simple and cost-effective approach for identifying phenotypic variation and differentiating genotypes. Evaluation of diverse genotypes under a particular agro-climatic condition is particularly important because genotype performance and expression of quantitative traits are influenced by environmental conditions. Previous studies have demonstrated substantial genetic diversity among cowpea germplasm and emphasized the importance of characterizing available genetic resources for their effective utilization in breeding programmes (Huynh et

et al., 2013; Carvalho *et al.*, 2017; Boukar *et al.*, 2019) [3, 2, 1]. Assessment of genetic diversity based on morphological traits can help identify genetically distinct and agronomically superior genotypes, facilitate selection of suitable parents for hybridization and support the development of varieties with desirable yield, earliness, adaptability and quality characteristics. Recent reviews also emphasize that effective utilization of cowpea genetic resources is essential for improving productivity, stress tolerance and market value under changing production environments.

Material and Methods

Experimental site and plant material

The present investigation entitled “Morphological Characterization and Assessment of Genetic Diversity among Cowpea (*Vigna unguiculata* (L.) Walp.) Genotypes under Western Uttar Pradesh Conditions” was conducted during the Zaid season of 2025 at the Horticulture Research Centre (HRC), Sardar Vallabhbhai Patel University of Agriculture and Technology, Modipuram, Meerut, Uttar Pradesh. The experimental site falls under the agro-climatic conditions of Western Uttar Pradesh and the soil of the experimental field was sandy loam.

The experimental material consisted of 25 cowpea genotypes, comprising 25 germplasm accessions obtained from the National Bureau of Plant Genetic Resources (NBPGR), New Delhi and Pant Lobia-5 as a check variety.

Experimental design and crop management

The genotypes were evaluated in a Randomized Block Design (RBD) with three replications, resulting in 78 experimental plots. The crop was planted at a spacing of 45 cm × 30 cm (row-to-row × plant-to-plant). Recommended agronomic practices were followed uniformly throughout the crop period to ensure proper growth and development of all genotypes. The details of the experimental design and spacing were adopted from the original experimental methodology.

Morphological characterization

Morphological and quantitative observations were recorded from five randomly selected and tagged plants from each genotype in each replication and the mean values were used for statistical analysis. The traits recorded included days to 50% flowering, days to maturity, plant height (cm), number of branches per plant, number of pods per plant, pod length (cm), number of seeds per plant, number of seeds per pod, single green pod weight (g), dry weight of leaves per plant, protein content (%) and green pod yield per plant (g). Days to 50% flowering was recorded as the number of days from sowing to the opening of at least one flower in 50% of the plants. Days to maturity was recorded when approximately 80–90% of the pods attained physiological maturity. Plant height was measured from the ground level to the terminal growing point, while branches and pods were counted from the tagged plants. Pod length was measured from the point of attachment to the tip of the pod. Green pod weight and total green pod yield were recorded using an electronic balance.

Statistical analysis

The experimental data were subjected to analysis of variance (ANOVA) to determine the significance of

differences among genotypes. Genotypic and phenotypic variances were estimated following Lush (1940), while genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were calculated according to Burton (1952) [7]. Broad-sense heritability and genetic advance were estimated following Johnson *et al.* (1955) [8]. To assess the relationship among morphological traits, genotypic and phenotypic correlation coefficients were estimated following Searle (1961) [9]. Path coefficient analysis was performed according to the procedure of Dewey and Lu (1959) [10] to determine the direct and indirect effects of component traits on green pod yield per plant.

Assessment of genetic diversity

Genetic diversity among the cowpea genotypes was assessed using Mahalanobis' D^2 statistics as described by Rao (1952) [11]. The generalized distance was calculated using the mean values of the morphological and quantitative traits. The genotypes were grouped into different clusters using Tocher's method, with genotypes having relatively smaller average D^2 values grouped together. Intra- and inter-cluster distances were calculated to determine the extent of genetic divergence among the clusters

