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Research article

Characterization of lablab bean (*Lablab purpureus* (L.) Sweet) germplasm for agro-morphological and biochemical traits of forage value

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Abstract

Lablab bean is one of the important legume crops of tropical and subtropical parts of the world. Its green pods possessed high nutritive value, while green foliage and vines provide hay and silage. Characterization of germplasm is the foremost step for genetic improvement of any crop. In the present study, 135 accessions of lablab bean, along with two checks, were characterized for eight qualitative and eleven quantitative traits, as well as three forage biochemical traits (total chlorophyll, total carotenoids, and total phenolics). Wide variability was observed among the lablab bean genotypes for all the agro-morphological and biochemical traits. In the majority of genotypes, growth habit was spreading, followed by semi-erect and erect. Narrow-leaf shape showed predominance over oval and hastate shapes. The green color of veins was predominant over purple color, while smooth pods were predominant over hairy pods. The leaves, flowers and pods showed wide color variation. The phenotypic coefficient of variance (PCV) was slightly higher than the genotypic coefficient of variance (GCV) for all the quantitative and forage biochemical traits. Traits such as plant height, number of branches, pod length, number of seeds per pod, green forage yield, and total phenols exhibited high estimates of all variability components, including GCV, PCV, broad-sense heritability, and genetic advance over the means. The best genotypes for total carotenoids were ICO411027 and ICO411085 (208.6 μg/g each), while for total phenols were ICO411060 and ICO411127 (29.7 mg/g each). The genotypes characterized here can be utilized to strengthen future lablab breeding programs.

Keywords: Agro-morphological, Carotenoids, Chlorophyll, Genetic variability, Lablab bean, Phenols

Introduction

Lablab bean (*Lablab purureus* (L.) Sweet) is the oldest legume, being cultivated from 1500 BC in India. It is one of the most diversified crops with multipurpose uses. The immature green pods and parts of the leaves are cooked as vegetables. The green pods of lablab bean are a rich source of protein (22.4–31.3%), carbohydrates (55%), fibre (5%), and fat (2%) (Khatun *et al.,* 2022). Green pods also contain adequate levels of minerals and vitamins for providing nutritional benefits to humans. Lablab bean possesses some medicinal properties and thus have the potential to be used in the pharmaceutical sector (Morris, 2009). This crop also has ornamental value and can be used as a green manure crop to improve soil fertility (Letting *et al.,* 2021). Lablab bean is a potential fodder crop in India and Africa as it can be grazed or harvested for cut-and-carry systems, hay and silage. Furthermore, it thrives well in varying temperature, soil type, and pH conditions; therefore, it is considered a climate-smart crop (Joshi *et al.*, 2020). The nutritional value of lablab bean forage depends on its digestibility and presence/ absence of the biochemicals affecting livestock health. The carotenoids in animals play an important role in visual function, antioxidant protection and immunity (Maoka, 2020). Phenolic compounds from leaves of lablab bean are reported to possess antioxidant and anti-inflammatory activities (Pramod *et al.,* 2020). The prime role of chlorophyll in plants is photosynthesis.

Table 1. List of lablab bean accessions used for characterization in present study

S No.	Accession no.	Other id	S No.	Accession no.	Other id	S No.	Accession no.	Other id
1	ICO392975	CAZRI-1258	47	ICO411053	LP-155	93	ICO411103	LP-319
2	ICO392976	CAZRI- 1259	48	ICO411054	LP-156	94	ICO411110	LP-339
3	ICO392977	CAZRI-1260	49	ICO411055	LP-157	95	ICO411111	LP-341
4	ICO392978	CAZRI-1261	50	ICO411056	LP-158	96	ICO411112	LP-342
5	ICO392979	LP-101	51	ICO411057	LP-159	97	ICO411113	LP-343
6	ICO392980	LP-103	52	ICO411058	LP-160	98	ICO411114	LP-344
7	ICO392981	LP-105	53	ICO411059	LP-161	99	ICO411118	LP-349
8	ICO392982	LP-106	54	ICO411060	LP-162	100	ICO411119	LP-351
9	ICO392983	LP-107	55	ICO411061	LP-163	101	ICO411120	LP-352
10	ICO392984	LP-108	56	ICO411062	LP-164	102	ICO411121	LP-355
11	ICO392985	LP-109	57	ICO411063	LP-201	103	ICO411122	LP-356
12	ICO392986	LP-111	58	ICO411064	LP-202	104	ICO411123	LP-360
13	ICO411013	LP-112	59	ICO411065	LP-203	105	ICO411124	LP-363
14	ICO411014	LP-113	60	ICO411066	LP-204	106	ICO411125	LP-365
15	ICO411017	LP-117	61	ICO411067	LP-206	107	ICO411126	LP-367
16	ICO411018	LP-118	62	ICO411068	LP-209	108	ICO411127	LP-368
17	ICO411019	LP-119	63	ICO411069	LP-210	109	ICO411128	LP-370
18	ICO411020	LP-120	64	ICO411071	LP-222	110	ICO411129	LP-371
19	ICO411021	LP-121	65	ICO411072	LP-223	111	ICO411130	LP-372
20	ICO411022	LP-122	66	ICO411073	LP-227	112	ICO411131	LP-373
21	ICO411023	LP-123	67	ICO411074	LP-228	113	ICO411132	LP-374
22	ICO411024	LP-124	68	ICO411075	LP-229	114	ICO411133	LP-377
23	ICO411027	LP-128	69	ICO411076	LP-230	115	ICO411134	LP-379
24	ICO411030	LP-131	70	ICO411077	LP-231	116	ICO411135	LP-380
25	ICO411031	LP-132	71	ICO411078	LP-232	117	ICO411136	LP-381
26	ICO411032	LP-133	72	ICO411079	LP-233	118	ICO411137	LP-383
27	ICO411033	LP-134	73	ICO411080	LP-234	119	ICO411138	LP-385
28	ICO411034	LP-135	74	ICO411081	LP-236	120	ICO411139	LP-388
29	ICO411035	LP-136	75	ICO411083	LP-237	121	ICO411140	LP-390
30	ICO411036	LP-137	76	ICO411084	LP-239	122	ICO411141	LP-392
31	ICO411037	LP-138	77	ICO411085	LP-240	123	ICO411144	LP-395
32	ICO411038	LP-139	78	ICO411086	LP-241	124	ICO411157	LP-408
33	ICO411039	LP-140	79	ICO411087	LP-242	125	ICO411158	LP-47
34	ICO411040	LP-141	80	ICO411088	LP-244	126	ICO411159	LP-208
35	ICO411041	LP-142	81	ICO411089	LP-245	127	ICO411160	LP-212
36	ICO411042	LP-143	82	ICO411090	LP-247	128	ICO411161	LP-213
37	ICO411043	LP-145	83	ICO411091	LP-248	129	ICO411162	LP-217
38	ICO411044	LP-146	84	ICO411092	LP-301	130	ICO411163	LP-218
39	ICO411045	LP-147	85	ICO411093	LP-302	131	ICO411164	LP-225
40	ICO411046	LP-148	86	ICO411094	LP-303	132	ICO411165	LP-836
41	ICO411047	LP-149	87	ICO411095	LP-305	133	ICO411166	LP-5.2

