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Morpho-biochemical characterization and heterosis studies in interspecific derived F_1 hybrids of okra (*Abelmoschus esculentus*)

S BHARGAV KIRAN[1], RAMESH KUMAR YADAV[1]*, SUMAN LATA[1], BRIJ BIHARI SHARMA[1], BHOOPAL SINGH TOMAR[1] and AVINASH TOMER[1]

ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India

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ABSTRACT

The present experiment was conducted during rainy (*kharif*) seasons of 2021, 2022 and 2023 at vegetable research farm, ICAR-Indian Agricultural Research Institute, New Delhi to study okra [*Abelmoschus esculentus* (L.) Moench] cv. Pusa Sawani, crossed with 3 wild accessions, viz. *A. manihot* var. *tetraphyllus* (IC 90476-1); IC-141055 and IC-141040 of *A. moschatus*. A total of 27 morphological and 9 biochemical parameters were characterized for parental species and their derived F_1 hybrids. Results showed that the hybrids possessed superior and beneficial traits than the parents and had a greater alliance with their wild parent. The mean performance of the quantitative characters and heterosis of the three interspecific derived F_1s differed significantly from parents. Almost all biochemical parameters value, except moisture were found high in wild accessions followed by interspecific derived F_1 hybrid and lowest in cultivated variety Pusa Sawani. Per cent disease incidence for yellow vein mosaic virus (YVMV) and enation leaf curl virus (ELCV) was 92 and 32, respectively in Pusa Sawani. However, both the wild accessions of *A. moschatus* namely (IC-141055) and (IC-141040) and their interspecific hybrids recorded no incidence of both the disease.

Keywords: *Abelmoschus*, Biochemical characterization, Heterosis, Interspecific F_{1s}, Morphological

Okra [*Abelmoschus esculentus* (L.) Moench] having chromosome number 2n = 2x = 130 is one of the important warm-season vegetable grown extensively in tropics, sub-tropics and during warmer season of the temperate areas in the world. India is largest producer of okra in the world, its production suffers due to various biotic stresses, especially yellow vein mosaic virus (YVMV) and enation leaf curl virus (ELCV). Yellow vein mosaic disease (YVMD), may causes yield losses up to 90–100% (Sastry and Singh 1974, Santhiya *et al.* 2022). Utilizing genetic resources to impart the resistance in cultivated okra is one way to develop breeding resources (Senevirathna *et al.* 2016). The wild species of okra possess several beneficial traits. A few of the beneficial traits of the wild okra species include dark green fruits, high mucilage, extended bearing, perennial growth, strong branching, drought resistance, high and low temperature tolerance, YVMV and ELCV resistance (Santhiya *et al.* 2022). When two plants with a high genetic distance are crossed, their offspring are more likely to exhibit heterosis. This is because the offspring will have a more diverse set of genes, which can lead to complementary interactions between them that result in improved traits. Research has shown that the genetic distance between parental lines has a strong correlation with the occurrence of heterosis in okra hybrids (Kumar and Reddy 2016). Breeders can use this information to select parental lines and produce offspring with desirable traits. Therefore, it is high time to go for in-depth research on the wild species and their interspecific derived hybrids to study morpho-biochemical characterization and heterosis studies.

MATERIALS AND METHODS

The experiment was conducted during rainy (*kharif*) seasons of 2021, 2022 and 2023 at vegetable research farm, ICAR-Indian Agricultural Research Institute Delhi (28°38′23″ N, 77°09′27″ E, at an altitude of 228.61 m amsl), New Delhi. Three accessions of wild species, viz. IC 90476-1 of *A. manihot* var. *tetraphyllus*; *A. moschatus* (IC-141055)-deep serrated leaf type with resistance to yellow vein mosaic virus (YVMV) and enation leaf curl virus (ELCV) diseases; and *A. moschatus* (IC-141040)-shallow serrated leaf type having YVMV resistance and tolerance to leafhopper were collected from National Bureau of Plant Genetic Resources, New Delhi and maintained at mother block in research farm, Division of Vegetable Science, ICAR-Indian Agricultural Research Institute, New Delhi. Crossing of wild okra species with cultivated okra was done during rainy (*kharif*) season

[1]ICAR-Indian Agricultural Research Institute, New Delhi.
*Corresponding author email: rkydavneh@gmail.com

of 2021 and crossed hybrids were evaluated during rainy (*kharif*) season of 2022 and 2023.

