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Characterisation of Indian jujube (*Ziziphus mauritiana* Lamk.) germplasm under semi-arid conditions

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ABSTRACT

A comprehensive characterization of 28 germplasm of Indian jujube (*Ziziphus mauritiana* Lamk.) was conducted for morphological traits of fruit and stone. Significant variability was observed in fruit shape apex and fruit colour at maturity. Twelve germplasm had round fruit apex and eleven germplasm exhibited pointed fruit apex, rest five showed flat apex of fruit. Fruit skin colour like yellow, light yellow, yellowish green, greenish yellow, light green with yellow shade, greenish, green, pale green, light green and mixture of greenish to yellowish was recorded. Most of germplasm (16) exhibited ridged and wart fruit surface and remaining had plain fruit surface. Germplasm Dandan, Safeda Selection, Rohtak Safeda, Seo, Hsaianaul, Katha Bombay, Thornless, Sanori and Kaithali had soft pulp texture whereas; Bawal Selection 1 and Umran had hard pulp texture. Remaining germplasm were grouped in medium soft pulp texture. Stone shapes further classified into oblong, oval, spindle, club, and falcate categories along with stone shape apex. Further the selected germplasm grouped as per DUS guidelines. Based on fruit shape, the maximum germplasm (10) fell in group of ovate fruit shape, followed by oval (eight germplasm) and had falcate (one germplasm). Similarly for pulp texture, most of germplasm (17) were grouped in medium pulp texture fruit. The two germplasm were grouped under hard pulp texture and rest of nine germplasm had soft pulp texture. Stone shape of fourteen germplasm fell in oval shape group, followed by club shape (five germplasm) and falcate, spindle, oblong group contain three germplasm in each. Wide variability was observed in various morphological traits and suggests differences in the evolutionary origins of these cultivars within the species.

Introduction

The Indian jujube (*Ziziphus mauritiana* Lamk.), commonly referred to as ber, pertains to the Rhamnaceae family and predominantly inhabits tropical regions spanning southern

Asia, Africa, Australia and including Taiwan and China (Pasternak *et al.*, 2009). Ber is renowned for its exceptional climatic adaptability, it is used for multipurpose under arid to semi-arid areas, playing a pivotal role in mitigating soil erosion and desertification (Pareek, 2001). The *Jhar beri* i.e. *Z. mauritiana* exhibits resilience to drought, salinity,

and desiccation (Grice, 1997). The ber tree contributes significantly to the sustenance of desert inhabitants by providing nutritious fruits for consumption, serving as an excellent agroforestry species, offering valuable fodder, and exhibiting medicinal properties. It is lauded as a “gift of mother nature” symbolizing the productive capacity of seemingly infertile ecosystems. Beyond its agricultural utility, the ber tree finds application in fencing, hedges, and windbreaks. The leaves are a staple in the diets of camels, cattle, sheep, and goats. Notably, the Indian jujube serves as a host for the lac insect *Kerria lacca*, and its leaves are utilized to feed tasar silkworms.

Ber fruits renowned for its nutritional and medicinal properties, its fruit surpasses the most preferred fruit apple in terms of vitamin C content, phosphorus, calcium, protein and carotene (Krishna *et al.*, 2014) and exceeds oranges in phosphorus, iron, vitamin C and carbohydrate content (Krishna and Parashar, 2013). The fruits are acknowledged for their sedative, flavonoid, anti-cancer, tonic, wound-healing, and anti-asthmatic properties (Ashraf *et al.*, 2015). Consequently, the Indian jujube is colloquially known as desert apple, Indian plum, or poor man’s apple, earning the title “King of arid zone fruits” (Shoba and Bharati, 2007). Its remarkable characteristics designate it as a “Famine Reserve Fruit.” Extracts from the fruits, leaves, and seeds exhibit antioxidant activity (Okala *et al.*, 2014; Dahiru and Obidoa, 2007). Sadeghi (2015) observed antibacterial activity and nanoparticles of gold during synthesis from *Z. mauritiana* extracts.