42	ICO411048	LP-150	88	ICO411096	LP-306	134	ICO411167	LP-13
43	ICO411049	LP-151	89	ICO411097	LP-309	135	ICO411168	LP-JLP-3
44	ICO411050	LP-152	90	ICO411098	LP-310	136	ICO411169	LP-S-27
45	ICO411051	L8P-153	91	ICO411101	LP-315	137	JLP-4	Bundel Sem-1
46	ICO411052	LP-154	92	ICO411102	LP-316			

Additionally, it is involved in various physiological processes and helps prevent chronic diseases in animals (Ferruzzi and Blakeslee, 2007).

The characterization of different agro-morphological traits is the first step to describe and classify the germplasm of a crop (Balduzzi *et al.,* 2017). The documentation of morphological features is necessary for selection of parents and their progenies in breeding programmes. In addition, understanding phenotypic variability in terms of agro-morphological characteristics is crucial for germplasm conservation and determining breeding strategies (Giraldo *et al.,* 2010). Furthermore, a comprehensive characterization and evaluation of lablab germplasm for forage yield and biochemical traits aid in identifying potential parental genotypes for developing high-yielding and nutritionally improved lablab bean cultivars (Gerrano *et al.,* 2019). Significant variability in various agro-morphological traits has been reported earlier in lablab bean germplasm in India (Shrikrishna and Ramesh, 2020; Kumar *et al.,* 2021; Vishnu and Radhamany, 2022; Patel *et al.,* 2022). However, these researchers investigated a smaller number of germplasm accessions, making it difficult to draw a valid conclusion about the germplasm variability. Thus, the present study was designed to characterize the lablab bean germplasm for various agro-morphological and forage biochemical traits, and to identify promising lablab bean genotypes for use in breeding programmes.

Materials and Methods

Plant materials and experimental design: The study utilized 135 lablab bean accessions of Indian origin (Table 1) as plant materials. The seeds were acquired from ICAR-National Bureau of Plant Genetic Resources, New Delhi, India. These 135 accessions, along with two checks (viz., Bundel Sem-1 and LP-S-27), were evaluated at the Central Research Farm, ICAR-Indian Grassland and Fodder Research Institute, Jhansi, India (27°17′ N, 75°22′ E) during the year 2020-21. Bundel Sem-1 is a forage lablab bean variety, which is used as a check for lablab bean coordinated trials in AICRP on Forage Crops and Utilization in India, while LP-S-27 is the local selection of forage type lablab bean. The experiment was laid out in an Augmented Design (Federer, 1961), consisting of 6 blocks, each with 50 rows. The checks were randomly distributed in each of the 6 blocks, while test entries were fixed in each block. The first five blocks contained 23 test entries and 2 checks, while the sixth block had 20 test entries and 2 checks. Each genotype was planted in paired rows of 3 m length with 40 cm spacing between rows. The distance between paired rows of two genotypes was 1 m and the plant-to-plant distance in each row was 25 cm. Standard cultural practices recommended for lablab bean were followed to raise a good crop stand.

Data collection in field: A total of 19 agro-morphological traits comprising eight qualitative and eleven quantitative traits were recorded as per the minimal descriptors in forage crops (Roy *et al.,* 2017) (Table 2). Visual observations were made to record the eight qualitative traits, namely early plant vigor, growth habit, leaf color, vein color, leaf shape, flower color, pod color, and pod pubescence. Three randomly selected plants were used for recording the quantitative traits such as plant height (cm), number of branches, leaf length (cm), leaf width (cm), days to 50% flowering, days to pod initiation, days to pod maturity, pod length (cm), pod width (cm) and number of seeds per pod. For recording green forage yield, all the plants of paired rows were harvested at 50% flowering and the plot yield was converted to t/ha.

Biochemical analysis: The leaf samples were taken at 50% flowering and dried by keeping in an oven at 60°C for about one week. The dried leaves were then used for estimation of biochemical traits.

Total chlorophyll and carotenoid contents: Total chlorophyll and total carotenoid in fresh leaves of lablab bean were determined using a spectrophotometer following the method of Jayraman (1981) and Davies (1976), respectively. Briefly, 0.2 g fresh leaves were ground into fine pulp with 5 ml of 80% acetone using pestle mortar. The paste was centrifuged at 4000 rpm for 15 min and the supernatant was collected. Then, 5 ml of 80% acetone was added to supernatant and centrifuged at 4000 rpm for 15 min. This procedure was repeated two more times. The final volume of supernatant was made 20 ml with 80% acetone and absorbance of the extract was measured at 663, 645 and 480 nm using a spectrophotometer (Pharo 100 Spectroquant®). The total chlorophyll (mg/g) was calculated by the following equation:

Table 2. List of agro-morphological traits recorded in lablab bean accessions

S. No.	Descriptors	Descriptor states
Qualitative traits		
1	Early plant vigour	Poor (1), good (2), very good (3)
2	Plant growth habit	Erect (1), semi erect (2) , spreading (3)
3	Leaf color	Light green (1), Green (2), Dark green (3)
4	Vein color	Green (1), Purple (5)
5	Leaf shape	Oval (1), hastate (2)
6	Flower color	White (1), light purple (2), dark purple (3), purple (5)
7	Pod color	Green (1), light purple (2), dark purple (3), white (5), red (7)
8	Pod pubescence	Smooth(1), hairy(3)
Quantitative traits		
1.	Plant height (cm)	Measured from ground to the tip of the plant at 50% flowering
2.	Number of branches	Counted on the main stem at 50% flowering
3.	Leaf length (cm)	Measured on the central leaflet of 5th fully grown leaf from base at 50% flowering
4.	Leaf width (cm)	Measured at the widest point on the central leaflet of 5th fully grown leaf from base at 50% flowering
5.	Days to 50 percent flowering	Recorded as the number of days from sowing to 50% flowering
6.	Days to pod initiation	Recorded as the number of days from sowing to days of pod initiation
7.	Days to initiation of pod maturity	Recorded as the number of days from sowing to days of initiation of pod maturity
8.	Pod length (cm)	Recorded at fully matured pods on main stem
9.	Pod width (cm)	Recorded at fully matured pods on main stem
10.	Number of seeds per pod	Recorded on matured pod on main stem after threshing
11.	Green forage yield (t/ha)	All the plants of paired rows were harvested at 50% flowering and plot yield was converted to t/ha

Total chlorophyll = [20.2 (A 645) + 8.02 (A 663)] × V/ (1000 × W)
The total carotenoid was calculated using the following equation and expressed as µg/g:
Total carotenoid = [A 480 + 0.114 (A 663) – 0.638 (A 645) × V/W
Where, A= absorbance at specific wavelengths, V= final volume of extract, W= fresh weight of leaves.

Total phenolic content: Total phenolic content in lablab bean leaves was estimated according to the Folin-Ciocalteu method as described by Makkar *et al.* (1993). In brief, 200 mg of dried leaves powder in triplicate were taken in test tubes containing 10 mL of 70% acetone and kept in a shaking water bath at 37°C for 2 hours. The tubes were cooled down to room temperature and centrifuged at 3000 rpm for 20 min. The supernatant was collected in fresh tubes and used for estimating total phenols. 100 µL of supernatant was taken in a test tube and mixed with 900 µL of distilled water. Concurrently, the blank was prepared in a separate tube by adding 1-mL of distilled water. Further, 0.5 mL of Folin-Ciocalteu reagent (1N) and 2.5 mL of 20% Na_2CO_3 (w/v) was added to each test tube. The test tubes were then incubated for 40 minutes at room temperature. The absorbance of the solution mixture was measured at 725 nm against a blank by using a UV-visible spectrophotometer. The total phenolic content was computed using a standard curve derived from tannic acid as per Makkar *et al.* (1993) and the results were depicted as mg/g of dry weight.

Statistical analysis: Descriptive statistics for all the quantitative traits including mean, standard error, range, coefficient of variance (CV), skewness, The genotypic coefficient of variance (GCV), phenotypic coefficient of variance (PCV), environmental coefficient of variance (ECV), broad-sense heritability (hBS), genetic advance over mean (GAM) were computed through RStudio using augmented RCBD R package version 0.1.7 (Aravind *et al.,* 2023). Pearson's simple correlation coefficients with significance, *p-values* and heat map among the quantitative traits were generated using RStudio software. Significance of correlation coefficients (*r*) at $p \leq$ 0.05 or 0.01 is indicated by * or **, respectively. Microsoft Excel-2013 ascertained graphical representations of variability for qualitative traits.

Results and Discussion

Diversity for qualitative traits: The qualitative traits of the evaluated lablab bean accessions are shown in Fig 1. Our results revealed wide variability for all the eight qualitative traits studied. Among the 137 lablab bean genotypes, 29 showed very good early plant vigour, while 60 possessed good and 48 exhibited poor early plant vigour. Spreading type growth habit (in 69 genotypes) showed predominance over semi-erect (in 39 genotypes) and erect type (in 29 genotypes). It has been observed that the color of the leaves was mainly green with 63, 64 and 10 genotypes with light green, green and dark green leaves, respectively. The majority of the lablab bean genotypes (132) exhibited green color leaf veins and only 5 genotypes showed purple color leaf veins. The narrow (ovate) leaf shape (in 126 genotypes) was

