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Morphological characterization of traditional bhendi varieties

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Abstract
Bhendi (*Abelmoschus esculentus*) is an important vegetable crop and it is a multiuse crop because its leaves, stem, floral parts, fruits and seeds are useful in many fields. This study investigated the morphological characterization among the traditional bhendi varieties as per DUS guidelines. The seeds of traditional bhendi varieties were evaluated for the morphological characteristics at Agricultural Research Station, Bhavanisagar during 2023. Red okra had red stem colour while others had green stem colour. White okra, tree okra and malai okra had red purple vein colour while others had green vein colour. The seed coat colour (olive green) character was similar in all varieties. The highly significant and positive correlation of petiole length, length of flower, fruit length at maturity stage and physiological maturity, fruit diameter at physiological maturity and number of locules characters would lead to simultaneous improvement for yield per plant. This study further leads to the use of morphological characteristics to characterize plant genetic resources. These characteristics may be exploited by plant breeders for further utilization of traditional bhendi varieties in varietal development programme.

Keywords: Okra, Morphological characteristics, distinct variation, correlation

Introduction
India is the second-largest producer of vegetables in the world. Vegetables are regarded as the century's most potent source of nutrients. The World Health Organization (WHO) recommends a daily minimum intake of 400 g of fruits and vegetables in order to prevent chronic diseases, specifically heart disease, cancer, and diabetes, and to provide sufficient micronutrients, most notably calcium, iron, iodine, vitamin A, and zinc (Who*et al.*, 2003) [1]. Vegetables are high in potassium, which helps to maintain healthy blood pressure, dietary fiber, which minimizes blood cholesterol levels and may reduce the risk of heart disease, folate (folic acid), which lowers the risk of birth defects, vitamin A, which endorses healthy eyes, skin and vitamin C, which not only confirms healthy teeth and gums but also helps with iron absorption (Schreinemachers *et al.*, 2018) [2].

Bhendi (*Abelmoschus esculentum*) is one of the important commercial vegetable crops which is grown in the tropical, subtropical and some warmer parts of temperate regions. It is commonly known as Okra or Lady's Finger in India. It belongs to the family Malvaceae. The area, production and productivity of bhendi in India are about 554.8 ha, 6818.7 MT and 12.3 MT/ha. India is the largest producer in the world of about 67.1% followed by Nigeria (15.4%) and Sudan (9.3%) (Singh *et al.*, 2014) [3]. Next to the tomato, bhendi is the fifth-largest producing vegetable in the nation. It is vulnerable to circumstances like frost, cold temperatures, water retention, and drought (Khatun *et al.*, 2011) [4]. It is a crop with multiple uses, but it is often eaten for its green, soft fruits, which are used in many different ways as vegetables. These fruits are an adequate source of minerals like calcium, potassium, and vitamins. It is prominently recognized that the mature okra seed has better nutritional value and is a potent source of protein and oil. The paper industry uses the crude fiber found in mature fruit and stems. In terms of nutrition, a 100g edible pod has probably 88.6g of water, 2.10g of protein, 8.20g of carbohydrate, 0.20g of fat and 1.70g of fiber (Singh *et al.*, 2014) [3].

Originally, traditional variety farming drove up low productivity as compared to improved variety production, but it generated higher production in just a few years under steady farming circumstances. Farmers quickly gravitate towards traditional varieties because of their historical background, distinctive identity, lack of formal crop improvement, correlation to the traditions and customs of many rural areas, and affiliation with an indigenous farming method.

Characterization of crops is the first and foremost step in the crop improvement programme (Carmen de Vicente *et al.*, 2006) [5]. Characterization of genetic resources, therefore refers to the process by which accessions are identified, differentiated or distinguished according to their characters (Samim*et al.*, 2018) [6]. The first stage in describing and classifying the cultivars, nevertheless, is morphological characterization. It is well known that the taxonomic reliability of morphological data can be questioned due to interactions with the environment and particularly unknown mechanisms of genetic control of these traits. The goal of this research work was to analyse the traditional varieties of okra based on morphological characteristics and it may be useful in varietal development programme based on specific traits.