Despite its historical significance, the ber fruit has witnessed diminished importance, gradually supplanted by costlier fruits such as apples, grapes, and strawberries. This underutilization is attributed to inadequate awareness, limited technological intervention, and insufficient attention from the global scientific community. Recognizing the urgency, there is a compelling need to focus on ber improvement by augmenting, characterizing, evaluating germplasm, and incorporating it into breeding programs for enhanced productivity and superior fruit quality. The characterization

and evaluation of *Z. mauritiana* germplasm predominantly rely on morphophysiological traits, with researchers utilizing morphological descriptors encompassing growth and fruiting habit to classify and distinguish various germplasm (Vashishtha, 2001 and Saran *et al.*, 2006). The variability in the germplasm is employed to develop high yielding variety as most of the varieties are released as a seedling selection (Meghwal and Singh, 2024). The judicious selection of cultivars assumes paramount importance for success. Consequently, there is an imperative for the improvement of *Z. mauritiana* for fruit quality across diverse agro-ecological environments. This study aims to estimate the morphological characteristics of collected germplasm, identify unique traits for ber quality improvement.

Material and Methods

A total of 28 ber germplasm (Table 1) were evaluated at CCS Haryana Agricultural University, RRS, Bawal for two years (2020-21 and 2022-23). The experiment site located at latitude 28.1°N, longitude 76.5°E with the mean sea level height of 266 m in South - West part of Haryana. The semi-arid climate of this region is typical and distinguished by scorching, dry summers and chill winters. The experiment was laid out in randomized block design replicated thrice. Nine characters of germplasm were recorded as per the stage mentioned in the DUS guidelines (Anonymous, 2013). Observations on the mature fruit and stone parameters were recorded when fruit was ready for harvesting. Further, germplasm was grouped into different categories to assess the distinctiveness. Characteristics were observed by the jury members and these parameters were matched with the descriptors to know the variability among different germplasm. The characteristics used to group the germplasm/ varieties are fruit maturity group, mature fruit: shape, pulp texture and stone shape as described in DUS guideline.

Table 1. List of evaluated 28 ber germplasm

Dandan	Tasbtso	Jhajjar Special	Kathaphal
Gola Gurgaon	Hsaianaul	Thornless	Umrn
Govindgarh Selection 3	Sandhura Narnaul	Vilati	Kaithali
Safeda Selection	Katha Bombay	Bawal Selection 1	Thar Sevika
Rohtak Safeda	Katha Gurgaon	Bawal Selection 2	Thar Bhubhraj
Bhadurgarhia	Narua	Illaichi	Narendra Ber Selection 1
Seo	Narkali	Sanori	Narendra Ber Selection 2

Results and Discussion

The Table 2 and Figure 1a, b, c) present a comprehensive analysis of various germplasm of Indian jujube, based on several morphological characteristics related to fruit and stone traits. Fruit of these ber germplasm varied in fruit shape apex, fruit shape, fruit colour, fruit surface, pulp texture, pulp cavity at stylar end and stem end, stone shape and shape of stone apex. As per DUS guideline, round fruit apex was noticed in Dandan, Gola Gurgaon, Safeda Selection, Rohtak Safeda, Bhadurgarhia, Hsaianaul, Katha Gurgaon, Narkali, Bawal Selection 1, Kathaphal, Umran, Narendra Ber Selection 2 while, it was pointed in Govindgarh Selection 3, Tasbtso, Sandhura Narnaul, Narua, Jhajjar Special, Thornless, Vilati, Sanori, Kaithali, Thar Sevika, Thar Bhubharaj germplasm. Germplasm Seo, Katha Bombay, Bawal Selection 2, Illaichi, Narendra Ber Selection 1 had flat fruit apex. Further it is clear from data that the shape of mature fruit varied significantly among ber germplasm. The oblong fruit shape was recorded in Bawal Selection 1, Bawal Selection 2, Umran, Narendra Ber Selection 2 while, oval fruit shape was found in Dandan, Gola Gurgaon, Bhadurgarhia, Seo, Hsaianaul, Narkali, Kathaphal, Narendra Ber Selection 1. Germplasm Govindgarh Selection 3, Tasbtso, Sandhura Narnaul, Jhajjar Special, Thornless, Vilati, Sanori, Kaithali, Thar Sevika, Thar Bhubharaj had ovate fruit shape. Further, Oblate and Falcate fruit shape was noticed in Rohatk Safeda, Illaichi and Narua, respectively. Safeda Selection, Katha Bombay, Katha Gurgaon exhibited round fruit shape.

