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Exploring the Concealed Treasure: Insights into the Genetic Variability of Crop Wild Relatives (CWR's) of Okra

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Authors' contributions

This work was carried out in collaboration among all authors. Authors PK, AS, MKS, ACM, SVD and HS conceived the idea. Author HS performed research work, and draft the entire manuscript with author PK. Authors VS and RK assisted in some computational work and edits the entire drafted manuscript. Author SS managed the literature searches. Author NR provided the necessary research facilities and infrastructure. All authors read and approved the final manuscript.

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ABSTRACT

Wild okra relatives constitute a vast genetic diversity for breeding, especially for stress tolerance and fruit quality improvement. However, their potential remains largely unexplored and underutilized, giving opportunities for future research. Therefore, this investigation was undertaken at ICAR-IIVR, Varanasi, during *Kharif* season of 2022-23 for evaluating 93 okra accessions with the

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objectives of assessing the magnitude of genetic variability and novelty. Data was collected on 16 qualitative characters by following the IBPGR descriptor [1]. Variations were observed among the different accessions based on their vegetative traits, inflorescence and fruit characteristics. Results obtained in this study revealed a high level of variability among the genotypes for the majority of the qualitative traits, except general aspect of growth, positioning of fruit on main stem and number of ridges per fruit. The vegetative growth characters *viz*., branching habit, stem pubescence and stem color exhibited a large diversity in the genotypes studied. In respect of branching habits it was obtained with 45.16% of strong branches, 33.33% of medium branches and 21.51% of orthotropic (single stem) branches recorded for genotypes. Stem pubescence varied among accessions with 58.06% of glabrous stem, 33.33% of slightly pubescent and 8.60% of conspicuously pubescent observed across all accessions. In the context of stem color, 50 accessions (53.76%) exhibited a typical green stem, 31 accessions (33.33%) exhibited a green stem with red patches, and 12 accessions (12.90%) showed a pronounced purple stem. This genetic variation providing a foundation for future breeding programs, enabling the development of new okra varieties with superior combinations of desirable traits and enhance qualitative traits of okra.

Keywords: Wild; okra; qualitative traits; IBPGR; variability.

1. INTRODUCTION

Okra [*Abelmoschus esculentus* (L.) Moench] is a warm-season, annual fruit vegetable crop predominantly cultivated in tropical and subtropical regions worldwide. Okra is an extremely nutritious crop, providing a significant contribution to daily nutritional requirements and also offering medicinal benefits, including its abundance in essential vitamins, minerals and antioxidants (Hamon and Charrier, 1997). Okra's popularity is increasing globally due to growing consumer awareness of its nutritional benefits [2]. *Abelmoschus esculentus* (2n = 130) is a naturally occurring amphidiploid and the single species of the genus cultivated globally. *Abelmoschus caillei* is the second most widely cultivated species, despite the existence of other edible wild relatives, including *Abelmoschus manihot* and *Abelmoschus moschatus* [3,4]. In addition to the pod, the fresh leaves of *Abelmoschus caillei* and *Abelmoschus manihot* are also edible and consumed in various regions, including Western and Central Africa and the South-Pacific Islands, respectively [5].

Abelmoschus manihot is an annual or perennial herb native to India, Nepal and southern China, growing up to 1-2 meters in height. In India, it is commonly found in the Terai region, foothills of the Himalayas, Western Ghats and Eastern Ghats [6]. Meanwhile, *Abelmoschus moschatus* is widely distributed across Western and Eastern Ghats [7]. This species is valued for its fragrant seeds, unripe pods, tender leaves and new shoots, which are consumed as nutritious vegetables rich in phytonutrients [8]. Additionally, *Abelmoschus angulosus* (2n = 56) is cultivated to a limited extent in certain parts of Asia and Africa [9]. In contrast, *Abelmoschus tuberculatus* is found only in wild forms, primarily in the semi-arid regions of northern and northwestern India [10].

Abelmoschus tuberculatus, native to Uttar Pradesh in North India, is also considered a probable ancestor of okra, suggesting that cultivated okra may have originated from India. Another probable ancestor, *Abelmoschus ficulneus* is a prickly annual herb characterized by its palmately 3-5-lobed glabrous leaves. With a chromosome count of 2n=72, this species is found in East Africa, indicating that northern Egypt or Ethiopia may be the geographical origin of *Abelmoschus esculentus* (okra). This suggests a possible African origin for okra, contradicting the earlier suggestion of an Indian origin. Further research is needed to clarify the evolutionary history of okra. *Abelmoschus enbeepeegearense* is a perennial, erect subshrub characterized by its tuberous root and green stem. This species is rarely found in grasslands and open hill slopes in the lower Western Ghats, specifically in Kerala, Nilgiri district of Tamil Nadu and Madikeri district of Karnataka, at an elevation of 250-500 meters above sea level. It faces intense grazing pressure in the areas where it occurs [11]. The species *Abelmoschus crinitus* is an erect, perennial, herbaceous plant that grows to a height of 50-200 cm, featuring tuberous roots. This plant is harvested from the wild for local use as a food source and in traditional medicine. Additionally, it is sometimes cultivated for its edible roots, highlighting its importance as a valuable resource.

The vulnerability of commercial okra varieties to various biotic stresses, including yellow vein mosaic virus (YVMV), enation leaf curl virus (ELCV), fruit and shoot borer, leafhopper and mites are major reason contributes to low productivity (Mishra et al., 2017; Das et al., 2020). Absence of resistance to begomoviruses in okra necessitates large-scale germplasm screening to identify potential sources of resistance, enabling effective management strategies [12]. Wild species related to okra have been identified as a valuable source of beneficial genes for breeding programs (Stalker, 1980). Specifically, resistance genes for these stresses have been found in okra wild species such as *A. manihot*, *A. tuberculatus* and *A. moschatus* (Rana et al., 1991); [7]. Therefore, evaluating, characterizing and utilizing okra genetic resources are crucial to expand the genetic base of commercial cultivars (Shetty et al., 2013). Characterization of genetic resources involves identifying, differentiating and distinguishing accessions based on their characteristics, providing insights into diversity within and between crop collections. This process enables the identification of unique accessions, which is essential for gene bank curators [13].

Germplasm characterization can be achieved through various methods, including descriptive analysis of quantitative and qualitative traits, assessment of biochemical parameters and molecular characterization techniques [14]. Morphological characterization is often employed as a preliminary assessment of genetic variability due to its rapid, cost-effective and straight forward nature. It is essential to evaluate morphological traits before proceeding to more in-depth studies, such as biochemical or molecular analyses [9]. Exploiting the vast variability within *Abelmoschus species* can reveal valuable insights into the structure and extent of desirable diversity within the species. By exploiting these variations, interspecific breeding programs can be developed to harness beneficial traits through the creation of hybrid populations. This study aimed to investigate the morphological variation among okra accessions to elucidate the species' systematic relationships and support the conservation and utilization of its genetic resources. The findings of this research contribute to a deep understanding of okra's genetic diversity and its potential applications.

2. MATERIALS AND METHODS

A collaborative research study was undertaken by Banda University of Agriculture and Technology, Banda, Uttar Pradesh, in association with ICAR-Indian Institute of Vegetable Research (ICAR-IIVR), Varanasi. The experiment was carried out at research farms of the ICAR-IIVR, Varanasi, using 93 okra accessions, including 88 wild relatives of ten distinct species and 5 cultivated variety in *Kharif* season of 2022-23. The experimental plot is located at *82.52°E longitude and 25.10°N latitude*. The okra genotypes were directly sown in the field with rows spaced 60 cm apart and individual plants spaced 30 cm apart in Augmented Block Design. The recommended cultural practices suggested for okra growing were followed in the research farm. For morphological evaluation, a random five plants was selected from each accession, ensuring accurate representation of the genotype's characteristics.

Qualitative traits of okra plants, encompassing vegetative and reproductive characteristics, were recorded based on the IBPGR's 1984 guidelines. The study examined several key characteristics of the okra plants, including plant vigour and architecture, whole plant pigmentation, pubescence and fruit traits, to gather a thorough understanding of their physical properties. Data for 13 characteristics *viz*., general aspect, branching, stem pubescence, stem colour, leaf shape, leaf color, shape of epicalyx segments, persistence of epicalyx segments, petal color, red coloration of petal base, position of fruit on main stem, fruit color and fruit pubescence were collected by visual assessment of a single observation of a group of plants or parts of plants (VG), whereas data for three characters *viz*., number of epicalyx segments, length of peduncle and number of ridges per fruit were collected via visual assessment of observations of individual plants or parts of plants (VS). Each 16 qualitative traits were categorized based on observed characteristics and then coded numerically (coded as 1, 2, or 3) to facilitate analysis. The coded qualitative data were analyzed by using SPSS, Software. A histogram analysis was performed to visualize the distribution of each traits across the all accessions. The histogram was generated the frequency and total share (%) of each accessions within the population and visualizing the overall diversity and distribution of traits within the population.

3. RESULTS AND DISCUSSION

The findings obtained from the research revealed a significant magnitude of genetic diversity and novelty among the assembled wild accessions of okra, offering a valuable reservoir of genetic resources for future breeding initiatives and genetic improvement programs. The results of the experiment is explained here.

