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INTEGRATIVE ANALYSIS OF MORPHOLOGICAL DESCRIPTORS AND IDEOTYPE SELECTION IN LENTIL (*LENS CULINARIS* MEDIK.) AT KYMORE PLATEAU, MADHYA PRADESH INDIA

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ABSTRACT

In the Present study, 92 genotypes, including farmer varieties and advanced breeding lines of lentil, from Kymore Plateau districts of Madhya Pradesh were characterized using 13 DUS descriptors with an aim to identify key distinguishing and phenotypically diverse traits. Phenotypic Variability was quantified by Shannon- Weaver diversity index (H') and validated with the help of Chi-square tests. High Diversity was exhibited by traits like Seed Testa colour, Seed size, Foliage: intensity of green colour and Plant Growth Habit while Cotyledon colour and Leaf pubescence showed no diversity. The Chi-square analysis revealed that Flower colour, Plant height, Seed size, Plant growth habit and Seed Testa colour were the strongest distinguishing traits among the genotypes. Ideotypes such as PL-8, NDL-1, PL-7, LH 82-6, IC 283384, MPL-33, PANT L-7, MPL-94, IC 267665, MPL-80, IPL-534, SUBRITA, PL-24, JBPL-146, IPL-315, L-1719, IPL-406, NARENDRA M2 were identified, these genotypes exhibited early/medium flowering, large/very large seeds, erect/semi-erect growth habit, medium plant height and dark/medium green foliage. These findings will assist in ideotype based selection, broaden the genetic base and facilitate varietal protection under PPV&FR guidelines.
Keywords : DUS Descriptors, Shannon-Weaver diversity index, Chi-square test, Ideotype selection

Introduction

With a genomic size of 4 Gb, Lentil (*Lens culinaris* L.) is the first domesticated annual cool-season grain legume (Polanco *et al*., 2018). A resilient crop that requires few inputs, lentils are cultivated in arid, chilly climates. In arid regions, it has considerable promise for climate resistance (Ghimire *et al*., 2019). The two subspecies of *Lens culinaris* are macrosperma and microsperma (Barulina, 1930). In the Indian subcontinent, the microsperma kinds are primarily observed that have smaller seeds (less than 25 g per 1000 seed weight) with cotyledons that are red, orange, and yellow. Indians consume it largely as "dal" and consider it to be one of the most nutrient-dense rabi pulse crop. The limiting amino acid in cereals, lysine, is present in considerable amounts in lentil seeds, which have a protein content ranging from 22 to 34.6% (Roy *et al*., 2025). The cool-season, self-pollinating annual legume lentil (*Lens culinaris* Medik.) is renowned for its capacity to adapt to a variety of agro-ecological circumstances. It exhibits significant variation in flower and pod colour, stem pigmentation, seed morphology (including size, shape, and coat pattern), and growth habits (compact, upright, semi-erect, or spreading) (Barulina, 1930; Summerfield *et al*., 1989; Kumar *et al*., 2024). These phenotypic variations are useful descriptors in breeding programs and are impacted by both genetics and environment. The limited genetic diversity poses a challenge in the development of high-yielding lentil varieties (Kumar *et al*., 2018). It has been noted that lentil accessions throughout India show relatively low genetic variation. Ongoing artificial selection and breeding, aimed primarily at a small number of desired traits to meet the growing demand, have led to diminished heterogeneity in the primary gene pool of lentils (Dikshit *et al*., 2016). Weak seedling development, minimal biomass, fragile stems, low harvest index, susceptibility to lodging, reduced conversion from

flower to pod, and stresses caused by climate are the main factors that decrease yields in lentils (Erskine *et al*., 2009). The first quick look into the genetic diversity of lentil (*Lens culinaris* Medik.) germplasm is provided by phenotypic variation as reflected by morphological descriptors. This helps breeders choose parents who can increase the crop's limited genetic base and protect it from biotic and abiotic challenges (Erskine *et al*., 1998; Kumar *et al*., 2024).

Even after the development of a number of new cultivars that are high yielding and stable over diverse locations with the help of consistent efforts by lentil breeders, the morphological descriptions of many cultivars are still not well defined. Assessing this morphological diversity is essential for identifying genetically distinct genotypes and broadening the genetic base of lentil. Statistical tools such as the Shannon–Weaver diversity index and the Chi-square test help quantify and validate this variation, enabling effective genotype discrimination and selection. In recent decades, India has seen the rise of extremely competitive varietal development programs, identifying and documenting diagnostic traits of varieties which requires precise identification keys and extensive descriptions on a comparative basis, highlighting different aspects of diversity. Therefore, it becomes necessary to characterise lentil varieties for their protection under Plant Variety Protection (PVP) legislation for varietal testing for distinctness, uniformity and stability (DUS) which is the least criterion for grant of protection of new plant varieties under the (PPV&FR) Act 2001. The Shannon–Weaver diversity index (H′) provides a single, comparable statistic of trait-level diversity across the collection by capturing both the richness (number of phenotypic classes) and evenness (distribution of genotypes across those classes) for each qualitative trait (Shannon & Weaver, 1949). The χ^2 test then identifies features that really distinguish accessions from one another by determining, whether the measured trait frequencies differ noticeably from a uniform (or otherwise predicted) distribution (Upadhyaya *et al*., 2008). Together, H′ and χ^2 identify the traits that contribute most to total diversity and validate their discriminating power, offering a strong, statistically supported argument for choosing complementing, diverse lentil genotypes to increase genetic gain in later breeding cycles. In Lentil Breeding the ideotypes that combine early flowering, bold seeds and erect growth habit are considered highly desirable for enhancing yield potential and adaptability. Early flowering helps to escape terminal heat and moisture stress (Erskine *et al*., 2009), large seed size increases market attractiveness and genetic gain (Muehlbauer *et al*., 2018) and erect growth habit improves harvest index and suitability for mechanized cultivation (Sharma *et al*., 2022). With this view in mind the present study was performed to quantify phenotypic variability and identify potential ideotypes in lentil for future improvement programmes.