The data presented in Table 2 and Figure 1 (a,b,c) showed variation in ripe fruit skin colour among the ber germplasm. Fruit skin colour like yellow, light yellow, yellowish green, greenish yellow, light green with yellow shade, greenish, green, pale green, light green and mixture of yellowish to greenish was recorded. This variation is mainly due to the prevailing agro-climatic condition during growing region, genetic inheritance of germplasm or may be due to fruits remained on the plant for a longer time to attain maturity/ripening or due to more uptakes of nutrients, water and translocation of more photosynthates from source to sink (Patel *et al.*, 1977). Differences in the fruit colour and fruit-bearing characteristics among various germplasm may be intrinsic traits of the germplasm itself (Krishna *et al.*, 2016). Fruit surface was plain in most of the local germplasm except for Safeda Selection, Rohtak Safeda, Tasbtso, Sandhura Narnaul, Narua, Jhajjar Special, Umran, Kaithali, Bawal Selection 1, Bawal Selection 2, Narendra Ber Selection 1, Narendra Ber Selection 2, Thar Sevika, Thar Bhubharaj, had ridged and wart fruit surface on maturity. Similar results were also reported by Singh *et al.* (2019), Krishna *et al.* (2016), and Kumar *et al.* (2024) among different ber germplasm.

The germplasm namely Dandan, Safeda Selection, Rohtak Safeda, Seo, Hsaianaul, Katha Bombay, Thornless, Sanori and Kaithali had soft pulp texture whereas; Bawal Selection

1 and Umran had hard pulp texture. Remaining germplasm (Gola Gurgaon, Govindgarh Selection 3, Bhadurgarhia, Tasbtso, Sandhura Narnaul, Katha Gurgaon, Narua, Narkali, Jhajjar Special, Vilati, Bawal Selection 2, Illaichi, Narendra Ber Selection 1, Narendra Ber Selection 2, Kathaphal, Thar Sevika and Thar Bhubharaj) were grouped in medium soft pulp texture. The most of ber germplasm had pulp cavity at stylar end while, it was absent in Dandan, Gola Gurgaon, Safeda Selection, Hsaianaul, Katha Bombay, Narkali, Bawal Selection 1, Sanori, Kathaphal germplasm. Similarly, pulp cavity at stem end was present in Dandan, Gola Gurgaon, Govindgarh Selection 3, Safeda Selection, Rohtak Safeda, Bhadurgarhia, Tasbtso, Hsaianaul, Sandhura Narnaul, Narua, Narkali, Jhajjar Special, Thornless, Vilati, Bawal Selection 1, Bawal Selection 2, Sanori, Kathaphal, Umran, Kaithali, Narendra Ber Selection 1, Narendra Ber Selection 2, Thar Sevika, Thar Bhubharaj germplasm and it was absent in few germplasm i.e., Seo, Katha Bombay, Katha Gurgaon and Illaichi. These variations in various traits of fruit among the germplasm might be due to the genetic features of particular germplasm (Kumar *et al.*, 2024).

Likewise fruit apex, the stone apex was recorded as acute in Dandan, Govindgarh Selection 3, Tasbtso, Sandhura Narnaul, Narkali, Jhajjar Special, Thornless, Vilati, Sanori, Umran, Kaithali, Thar Sevika, Thar Bhubharaj, Narendra Ber Selection 2 while, apex of stone was obtuse in Gola Gurgaon, Safeda Selection, Rohtak Safeda, Bhadurgarhia, Seo, Hsaianaul, Katha Bombay, Katha Gurgaon, Narua, Bawal Selection 1, Bawal Selection 2, Illaichi, Kathaphal, Narendra Ber Selection 1. Further, the oblong stone was noticed in Dandan, Narua, Kaithali while, most of germplasm exhibited oval stone shape i.e., Gola Gurgaon, Safeda Selection, Rohtak Safeda, Bhadurgarhia, Seo, Hsaianaul, Katha Bombay, Katha Gurgaon, Narkali, Bawal Selection 1, Bawal Selection 2, Illaichi, Sanori, Kathaphal. The club stone shape was found in Govindgarh Selection 3, Jhajjar Special, Thornless, Vilati, Umran. Further, falcate stone shape was noticed in Tasbtso, Sandhura Narnaul, Thar Sevika and spindle type stone was found in Narendra Ber Selection 1, Narendra Ber Selection 2, Thar Bhubharaj. The findings of this research are also confirmed by the earlier researchers (Singh *et al.*, 2019; Krishna *et al.*, 2016 and Kumar *et al.*, 2024).

