**Phenotypic Diversity and Trait Analysis of Soybean Recombinant Inbred Lines**

**Abstract**

Soybeans (*Glycine max* (L.) Merrill), generally recognized as the “Golden bean,” is a vivacious oilseed and food legume crop appreciated for its high-quality protein, oil content and health-encouraging compounds. To enable soybean enhancement, in the current investigation, genetic diversity was evaluated among 118 soybean genotypes, including 115 recombinant inbred lines (RILs) along with three cultivars *viz*., JS 97-52, NRC-37, JS-335 in *Kharif,* 2022 at All India Coordinated Research project (AICRP) Soybean Seed Breeding Farm, Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur, Madhya Pradesh (M. P.), India. The experiment was laid out in an Augmented Block Design (ABD) and phenotypic characterization was performed based on 16 different morphological characters as per Protection of Plant Varieties and Farmers’ Rights Authority (PPVFRA), Distinctness, Uniformity and Stability (DUS) testing guidelines. Substantial variability was experimented across traits for instance growth habit, leaf size, seed shape, seed coat luster and hilum colour. Traits like hypocotyl colour, flower colour and pod pubescence displayed low diversity, signifying strong selection pressure, whereas seed-related traits exposed comparatively higher diversity, offering aptitude for genetic enhancement. The Shannon-Weaver diversity index inveterate presence of moderate to high variability in crucial agronomic and seed characteristics, emphasizing their significance in breeding programmes. The investigation highpoints the incidence of extensive morphological diversity among the evaluated RILs, providing valuable evidence for the selection of superior genotype (s), lengthening the genetic base and developing high-yielding, stress-resilient soybean cultivar (s). Insights gained from this study will guide strategic breeding intervention to enhance soybean productivity and environmental adaptability.

**Keywords:** Genetic diversity, Germplasm evaluation, Morphological characterization, Recombinant Inbred Lines (RILs), Soybean (*Glycine max*)

1. **Introduction**

One of the most important oilseed crops in the world, soybeans (*Glycine max* (L.) Merill) are also highly valued as food legumes [1, 2, 3]. These are commonly known as “Golden bean” [4, 5]. Its seeds are highly treasured for their irritating composition, including high quality protein, vegetable oil, isoflavones and indispensable minerals [6, 7]. It is utilized in an extensive range of food cholesterol content [8, 9]. As a complete plant-based protein source, soybean is recognised as a health promoting food [10, 11]. On a moisture-free basis, its seeds have 18-23% oil and 38-44% protein, with the protein being deemed complete because of its well-balanced amino acid composition. Products like tofu, soya milk and soya sauce frequently include them [12, 13, 14]. Moreover, it aids as a cost-effective meat alternative in vegan diets and displays potential as a support for lab grown meat production. Furthermore, bio-degradable materials derived from soybean protein are being explored as sustainable alternatives for traditional plastics [5].

Initially developed for mouse genetics, Recombinant Inbred Lines (RILs) are now extensively employed in plant genetics owing to the ease of self-fertilization. RILs stably capture genetic variation, making them valuable for genetic investigations. As inbred lines, they permit for repeated measurements and long-term data collection across investigations [15]. In plant breeding, inbred lines are created from a heterozygous population or F2 progeny through recurrent self-pollination. To achieve the homozygosity typically requires 6-10 generations, captivating about 3-5 years with two growing seasons annually. These inbred lines are then utilized to produce hybrid lines for exploiting heterosis [16].

The key goal of plant breeding is to improve desired plant features in order to create new genotypes from available genetic resources [17]. Collection of germplasm, which are important genetic resources, are necessary for the proper assembly of plant genes [18]. It is critical to examine plant morphological features to characterize the germplasm before assembly. A crop species genetic diversity can be evaluated with the help of such morphological characterization [19-23] which still remains the essential tactic for evaluating genetic diversity facilitating a cost-effective and practical means to evaluate phenotypic traits [24, 25]. To analyse variability among soybean genotypes using different morphological characters offers crucial insights for effective selection and breeding programmes [26]. The assessment of such variability is crucial for the detection of superior genotypes, broadening the genetic base and ensuring the development of high yielding, stress resilient cultivars [27]. To simplify future breeding programmes, morphological analysis was conducted in present investigation to assess and recognize putative genetic diversity exist among soybean RILs.

**2. Materials and Method**

**2.1 Characteristics of experimental site**

The field experiment was conducted at Jabalpur, which is classified as agroclimatic subregion 10.1 (subhumid dry eco-region) by the National Bureau of Soil Science and Land Use Planning (ICAR), experiences a subtropical, semi-arid climate characterized by hot, dry summers and cool, rainy winters. Jabalpur is geographically situated at a latitude of 23.90°N and a longitude of 79.58°E, with an elevation of approximately 411.87 meters above mean sea level. The region consists of a narrow plain enclosed by highlands, with fertile alluvial black cotton soil in the western and southern parts. The region receives significant rainfall, with peak precipitation typically occurring between mid-August and late August. In *kharif* 2022, temperature fluctuations arrayed between **29.4°C and 31.9°C**, while relative humidity varied widely, reaching a maximum of **93%** during the monsoon period and dropping to **40%** in drier weeks. The area records multiple rainy days, influencing soil moisture availability and sunshine duration varies seasonally, with the highest recorded in mid to late October, 2022. These climatic conditions make Jabalpur as an important region for agricultural activities, particularly in the **Rice-Wheat cropping zone**, while also creating a favourable environment for the incidence of different crop diseases.

**2.2 Experimental details**

The present study was conducted during the ***Kharif* 2022** season at the **AICRP Soybean Seed Breeding Farm**, Department of **Genetics and Plant Breeding**, College of Agriculture, **JNKVV, Jabalpur, Madhya Pradesh, India (Fig. 1).** The experimental material comprised **118 soybean genotypes,** including **115 Recombinant Inbred Lines (RILs)** and three varieties *viz*., **JS 97-52, NRC-37 and JS-335**, obtained from **ICAR-National Soybean Research Institute (NSRI), Indore**. The experiment was laid out in an **Augmented Block Design (ABD)** as proposed by Federer (1956), which is extensively employed in plant breeding trials to evaluate a large number of genotypes under resource constraints. This design allowed for unreplicated test entries while incorporating replicated checks to estimate experimental variance, adjust environmental variation, and ensure reliable comparisons. The plot size was **0.40 × 3 sq.m**, with a **row spacing of 40 cm** and **plant spacing of 7 cm**. Phenotypic characterization of genotypes was carried out based on 16 morphological traits, including hypocotyl colour, growth type, growth habit, leaf shape, leaf size (lateral leaflet), leaf intensity of green colour, flower colour, pod pubescence, pod pubescence colour, pod colour, pod intensity of brown colour, seed shape, ground colour of testa, seed coat luster, hilum colour, and hilum funicle colour. Observations were recorded from five randomly selected plants following the guidelines prescribed by the Protection of Plant Varieties and Farmers’ Rights Authority (PPVFRA) and the Distinctiveness, Uniformity and Stability (DUS) testing standards for soybean. The qualitative characterization of traits was conducted employing descriptors provided by the International Union for the Protection of New Varieties of Plants (UPOV, 1998) [28]. Genetic relationships and variations among the genotypes were analysed based on qualitative data. To elucidate the clustering patterns among the genotypes, a dendrogram was generated employing the Unweighted Pair Group Method with Arithmetic Mean (UPGMA) algorithm. The analysis was carried out using NTSYSpc software to validate genotype groupings and assess the extent of genetic diversity [29]. These phenotypic assessments provided valuable insights into the genetic variability among the genotypes, supporting the identification of promising lines for breeding programmes of soybean improvement.