Morphological characterization of parents and progenies: The morphological characterization was done in three interspecific hybrids, namely Pusa Sawani × IC 90476-1, Pusa Sawani × IC -141055 and Pusa Sawani × IC-141040 along with their parental species using NBPGR Minimal Descriptor (Kaul *et al.* 2022). Data collected were subjected to analysis of variance (ANOVA) to determine significant differences between the different hybrids and parental species. Per cent disease incidence (PDI) was calculated as per methods given by Bag *et al.* (2014) and Venkataravanappa *et al.* (2022). Adult whiteflies count (AWC) on each genotype was calculated as per Borad *et al.* (1993).

Estimation of heterosis (%) in interspecific hybrids: To estimate heterosis in interspecific hybrids, the following steps were taken:

Three interspecific hybrids between Pusa Sawani × *A. manihot* var. *tetraphyllus* (IC 90476-1), Pusa Sawani × *A. moschatus* (IC-141055) and Pusa Sawani × *A. moschatus* (IC-141040) were made. Heterosis was estimated for each trait by calculating the deviation of the F_1 mean from the mid-parent (relative heterosis) and the better parent (heterobeltiosis) (Arunachalam 1974).

Biochemical analysis

Sample preparation: Fresh okra pods were taken from each replication to assess the tissue nutrient and subjected to a series of washings using tap water, 0.2% Teepol solution, 0.1 N HCI, and double-distilled water and kept in labelled paper bags followed by cleaning and finally dried in a hot air oven at a temperature of 70°C. The dried sample was then pulverised and filtered with a 1 mm screen and this powder used for tissue nutrient analysis.

Estimation of chlorophyll and carotenoid content: Chlorophyll and carotenoid content were measured by extracting 0.05 g of leaf material in 10 ml of dimethylsulfoxide (DMSO). The chlorophyll and carotenoid content was calculated using the formula given by Arnon (1949).

Estimation of total phenols: 0.1 g of the okra pod was ground in 5 ml of 80% ethanol and the homogenate was centrifuged at 5,000 rpm for 20 min to separate the supernatant. Different aliquots (ranging from 0.2–2 ml) of the dissolved supernatant were pipetted into test tubes (Singleton *et al.* 1999). After 3 min, 2 ml of 20% Na-CO solution was added to each tube and absorbance was measured at 650 nm against a reagent blank. The final result was reported as mg/100 g (Malick and Singh 1980)

Estimation of moisture content: Moisture content was determined by drying a known weight (100 g) of the sample in an oven at 60±5°C to a constant weight. The final weight of the sample after drying was weighed and expressed as percentage.

Estimation of mucilage: Fresh pods were crushed, and soaked in water for 5–6 h then boiled for 30 min and left to stand for 1 h to allow complete release of the mucilage into the water and acetone was added to precipitate the mucilage and passed through 80 mesh sieves. Finally, dried in a 40°C oven, and then placed in a desiccator at 30°C and 45% relative humidity.

Estimation of sugar content: Sugar content estimation principle was based on Anthrone method and it is the basis of rapid and convenient determination of hexoses, aldopentoses and hexuronic acid either free or present in polysaccharides and measured spectrophotometrically at 630 nm.

$$\text{Amount of carbohydrates present in sample (\%)} = \frac{\text{Sugar value from graph (mg)} \times \text{Total volume of extract (ml)}}{\text{Aliquots sample used} \times \text{wt. of sample (mg)}} \times 100$$