The data presented in Table 3 represents grouping of ber germplasm based on selected characteristics as per DUS guidelines. The diverse morphological characteristics among the cultivars highlight the rich genetic diversity within *Z. mauritiana*. This information is crucial for breeders and researchers in selecting appropriate cultivars for specific agro-ecological environments and for the improvement of ber quality. Further, the distinct characteristics observed in certain cultivars can guide breeding programs aimed at enhancing specific traits of interest.

Table 2. Variability in fruit and stone traits of ber germplasm

Germplasm	Fruit shape apex	Mature fruit shape	Mature fruit colour	Fruit surface	Pulp texture	Pulp cavity stylar end	Pulp cavity stem end	Stone shape apex	Stone shape
Dandan	Round	Oval	Pale green	Plain	Soft	Absent	Present	Acute	Oblong
Gola Gurgaon	Round	Oval	Yellowish green	Plain	Medium soft	Absent	Present	Obtuse	Oval
Govindgarh Selection 3	Pointed	Ovate	Greenish yellow	Plain	Medium soft	Present	Present	Acute	Club
Safeda Selection	Round	Round	Light yellow	Ridged and wart	Soft	Absent	Present	Obtuse	Oval
Rohtak Safeda	Round	Oblate	Yellowish	Ridged and wart	Soft	Present	Present	Obtuse	Oval
Bhadurgarhia	Round	Oval	Yellowish green	Plain	Medium soft	Present	Present	Obtuse	Oval
Seo	Flat	Oval	Yellowish green	Plain	Soft	Present	Absent	Obtuse	Oval
Tasbtso	Pointed	Ovate	Light green with yellow shade	Ridged and wart	Medium soft	Present	Present	Acute	Falcate
Hsaianaul	Round	Oval	Yellowish	Plain	Soft	Absent	Present	Obtuse	Oval
Sandhura Nar-naul	Pointed	Ovate	Greenish	Ridged and wart	Medium soft	Present	Present	Acute	Falcate
Katha Bombay	Flat	Round	Yellowish green	Plain	Soft	Absent	Absent	Obtuse	Oval
Katha Gurgaon	Round	Round	Greenish yellow	Plain	Medium soft	Present	Absent	Obtuse	Oval
Narua	Pointed	Falcate	Greenish yellow	Ridged and wart	Medium soft	Present	Present	Obtuse	Oblong
Narkali	Round	Oval	Yellowish green	Plain	Medium soft	Absent	Present	Acute	Oval
Jhajjar Special	Pointed	Ovate	Greenish yellow	Ridged and wart	Medium soft	Present	Present	Acute	Club
Thornless	Pointed	Ovate	Yellowish green	Plain	Soft	Present	Present	Acute	Club
Vilati	Pointed	Ovate	Green	Plain	Medium soft	Present	Present	Acute	Club
Bawal Selection 1	Round	Oblong	Green	Ridged and wart	Hard	Absent	Present	Obtuse	Oval
Bawal Selection 2	Flat	Oblong	Green	Ridged and wart	Medium soft	Present	Present	Obtuse	Oval
Illaichi	Flat	Oblate	Yellowish green	Ridged and wart	Medium soft	Present	Absent	Obtuse	Oval
Sanori	Pointed	Ovate	Light green with yellow shade	Ridged and wart	Soft	Absent	Present	Acute	Oval

Kathaphal	Round	Oval	Reddish green	Plain	Medium soft	Absent	Present	Obtuse	Oval
Umran	Round	Oblong	Pale green	Ridged and wart	Hard	Present	Present	Acute	Club
Kaithali	Pointed	Ovate	Yellowish green	Ridged and wart	Soft	Present	Present	Acute	Oblong
Thar Sevika	Pointed	Ovate	Green light	Ridged and wart	Medium soft	Present	Present	Acute	Falcate
Thar Bhubhraj	Pointed	Ovate	Greenish	Ridged and wart	Medium soft	Present	Present	Acute	Spindle
Narendra Ber Selection 1	Flat	Oval	Light green	Ridged and wart	Medium soft	Absent	Present	Obtuse	Spindle
Narendra Ber Selection 2	Round	Oblong	Yellowish green	Ridged and wart	Medium soft	Present	Present	Acute	Spindle