3.1 Vegetative Characteristics

The data related to vegetative characteristics like general aspect, branching, stem pubescence and stem color is presented in Table 1 and illustrated in Fig. 1. With respect to general aspect of growth habits recorded among 93 accessions revealed a predominantly erect growth pattern, with 73 accessions (78.49%) i.e. *A. ficulneus* (12 accessions), *A. tuberculatus* (13 accessions), *A. tetraphyllus* (11 accessions), *A. tetraphyllus spp. manihot* (11 accessions), *A. moschatus* (9 accessions), *A. caillei* (6 accessions), *A. angulosus* (4 accessions), *A. manihot* (VRO-W-MH-1). *A. nova* (VRO-W-N-1) and *A. esculentus* (P. Sawani, Arka Anamika, VRO-6, Kashi Vibhuti and VRO-R-8) exhibiting erect growth. In contrast, 18 accessions (19.35%) i.e. *A. ficulneus* (7 accessions), *A. tuberculatus* (2 accessions), *A. tetraphyllus* (4 accessions), *A. moschatus* (4 accessions), *A. enbeepeegearense* (VRO-W-EN-1) demonstrated medium growth, while only 2 accessions (2.15%) of *A. crintitus* showed procumbent growth. These findings indicate a strong inclination towards erect growth in the majority of accessions, with a smaller proportion exhibiting alternative growth habits. This insight has important implications for okra breeding and improvement programs, as erect growth is often associated with desirable traits such as increased yield, improved disease resistance and enhanced adaptability to different environments. An assessment of branching habits based on visual observations revealed that the majority of accessions (42, comprising 45.16%) i.e. *A. ficulneus* (14 accessions), *A. tetraphyllus* (5 accessions), *A. tetraphyllus spp. manihot* (10 accessions), *A. moschatus* (9 accessions), *A. caillei* (1 accessions), *A. manihot* (VRO-W-MH-1) *A. enbeepeegearense* (VRO-W-EN-1) and *A. nova* (VRO-W-N-1) exhibited strong branching. In contrast, 31 accessions (33.33%) i.e. *A. ficulneus* (4 accessions), *A. tuberculatus* (3 accessions), *A. tetraphyllus* (7 accessions), *A. tetraphyllus spp. manihot* (1 accessions), *A. moschatus* (3 accessions), *A. caillei* (5 accessions), *A. angulosus* (2 accessions), *A. crinitus* (VRO-W-CT-1 and VRO-W-CT-2) and *A. esculentus* (P. Sawani, Arka Anamika, Kashi Vibhuti and VRO-R-8) presented medium branching, while 20 accessions (21.51%) i.e. *A. ficulneus* (1 accessions), *A. tuberculatus* (12 accessions), *A. tetraphyllus* (3 accessions), *A. moschatus* (1 accessions), *A. angulosus* (2 accessions) and *A. esculentus* (VRO-6) showed orthotropic stem only. By elucidating the genetic basis of branching habits breeders and researchers can leverage this to develop targeted breeding strategies, exploiting the genetic diversity present in accessions with desirable branching phenotypes to enhance okra yields and adaptability. Similar findings for general aspect and branching habits was also recorded by Binalfew & Alemu [15] and Aiwansoba et al*.* (2019) in okra. An examination of stem pubescence revealed a range of characteristics among the accessions. Specifically, 54 accessions (58.06%) i.e. *A. ficulneus* (19 accessions), *A. tuberculatus* (10 accessions), *A. tetraphyllus* (5 accessions), *A. tetraphyllus spp. manihot* (7 accessions), *A. moschatus* (4 accessions), *A. caillei* (1 accessions), *A. angulosus* (1 accessions), *A. crinitus* (VRO-W-CT-1 and VRO-W-CT-2) and *A. esculentus* (P. Sawani, Arka Anamika, VRO-6, Kashi Vibhuti and VRO-R-8) exhibited glabrous stems, indicating a complete lack of pubescence. Conversely, 31 accessions (33.33%) i.e. *A. tuberculatus* (5 accessions), *A. tetraphyllus* (10 accessions), *A. tetraphyllus spp. manihot* (4 accessions), *A. moschatus* (4 accessions), *A. caillei* (4 accessions), *A. angulosus* (3 accessions) and *A. enbeepeegearense* (VRO-W-EN-1) showed slight pubescence, while 8 accessions (8.60%) i.e. *A. moschatus* (5 accessions), *A. caillei* (1 accessions), *A. manihot* (VRO-W-MH-1) and *A. nova* (VRO-W-N-1) showed conspicuous pubescence, characterized by a dense and prominent covering of hairs on the stem surface. By exploiting genetic potential of okra accessions with desirable pubescence traits can significantly enhance the crop's disease resistance, stem strength and adaptability. Variation in stem pubescence was also observed by Williams and Yesudhas [16] in tomato. In the context of stem coloration there was significant variation was observed among the accessions for this trait. The results showed that 50 accessions (53.76%) i.e. *A. tuberculatus* (15 accessions), *A. tetraphyllus* (3 accessions), *A. tetraphyllus spp. manihot* (6 accessions), *A. moschatus* (6 accessions), *A. caillei* (6 accessions), *A. angulosus* (4 accessions), *A. manihot* (VRO-W-MH-1), *A. crinitus* (VRO-W-CT-1 and VRO-W-CT-2), *A. enbeepeegearense* (VRO-W-EN-1), *A. nova* (VRO-W-N-1) and *A. esculentus* (P. Sawani, Arka Anamika, VRO-6, Kashi Vibhuti and VRO-R-8) exhibited a typical green stem color. Meanwhile, 31 accessions (33.33%) i.e. *A. ficulneus* (19 accessions), *A. tetraphyllus* (4 accessions), *A. tetraphyllus spp. manihot* (1 accessions) and *A. moschatus* (7 accessions) displayed a green stem color with red patches, indicating a combination of anthocyanin pigmentation. Furthermore, 8 accessions of *A. tetraphyllus* and 4 accessions of *A. tetraphyllus spp. manihot* showed a pronounced purple stem color, suggesting a dominant expression of anthocyanin pigments. The genetic variation in stem coloration and pubescence among okra accessions offers a valuable resource for breeders to develop improved okra varieties with enhanced stress tolerance, adaptability, increased nutritional value and desirable traits. This result is in accordance with Anyaoha et al. [17], Oppong-Sekyere et al. [18], Temam et al. [19] and Osawaru et al. [20].

3.2 Leaves Characteristics

An examination of 93 okra accessions for leaf shape revealed a diverse range, aligning with the 11 distinct types of leaf classified by the International Board for Plant Genetic Resources [1]. These shapes were denoted by numbers 1-11 based on their morphology (Table 1 and Fig. 2). Notably, *A. enbeepeegearense* (VRO-W-EN-1) exhibited leaf shape type 1, while the remaining accessions displayed varying frequencies of different leaf shapes. Specifically, 31 accessions i.e. *A. tuberculatus* (13 accessions), *A. tetraphyllus* (7 accessions), *A. moschatus* (1 accessions), *A. caillei* (6 accessions), *A. angulosus* (3 accessions) and *A. nova* (VRO-W-N-1) exhibited leaf shape type 2, 20 accessions i.e. *A. tuberculatus* (1 accession), *A. tetraphyllus* (6 accessions), *A. moschatus* (7 accessions), *A. angulosus* (1 accession) and *A. esculentus* (P. Sawani, Arka Anamika, VRO-6, Kashi Vibhuti and VRO-R-8) showed leaf shape type 3, 10 accessions i.e. *A. tuberculatus* (1 accession), *A. tetraphyllus spp. manihot* (6 accessions), *A. moschatus* (2 accessions) and *A. manihot* (VRO-W-MH-1). exhibited leaf shape type 4, 2 accessions of *A. crinitus* (VRO-W-CT-1 and VRO-W-CT-2) displayed leaf shape type 5, 6 accessions i.e. *A. tetraphyllus* (1 accession), *A. tetraphyllus spp. manihot* (2 accessions) and *A. moschatus* (3 accessions), showed leaf shape type 6, 20 accessions i.e. *A. ficulneus* (16 accessions), *A. tetraphyllus* (1 accession), *A. tetraphyllus spp. manihot* (3 accessions) exhibited leaf shape type 7 and 3 accessions of *A. ficulneus* exhibited leaf shape type 9. This observed diversity in leaf shape highlights the genetic variation within the species, underscoring the potential for further research into the morphological characteristics of these accessions. In terms of leaf coloration on the basis of visual appearance according to IBPGR, 1984 guidelines revealed a predominance of green pigmentation among the accessions. Specifically, 78 accessions (83.87%) i.e. *A. ficulneus* (19 accessions), *A. tuberculatus* (15 accessions), *A. tetraphyllus* (15 accessions), *A. tetraphyllus spp. manihot* (11 accessions), *A. moschatus* (4 accessions), *A. angulosus* (4 accessions), *A. manihot* (VRO-W-MH-1), *A. crinitus* (VRO-W-CT-1 and VRO-W-CT-2), *A. enbeepeegearense* (VRO-W-EN-1), *A. nova* (VRO-W-N-1) and *A. esculentus* (P. Sawani, Arka Anamika, VRO-6, Kashi Vibhuti and VRO-R-8) exhibited a uniform green leaf color, characteristic of chlorophyll pigmentation. In contrast, 9 accessions of *A. moschatus* and 6 accessions of *A. caillei* displayed green leaves with red veins, indicating a degree of anthocyanin pigmentation in the vascular tissue. Notably, no accessions (0%) showed a completely red leaf color, suggesting a lack of dominant anthocyanin expression in the leaf lamina. Similar result was also reported by Muluken et al. [21], Oppong-Sekyere et al. [18] and Ahiakpa [22] while disagreed with Adeoluwa and Kehinde [23] who reported that uniform green leaf color for all the accessions. The significance of examining leaf characteristics has also been highlighted by Zhang et al. [24], emphasizing its importance in plant research.

3.3 Floral Characteristics

The data pertaining floral characteristics *viz.,* number of epicalyx segments, shape of epicalyx segments, persistence of epicalyx segments, petal color and red coloration of petal base is depicted in Table 1 and illustrated in Fig. 4. With respect to number of epicalyx segments, four distinct categories of epicalyx segment numbers were observed across the okra accessions. Twenty-six accessions (27.96%) i.e. *A. ficulneus* (12 accessions), *A. tuberculatus* (2 accessions), *A. caillei* (6 accessions), *A. angulosus* (4 accessions), *A. manihot* (VRO-W-MH-1) and *A. nova* (VRO-W-N-1) had 5-7 epicalyx segments, while 38 accessions (40.86%) i.e. *A. ficulneus* (7 accessions), *A. tuberculatus* (13 accessions), *A. moschatus* (13 accessions) and *A. esculentus* (P. Sawani, Arka Anamika, VRO-6, Kashi Vibhuti and VRO-R-8) had 8 to 10 epicalyx segments.

Table 1. List of accessions used in experiment

S. No.	Species	Genotypes
01.	***Abelmoschus ficulneus***	VRO-W-F-1, VRO-W-F-2, VRO-W-F-3, VRO-W-F-4, VRO-W-F-5, VRO-W-F-6, VRO-W-F-7, VRO-W-F-8, VRO-W-F-9, VRO-W-F-10, VRO-W-F-11, VRO-2-F-12, VRO-W-F-13, VR0-W-F-14, F-15, VRO-W-F-16, VRO-W-F-17, VRO-W-F-18 & VRO-W-F-19
02.	***Abelmoschus tuberculatus***	VRO-W-T-1, VRO-W T-2, VRO-W T-3, T-4, VRO-W-T-5, VRO-W-T-6, VRO-W-T-7, VRO-W-T-8, VRO-W-T-9, VRO-W-T-10, VRO-W-T-12, VRO-W-T-14, T-15, VRO-W-T-16 and VRO-W-T-17
03.	***Abelmoschus tetraphyllus***	VRO-W-TP-1, VRO-W-TP-3, VRO-W-TP-4, VRO-W-TP-12, VRO-W-TP-13, VRO-W-TP-16, VRO-W-TP-19, VRO-W-TP-22, VRO-W-TP-23, VRO-W-TP-24, VRO-W-TP-25, VRO-W-TP-20, VRO-W-TP-30, VRO-W-TP-31, VRO-W-TP-32, VRO-W-TPM-1, VRO-W-TPM-2, VRO-W-TPM-3, VRO-W-TPM-4, VRO-W-TPM-9, VRO-W-TPM-10, VRO-W-TPM-31, VRO-W-TPM-12, VRO-W-TPM-13, VRO-W-TPM-23 and VRO-W-TPM-34
04.	***Abelmoschus moschatus***	EC-360915, IC-140985, IC-470647, IC-021114, EC-361018, IC-039308, EC-360095, EC-361007, C-329394, EC-360953, EC-360915, IC-469583 and IC-47737
05.	***Abelmoschus caillei***	VRO-W-C-1, VRO-W-C-2, VRO-W-C-3, VRO-W-C-4, VRO-W-C-5 and VRO-W-C-6
06.	***Abelmoschus angulosus***	VRO-W-A-1, VRO-W-A-2, VRO-W-A-3 and VRO-W-A-4
07.	***Abelmoschus manihot***	VRO-W-MH-1
08.	***Abelmoschus crinitus***	VRO-W-CT-1 and VRO-W-CT-2
09.	***Abelmoschus enbeepeegearense***	VRO-W-EN-1
10.	***Abelmoschus nova***	VRO-W-N-1
11.	***Abelmoschus esculentus***	Pusa Sawani, Arka Anamika, VRO-6, Kashi Vibhuti and VRO-R-8