Materials and Methods

The 12 traditional varieties of okra were collected from traditional vegetable growing farmers of Tamil Nadu. The varieties were analyzed at experimental farm of Agricultural Research Station, Bhavanisagar with three replications and minimum plot size of about 4.5m × 3m. The spacing between plants were 60cm × 30cm and the observation were made on 30 plants in which 10 plants per replication. The varieties were assessed for 31 characters namely stem colour, node number on stem at which first flower opens, stem diameter (cm), sinus depth of leaf blade (cm), length of leaf blade(cm), width of leaf blade (cm), serration of margin of leaf blade, colour between veins of leaf blade, colour of vein, length of petiole (cm), flowering time (Days to 50% flowering with atleast one open flower), petal colour, colour of petal base (Red purple), length of flower (cm), diameter of flower from the top of the fully opened flower (cm), male sterility, fruit colour, fruit length at marketable stage on main stem (cm), diameter of fruit at mid length (cm), ridges of fruit, surface between ridges of the fruit, pubescence of fruit, constriction of fruit at basal part, shape of fruit apex, number of locules in fruit, length of fruit at physiological maturity (cm), diameter of fruitat physiological maturity (cm), number of productive branches, height of the plant (cm) and seed coat colour according to distinctiveness, uniformity and stability guidelines (PPV &FRA, 2001) [7]. One character was measured by a single observation of a group of plants or parts of plants (MG), 16 characters were measured by a number of individual plant or parts of plants (MS), 8 characters were visual assessment by a single observation of a group of plants or parts of plants (VG), and 6 characters were visual assessment by observations of individual plant or parts of plants.

Data Analysis

Data were grouped into qualitative and quantitative characters and subjected to statistical analysis. Correlation analysis were done to find out the extent of association among the quantitative characters using Pearson's correlation coefficient in SPSS software.

Results and Discussion

A set of morphological traits listed in the DUS test standards for okra were used to characterize 12 traditional varieties of okra. These characters were used to manifest the distinctiveness, uniformity and stability of a variety based on that protection is given to that variety. These characteristics did not show any variation in their expression throughout the study. There were no off-type plants in the field, and hence they were considered to be uniform in these characters. The expression of each character was found to be stable throughout the study, thus validating their stability and consistency. The variation in the morphological characteristics among the varieties are shown in Table 1.

Table 1: Morphological characteristics of traditional bhendi varieties

Varieties	Stem colour	Depth of leaf blade (cm)	Vein colour	Petiole length (cm)	Colour of petal base (Red purple)	Fruit colour	Fruit pubescence	Height of plant (cm)	Seed coat colour
Green okra long	Green	Medium	Green	Short	Inside only	Green	Medium	71.0	Olive green
Red okra	Red	Medium	Green	Medium	Both sides	Dark red purple	Strong	70.8	Olive green
Elephant husk okra	Light green	Medium	Green	Long	Inside only	Light green	Weak	74.0	Olive green
Green okra short	Light green	Deep	Green	Medium	Inside only	Green	Strong	57.1	Olive green
Star okra	Light green	Deep	Green	Long	Inside only	Light green	Weak	79.2	Olive green
7-line okra	Green	Deep	Green	Medium	Both sides	Green	Strong	58.8	Olive green
White okra	Green	Medium	Red purple	Medium	Both sides	Light green	Strong	66.5	Olive green
Tree okra	Light green	Medium	Red purple	Medium	Inside only	Light green	Medium	61.0	Olive green
Green round okra	Light green	Medium	Green	Long	Inside only	Light green	Medium	56.2	Olive green
Cow horn okra	Green	Deep	Green	Long	Inside only	Green	Weak	41.1	Olive green
Red round okra	Green	Deep	Green	Medium	Both sides	Green	Weak	71.2	Olive green
Malai okra	Green	Deep	Red purple	Long	Inside only	Green	Weak	45.3	Olive green