Result

Genetic variability for yield and its contributing traits

Analysis of variance revealed significant differences among the cowpea genotypes for all the traits studied, indicating the presence of considerable genetic variability in the experimental material. The studied traits included days to 50% flowering, days to maturity, plant height, number of branches per plant, number of pods per plant, pod length, number of seeds per pod, number of seeds per plant, single green pod weight, dry weight of leaves per plant, protein content and green pod yield per plant. The mean performance of the genotypes showed substantial variation for both phenological and yield-related traits. Days to 50% flowering ranged from 40.63 to 63.43 days, while days to maturity varied from 64.21 to 87.15 days. Plant height showed a wide range of 42.07–160.40 cm, indicating considerable variability for plant architecture. Number of pods per plant ranged from 16.50 to 40.24, whereas pod length varied from 8.88 to 19.57 cm. Number of seeds per pod and number of seeds per plant ranged from 9.73–15.91 and 240.11–588.42, respectively. Single green pod weight varied from 6.50 to 9.40 g. Green pod yield per plant exhibited considerable variability, ranging from 153.10 to 393.88 g, with a mean of 258.38 g. Among the evaluated genotypes, IC-536723 recorded the highest green pod yield per plant (393.88 g), followed by IC-202867 (366.90 g) and EC-724796 (340.19 g).

The estimates of GCV and PCV indicated substantial genetic variation for several traits. GCV ranged from 8.63% for single green pod weight to 36.59% for plant height, while PCV ranged from 9.47 to 37.19%. Plant height exhibited the highest GCV (36.59%) and PCV (37.19%), followed by dry weight of leaves per plant and number of seeds per plant. The relatively narrow differences between GCV and PCV for most traits indicated comparatively lower environmental influence on trait expression.

Broad-sense heritability ranged from 78.50 to 98.22%, with the highest estimate recorded for dry weight of leaves per plant (98.22%), followed by plant height (96.76%), number

of seeds per plant (96.69%) and green pod yield per plant (96.51%). Genetic advance as percentage of mean was highest for plant height (74.14%), followed by dry weight of leaves per plant (64.10%), number of seeds per plant (54.29%), green pod yield per plant (48.39%) and number of pods per plant (39.90%). The combination of high heritability with high genetic advance for plant height, number of pods per plant, number of seeds per plant, dry weight of leaves and green pod yield suggested substantial scope for selection based on phenotypic performance.

Association of yield with component traits

The correlation analysis revealed significant associations between green pod yield and several yield-contributing traits. Green pod yield per plant showed significant positive correlations with number of branches per plant ($r = 0.568$), number of pods per plant ($r = 0.786$), pod length ($r = 0.399$), number of seeds per pod ($r = 0.608$), number of seeds per plant ($r = 0.482$), single green pod weight ($r = 0.480$) and dry weight of leaves per plant ($r = 0.937$). Protein content showed a significant negative association with green pod yield ($r = -0.299$).

The strong positive association of green pod yield with number of pods per plant and dry weight of leaves per plant indicated their importance as potential selection criteria for improving productivity. Path coefficient analysis further demonstrated that the correlation between yield and its component characters was influenced by both direct and indirect effects, emphasizing the importance of considering component traits simultaneously during selection.

Genetic divergence among cowpea genotypes

Mahala Nobis (D^2) analysis revealed significant genetic divergence among the evaluated cowpea genotypes. Based on Tocher's method, the genotypes were grouped into three clusters. Cluster I comprised 12 genotypes, Cluster II comprised 6 genotypes and Cluster III comprised 7 genotypes. The clustering pattern indicated considerable genetic diversity among the experimental material.

The average intra-cluster distance was highest in Cluster III (2.821), followed by Cluster II (2.573), while Cluster I showed the lowest intra-cluster distance (2.305). The lower intra-cluster distance of Cluster I indicated greater similarity among its constituent genotypes, whereas the relatively higher value for Cluster III indicated greater variability within that cluster.

The maximum inter-cluster distance was observed between Cluster II and Cluster III (5.340), followed by Cluster I and Cluster II (4.059). The minimum inter-cluster distance was observed between Cluster I and Cluster III (3.155). The higher inter-cluster distances compared with intra-cluster distances confirmed substantial genetic divergence among the clusters. Therefore, genotypes belonging to Cluster II and Cluster III may be considered promising divergent parental groups for future hybridization programmes.

Cluster mean performance and identification of promising genotypes

Considerable differences were observed among clusters for the studied traits. Cluster II exhibited the highest mean values for several important yield-contributing characters, including plant height (128.39 cm), number of branches per plant (6.36), number of pods per plant (36.75), pod length (16.13 cm), number of seeds per pod (15.06), number of

seeds per plant (452.54), single pod weight (8.70 g), dry weight of leaves per plant (15.14 g) and green pod yield per plant (348.33 g).