Materials and Methods

The present study was conducted on 92 lentil genotypes including two checks viz. IPL-316 and JL-3, farmer varieties and advanced breeding lines (Table 1). The field experiment was conducted on Seed Breeding Farm, Department of Genetics and Plant Breeding, JNKVV, Jabalpur during the 2024-25 and 2025-26 cropping seasons.

Experimental material and Data Collection

The experiment was laid out in a randomized block design with two replications. Each genotype was planted in single rows of 2m with a 25 cm row-to-row spacing and a 10 cm plant-to-plant spacing. The data was collected from 13 Morphological Descriptors at prescribed crop stage according to DUS guidelines for Lentil. The observations were recorded on traits like Time of flowering, Foliage: Intensity of green colour, Plant Height, Stem Anthocyanin colouration, Leaflet size, Flower Colour, Pod Anthocyanin Colouration, Seed Size, Seed Testa Mottling, Seed Testa Colour, Plant Growth Habit , Cotyledon Colour and Leaf Pubescence. The mean data of both the cropping seasons were used for analysis for traits like Time of Flowering, Plant Height and Seed Size and Qualitative characterization was done according to lentil descriptors of the Protection of Plant Varieties and Farmers' Rights Act (PPV and FRA., 2007).

Statistical Analysis

Lentil genotypes were morphologically characterized using a set of qualitative descriptors that were based on accepted practices. The following method as described by Hutchenson (1970) was used to get each trait's Shannon–Weaver diversity index (H′), which measures phenotypic variability among genotypes:

$$H' = \left[\sum \left(\frac{n}{N} \right) \times \left\{ \log 2 \left(\frac{n}{N} \right) \times (-1) \right\} \right] / \log 2k$$

Where, *H′* is the standardized Shannon Weaver Diversity Index, *k* is the number of phenotypic classes for a character, "*n*" is the frequency of a phenotypic class of that character and "*N*" is the total number of observations for that character The index allows for a comparative assessment of variety across attributes by providing a combined measure of richness (number of

categories) and evenness (distribution across categories). The Chi-square (χ^2) test was used for each descriptor to determine the significance of variance in trait frequencies among genotypes. Under the null hypothesis of no variation, the test determines if observed frequencies differ noticeably from predicted frequencies. This is the calculation of the test statistic:

$$\chi^2 = \frac{\sum(O_i - E_i)^2}{E_i}$$

where O_i and E_i represent the i^{th} phenotypic classes observed and expected frequencies, respectively. A non-random distribution and successful trait-based genotype discrimination are shown by a significant χ^2 value ($p < 0.05$).

R program (version 4.4.3) was used for all calculations and graphical displays, along with pertinent packages like ggplot2, dplyr, and custom scripts for diversity index calculation.

Results and Discussion

Frequency and Percentage Distribution of Morphological Traits among Genotypes

Phenotypic assessment on 13 Morphological descriptors showed sufficient variability for traits like Time of flowering, Foliage: Intensity of green colour, Plant Height, Stem Anthocyanin colouration, Leaflet size, Flower Colour, Pod Anthocyanin Colouration, Seed Size, Seed Testa Mottling, Seed Testa Colour and Plant Growth Habit, however 2 traits viz, Leaf Pubescence and Cotyledon Colour showed no variations among the genotypes. Among the 92 genotypes maximum exhibited early flowering i.e. 66.3% and while 33.7% of genotypes were medium flowering whereas no genotype was late flowering. The trait Foliage: Intensity of green colour also exhibited considerable variation where maximum proportion genotypes had medium intensity of green foliage around 47.83%, followed by light green foliage 30.43% and dark green foliage was seen in 21.74% genotypes. Leaves showing dark green foliage correspond to higher chlorophyll concentration which gives an edge in selection as it contributes to higher photosynthesis ultimately leading to plant's biomass which persists for a longer time and contribute to stay green character in advanced phases of growth. Almost 91.3% genotypes were medium in height between 60-80cms, only 8 genotypes were short i.e. less than 60 cm in height and no genotypes were beyond 80cm. The slender stem in lentil shows anthocyanin pigmentation which was visible in 69.57% of genotypes whereas no pigmentation was seen in the remaining 30.43%. Maximum portion of genotypes had violet flowers 93.48% and only 6 genotypes had white flower they were MPL- 47, KOTA M1, IPL-406, SUBRITA, MPL-65, MPL-17. The trait leaflet size varied from large (19.57%), medium (59.78%) and small (20.65%). Brown seed Testa colour was the most common among the genotypes (53.26%) followed by Grey(21.74%). Black (14.13%) and Green (10.87%). It has been reported by Sivaram Reddy *et al*., 2024 that Black lentils consist of higher number of polyphenols as compared to brown lentils. Majority of the genotypes showed presence of Seed Testa mottling (84.78%) and the remaining lacked mottling. The most common cotyledon colour was orange exhibited by all genotypes as it was reported by Choudhary *et al*., 2017, Thalyari *et al*., 2022. Sharma and Emami (2002); Bakhsh *et al.* (2013); Singh *et al.* (2014). Dixit *et al.* (2011) showed that cotyledon colour was controlled by single gene hence, trait is less influenced by the environment. 42.39% of genotypes had medium seed size followed by large, very large and small. Around 64.13% genotypes showed Semi Erect growth habit whereas only 30.43% had erect growth and 5 genotypes grew horizontally. The Erect growth habit is a highly preferred trait for selection as they receive adequate amount of sunlight and perform photosynthesis efficiently. Similar results were reported by Dixit *et al*., 2011; Sharma *et al*., 2022; Reddy *et al*., 2024 as shown in Table 2 , Figure 1.