Distinct variation was observed in morphological characteristics (Table 1) within the traditional varieties. Green okra long, 7-line okra, white okra, cowhorn okra, red round okra and malai okra varieties had green stem colour, while

elephant husk okra, green okra short, star okra, tree okra and green round okra had light green stem colour and red okra variety had red stem colour (Fig 1a). These findings were consistent with the reports of Matthew *et al.* (2018) [8], Singh *et al.* (2015) [9], Oppong-Sekyere *et al.* (2011) [10], Tesfa *et al.* (2016) [11] with respect to okra cultivars. Leaf blade depth was medium in green okra long, red okra, elephant husk okra, white okra, tree okra and green round okra varieties while green okra short, star okra, 7-line okra, cow horn okra, red round okra and malai okra varieties had deep leaf blade depth.

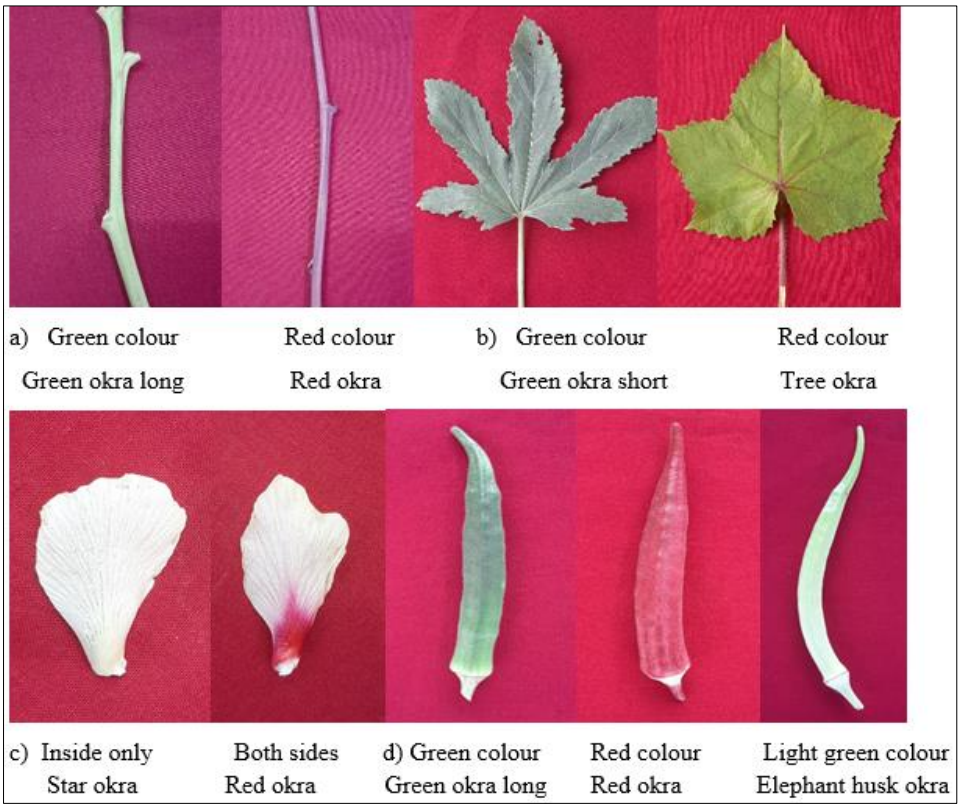

Fig 1: Morphological characteristics of traditional bhendi varieties, a) Variation in stem colour, b) Variation in leaf vein colour, c) Variation in colour of petal base, d) Variation in fruit colour

Distinct variation exists among the varieties with regards to vein colour. White okra, tree okra and malai okra showed red purple vein colour while other varieties showed green vein colour (Fig 1b). These findings were similar with the reports of Singh *et al.* (2015) [9], Oppong-Sekyere *et al.* (2011) [10] in okra varieties.