**Fig.1 Experimental location**

**3. Results and Discussion**

The morphological characterization of 118 soybean genotypes revealed substantial variation across 16 morphological characters (Table 1). Hypocotyl colour was predominantly absent in most of the genotypes, except for JS-335, which displayed anthocyanin pigmentation. Growth type analysis designated that all genotypes tracked a semi-determinate growth pattern, while growth habit was categorized as erect in 25 genotypes and semi-erect in 93 genotypes. Leaf shape assessment displayed those 115 genotypes had a pointed ovate shape, whereas JS-335, RIL 107-131 and NRC-37 exhibited a rounded ovate shape [(Fig. 2(a))]. Leaf size classification indicated that 10 genotypes had small leaves, 103 medium leaves, and 5 with large leaves including RIL115-265, RIL107-31, RIL107-35, RIL107-68, and NRC-37. Regarding leaf intensity of green colour, 110 genotypes displayed a green hue, while 8 genotypes *viz*., RIL 115-1, RIL115-239, RIL115-253, RIL115-265, RIL107-24, RIL107-31, RIL107-161 and JS-335 exhibited dark green foliage. Flower colour was predominantly white, except JS-335, which had violet flowers [(Fig. 2(b))]. Pod pubescence was present in 117 genotypes, while JS-335 was the only glabrous genotype [(Fig. 2 (c))]. Likewise, 117 genotypes displayed tawny pubescence colour, with no cases of grey pubescence. Pod colour visualization exposed that all genotypes had a brown pod colour, with medium intensity. Seed shape was spherical in 83 genotypes and elliptical in 35 genotypes. Seed coat colour was uniformly yellow across all genotypes, while seed coat luster varied, 61 genotypes having a shiny coat while 57 demonstrating a dull coat. Hilum colour was evident brown in 47 genotypes whereas black in 71 genotypes. Similarly, 47 genotypes had a hilum funicle colour matching the testa, while 71 genotypes displayed a different hilum funicle colour.