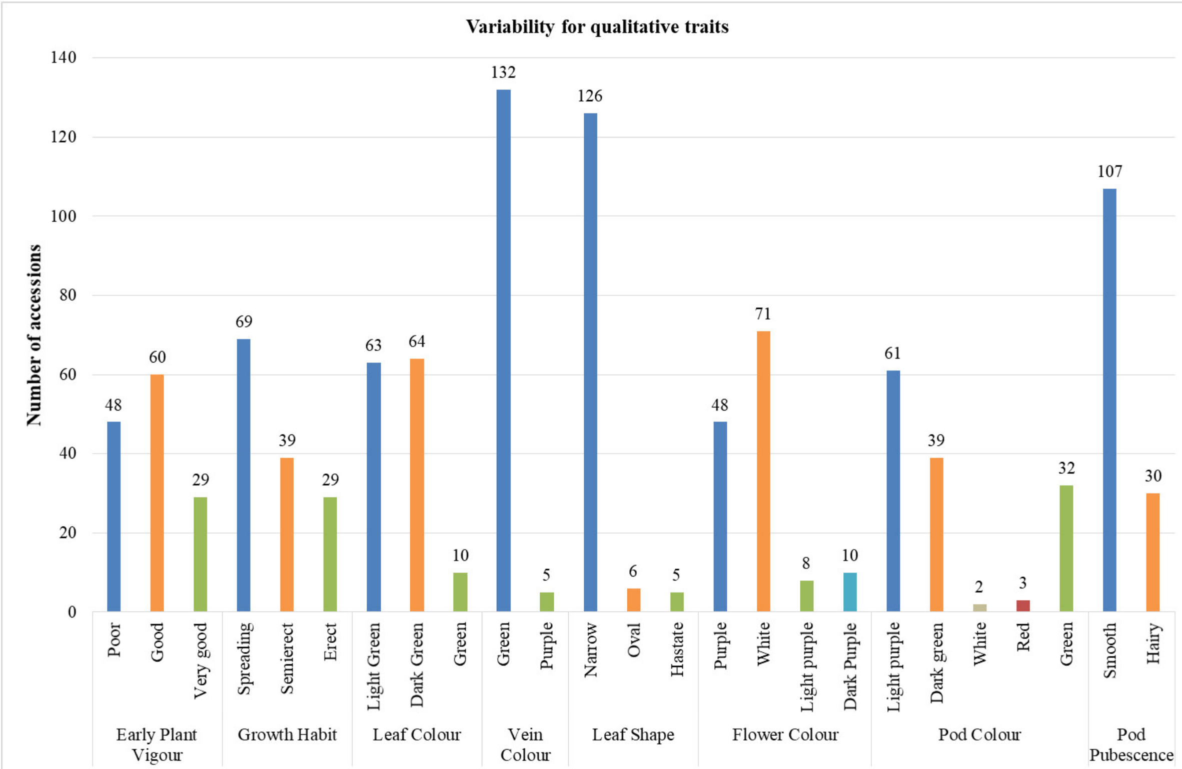

Fig 1. Variability for qualitative traits in lablab bean accessions

predominant over oval (in 6 genotypes) and hastate type (in 5 genotypes). Flower color varied from light purple to dark purple or white. The white, light purple, purple and dark purple flowers were observed in 71, 8, 48 and 10 genotypes, respectively. Great diversity was recorded for pod color, where light purple (61) and green pods (71) constituted the maximum numbers, while red and white pods were observed in 3 and 2 genotypes, respectively. Regarding pod pubescence, 107 genotypes exhibited smooth pods and the remaining 30 genotypes displayed hairy pods. Ram Bahadur *et al.* (2016) evaluated twenty three lablab bean germplasm and observed considerable variation for flower color, pod color, vine color, seed color, leaf size, pod form and pod type. Shrikrishna and Ramesh (2020) recorded 25 morphological descriptor traits in five lablab bean genotypes. These genotypes showed distinctness for 12 of the 25 descriptor traits namely stem pigmentation, leaf color, leaf hairiness, growth habit, branch orientation, flower bud color, standard petal color, wing petal color, pod curvature, pod pubescence, pod constriction and seed color. Recently, Khatun *et al.* (2022), Letting *et al.* (2022) and Das *et al.* (2023) also observed great variability for plant, leaf, flower, pod and seed attributing traits in lablab bean germplasm. The qualitative characters are considered as diagnostic markers for germplasm characterization and classification, thus reducing duplications in genebanks. These characters are easy to score, selectively neutral, relatively stable and governed by single or oligo-genes, therefore providing a unique description of the given germplasm (Fu, 2015).

Diversity for quantitative traits: Descriptive statistics revealed presence of wide variability in the ten quantitative traits of the lablab bean germplasm studied (Table 3). Plant height ranged from 35.0–210.0 cm with a mean of 119.5 cm. Number of branches varied between 2.0–11.0 with an average of 6.3. The length of the leaf was 7.4 cm with a range of 4.5–11.0 cm, while the width of the leaf was in the range of 4.0–10.6 cm with a mean of 7.1 cm. Lablab bean genotypes took 99.0–126.0 days to 50% flowering with a mean of 114.6 days. Days to pod initiation and pod maturity varied from 114.0–138.0 days (mean: 122.0 days) and 175.0–191.0 days (mean: 182.1 days), respectively. The mean pod length and width was 4.6 and 1.3 cm and ranged between 2.0–7.0 and 0.5–2.3 cm, respectively. The number of seeds per pod varied from 2.0–7.0 with an average of 3.9. Green forage yield ranged from 8.5–35.7 t/ha with a mean of 21.3 t/ha. The distribution pattern of all the quantitative traits was unimodal and symmetrical except leaf width and days to 50% flowering, which showed positive and negative skewness, respectively (Table 3). The selected genotypes with highest and lowest values of each quantitative trait

Table 3. Descriptive statistics of quantitative and forage biochemical traits of lablab bean accessions

S. No.	Trait	Genotypes			Checks			SE	CV (5%)	Skewness
		Min	Max	Mean	Bundel Sem-1	LP-S-27	Mean			
1	Plant height (cm)	35.0	210.0	119.5	140.7	140.8	140.7	3.18	15.96	-0.37 ^{ns}
2	Number of branches	2.0	11.0	6.3	7.6	7.4	7.5	0.18	11.65	-0.37 ^{ns}
3	Leaf length (cm)	4.5	11.0	7.4	8.1	8.4	8.2	0.11	18.78	0.04 ^{ns}
4	Leaf width (cm)	4.0	10.6	7.1	7.9	7.7	7.8	0.11	17.84	0.42*
5	Days to 50% flowering	99.0	126.0	114.6	116.5	117.0	116.8	0.48	13.08	-0.73**
6	Days to pod initiation	114.0	138.0	122.0	124.7	124.5	124.6	0.45	7.95	0.23 ^{ns}
7	Days to pod maturity	175.0	191.0	182.1	179.3	182.7	181.0	0.46	1.71	0.11 ^{ns}
8	Pod length (cm)	2.0	7.0	4.6	4.4	5.2	4.8	0.11	7.32	-0.12 ^{ns}
9	Pod width (cm)	0.5	2.3	1.3	1.3	1.6	1.5	0.03	13.4	0.22 ^{ns}
10	Number of seeds per pod	2.0	7.0	3.9	4.1	4.7	4.4	0.13	9.47	0.02 ^{ns}
11	Green forage yield (t/ha)	85.0	356.7	212.7	273.6	310.5	292.0	6.45	13.03	0.08 ^{ns}
12	Total chlorophyll (mg/g)	1.06	3.58	1.86	2.42	1.85	2.14	0.05	25.48	1.49**
13	Total carotenoids (μg/g)	41.11	208.61	86.78	96.05	94.57	95.3	2.56	21.97	2.01**
14	Total phenols (mg/g)	1.34	29.69	9.78	11.26	11.44	11.4	0.54	12.1	0.9**

SE: Standard error; CV: Coefficient of variation; ns: Non-significant, *: Significant at $p \leq 5\%$, **: Significant at $p \leq 1\%$

are illustrated in Table 4. These genotypes can be used in lablab bean improvement programmes in India. Previously, Pachkhande *et al.* (2021) observed wide variability for 13 morphometric traits in eight lablab bean genotypes. Similarly, Kumar *et al.* (2021) and Letting *et al.* (2022) also reported significant differences among 15 and 277 lablab bean accessions, respectively for 14 quantitative traits each. Arya *et al.* (2021) reported wide variation for 18 morpho-agronomic traits among 30 cowpea genotypes.