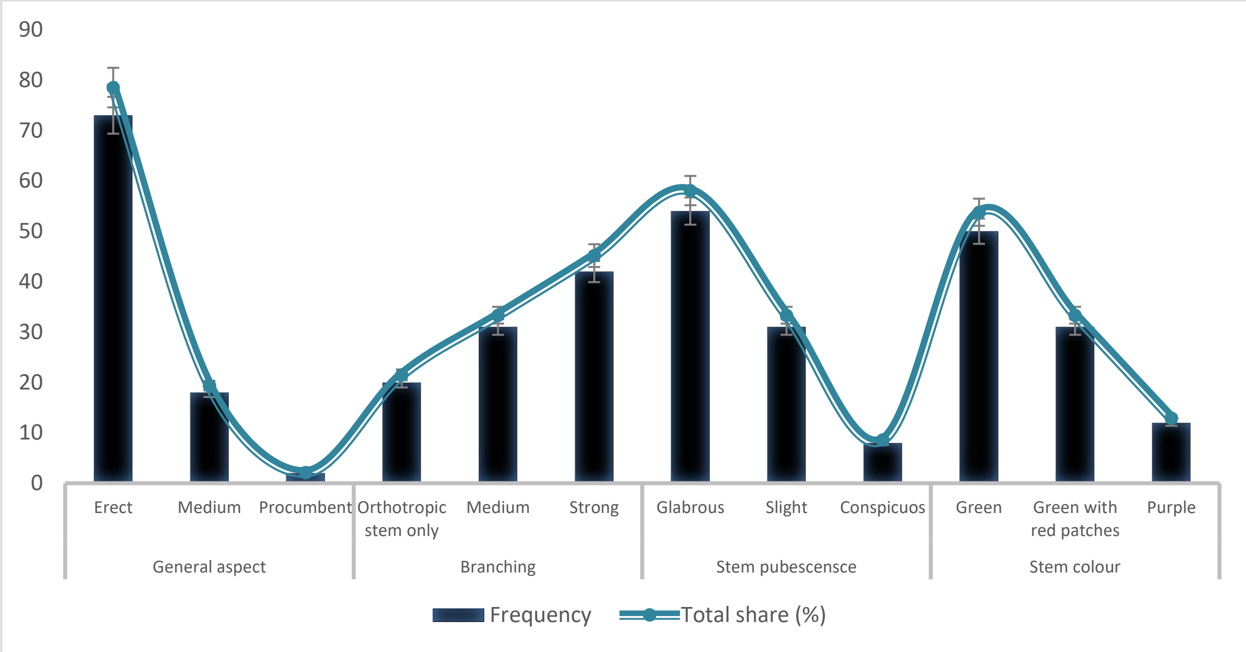

Fig. 1. Number of okra genotypes as distributed into categories of vegetative characteristics

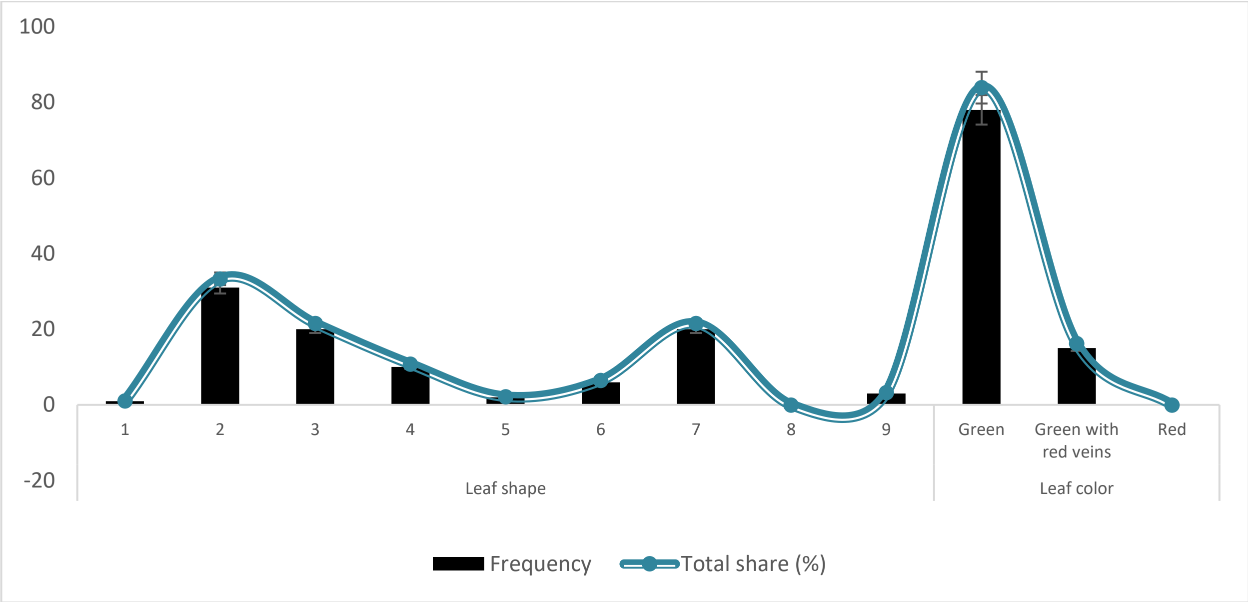

Fig. 2. Number of okra genotypes as distributed into categories of leaves characteristics

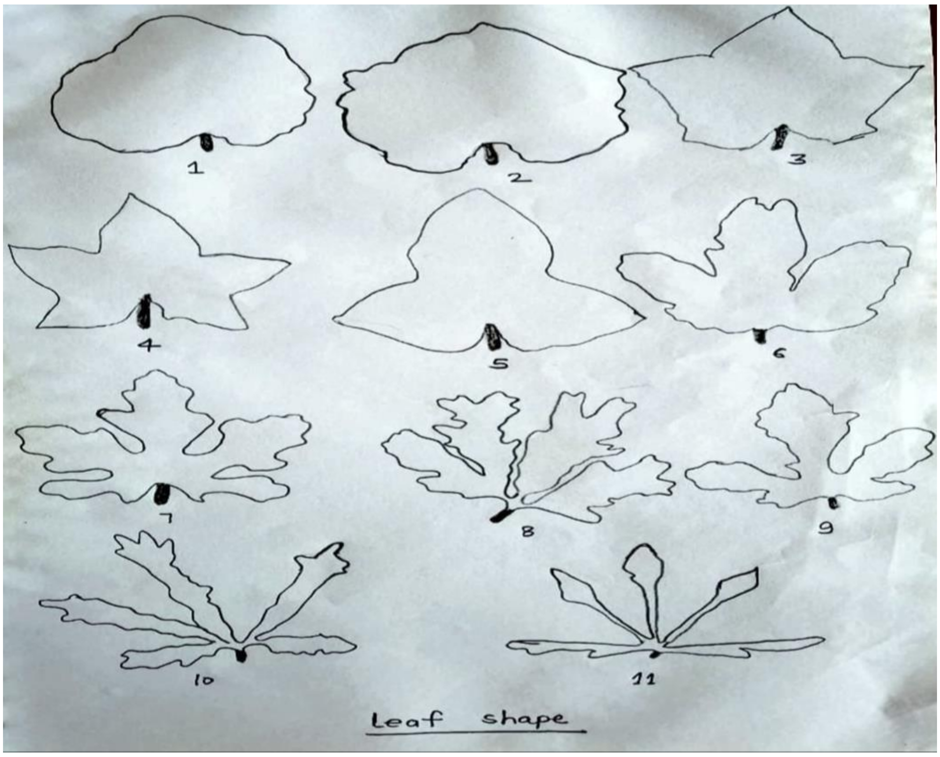

Fig. 3. Leaf Shape Descriptor Key for *Abelmoschus* (Medik.)

In contrast, 3 accessions (3.23%) two accession of *A. crinitus* (VRO-W-CT-1 and VRO-W-CT-2) and one accession of *A. enbeepeegearense* (VRO-W-EN-1) deviated significantly from this norm, demonstrating an exceptional characteristic with more than 10 epicalyx segments. Additionally, 15 accessions *A. tetraphyllus* and 11 accessions of *A. tetraphyllus spp. manihot* departed from the expected range had only 4 epicalyx segments, which falls outside the recommended guidelines set by IBPGR. This range of epicalyx segment numbers highlights the diversity within the okra accessions. This result is in accordance with Sandeep et al. [25] and contrary with Binalfew & Alemu [15] who found more than 10 epicalyx in 82.9% accessions. In terms of study of the shape of epicalyx the results showed that 56 accessions (60.22%) i.e. *A. ficulneus* (19 accessions), *A. tuberculatus* (15 accessions), *A. moschatus* (13 accessions), *A. crinitus* (VRO-W-CT-1 and VRO-W-CT-2), *A. enbeepeegearense* (VRO-W-EN-1) and *A. nova* (VRO-W-N-1) and *A. esculentus* (P. Sawani, Arka Anamika, VRO-6, Kashi Vibhuti and VRO-R-8) exhibited a linear epicalyx morphology, characterized by a narrow and elongated shape. Meanwhile, 6 accessions of *A. caillei* (accessions) and 1 accession of *A. angulosus* displayed a lanceolate epicalyx shape. Furthermore, 15 accessions of *A. tetraphyllus*, 11 accessions of *A. tetraphyllus spp. manihot* 3 accessions of *A. angulosus* and 1 accession of *A. manihot* (VRO-W-MH-1) showed a triangular epicalyx shape, indicating a broad and angular morphology. This diversity in epicalyx shape underscores the genetic variability within the accessions, presenting opportunities for okra improvement through targeted breeding programs. Similar findings was also reported by Sandeep et al. [25] and Saifullah and Rabbani [26] reported linear shape in 86 accessions, lanceolate in 32 accessions and triangular in 3 accessions. As far as epicalyx persistence is concern an examination of epicalyx persistence revealed variation in persistence of epicalyx among the accessions. Specifically, 59 accessions (63.44%) i.e. *A. ficulneus* (19 accessions), *A. tuberculatus* (10 accessions), *A. tetraphyllus* (7 accessions), *A. tetraphyllus spp. manihot* (6 accessions), *A. moschatus* (5 accessions), *A. caillei* (6 accessions), *A. enbeepeegearense* (VRO-W-EN-1) and *A. esculentus* (P. Sawani, Arka Anamika, VRO-6, Kashi Vibhuti and VRO-R-8) exhibited non-persistent epicalyx, characterized by complete abscission within seven days after flowering. In contrast, 5 accessions *A. tuberculatus*, 2 accessions of *A. moschatus*, 4 accessions of *A. angulosus* displayed partially persistent epicalyx, remaining attached for up to seven days post-flowering. Notably, 23 accessions (24.73%) i.e. *A. tetraphyllus* (8 accessions), *A. tetraphyllus spp. manihot* (5 accessions), *A. moschatus* (6 accessions), *A. manihot* (VRO-W-MH-1), *A. crinitus* (VRO-W-CT-1 and VRO-W-CT-2) and *A. nova* (VRO-W-N-1) showed persistent epicalyx, remaining attached beyond seven days after flowering. The diversity in epicalyx segment number, shape and persistence among okra accessions provides valuable insights for breeding programs, morphological studies and genetic research, offering opportunities to explore the genetic basis of epicalyx segment and its potential impact on okra's agronomic traits. Silva et al. [27] reported that majority of the accessions present from eight to 10 epicalyx segments, non-persistent and lanceolate in shape.

