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Distinctness, Uniformity and Stability Characterization of Soybean *Glycine max* [L.] Merrill Genotypes

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Soybean is a significantly important leguminous crop known for its high protein (~40%) and oil (~20%) content, making it essential in human nutrition and animal feed. The current research was conducted during the *Kharif,* 2024 at the Zonal Agricultural Research Station, Morena, RVSKVV,

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Gwalior to assess qualitative characters among 60 soybean genotypes acquired from different institutions in a Randomized Block Design (RBD) with two replications. Eleven qualitative traits including hypocotyl and flower colour, leaf shape and shade, pod pubescence, growth habit, seed shape, seed coat and hilum colour and luster were recorded visually. Substantial phenotypic variation was observed. Anthocyanin pigmentation in the hypocotyl was present in 37 genotypes (61.67%); flower colour was violet in 37 (61.67%) and white in 23 genotypes (38.33%). Seed coat luster also varied where 38 genotypes (63.33%) were shiny while 22 (36.67%) were dull. Variation was also seen in leaf shape, pod surface, growth habit and hilum colour. A dendrogram was also constructed based on the qualitative traits which classified the genotypes into two primary clusters: a major contained 37 genotypes and a minor comprehend 23 genotypes. This morphological characterization provides valuable baseline information for selecting superior genotype (s) for further utilization in breeding programmes. The observed diversity can be effectively utilized for genetic improvement and conservation.

Keywords: Genetic diversity; germplasm evaluation; morphological characterization; phenotypic variation; soybean (Glycine max); qualitative traits.

1. INTRODUCTION

Glycine max [L.] Merrill stands as one of the most economically valuable and nutritionally rich leguminous crops cultivated worldwide. Its seeds are notable for their high content of quality protein (~40%) and oil (~20%), positioning it as a staple in plant-based human diets and a major ingredient in livestock feed (Mishra et al., 2020; Mishra et al., 2021a; Mishra et al., 2024a; Jhariya et al., 2025a). The protein profile of soybean is particularly advantageous due to its abundance of essential amino acids, including lysine, leucine and isoleucine making it an ideal source of complete plant protein and a critical component in vegetarian and vegan nutrition (Upadhyay et al., 2020; Mishra et al., 2024b; Jhariya et al., 2025b; Gautam et al., 2025a). Beyond its nutritional contributions, soybean plays a pivotal role as a raw material in numerous industrial applications. It serves as a sustainable feedstock for biodiesel production, thereby supporting global efforts toward renewable energy solutions (Mishra et al., 2021b; Sharma et al., 2021; Jhariya et al., 2025c; Gautam et al., 2025b). Additionally, soybean-based products are extensively utilized across diverse sectors, including food processing, pharmaceuticals, cosmetics, adhesives and lubricants, highlighting the crop's vast industrial applicability and economic significance (Tripathi et al., 2022; Sharma et al., 2023; Mishra et al., 2024c; Jhariya et al., 2025d).

From an agronomic perspective, soybean exhibits exceptional adaptability to a wide range of agro-climatic conditions, encompassing both temperate and tropical environments. This adaptability is complemented by its symbiotic relationship with *Bradyrhizobium* spp., which enables atmospheric nitrogen fixation within root nodules (Almeida Ribeiro et al., 2015; Mishra et al., 2021c; de Namozov et al., 2022; Gautam et al., 2025c). This biological nitrogen fixation substantially reduces the dependence on synthetic nitrogen fertilizers, lowering input costs and contributing to sustainable farming systems by enhancing soil fertility and reducing environmental impact (Bender et al., 2022; Hu et al., 2023; Jhariya et al., 2025e). Soybean's relatively short growth cycle, ability to improve soil structure and compatibility with multiple cropping systems make it a vital component in sustainable agricultural practices. Its integration into crop rotation schemes, particularly with cereals helps in breaking pest and disease cycles, restoring soil nutrients and boosting overall farm productivity (Yang et al., 2020; Shah et al., 2021; Mishra et al., 2025a; Mishra et al., 2025b).

The efficiency of crop improvement programmes relies heavily on a comprehensive understanding of the extent and nature of genetic diversity available within the germplasm (Mishra et al., 2022; Asati et al., 2023; Khadivi, 2023; Salgotra & Chauhan, 2023; Mishra et al., 2024d). Morphological characterization is the first and most fundamental step in the evaluation of genetic resources as it allows for the identification and selection of desirable traits based on visible and measurable features (Makwana et al., 2023; Yadav et al., 2023; Paliwal et al., 2024; Mishra et al., 2025a). These traits such as plant height, branching pattern, pod number, seed weight and phenological stages serve as key indicators of agronomic performance and yield potential. In soybean, morphological traits are often influenced by both genetic and environmental factors, making their evaluation critical for identifying genotypes with stable and superior performance under specific conditions (Karyawati et al., 2025; Amjid & Ustun, 2025). Characterization based on morphological descriptors not only aids in the classification and conservation of germplasm but also provides valuable insights for parent selection for further use in hybridization programmes, trait inheritance studies and the development of ideotype (Ramteke et al., 2010; Ramteke & Muralitharan, 2012; Mishra et al., 2022; Sharma et al., 2023; Mishra et al., 2025b).