Table 1 Categorization of RILs on the basis of morphological traits

| **Character** | **Status** | **Genotype** | **Frequency** |
| --- | --- | --- | --- |
| 1. Hypocotyl colour: Anthocyanin pigmentation | Absent | RIL 115-1,RIL 115-4, RIL 115-36, RIL 115-41, RIL 115-42, RIL 115-43, RIL 115-45, RIL 115-51, RIL 115-57, RIL 115-62, RIL 115-64, RIL 115-65, RIL 115-66, RIL 115-67, RIL 115-69, RIL 115-71, RIL 115-74, RIL 115-76, RIL 115-89, RIL 115-91, RIL 115-92, RIL 115-93, RIL 115-96, RIL 115-99, RIL 115-108, RIL 115-118, RIL 115-132, RIL 115-140, RIL 115-141, RIL 115-144, RIL 115-150, RIL 115-153, RIL 115-154, RIL 115-155, RIL 115-156, RIL 115-159, RIL 115-160, RIL 115-161, RIL 115-162, RIL 115-163, RIL 115-164, RIL 115-166, RIL 115-167, RIL 115-169, RIL 115-171, RIL 115-173, RIL 115-175, RIL 115-176, RIL 115-177, RIL 115-178, RIL 115-179, RIL 115-181, RIL 115-182, RIL 115-183, RIL 115-184, RIL 115-188, RIL 115-193, RIL 115-194, RIL 115-199, RIL 115-206, RIL 115-211, RIL 115-221, RIL 115-222, RIL 115-223, RIL 115-225, RIL 115-227, RIL 115-230, RIL 115-233, RIL 115-237, RIL 115-238, RIL 115-239, RIL 115-243, RIL 115-252, RIL 115-253, RIL 115-256, RIL 115-258, RIL 115-260, RIL 115-265, RIL 115-267, RIL 115-268, RIL 115-269, RIL 115-272, RIL 115-273, RIL 115-274, RIL 115-277, RIL 107-38, RIL 107-63, RIL 107-77, RIL 107-99, RIL 107-166, RIL 107-24, RIL 107-31, RIL 107-35, RIL 107-43, RIL 107-44, RIL 107-46, RIL 107-57, RIL 107-68, RIL 107-71, RIL 107-72, RIL 107-73, RIL 107-74, RIL 107-75, RIL 107-79, RIL 107-80, RIL 107-87, RIL 107-88, RIL 107-96, RIL 107-103, RIL 107-128, RIL 107-131, RIL 107-137, RIL 107-139, RIL 107-151, RIL 107-161, JS 97-52, NRC-37 | 117 |
| Present | JS-335 | 1 |
| 1. Plant: Growth type | Determinate | Nil | 0 |
| Semi-determinate | RIL 115-1,RIL 115-4, RIL 115-36, RIL 115-41, RIL 115-42, RIL 115-43, RIL 115-45, RIL 115-51, RIL 115-57, RIL 115-62, RIL 115-64, RIL 115-65, RIL 115-66, RIL 115-67, RIL 115-69, RIL 115-71, RIL 115-74, RIL 115-76, RIL 115-89, RIL 115-91, RIL 115-92, RIL 115-93, RIL 115-96, RIL 115-99, RIL 115-108, RIL 115-118, RIL 115-132, RIL 115-140, RIL 115-141, RIL 115-144, RIL 115-150, RIL 115-153, RIL 115-154, RIL 115-155, RIL 115-156, RIL 115-159, RIL 115-160, RIL 115-161, RIL 115-162, RIL 115-163, RIL 115-164, RIL 115-166, RIL 115-167, RIL 115-169, RIL 115-171, RIL 115-173, RIL 115-175, RIL 115-176, RIL 115-177, RIL 115-178, RIL 115-179, RIL 115-181, RIL 115-182, RIL 115-183, RIL 115-184, RIL 115-188, RIL 115-193, RIL 115-194, RIL 115-199, RIL 115-206, RIL 115-211, RIL 115-221, RIL 115-222, RIL 115-223, RIL 115-225, RIL 115-227, RIL 115-230, RIL 115-233, RIL 115-237, RIL 115-238, RIL 115-239, RIL 115-243, RIL 115-252, RIL 115-253, RIL 115-256, RIL 115-258, RIL 115-260, RIL 115-265, RIL 115-267, RIL 115-268, RIL 115-269, RIL 115-272, RIL 115-273, RIL 115-274, RIL 115-277, RIL 107-38, RIL 107-63, RIL 107-77, RIL 107-99, RIL 107-166, RIL 107-24, RIL 107-31, RIL 107-35, RIL 107-43, RIL 107-44, RIL 107-46, RIL 107-57, RIL 107-68, RIL 107-71, RIL 107-72, RIL 107-73, RIL 107-74, RIL 107-75, RIL 107-79, RIL 107-80, RIL 107-87, RIL 107-88, RIL 107-96, RIL 107-103, RIL 107-128, RIL 107-131, RIL 107-137, RIL 107-139, RIL 107-151, RIL 107-161, JS 97-52, NRC-37, JS-335 | 118 |
| 1. Plant: growth habit | Erect | RIL 115-71, RIL 115-188, RIL 115-199, RIL 115-211, RIL 115-221, RIL 115-222, RIL 115-223, RIL 115-225, RIL 115-227, RIL 115-230, RIL 115-233, RIL 115-237, RIL 115-238, RIL 115-239, RIL 115-252, RIL 115-258, RIL 107-63, RIL 107-77, RIL 107-166, RIL 107-24, RIL 107-35, RIL 107-44, RIL 107-68, RIL 107-71, JS-335 | 25 |
| Semi-erect | RIL 115-1,RIL 115-4, RIL 115-36, RIL 115-41, RIL 115-42, RIL 115-43, RIL 115-45, RIL 115-51, RIL 115-57, RIL 115-62, RIL 115-64, RIL 115-65, RIL 115-66, RIL 115-67, RIL 115-69, RIL 115-74, RIL 115-76, RIL 115-89, RIL 115-91, RIL 115-92, RIL 115-93, RIL 115-96, RIL 115-99, RIL 115-108, RIL 115-118, RIL 115-132, RIL 115-140, RIL 115-141, RIL 115-144, RIL 115-150, RIL 115-153, RIL 115-154, RIL 115-155, RIL 115-156, RIL 115-159, RIL 115-160, RIL 115-161, RIL 115-162, RIL 115-163, RIL 115-164, RIL 115-166, RIL 115-167, RIL 115-169, RIL 115-171, RIL 115-173, RIL 115-175, RIL 115-176, RIL 115-177, RIL 115-178, RIL 115-179, RIL 115-181, RIL 115-182, RIL 115-183, RIL 115-184, RIL 115-193, RIL 115-194, RIL 115-206, RIL 115-243, RIL 115-253, RIL 115-256, RIL 115-260, RIL 115-265, RIL 115-267, RIL 115-268, RIL 115-269, RIL 115-272, RIL 115-273, RIL 115-274, RIL 115-277, RIL 107-38, RIL 107-99, RIL 107-166, RIL 107-24, RIL 107-31, RIL 107-43, RIL 107-46, RIL 107-57, RIL 107-72, RIL 107-73, RIL 107-74, RIL 107-75, RIL 107-79, RIL 107-80, RIL 107-87, RIL 107-88, RIL 107-96, RIL 107-103, RIL 107-128, RIL 107-131, RIL 107-137, RIL 107-139, RIL 107-151, RIL 107-161, JS 97-52, NRC-37 | 93 |
| 1. Flower colour | White | RIL 115-1,RIL 115-4, RIL 115-36, RIL 115-41, RIL 115-42, RIL 115-43, RIL 115-45, RIL 115-51, RIL 115-57, RIL 115-62, RIL 115-64, RIL 115-65, RIL 115-66, RIL 115-67, RIL 115-69, RIL 115-71, RIL 115-74, RIL 115-76, RIL 115-89, RIL 115-91, RIL 115-92, RIL 115-93, RIL 115-96, RIL 115-99, RIL 115-108, RIL 115-118, RIL 115-132, RIL 115-140, RIL 115-141, RIL 115-144, RIL 115-150, RIL 115-153, RIL 115-154, RIL 115-155, RIL 115-156, RIL 115-159, RIL 115-160, RIL 115-161, RIL 115-162, RIL 115-163, RIL 115-164, RIL 115-166, RIL 115-167, RIL 115-169, RIL 115-171, RIL 115-173, RIL 115-175, RIL 115-176, RIL 115-177, RIL 115-178, RIL 115-179, RIL 115-181, RIL 115-182, RIL 115-183, RIL 115-184, RIL 115-188, RIL 115-193, RIL 115-194, RIL 115-199, RIL 115-206, RIL 115-211, RIL 115-221, RIL 115-222, RIL 115-223, RIL 115-225, RIL 115-227, RIL 115-230, RIL 115-233, RIL 115-237, RIL 115-238, RIL 115-239, RIL 115-243, RIL 115-252, RIL 115-253, RIL 115-256, RIL 115-258, RIL 115-260, RIL 115-265, RIL 115-267, RIL 115-268, RIL 115-269, RIL 115-272, RIL 115-273, RIL 115-274, RIL 115-277, RIL 107-38, RIL 107-63, RIL 107-77, RIL 107-99, RIL 107-166, RIL 107-24, RIL 107-31, RIL 107-35, RIL 107-43, RIL 107-44, RIL 107-46, RIL 107-57, RIL 107-68, RIL 107-71, RIL 107-72, RIL 107-73, RIL 107-74, RIL 107-75, RIL 107-79, RIL 107-80, RIL 107-87, RIL 107-88, RIL 107-96, RIL 107-103, RIL 107-128, RIL 107-131, RIL 107-137, RIL 107-139, RIL 107-151, RIL 107-161, JS 97-52, NRC-37 | 117 |
| Violet | JS-335 | 1 |
| 1. Leaf shape | Lanceolate | Nil | 0 |
| Pointed ovate | RIL 115-1,RIL 115-4, RIL 115-36, RIL 115-41, RIL 115-42, RIL 115-43, RIL 115-45, RIL 115-51, RIL 115-57, RIL 115-62, RIL 115-64, RIL 115-65, RIL 115-66, RIL 115-67, RIL 115-69, RIL 115-71, RIL 115-74, RIL 115-76, RIL 115-89, RIL 115-91, RIL 115-92, RIL 115-93, RIL 115-96, RIL 115-99, RIL 115-108, RIL 115-118, RIL 115-132, RIL 115-140, RIL 115-141, RIL 115-144, RIL 115-150, RIL 115-153, RIL 115-154, RIL 115-155, RIL 115-156, RIL 115-159, RIL 115-160, RIL 115-161, RIL 115-162, RIL 115-163, RIL 115-164, RIL 115-166, RIL 115-167, RIL 115-169, RIL 115-171, RIL 115-173, RIL 115-175, RIL 115-176, RIL 115-177, RIL 115-178, RIL 115-179, RIL 115-181, RIL 115-182, RIL 115-183, RIL 115-184, RIL 115-188, RIL 115-193, RIL 115-194, RIL 115-199, RIL 115-206, RIL 115-211, RIL 115-221, RIL 115-222, RIL 115-223, RIL 115-225, RIL 115-227, RIL 115-230, RIL 115-233, RIL 115-237, RIL 115-238, RIL 115-239, RIL 115-243, RIL 115-252, RIL 115-253, RIL 115-256, RIL 115-258, RIL 115-260, RIL 115-265, RIL 115-267, RIL 115-268, RIL 115-269, RIL 115-272, RIL 115-273, RIL 115-274, RIL 115-277, RIL 107-38, RIL 107-63, RIL 107-77, RIL 107-99, RIL 107-166, RIL 107-24, RIL 107-31, RIL 107-35, RIL 107-43, RIL 107-44, RIL 107-46, RIL 107-57, RIL 107-68, RIL 107-71, RIL 107-72, RIL 107-73, RIL 107-74, RIL 107-75, RIL 107-79, RIL 107-80, RIL 107-87, RIL 107-88, RIL 107-96, RIL 107-103, RIL 107-128, RIL 107-137, RIL 107-139, RIL 107-151, RIL 107-161, JS 97-52 | 115 |
| Round ovate | JS-335, RIL 107-131, NRC-37 | 3 |
| 1. Leaf: size of lateral leaflet | Small | RIL 115-96, RIL 115-171, RIL 115-194, RIL 115-211, RIL 115-233, RIL 107-38, RIL 107-63, RIL 107-99, RIL 107-166, RIL 107-103 | 10 |