Cluster I recorded the earliest flowering (42.97 days) and maturity (70.03 days), whereas Cluster III exhibited the latest flowering (60.82 days) and maturity (84.14 days). Green pod yield per plant was highest in Cluster II (348.33 g) and lowest in Cluster III (224.32 g). Thus, Cluster II was identified as the most promising cluster for yield and its contributing traits, while the large inter-cluster distance between Clusters II and III suggested their potential usefulness as divergent parental groups.

Among individual genotypes, IC-536723 was identified as particularly promising, recording the highest green pod yield per plant (393.88 g), highest number of seeds per pod (15.91) and highest dry weight of leaves per plant (17.41 g). EC-724326 recorded the highest number of branches (8.73) and pods per plant (40.24), whereas EC-724796 recorded the highest number of seeds per plant (588.42). EC-725161 recorded the highest pod length (19.57 cm) and protein content (25.86%). These genotypes may therefore be considered valuable sources for selection and future breeding programmes.

Contribution of traits to genetic divergence

The contribution of individual traits to total genetic divergence varied considerably. Days to maturity contributed the maximum (12.38%), followed by days to 50% flowering (11.03%), pod length (10.32%), number of seeds per pod (10.03%) and number of branches per plant (10.01%). Plant height, protein content and number of pods per plant contributed 9.00, 8.94 and 7.68%, respectively. Green pod yield per plant contributed 3.55% to the total divergence. The results indicated that phenological traits, pod characteristics and seed-related traits played an important role in differentiating the cowpea genotypes. Therefore, these traits may receive greater consideration while selecting diverse parents for breeding programmes.

The present findings agree with those of Manggoel *et al.*, (2012) ^[5] conducted an experiment on 10 cowpea accessions. The accessions exhibited significant variability for days to 50% flowering, number of peduncles per plant, flowers per plant, pods per plant, seeds per pod, pod length, 100-seed weight and grain yield. Khanpara *et al.* (2016) ^[12] evaluated 60 genotypes of vegetable cowpea and reported the highest variation for green pod yield per plant followed by pod weight, number of pods per plant and plant height. Higher values of PCV than GCV were observed for green pod yield per plant, number of pods per plant, pod length and number of seeds per pod.

Discussion

Significant differences among cowpea genotypes for all studied traits indicated the presence of substantial genetic variability, providing good scope for selection and genetic improvement. Similar variability for flowering, pod characters and yield traits was reported by Manggoel *et al.* (2012) ^[5] and Khanpara *et al.* (2016) ^[12]. The relatively high GCV and PCV, particularly for plant height and yield-related traits, indicated considerable genetic variation with comparatively limited environmental influence. High heritability coupled with high genetic advance for plant height, number of pods per plant, number of seeds per plant, dry weight of leaves and green pod yield suggested the

predominance of genetic effects and good prospects for selection. Khanpara *et al.* (2016) ^[12] also reported similar findings in vegetable cowpea. Green pod yield showed significant positive associations with number of branches, pods per plant, pod length, seeds per pod, seeds per plant, single pod weight and dry weight of leaves. The strong association with number of pods per plant and dry weight of leaves indicated their potential usefulness as selection criteria. The negative association of protein content with yield suggested the need for careful selection to combine high yield with nutritional quality. Mahala Nobis D² analysis revealed considerable genetic divergence among the genotypes, with three clusters identified. The maximum divergence between Clusters II and III indicated their

potential usefulness as divergent parental groups for hybridization. Cluster II was the most promising cluster because of its superior performance for major yield-contributing traits. Among individual genotypes, IC-536723 was identified as the most promising for green pod yield, while EC-724326, EC-724796 and EC-725161 were valuable sources for specific desirable traits. Overall, the study demonstrated substantial genetic variability, high heritability and genetic divergence among the cowpea genotypes. Plant height, number of pods per plant, number of seeds per plant and green pod yield may be given priority during selection, while IC-536723 and genetically divergent genotypes from Clusters II and III may be utilized in future breeding programmes.

Table 1: Distribution of twenty-six cow pea genotypes in different cluster.

Cluster	Number of Genotypes	Genotypes
1	12	EC-724774, EC-724787, EC-724971, EC-724778, EC-725077, EC-724780, EC-724930, EC-724784, EC-734817, IC-539688, IC-522271, IC-198329
2	6	EC-724326, EC-724911, EC-724880, EC-724779, EC-724796, IC-202867, IC-536723
3	7	EC-725102, EC-724824, EC-724768, EC-724949, EC-724779, EC-725174, EC725161

Table 2: Average intra and inter cluster distance representing the Mahalanobis distance between clusters and D-values (square root of D²) and D2 (in bracket) value for three cluster in twenty-five accession of cowpea.