Given the increasing demand for high-yielding and climate-resilient soybean cultivars, morphological characterization offers a cost-effective and accessible approach to phenotyping of a wide range of genotypes. It forms the foundation for advanced genetic investigations and supports the selection of parental lines for accomplishing breeding programmes aimed to enhance productivity and adaptability (Shilpashree et al., 2021; Fang et al., 2024; Mishra et al., 2024e; Rather et al., 2025; Tlahig et al., 2025). In this context, the present investigation was undertaken to evaluate the morphological variability among diverse soybean genotypes employing main agro-morphological descriptors. The objective was to identify phenotypically distinct and agronomically superior genotype (s) that can be utilized in future breeding efforts for the development of improved cultivar (s) with enhanced yield potential and environmental flexibility.

2. MATERIALS AND METHOD

2.1 Experimental Site

The field experiment was carried out during the *kharif,* 2024 at the Research Farm, Zonal Agricultural Research Station, Morena, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, Madhya Pradesh, India. Geographically, the experimental site is located at 26.5°N latitude and 78.0°E longitude with an elevation of approximately 177 meters above mean sea level. The soil type of the experimental field was medium-black (Vertisol), characterized by good drainage capacity and uniform topography making it suitable for field experimentation. The site is representative of a semi-arid, monsoonal climate with ambient temperatures during the cropping period ranging between 25°C- 30°C, conditions favourable for optimal soybean growth and development. Rainfall during the season was within the low to moderate range, consistent with the crop's agro-climatic adaptability. However, the region remains vulnerable to occasional climatic aberrations, including intermittent drought, prolonged rainfall and episodic water logging, which may contribute to variability in crop performance and yield outcomes.

2.2 Experimental Details

The experiment was designed in a Randomized Block Design (RBD) with two replications to ensure statistical competence and minimize environmental variability. A total of 60 soybean genotypes were evaluated, acquired from diverse institutions including the College of Agriculture, JNKVV, Jabalpur, M.P., India, RAK College of Agriculture, Sehore, M. P., India and Zonal Agricultural Research Station, Morena, RVSKVV, Gwalior, M.P., India, thereby encompassing a broad genetic base. Each experimental plot comprised rows spaced 30 cm apart, with a plant-to-plant distance of 10 cm and each row extended to a length of 5 meters. Standard agronomical practices including land preparation, sowing, nutrient management and plant protection measures were uniformly implemented across all plots to ensure optimal crop growth and the generation of accurate and reproducible phenotypic data. Data were collected from 5 randomly selected plants from each replication of each genotype.

3. RESULTS AND DISCUSSION

In the present study, sixty soybean genotypes were evaluated for eleven qualitative traits to assess phenotypic variation and aid in genotype identification. Visual observation revealed presence of significant variability across several traits (Table 1; Table 2; Table 3; Fig. 1). Hypocotyl colour displayed the presence of anthocyanin pigmentation in 37 genotypes, while 23 exhibited no pigmentation. Regarding flower colour (Fig. 1: A), 37 genotypes had violet flowers while 23 had white flowers. The intensity of green colour in leaves (Fig. 1: B) also differed, with 43 genotypes showing dark green while 17 genotypes had green foliage. Pod pubescence (Fig. 1: C) was present in 28 genotypes, while the remaining 32 were glabrous; however, all genotypes exhibited tawny pubescence colour, indicating uniformity in this trait. Leaf shape (Fig. 1: D) also varied, where 50 genotypes displayed pointed ovate leaves, six lanceolate and four with round ovate leaflets. Growth habit analysis exhibited that 48 genotypes had a semi-erect growth habit while 12 were erect. Seed shape (Fig. 1: E) was predominantly spherical in 56 genotypes while only four exhibited an elliptical form. Seed coat colour (Fig. 1: F), excluding the hilum, was mainly yellow of 54 genotypes, while six genotypes showed a yellow-green colour. None of the genotype exhibited green or black seed coats. In terms of seed coat luster (Fig. 1: G), 38 genotypes were shiny whereas, 22 were dull. Hilum colour (Fig. 1: H) also varied among genotypes, as 29 genotypes exhibiting black, 17 brown, nine grey whereas five yellow hilum colour. This observed morphological diversity provides important baseline information for selecting parental genotype (s) to further use in breeding programmes and contributes to the classification, conservation and improvement of soybean germplasm.

A dendrogram was also constructed based on the qualitative traits of 60 soybean genotypes (Fig. 2), which classified the genotypes into two primary clusters: one major and one minor. The minor cluster comprised 23 genotypes and was further divided into two sub-clusters-designated as the major sub-cluster and the minor sub-cluster. The major sub-cluster of the minor cluster contained 16 genotypes, including Cat-87, PS-1569, ASB-93, JS-22-01, RVS-23-26, JS-24-26, RVS-23-20, Himso-1695, JS-23-05, JS-26, JS-20-79, NRC-138, AMS-2021-3, RVSM-2012-4, JS-21-17 and NRC-201. The minor sub-cluster included seven genotypes: RVS-23-5, Rajsoya-24, DLSB-40, JS-20-116, NRC-192, KDSIS-1394 and BAUS(M)-6. Similarly, the major cluster, consisting of 37 genotypes, was also divided into major and minor sub-clusters. The major sub-cluster contained 24 genotypes *viz*., MAUS-787, MACS-824, RVS-23-10, RVS-23-12, AS-26, NRC-255, NRC-152, NRCSL-7, VLS-104, AMS-264, KDS-1203, RSC-10-52, AMS-100-39, NRC-166, RVS-2001-4, MAUS-791, KDS-1201, JS-21-07, Pusa Sipani BS-8, NRCSL-4, RSC-10-46, RVS-23-15, JS-22-12 and JS-25-03. The minor sub-cluster comprised 13 genotypes *i. e*., ASB-85, Cat 492-A, SL-1315, KBSL-23-36, SL-311, NRC-142, AUKS-21-5, RVS-23-23, KSS-213, TS-208, DS-1510, JS-20-94 and CAUMS-3.