Estimation of ascorbic acid content: 5 g of okra pod sample was ground with neutral glass powder in a mortar. The mixture was then mixed with an equal volume of 6% metaphosphoric acid EDTA solution and made up to a total volume of 50 ml with 3% metaphosphoric acid. After centrifuging at 5000 rpm for 10 min and filtering through Whatman No.1 filter paper, the extract was collected in a volumetric flask. Then, 2.8 ml of distilled water was added to each test tube, bringing the total volume to 4 ml. Finally, 0.4 ml of Folin-Ciocalteu reagent was added and read against the blank in a spectrophotometer at 760 nm.

$$\text{Ascorbic acid (mg/100 g)} = \frac{\text{Total volume of the extract} \times \text{Concentration of ascorbic acid} \times 100 \times 1}{\text{Weight of sample} \times \text{Amount of aliquot}} \times 100$$

The ANOVA analysis was done by OPSTAT software (Sheron *et al.* 1998) and multiple comparison was performed by DMRT.

RESULTS AND DISCUSSION

Morphological characterization

Leaf character: Leaf character is an important trait in okra as leaves are major site for sucking insects that transfers viruses (YVMV and ELCV). Small to medium serrated leaves showed less YVMV incidence than non-serrated leaf because the leaf area is directly proportional to the disease infestation. The mean leaf hopper (nymph) population was found higher in cultivated *A. esculentus* genotypes than in wild species. Additionally, it was noted that adult whitefly count (AWC) was found maximum in Pusa Sawani (35.5). The wild genotypes especially *A. moschatus* (2.3 and 2.8) and their hybrids (4.0 and 4.5) recorded low AWC due to hairy leaves and these results were supported by the earlier researchers (Badiger and Yadav 2019). Due to hairy leaves whitefly could not feed and spread the yellow vein mosaic and enation leaf curl diseases in *A. moschatus*. Similar findings were reported by Prabu *et al.* (2009). Small-leaves species and deep serrated leaves of interspecific derived F_1s showed less infestation (Fig. 1).

Fruit colour and fruit length: Dark green fruits with medium length are preferred over the light green because

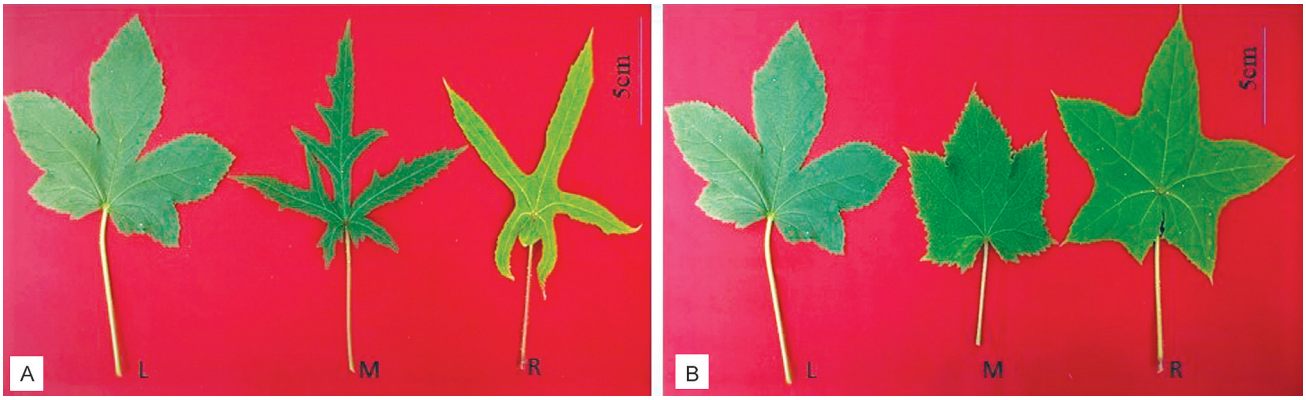

Fig. 1 Depiction of the morphological variation of leaves.
(A) Pusa Sawani crossed with *A. moschatus* (IC-141055): L, Left (Pusa Sawani); M, Middle (F_1 of Pusa Sawani and IC-141055); R, IC-141055; (B) Pusa Sawani crossed with *A. moschatus* (IC-141040): L, Left (Pusa Sawani); M, Middle (F_1 of Pusa Sawani and IC-141040); R, Right, IC-141040.