A study of petal coloration was conducted to assess the variation in floral characteristics among the accessions. The results showed that the 19 accessions (20.43%) of *A. ficulneus* exhibited unique white coloration of petals. Meanwhile, 2 accessions *A. tuberculatus*, 8 accessions of *A. tetraphyllus* and 8 accessions of *A. tetraphyllus spp. manihot* displayed cream coloured petals and the majority, 56 accessions (60.22%) i.e. *A. tuberculatus* (13 accessions), *A. tetraphyllus* (7 accessions), *A. tetraphyllus spp. manihot* (3 accessions), *A. moschatus* (13 accessions), *A. caillei* (6 accessions), *A. angulosus* (4 accessions), *A. manihot* (VRO-W-MH-1), *A. crinitus* (VRO-W-CT-1 and VRO-W-CT-2), *A. enbeepeegearense* (VRO-W-EN-1), *A. nova* (VRO-W-N-1) and *A. esculentus* (P. Sawani, Arka Anamika, VRO-6, Kashi Vibhuti and VRO-R-8) showed yellow coloration. This result is in accordance with Reddy et al. (2023) for cream and yellow color petal while white color in *A. ficulneus* was also found by Sandeep et al. [25]. In terms of red coloration of petal base the distribution of red pigmentation at the petal base exhibited a dichotomy among the accessions. A subset of 44 accessions (47.31%) i.e. *A. ficulneus* (19 accessions), *A. tuberculatus* (10 accessions), *A. tetraphyllus* (7 accessions), *A. tetraphyllus spp. manihot* (5 accessions), *A. caillei* (2 accessions) and *A. angulosus* (1 accession) displayed only one side red pigmentation, confined to the interior surface of the petal base. In contrast, 49 accessions (52.69%) i.e. *A. tuberculatus* (6 accessions), *A. tetraphyllus* (8 accessions), *A. tetraphyllus spp. manihot* (6 accessions), *A. moschatus* (13 accessions), *A. caillei* (4 accessions), *A. angulosus* (3 accessions), *A. manihot* (VRO-W-MH-1), *A. enbeepeegearense* (VRO-W-EN-1), *A. nova* (VRO-W-N-1) and *A. esculentus* (P. Sawani, Arka Anamika, VRO-6, Kashi Vibhuti and VRO-R-8) exhibited a both sides red color or bidirectional expression, with red coloration manifesting on both the adaxial and abaxial surfaces of the petal base. Reddy et al. (2023) also observed distribution of red coloration 31.6% accessions exhibiting coloration only on the inside and 68.4% accessions exhibiting coloration on both sides. Some researchers, Kyriakopoulou et al. [28] and Saifullah and Rabbani [26] were observed both sides red coloration in maximum accessions.

3.4 Fruits Characteristics

A comprehensive analysis of fruits characteristics i.e. length of peduncle (cm), positioning of fruit on main stem, fruit coloration, fruit pubescence and number of ridges per fruit is presented in Table 1 and Fig. 5. With respect to peduncle length data analysis resulting in the identification of two distinct morphological categories. The first group, comprising 73 accessions (78.49%) i.e. *A. ficulneus* (19 accessions), *A. tuberculatus* (15 accessions), *A. tetraphyllus* (15 accessions), *A. tetraphyllus spp. manihot* (8 accessions), *A. caillei* (6 accessions), *A. angulosus* (accessions), *A. enbeepeegearense* (VRO-W-EN-1) and *A. esculentus* (P. Sawani, Arka Anamika, VRO-6, Kashi Vibhuti and VRO-R-8) exhibited peduncles length within the 1-3 cm range. In stark contrast, 20 accessions (21.51%) i.e. *A. tetraphyllus spp. manihot* (3 accessions), *A. moschatus* (13 accessions), *A. manihot* (VRO-W-MH-1), *A. crinitus* (VRO-W-CT-1 and VRO-W-CT-2) and *A. nova* (VRO-W-N-1) exhibited longer peduncles exceeding 3 cm in length indicating a notable deviation from the predominant pattern. This pronounced disparity in peduncle length underscores the extensive genetic diversity inherent to the okra accessions, providing a valuable foundation for future research endeavors, plant breeding initiatives and genetic studies aimed at elucidating the underlying mechanisms governing this trait. Similarly, comparable results were reported by other investigators, including Anyaoha et al. [17] and Silva et al. [27]. The fruit positioning on the main stem exhibited a uniform pattern among the accessions, with 93 accessions (100%) displaying an erect orientation. Notably, no accessions exhibited horizontal or pendulous fruit positioning, indicating a consistent upright growth habit. This findings is in accordance with the result of Komolafe et al. [29] and Silva et al. [27].

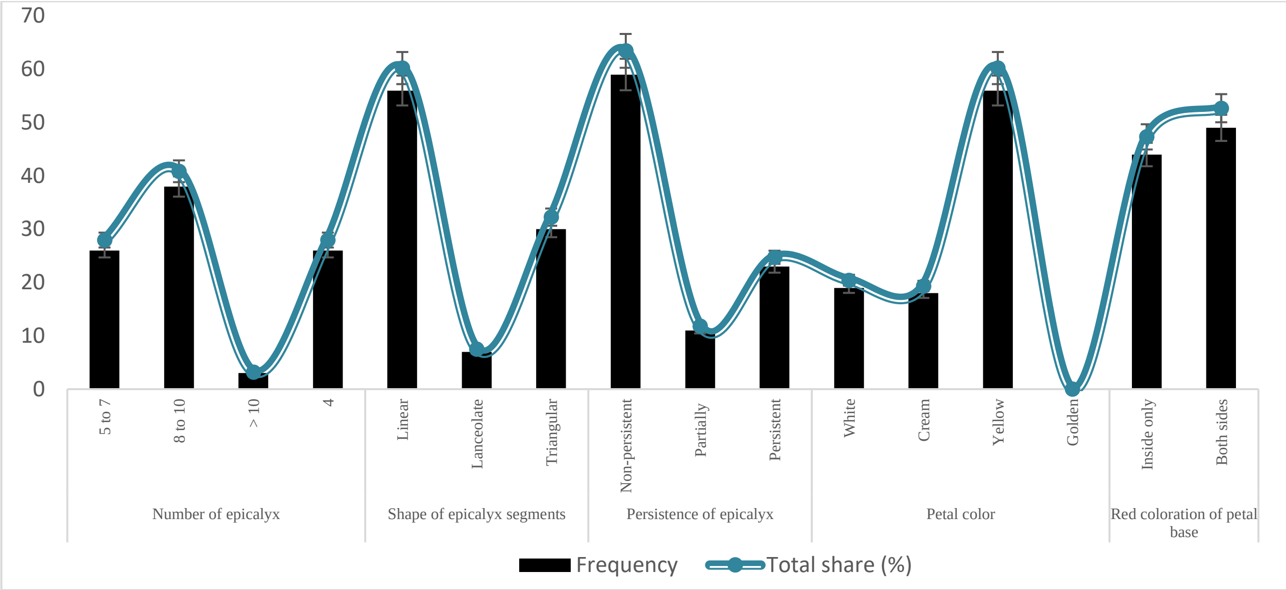

Fig. 4. Number of okra genotypes as distributed into categories of floral characteristics

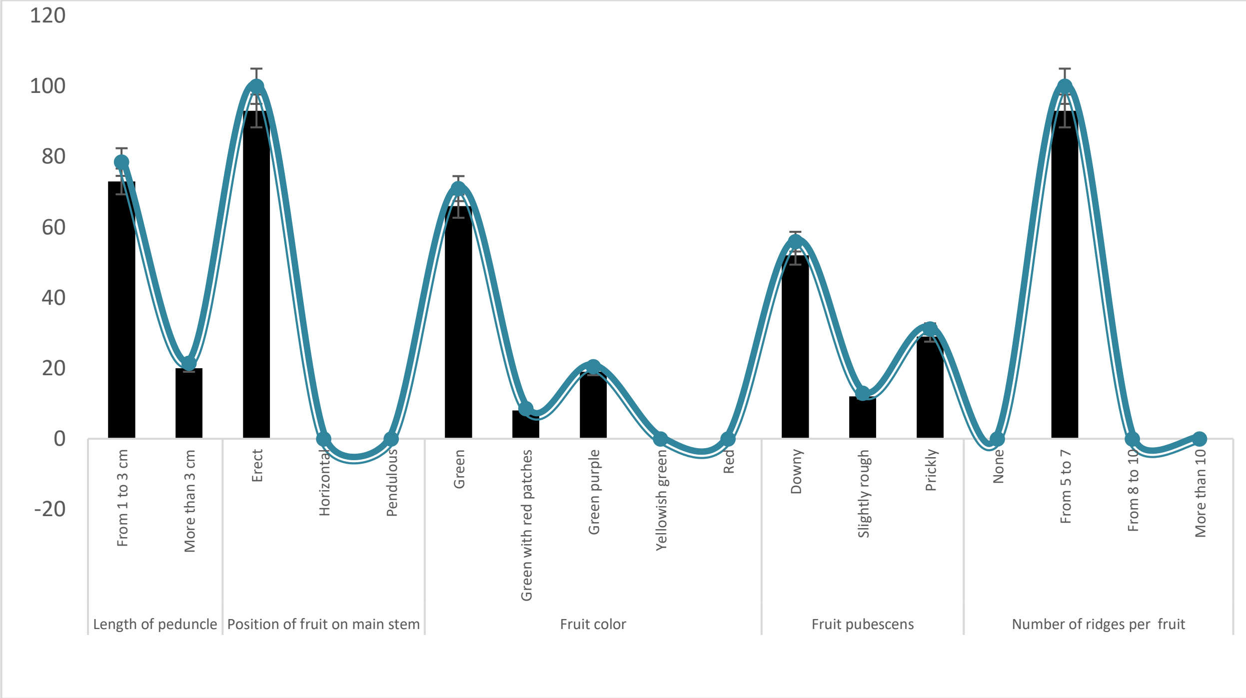

Fig. 5. Number of okra genotypes as distributed into categories of fruits characteristics

