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EVALUATION OF COWPEA (*Vigna unguiculata* L.) CORE SET GERMPLASM FOR FODDER TRAITS UNDER WESTERN HIMALAYAN CONDITIONS

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ABSTRACT

Cowpea (*Vigna unguiculata* L. Walp.) is an important dual-purpose legume crop valued for both grain and fodder production. The present study evaluated 254 cowpea genotypes for variability in eleven important fodder-associated traits to identify superior genotypes for fodder improvement. Substantial variability was observed among genotypes for all traits, representing a wide genetic diversity in the national cowpea core set for selection. High coefficients of variation (CV) were recorded for shoot biomass (55.6%), number of primary branches (54.7%), and leaf biomass (52.1%), reflecting considerable diversity. Plant height ranged from 33 to 370 cm, while shoot biomass varied from 25 to 1509 g per plant. Genotypes such as IC420591 exhibited superior shoot and leaf biomass, whereas EC240702 recorded the highest leaf area. Raincloud plots revealed broad variation and distribution patterns across traits, highlighting the presence of diverse phenotypic classes. Trait association analysis using heat maps indicated significant positive and negative correlations among fodder traits. Principal Component Analysis (PCA) showed that the first two principal components explained 52.2% of the total variation. The PCA biplot revealed strong positive associations of shoot biomass with leaf biomass, stem biomass, leaf-stem ratio, number of internodes, and number of primary branches. These findings provide valuable information for the selection of promising cowpea genotypes and the development of high-yielding fodder cultivars.

Keywords **:** Cowpea, Variability, Coefficients of variation, Raincloud plots.

Introduction

Cowpea (*Vigna unguiculata* L. Walp.) is a warm-season legume crop cultivated across arid, semi-arid, and tropical regions of the world. It plays a pivotal role in smallholder farming systems, primarily functioning as a dual-purpose crop that simultaneously provides protein-rich grain for human nutrition and high-quality green forage or hay for livestock (Tarawali *et al.*, 1997; Horn *et al.*, 2016; Boukar *et al.*, 2019; Raina *et al.*, 2023). Livestock productivity depends directly on the quality and quantity of fodder. Farmers usually feed animals the leftover stalks and straw from crops like rice, wheat, and barley. However, this food is low in protein and doesn't give them much energy because the tough, woody fibers in the plant walls make it hard to digest. (Banik *et al.* 2021). So, the leguminous crops can be a better option for increasing the quality of feed for livestock (Singh *et al*. 2003; Pitman, 2015). Cowpea being rich in proteins is a valuable alternative fodder crop as it produces significantly higher biomass than many other legume crops such as common bean, lentil, chickpea, pea, and moong bean. Cowpea green fodder has a crude protein content ranging from 14% to 21% (Habte *et al*., 2023; Sanfo *et al*., 2023), while its seeds contain 18–26% protein (Adeyanju *et al.,* 2012). The crude protein content of cowpea hay used for animal feed has been reported to range from 17% to 27%. Additionally, (Acid Detergent Fiber) ADF in cowpea hay ranges from 25% to 57%, while Neutral Detergent Fiber (NDF) varies between 25% and 60% (Basaran *et al.,* 2011; Ayan *et al.,* 2012; Idikut *et al*., 2015; Ayan *et al.,* 2017; Omar *et al.,* 2018). Mineral contents of cowpea hay are also substantial, with potassium ranging from 1.3% to 1.65%, magnesium 0.46 0.51%, calcium 1.04–1.32%, and phosphorus 0.34–0.37% (Ayan *et al*., 2012). This chemical composition confirms that cowpea green fodder and hay are high-quality feed sources for livestock. Its profound capacity for atmospheric nitrogen fixation and low water requirement makes it an indispensable component for enhancing soil fertility and ensuring agricultural sustainability under changing climatic regimes (Pottorff *et al.,* 2012). According to the Food and Agriculture Organization, the global cowpea production in 2021 was approximately 8.99 million metric tons harvested from an area of around 14.91 million hectares (FAOSTAT, 2024). In India, it is cultivated largely in Rajasthan, Maharashtra, Karnataka, Gujarat, Tamil Nadu, Andhra Pradesh and Madhya Pradesh. In India, the area under this crop was 55,800 hectares with a production of 35,600 tonnes and a productivity of 638.6 kg per ha (INDIASTAT, 2024). The present investigation was undertaken to evaluate a diverse core set of 254 cowpea genotypes for eleven fodder traits. The primary objectives were to: 1) Assess the extent of genetic variability across the germplasm core set. 2) Elucidate the patterns of positive and negative trait associations for shoot biomass components. 3) Identify superior, high-yielding vegetative genotypes (such as IC420591 and EC240702) capable of serving as cultivars for fodder cultivation.