Fig. 2 Depiction of the morphological variation (size) of fruits Pusa Sawani crossed with *A. tetraphyllus* (IC 90476-1).
L, Pusa Sawani; M, F_1 of Pusa Sawani crossed with (IC 90476-1); R, Fruit of *A. tetraphyllus* (IC 90476-1).

of customer's preference. Light green fruits were found in the parental species. Better fruit colour and quality were recorded in F_1s than wild parents (Fig. 2). The fruit colour and quality can be improved by repeatedly backcrossing with cultivated okra and selecting the desired traits (large fruit size) (Kumar *et al.* 2016, Das *et al.* 2022, Badiger *et al.* 2023).

The erect plant type for okra allows for intensification of plant population and higher fruit yield. This study found higher diversity in fruit size, shape and length among parents and crosses. These results were also supported by Sekyere *et al.* (2011). Additionally, Adeniji and Aremu (2007) and Varshitha *et al.* (2020) reported that these traits have greater variability in okra plants.

Fruit length was shorter in all the interspecific hybrids with mean value of 9 cm than in the cultivated (14.6 cm), exhibiting negative heterosis over the mid and better parent. However, smaller fruits are preferred for canning and pickling, making these hybrids potentially desirable for those purposes (Olivera *et al.* 2012, Varshitha *et al.* 2020).

Disease screening: The PDI for YVMV at 90 days after sowing varies from 0.0 to 92 and for ELCV from 0.0 to 32 (Table 1). The highest PDI for both YVMV and ELCV was recorded for Pusa Sawani 92 and 32, respectively, which indicated its susceptibility to YVMV and ELCV. The wild species *A. tetraphyllus* also recorded YVMV but there was no incidence of ELCV. However, there was no incidence of both the diseases in two accessions of *A. moschatus*. The hybrids derived from *A. moschatus* were also free from both the diseases. Therefore, *A. moschatus* can be used as stable source of resistance for transfer of YVMV and ELCV resistance in cultivated okra. Similar finding was also reported by several researchers in okra (Santhiya *et al.* 2022, Puneeth *et al.* 2022). The phenomenon of heterosis is discussed in relation to the development of high-yielding and stable okra genotypes for viral diseases through interspecific hybridization. Despite differences observed among interspecific crosses of different wild species, hybrids were generally vigorous and displayed greater desirable heterosis in positive and negative directions for most of the traits, viz. fruit length, fruit weight and fruit yield per plant. These findings provide valuable insights into the genetic makeup of the hybrids and their potential for developing new cultivars with desirable traits

Mean performance and heterosis (%): Mean performance for 4 parentals species and their hybrids has been presented in Table 1. F_1s derived from these crosses had shown considerable difference in the mean performance and heterosis over mid parent and better parent for various vigour related traits, including yield.

The heterosis value was positive for most of the traits (Fig. 3), however some of the important traits, like fruit length (-15.29 to -58.69%), fruit diameter (-5.1 to -38.4%), first flowering node (-6.4 to -15.5%) and number of nodes on main stem (-2.39 to -24.65%) recorded heterosis in negative direction (Fig. 3 A–C). Additionally, the fruits of the