Diversity for forage biochemical traits: Descriptive statistics showed wide variability for total chlorophyll, total carotenoids and total phenols among the 137 lablab bean accessions (Table 3). Total chlorophyll content ranged from 1.1 to 3.6 mg/g with a mean of 1.9 mg/g. The mean concentration of total carotenoids was 86.8 μg/g with a range of 41.1-208.6 μg/g. Total phenol was in the range of 1.3-29.7 mg/g with an average of 9.8 mg/g. All the three forage biochemical traits showed non-symmetrical distribution with positive skewness (Table 3). The promising lablab bean accessions with highest and lowest values of total chlorophyll, total carotenoids and total phenols are provided in Table 4. These accessions can serve as potential donors for improving the forage quality of lablab bean, while also developing genetic resources for molecular studies.

The composition of chlorophyll, carotenoids and phenols is reported to be genotype dependent (Rai *et al.,* 2014). Besides, agronomic practices, harvest stage, and climate factors also contribute to variations in chlorophyll, carotenoids, and phenols levels (Ninfali and Bacchiocca, 2003). Carotenoids and phenolic compounds possess antioxidant activities, thereby helping to maintain the health status of animals (Maoka, 2020; Pramod *et al.,* 2020). Most studies conducted on lablab bean have reported variations in chlorophyll, carotenoids, and phenols content in edible pods (Rai *et al.,* 2014; Mithlesh *et al.,* 2017; Das *et al.,* 2023). Very few studies have analyzed these traits in the green leaves of lablab bean. Kumar *et al.* (2018) reported 1.57 to 1.99 mg/g of total chlorophyll in leaves of lablab bean varieties. Rajput and Patil (2017) observed 1.87 and 1.46 mg/g fresh weight of total chlorophyll and total carotenoids, respectively in leaves of fodder type lablab bean genotypes. D'Souza and Devaraj (2010) recorded 2.21 mg/g of total phenols in fresh leaves of lablab bean. Kaur *et al.* (2018) reported a range of 1.55 to 3.73 mg/g for total phenols, 1.04 to 2.37 mg/g for tannins, 2.91 to 6.68 mg/g for flavonoid and 8.52 to 11.84 mg/g for saponin in plant samples of ten cowpea genotypes.

Genetic variability parameters: The GCV, PCV, hBS and GAM were used to estimate genetic variability in lablab bean accessions (Table 5). The PCV values were slightly higher than the GCV values for all the quantitative and forage biochemical traits. High GCV

Table 4. List of promising lablab bean accessions for quantitative and forage biochemical traits

S No.	Trait	Promising accessions	
		Highest	**Lowest**
1.	Plant height	ICO411018 (210.0 cm), ICO411077 (190.0 cm)	ICO392984 (35.0 cm), ICO411103 (40.0 cm)
2.	Number of branches	ICO411044 (11.0), ICO411052 (11.0)	ICO411037 (2), ICO411163 (2)
3.	Leaf length	ICO411131 (11.0 cm), CO411060 (10.4 cm)	ICO411024 (4.5 cm), ICO411069 (4.5 cm)
4.	Leaf width	ICO411060 (10.6 cm), CO411061 (10.6 cm)	ICO411069 (4.0 cm), ICO411024 (4.5 cm)
5.	Days to 50% flowering	ICO411068, ICO411103, ICO411166, ICO411125 (126 days each)	ICO141132 (99.0 days), ICO411067 (99.0 days)
6.	Days to pod initiation	ICO411160 (138 days), ICO411162 (136.0 days)	ICO411032 (114.0 days), ICO392976 (115.0 days)
7.	Initiation of pod maturity	ICO411061 (191.0 days), ICO411060 (190.0 days)	ICO392975 (176.0 days), ICO392976 (176.0 days)
8.	Pod length	ICO411080 (7.0 cm), ICO411074 (7.0 cm)	ICO411090 (2.0 cm), ICO411093 (2.0 cm)
9.	Pod width	ICO392975 (2.3 cm), ICO411013 (2.1 cm)	ICO411098 (0.5 cm), ICO411079 (0.6 cm)
10.	Number of seeds per Pod	ICO411079 (7.0) , ICO411114 (7.0)	ICO411138 (2.0), ICO411168 (2.0)
11.	Green forage yield	ICO411120 (35.7 t/ha), ICO411054 (35.5 t/ha), ICO411047 (34.8 t/ha)	ICO411021 (8.5 t/ha), ICO411168 (9.3 t/ha)
12.	Total chlorophyll	ICO411027, ICO421577 ICO411085 (3.6 mg/g each)	ICO411033, ICO411089 (1.1 mg/g each)
13.	Total carotenoids	ICO411027, ICO411085 (208.6 μg/g each)	ICO411022, ICO411081 (41.1 μg/g each)
14.	Total phenols	ICO411060 (29.7 mg/g), ICO411127 (29.7 mg/g), ICO411095 (24.9 mg/g)	ICO411071, ICO411137, ICO392984 (1.3 mg/g each)

Table 5. Genetic parameters for quantitative and forage biochemical traits of lablab bean accessions