(a) (b) (c)

Fig. 6. Variation in stem color among the okra genotypes: a) Green, b) Green with red patches c) Purple

(a) (b)

Fig. 7. Variation in leaf color among the okra genotypes: a) Green and b) Green with red veins

(a) (b) (c)

Fig. 8. Variation in petal color among the okra genotypes: a) White, b) Cream and c) Yellow

The observation on fruit coloration exhibited variation among the accessions with a range of hues observed. The majority of accessions, 66 (70.97%) i.e. *A. tuberculatus* (15 accessions), *A. tetraphyllus* (11 accessions), *A. tetraphyllus spp. manihot* (15 accessions), *A. moschatus* (3 accessions), *A. caillei* (6 accessions), *A. angulosus* (4 accessions), *A. manihot* (VRO-W-MH-1), *A. crinitus* (VRO-W-CT-1 and VRO-W-CT-2), *A. enbeepeegearense* (VRO-W-EN-1), *A. nova* (VRO-W-N-1) and *A. esculentus* (P. Sawani, Arka Anamika, VRO-6, Kashi Vibhuti and VRO-R-8) displayed green fruit, while 8 accessions (8.60%) *A. moschatus* showed green fruit with red patches. A distinct subgroup of *A. ficulneus* 19 accessions (20.43%) of *A. ficulneus* exhibited a unique green-purple coloration. Notably, no accessions displayed yellowish green or red fruit coloration. This result is in agreement with previous studies, Oppong-Sekyere et al. [18] and Temam et al. [19]. The examination of fruit pubescence exhibited variation among the accessions, with three distinct textures observed. The majority of accessions 52 (55.91%) i.e. *A. ficulneus* (19 accessions), *A. tuberculatus* (6 accessions), *A. tetraphyllus* (11 accessions), *A. tetraphyllus spp. manihot* (4 accessions), *A. moschatus* (4 accessions), *A. caillei* (2 accessions), *A. enbeepeegearense* (VRO-W-EN-1) and *A. esculentus* (P. Sawani, Arka Anamika, VRO-6, Kashi Vibhuti and VRO-R-8), displayed downy fruit pubescence. A smaller subgroup of 4 accessions *A. tuberculatus,* 1 accession of *A. tetraphyllus spp. manihot*, 3 accessions of *A. moschatus*, 4 accessions of *A. caillei* showed slightly rough fruit, indicating a moderate degree of pubescence. Notably, 29 accessions (31.18%) i.e. *A. tuberculatus* (5 accessions), *A. tetraphyllus* (4 accessions), *A. tetraphyllus spp. manihot* (6 accessions), *A. moschatus* (6 accessions), *A. angulosus* (4 accessions), *A. manihot* (VRO-W-MH-1), *A. crinitus* (VRO-W-CT-1 and VRO-W-CT-2), and *A. nova* (VRO-W-N-1) exhibited prickly fruit, suggesting a more pronounced and rigid pubescence. These findings are also supports those of Bish et al. (1995), Anyaoha et al. [17] and Thomas (1991) who found the downy type of fruit pubescence to be the most pronounced, followed by slightly rough, while prickly fruits were the least in the okra accessions. The number of ridges per fruit exhibited a uniform pattern among the accessions, with 93 accessions (100%) exhibited a 5 ridges. Notably, no accessions had 0 ridges (0%), 8 to 10 ridges (0%), or more than 10 ridges (0%), indicating a consistent and limited variation in fruit ridge number. Similar findings have also been documented by other researchers, Das et al*.* (2022), Silva et al. [27] and Anyaoha et al. [17]. The presence of variation in fruit color, pubescence and peduncle length among accessions offers a valuable resource for genetic improvement of crops. Fruit color variation can enhance visual appeal and market value, while differences in pubescence can influence disease resistance and pest tolerance. Additionally, variation in peduncle length can impact fruit positioning, exposure and yield potential. Harnessing this genetic diversity through selective breeding can lead to the development of elite crop varieties with improved quality, resilience and productivity, thereby addressing the evolving needs of agriculture and food security. Variation in fruit color was also reported by Salim et al. [30] in tomato.

(a) **(b)** **(c)**

Fig. 9. Variation in fruit color among the okra genotypes: a) Green, b) Green with red patches and c) Green-purple

Table 2. Distribution of okra genotypes by qualitative traits: number of genotypes (frequency) and total (%) based on IBPGR (1984) descriptor

Descriptor	State	Frequency	Total (%)	Accessions
General aspect	Erect	73	78.49	VRO-W-F-2, VRO-W-F-4, VRO-W-F-6, VRO-W-F-7, VRO-W-F-8, VRO-W-F-9, VRO-W-F-10, VRO-W-F-12, VR0-W-F-14, VRO-W-F-15, VRO-W-F-16, VRO-W-F-18, VRO-W-T-1, VRO-W-T-2, VRO-W-T-3, VRO-W-T-4, VRO-W-T-7, VRO-W-T-8, VRO-W-T-9, VRO-W-T-10, VRO-W-T-12, VRO-W-T-14, VRO-W-T-15, VRO-W-T-16, VRO-W-T-17, VRO-W-TP-3, VRO-W-TP-12, VRO-W-TP-13, VRO-W-TP-16, VRO-W-TP-19, VRO-W-TP-24, VRO-W-TP-25, VRO-W-TP-20, VRO-W-TP-30, VRO-W-TP-31, VRO-W-TP-32, VRO-W-TPM-1, VRO-W-TPM-2, VRO-W-TPM-3, VRO-W-TPM-4, VRO-W-TPM-9, VRO-W-TPM-10, VRO-W-TPM-31, VRO-W-TPM-12, VRO-W-TPM-13, VRO-W-TPM-23, VRO-W-TPM-34, EC-360915, IC-039308, EC-360095, EC-361007, EC-329394, EC-360953, EC-360853, IC-469583, IC-47737, VRO-W-C-1, VRO-W-C-2, VRO-W-C-3, VRO-W-C-4, VRO-W-C-5, VRO-W-C-6, VRO-W-A-1, VRO-W-A-2, VRO-W-A-3, VRO-W-A-4, VRO-W-MH-1, VRO-W-N-1, VRO-R-8 ©, Pusa Sawani ©, Arka Anamika ©, VRO-6 © and Kashi Vibhuti ©
	Medium	18	19.35	VRO-W-F-1, VRO-W-F-3, VRO-W-F-5, VRO-W-F-11, VRO-W-F-13, VRO-W-F-17, VRO-W-F-19, VRO-W-T-5, VRO-W-T-6, VRO-W-TP-1, VRO-W-TP-4, VRO-W-TP-22, VRO-W-TP-23, IC-140985, IC-470647, IC-021114, EC-361018 and VRO-W-EN-1
	Procumbent	2	2.15	VRO-W_CT-1 and VRO-W-CT-1
Branching	Orthotropic stem only	20	21.51	VRO-W-F-15, VRO-W-T-1, VRO-W-T-3, VRO-W-T-4, VRO-W-T-6, VRO-W-T-7, VRO-W-T-9, VRO-W-T-10, VRO-W-T-12, VRO-W-T-14, VRO-W-T-15, VRO-W-T-16, VRO-W-T-17, VRO-W-TP-12, VRO-W-TP-23, VRO-W-TP-20, EC-361018, VRO-W-A-2, VRO-W-A-4 and VRO-6 ©
	Medium	31	33.33	VRO-W-F-7, VRO-W-F-9, VRO-W-F-18, VRO-W-F-19, VRO-W-T-2, VRO-W-T-5, VRO-W-T-8, VRO-W-TP-3, VRO-W-TP-16, VRO-W-TP-19, VRO-W-TP-22, VRO-W-TP-24, VRO-W-TP-25, VRO-W-TP-30, VRO-W-TPM-2, EC-360953, IC-469583, IC-47737, VRO-W-C-1, VRO-W-C-2, VRO-W-C-4, VRO-W-C-5, VRO-W-C-6, VRO-W-A-1, VRO-W-A-3, VRO-W-CT-1, VRO-W-CT-2, VRO-R-8 ©, Pusa Sawani ©, Arka Anamika © and Kashi Vibhuti ©
	Strong	42	45.16	VRO-W-F-1, VRO-W-F-2, VRO-W-F-3, VRO-W-F-4, VRO-W-F-5, VRO-W-F-6, VRO-W-F-8, VRO-W-F-10, VRO-W-F-11, VRO-W-F-12, VRO-W-F-13, VR0-W-F-14, VRO-W-F-16, VRO-W-F-17, VRO-W-TP-1, VRO-W-TP-4, VRO-W-TP-13, VRO-W-TP-31, VRO-W-TP-32, VRO-W-TPM-1, VRO-W-TPM-3, VRO-W-TPM-4, VRO-W-TPM-9, VRO-W-TPM-10, VRO-W-TPM-31, VRO-W-TPM-12, VRO-W-TPM-13, VRO-W-TPM-23, VRO-W-TPM-34, EC-360915, IC-140985, IC-470647, IC-021114, IC-039308, EC-360095, EC-361007, EC-329394, EC-360853, VRO-W-C-3, VRO-W-MH-1, VRO-W-EN-1 and VRO-W-N-1