Materials and Methods

Site of the experiment: The experiment was undertaken during 2023 at research field and Stress physiology laboratory of the Division of Genetics and Plant Breeding, Faculty of Agriculture, Wadura, SKUAST-K (34^0 17′ North and 74^0 33′ East at an altitude of 1594 masl). The soil of the experimental site is a typical incept soil with clay loam texture. The pH was almost neutral (7.2), with organic carbon 0.65%, electrical conductivity of 0.18 dS/m and CEC of 16 meq/kg. All the accessions were grown as four rows of four-meter length, with 15 cm x 40 cm spacing, in an augmented block design with four checks. The mean minimum and maximum 0 temperatures (May-September) were 10.63 ^{0}C and 22.48 ^{0}C, with the lowest (16.43 ^{0}C) and highest (25.61 ^{0}C) maximum recorded in May and July respectively.

Experimental material: A set of 254 genotypes of cowpea representing a diverse set of the national core set NBPGR, New Delhi, including four checks (SHCP-1, SHCP-2, WCP-1, WCP-2), were released by SKUAST-Kashmir.

Experimental design: All the accessions were grown as four rows of four-meter length, with 15 cm x 40 cm spacing, in an augmented block design (ABD) with four checks.

Crop management: The management practices were uniform and homogeneous. The crop was irrigated intermittently to avoid drought stress that would have confounded the results. The shoot weight was measured after the completion of flowering. Three plants were taken from each genotype row and weighed immediately to avoid confusion.

Fodder traits recorded in the present study

Phenotypic characterization was carried out based on eleven fodder traits using the ICAR-NBPGR plant descriptors for cowpea.

Branch angle (Degree)-The angle between the branch and the main stem.

Leaf length(cm)-Leaf length was recorded in centimeters at the flowering time.

Leaf breadth(cm)-Leaf breadth was recorded in centimeters at the flowering time.

Leaf area (cm^2)-Leaf area was measured by multiplying the leaf's length and breadth.

Plant height(cm)-Length of the shoot from the base of the stem to the tip of the canopy and measured after completion of flowering.

Number of primary branches-Branches arising from main stem were considered as basal or primary branches which were counted and recorded at the time of harvest.

Number of internodes-Number of internodes counted and recorded at the time of harvest.

Shoot biomass(gm)-Shoot biomass was measured as the total shoot weight of the plant using a weighing balance.

Stem biomass (gm)-Stem biomass was measured as the stem weight of the shoot.

Leaf biomass (gm)-Leaf biomass was measured as the leaf weight of the shoot.

Leaf /stem ratio-Measured as the ratio of leaf weight of shoot to stem weight of shoot.

Results

Variability for fodder traits: There was substantial variability in eleven fodder traits in the 254 cowpea core set of germplasm (Table 1).

Branch angle: The Branch angle had a mean value of 63.45±0.123 with a range of 28.33 to 90 and CV of 24.8. Among genotypes, SCP-2 (90^0), Local bold (90^0), IC202710 (90^0), EC738126 (90^0) and EC240858 (90^0) had maximum values, whereas the minimum value was recorded in IC80413 (28.33^0).

Leaf length: Leaf length had a mean value of 9.33±0.086 with a range of 4.97 to 14.5 and a CV of 15.4. Among genotypes, EC724805 (14.50), IC472264 (13.83), IC437181 (13.67), EC100034(13.37) and EC243971 (12.20) had maximum values, whereas the minimum value was recorded in EC109493-2744-1 (4.97).