Several researchers have also undertaken similar studies to assess genetic diversity in soybean using morphological and agronomical traits (Sudarić et al., 2006; Gupta et al., 2010; Ramteke & Murlidharan, 2012; Pawale et al., 2019; Singh et al., 2021; Mishra et al., 2022; Sivabharati et al., 2022; Pachori et al., 2023; Thakur et al., 2024). Consistent with the findings of the present investigation, Kachare et al. (2019) evaluated 45 soybean genotypes based on eleven qualitative traits. Their analysis revealed the classification of plant growth habit into four distinct categories: erect, semi-erect, spreading and semi-spreading. Among the genotypes examined, the majority (27 genotypes) exhibited a semi-erect growth habit followed by 14 genotypes classified as erect, three as spreading and one genotype as semi-spreading. Sharma et al. (2023) conducted a controlled environment study involving 60 soybean genotypes to characterize genetic diversity based on 12 qualitative morphological descriptors. The analysis revealed existence of substantial phenotypic variability enabling the classification of genotypes into distinct dendrogram clusters and facilitating the identification of unique traits for future breeding and germplasm conservation efforts. Likewise, Ullah et al. (2024) evaluated 59 soybean genotypes across two consecutive seasons under rainfed conditions using an augmented block design to assess both qualitative and quantitative trait variability. Sharma et al. (2025) also investigated 30 soybean genotypes and classified them according to the Distinctness, Uniformity and Stability (DUS) guidelines. Significant variation was reported in traits such as growth habit, flower colour, seed morphology and disease resistance. The findings underscore the potential of these traits in developing pest-resistant varieties suitable for mechanized farming and varietal differentiation. In a related study, Mishra et al. (2025a) assessed 118 soybean genotypes. The evaluation was made based on 16 morphological traits in accordance with DUS criteria revealed presence of moderate to high phenotypic diversity, particularly in seed-related characteristics. The study identified promising Recombinant Inbred Lines (RILs) possessing traits valuable for the development of high-yielding, stress-tolerant soybean cultivars (Rajpoot et al.).

Table 1. Distribution of soybean genotypes based on qualitative traits as per the PPV& FRA(2009) and Ramteke & Murlidharan (2012)