Descriptor	State	Frequency	Total (%)	Accessions
Stem pubescence	Glabrous	54	58.06	VRO-W-F-1, VRO-W-F-2, VRO-W-F-3, VRO-W-F-4, VRO-W-F-5, VRO-W-F-6, VRO-W-F-7, VRO-W-F-8, VRO-W-F-9, VRO-W-F-10, VRO-W-F-11, VRO-W-F-12, VRO-W-F-13, VR0-W-F-14, VRO-W-F-15, VRO-W-F-16, VRO-W-F-17, VRO-W-F-18, VRO-W-F-19, VRO-W-T-1, VRO-W-T-2, VRO-W-T-3, VRO-W-T-4, VRO-W-T-7, VRO-W-T-8, VRO-W-T-9, VRO-W-T-12, VRO-W-T-14, VRO-W-T-16, VRO-W-TP-1, VRO-W-TP-3, VRO-W-TP-13, VRO-W-TP-24, VRO-W-TP-31, VRO-W-TPM-1, VRO-W-TPM-3, VRO-W-TPM-4, VRO-W-TPM-9, VRO-W-TPM-31, VRO-W-TPM-23, VRO-W-TPM-34, IC-470647, IC-021114, EC-329394, EC-360853, VRO-W-C-5, VRO-W-A-2, VRO-W-CT-1, VRO-W-CT-2, VRO-R-8 ©, Pusa Sawani ©, Arka Anamika ©, VRO-6 © and Kashi Vibhuti ©
	Slight	31	33.33	VRO-W-T-5, VRO-W-T-6, VRO-W-T-10, VRO-W-T-15, VRO-W-T-17, VRO-W-TP-4, VRO-W-TP-12, VRO-W-TP-16, VRO-W-TP-19, VRO-W-TP-22, VRO-W-TP-23, VRO-W-TP-25, VRO-W-TP-20, VRO-W-TP-30, VRO-W-TP-32, VRO-W-TPM-2, VRO-W-TPM-10, VRO-W-TPM-12, VRO-W-TPM-13, EC-360915, IC-140985, IC-039308, EC-360095, VRO-W-C-1, VRO-W-C-2, VRO-W-C-4, VRO-W-C-6, VRO-W-A-1, VRO-W-A-3, VRO-W-A-4 and VRO-W-EN-1
	Conspicuous	8	8.60	EC-361018, EC-361007, EC-360953, IC-469583, IC-47737, VRO-W-C-3, VRO-W-MH-1 and VRO-W-N-1.
Stem colour	Green	50	53.76	VRO-W-T-1, VRO-W-T-2, VRO-W-T-3, VRO-W-T-4, VRO-W-T-5, VRO-W-T-6, VRO-W-T-7, VRO-W-T-8, VRO-W-T-9, VRO-W-T-10, VRO-W-T-12, VRO-W-T-14, VRO-W-T-15, VRO-W-T-16, VRO-W-T-17, VRO-W-TP-1, VRO-W-TP-4, VRO-W-TP-20, VRO-W-TPM-3, VRO-W-TPM-9, VRO-W-TPM-10, VRO-W-TPM-31, VRO-W-TPM-23, VRO-W-TPM-34, IC-470647, IC-021114, EC-361018, IC-039308, EC-360953, IC-47737, VRO-W-C-1, VRO-W-C-2, VRO-W-C-3, VRO-W-C-4, VRO-W-C-5, VRO-W-C-6, VRO-W-A-1, VRO-W-A-2, VRO-W-A-3, VRO-W-A-4, VRO-W-MH-1, VRO-W-CT-1, VRO-W-CT-2, VRO-W-EN-1, VRO-W-N-1, VRO-R-8 ©, Pusa Sawani ©, Arka Anamika ©, VRO-6 © and Kashi Vibhuti ©
	Green with red patches	31	33.33	VRO-W-F-1, VRO-W-F-2, VRO-W-F-3, VRO-W-F-4, VRO-W-F-5, VRO-W-F-6, VRO-W-F-7, VRO-W-F-8, VRO-W-F-9, VRO-W-F-10, VRO-W-F-11, VRO-W-F-12, VRO-W-F-13, VR0-W-F-14, VRO-W-F-15, VRO-W-F-16, VRO-W-F-17, VRO-W-F-18, VRO-W-F-19, VRO-W-TP-13, VRO-W-TP-16, VRO-W-TP-22, VRO-W-TP-23, VRO-W-TPM-12, EC-360915, IC-140985, EC-360095, EC-361007, EC-329394, EC-360853 and IC-469583.
	Purple	12	12.90	VRO-W-TP-3, VRO-W-TP-12, VRO-W-TP-19, VRO-W-TP-24, VRO-W-TP-25, VRO-W-TP-30, VRO-W-TP-31, VRO-W-TP-32, VRO-W-TPM-1, VRO-W-TPM-2, VRO-W-TPM-4 and VRO-W-TPM-13.

Descriptor	State	Frequency	Total (%)	Accessions
Leaf shape	1	1	1.08	VRO-W-EN-1
	2	31	33.33	VRO-W-T-1, VRO-W-T-3, VRO-W-T-4, VRO-W-T-6, VRO-W-T-7, VRO-W-T-8, VRO-W-T-9, VRO-W-T-10, VRO-W-T-12, VRO-W-T-14, VRO-W-T-15, VRO-W-T-16, VRO-W-T-17, VRO-W-TP-16, VRO-W-TP-19, VRO-W-TP-22, VRO-W-TP-23, VRO-W-TP-24, VRO-W-TP-25, VRO-W-TP-20, IC-039308, VRO-W-C-1, VRO-W-C-2, VRO-W-C-3, VRO-W-C-4, VRO-W-C-5, VRO-W-C-6, VRO-W-A-1, VRO-W-A-2, VRO-W-A-4 and VRO-W-N-1.
	3	20	21.51	VRO-W-T-2, VRO-W-TP-1, VRO-W-TP-4, VRO-W-TP-12, VRO-W-TP-13, VRO-W-TP-31, VRO-W-TP-32, IC-140985, IC-021114, EC-361018, EC-361007, EC-329394, EC-360953, IC-469583, VRO-W-A-3, VRO-R-8 ©, Pusa Sawani ©, Arka Anamika ©, VRO-6 © and Kashi Vibhuti ©
	4	10	10.75	VRO-W-T-5, VRO-W-TPM-3, VRO-W-TPM-4, VRO-W-TPM-9, VRO-W-TPM-10, VRO-W-TPM-12, VRO-W-TPM-13, IC-470647, IC-47737 and VRO-W-MH-1
	5	2	2.15	VRO-W-CT-1 and VRO-W-CT-2
	6	6	6.45	VRO-W-TP-3, VRO-W-TPM-1, VRO-W-TPM-2, EC-360915, EC-360095 and EC-360853
	7	20	21.51	VRO-W-F-1, VRO-W-F-3, VRO-W-F-4, VRO-W-F-5, VRO-W-F-6, VRO-W-F-8, VRO-W-F-9, VRO-W-F-10, VRO-W-F-11, VRO-W-F-12, VRO-W-F-13, VR0-W-F-14, VRO-W-F-15, VRO-W-F-16, VRO-W-F-18, VRO-W-F-19, VRO-W-TP-30, VRO-W-TPM-31, VRO-W-TPM-23 and VRO-W-TPM-34
	8	0	0.00	
	9	3	3.23	VRO-W-F-2, VRO-W-F-7 and VRO-W-F-17
Leaf color	Green	78	83.87	VRO-W-F-1, VRO-W-F-2, VRO-W-F-3, VRO-W-F-4, VRO-W-F-5, VRO-W-F-6, VRO-W-F-7, VRO-W-F-8, VRO-W-F-9, VRO-W-F-10, VRO-W-F-11, VRO-W-F-12, VRO-W-F-13, VR0-W-F-14, VRO-W-F-15, VRO-W-F-16, VRO-W-F-17, VRO-W-F-18, VRO-W-F-19, VRO-W-T-1, VRO-W-T-2, VRO-W-T-3, VRO-W-T-4, VRO-W-T-5, VRO-W-T-6, VRO-W-T-7, VRO-W-T-8, VRO-W-T-9, VRO-W-T-10, VRO-W-T-12, VRO-W-T-14, VRO-W-T-15, VRO-W-T-16, VRO-W-T-17, VRO-W-TP-1, VRO-W-TP-3, VRO-W-TP-4, VRO-W-TP-12, VRO-W-TP-13, VRO-W-TP-16, VRO-W-TP-19, VRO-W-TP-22, VRO-W-TP-23, VRO-W-TP-24, VRO-W-TP-25, VRO-W-TP-20, VRO-W-TP-30, VRO-W-TP-31, VRO-W-TP-32, VRO-W-TPM-1, VRO-W-TPM-2, VRO-W-TPM-3, VRO-W-TPM-4, VRO-W-TPM-9, VRO-W-TPM-10, VRO-W-TPM-31, VRO-W-TPM-12, VRO-W-TPM-13, VRO-W-TPM-23, VRO-W-TPM-34, IC-039308, EC-361007, IC-469583, IC-47737, VRO-W-A-1, VRO-W-A-2, VRO-W-A-3, VRO-W-A-4, VRO-W-MH-1, VRO-W-CT-1, VRO-W-CT-2, VRO-W-EN-1, VRO-W-N-1, VRO-R-8 ©, Pusa Sawani ©, Arka Anamika ©, VRO-6 © and Kashi Vibhuti ©
	Green with red veins	15	16.13	EC-360915, IC-140985, IC-470647, IC-021114, EC-361018, EC-360095, EC-329394, EC-360953, EC-360853, VRO-W-C-1, VRO-W-C-2, VRO-W-C-3, VRO-W-C-4, VRO-W-C-5 and

Descriptor	State	Frequency	Total (%)	Accessions
				VRO-W-C-6
	Red	0	0.00	
Number of epicalyx segments	From 5 to 7	26	27.96	VRO-W-F-1, VRO-W-F-2, VRO-W-F-3, VRO-W-F-5, VRO-W-F-6, VRO-W-F-7, VRO-W-F-9, VRO-W-F-11, VRO-W-F-12, VRO-W-F-13, VR0-W-F-14, VRO-W-F-16, VRO-W-T-5, VRO-W-T-8, VRO-W-C-1, VRO-W-C-2, VRO-W-C-3, VRO-W-C-4, VRO-W-C-5, VRO-W-C-6, VRO-W-A-1, VRO-W-A-2, VRO-W-A-3, VRO-W-A-4, VRO-W-MH-1, VRO-W-N-1
	From 8 to 10	38	40.86	VRO-W-F-4, VRO-W-F-8, VRO-W-F-10, VRO-W-F-15, VRO-W-F-17, VRO-W-F-18, VRO-W-F-19, VRO-W-T-1, VRO-W-T-2, VRO-W-T-3, VRO-W-T-4, VRO-W-T-6, VRO-W-T-7, VRO-W-T-9, VRO-W-T-10, VRO-W-T-12, VRO-W-T-14, VRO-W-T-15, VRO-W-T-16, VRO-W-T-17, EC-360915, IC-140985, IC-470647, IC-021114, EC-361018, IC-039308, EC-360095, EC-361007, EC-329394, EC-360953, EC-360853, IC-469583, IC-47737, VRO-R-8 ©, Pusa Sawani ©, Arka Anamika ©, VRO-6 © and Kashi Vibhuti ©.
	More than 10	3	3.23	VRO-W-CT-1, VRO-W-CT-2 and VRO-W-EN-1
	Less than 5 (4)	26	27.96	VRO-W-TP-1, VRO-W-TP-3, VRO-W-TP-4, VRO-W-TP-12, VRO-W-TP-13, VRO-W-TP-16, VRO-W-TP-19, VRO-W-TP-22, VRO-W-TP-23, VRO-W-TP-24, VRO-W-TP-25, VRO-W-TP-20, VRO-W-TP-30, VRO-W-TP-31, VRO-W-TP-32, VRO-W-TPM-1, VRO-W-TPM-2, VRO-W-TPM-3, VRO-W-TPM-4, VRO-W-TPM-9, VRO-W-TPM-10, VRO-W-TPM-31, VRO-W-TPM-12, VRO-W-TPM-13, VRO-W-TPM-23 and VRO-W-TPM-34.
Shape of epicalyx segments	Linear	56	60.22	VRO-W-F-1, VRO-W-F-2, VRO-W-F-3, VRO-W-F-4, VRO-W-F-5, VRO-W-F-6, VRO-W-F-7, VRO-W-F-8, VRO-W-F-9, VRO-W-F-10, VRO-W-F-11, VRO-W-F-12, VRO-W-F-13, VR0-W-F-14, VRO-W-F-15, VRO-W-F-16, VRO-W-F-17, VRO-W-F-18, VRO-W-F-19, VRO-W-T-1, VRO-W-T-2, VRO-W-T-3, VRO-W-T-4, VRO-W-T-5, VRO-W-T-6, VRO-W-T-7, VRO-W-T-8, VRO-W-T-9, VRO-W-T-10, VRO-W-T-12, VRO-W-T-14, VRO-W-T-15, VRO-W-T-16, VRO-W-T-17, EC-360915, IC-140985, IC-470647, IC-021114, EC-361018, IC-039308, EC-360095, EC-361007, EC-329394, EC-360953, EC-360853, IC-469583, IC-47737, VRO-W-CT-1, VRO-W-CT-2, VRO-W-EN-1, VRO-W-N-1, VRO-R-8 ©, Pusa Sawani ©, Arka Anamika ©, VRO-6 © and Kashi Vibhuti ©.
	Lanceolate	7	7.53	VRO-W-C-1, VRO-W-C-2, VRO-W-C-3, VRO-W-C-4, VRO-W-C-5, VRO-W-C-6, VRO-W-A-2.
	Triangular	30	32.26	VRO-W-TP-1, VRO-W-TP-3, VRO-W-TP-4, VRO-W-TP-12, VRO-W-TP-13, VRO-W-TP-16, VRO-W-TP-19, VRO-W-TP-22, VRO-W-TP-23, VRO-W-TP-24, VRO-W-TP-25, VRO-W-TP-20, VRO-W-TP-30, VRO-W-TP-31, VRO-W-TP-32, VRO-W-TPM-1, VRO-W-TPM-2, VRO-W-TPM-3, VRO-W-TPM-4, VRO-W-TPM-9, VRO-W-TPM-10, VRO-W-TPM-31, VRO-W-TPM-12, VRO-W-TPM-13, VRO-W-TPM-23, VRO-W-TPM-34, VRO-W-A-1, VRO-W-A-3, VRO-W-A-4 and VRO-W-MH-1.