Shannon Weaver Diversity Index

The richness and evenness of the phenotypic classes of traits are taken into account by the Shannon-Weaver diversity index (H'). In the present study SWDI ranged from 0.000 to 1.185 which suggests a wide variation in trait diversity. (H') was found the highest for seed Testa colour (1.185) followed by Seed Size (1.058) which was at par with Foliage: Intensity of green colour (1.047). These high values of (H') indicate a very balanced distribution of genotypes among the phenotypic categories and a wider range of phenotypic expressions. This indicates that these descriptors are highly polymorphic and therefore very useful for assessing genetic variability and are excellent candidates for inclusion in DUS testing. On the other hand, low Shannon-Weaver diversity index was found for seed Testa mottling (0.426), plant height (0.295) and flower colour (0.241) indicating limited variation among the genotypes which can be attributed to high selection pressure resulting in the fixation of traits across the germplasm. There was no diversity among the genotypes for traits like Cotyledon Colour and Leaf Pubescence both with 0 (H'). Particularly in seed morphology and foliage-related attributes, the observed variation points to the possibility of genetic

gain and selection. These results are in accordance with previous studies by Ghimire *et al*., 2019, Tripathi *et al*., 2022

Chi- square test

Although the evenness and richness of trait categories are used to estimate phenotypic diversity by the Shannon-Weaver diversity index, the Chi-square test is a supplementary statistical tool that determines whether observed trait distributions significantly differ from expected frequencies, supporting or improving diversity interpretations. Significant phenotypic diversity among genotypes was shown by the Chi-square analysis, which showed that all characteristics showed extremely significant deviations from the expected frequency (Table 3). The traits with the highest χ^2 values were Flower Colour ($\chi^2 = 69.57$, $p < 0.0001$), Plant Height ($\chi^2 = 62.78$, $p < 0.0001$), and Seed Size ($\chi^2 = 53.48$, $p < 0.0001$). These traits show a strong divergence among the genotypes indicating their high discriminating power. Despite having comparatively lower chi-square values, traits such as Foliage Intensity of Green Colour ($\chi^2 = 9.74$, $p = 0.0077$) and Time of Flowering ($\chi^2 = 9.78$, $p = 0.0018$) were statistically significant suggesting a uniform distribution among the genotypes. It is noteworthy that even traits with lower Shannon-Weaver diversity, like Flower Colour and Plant Height, showed highly significant chi-square values. This suggests that even though the distribution was uneven overall as seen that the majority of genotypes had the same colour and height, but the traits were still useful for differentiating between specific genotypes, the chi-square test does, however, show that the groups are not evenly represented, which is statistically significant. The Chi-square analysis revealed that flower colour, plant height, seed size, plant growth habit and seed Testa colour were the strongest distinguishing traits among the genotypes. These traits are useful for the assessment of genetic diversity and can be utilized as markers for genotype characterisation. These results are in accordance with Sharma *et al*., 2022, Tripathi *et al*., 2022.

Trait Classification based on diversity and significance

Based on their Chi-square significant values and Shannon-Weaver diversity index, all morphological traits were categorized into classes as shown in Table 3. Traits like Seed Testa colour, Seed size and Plant growth habit show high Shannon-Diversity index as well as high chi square which indicates that they have high potential of genotype differentiation. Despite their statistical significance, characteristics like Time of Flowering, Stem anthocyanin and Pod anthocyanin showed little variation, indicating a small number of variance but a high capacity for discrimination. Traits such as seed Testa mottling, plant height, and flower colour displayed both low Shannon-Weaver Diversity and low Chi-square statistics, suggesting minimal variation among genotypes for these characters and limited value for selection or classification purposes.

Ideotype selection

The integrative analysis of Shannon-Weaver Diversity Index and Chi- square provided a robust framework to shortlist some key morphological traits that can be targeted for ideotype development in lentil. The selected traits had potential discriminatory power as they showed significant variation among genotypes reflecting strong inter-genotypic differentiation. Apart from this these traits demonstrated broad variability across germplasm signifying a rich gene pool that can be exploited for crop improvement. Hence the most promising traits include: early to medium flowering, erect/semi erect growth habit, medium plant height, medium to dark green foliage and large-very large seed size, The genotypes such as PL-8, NDL-1, PL-7, LH 82-6, IC 283384, MPL-33, PANT L-7, MPL-94, IC 267665, MPL-80, IPL-534, SUBRITA, PL-24, JBPL-146, IPL-315, L-1719, IPL-406, NARENDRA M2 fulfilled all of these criteria and can be considered potential ideotypes for breeding programmes. These accessions combine large seed size with desirable plant architecture, early phenology, suitability for mechanical cultivation and market preferred seed quality traits making them ideal choices for parents in ideotype breeding.