Table 1 Mean performance of various attributes of parents and their F_1s

Character	P_1	P_2	P_3	P_4	H_1	H_2	H_3
First flowering node (FFN)	6.67±0.33^{b}	8.33±0.33^{a}	6.33±0.33^{c}	7.33±0.33^{b}	6.33±0.33^{c}	7.33±0.33^{b}	6.33±0.33^{c}
Days to first flowering (DFF)	44.66±0.88^{c}	54.33±0.88^{a}	47.66±0.88^{b}	45±0.57b^{c}	47±0.57^{bc}	52.3±0.88^{a}	47±1.1^{bc}
Days to fruit maturity (DFM)	75.33±0.33^{f}	125.33±0.88^{a}	81.66±0.66^{d}	92.33±0.88^{c}	112.33±1.45^{b}	79±1.15^{e}	80.3±0.88^{de}
Internodal length (cm) (INL)	5±0.11^{c}	7.03±0.14^{a}	2.1±0.05^{e}	4.1±0.12^{d}	6.4±0.17^{b}	6.3±0.14^{b}	5.2±0.08^{c}
Number of nodes on main stem (NNMS)	24.3±0.33^{b}	28±0.57^{a}	21±0.05^{c}	22±0.66^{c}	27.33±0.88^{a}	18.3±0.88^{d}	20.3±0.88^{ed}
Plant height (cm) (PHT)	97.3±0.88^{c}	67.66±0.88^{g}	85.3±0.88^{e}	92±0.57^{d}	145±1.15^{a}	84.33±0.88^{f}	102±1.15^{b}
Stem diameter (cm) (SD)	1.93±0.08^{ab}	1.93±0.08^{ab}	1.3±0.05^{c}	1.7±0.08^{b}	2.1±0.08^{a}	2±0.11^{ab}	1.8±0.11^{b}
Number of branches/plant (NBP)	3.33±0.33^{c}	12.33±0.88^{a}	3.66±0.66^{c}	3.66±0.33^{c}	6.33±0.33^{b}	3.66±0.33^{c}	3.66±0.33^{c}
Leaf length (cm) (LL)	12.5±0.5^{cd}	11.9±0.55^{de}	14.9±0.17^{a}	13.4±0.11^{bc}	11.3±0.17^{e}	13.6±0.20^{b}	13.3±0.17^{bc}
Leaf width (cm) (LW)	11.5±0.28^{bc}	10±0.11^{d}	12.1±0.20^{ab}	11.2±0.14^{c}	9.3±0.14^{d}	12.5±0.28^{a}	11.7±0.12^{bc}
Leaf petiole length (cm) (LPL)	9.63±0.32^{d}	8.53±0.08^{e}	17.96±0.08^{a}	12.43±0.12^{c}	7.67±0.14^{f}	14.26±0.14^{b}	9.5±0.11^{d}
Epicalyx length (cm) (ECL)	0.96±0.08^{b}	0.63±0.03^{c}	1.56±0.08^{a}	1.26±0.08^{b}	1±0.11^{b}	1.23±0.08^{b}	1.23±0.08^{b}
Epicalyx width (mm) (ECW)	1.26±0.08^{c}	2.56±0.08^{a}	2.23±0.08^{ab}	1.66±0.08^{c}	2.03±0.14^{b}	1.56±0.14^{c}	1.5±0.11^{c}
Epicalyx number (ECN)	10.66±0.33^{a}	6.66±0.33^{c}	7.66±0.33^{bc}	8.66±0.33^{b}	8.33±0.33^{b}	8.33±0.33^{b}	10.33±0.33^{a}
Flower length (cm) (FLL)	4.93±0.08^{c}	4±0.11^{d}	5.33±0.08^{b}	5.66±0.08^{a}	4.03±0.08^{d}	5.13±0.19^{bc}	5.23±0.08^{bc}
Flower diameter (cm) (FLD)	4.33±0.08^{a}	3.2±0.11^{c}	3.3±0.05^{c}	4.5±0.05^{a}	3.7±0.14^{b}	3.9±0.14^{b}	4.37±0.11^{a}
Flower pedicel length (cm) (FPL)	1.47±0.05^{b}	1.03±0.08^{c}	1.63±0.08^{ab}	1.73±0.08^{a}	1.33±0.14^{bc}	1.46±0.12^{ab}	1.5±0.11^{ab}
Fruit length (cm) (FTL)	14.6±0.32^{a}	2.66±0.08^{f}	12.96±0.17^{b}	12.7±0.17^{bc}	6.03±0.14^{e}	9.9±0.17^{d}	12.36±0.17^{c}
Fruit diameter (cm) (FTD)	1.36±0.33^{c}	1.33±0.08^{c}	2±0.17^{a}	1.5±0.08^{bc}	1.8±0.11^{ab}	1.9±0.11^{ab}	2.16±0.12^{a}
Number of ridges/fruit (NRP)	5	5	5	5	5	5	5
Number of fruits/plant (NFP)	19.3±0.33^{d}	23.66±0.66^{b}	17.33±0.88^{e}	20.33±0.88^{c}	33±0.88^{a}	15.3±0.88^{f}	17.3±0.88^{e}
Fruit weight (FW)	12.6±0.26^{b}	3.16±0.08^{f}	14.03±0.20^{a}	12.53±0.14^{b}	5.36±0.20^{e}	6.96±0.14^{d}	11.66±0.33^{c}
Fruit yield/plant (g) (FYP)	139.6±1.30^{e}	61.33±0.88^{g}	216.33±0.88^{a}	172±1.73^{c}	180.33±1.45^{b}	120±1.15^{f}	161.3±1.45^{d}
Per cent disease incidence (YVMV)	92	0.3	0.0	0.0	3.3	0.0	0.0
Per cent disease incidence (ELCV)	32	0.0	0.0	0.0	0.0	0.0	0.0
Average whitefly count	35.5	6.5	2.8	2.3	8.0	4.0	4.5