Leaf breadth: Leaf breadth had a mean value of 5.25±0.090 with a range of 2.03 to 17.00 and CV of 28.5. Among genotypes, EC240702 (17.00), EC724539 (16.23), EC367698 (11.00), IC471938 (8.30) and EC125673 (8.13) had maximum values, whereas the minimum value was recorded in IC257430 (2.03).

Leaf area: Leaf area had a mean value of 49.68±1.075 with a range of 13.95 to 165.47 and CV of 35.9. Among genotypes, EC240702 (165.47), EC724805 (107.78), IC437181 (100.68), IC471938 (97.94) and EC125673 (91.64) had maximum values, whereas the minimum value was recorded in C-80 (13.95).

Plant height(cm): Plant height had a mean value of 156.38 ±3.57 with a range of 33.00 to 370.00 and CV of 36.40. Among genotypes, EC-738233(370), IC-978007(315), IC-331106(310,) IC-58905(305) and EC-390280(302) were tall whereas the genotype IC-415416(33) was short in height.

Number of primary branches: Number of primary branches had a mean value 4.04 ±0.13 with a range of 00 to 13.00 and CV of 54.70. Among genotype IC209151 (13) had the maximum value, whereas the minimum value was recorded in EC99574 (0).

Number of internodes: Number of internodes had a mean value of 14.56±0.27 with a range of 4.00 to 32.00 and CV of 30.90. Among genotypes, EC240765 (32) had a maximum value whereas the minimum value was recorded in EC738089 (4).

Shoot biomass(gm): Shoot biomass had a mean value of 265.97 (gm) ±12.10 with a range of 25.00 to 1509.00 and CV of 55.60. Among genotypes, IC420591 (1509 gm) had the maximum value, whereas the minimum value was recorded in IC415416 (25gm).

Stem biomass: Stem biomass had a mean value of 172.43 (gm) ±7.37with a range of 12.00 to 947.00 and a CV of 51.10. Among genotypes, IC420591 (811gm) had the maximum value, whereas the minimum value was recorded in IC415416 (12gm).

Leaf biomass: Leaf biomass had a mean value of 93.50 (gm) ±5.184 with a range of 5.00 to 698.00 and CV of 52.10. Among genotypes, IC420591 (698 gm) had the maximum value, whereas the minimum value was recorded in EC16205 (5 gm).

Leaf stem ratio: Leaf stem ratio had a mean value of 0.53 (gm)±0.01 with a range of 0.07 to 3.03 and a CV of 38.90. Among genotypes, EC332352 (3.03) had the maximum value, whereas the minimum value was recorded in EC724754 (0.07).

Raincloud plots for fodder traits

A raincloud plot is a hybrid of a dot plot, box plot and kernel density plot, which shows peaks in data. It is used to visualise the distribution of numerical data. They show in data the overall shape of the distribution, the location of center (median), how spread out the data and the presence of any outliers. The variation pattern for various fodder traits is presented in the form of raincloud plots (Figure 1).

Pearson's correlation among fodder traits

A heat map of eleven fodder traits shows trait correlation in terms of colour and intensity was also created based on the different trait associations. Positive correlation is represented with the colour dark blue, negative correlation with the colour dark red, and no correlation with the colour white (Figure 2).

PCA biplot for fodder traits

The biplot was constructed based on 1^{st} two PCs that accounted for 52.2 percent of variation in order to capture the most significant trait contribution towards the total variation as well as their relationship with the trait of interest. PC relation of the 1^{st} two PCs that were used to construct the biplot (Figure 3). In terms of the biplot the relationship and the variance contribution are depicted in terms of the angle between the traits and length of the arrow respectively. In terms of biplot shoot biomass was significantly positively correlated with leaf biomass, stem biomass leaf /stem ratio, number of internodes and number of primary branches.

Table 1 : Descriptive statistics of fodder traits in cowpea core collection

Statistic	Minimum	Maximum	Mean	SD	CV (%)
BA	28.33	90	63.45	15.75	24.8
LL	4.97	14.5	9.33	1.43	15.4
LB	2.03	17	5.25	1.49	28.5
LA	13.95	165.47	49.68	17.82	35.9
PH	33	370	155.89	57.33	36.7
NPB	0	13	4.04	2.21	54.7
NINT	4	32	14.56	4.49	30.9
SBM	25	1509	265.97	181.66	55.6
STBM	12	947	172.43	102.87	51.1
LBM	5	698	93.5	86.39	52.1
L/S Ratio	0.07	3.03	0.53	0.26	38.9

Where: BA-branch angle, LL-leaf length, LB-leaf breadth, LA-leaf area, PH-plant height, NPB-number of primary branches, NINT-number of internodes, SBM-shoot biomass, STBM-stem biomass, LBM-leaf biomass, L/S-leaf stem ratio.