Conclusion

The Current work demonstrated that morphological characterisation is a crucial method for evaluation of phenotypic variability in Lentils which can be backed up by statistical techniques like the Chi-square test and Shannon-Weaver diversity index. The 11 out of 13 traits studied exhibited significant variation, but the most diverse were Seed Testa colour, seed size, Foliage: intensity of green colour, plant growth habit and leaflet size. Highly significant differences in trait distributions were validated by the Chi-square test, highlighting their potential for genotype discrimination. Crucially, the categorization of traits into discrete groups was made possible by the joint application of the Chi-square test and the Shannon-Weaver index, which made it possible to identify those with great discriminating power and high diversity. Time of flowering, Plant Height, Foliage: intensity of green colour, seed size, and plant growth

habit were shown to be very informative, whereas ideotypes such as PL-8, NDL-1, PL-7, LH 82-6, IC 283384, MPL-33, PANT L-7, MPL-94, IC 267665, MPL-80, IPL-534, SUBRITA, PL-24, JBPL-146, IPL-315, L-1719, IPL-406, NARENDRA M2 were identified as prospective ideotypes that can be utilised as parental lines for future breeding efforts. Overall, integrating phenotypic frequency analysis with diversity and significance testing improves ideotype selection and adds up to expanding lentil's genetic base. These findings not only enhance breeding efforts for yield and adaptability, but also lays the groundwork for varietal identification and protection under the PPV&FR Act, improving both the scientific and legal aspects of lentil development.

Table 1 : List of Genotypes of Lentil used in the Study

S.No	Genotype	S.No	Genotype	S.No	Genotype	S.No	Genotype
1	PL-8	24	DPL-62	47	LL-1255	70	SUBRITA
2	VL-507	25	IC 310826	48	IC 268233	71	PL-5
3	IC 282288	26	IC 384474	49	IC 267659	72	IC 267662
4	VL-1	27	JBPL-152	50	L 1719	73	IC 331541
5	NDL-1	28	MPL-101	51	MPL-4	74	IC 384469
6	PL-7	29	IC 331545	52	RLG-5	75	IC 296883
7	JL-1	30	MPL- 47	53	IPL-406	76	IC 321535
8	PL-24	31	IC 268245	54	PL-4	77	PL-7712
9	IPL316	32	IC 283384	55	IC 311161	78	IC 331597
10	JL3	33	MPL-33	56	PANT L-7	79	IPL-220
11	LH 82-6	34	KOTA M1	57	MPL-94	80	IC 296884
12	IC 268329	35	LH 84-8	58	PL-32	81	IPL-81
13	WBL-77	36	BARAHIA	59	LL-56	82	K 75
14	IC 341355	37	PL-63	60	IC 267665	83	NARENDRA M2
15	MPL-68	38	RK 6031	61	MPL-80	84	IC 406706
16	L-4076	39	IC 385825	62	RVL-13-5	85	VL-103
17	MPL-92	40	ASHA	63	MPL-91	86	RLG 192
18	DPL-15	41	PL 406	64	MPL-61	87	LH 89-48
19	MPL-35	42	IC 328451	65	IPL-534	88	MPL-65
20	JBPL-146	43	IC 396043	66	IC 334281	89	JBPL-148
21	IPL 315	44	MPL- 105	67	PL-532	90	MPL-17
22	RANJAN	45	MPL-13	68	IC 315944	91	MPL-83
23	MPL-15	46	SSI-5	69	IC 355621	92	VL-156