Descriptor	State	Frequency	Total (%)	Accessions
Persistence of epicalyx segments	Non-persistent seven days after flowering	59	63.44	VRO-W-F-1, VRO-W-F-2, VRO-W-F-3, VRO-W-F-4, VRO-W-F-5, VRO-W-F-6, VRO-W-F-7, VRO-W-F-8, VRO-W-F-9, VRO-W-F-10, VRO-W-F-11, VRO-W-F-12, VRO-W-F-13, VR0-W-F-14, VRO-W-F-15, VRO-W-F-16, VRO-W-F-17, VRO-W-F-18, VRO-W-F-19, VRO-W-T-1, VRO-W-T-3, VRO-W-T-4, VRO-W-T-6, VRO-W-T-7, VRO-W-T-8, VRO-W-T-10, VRO-W-T-14, VRO-W-T-16, VRO-W-T-17, VRO-W-TP-4, VRO-W-TP-13, VRO-W-TP-19, VRO-W-TP-22, VRO-W-TP-24, VRO-W-TP-25, VRO-W-TP-20, VRO-W-TPM-9, VRO-W-TPM-10, VRO-W-TPM-12, VRO-W-TPM-13, VRO-W-TPM-23, VRO-W-TPM-34, EC-361018, EC-360095, EC-361007, EC-360953, EC-360853, VRO-W-C-1, VRO-W-C-2, VRO-W-C-3, VRO-W-C-4, VRO-W-C-5, VRO-W-C-6, VRO-W-EN-1, VRO-R-8 ©, Pusa Sawani ©, Arka Anamika ©, VRO-6 © and Kashi Vibhuti ©
	Partially persistent (up to seven days)	11	11.83	VRO-W-T-2, VRO-W-T-5, VRO-W-T-9, VRO-W-T-12, VRO-W-T-15, IC-140985, IC-021114, VRO-W-A-1, VRO-W-A-2, VRO-W-A-3 and VRO-W-A-4
	Persistent	23	24.73	VRO-W-TP-1, VRO-W-TP-3, VRO-W-TP-12, VRO-W-TP-16, VRO-W-TP-23, VRO-W-TP-30, VRO-W-TP-31, VRO-W-TP-32, VRO-W-TPM-1, VRO-W-TPM-2, VRO-W-TPM-3, VRO-W-TPM-4, VRO-W-TPM-31, EC-360915, IC-470647, IC-039308, EC-329394, IC-469583, IC-47737, VRO-W-MH-1, VRO-W-CT-1, VRO-W-CT-2 and VRO-W-N-1
Petal color	White (Specific)	19	20.43	VRO-W-F-1, VRO-W-F-2, VRO-W-F-3, VRO-W-F-4, VRO-W-F-5, VRO-W-F-6, VRO-W-F-7, VRO-W-F-8, VRO-W-F-9, VRO-W-F-10, VRO-W-F-11, VRO-W-F-12, VRO-W-F-13, VR0-W-F-14, VRO-W-F-15, VRO-W-F-16, VRO-W-F-17, VRO-W-F-18 and VRO-W-F-19
	Cream	18	19.35	VRO-W-T-7, VRO-W-T-12, VRO-W-TP-3, VRO-W-TP-4, VRO-W-TP-12, VRO-W-TP-16, VRO-W-TP-19, VRO-W-TP-22, VRO-W-TP-23, VRO-W-TP-25, VRO-W-TPM-1, VRO-W-TPM-2, VRO-W-TPM-3, VRO-W-TPM-4, VRO-W-TPM-31, VRO-W-TPM-13, VRO-W-TPM-23 and VRO-W-TPM-34
	Yellow	56	60.22	VRO-W-T-1, VRO-W-T-2, VRO-W-T-3, VRO-W-T-4, VRO-W-T-5, VRO-W-T-6, VRO-W-T-8, VRO-W-T-9, VRO-W-T-10, VRO-W-T-14, VRO-W-T-15, VRO-W-T-16, VRO-W-T-17, VRO-W-TP-1, VRO-W-TP-13, VRO-W-TP-24, VRO-W-TP-20, VRO-W-TP-30, VRO-W-TP-31, VRO-W-TP-32, VRO-W-TPM-9, VRO-W-TPM-10, VRO-W-TPM-12, EC-360915, IC-140985, IC-470647, IC-021114, EC-361018, IC-039308, EC-360095, EC-361007, EC-329394, EC-360953, EC-360853, IC-469583, IC-47737, VRO-W-C-1, VRO-W-C-2, VRO-W-C-3, VRO-W-C-4, VRO-W-C-5, VRO-W-C-6, VRO-W-A-1, VRO-W-A-2, VRO-W-A-3, VRO-W-A-4, VRO-W-MH-1, VRO-W-CT-1, VRO-W-CT-2, VRO-W-EN-1, VRO-W-N-1, VRO-R-8 ©, Pusa Sawani ©, Arka Anamika ©, VRO-6 © and Kashi Vibhuti ©

Descriptor	State	Frequency	Total (%)	Accessions
	Golden	0	0.00	
Red coloration of petal base	Inside only	44	47.31	VRO-W-F-1, VRO-W-F-2, VRO-W-F-3, VRO-W-F-4, VRO-W-F-5, VRO-W-F-6, VRO-W-F-7, VRO-W-F-8, VRO-W-F-9, VRO-W-F-10, VRO-W-F-11, VRO-W-F-12, VRO-W-F-13, VR0-W-F-14, VRO-W-F-15, VRO-W-F-16, VRO-W-F-17, VRO-W-F-18, VRO-W-F-19, VRO-W-T-1, VRO-W-T-2, VRO-W-T-3, VRO-W-T-4, VRO-W-T-5, VRO-W-T-6, VRO-W-T-8, VRO-W-T-9, VRO-W-T-10, VRO-W-T-12, VRO-W-TP-13, VRO-W-TP-16, VRO-W-TP-22, VRO-W-TP-23, VRO-W-TP-20, VRO-W-TP-31, VRO-W-TP-32, VRO-W-TPM-1, VRO-W-TPM-2, VRO-W-TPM-4, VRO-W-TPM-10, VRO-W-TPM-12, VRO-W-C-3, VRO-W-C-4 and VRO-W-A-1
	Both sides	49	52.69	VRO-W-T-7, VRO-W-T-14, VRO-W-T-15, VRO-W-T-16, VRO-W-T-17, VRO-W-TP-1, VRO-W-TP-3, VRO-W-TP-4, VRO-W-TP-12, VRO-W-TP-19, VRO-W-TP-24, VRO-W-TP-25, VRO-W-TP-30, VRO-W-TPM-3, VRO-W-TPM-9, VRO-W-TPM-31, VRO-W-TPM-13, VRO-W-TPM-23, VRO-W-TPM-34, EC-360915, IC-140985, IC-470647, IC-021114, EC-361018, IC-039308, EC-360095, EC-361007, EC-329394, EC-360953, EC-360853, IC-469583, IC-47737, VRO-W-C-1, VRO-W-C-2, VRO-W-C-5, VRO-W-C-6, VRO-W-A-2, VRO-W-A-3, VRO-W-A-4, VRO-W-MH-1, VRO-W-CT-1, VRO-W-CT-2, VRO-W-EN-1, VRO-W-N-1, VRO-R-8 ©, Pusa Sawani ©, Arka Anamika ©, VRO-6 © and Kashi Vibhuti ©
Length of peduncle	From 1 to 3 cm	73	78.49	VRO-W-F-1, VRO-W-F-2, VRO-W-F-3, VRO-W-F-4, VRO-W-F-5, VRO-W-F-6, VRO-W-F-7, VRO-W-F-8, VRO-W-F-9, VRO-W-F-10, VRO-W-F-11, VRO-W-F-12, VRO-W-F-13, VR0-W-F-14, VRO-W-F-15, VRO-W-F-16, VRO-W-F-17, VRO-W-F-18, VRO-W-F-19, VRO-W-T-1, VRO-W-T-2, VRO-W-T-3, VRO-W-T-4, VRO-W-T-5, VRO-W-T-6, VRO-W-T-7, VRO-W-T-8, VRO-W-T-9, VRO-W-T-10, VRO-W-T-12, VRO-W-T-14, VRO-W-T-15, VRO-W-T-16, VRO-W-T-17, VRO-W-TP-1, VRO-W-TP-3, VRO-W-TP-4, VRO-W-TP-12, VRO-W-TP-13, VRO-W-TP-16, VRO-W-TP-19, VRO-W-TP-22, VRO-W-TP-23, VRO-W-TP-24, VRO-W-TP-25, VRO-W-TP-20, VRO-W-TP-30, VRO-W-TP-31, VRO-W-TP-32, VRO-W-TPM-1, VRO-W-TPM-2, VRO-W-TPM-3, VRO-W-TPM-4, VRO-W-TPM-9, VRO-W-TPM-31, VRO-W-TPM-23, VRO-W-TPM-34, VRO-W-C-1, VRO-W-C-2, VRO-W-C-3, VRO-W-C-4, VRO-W-C-5, VRO-W-C-6, VRO-W-A-1, VRO-W-A-2, VRO-W-A-3, VRO-W-A-4, VRO-W-EN-1, VRO-R-8 ©, Pusa Sawani ©, Arka Anamika ©, VRO-6 © and Kashi Vibhuti ©
	More than 3 cm	20	21.51	VRO-W-TPM-10, VRO-W-TPM-12, VRO-W-TPM-13, EC-360915, IC-140985, IC-470647, IC-021114, EC-361018, IC-039308, EC-360095, EC-361007, EC-329394, EC-360953, EC-360853, IC-469583, IC-47737, VRO-W-MH-1, VRO-W-CT-1, VRO-W-CT-2 and VRO-W-N-1
Position of fruit on main stem	Erect	93	100.00	VRO-W-F-1, VRO-W-F-2, VRO-W-F-3, VRO-W-F-4, VRO-W-F-5, VRO-W-F-6, VRO-W-F-7, VRO-W-F-8, VRO-W-F-9, VRO-W-F-10, VRO-W-F-11, VRO-W-F-12, VRO-W-F-13, VR0-W-F-14, VRO-W-F-15, VRO-W-F-16, VRO-W-F-17, VRO-W-F-18, VRO-W-F-19, VRO-W-T-1, VRO-