Trait	GCV	GCV category	PCV	PCV category	ECV	hBS	hBS category	GAM	GAM category
Plant height	28.61	High	28.89	High	4.01	98.07	High	58.45	High
Number of branches	30.83	High	33.04	High	11.87	87.1	High	59.37	High
Leaf length	13.77	Medium	16.38	Medium	8.86	70.7	High	23.89	High
Leaf width	16.54	Medium	18.34	Medium	7.92	81.35	High	30.77	High
Days to 50% flowering	3.26	Low	4.49	Low	3.09	52.75	Medium	4.89	Low
Days to pod initiation	3.88	Low	4.34	Low	1.95	79.73	High	7.14	Low
Days to pod maturity	1.68	Low	2.4	Low	1.71	49.04	Medium	2.43	Low
Pod length	21.16	High	22.41	High	7.38	89.16	High	41.23	High
Pod width	16.72	Medium	21.53	High	13.56	60.33	High	26.79	High
Number of seeds per pod	30.28	High	31.78	High	9.66	90.76	High	59.5	High
Green forage yield	36.5	High	36.56	High	2.1	99.67	High	75.17	High
Total chlorophyll	13.66	Medium	29.21	High	25.81	21.88	Low	13.18	Medium
Total carotenoids	26.39	High	34.47	High	22.17	58.64	Medium	41.7	High
Total phenols	61.7	High	62.92	High	12.33	96.16	High	124.81	High

GCV: Genotypic coefficient of variance; PCV: Phenotypic coefficient of variance; ECV: Environmental coefficient of variance; hBS: Broad sense heritability; GAM: Genetic advance over means and PCV values were observed for plant height, number of branches, pod length, number of seeds per pod, green forage yield, total carotenoids and total phenols, indicating presence of high amount of inherent genetic variability, and therefore improvement of these traits can be attained by selection. Medium GCV and PCV values were recorded for leaf length and leaf width, while days to 50% flowering, days to pod initiation and days to pod maturity showed low values of GCV. Medium and low values of GCV and PCV suggest that these characters are influenced by the environment, and selection may not be effective for improving these traits. Previous researchers have also analyzed genetic variability in lablab bean germplasm and reported low to high GCV and PCV values for different morphological traits (Thasneem et al., 2022; Patel et al., 2022; Kumar et al., 2021; and Gamit *et al.,* 2020).

Low hBS estimate was recorded for total chlorophyll, while medium hBS estimates were observed for days to 50% flowering, days to pod maturity and total carotenoids (Table 5). Other traits such as plant height, number of branches, leaf length, leaf width, days to pod initiation, pod length, pod width, number of seeds per pod, green forage yield and total phenols showed high estimates of hBS. High heritability estimates implies easy selection of traits under improvement in segregating generations (Letting *et al.,* 2022). Heritability estimate alone provides no indication of the amount of genetic improvement that would result from selection of individual genotypes. Heritability coupled with GAM is more desirable than heritability alone in predicting the response to selection (Nguyen *et al.*, 2019; Kumar *et al.*, 2021). Low GAM was observed for days to 50% flowering, days to pod initiation and days to pod maturity (Table 5). Medium GAM was recorded for total chlorophyll, while high GAM was observed for plant height, number of branches, leaf length, leaf width, pod length, pod width, number of seeds per pod, green forage yield, total carotenoids and total phenols. Traits such as plant height, number of branches, pod length, number of seeds per pod, green forage yield, and total phenols had high estimates of all the variability components, including GCV, PCV, hBS, and GAM. This implies that these traits are governed by additive gene action and direct selection for these traits would be fruitful in lablab bean improvement programmes. Previous studies also reported high estimates of PCV, GCV, hBS and GAM for days to 50% flowering and number of branches (Letting *et al.,* 2022), pod length and pod diameter (Kumar *et al.,* 2021), plant height and seed yield (Choudhary *et al.,* 2016), days to 50% flowering, days to pod maturity, pod length, pod width, plant height and number of seeds per pod (Chaitanya *et al.,* 2014) in lablab bean. Rai *et al.* (2014) reported moderately high PCV and GCV for protein, phenol, chlorophyll b and carotenoid in Indian lablab bean genotypes.

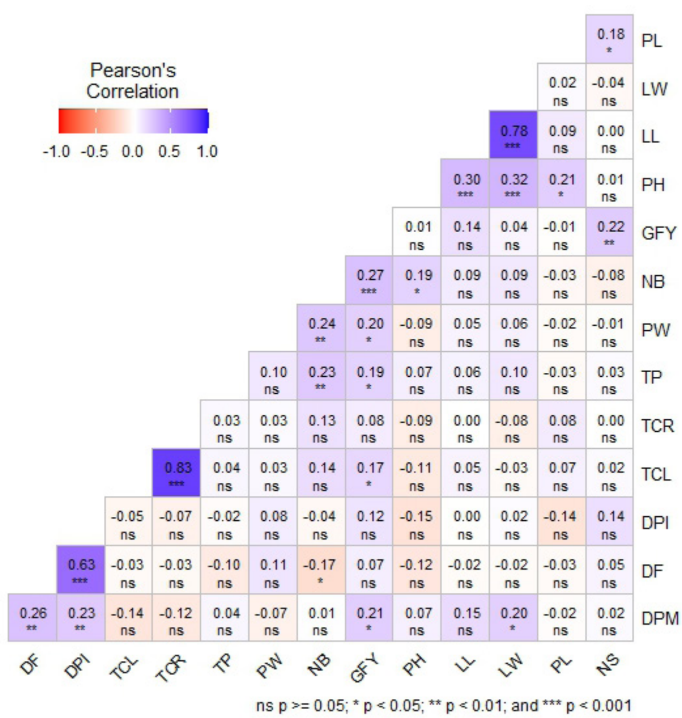

Fig 2. Correlation among quantitative and forage biochemical traits in lablab bean genotypes **[**DPM: Days to pod maturity, DF: Days to 50% flowering, DPI: Days to pod initiation, TCL: Total chlorophyll, TCR: Total carotenoids, TP: Total phenols, PW: Pod width, NB: Number of branches, GFY: Green fodder yield, PL: Plant height, LL: Leaf length, LW: Leaf width, PL: Pod length]