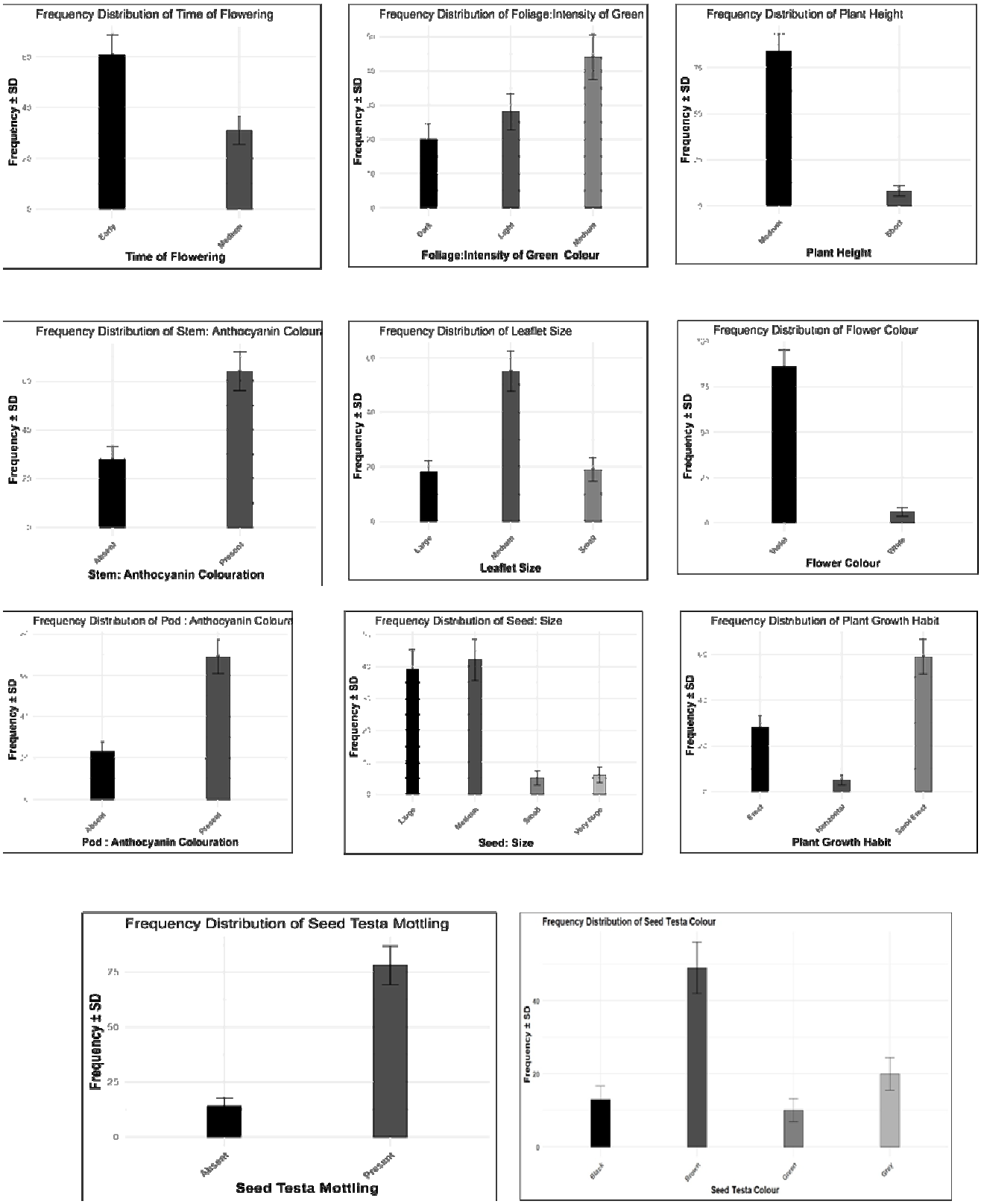

Fig. 1 : Graphical Representation of Distribution of Morphological Traits among the Genotypes

Table 2 : Classification of Genotypes according to DUS score and Morphology

Trait	Variation	DUS score	Frequency	Percentage	Genotypes
Time of Flowering	Early	3	61	66.3	PL-8, NDL-1, PL-7, IPL316, JL3, LH 82-6, IC 268329, WBL-77, IC 341355, MPL-68, L-4076, MPL-92, DPL-15, MPL-35, RANJAN, MPL-15, DPL-62, IC 310826, IC 384474, JBPL-152, IC 331545, MPL- 47, IC 268245, IC 283384, MPL-33, KOTA M1, BARAHIA, RK 6031, ASHA, PL 406, IC 328451, IC 396043, SSI-5, MPL-4, PL-4, IC 311161, PANT L-7, MPL-94, PL-32, IC 267665, MPL-80, RVL-13-5, MPL-61, IPL-534, IC 334281, PL-532, IC 315944, IC 355621, SUBRITA, IC 267662, IC 331541, IC 384469, IC 296883, IC 321535, IC 331597, IC 296884, IC 406706, JBPL-148, MPL-17, MPL-83, VL-156
	Medium	5	31	33.7	VL-507, IC 282288, VL-1, JL-1, PL-24, JBPL-146, IPL 315, MPL-101, LH 84-8, PL-63, IC 385825, MPL- 105, MPL-13, LL-1255, IC 268233, IC 267659, L 1719, RLG-5, IPL-406, LL-56, MPL-91, PL-5, PL-7712, IPL-220, IPL-81, K 75, NARENDRA M2, VL-103, RLG 192, LH 89-48, MPL-65
Foliage: Intensity of Green Colour	Dark	3	20	21.74	PL-8, NDL-1, PL-7, JL-1, PL-24, JL3, IPL 315, RANJAN, IC 283384, KOTA M1, LH 84-8, BARAHIA, IC 385825, LL-1255, PL-4, PANT L-7, LL-56, IC 267662, IC 321535, RLG 192
	Light	1	28	30.43	VL-507, IC 282288, VL-1, IC 268329, MPL-68, MPL-35, DPL-62, IC 384474, MPL-101, MPL-13, SSI-5, IC 268233, IC 267659, MPL-4, PL-32, RVL-13-5, MPL-91, MPL-61, IC 334281, PL-532, PL-5, PL-7712, IPL-220, VL-103, LH 89-48, MPL-65, JBPL-148, MPL-17
	Medium	2	44	47.83	IPL316, LH 82-6, WBL-77, IC 341355, L-4076, MPL-92, DPL-15, JBPL-146, MPL-15, IC 310826, JBPL-152, IC 331545, MPL- 47, IC 268245, MPL-33, PL-63, RK 6031, ASHA, PL 406, IC 328451, IC 396043, MPL- 105, L 1719, RLG-5, IPL-406, IC 311161, MPL-94, IC 267665, MPL-80, IPL-534, IC 315944, IC 355621, SUBRITA, IC 331541, IC 384469, IC 296883, IC 331597, IC 296884, IPL-81, K 75, NARENDRA M2, IC 406706, MPL-83, VL-156
Plant Height	Medium	5	84	91.3	IC 282288, NDL-1, PL-7, JL-1, PL-24, IPL316, JL3, LH 82-6, IC 268329, WBL-77, IC 341355, MPL-68, L-4076, DPL-15, MPL-35, JBPL-146, IPL 315, RANJAN, MPL-15, DPL-62, IC 310826, IC 384474, JBPL-152, MPL-101, IC 331545, MPL- 47, IC 283384, MPL-33, KOTA M1, LH 84-8, BARAHIA, PL-63, RK 6031, IC 385825, ASHA, PL 406, IC 328451, IC 396043, MPL- 105, MPL-13, SSI-5, LL-1255, IC 268233, IC 267659, L 1719, MPL-4, RLG-5, IPL-406, PL-4, IC 311161, PANT L-7, MPL-94, LL-56, IC 267665, MPL-80, RVL-13-5, MPL-91, MPL-61, IPL-534, IC 334281, PL-532, IC 315944, IC 355621, SUBRITA, PL-5, IC 267662, IC 384469, IC 296883, IC 321535, PL-7712, IC 331597, IPL-220, IC 296884, IPL-81, K 75, NARENDRA M2, IC 406706, VL-103, RLG 192, LH 89-48, MPL-65, JBPL-148, MPL-17, MPL-83
	Short	3	8	8.7	PL-8, VL-507, VL-1, MPL-92, IC 268245, PL-32, IC 331541, VL-156
Stem: Anthocyanin Colouration	Absent	1	28	30.43	VL-507, VL-1, NDL-1, PL-7, JL-1, PL-24, IPL316, LH 82-6, MPL-15, IC 283384, KOTA M1, LH 84-8, ASHA, PL 406, IC 396043, MPL-105, MPL-13, L 1719, MPL-80, IC 267662, IC 384469, IC 321535, K 75, NARENDRA M2, IC 406706, VL-103, RLG 192, LH 89-48
	Present	9	64	69.57	PL-8, IC 282288, JL3, IC 268329, WBL-77, IC 341355, MPL-68, L-4076, MPL-92, DPL-15, MPL-35, JBPL-146, IPL 315, RANJAN, DPL-62, IC 310826, IC 384474, JBPL-152, MPL-101, IC 331545, MPL- 47, IC 268245, MPL-33, BARAHIA, PL-63, RK 6031, IC 385825, IC 328451, SSI-5, LL-1255, IC 268233, IC 267659, MPL-4, RLG-5, IPL-406, PL-4, IC 311161, PANT L-7, MPL-94, PL-32, LL-56, IC 267665, RVL-13-5, MPL-91, MPL-61, IPL-534, IC 334281, PL-532, IC 315944, IC 355621, SUBRITA, PL-5, IC 331541, IC 296883, PL-7712, IC 331597, IPL-220, IC 296884, IPL-81, MPL-65, JBPL-148, MPL-17, MPL-83, VL-156
Leaf Pubescence	Present	1	92	100	PL-8, VL-507, IC 282288, VL-1, NDL-1, PL-7, JL-1, PL-24, IPL316, JL3, LH 82-6, IC 268329, WBL-77, IC 341355, MPL-68, L-4076, MPL-