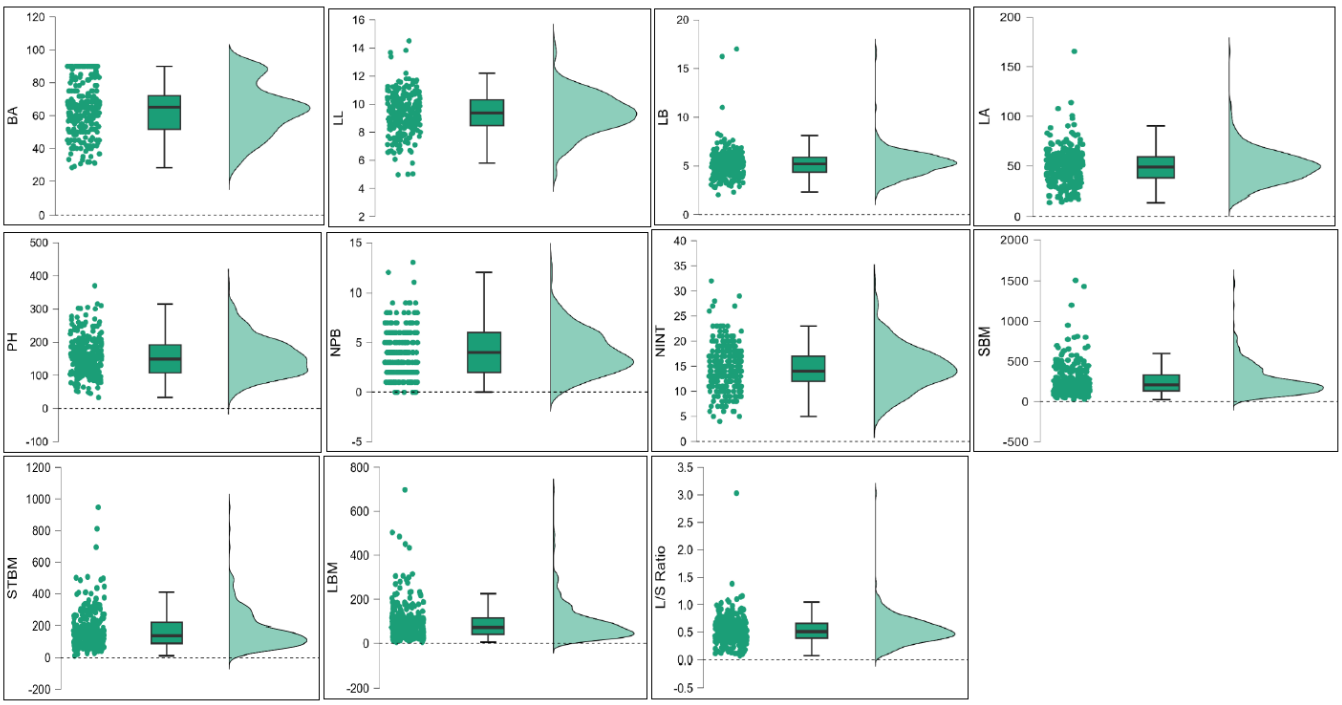

Fig. 1 : Rain cloud plots for cowpea fodder traits, where: BA-branch angle, LL-leaf length, LB-leaf breadth, LA-leaf area, PH-plant height, NPB-number of primary branches, NINT-number of internodes, SBM-shoot biomass, STBM-stem biomass, LBM-leaf biomass, L/S-leaf stem ratio.