Correlation analysis: Pearson correlation coefficients among the quantitative and forage biochemical traits are depicted in Fig 2. The association of green fodder yield with days to pod maturity, total chlorophyll, total phenols, pod width, number of branches and number of seeds per pod was significant in positive direction. Days to 50% flowering showed significant positive correlation with days to pod initiation and days to pod maturity, while it was negatively correlated with number of branches. The correlation of plant height with leaf length, leaf width, pod length and number of branches was significant in a positive direction. Days to pod maturity recorded significant positive association with days to pod initiation and leaf width. The correlation among the desired traits is helpful for plant breeders for their simultaneous improvement. Previous studies also conducted correlation analysis among agro-morphological traits in lablab bean and reported significant and positive correlation among some of the traits (Choudhary *et al*., 2016; Vishnu and Radhmany, 2022; Khatun *et al*., 2022). Total carotenoids and total chlorophyll displayed significant positive association. Total phenols were not correlated with total carotenoids and total chlorophyll, while it was positively correlated with the number of branches. Other quantitative traits did not show correlation with any of the forage biochemical traits. Similarly, Kumari *et al.* (2022) did not find correlation of phenols with vitamin C and other quality traits in lablab bean. Gupta *et al.* (2017) also did not observe correlation between agro-morphological traits and total chlorophyll content in lablab bean.

Conclusion

The results of our study indicate the existence of significant variation for agro-morphological and forage biochemical traits among the Indian lablab bean germplasm under study. The lablab bean accessions characterized here for qualitative traits will help in their conservation by avoiding duplications in gene banks. The PCV values were slightly higher than GCV values for all the agro-morphological and biochemical traits, indicating that the environment less influences these traits. High estimates of GCV, PCV, hBS, and GAM for plant height, number of branches, pod length, number of seeds per pod, green forage yield, and total phenols imply the predominance of additive gene action, and direct selection for these traits would be fruitful. The contrasting lablab bean genotypes identified in present study for different agro-morphological and forage biochemical traits can serve as potential donors for lablab bean improvement programmes along with developing genetic resources for molecular studies.

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References

Aravind, J., S. Mukesh Sankar, D. P. Wankhede and V. Kaur. 2023. Augmented RCBD: Analysis of Augmented Randomised Complete Block Designs. R package version 0.1.7

Arya, R. K., R. Panchta and N. N. Vu. 2021. Morphological characterization of cowpea genotypes and its utility for DUS testing. *Range Management and Agroforestry* 42: 49-58.

Balduzzi, M., B. M. Binder, A. Bucksch, C. Chang, L. Hong, A. S. Iyer-Pascuzzi, C. Pradal, and E. E. Sparks. 2017. Reshaping plant biology: qualitative and quantitative descriptors for plant morphology. *Frontiers in Plant Science* 3; 8:117. https://doi.org/10.3389/fpls.2017.00117

Chaitanya, V., R. V. Reddy and P. A. Kumar. 2014. Variability, heritability and genetic advance in indigenous dolichos bean (Dolichos lablab L. var Typicus) genotypes. *Plant Archives* 14: 503-506.

Choudhary, J., S. S. Kushwah, O. P. Singh and I. S. Naruka. 2016. Studies on genetic variability and character association in Indian bean [*Lablab purpureus* (L.) Sweet]. *Legume Research-An International Journal* 39: 336-342.

D'Souza, M. R. and V. R. Devaraj. 2010. Biochemical responses of Hyacinth bean (*Lablab purpureus)* to salinity stress. *Acta Physiologiae Plantarum* 32: 341-353. https://doi.org/10.1007/s11738-009-0412-2

Das D, K. Pal, N. Sahana, P. Mondal, A. Das, S. Chowdhury, S. Mandal and G. K. Pandit. 2023. Evaluation of morphological and biochemical parameters and antioxidant activity and profiling of volatile compounds in fifteen Dolichos bean (Lablab purpureus L.) genotypes of India. *Food Chemistry Advances* 2: 100164. https://doi.org/10.1016/j.focha.2022.100164

Davies, B. H. 1976. Carotenoids. In: T. W. Goodwin (ed). *Chemistry and Biochemistry of Plant Pigments*, Vol. 2. Academic Press, London, New York, San Francisco. pp 38-165.

Federer, W. T. 1961. Augmented designs with one way elimination of heterogeneity. *Biometrics* 17: 447-473.

Ferruzzi, M. G. and J. Blakeslee. 2007. Digestion, absorption, and cancer preventative activity of dietary chlorophyll derivatives. *Nutrition Research* 27: 1-12.

Fu, Y. B. 2015. Understanding crop genetic diversity under modern plant breeding. *Theoretical and Applied Genetics* 128: 2131-2142.

Gamit, U. C., L. L. Jivani, H. P. Ponkia, A. Balas and Vadavia A.T. 2020. Study of genetic variability and heritability in Indian bean (*Lablab purpureus* L.). *Electronic Journal of Plant Breeding* 11: 328-330.

Gerrano, A. S., W. S. J. van Rensburg, S. L. Venter, N. G. Shargie, B. A. Amelework, H. Shimelis and M. T.

Labuschagne. 2019. Selection of cowpea genotypes based on grain mineral and total protein content. *Acta Agriculturae Scandinavica Section B Soil and Plant Science* 62: 155-166.

Giraldo, E., M. López-Corrales and J. I. Hormaza. 2010. Selection of the most discriminating morphological qualitative variables for characterization of fig germplasm. *Journal of the American Society for Horticultural Science* 135: 240-249.

Gupta, M., K. P. Rao and V. B. Rajwade. 2017. Correlation study of floral traits, yield and nutritional parameters in dolichos bean (*Lablab purpureus* L.) genotypes under Allahabad agro climatic zone. *Journal of Pharmacognosy and Phytochemistry* 6: 1585-1591.

Jayraman, J. 1981. *Laboratory Manual in Biochemistry*. Wiley Eastern Pvt. Ltd., New Delhi, India.

Joshi, B. K., R. Shrestha, D. Gauchan and Shrestha A. 2020. Neglected, underutilized, and future smart crop species in Nepal. *Journal of Crop Improvement* 34: 291-313.

Kaur, H., M. Goyal and D. P. Singh. 2018. Comparative evaluation of cowpea (*Vigna unguiculata* L.) genotypes for nutritional quality and antioxidant potential. *Range Management and Agroforestry* 39: 260-268.