					92, DPL-15, MPL-35, JBPL-146, IPL 315, RANJAN, MPL-15, DPL-62, IC 310826, IC 384474, JBPL-152, MPL-101, IC 331545, MPL- 47, IC 268245, IC 283384, MPL-33, KOTA M1, LH 84-8, BARAHIA, PL-63, RK 6031, IC 385825, ASHA, PL 406, IC 328451, IC 396043, MPL-105, MPL-13, SSI-5, LL-1255, IC 268233, IC 267659, L 1719, MPL-4, RLG-5, IPL-406, PL-4, IC 311161, PANT L-7, MPL-94, PL-32, LL-56, IC 267665, MPL-80, RVL-13-5, MPL-91, MPL-61, IPL-534, IC 334281, PL-532, IC 315944, IC 355621, SUBRITA, PL-5, IC 267662, IC 331541, IC 384469, IC 296883, IC 321535, PL-7712, IC 331597, IPL-220, IC 296884, IPL-81, K 75, NARENDRA M2, IC 406706, VL-103, RLG 192, LH 89-48, MPL-65, JBPL-148, MPL-17, MPL-83, VL-156
Leaflet Size	Large	7	18	19.57	IC 282288, IPL316, MPL-68, MPL-15, PL-63, RK 6031, IC 385825, ASHA, PL 406, SSI-5, LL-1255, IC 268233, IC 267659, L 1719, MPL-80, PL-532, IC 355621, IC 321535
	Medium	5	55	59.78	PL-8, VL-507, VL-1, NDL-1, JL-1, PL-24, JL3, LH 82-6, IC 268329, WBL-77, L-4076, MPL-92, DPL-15, JBPL-146, IPL 315, RANJAN, DPL-62, MPL-101, MPL- 47, LH 84-8, BARAHIA, IC 328451, IC 396043, MPL- 105, MPL-13, MPL-4, RLG-5, IPL-406, PL-4, IC 311161, PANT L-7, MPL-94, PL-32, LL-56, IC 267665, RVL-13-5, MPL-91, IPL-534, IC 334281, IC 315944, SUBRITA, PL-5, IC 267662, IC 296883, PL-7712, IC 331597, IPL-81, K 75, NARENDRA M2, IC 406706, VL-103, RLG 192, MPL-65, MPL-83, VL-156
	Small	3	19	20.65	PL-7, IC 341355, MPL-35, IC 310826, IC 384474, JBPL-152, IC 331545, IC 268245, IC 283384, MPL-33, KOTA M1, MPL-61, IC 331541, IC 384469, IPL-220, IC 296884, LH 89-48, JBPL-148, MPL-17
Flower Colour	Violet	4	86	93.48	PL-8, VL-507, IC 282288, VL-1, NDL-1, PL-7, JL-1, PL-24, IPL316, JL3, LH 82-6, IC 268329, WBL-77, IC 341355, MPL-68, L-4076, MPL-92, DPL-15, MPL-35, JBPL-146, IPL 315, RANJAN, MPL-15, DPL-62, IC 310826, IC 384474, JBPL-152, MPL-101, IC 331545, IC 268245, IC 283384, MPL-33, LH 84-8, BARAHIA, PL-63, RK 6031, IC 385825, ASHA, PL 406, IC 328451, IC 396043, MPL- 105, MPL-13, SSI-5, LL-1255, IC 268233, IC 267659, L 1719, MPL-4, RLG-5, PL-4, IC 311161, PANT L-7, MPL-94, PL-32, LL-56, IC 267665, MPL-80, RVL-13-5, MPL-91, MPL-61, IPL-534, IC 334281, PL-532, IC 315944, IC 355621, PL-5, IC 267662, IC 331541, IC 384469, IC 296883, IC 321535, PL-7712, IC 331597, IPL-220, IC 296884, IPL-81, K 75, NARENDRA M2, IC 406706, VL-103, RLG 192, LH 89-48, JBPL-148, MPL-83, VL-156
	White	1	6	6.52	MPL- 47, KOTA M1, IPL-406, SUBRITA, MPL-65, MPL-17
Pod : Anthocyanin Colouration	Absent	1	23	25	IC 268329, MPL-68, DPL-15, IC 331545, IC 283384, BARAHIA, PL-63, RK 6031, IC 385825, MPL- 105, LL-1255, MPL-4, IPL-406, LL-56, IC 267665, MPL-80, RVL-13-5, IC 315944, IC 384469, IC 296883, IC 321535, PL-7712, IC 331597
	Present	9	69	75	PL-8, VL-507, IC 282288, VL-1, NDL-1, PL-7, JL-1, PL-24, IPL316, JL3, LH 82-6, WBL-77, IC 341355, L-4076, MPL-92, MPL-35, JBPL-146, IPL 315, RANJAN, MPL-15, DPL-62, IC 310826, IC 384474, JBPL-152, MPL-101, MPL- 47, IC 268245, MPL-33, KOTA M1, LH 84-8, ASHA, PL 406, IC 328451, IC 396043, MPL-13, SSI-5, IC 268233, IC 267659, L 1719, RLG-5, PL-4, IC 311161, PANT L-7, MPL-94, PL-32, MPL-91, MPL-61, IPL-534, IC 334281, PL-532, IC 355621, SUBRITA, PL-5, IC 267662, IC 331541, IPL-220, IC 296884, IPL-81, K 75, NARENDRA M2, IC 406706, VL-103, RLG 192, LH 89-48, MPL-65, JBPL-148, MPL-17, MPL-83, VL-156
Seed: Size	Large	7	39	42.39	PL-8, VL-507, VL-1, NDL-1, PL-7, PL-24, LH 82-6, IC 268329, IC 341355, L-4076, MPL-92, DPL-15, MPL-35, JBPL-146, IPL 315, MPL-15, DPL-62, IC 283384, MPL-33, MPL- 105, MPL-13, SSI-5, IC 268233, L 1719, IPL-406, PANT L-7, MPL-94, PL-32, IC 267665, MPL-80, MPL-91, MPL-61, IPL-534, PL-532, SUBRITA, IC 331541, NARENDRA M2, MPL-65, MPL-17
	Medium	5	42	45.65	JL-1, JL3, WBL-77, MPL-68, RANJAN, IC 310826, IC 384474, JBPL-152, MPL-101, IC 331545, MPL- 47, IC 268245, KOTA M1, LH 84-8, BARAHIA, PL-63, RK 6031, IC 385825, ASHA, PL 406, IC 328451, IC 396043, LL-1255, RLG-5, PL-4, LL-56, IC 334281, IC 355621, IC 267662, IC 384469, IC 321535, PL-7712, IC 331597, IC 296884, IPL-81, K 75, IC 406706, VL-103, RLG 192, JBPL-148, MPL-83, VL-156