| Medium | RIL 115-1,RIL 115-4, RIL 115-36, RIL 115-41, RIL 115-42, RIL 115-43, RIL 115-45, RIL 115-51, RIL 115-57, RIL 115-62, RIL 115-64, RIL 115-65, RIL 115-66, RIL 115-67, RIL 115-69, RIL 115-71, RIL 115-74, RIL 115-76, RIL 115-89, RIL 115-91, RIL 115-92, RIL 115-93, RIL 115-99, RIL 115-108, RIL 115-118, RIL 115-132, RIL 115-140, RIL 115-141, RIL 115-144, RIL 115-150, RIL 115-153, RIL 115-154, RIL 115-155, RIL 115-156, RIL 115-159, RIL 115-160, RIL 115-161, RIL 115-162, RIL 115-163, RIL 115-164, RIL 115-166, RIL 115-167, RIL 115-169, RIL 115-173, RIL 115-175, RIL 115-176, RIL 115-177, RIL 115-178, RIL 115-179, RIL 115-181, RIL 115-182, RIL 115-183, RIL 115-184, RIL 115-188, RIL 115-193, RIL 115-199, RIL 115-206, RIL 115-221, RIL 115-222, RIL 115-223, RIL 115-225, RIL 115-227, RIL 115-230, RIL 115-237, RIL 115-238, RIL 115-239, RIL 115-243, RIL 115-252, RIL 115-253, RIL 115-256, RIL 115-258, RIL 115-260, RIL 115-267, RIL 115-268, RIL 115-269, RIL 115-272, RIL 115-273, RIL 115-274, RIL 115-277, RIL 107-77, RIL 107-24, RIL 107-43, RIL 107-44, RIL 107-46, RIL 107-57, RIL 107-71, RIL 107-72, RIL 107-73, RIL 107-74, RIL 107-75, RIL 107-79, RIL 107-80, RIL 107-87, RIL 107-88, RIL 107-96, RIL 107-128, RIL 107-131, RIL 107-137, RIL 107-139, RIL 107-151, RIL 107-161, JS 97-52 | 103 |
| Large | RIL 115-265, RIL 107-31, RIL 107-35, RIL 107-68, NRC-37 | 5 |
| 1. Leaf colour | Green | RIL 115-4, RIL 115-36, RIL 115-41, RIL 115-42, RIL 115-43, RIL 115-45, RIL 115-51, RIL 115-57, RIL 115-62, RIL 115-64, RIL 115-65, RIL 115-66, RIL 115-67, RIL 115-69, RIL 115-71, RIL 115-74, RIL 115-76, RIL 115-89, RIL 115-91, RIL 115-92, RIL 115-93, RIL 115-96, RIL 115-99, RIL 115-108, RIL 115-118, RIL 115-132, RIL 115-140, RIL 115-141, RIL 115-144, RIL 115-150, RIL 115-153, RIL 115-154, RIL 115-155, RIL 115-156, RIL 115-159, RIL 115-160, RIL 115-161, RIL 115-162, RIL 115-163, RIL 115-164, RIL 115-166, RIL 115-167, RIL 115-169, RIL 115-171, RIL 115-173, RIL 115-175, RIL 115-176, RIL 115-177, RIL 115-178, RIL 115-179, RIL 115-181, RIL 115-182, RIL 115-183, RIL 115-184, RIL 115-188, RIL 115-193, RIL 115-194, RIL 115-199, RIL 115-206, RIL 115-211, RIL 115-221, RIL 115-222, RIL 115-223, RIL 115-225, RIL 115-227, RIL 115-230, RIL 115-233, RIL 115-237, RIL 115-238, RIL 115-243, RIL 115-252, RIL 115-256, RIL 115-258, RIL 115-260, RIL 115-267, RIL 115-268, RIL 115-269, RIL 115-272, RIL 115-273, RIL 115-274, RIL 115-277, RIL 107-38, RIL 107-63, RIL 107-77, RIL 107-99, RIL 107-166, RIL 107-35, RIL 107-43, RIL 107-44,RIL 107-46, RIL 107-57, RIL 107-68, RIL 107-71, RIL 107-72, RIL 107-73, RIL 107-74, RIL 107-75, RIL 107-79, RIL 107-80, RIL 107-87, RIL 107-88, RIL 107-96, RIL 107-103, RIL 107-128, RIL 107-131, RIL 107-137, RIL 107-139, RIL 107-151, JS 97-52, NRC-37 | 110 |
| Dark green | RIL 115-1, RIL 115-239, RIL 115-253, RIL 115-265, RIL 107-24, RIL 107-31, RIL 107-161, JS-335 | 8 |
| 1. Pod : Pubescence | Glabrous (Absent) | JS-335 | 1 |
| Pubescent (Present) | RIL 115-1,RIL 115-4, RIL 115-36, RIL 115-41, RIL 115-42, RIL 115-43, RIL 115-45, RIL 115-51, RIL 115-57, RIL 115-62, RIL 115-64, RIL 115-65, RIL 115-66, RIL 115-67, RIL 115-69, RIL 115-71, RIL 115-74, RIL 115-76, RIL 115-89, RIL 115-91, RIL 115-92, RIL 115-93, RIL 115-96, RIL 115-99, RIL 115-108, RIL 115-118, RIL 115-132, RIL 115-140, RIL 115-141, RIL 115-144, RIL 115-150, RIL 115-153, RIL 115-154, RIL 115-155, RIL 115-156, RIL 115-159, RIL 115-160, RIL 115-161, RIL 115-162, RIL 115-163, RIL 115-164, RIL 115-166, RIL 115-167, RIL 115-169, RIL 115-171, RIL 115-173, RIL 115-175, RIL 115-176, RIL 115-177, RIL 115-178, RIL 115-179, RIL 115-181, RIL 115-182, RIL 115-183, RIL 115-184, RIL 115-188, RIL 115-193, RIL 115-194, RIL 115-199, RIL 115-206, RIL 115-211, RIL 115-221, RIL 115-222, RIL 115-223, RIL 115-225, RIL 115-227, RIL 115-230, RIL 115-233, RIL 115-237, RIL 115-238, RIL 115-239, RIL 115-243, RIL 115-252, RIL 115-253, RIL 115-256, RIL 115-258, RIL 115-260, RIL 115-265, RIL 115-267, RIL 115-268, RIL 115-269, RIL 115-272, RIL 115-273, RIL 115-274, RIL 115-277, RIL 107-38, RIL 107-63, RIL 107-77, RIL 107-99, RIL 107-166, RIL 107-24, RIL 107-31, RIL 107-35, RIL 107-43, RIL 107-44, RIL 107-46, RIL 107-57, RIL 107-68, RIL 107-71, RIL 107-72, RIL 107-73, RIL 107-74, RIL 107-75, RIL 107-79, RIL 107-80, RIL 107-87, RIL 107-88, RIL 107-96, RIL 107-103, RIL 107-128, RIL 107-131, RIL 107-137, RIL 107-139, RIL 107-151, RIL 107-161, JS 97-52, NRC-37 | 117 |
| 1. Pod: Pubescence colour | Grey | Nil | 0 |
| Tawny | RIL 115-1,RIL 115-4, RIL 115-36, RIL 115-41, RIL 115-42, RIL 115-43, RIL 115-45, RIL 115-51, RIL 115-57, RIL 115-62, RIL 115-64, RIL 115-65, RIL 115-66, RIL 115-67, RIL 115-69, RIL 115-71, RIL 115-74, RIL 115-76, RIL 115-89, RIL 115-91, RIL 115-92, RIL 115-93, RIL 115-96, RIL 115-99, RIL 115-108, RIL 115-118, RIL 115-132, RIL 115-140, RIL 115-141, RIL 115-144, RIL 115-150, RIL 115-153, RIL 115-154, RIL 115-155, RIL 115-156, RIL 115-159, RIL 115-160, RIL 115-161, RIL 115-162, RIL 115-163, RIL 115-164, RIL 115-166, RIL 115-167, RIL 115-169, RIL 115-171, RIL 115-173, RIL 115-175, RIL 115-176, RIL 115-177, RIL 115-178, RIL 115-179, RIL 115-181, RIL 115-182, RIL 115-183, RIL 115-184, RIL 115-188, RIL 115-193, RIL 115-194, RIL 115-199, RIL 115-206, RIL 115-211, RIL 115-221, RIL 115-222, RIL 115-223, RIL 115-225, RIL 115-227, RIL 115-230, RIL 115-233, RIL 115-237, RIL 115-238, RIL 115-239, RIL 115-243, RIL 115-252, RIL 115-253, RIL 115-256, RIL 115-258, RIL 115-260, RIL 115-265, RIL 115-267, RIL 115-268, RIL 115-269, RIL 115-272, RIL 115-273, RIL 115-274, RIL 115-277, RIL 107-38, RIL 107-63, RIL 107-77, RIL 107-99, RIL 107-166, RIL 107-24, RIL 107-31, RIL 107-35, RIL 107-43, RIL 107-44, RIL 107-46, RIL 107-57, RIL 107-68, RIL 107-71, RIL 107-72, RIL 107-73, RIL 107-74, RIL 107-75, RIL 107-79, RIL 107-80, RIL 107-87, RIL 107-88, RIL 107-96, RIL 107-103, RIL 107-128, RIL 107-131, RIL 107-137, RIL 107-139, RIL 107-151, RIL 107-161, JS 97-52, NRC-37 | 117 |
| 1. Pod colour | Yellow | Nil | 0 |
| Brown | RIL 115-1,RIL 115-4, RIL 115-36, RIL 115-41, RIL 115-42, RIL 115-43, RIL 115-45, RIL 115-51, RIL 115-57, RIL 115-62, RIL 115-64, RIL 115-65, RIL 115-66, RIL 115-67, RIL 115-69, RIL 115-71, RIL 115-74, RIL 115-76, RIL 115-89, RIL 115-91, RIL 115-92, RIL 115-93, RIL 115-96, RIL 115-99, RIL 115-108, RIL 115-118, RIL 115-132, RIL 115-140, RIL 115-141, RIL 115-144, RIL 115-150, RIL 115-153, RIL 115-154, RIL 115-155, RIL 115-156, RIL 115-159, RIL 115-160, RIL 115-161, RIL 115-162, RIL 115-163, RIL 115-164, RIL 115-166, RIL 115-167, RIL 115-169, RIL 115-171, RIL 115-173, RIL 115-175, RIL 115-176, RIL 115-177, RIL 115-178, RIL 115-179, RIL 115-181, RIL 115-182, RIL 115-183, RIL 115-184, RIL 115-188, RIL 115-193, RIL 115-194, RIL 115-199, RIL 115-206, RIL 115-211, RIL 115-221, RIL 115-222, RIL 115-223, RIL 115-225, RIL 115-227, RIL 115-230, RIL 115-233, RIL 115-237, RIL 115-238, RIL 115-239, RIL 115-243, RIL 115-252, RIL 115-253, RIL 115-256, RIL 115-258, RIL 115-260, RIL 115-265, RIL 115-267, RIL 115-268, RIL 115-269, RIL 115-272, RIL 115-273, RIL 115-274, RIL 115-277, RIL 107-38, RIL 107-63, RIL 107-77, RIL 107-99, RIL 107-166, RIL 107-24, RIL 107-31, RIL 107-35, RIL 107-43, RIL 107-44,RIL 107-46, RIL 107-57, RIL 107-68, RIL 107-71, RIL 107-72, RIL 107-73, RIL 107-74, RIL 107-75, RIL 107-79, RIL 107-80, RIL 107-87, RIL 107-88, RIL 107-96, RIL 107-103, RIL 107-128, RIL 107-131, RIL 107-137, RIL 107-139, RIL 107-151, RIL 107-161, JS 97-52, NRC-37, JS-335 | 118 |
| Black | Nil | 0 |
| 1. Pod: Intensity of brown colour | Light | Nil | 0 |
| Medium | RIL 115-1,RIL 115-4, RIL 115-36, RIL 115-41, RIL 115-42, RIL 115-43, RIL 115-45, RIL 115-51, RIL 115-57, RIL 115-62, RIL 115-64, RIL 115-65, RIL 115-66, RIL 115-67, RIL 115-69, RIL 115-71, RIL 115-74, RIL 115-76, RIL 115-89, RIL 115-91, RIL 115-92, RIL 115-93, RIL 115-96, RIL 115-99, RIL 115-108, RIL 115-118, RIL 115-132, RIL 115-140, RIL 115-141, RIL 115-144, RIL 115-150, RIL 115-153, RIL 115-154, RIL 115-155, RIL 115-156, RIL 115-159, RIL 115-160, RIL 115-161, RIL 115-162, RIL 115-163, RIL 115-164, RIL 115-166, RIL 115-167, RIL 115-169, RIL 115-171, RIL 115-173, RIL 115-175, RIL 115-176, RIL 115-177, RIL 115-178, RIL 115-179, RIL 115-181, RIL 115-182, RIL 115-183, RIL 115-184, RIL 115-188, RIL 115-193, RIL 115-194, RIL 115-199, RIL 115-206, RIL 115-211, RIL 115-221, RIL 115-222, RIL 115-223, RIL 115-225, RIL 115-227, RIL 115-230, RIL 115-233, RIL 115-237, RIL 115-238, RIL 115-239, RIL 115-243, RIL 115-252, RIL 115-253, RIL 115-256, RIL 115-258, RIL 115-260, RIL 115-265, RIL 115-267, RIL 115-268, RIL 115-269, RIL 115-272, RIL 115-273, RIL 115-274, RIL 115-277, RIL 107-38, RIL 107-63, RIL 107-77, RIL 107-99, RIL 107-166, RIL 107-24, RIL 107-31, RIL 107-35, RIL 107-43, RIL 107-44,RIL 107-46, RIL 107-57, RIL 107-68, RIL 107-71, RIL 107-72, RIL 107-73, RIL 107-74, RIL 107-75, RIL 107-79, RIL 107-80, RIL 107-87, RIL 107-88, RIL 107-96, RIL 107-103, RIL 107-128, RIL 107-131, RIL 107-137, RIL 107-139, RIL 107-151, RIL 107-161, JS 97-52, NRC-37, JS-335 | 118 |