Characters	Classes	Genotypes
Hypocotyl colour	Present	JS-22-12, JS-25-03, JS-21-07, JS-20-94, RVS-23-10, RVS-23-15, RVS-23-23, RVS-2001-4, RVS-23-12, RSC-10-46, RSC-10-52, AS-26, ASB-85, AMS-264, AMS-100-39, AUKS-21-5, TS-208, DS 1510, CAUMS-3, Cat492A, NRC-142, NRC-255, NRC-166, NRC-152, NRCSL-7, NRCSL-4, KDS-1203, KDS-1201, KSS-213, KBSL-23-36, Pusa Sipani BS 8, MAUS-787, MAUS-791, MACS-824, SL-311, SL-1315, VLS-104
	Absent	JS-26, JS-20-79, JS-20-116, JS-22-01, JS-23-05, JS-24-26, JS-21-17, RVS-23-26, RVS-23-5, RVS-23-20, RVSM-2012-4, ASB-93, AMS-2021-3, Rajsoya-24, DLSB-40, Himso 1695, Cat 87, NRC-201, NRC-138, NRC-192, KDSIS-1394, BAUS(M)-6, PS 1569
Flower colour	Violet	JS-22-12, JS-25-03, JS-21-07, JS-20-94, RVS-23-10, RVS-23-15, RVS-23-23, RVS-2001-4, RVS-23-12, RSC-10-46, RSC-10-52, AS-26, ASB-85, AMS-264, AMS-100-39, AUKS-21-5, TS-208, DS 1510, CAUMS-3, Cat492A, NRC-142, NRC-255, NRC-166, NRC-152, NRCSL-7, NRCSL-4, KDS-1203, KDS-1201, KSS-213, KBSL-23-36, Pusa Sipani BS 8, MAUS-787, MAUS-791, MACS-824, SL-311, SL-1315, VLS-104
	White	JS-26, JS-20-79, JS-20-116, JS-22-01, JS-23-05, JS-24-26, JS-21-17, RVS-23-26, RVS-23-5, RVS-23-20, RVSM-2012-4, ASB-93, AMS-2021-3, Rajsoya-24, DLSB-40, Himso 1695, Cat 87, NRC-201, NRC-138, NRC-192, KDSIS-1394, BAUS(M)-6, PS 1569
Leaf shape	Round Ovate	RVS-23-5, TS-208, NRC-152, NRCSL-7
	Pointed Ovate	JS-26, JS-20-79, JS-20-116, JS-22-01, JS-23-05, JS-24-26, JS-21-17, JS-22-12, JS-25-03, JS-21-07, JS-20-94, RVS-23-10, RVS-23-15, RVS-23-23, RVS-2001-4, RVS-23-12, RVS-23-26, RVS-23-20, RVSM-2012-4, RSC-10-46, RSC-10-52, AS-26, ASB-93, AMS-100-39, AMS-2021-3, AUKS-21-5, DS 1510, CAUMS-3, Cat492A, Cat 87, NRC-142, NRC-255, NRC-201, NRC-138, NRC-192, NRCSL-4, KDS-1203, KDS-1201, KSS-213, KBSL-23-36, Pusa Sipani BS 8, MACS-824, Rajsoya-24, DLSB-40, Himso 1695, KDSIS-1394, BAUS(M)-6, SL-311, SL-1315, VLS-104
	Lanceolate	ASB-85, AMS-264, NRC-166, PS 1569, MAUS-787, MAUS-791,
Leaf colour	Dark green	JS-26, JS-20-79, JS-20-116, JS-22-12, JS-23-05, JS-25-03, JS-20-94, RVS-23-15, RVS-23-23, RVS-23-5, RVS-23-20, RVSM-2012-4, RSC-10-46, RSC-10-52, ASB-85, ASB-93, AMS-264, AMS-100-39, AUKS-21-5, TS-208, NRC-166, NRCSL-4, CAUMS-3, Cat492A, Cat 87, DS 1510, Rajsoya-24, DLSB-40, Himso 1695, KDS-1203, KDS-1201, KDSIS-1394, KSS-213, KBSL-23-36, BAUS(M)-6, Pusa Sipani BS 8, PS 1569, MAUS-787, MAUS-791, MACS-824, SL-311, SL-1315, VLS-104
	Green	JS-22-01, JS-24-26, JS-21-07, JS-21-17, RVS-23-26, RVS-23-10, RVS-23-12, RVS-2001-4, AS-26, NRC-152, NRC-138, NRC-192, NRC-142, NRC-255, NRC-201, AMS-2021-3, RVS-23-23,
Pod pubescence	Pubescent	JS-26, JS-20-79, JS-22-01, JS-23-05, JS-24-26, JS-21-17, JS-20-94, RVS-23-26, RVS-23-20, RVSM-2012-4, ASB-85, ASB-93, AMS-2021-3, AUKS-21-5, TS-208, CAUMS-3, Cat492A, Cat 87, DS 1510, Himso 1695, NRC-142, NRC-201, NRC-138, KSS-213, KBSL-23-36, PS 1569, SL-311, SL-1315
	Glabrous	JS-20-116, JS-22-12, JS-25-03, JS-21-07, RVS-23-10, RVS-23-15, RVS-2001-4, RVS-23-5, RVS-23-12, RSC-10-46, RSC-10-52, AS-26, AMS-264, AMS-100-39, Rajsoya-24, DLSB-40, NRC-166, NRC-255, NRC-152, NRC-192, NRCSL-4, NRCSL-7, KDS-1203, KDS-1201, KDSIS-1394, KSS-213, BAUS(M)-6, Pusa Sipani BS 8, MAUS-787, MAUS-791, MACS-824, VLS-104
Pod pubescence colour	Tawny	JS-26, JS-20-79, JS-22-01, JS-23-05, JS-24-26, JS-21-17, JS-20-94, RVS-23-26, RVS-23-20, RVSM-2012-4, ASB-85, ASB-93, AMS-2021-3, AUKS-21-5, TS-208, CAUMS-3, Cat492A, Cat 87, DS 1510, Himso 1695, NRC-142, NRC-201, NRC-138, KSS-213, KBSL-23-36, PS 1569, SL-311, SL-1315
Plant growth habit	Semi erect	JS-20-116, JS-22-12, JS-22-01, JS-24-26, JS-25-03, JS-21-07, JS-21-17, JS-20-94, RVS-23-26, RVS-23-10, RVS-23-15, RVS-23-23, RVS-23-5, RVS-23-12, RVS-23-20, RVSM-2012-4, RVS-2001-4, RSC-10-46, RSC-10-52, ASB-85, ASB-93, AMS-2021-3, AMS-264,