	Small	3	5	5.43	IC 311161, IC 315944, IC 296883, IPL-220, LH 89-48
	Very large	9	6	6.52	IC 282288, IPL316, IC 267659, MPL-4, RVL-13-5, PL-5
Cotyledon Colour	Orange	3	92	100	PL-8, VL-507, IC 282288, VL-1, NDL-1, PL-7, JL-1, PL-24, IPL316, JL3, LH 82-6, IC 268329, WBL-77, IC 341355, MPL-68, L-4076, MPL-92, DPL-15, MPL-35, JBPL-146, IPL 315, RANJAN, MPL-15, DPL-62, IC 310826, IC 384474, JBPL-152, MPL-101, IC 331545, MPL- 47, IC 268245, IC 283384, MPL-33, KOTA M1, LH 84-8, BARAHIA, PL-63, RK 6031, IC 385825, ASHA, PL 406, IC 328451, IC 396043, MPL-105, MPL-13, SSI-5, LL-1255, IC 268233, IC 267659, L 1719, MPL-4, RLG-5, IPL-406, PL-4, IC 311161, PANT L-7, MPL-94, PL-32, LL-56, IC 267665, MPL-80, RVL-13-5, MPL-91, MPL-61, IPL-534, IC 334281, PL-532, IC 315944, IC 355621, SUBRITA, PL-5, IC 267662, IC 331541, IC 384469, IC 296883, IC 321535, PL-7712, IC 331597, IPL-220, IC 296884, IPL-81, K 75, NARENDRA M2, IC 406706, VL-103, RLG 192, LH 89-48, MPL-65, JBPL-148, MPL-17, MPL-83, VL-156
Seed Testa Mottling	Absent	1	14	15.22	PL-8, IC 282288, VL-1, PL-7, PL-24, JL3, IC 385825, IC 267659, PANT L-7, RVL-13-5, IC 334281, SUBRITA, PL-5, K 75
	Present	3	78	84.78	VL-507, NDL-1, JL-1, IPL316, LH 82-6, IC 268329, WBL-77, IC 341355, MPL-68, L-4076, MPL-92, DPL-15, MPL-35, JBPL-146, IPL 315, RANJAN, MPL-15, DPL-62, IC 310826, IC 384474, JBPL-152, MPL-101, IC 331545, MPL- 47, IC 268245, IC 283384, MPL-33, KOTA M1, LH 84-8, BARAHIA, PL-63, RK 6031, ASHA, PL 406, IC 328451, IC 396043, MPL- 105, MPL-13, SSI-5, LL-1255, IC 268233, L 1719, MPL-4, RLG-5, IPL-406, PL-4, IC 311161, MPL-94, PL-32, LL-56, IC 267665, MPL-80, MPL-91, MPL-61, IPL-534, PL-532, IC 315944, IC 355621, IC 267662, IC 331541, IC 384469, IC 296883, IC 321535, PL-7712, IC 331597, IPL-220, IC 296884, IPL-81, NARENDRA M2, IC 406706, VL-103, RLG 192, LH 89-48, MPL-65, JBPL-148, MPL-17, MPL-83, VL-156
Seed Testa Colour	Black	5	13	14.13	VL-1, DPL-15, MPL-35, JBPL-152, MPL- 47, MPL-33, IC 396043, IC 268233, L 1719, MPL-91, IPL-534, IC 334281, JBPL-148
	Brown	4	49	53.26	IC 282288, IPL316, JL3, DPL-62, IC 310826, IC 384474, IC 331545, KOTA M1, BARAHIA, IC 385825, ASHA, PL 406, IC 328451, MPL-105, MPL-13, LL-1255, RLG-5, IPL-406, PL-4, IC 311161, PANT L-7, MPL-94, LL-56, IC 267665, MPL-80, PL-532, IC 315944, IC 355621, SUBRITA, IC 267662, IC 331541, IC 384469, IC 296883, IC 321535, PL-7712, IC 331597, IPL-220, IC 296884, IPL-81, K 75, NARENDRA M2, IC 406706, VL-103, RLG 192, LH 89-48, MPL-65, MPL-17, MPL-83, VL-156
	Green	1	10	10.87	IC 268329, MPL-101, PL-63, RK 6031, SSI-5, IC 267659, PL-32, RVL-13-5, MPL-61, PL-5
	Grey	2	20	21.74	PL-8, VL-507, NDL-1, PL-7, JL-1, PL-24, LH 82-6, WBL-77, IC 341355, MPL-68, L-4076, MPL-92, JBPL-146, IPL 315, RANJAN, MPL-15, IC 268245, IC 283384, LH 84-8, MPL-4
Plant Growth Habit	Erect	1	28	30.43	PL-8, VL-507, VL-1, PL-24, JL3, IC 268329, WBL-77, IC 341355, DPL-62, IC 310826, IC 384474, JBPL-152, IC 268245, MPL-33, IC 328451, IC 396043, MPL- 105, IC 268233, L 1719, IC 311161, PANT L-7, RVL-13-5, MPL-61, IC 267662, IC 331541, IC 296884, IPL-81, MPL-83
	Horizontal	5	5	5.43	IC 385825, RLG-5, RLG 192, MPL-65, JBPL-148
	Semi Erect	3	59	64.13	IC 282288, NDL-1, PL-7, JL-1, IPL316, LH 82-6, MPL-68, L-4076, MPL-92, DPL-15, MPL-35, JBPL-146, IPL 315, RANJAN, MPL-15, MPL-101, IC 331545, MPL- 47, IC 283384, KOTA M1, LH 84-8, BARAHIA, PL-63, RK 6031, ASHA, PL 406, MPL-13, SSI-5, LL-1255, IC 267659, MPL-4, IPL-406, PL-4, MPL-94, PL-32, LL-56, IC 267665, MPL-80, MPL-91, IPL-534, IC 334281, PL-532, IC 315944, IC 355621, SUBRITA, PL-5, IC 384469, IC 296883, IC 321535, PL-7712, IC 331597, IPL-220, K 75, NARENDRA M2, IC 406706, VL-103, LH 89-48, MPL-17, VL-156