P_1, Pusa Sawani; P_2, *A. manihot* var. *tetraphyllus* (IC 90476-1); P_3, *A. moschatus* (IC-141055); P_4, *A. moschatus* (IC-141040); H_1, $P_1\times P_2$; H_2, $P_1\times P_3$; H_3, $P_1\times P_4$.

hybrids exhibited intermediate length, with strong hairiness and concave fruit surfaces between ridges. Most of traits which were qualitative in nature are genetically controlled and less dependent on environmental factors. Similar results were reported by Sinha and Mishra (2013) and Bashar *et al.* (2015). Yield related characters of F_1s mostly tend towards the wild parent as reported by Sandeep *et al.* (2022). These findings corroborated with those of previous studies on morphological characteristics to confirm the hybridity of interspecific crosses of *Abelmoschus* species (Akhond *et al.* 2000, Kumar *et al.* 2016, Das *et al.* 2022).

Biochemical analysis

Chlorophyll and carotenoid content: The maximum chlorophyll a, chlorophyll b and total chlorophyll was found more in the wild species, viz. IC-141040, IC-141055,

Fig. 3 Representation of per cent heterosis in positive and negative direction for the traits. (A) Per cent heterosis in Pusa Sawani × IC 90476-1; (B) Per cent heterosis in Pusa Sawani × IC-141055; (C) Per cent heterosis in Pusa Sawani × IC-141040.

IC 90476-1 followed by cultivated species. The interspecific crosses also showed higher value than the cultivated parents (Table 2). Similar trends were observed for carotenoid content which was found maximum in IC 90476-1 (1.61 mg/g) followed by IC-141055 and IC-141040 i.e. 1.56 and 1.54 mg/g respectively.

Phenol content: It was found maximum in the wild species with 28.5, 27.5 and 23.6 mg/g for IC-141040, IC-141055 and IC 90476-1, respectively followed by the interspecific derived F_1s i.e. 25.2, 25.1 and 24.5 mg/g for Pusa Sawani × IC 90476-1, Pusa Sawani × IC-141040 and Pusa Sawani × IC-141055, respectively. The lowest phenolic content was observed in Pusa Sawani with 15.53 mg/g.

Moisture content: It was found maximum (90%) in Pusa Sawani and Pusa Sawani × IC-141055 followed by Pusa Sawani × IC 90476-1, Pusa Sawani × IC-141040 with 89% and 88%, respectively and low in wild species with 88%, 87% and 86% in IC 90476-1, IC-141055 and IC-141040, respectively.

Mucilage content: It was found maximum in the wild species with 5.87% and 5.48% for IC-141040, IC-141055 respectively. F_1s had mucilage content 5.46%, 5.33% and 5.03% for Pusa Sawani × IC-141040, Pusa Sawani × IC-141055 and Pusa Sawani × IC 90476-1 respectively and lowest was found in Pusa Sawani (3.49%).