Descriptor	State	Frequency	Total (%)	Accessions
				W-T-2, VRO-W-T-3, VRO-W-T-4, VRO-W-T-5, VRO-W-T-6, VRO-W-T-7, VRO-W-T-8, VRO-W-T-9, VRO-W-T-10, VRO-W-T-12, VRO-W-T-14, VRO-W-T-15, VRO-W-T-16, VRO-W-T-17, VRO-W-TP-1, VRO-W-TP-3, VRO-W-TP-4, VRO-W-TP-12, VRO-W-TP-13, VRO-W-TP-16, VRO-W-TP-19, VRO-W-TP-22, VRO-W-TP-23, VRO-W-TP-24, VRO-W-TP-25, VRO-W-TP-20, VRO-W-TP-30, VRO-W-TP-31, VRO-W-TP-32, VRO-W-TPM-1, VRO-W-TPM-2, VRO-W-TPM-3, VRO-W-TPM-4, VRO-W-TPM-9, VRO-W-TPM-10, VRO-W-TPM-31, VRO-W-TPM-12, VRO-W-TPM-13, VRO-W-TPM-23, VRO-W-TPM-34, EC-360915, IC-140985, IC-470647, IC-021114, EC-361018, IC-039308, EC-360095, EC-361007, EC-329394, EC-360953, EC-360853, IC-469583, IC-47737, VRO-W-C-1, VRO-W-C-2, VRO-W-C-3, VRO-W-C-4, VRO-W-C-5, VRO-W-C-6, VRO-W-A-1, VRO-W-A-2, VRO-W-A-3, VRO-W-A-4, VRO-W-MH-1, VRO-W-CT-1, VRO-W-CT-2, VRO-W-EN-1, VRO-W-N-1, VRO-R-8 ©, Pusa Sawani ©, Arka Anamika ©, VRO-6 © and Kashi Vibhuti ©
	Horizontal	0	0.00	
	Pendulous	0	0.00	
Fruit color	Green	66	70.97	VRO-W-T-1, VRO-W-T-2, VRO-W-T-3, VRO-W-T-4, VRO-W-T-5, VRO-W-T-6, VRO-W-T-7, VRO-W-T-8, VRO-W-T-9, VRO-W-T-10, VRO-W-T-12, VRO-W-T-14, VRO-W-T-15, VRO-W-T-16, VRO-W-T-17, VRO-W-TP-1, VRO-W-TP-3, VRO-W-TP-4, VRO-W-TP-12, VRO-W-TP-13, VRO-W-TP-16, VRO-W-TP-19, VRO-W-TP-22, VRO-W-TP-23, VRO-W-TP-24, VRO-W-TP-25, VRO-W-TP-20, VRO-W-TP-30, VRO-W-TP-31, VRO-W-TP-32, VRO-W-TPM-1, VRO-W-TPM-2, VRO-W-TPM-3, VRO-W-TPM-4, VRO-W-TPM-9, VRO-W-TPM-10, VRO-W-TPM-31, VRO-W-TPM-12, VRO-W-TPM-13, VRO-W-TPM-23, VRO-W-TPM-34, EC-360915, IC-470647, IC-021114, EC-329394, EC-360953, VRO-W-C-1, VRO-W-C-2, VRO-W-C-3, VRO-W-C-4, VRO-W-C-5, VRO-W-C-6, VRO-W-A-1, VRO-W-A-2, VRO-W-A-3, VRO-W-A-4, VRO-W-MH-1, VRO-W-CT-1, VRO-W-CT-2, VRO-W-EN-1, VRO-W-N-1, VRO-R-8 ©, Pusa Sawani ©, Arka Anamika ©, VRO-6 © and Kashi Vibhuti ©
	Green with red patches	8	8.60	IC-140985, EC-361018, IC-039308, EC-360095, EC-361007, EC-360853, IC-469583 and IC-47737
	Green-purple (specific)	19	20.43	VRO-W-F-1, VRO-W-F-2, VRO-W-F-3, VRO-W-F-4, VRO-W-F-5, VRO-W-F-6, VRO-W-F-7, VRO-W-F-8, VRO-W-F-9, VRO-W-F-10, VRO-W-F-11, VRO-W-F-12, VRO-W-F-13, VR0-W-F-14, VRO-W-F-15, VRO-W-F-16, VRO-W-F-17, VRO-W-F-18 and VRO-W-F-19
	Yellowish green		0.00	
	Red		0.00	
Fruit pubescence	Downy	52	55.91	VRO-W-F-1, VRO-W-F-2, VRO-W-F-3, VRO-W-F-4, VRO-W-F-5, VRO-W-F-6, VRO-W-F-7, VRO-W-F-8, VRO-W-F-9, VRO-W-F-10, VRO-W-F-11, VRO-W-F-12, VRO-W-F-13, VR0-W-F-

Descriptor	State	Frequency	Total (%)	Accessions
				14, VRO-W-F-15, VRO-W-F-16, VRO-W-F-17, VRO-W-F-18, VRO-W-F-19, VRO-W-T-4, VRO-W-T-5, VRO-W-T-6, VRO-W-T-8, VRO-W-T-14, VRO-W-T-16, VRO-W-TP-4, VRO-W-TP-12, VRO-W-TP-13, VRO-W-TP-16, VRO-W-TP-19, VRO-W-TP-22, VRO-W-TP-23, VRO-W-TP-25, VRO-W-TP-30, VRO-W-TP-31, VRO-W-TP-32, VRO-W-TPM-9, VRO-W-TPM-12, VRO-W-TPM-13, VRO-W-TPM-23, IC-140985, IC-021114, EC-360095, IC-47737, VRO-W-C-1, VRO-W-C-4, VRO-W-EN-1, VRO-R-8 ©, Pusa Sawani ©, Arka Anamika ©, VRO-6 © and Kashi Vibhuti ©
	Slightly rough	12	12.90	VRO-W-T-1, VRO-W-T-2, VRO-W-T-3, VRO-W-T-7, VRO-W-TPM-2, EC-329394, EC-360953, IC-469583, VRO-W-C-2, VRO-W-C-3, VRO-W-C-5 and VRO-W-C-6
	Prickly	29	31.18	VRO-W-T-9, VRO-W-T-10, VRO-W-T-12, VRO-W-T-15, VRO-W-T-17, VRO-W-TP-1, VRO-W-TP-3, VRO-W-TP-24, VRO-W-TP-20, VRO-W-TPM-1, VRO-W-TPM-3, VRO-W-TPM-4, VRO-W-TPM-10, VRO-W-TPM-31, VRO-W-TPM-34, EC-360915, IC-470647, EC-361018, IC-039308, EC-361007, EC-360853, VRO-W-A-1, VRO-W-A-2, VRO-W-A-3, VRO-W-A-4, VRO-W-MH-1, VRO-W-CT-1, VRO-W-CT-2 and VRO-W-N-1
Number of ridges per fruit	None	0	0.00	
	From 5 to 7	93	100.00	VRO-W-F-1, VRO-W-F-2, VRO-W-F-3, VRO-W-F-4, VRO-W-F-5, VRO-W-F-6, VRO-W-F-7, VRO-W-F-8, VRO-W-F-9, VRO-W-F-10, VRO-W-F-11, VRO-W-F-12, VRO-W-F-13, VR0-W-F-14, VRO-W-F-15, VRO-W-F-16, VRO-W-F-17, VRO-W-F-18, VRO-W-F-19, VRO-W-T-1, VRO-W-T-2, VRO-W-T-3, VRO-W-T-4, VRO-W-T-5, VRO-W-T-6, VRO-W-T-7, VRO-W-T-8, VRO-W-T-9, VRO-W-T-10, VRO-W-T-12, VRO-W-T-14, VRO-W-T-15, VRO-W-T-16, VRO-W-T-17, VRO-W-TP-1, VRO-W-TP-3, VRO-W-TP-4, VRO-W-TP-12, VRO-W-TP-13, VRO-W-TP-16, VRO-W-TP-19, VRO-W-TP-22, VRO-W-TP-23, VRO-W-TP-24, VRO-W-TP-25, VRO-W-TP-20, VRO-W-TP-30, VRO-W-TP-31, VRO-W-TP-32, VRO-W-TPM-1, VRO-W-TPM-2, VRO-W-TPM-3, VRO-W-TPM-4, VRO-W-TPM-9, VRO-W-TPM-10, VRO-W-TPM-31, VRO-W-TPM-12, VRO-W-TPM-13, VRO-W-TPM-23, VRO-W-TPM-34, EC-360915, IC-140985, IC-470647, IC-021114, EC-361018, IC-039308, EC-360095, EC-361007, EC-329394, EC-360953, EC-360853, IC-469583, IC-47737, VRO-W-C-1, VRO-W-C-2, VRO-W-C-3, VRO-W-C-4, VRO-W-C-5, VRO-W-C-6, VRO-W-A-1, VRO-W-A-2, VRO-W-A-3, VRO-W-A-4, VRO-W-MH-1, VRO-W-CT-1, VRO-W-CT-2, VRO-W-EN-1, VRO-W-N-1, VRO-R-8 ©, Pusa Sawani ©, Arka Anamika ©, VRO-6 © and Kashi Vibhuti ©
	From 8 to 10	0	0.00	
	More than 10	0	0.00	

4. CONCLUSIONS

Variability studies in crop species aim to uncover genetic differences and patterns within germplasm, providing insights for crop improvement. This study successfully distinguished okra genotypes using qualitative characters, revealing high genetic variation among the germplasm. This finding creates opportunities for genetic improvement of okra lines through breeding programs. The results suggest that selecting diverse accessions from wild relatives and introgression desirable traits into the cultivated gene pool through interspecific hybridization can enhance crop diversification and improvement.

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 the manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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