| Dark | Nil | 0 |
| 1. Seed: Shape | Spherical | RIL 115-1,RIL 115-4, RIL 115-42, RIL 115-43, RIL 115-51, RIL 115-57, RIL 115-62, RIL 115-64, RIL 115-65, RIL 115-67, RIL 115-71, RIL 115-74, RIL 115-89, RIL 115-91, RIL 115-92, RIL 115-93, RIL 115-99, RIL 115-108, RIL 115-118, RIL 115-132, RIL 115-140, RIL 115-141, RIL 115-150, RIL 115-153, RIL 115-154, RIL 115-156, RIL 115-159, RIL 115-160, RIL 115-162, RIL 115-163, RIL 115-164, RIL 115-166, RIL 115-167, RIL 115-169, RIL 115-171, RIL 115-173, RIL 115-176, RIL 115-177, RIL 115-178, RIL 115-179, RIL 115-181, RIL 115-182, RIL 115-183, RIL 115-184, RIL 115-188, RIL 115-193, RIL 115-199, RIL 115-211, RIL 115-221, RIL 115-222, RIL 115-223, RIL 115-225, RIL 115-227, RIL 115-233, RIL 115-237, RIL 115-238, RIL 115-239, RIL 115-243, RIL 115-252, RIL 115-258, RIL 115-265, RIL 115-267, RIL 115-272, RIL 115-273, RIL 115-274, RIL 115-277, RIL 107-38, RIL 107-63, RIL 107-77, RIL 107-99, RIL 107-166, RIL 107-24, RIL 107-43, RIL 107-68, RIL 107-72, RIL 107-74, RIL 107-75, RIL 107-80, RIL 107-87, RIL 107-88, RIL 107-96, RIL 107-128, NRC-37 | 83 |
| Elliptical | RIL 115-36, RIL 115-41, RIL 115-45, RIL 115-66, RIL 115-69, RIL 115-76, RIL 115-96, RIL 115-144, RIL 115-155, RIL 115-156, RIL 115-161, RIL 115-175, RIL 115-194, RIL 115-206, RIL 115-230, RIL 115-253, RIL 115-256, RIL 115-260, RIL 115-268, RIL 115-269, RIL 107-31, RIL 107-35, RIL 107-44, RIL 107-46, RIL 107-57, RIL 107-71, RIL 107-73, RIL 107-79, RIL 107-103, RIL 107-131, RIL 107-137, RIL 107-139, RIL 107-151, RIL 107-161, JS 97-52 | 35 |
| 1. Seed : Colour | Yellow | RIL 115-1,RIL 115-4, RIL 115-36, RIL 115-41, RIL 115-42, RIL 115-43, RIL 115-45, RIL 115-51, RIL 115-57, RIL 115-62, RIL 115-64, RIL 115-65, RIL 115-66, RIL 115-67, RIL 115-69, RIL 115-71, RIL 115-74, RIL 115-76, RIL 115-89, RIL 115-91, RIL 115-92, RIL 115-93, RIL 115-96, RIL 115-99, RIL 115-108, RIL 115-118, RIL 115-132, RIL 115-140, RIL 115-141, RIL 115-144, RIL 115-150, RIL 115-153, RIL 115-154, RIL 115-155, RIL 115-156, RIL 115-159, RIL 115-160, RIL 115-161, RIL 115-162, RIL 115-163, RIL 115-164, RIL 115-166, RIL 115-167, RIL 115-169, RIL 115-171, RIL 115-173, RIL 115-175, RIL 115-176, RIL 115-177, RIL 115-178, RIL 115-179, RIL 115-181, RIL 115-182, RIL 115-183, RIL 115-184, RIL 115-188, RIL 115-193, RIL 115-194, RIL 115-199, RIL 115-206, RIL 115-211, RIL 115-221, RIL 115-222, RIL 115-223, RIL 115-225, RIL 115-227, RIL 115-230, RIL 115-233, RIL 115-237, RIL 115-238, RIL 115-239, RIL 115-243, RIL 115-252, RIL 115-253, RIL 115-256, RIL 115-258, RIL 115-260, RIL 115-265, RIL 115-267, RIL 115-268, RIL 115-269, RIL 115-272, RIL 115-273, RIL 115-274, RIL 115-277, RIL 107-38, RIL 107-63, RIL 107-77, RIL 107-99, RIL 107-166, RIL 107-24, RIL 107-31, RIL 107-35, RIL 107-43, RIL 107-44, RIL 107-46, RIL 107-57, RIL 107-68, RIL 107-71, RIL 107-72, RIL 107-73, RIL 107-74, RIL 107-75, RIL 107-79, RIL 107-80, RIL 107-87, RIL 107-88, RIL 107-96, RIL 107-103, RIL 107-128, RIL 107-131, RIL 107-137, RIL 107-139, RIL 107-151, RIL 107-161, JS 97-52, NRC-37, JS-335 | 118 |
| Yellow green | Nil | 0 |
| Green | Nil | 0 |
| Black | Nil | 0 |
| 1. Seed coat: Lusture | Shiny | RIL 115-4, RIL 115-42, RIL 115-57, RIL 115-64, RIL 115-67, RIL 115-71, RIL 115-74, RIL 115-76, RIL 115-89, RIL 115-91, RIL 115-96, RIL 115-99, RIL 115-108, RIL 115-153, RIL 115-155, RIL 115-159, RIL 115-161, RIL 115-166, RIL 115-167, RIL 115-173, RIL 115-175, RIL 115-176, RIL 115-177, RIL 115-179, RIL 115-181, RIL 115-182, RIL 115-183, RIL 115-188, RIL 115-193, RIL 115-194, RIL 115-211, RIL 115-221, RIL 115-222, RIL 115-223, RIL 115-227, RIL 115-233, RIL 115-238, RIL 115-239, RIL 115-243, RIL 115-252, RIL 115-253, RIL 115-258, RIL 115-265, RIL 115-267, RIL 115-268, RIL 115-269, RIL 115-272, RIL 115-273, RIL 115-277, RIL 107-38, RIL 107-63, RIL 107-77, RIL 107-24, RIL 107-46, RIL 107-68, RIL 107-71, RIL 107-74, RIL 107-88, RIL 107-96, RIL 107-128, JS-335 | 61 |
| Dull | RIL 115-1, RIL 115-36, RIL 115-41, RIL 115-43, RIL 115-45, RIL 115-51, RIL 115-62, RIL 115-65, RIL 115-66, RIL 115-69, RIL 115-92, RIL 115-93, RIL 115-118, RIL 115-132, RIL 115-140, RIL 115-141, RIL 115-144, RIL 115-150, RIL 115-154, RIL 115-156, RIL 115-160, RIL 115-162, RIL 115-163, RIL 115-164, RIL 115-169, RIL 115-171, RIL 115-178, RIL 115-184, RIL 115-199, RIL 115-206, RIL 115-225, RIL 115-230, RIL 115-237, RIL 115-256, RIL 115-260, RIL 115-274, RIL 107-99, RIL 107-166, RIL 107-31, RIL 107-35, RIL 107-43, RIL 107-44, RIL 107-57, RIL 107-72, RIL 107-73, RIL 107-75, RIL 107-79, RIL 107-80, RIL 107-87, RIL 107-103, RIL 107-131, RIL 107-137, RIL 107-139, RIL 107-151, RIL 107-161, JS 97-52, NRC-37 | 57 |
| 1. Seed: Hilum colour | Yellow | Nil | 0 |
| Grey | Nil | 0 |
| Brown | RIL 115-4, RIL 115-153, RIL 115-155, RIL 115-156, RIL 115-164, RIL 115-167, RIL 115-169, RIL 115-173, RIL 115-175, RIL 115-176, RIL 115-179, RIL 115-181, RIL 115-182, RIL 115-183, RIL 115-188, RIL 115-193, RIL 115-199, RIL 115-221, RIL 115-222, RIL 115-225, RIL 115-227, RIL 115-238, RIL 115-252, RIL 115-256, RIL 115-258, RIL 115-265, RIL 115-267, RIL 115-269, RIL 115-272, RIL 115-274, RIL 115-277, RIL 107-77, RIL 107-99, RIL 107-166, RIL 107-24, RIL 107-31, RIL 107-35, RIL 107-44, RIL 107-57, RIL 107-75, RIL 107-80, RIL 107-88, RIL 107-131, RIL 107-139, RIL 107-151, RIL 107-161, NRC-37 | 47 |
| Black | RIL 115-1, RIL 115-36, RIL 115-41, RIL 115-42, RIL 115-43, RIL 115-45, RIL 115-51, RIL 115-57, RIL 115-62, RIL 115-64, RIL 115-65, RIL 115-66, RIL 115-67, RIL 115-69, RIL 115-71, RIL 115-74, RIL 115-76, RIL 115-89, RIL 115-91, RIL 115-92, RIL 115-93, RIL 115-96, RIL 115-99, RIL 115-108, RIL 115-118, RIL 115-132, RIL 115-140, RIL 115-141, RIL 115-144, RIL 115-150, RIL 115-154, RIL 115-159, RIL 115-160, RIL 115-161, RIL 115-162, RIL 115-163, RIL 115-166, RIL 115-171, RIL 115-177, RIL 115-178, RIL 115-184, RIL 115-194, RIL 115-206, RIL 115-211, RIL 115-223, RIL 115-230, RIL 115-233,, RIL 115-237, RIL 115-239, RIL 115-243, RIL 115-253, RIL 115-260, RIL 115-268, RIL 115-273, RIL 107-38, RIL 107-63, RIL 107-43, RIL 107-46, RIL 107-68, RIL 107-71, RIL 107-72, RIL 107-73, RIL 107-74, RIL 107-79, RIL 107-87, RIL 107-96, RIL 107-103, RIL 107-128, RIL 107-137, JS 97-52, JS-335 | 71 |
| Variegated | NIL | 0 |
| 1. Seed: Colour of hilum funicle | Same as testa | RIL 115-4, RIL 115-153, RIL 115-155, RIL 115-156, RIL 115-164, RIL 115-167, RIL 115-169, RIL 115-173, RIL 115-175, RIL 115-176, RIL 115-179, RIL 115-181, RIL 115-182, RIL 115-183, RIL 115-188, RIL 115-193, RIL 115-199, RIL 115-221, RIL 115-222, RIL 115-225, RIL 115-227, RIL 115-238, RIL 115-252, RIL 115-256, RIL 115-258, RIL 115-265, RIL 115-267, RIL 115-269, RIL 115-272, RIL 115-274, RIL 115-277, RIL 107-77, RIL 107-99, RIL 107-166, RIL 107-24, RIL 107-31, RIL 107-35, RIL 107-44, RIL 107-57, RIL 107-75, RIL 107-80, RIL 107-88, RIL 107-131, RIL 107-139, RIL 107-151, RIL 107-161, NRC-37 | 47 |
| Different from testa | RIL 115-1, RIL 115-36, RIL 115-41, RIL 115-42, RIL 115-43, RIL 115-45, RIL 115-51, RIL 115-57, RIL 115-62, RIL 115-64, RIL 115-65, RIL 115-66, RIL 115-67, RIL 115-69, RIL 115-71, RIL 115-74, RIL 115-76, RIL 115-89, RIL 115-91, RIL 115-92, RIL 115-93, RIL 115-96, RIL 115-99, RIL 115-108, RIL 115-118, RIL 115-132, RIL 115-140, RIL 115-141, RIL 115-144, RIL 115-150, RIL 115-154, RIL 115-159, RIL 115-160, RIL 115-161, RIL 115-162, RIL 115-163, RIL 115-166, RIL 115-171, RIL 115-177, RIL 115-178, RIL 115-184, RIL 115-194, RIL 115-206, RIL 115-211, RIL 115-223, RIL 115-230, RIL 115-233, RIL 115-237, RIL 115-239, RIL 115-243, RIL 115-253, RIL 115-260, RIL 115-268, RIL 115-273, RIL 107-38, RIL 107-63, RIL 107-43, RIL 107-46, RIL 107-68, RIL 107-71, RIL 107-72, RIL 107-73, RIL 107-74, RIL 107-79, RIL 107-87, RIL 107-96, RIL 107-103, RIL 107-128, RIL 107-137, JS 97-52, JS-335 | 71 |