Characters	Classes	Genotypes
		AMS-100-39, TS-208, Rajsoya-24, DLSB-40, DS 1510, CAUMS-3, NRC-142, NRC-201, NRC-152, NRC-138, NRC-192, NRCSL-7, NRCSL-4, KDS-1203, KDS-1201, KDSIS-1394, KSS-213, KBSL-23-36, BAUS(M)-6, Pusa Sipani BS 8, MAUS-787, MAUS-791, MACS-824, SL-311, VLS-104
	Erect	JS-26, JS-20-79, JS-23-05, AS-26, AUKS-21-5, Himso 1695, Cat492A, Cat 87, NRC-166, NRC-255, PS 1569, SL-1315
Seed shape	Spherical	VLS-104, MAUS-787, NRC-138, ASB-85
	Elliptical	JS-26, JS-20-79, JS-23-05, JS-20-116, JS-22-12, JS-22-01, JS-24-26, JS-25-03, JS-21-07, JS-21-17, JS-20-94, RVS-23-26, RVS-23-10, RVS-23-15, RVS-23-23, RVS-23-5, RVS-23-12, RVS-23-20, RVSM-2012-4, RVS-2001-4, RSC-10-46, RSC-10-52, ASB-93, AMS-2021-3, AMS-264, AMS-100-39, TS-208, Rajsoya-24, DLSB-40, DS 1510, CAUMS-3, NRC-142, NRC-201, NRC-152, NRC-192, NRC-166, NRC-255, NRCSL-7, NRCSL-4, KDS-1203, KDS-1201, KDSIS-1394, KSS-213, KBSL-23-36, BAUS(M)-6, Pusa Sipani BS 8, MAUS-791, MACS-824, AS-26, AUKS-21-5, Himso 1695, Cat492A, Cat 87, PS 1569, SL-311, SL-1315
Seed coat colour	Yellow	JS-26, JS-20-79, JS-23-05, JS-20-116, JS-22-12, JS-22-01, JS-24-26, JS-25-03, JS-21-07, JS-21-17, JS-20-94, RVS-23-26, RVS-23-10, RVS-23-15, RVS-23-23, RVS-23-5, RVS-23-12, RVS-23-20, RVSM-2012-4, RSC-10-46, RSC-10-52, ASB-93, AMS-264, AMS-100-39, TS-208, Rajsoya-24, DLSB-40, CAUMS-3, NRC-142, NRC-201, NRC-152, NRC-192, NRC-255, NRCSL-7, NRCSL-4, KDS-1203, KDS-1201, KDSIS-1394, KSS-213, KBSL-23-36, BAUS(M)-6, Pusa Sipani BS 8, MAUS-787, NRC-138, ASB-85, MAUS-791, MACS-824, AS-26, AUKS-21-5, Himso 1695, Cat 87, PS 1569, SL-311, VLS-104
	Yellow Green	RVS-2001-4, AMS-2021-3, DS 1510, Cat492A, NRC-166, SL-1315
Seed luster	Shiny	JS-20-116, JS-22-12, JS-22-01, JS-25-03, JS-21-07, RVS-23-26, RVS-23-15, RVS-23-23, RVS-2001-4, RSC-10-46, RSC-10-52, ASB-93, AMS-264, AMS-100-39, NRC-142, NRC-152, NRC-192, NRC-166, NRC-255, NRCSL-7, NRCSL-4, KDS-1203, KDS-1201, KDSIS-1394, KSS-213, KBSL-23-36, BAUS(M)-6, Pusa Sipani BS 8, MAUS-791, AS-26, AUKS-21-5, ASB-85, Cat492A, Cat 87, PS 1569, SL-311, SL-1315, VLS-104
	Dull	JS-26, JS-20-79, JS-24-26, JS-23-05, JS-21-17, JS-20-94, RVS-23-10, RVS-23-5, RVS-23-12, RVS-23-20, RVSM-2012-4, AMS-2021-3, TS-208, Rajsoya-24, DLSB-40, DS 1510, Himso 1695, CAUMS-3, NRC-201, NRC-138, MAUS-787, MACS-824
Seed hilum colour	Brown	JS-26, JS-20-79, JS-22-01, JS-23-05, JS-21-17, RVS-23-5, RVS-23-12, RVS-23-20, ASB-85, ASB-93, Himso 1695, Cat492A, NRC-166, NRC-138, KDS-1201, KBSL-23-36, SL-311
	Grey	RSC-10-52, AMS-264, AMS-100-39, TS-208, NRC-255, NRC-152, KDS-1203, KDSIS-1394, MACS-824
	Yellow	JS-24-26, AS-26, NRCSL-7, BAUS(M)-6, VLS-104
	Black	JS-20-116, JS-22-12, JS-25-03, JS-21-07, JS-20-94, RVS-23-26, RVSM-2012-4, RVS-23-10, RVS-23-15, RVS-23-23, RVS-2001-4, RSC-10-46, AMS-2021-3, AUKS-21-5, Rajsoya-24, DLSB-40, Cat 87, NRC-142, NRCSL-4, NRC-201, NRC-192, PS 1569, DS 1510, CAUMS-3, KSS-213, Pusa Sipani BS 8, MAUS-787, MAUS-791, SL-1315

Table. 2 Morphological characterizations of soybean genotypes for different qualitative characters as per the PPV&FRA (2009) and Ramteke & Murlidharan (2012)