There was wide variation among the varieties with regards to petiole length. The petiole length was short in green okra long variety. Medium petiole length was observed in red okra, green okra short, 7-line okra, white okra, tree okra and red round okra varieties while elephant husk okra, star okra, green round okra, cow horn okra and malai okra showed long petiole length. The colour of red purple petal base was observed inside only in green okra long, elephant husk okra, green okra short, star okra, tree okra, green round okra, cowhorn okra and malai okra varieties while it was both sides of petal base in red okra, 7-line okra, white okra and red round okra varieties (Fig 1c).

The variations in fruit colour were observed in the traditional bhendi varieties. The fruit colour at harvesting was green in green okra long, green okra short, 7-line okra, cowhorn okra, red round okra and malai okra varieties while elephant husk okra, star okra, white okra, tree okra and green round okra varieties had light green fruit colour. The distinct dark red purple fruit colour was observed in red okra variety (Fig 1d). Similar results were observed with the report of Joshi *et al.* (2021) [12], Saifullah *et al.* (2009) [13], Samim *et al.* (2018) [6]. There was wide variation among the varieties in fruit pubescence character. The fruit pubescence was medium in green okra long, tree okra and green round okra varieties while it was strong in red okra, green okra short, 7-line okra and white okra varieties and the pubescence was weak in elephant husk okra, star okra, cowhorn okra, red round okra and malai okra varieties. Wide variation was observed among the varieties with regards to plant height at maturity. The maximum plant height was observed in star okra variety (79.2cm) and minimum plant height was observed in cow horn okra variety (41.1cm). The seed coat colour (olive green) was similar in all varieties.

Correlation analysis

Correlation analysis between varieties is of great importance in breeding programme and for cultivation purposes because it helps in identifying the varieties for higher yield and other purpose (Akinyele *et al.*, 2006) [14].

The correlation coefficients were made for 17 quantitative characters of all traditional bhendi varieties were studied and it was shown in table 2. The result revealed that petiole length was significantly and positively correlated with stem diameter ($r = 0.612$) which indicated that petiole length will be increased when there was increase in stem diameter. Length of leaf blade had highly significant and positively correlated with depth of leaf blade ($r = 0.757$) which indicated that this character will be increased with the increase of length of leaf blade.

Table 2: Correlation analysis among 17 quantitative characters of traditional bhendi varieties

	Stem diameter	**Depth of leaf Blade**	**Length of leaf blade**	**Width of leaf blade**	**Petiole length**	**Flowering time**	**Length of flower**	**Diameter of flower**	**Fruit length @ MS**	**Fruit diameter @ MS**	**Number of locules**	**Fruit length @ PM**	**Fruit diameter@ PM**	**No. of. Pods per plant**	**No. of. Productive branches**	**Plant height**	**No. of. Seeds per pod**
Stem diameter	1																
Depth of leaf blade	0.004	1															
Length of leaf blade	0.073	0.757**	1														
Width of leaf blade	-0.134	0.763**	0.762**	1													
Petiole length	0.612*	0.128	0.173	0.251	1												
Flowering time	0.353	-0.046	0.164	-0.174	0.455	1											
Length of flower	0.553	0.21	0.218	0.081	0.793**	0.422	1										
Diameter of flower	0.427	0.235	0.079	0.07	0.577*	0.101	0.888**	1									
Fruit length @ MS	0.18	-0.395	-0.047	0.041	0.371	-0.198	0.178	0.138	1								
Fruit diameter @ MS	-0.075	0.476	0.36	0.219	0.095	0.013	0.201	0.108	-0.341	1							
Number of locules	-0.042	0.21	0.225	0.128	0.264	0.076	0.411	0.289	-0.019	0.801**	1						
Fruit length @ PM	-0.057	-0.389	-0.027	0.044	0.258	-0.185	0.022	-0.051	0.802**	0.104	0.312	1					
Fruit diameter @ PM	-0.21	0.431	0.463	0.265	0.061	0.039	0.207	0.115	-0.232	0.915**	0.677*	0.223	1				
No. of. pods/plant	-0.622*	-0.15	-0.231	-0.051	-0.359	-0.522	-0.458	-0.369	0.119	0.267	0.018	0.426	0.411	1			
No. Of Productive branches	0.482	-0.441	-0.355	-0.374	0.558	0.489	0.452	0.237	0.178	-0.389	-0.269	-0.062	-0.351	-0.252	1		
Plant height	-0.044	-0.391	-0.151	-0.127	-0.331	-0.324	-0.592*	-0.631*	0.185	0.122	0.123	0.457	0.017	0.251	-0.301	1	
No. of seeds/pod	-0.081	-0.171	0.041	0.073	0.424	0.006	0.289	0.186	0.608*	0.231	0.241	0.744**	0.436	0.535	0.176	-0.015	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Width of leaf blade had highly significant and positively correlated with depth of leaf blade (r = 0.763) and length of leaf blade (r = 0.762). This indicated that depth of leaf blade and length of leaf blade will be increased with the increase of width of leaf blade. Diameter of flower (r = 0.577) and length of flower (r = 0.793) had highly significant and positively correlated with petiole length which indicated that when diameter and length of flower increases, petiole length also increases. Diameter of flower had highly significant and positively correlated with length of flower (r = 0.888) which indicated that length of flower will be increased when there is increase in diameter of flower.