|  |  |  |
| --- | --- | --- |
| **(a)** |  |  |
| **Round ovate leaf** | **Pointed ovate leaf** |
| **(b)** |  |  |
| **Violet** | **White** |
| **(c)** |  |  |
| **Glabrous pod** | **Pubescent pod** |
| Fig. 2 Morphological characters of soybean: (a) Leaf shape; (b) Flower colour; (c) Pod pubescence | | |

A dendrogram was constructed based on the frequency of qualitative traits of 118 genotypes to assess their genetic relationships (Table 2; Fig. 3). The analysis grouped the genotypes into two primary clusters - one major and one minor - along with a distinct, unique cluster. The minor cluster comprised 40 genotypes and was further divided into two subclusters. Within the minor cluster, the larger subcluster included 27 genotypes, while the smaller subcluster comprised 13 genotypes including NRC-37, RIL115-156, RIL115-256, RIL107-80, RIL107-131, RIL107-139, RIL107-151, RIL107-161, RIL115-155, RIL115-175, RIL115-269, RIL107-35, and RIL107-44. Likewise, the major cluster contained 77 genotypes, which were also subdivided into two subclusters. The major subcluster encompassed 64 genotypes, whereas the minor subcluster included 13 genotypes *viz.,* RIL115-239, RIL115-211, RIL115-233, RIL107-63, RIL115-71, RIL115-223, RIL107-68, RIL107-71, RIL115-4, RIL115-153, RIL115-167, RIL155-173 and RIL115-176. Moreover, a distinct unique cluster was formed solely by JS 335, suggesting its significant genetic divergence from the other genotypes.