S. No.	Genotype	Hypocotyl colour	Flower colour	Leaf shape	Leaf colour	Pod pubescence	Pod pubescence colour	Plant growth habit	Seed shape	Seed colour	Seed luster	Seed hilum colour
1	JS-26	Absent	White	PO	DG	Present	Tawny	Erect	Elliptical	Yellow	Dull	Brown
2	JS-20-79	Absent	White	PO	DG	Present	Tawny	Erect	Elliptical	Yellow	Dull	Brown
3	JS-20-116	Absent	White	PO	DG	Absent	Absent	Semi-erect	Elliptical	Yellow	Shiny	Black
4	JS-22-01	Absent	White	PO	G	Present	Tawny	Semi-erect	Elliptical	Yellow	Shiny	Brown
5	JS-22-12	Present	Purple	PO	DG	Absent	Absent	Semi-erect	Elliptical	Yellow	Shiny	Black
6	JS-23-05	Absent	White	PO	DG	Present	Tawny	Erect	Elliptical	Yellow	Dull	Brown
7	JS-24-26	Absent	White	PO	G	Present	Tawny	Semi-erect	Elliptical	Yellow	Dull	Yellow
8	JS-25-03	Present	Purple	PO	DG	Absent	Absent	Semi-erect	Elliptical	Yellow	Shiny	Black
9	JS-21-07	Present	Purple	PO	G	Absent	Absent	Semi-erect	Elliptical	Yellow	Shiny	Black
10	JS-21-17	Absent	White	PO	G	Present	Tawny	Semi-erect	Elliptical	Yellow	Dull	Brown
11	JS-20-94	Present	Purple	PO	DG	Present	Tawny	Semi-erect	Elliptical	Yellow	Dull	Black
12	RVS-23-26	Absent	White	PO	G	Present	Tawny	Semi-erect	Elliptical	Yellow	Shiny	Black
13	RVS-23-10	Present	Purple	PO	G	Absent	Absent	Semi-erect	Elliptical	Yellow	Dull	Black
14	RVS-23-15	Present	Purple	PO	DG	Absent	Absent	Semi-erect	Elliptical	Yellow	Shiny	Black
15	RVS-23-23	Present	Purple	PO	DG	Present	Tawny	Semi-erect	Elliptical	Yellow	Shiny	Black
16	RVS-2001-4	Present	Purple	PO	G	Absent	Absent	Semi-erect	Elliptical	Yellow Green	Shiny	Black
17	RVS-23-5	Absent	White	RO	DG	Absent	Absent	Semi-erect	Elliptical	Yellow	Dull	Brown
18	RVS-23-12	Present	Purple	PO	G	Absent	Absent	Semi-erect	Elliptical	Yellow	Dull	Brown
19	RVS-23-20	Absent	White	PO	DG	Present	Tawny	Semi-erect	Elliptical	Yellow	Dull	Brown
20	RVSM-2012-4	Absent	White	PO	DG	Present	Tawny	Semi-erect	Elliptical	Yellow	Dull	Black
21	RSC-10-46	Present	Purple	PO	DG	Absent	Absent	Semi-erect	Elliptical	Yellow	Shiny	Black
22	RSC-10-52	Present	Purple	PO	DG	Absent	Absent	Semi-erect	Elliptical	Yellow	Shiny	Gray
23	AS-26	Present	Purple	PO	G	Absent	Absent	Erect	Elliptical	Yellow	Shiny	Yellow
24	ASB-85	Present	Purple	L	DG	Present	Tawny	Semi-erect	Spherical	Yellow	Shiny	Brown
25	ASB-93	Absent	White	PO	DG	Present	Tawny	Semi-erect	Elliptical	Yellow	Shiny	Brown
26	AMS-264	Present	Purple	L	DG	Absent	Absent	Semi-erect	Elliptical	Yellow	Shiny	Gray
27	AMS-2021-3	Absent	White	PO	G	Present	Tawny	Semi-erect	Elliptical	Yellow Green	Dull	Black
28	AMS-100-39	Present	Purple	PO	DG	Absent	Absent	Semi-erect	Elliptical	Yellow	Shiny	Gray
29	AUKS-21-5	Present	Purple	PO	DG	Present	Tawny	Erect	Elliptical	Yellow	Shiny	Black
30	TS-208	Present	Purple	RO	DG	Present	Tawny	Semi-erect	Elliptical	Yellow	Dull	Gray
31	Rajsoya-24	Absent	White	PO	DG	Absent	Absent	Semi-erect	Elliptical	Yellow	Dull	Black

S. No.	Genotype	Hypocotyl colour	Flower colour	Leaf shape	Leaf colour	Pod pubescence	Pod pubescence colour	Plant growth habit	Seed shape	Seed colour	Seed luster	Seed hilum colour
32	DLSB-40	Absent	White	PO	DG	Absent	Absent	Semi-erect	Elliptical	Yellow	Dull	Black
33	DS 1510	Present	Purple	PO	DG	Present	Tawny	Semi-erect	Elliptical	Yellow Green	Dull	Black
34	Himso 1695	Absent	White	PO	DG	Present	Tawny	Erect	Elliptical	Yellow	Dull	Brown
35	CAUMS-3	Present	Purple	PO	DG	Present	Tawny	Semi-erect	Elliptical	Yellow	Dull	Black
36	Cat 492-A	Present	Purple	PO	DG	Present	Tawny	Erect	Elliptical	Yellow Green	Shiny	Brown
37	Cat-87	Absent	White	PO	DG	Present	Tawny	Erect	Elliptical	Yellow	Shiny	Black
38	NRC-142	Present	Purple	PO	G	Present	Tawny	Semi-erect	Elliptical	Yellow	Shiny	Black
39	NRC-201	Absent	White	PO	G	Present	Tawny	Semi-erect	Elliptical	Yellow	Dull	Black
40	NRC-255	Present	Purple	PO	G	Absent	Absent	Erect	Elliptical	Yellow	Shiny	Gray
41	NRC-166	Present	Purple	L	DG	Absent	Absent	Erect	Elliptical	Yellow Green	Shiny	Brown
42	NRC-152	Present	Purple	RO	G	Absent	Absent	Semi-erect	Elliptical	Yellow	Shiny	Gray
43	NRC-138	Absent	White	PO	G	Present	Tawny	Semi-erect	Spherical	Yellow	Dull	Brown
44	NRC-192	Absent	White	PO	G	Absent	Absent	Semi-erect	Elliptical	Yellow	Shiny	Black
45	NRCSL-7	Present	Purple	RO	DG	Absent	Absent	Semi-erect	Elliptical	Yellow	Shiny	Yellow
46	NRCSL-4	Present	Purple	PO	DG	Absent	Absent	Semi-erect	Elliptical	Yellow	Shiny	Black
47	KDS-1203	Present	Purple	PO	DG	Absent	Absent	Semi-erect	Elliptical	Yellow	Shiny	Gray
48	KDS-1201	Present	Purple	PO	DG	Absent	Absent	Semi-erect	Elliptical	Yellow	Shiny	Brown
49	KDSIS-1394	Absent	White	PO	DG	Absent	Absent	Semi-erect	Elliptical	Yellow	Shiny	Gray
50	KSS-213	Present	Purple	PO	DG	Present	Tawny	Semi-erect	Elliptical	Yellow	Shiny	Black
51	KBSL-23-36	Present	Purple	PO	DG	Present	Tawny	Semi-erect	Elliptical	Yellow	Shiny	Brown
52	BAUS(M)-6	Absent	White	PO	DG	Absent	Absent	Semi-erect	Elliptical	Yellow	Shiny	Yellow
53	Pusa Sipani BS 8	Present	Purple	PO	DG	Absent	Absent	Semi-erect	Elliptical	Yellow	Shiny	Black
54	PS-1569	Absent	White	L	DG	Present	Tawny	Erect	Elliptical	Yellow	Shiny	Black
55	MAUS-787	Present	Purple	L	DG	Absent	Absent	Semi-erect	Spherical	Yellow	Dull	Black
56	MAUS-791	Present	Purple	L	DG	Absent	Absent	Semi-erect	Elliptical	Yellow	Shiny	Black
57	MACS-824	Present	Purple	PO	DG	Absent	Absent	Semi-erect	Elliptical	Yellow	Dull	Gray
58	SL-311	Present	Purple	PO	DG	Present	Tawny	Semi-erect	Elliptical	Yellow	Shiny	Brown
59	SL-1315	Present	Purple	PO	DG	Present	Tawny	Erect	Elliptical	Yellow Green	Shiny	Black
60	VLS-104	Present	Purple	PO	DG	Absent	Absent	Semi-erect	Spherical	Yellow	Shiny	Yellow