Table 3. Grouping of ber germplasm based on selected characteristics

Characters	Expression and Notes	No. of germplasm	Germplasm
Mature fruit: Shape	Oblong (1)	4	Bawal Selection 1, Bawal Selection 2, Umran, Narendra Ber Selection 2
	Oval (2)	8	Dandan, Gola Gurgaon, Bhadurgarhia, Seo, Hsaianaul, Narkali, Kathaphal, Narendra Ber Selection 1
	Ovate (3)	10	Govindgarh Selection 3, Tasbtso, Sandhura Narnaul, Jhajjar Special, Thornless, Vilati, Sanori, Kaithali, Thar Sevika, Thar Bhubharaj
	Oblate (4)	2	Rohatk Safeda, Illaichi
	Round (5)	3	Safeda Selection, Katha Bombay, Katha Gurgaon
	Falcate (6)	1	Narua
Pulp texture	Soft (3)	9	Dandan, Safeda Selection, Rohtak Safeda, Seo, Hsaianaul, Katha Bombay, Thornless, Sanori, Kaithali
	Medium (5)	17	Gola Gurgaon, Govindgarh Selection 3, Bhadurgarhia, Tasbtso, Sandhura Narnaul, Katha Gurgaon, Narua, Narkali, Jhajjar Special, Vilati, Bawal Selection 2, Kathaphal, Illaichi, Thar Sevika, Thar Bhubharaj, Narendra Ber Selection 1, Narendra Ber Selection 2
	Hard (7)	2	Bawal Selection 1, Umran
Stone shape	Oblong (1)	3	Dandan, Narua, Kaithali
	Oval (2)	14	Gola Gurgaon, Safeda Selection, Rohtak Safeda, Bhadurgarhia, Seo, Hsaianaul, Katha Bombay, Katha Gurgaon, Narkali, Bawal Selection 1, Bawal Selection 2, Illaichi, Sanori, Kathaphal
	Spindle (3)	3	Thar Bhubharaj, Narendra Ber Selection 1, Narendra Ber Selection 2
	Club (4)	5	Govindgarh Selection 3, Jhajjar Special, Thornless, Vilati, Umran
	Falcate (5)	3	Tasbtso, Sandhura Narnaul, Thar Sevika

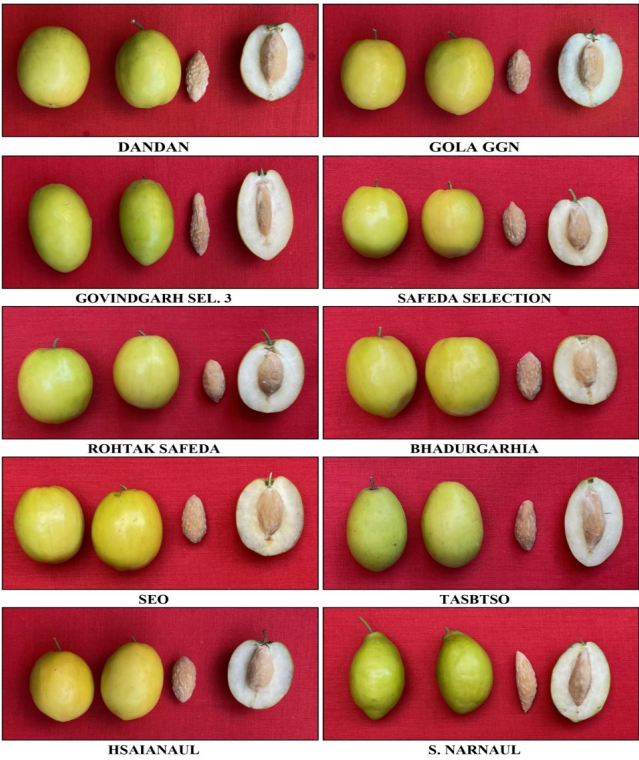


Fig. 1a. Divergence in the morphological characteristics of the ber germplasm



Fig. 1b. Divergence in the morphological characteristics of the ber germplasm



Fig. 1c. Divergence in the morphological characteristics of the ber germplasm

Conclusion

The morphological characterization of Indian jujube (*Ziziphus mauritiana* Lamk.) germplasm revealed significant variation in fruit and stone traits, including fruit shape, colour, surface, pulp texture, and cavity presence, as well as stone shape and apex type. These differences, influenced by genetic and environmental factors, highlight the rich genetic diversity within the species. Such variability is essential for cultivar identification, selection, and breeding programs aimed at trait improvement and suitability to specific agro-climatic conditions, in accordance with DUS guidelines.

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Conflict of Interest

The authors declare no conflict of interest.

Data Sharing

All relevant data are within the manuscript.

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