Table 2 Frequency distribution of different qualitative characters

|  |  |  |  |
| --- | --- | --- | --- |
| **Characters** | **Categorisation** | **Number** | **Frequency (%)** |
| 1. Hypocotyl colour: Anthocyanin pigmentation | Absent | 117 | 99.15 |
| Present | 1 | 0.85 |
| 1. Plant: Growth type | Determinate | 0 | 0 |
| Semi-determinate | 118 | 100 |
| 1. Plant: growth habit | Erect | 25 | 21.19 |
| Semi-erect | 93 | 78.81 |
| 1. Flower colour | White | 117 | 99.15 |
| Violet | 1 | 0.85 |
| 1. Leaf shape | Lanceolate | 0 | 0 |
| Pointed ovate | 115 | 97.46 |
| Round ovate | 3 | 2.54 |
| 1. Leaf: size of lateral leaflet | Small | 10 | 8.47 |
| Medium | 103 | 87.29 |
| Large | 5 | 4.24 |
| 1. Leaf colour | Green | 110 | 93.22 |
| Dark green | 8 | 6.78 |
| 1. Pod: Pubescence | Glabrous (Absent) | 1 | 0.85 |
| Pubescent (Present) | 117 | 99.15 |
| 1. Pod: Pubescence colour | Grey | 0 | 0 |
| Tawny | 117 | 99.15 |
| 1. Pod colour | Yellow | 0 | 0 |
| Brown | 118 | 100 |
| Black | 0 | 0 |
| 1. Pod: Intensity of brown colour | Light | 0 | 0 |
| Medium | 118 | 100 |
| Dark | 0 | 0 |
| 1. Seed: Shape | Spherical | 83 | 70.34 |
| Elliptical | 35 | 29.66 |
| 1. Seed: Colour | Yellow | 118 | 100 |
| Yellow green | 0 | 0 |
| Green | 0 | 0 |
| Black | 0 | 0 |
| 1. Seed coat: Lusture | Shiny | 61 | 51.69 |
| Dull | 57 | 48.31 |
| 1. Seed: Hilum colour | Yellow | 0 | 0 |
| Grey | 0 | 0 |
| Brown | 47 | 39.83 |
| Black | 71 | 60.17 |
| Variegated | 0 | 0 |
| 1. Seed: Colour of hilum funicle | Same as testa | 47 | 39.83 |
| Different from testa | 71 | 60.17 |