Khatun, R., M. I. Uddin, M. M. Uddin, M. T. Howlader and M. S. Haque. 2022. Analysis of qualitative and quantitative morphological traits related to yield in country bean (*Lablab purpureus* L. sweet) genotypes. *Heliyon* 8: e11631. https://doi.org/10.1016/j.heliyon.2022.e11631

Kumar, H., S. M. Ghawade, Shivaputra and M. L. Meghwal. 2018. Effect of gamma radiations on growth, yield and quality traits of *dolichos* bean (*Lablab purpureus* L.). *International Journal of Current Microbiology and Applied Sciences* 6: 853-859.

Kumar, U., P. K. Prasad, R. K. Tiwari, S. Ghosh, B. M. Sinha and L. M. Yadav. 2021. Estimation of genetic variability and genetic divergence in dolichos bean [*Lablab purpureus* (L.) Sweet.] genotypes. *Legume Research-An International Journal* 44: 916-920.

Kumari, M., P. Naresh, G. C. Acharya, K. Laxminarayana, H. S. Singh, B. R. Raghu and T. S. Aghora. 2022. Nutritional diversity of Indian lablab bean (*Lablab purpureus* L. Sweet): An approach towards biofortification. *South African Journal of Botany* 149: 189-95.

Letting, F. K., P. B. Venkataramana and P. A. Ndakidemi. 2021. Breeding potential of lablab [*Lablab purpureus* (L.) Sweet]: a review on characterization and bruchid studies towards improved production and utilization in Africa. *Genetic Resources and Crop Evolution* 68: 3081-3101.

Letting, F. K., P. B. Venkataramana and P. A. Ndakidemi. 2022. Pre-Breeding prospects of Lablab (*Lablab purpureus* (L.) Sweet) accessions in Tanzania: Morphological characterization and genetic diversity analysis. *Agronomy* 12: 2272. https://doi.org/10.3390/agronomy12102272

Makkar, H. P. S., M. Blummel, N. K. Borowy and K. Becker. 1993. Gravimetric determination of tannins and their correlations with chemical and protein precipitation methods. *Journal of the Science of Food and Agriculture* 61: 161-165.

Maoka, T. 2020. Carotenoids as natural functional pigments. *Journal of Natural Medicines* 74:1-16.

Mithlesh, G., R. K. Prasada and V. B. Rajwade. 2017. Correlation study of floral traits, yield and nutritional parameters in *Dolichos* bean (*Lablab purpureus* L.) genotypes under Allahabad agro climatic zone. *Journal of Pharmacognosy and Phytochemistry* 6: 1585-1591.

Morris, J. B. 2009. Morphological and reproductive characterization in hyacinth bean, *Lablab purpureus* (L.) sweet germplasm with clinically proven nutraceutical and pharmaceutical traits for use as a medicinal food. *Journal of Dietary Supplements* 6: 263-279.

Nguyen, N. V., R. K. Arya and R. Panchta. 2019. Studies on genetic parameters, correlation and path coefficient analysis in cowpea. *Range Management and Agroforestry* 40: 49-58.

Ninfali, P. and M. Bacchiocca. 2003. Polyphenols and antioxidant capacity of vegetables under fresh and frozen conditions. *Journal of Agricultural and Food Chemistry* 51: 2222-2226.

Pachkhande, D. N., G. S. Mankar, S. G. Shamkuwar, S. A. Afsar and N. P. Malge. 2021. Morphological variation and yield performance of photo-insensitive Dolichos bean [*Dolichos lablab* (L.) Sweet] genotypes. *Journal of Pharmacognosy and Phytochemistry* 10: 1203-1205.

Patel, D. P., K. G. Modha, A. D. Kyada, J. Pranati, M. R. Prajapati, B. H. Kale and R. K. Patel. 2022. Genetic variability analysis for yield and yield attributes among determinate "Wal" type Indian bean [*Lablab purpureus* (L.) Sweet] genotypes. *Electronic Journal of Plant Breeding* 13: 1207-1213.

Pramod, C., N. Sudhakaran and J. Harindran. 2020. Anti-inflammatory effects of Lablab purpureus Linn in polyphenolic fraction from methanolic leaf extract on experimental animal model. *The Pharma Innovation Journal* 9: 338-344.

Rai, N., K. K. Rai, G. Tiwari and S. Kumar. 2014. Nutritional and antioxidant properties and their inter-relationship with pod characters in an under-exploited vegetable, Indian bean (*Lablab purpureus*). *Indian Journal of Agricultural Sciences* 84: 1051-1055.

Rajput, R. D. and R. P. Patil. 2017. Spectrophotometric analysis of chlorophylls and carotenoids from some cultivated fodder crops. *BIOINFOLET-A Quarterly Journal of Life Sciences* 14: 215-216.

Ram Bahadur, K. C., B. K. Joshi and S. P. Dahal. 2016.

Diversity analysis and physico-morphlogical characteritics of indigenous germplasm of lablab bean. *Journal of Nepal Agricultural Research Council* 2: 15-21.

Roy, A. K., K. Dinesh, A. K. Sharma, A. K. Mall, D. R. Malaviya and P. Kaushal. 2017. *Minimal Descriptors in Forage Crops*. AICRP on Forage Crops & Utilisation, ICAR-IGFRI, Jhansi. pp 136.

Shrikrishna, P. D. and S. Ramesh. 2020. Visually assayable morphological descriptors-based establishment of distinctiveness [D], uniformity [U] and stability [S] of dolichos bean (*Lablab purpureus* L. Sweet var. Lignosus) genotypes. *Plant Genetic Resources* 18: 105-108.

Thasneem, S. N., M. Sreenivas, K. Nagaraju, P. Saidaiah and S. R. Pandravada. 2022. Variability, heritability (h2b) and genetic advance studies in dolichos bean (*Lablab purpureus* L.) genotypes. *The Pharma Innovation Journal* 11: 6005-6008.

Vishnu, V. S. and P. M. Radhamany. 2022. Assessment of variability in *Lablab purpureus* (L.) Sweet germplasm based on quantitative morphological and biochemical traits. *Genetic Resources and Crop Evolution* 69: 1535-1546.