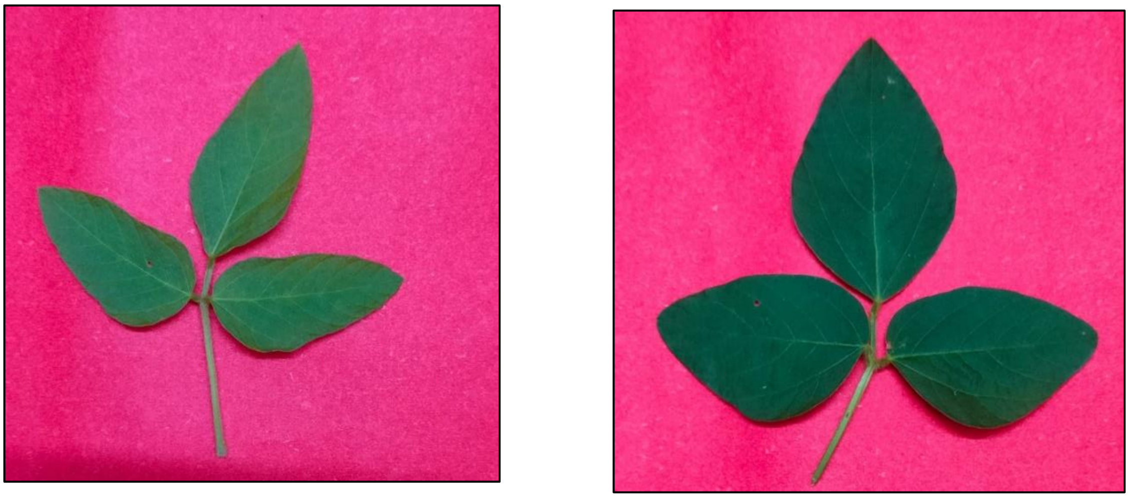
Table 3. Frequency distribution of phenological, morphological and seed traits of soybean genotypes

Description	Category	Number of genotypes	Frequency (%)
Hypocotyl color	Absent	37	61.67
	Present	23	38.33
Leaf shape	Pointed ovate	50	83.33
	Round ovate	4	6.67
	Lanceolate	6	10.00
Leaf colour	Green	17	28.33
	Dark green	43	71.67
Plant growth habit	Erect	12	20.00
	Semi erect	48	80.00
Flower colour	White	37	61.67
	Violet	23	38.33
Pod pubescence	Absent	32	53.33
	Present	28	46.67
Seed shape	Elliptical	4	6.67
	Spherical	56	93.33
Seed colour	Yellow	54	90.00
	Yellow green	6	10.00
	Green	0	0
	Black	0	0
Seed lusture	Shiny	38	63.33
	Dull	22	36.67
Seed hilum color	Black	29	48.33
	Brown	17	28.33
	Gray	9	15.00
	Yellow	5	8.33