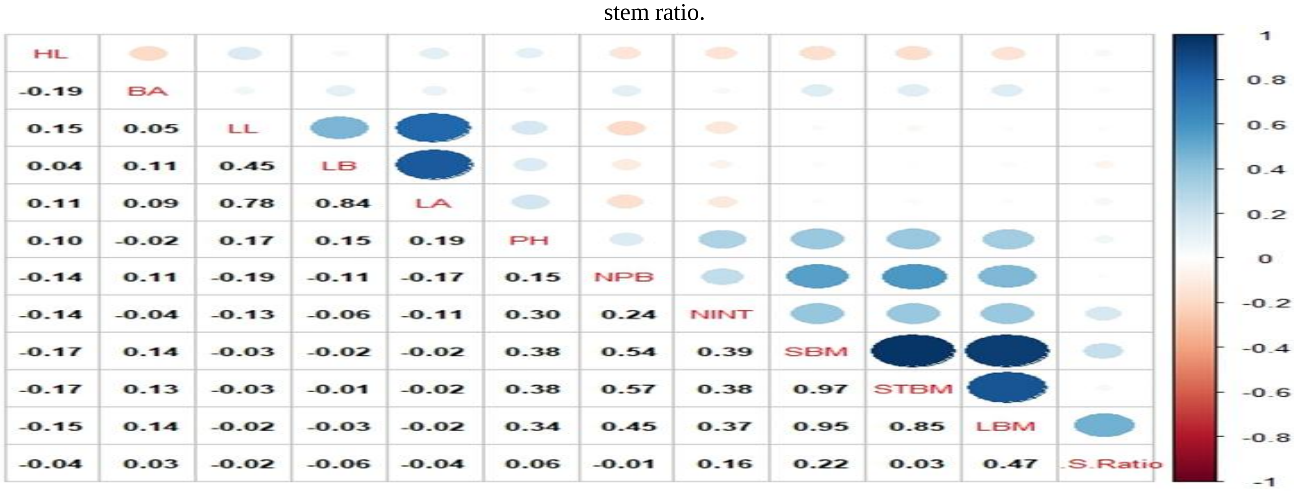

Fig. 2 : Heat map for cowpea fodder traits, where: HL = Hypocotyl length, BA = Branch angle, LL = Leaf length, LB = Leaf breadth, LA = Leaf area, PH = Plant height, NPB = Number of primary branches, NINT = Number of internodes, SBM = Shoot biomass, STBM = Stem biomass, LBM = Leaf biomass, L/S Ratio = Leaf/Stem ratio.

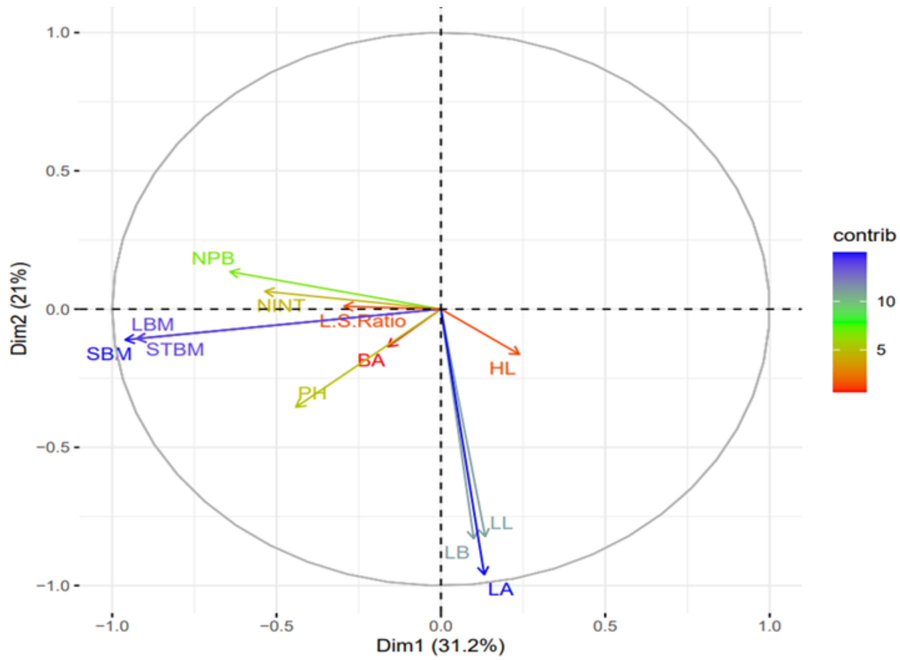

Fig. 3 : PCA biplot for cowpea fodder traits, HL = Hypocotyl length, BA = Branch angle, LL = Leaf length, LB = Leaf breadth, LA = Leaf area, PH = Plant height, NPB = Number of primary branches, NINT = Number of internodes, SBM = Shoot biomass, STBM = Stem biomass, LBM = Leaf biomass, L/S Ratio = Leaf/Stem ratio.