Sugar content: It was found highest in the wild species with 6.5%, 6.2%, 6.1% for IC 90476-1, IC-

Table 2 Biochemical parameters of parents and their F_1s

Trait	P_1	P_2	P_3	P_4	H_1	H_2	H_3
Chlorophyll a (mg/g)	0.90±0.003^{b}	0.95±0.07^{b}	1.06±0.033^{a}	1.11±0.006^{a}	0.95±0.003^{b}	0.95±0.003^{b}	0.97±0.007^{b}
Chlorophyll b (mg/g)	0.81±0.03^{d}	0.89±0.01^{c}	0.96±0.03^{b}	1.04±0.03^{a}	0.86±0.07^{cd}	0.87±0.06^{cd}	0.89±0.01^{c}
Total chlorophyll (mg/g)	1.72±0.006^{d}	1.84±0.009^{c}	2.03±0.06^{b}	2.15±0.009^{a}	1.82±0.006^{c}	1.82±0.009^{c}	1.84±0.015^{c}
Carotenoid (mg/g)	1.42±0.007^{c}	1.61±0.009^{a}	1.56±0.003^{ab}	1.54±0.006^{b}	1.52±0.003^{b}	1.53±0.003^{b}	1.51±0.003b
Phenol (mg/g)	15.53±0.06^{f}	23.66±0.08^{e}	27.5±0.05^{b}	28.5±0.05^{a}	25.2±0.05^{c}	24.5±0.05^{d}	25.1±0.05^{c}
Moisture content (g)	90±0.20^{a}	88±0.34^{c}	87±0.23^{d}	86±0.08^{e}	89±0.12^{b}	90±0.11^{a}	88±0.08^{c}
Mucilage (%)	3.49±0.01^{f}	4.87±0.01^{e}	5.48±0.01^{b}	5.87±0.03^{a}	5.03±0.06^{d}	5.33±0.03^{c}	5.46±0.03^{b}
Sugar (%)	4.6±0.03^{e}	6.5±0.06^{a}	6.1±0.05^{b}	6.2±0.03^{b}	5.8±0.02^{c}	5.8±0.03^{c}	5.6±0.03^{d}
Ascorbic acid (µg/g)	10.4±0.03^{g}	15.5±0.03^{c}	18.5±0.06^{a}	17.1±0.05^{b}	13.5±0.03^{e}	14.5±0.03^{d}	12.7±0.05^{f}

P_1, Pusa Sawani; P_2, *A. manihot* var. *tetraphyllus* (IC 90476-1); P_3, *A. moschatus* (IC-141055); P_4, *A. moschatus* (IC-141040); H_1, $P_1\times P_2$; H_2, $P_1\times P_3$; H_3, $P_1\times P_4$.

141040 and IC-141055 respectively followed by interspecific derived F_1s i.e. 5.8 for both Pusa Sawani × IC-141055 and Pusa Sawani × IC 90476-1, and 5.6% for Pusa Sawani × IC-141040 and lowest with 4.6% in Pusa Sawani.

Ascorbic acid content: It was found maximum in the wild species with 18.5, 17.1, 15.5 µg/g for IC-141055, IC-141040 and IC 90476-1 respectively. F_1s recorded 14.5, 13.5 and 12.7 µg/g for Pusa Sawani × IC-141055, Pusa Sawani × IC 90476-1 and Pusa Sawani × IC-141040 respectively, and lowest in Pusa Sawani with 10.4 µg/g.

Wild species of okra has rich source of biochemical components and these quality parameters also can be improved by interspecific hybridization. This was further supported by the findings of Piloo and Kabir (2011) described that the dark green varieties are rich in total carotenoid content. Similar findings have been reported for the improvement of biochemical constituents, viz. carotene, ascorbic acid, minerals, fatty acids in the interspecific crosses of *C. annum* × *C. frutescens* (Pinar *et al.* 2023).

This study focused on the morphological and biochemical characterization of cultivated, wild okra species and their interspecific hybrids, and the results indicated that interspecific hybrids had heterosis in a desirable direction for yield and other horticulturally important traits and this method of estimating heterosis provides a useful tool for plant breeders to select the most promising hybrid combinations for improving crop yield and other desirable traits.

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