A. White

B. Purple

A. Flower Colour



A. Green **B. Dark Green**

B. Leaf Colour Intensity

A. Glabrous **B. Pubescent (Tawny)**

C. Pod pubescence

A. Pointed ovate **B. Round ovate** **C. Lanceolate**

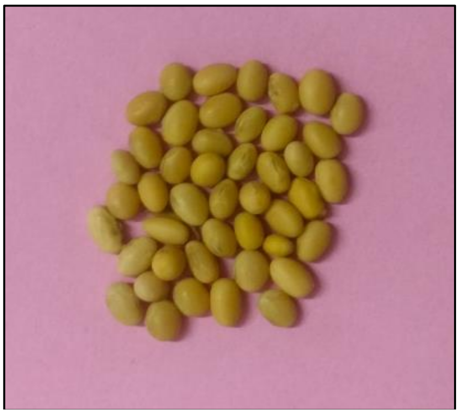
D. Leaf Shape

A. Elliptical **B. Spherical**

E. Seed shape

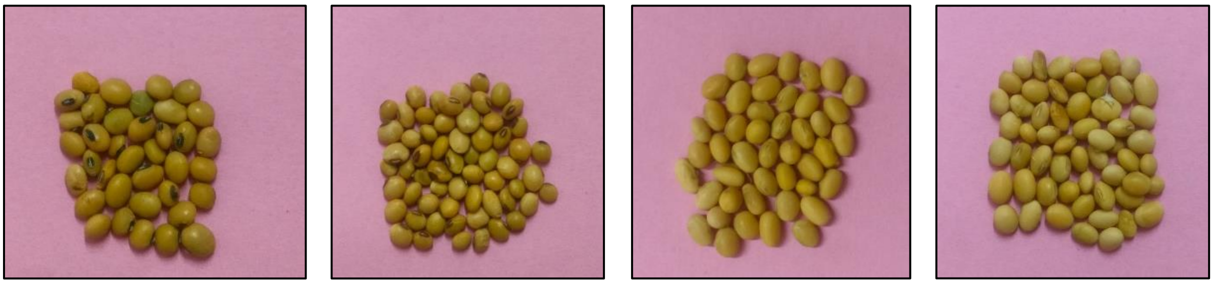
A. Yellow **B. Yellow Green**

F. Seed colour



A. Dull **B. Shiny**

G. Seed lustre



A. Black **B. Brown** **C. Yellow** **D. Grey**

H. Seed Hilum colour

Fig. 1. Distinct morphological features of soybean genotypes

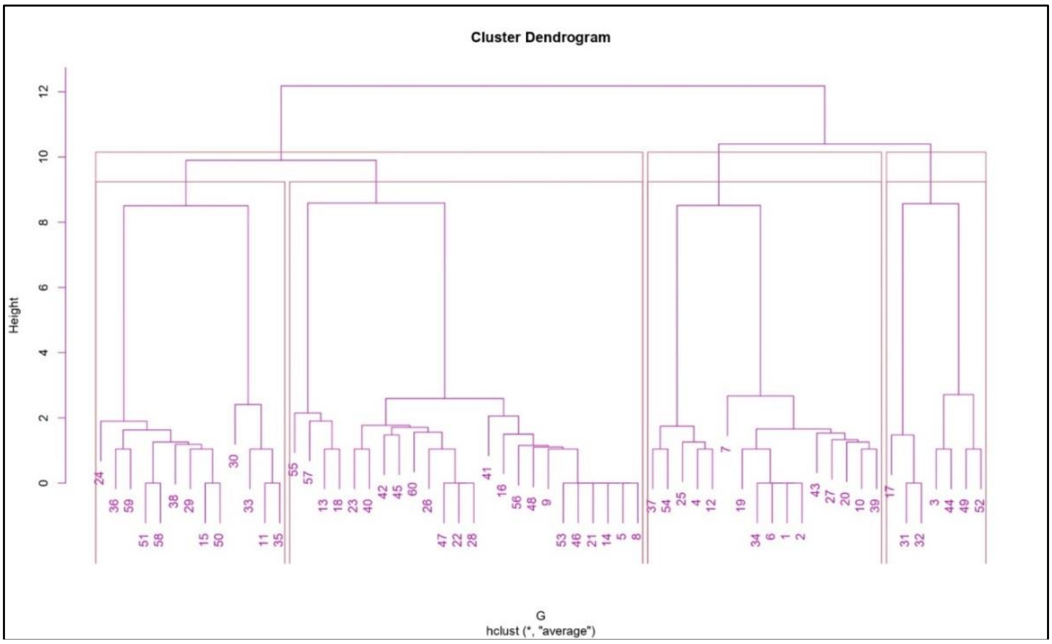


Fig. 2. Dendrogram showing relationship among soybean genotypes based upon different qualitative traits

(Note: The number denoted in Fig. 2 denotes the name of genotypes, which can be referred from Table 2.)

4. CONCLUSION

The present investigation revealed existence of considerable morphological variability among sixty soybean genotypes, indicating a broad genetic base and significant potential for selection and genetic improvement. Distinct differences were observed across eleven qualitative traits, including hypocotyl and flower colour, leaf shape and shade, pod pubescence, seed morphology, and growth habit. Such diversity is crucial for identifying unique genotype (s) that possess desirable agronomical and morphological traits. The variation recorded in hypocotyl pigmentation, flower and seed coat characteristics and plant architecture provides valuable phenotypic markers that can aid in genotype differentiation and parent selection for future breeding programmes. These findings contribute to the initial phase of genotype screening and germplasm categorization, which is essential for effective crop improvement strategies. Given the increasing need for climate-resilient and high-yielding soybean varieties, the diverse genotypes identified in this investigation offer promising material for further evaluation. To fully exploit this morphological variability, it is recommended that selected genotype (s) be subjected to molecular characterization, trait-specific screening and multi-location trials to determine their genetic stability and adaptability across environments. The integration of morphological and molecular data may enhance breeding precision and support the development of superior soybean cultivars to be tailored for diverse agro-ecological circumstances.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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