Fig. 4 : Difference between Number of branches, branch angle and shoot biomass of diverse cowpea genotypes.

Discussion

Variability for fodder traits

Variability refers to the presence of differences among the individuals of a plant population. Variability results due to the differences either in the genetic constitution of the individuals of a population or in the environment in which they are grown. The knowledge of the nature and magnitude of variation present in base material is of great importance for effective selection of superior genotypes from breeding material. The material used in the present study possessed a broad range of variability for these traits as depicted by higher mean, broad range, and high coefficient of variation among these traits, highest CV was recorded for shoot biomass (55.60%) followed by the number of primary branches (54.70%), Leaf biomass (52.10%), Stem biomass (51.10), Leaf/Stem ratio (38.90%), Plant height (36.70), Leaf area (35.90%), number of internodes (30.90%), Leaf breadth (28.50) and Branch angle (24.80) while as CV for Leaf length (15.40%) were comparatively lower. Several earlier works have reported substantial diversity in leaf length and leaf breadth in fodder cowpea ranging from 8.75 to 17.39 cm and 4.35 to 10.05 cm (Malarvizhi *et al.*, 2005), 8.27 to 18.09 cm and 6.78 to 17.47 cm (Soni *et al.*, 2018), 4.8 to 14.7 cm and 3.4 to 8.9 cm (Surender *et al*., 2023), 7.35 to 10.86

cm and 3.85 to 8.39 cm (Vamshi *et al.,* 2022), respectively. Plant height ranges from 56.43 to 207.80 cm (Soni *et al*., 2018), 36 to 122.5 cm (Vamshi *et al*., 2022), 8.2 to 53.5 cm (Surender *et al.*, 2023) and 65 to 167.33 cm (Rathod *et al*., 2024). Green fodder ranges from 43.2 to 137.2 gm (Malarvizhi, 2005), 65 to 329.28 gm (Vamshi *et al*., 2022), 77.8 to 154.3 gm (Surender *et al.*, 2023). Leaf stem ratio ranges from 0.99 to 2.47 (Soni *et al.*, 2018), 0.65 to 0.84 (Surender *et al*., 2023) 0.48 to 1.04 (Rathod *et al*., 2024). Selection based on these characters would result in obtaining desirable fodder cowpea genotypes. These results are similar to the findings of Sharma *et al*. (1988) for plant height, green fodder yield and number of branches and Malarvizhi *et al*. (2005) for number of branches and green fodder yield in fodder cowpea genotypes.

Trait association between fodder traits

The Pearson correlation analysis of eleven fodder traits is presented in heat map 2 Figure 2. The heat map shows a positive correlation of shoot biomass with stem biomass (0.97), leaf biomass (0.95), number of primary branches (0.54), number of internodes (0.39) and leaf stem ratio (0.22). Stem biomass and leaf biomass were significantly positively correlated. Leaf biomass was positively correlated with leaf stem ratio. Leaf area positively correlated with leaf breadth (0.84) and leaf length (0.78). Similar results have been reported by Malarvizhi *et al.* (2005), Soni *et al*. (2018) and Sahai *et al.* (2013).

Conclusion

In the present study, we screened a set of 254 cowpea genotypes of national core collection using fodder traits to identify effective traits for improving cultivars. We identified some genotypes such as IC420591 and EC240702 that produce high shoot biomass with stem biomass and leaf biomass, making these genotypes important for use directly in breeding programmes or as potential genetic resources for future crop improvement programmes. PCA biplot analysis proved that overall shoot weight is closely associated with leaf weight, stem weight, number of internodes and number of branches. A number of genotypes were found to have significantly better performance as compared to checks for fodder yield.

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