Clusters	I	II	III
I	2.305		
II	4.059	2.573	
III	3.155	5.340	2.821

Table 3: Average cluster distance means representing the Mahalanobis distance value for three cluster in twelve morphological traits of twenty-five accession of cowpea.

Clusters		Days to 50% flowering	Days to maturity	Plant height (cm)	Number of branches per plant	Number of Pods/plants	Length of pods (cm)	Number of Seeds /pods	Number of seeds/plants	Single pod weight (g)	Dry weight leaf/plant (g)	Protein content (%)	Green pod yield per plant (g)
I	Mean	42.97	70.03	90.82	4.68	28.75	14.66	12.34	351.26	8.24	9.61	23.43	233.26
	± SE	1.55	2.96	30.07	0.46	4.28	1.9	1.41	67.84	0.69	2.22	1.7	40.59
II	Mean	46.13	73.84	128.39	6.36	36.75	16.13	15.06	452.54	8.7	15.14	21.79	348.33
	± SE	5.65	5.06	45.61	1.35	3.24	1.6	0.71	119.48	0.36	2.87	1.04	27.1
III	Mean	60.82	84.14	89.98	4.67	24.63	15.34	10.96	305.37	8.29	8.64	23.43	224.32
	± SE	3.61	2.29	29.82	0.69	4.43	4.24	1.53	75.72	1.05	1.5	1.85	33.36

Table 4: Percent contribution of 12 traits for divergence

Trait	Contribution (%)
Days to maturity	12.38
Days to 50% flowering	11.03
Length of pods (cm)	10.32
Number of Seeds per pod	10.03
Number of branches per plant	10.01
Plant height (cm)	9.00
Protein content (%)	8.94
Number of pods/plants	7.68
Number of seeds/plants	6.74
Single pod weight (g)	6.06
Dry weight leaf/plant (g)	4.24
Grain yield per plant (g)	3.55

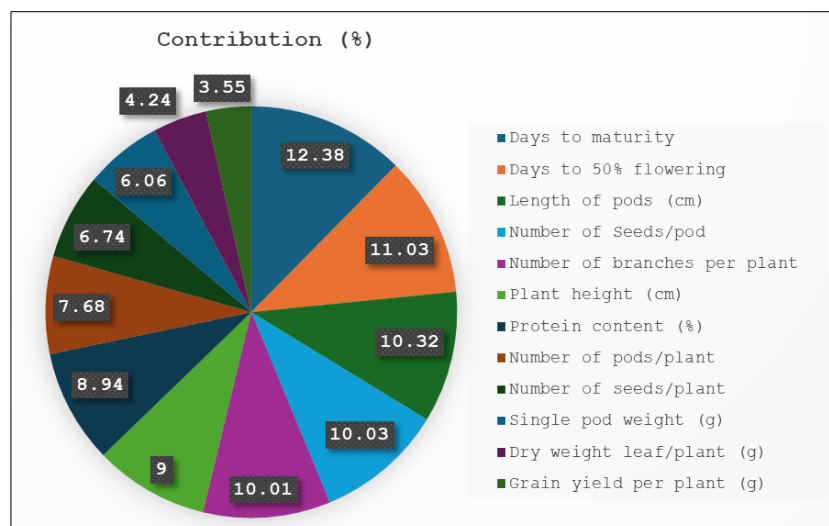


Fig 1: Percent contribution of 12 traits for divergence

Conclusion

The present investigation revealed substantial genetic variability and diversity among the cowpea genotypes for yield and its contributing traits. High heritability coupled with high genetic advance for plant height, number of pods per plant, number of seeds per plant, dry weight of leaves and green pod yield indicated good prospects for effective selection. Green pod yield showed strong positive association with number of pods per plant and dry weight of leaves, suggesting their usefulness as selection criteria. Mahalanobis D^2 analysis revealed considerable genetic divergence, with maximum divergence between Clusters II and III. Cluster II was the most promising cluster for yield and its component traits. Among individual genotypes, IC-536723 was identified as the most promising genotype for green pod yield, while EC-724326, EC-724796 and EC-725161 showed superiority for specific desirable traits. These genotypes and divergent clusters may therefore be utilized as valuable genetic resources in future cowpea improvement and hybridization programmes.

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