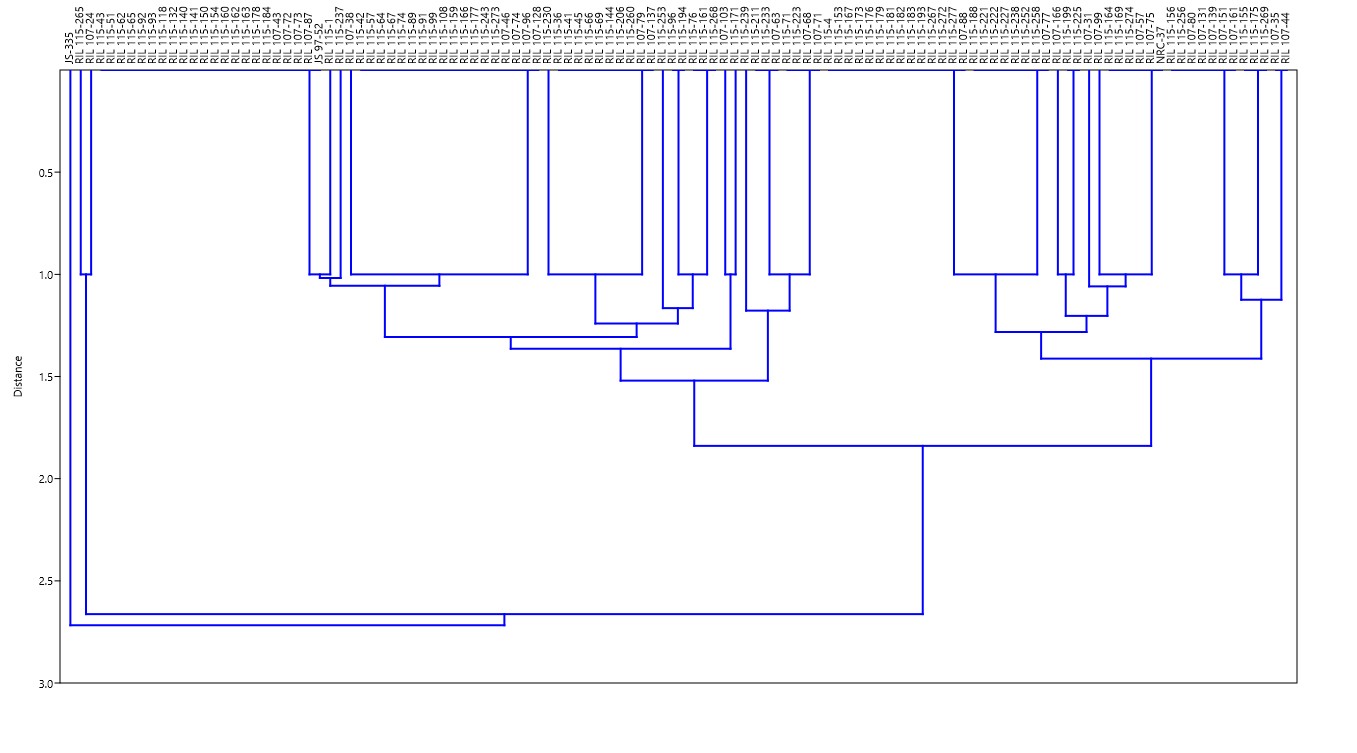


Fig. 3 Dendrogram of genotypes categorised into different clusters as per their qualitative traits

The Shannon-Weaver diversity index analysis of traits exposed varying levels of genetic diversity across different morphological characters (Table 3). Traits such as hypocotyl colour, flower colour, and pod pubescence exhibited very low diversity, indicating a high degree of uniformity and strong selection pressure for these features within the population. Moderate diversity was detected for plant growth habit and leaf size, signifying presence of some variability in plant architecture and canopy structure, which could be valuable for breeding programmes targeting for different agronomic systems. Seed-related traits, including seed shape, seed coat lustre, and hilum colour, showed relatively higher diversity compared to vegetative and floral traits. This highlights a greater degree of genetic variation in seed characteristics, which is crucial for enhancing market acceptability, adaptability, and genetic enhancement. Overall, the analysis advocates that while vegetative and floral traits are largely conserved, significant variability exists in seed traits, offering opportunities for future selection and breeding efforts in soybean. These finding align with the previous studies conducted by [20, 22, 30 and 31].

Table 3 Shannon weaver diversity index for qualitative characters

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Character** | **HC** | **GH** | **FC** | **LS** | **LSLL** | **LC** | **PP** | **SS** | **SL** | **SHC** | **SHF** | **Total** |
| **H’ value** | 0.0489 | 0.5165 | 0.0489 | 0.1184 | 0.462 | 0.248 | 0.0489 | 0.607 | 0.692 | 0.673 | 0.673 | **0.376** |

Abbreviations: HC: Hypocotyl colour, GH: Growth habit, FC: Flower colour, LS: Leaf shape, LSLL: Leaf size of lateral leaflet, LC : Leaf colour, PP: Pod pubescence, SS: Seed shape, SL: Seed lusture, SHC: Seed hilum colour, SHF: Seed colour of hilum funicle

The findings of the present investigation suggest that although certain morphological traits in soybean, for instance hypocotyl and flower colour and pod pubescence, have undergone strong selection and stabilization, considerable genetic variability still persists in seed-related traits like seed shape, seed coat luster and hilum colour. This indicates that while vegetative and floral traits may have reached near-uniformity due to breeding efforts focused on agronomic stability, seed traits remain a valuable reservoir of genetic diversity for future crop improvement [32]. The formation of distinct clusters, particularly the unique position of JS-335, highlights the presence of novel genetic attributes in genotype that could be strategically utilized to introduce fresh variability and broaden the genetic base of soybean breeding programmes [33,34]. Furthermore, the moderate diversity investigated in growth habit and leaf size traits which recommends potential for breeding new varieties better suited to diverse agro-ecological circumstances. Overall, these results underline the perilous need to conserve and utilize the existing genetic variation in soybean, focusing on seed traits and unique genotypes, to meet future demands for yield improvement, stress tolerance and market preferences [18, 35, 36, 37].

**Conclusion**

The development and utilization of Recombinant Inbred Lines (RILs) play a crucial role in advancing soybean breeding objectives, predominantly in accomplishing genetic stability and enhancing the efficiency of selection for wanted characters. Through extensive phenotypic characterization, RILs offer a powerful platform for recognizing and exploiting genetic variation crucial for improving yield, stress resilience, nutritional quality and market-preferred seed traits. The stable homozygosity of RILs facilitates repeated evaluations across diverse environments, thereby enabling the precise mapping of trait-linked markers and accelerating molecular breeding efforts. Looking ahead, the integration of morphological characterization with genomic tools such as Quantitative Trait Locus (QTL) mapping and genome-wide association studies (GWAS) may further enhance the competence to dissect complex characters in soybean. This will support the development of climate-resilient, high-yielding cultivars tailored to evolving agricultural demands. Moreover, the conservation and strategic utilization of diverse RIL populations may be essential for maintaining genetic diversity, ensuring long-term sustainability and meeting global food and nutritional security goals.

**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 the writing or editing of this manuscript.

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