The number of locules had highly significant and positively correlated with diameter of fruit at maturity stage (r = 0.801). This indicated that diameter of fruit at maturity stage will be increased with the increase in the number of locules. The fruit length at physiological maturity had highly significant and positively correlated with fruit length at maturity stage (r = 0.802) which indicated that fruit length at physiological maturity will be increased when there is increase in fruit length at maturity stage. This observation was supported by Tesfa *et al.* (2016) [11], Duzyaman *et al.* (2005) [15] in the analysis of okra cultivars. The fruit diameter at physiological maturity had highly significant and positively correlated with diameter of fruit at maturity stage (r = 0.915) and number of locules (r = 0.677). This indicated that increase in diameter of fruit at maturity stage and number of locules will increase the fruit diameter at physiological maturity stage.

The number of seeds/pods was significantly positively correlated with fruit length at maturity stage (r = 0.608) and fruit length at physiological maturity (r = 0.744) which indicated that number of seeds/pods will be increased with fruit length at maturity stage and fruit length at physiological maturity. This finding was supported by Hayati *et al.* (2020) [16] and Tesfa *et al.* (2016) [11] with respect to fruit length at maturity stage.

The number of pods/plants had negatively correlated with stem diameter (r = -0.622). Plant height had negatively correlated with length of flower (r = -0.592) and diameter of flower (r = -0.631).

Hence, length of leaf blade, petiole length, length of flower, fruit length at maturity stage and physiological maturity, fruit diameter at physiological maturity and number of locules characters were more important for higher seed yield in traditional bhendi varieties.

Conclusion

It was concluded that variation existed in both qualitative and quantitative characters of traditional bhendi varieties. Existence of different identification states for morphological characters like stem colour, depth of leaf blade, vein colour, petiole length, colour of petal base (red purple), fruit colour, fruit pubescence, plant height confirms wide phenotypic variation among the varieties. Likewise, there was similarity in all varieties with respect to seed coat colour. The traditional bhendi varieties studied in this study showed significant variation in morphological characteristics, demonstrating the potential and use of morphological characteristics as a tool for the selection and protection of superior varieties. This study identified that red okra, elephant husk okra, green round okra varieties showed desirably distinct morphological characters in most of the categories which helps in considering these varieties for any improvement programme and conservation purposes. 7-line okra and elephant husk okra varieties were showed higher potential in terms of yield character. This study confirmed use of morphological characteristics for distinguishing plant genetic resources. The highly significant and positive correlation of petiole length, length of flower, fruit length at maturity stage and physiological maturity, fruit diameter at physiological maturity and number of locules characters indicated that screening and selection of these characters would lead to simultaneous improvement for yield per plant.

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