Table 3 : Classification of Traits based on Diversity and Significance of Variation

Trait	Shannon Weaver Diversity Index (SWDI)	Chi-square	p_value	Class
Time of Flowering	0.639	9.783	0.001762	**Class-2** Low Shannon &Low Chi-Square
Foliage: Intensity of Green Colour	1.047	9.739	0.007677	**Class-1** High Shannon and Low Chi Square
Plant Height	0.295	62.783	2.31E-15	**Class-4**Low Shannon and High Chi Square
Stem: Anthocyanin Colouration	0.615	14.087	0.000175	**Class-2** L ow Shannon and Low Chi Square
Leaf Pubescence	0	NA	NA	NA
Leaflet Size	0.953	28.978	5.10E-07	**Class-1** High Shannon and Low Chi Square
Flower Colour	0.241	69.565	7.39E-17	**Class- 4** Low Shannon and High Chi Square
Pod : Anthocyanin Colouration	0.562	23	1.62E-06	**Class-2** Low Shannon and Low Chi Square
Seed: Size	1.058	53.478	1.45E-11	**Class 3**-High Shannon and High Chi Square
Cotyledon Colour	0	NA	NA	NA
Seed Testa Mottling	0.426	44.522	2.52E-11	**Class- 4** Low Shannon and High Chi Square
Seed Testa Colour	1.185	41.478	5.18E-09	**Class 3**- High Shannon and High Chi square
Plant Growth Habit	0.805	47.891	3.99E-11	**Class 3**- High Shannon and High Chi Square

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