DOI : 10.58993/ijh/2024.81.4.4
Indian J. Hortic. 81(4), December 2024: 359-365

Evaluation of ber genotypes grown under semi-arid condition

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ABSTRACT

The present investigation was conducted for evaluation of Indian jujube genotypes, wherein a total of 25 ber genotypes were evaluated for both qualitative and quantitative traits. Out of studied genotypes, Narendra Ber Sel.1 (31.14 g) proved superior in terms of fruit weight also having the maximum stone weight (1.84 g). The longest fruit (44.06 mm) and stone (30.28 mm) was reported in Chuhhara, while highest fruit width was noticed in Bhadurgarhia (34.86 mm). The genotype Illaichi had the smallest fruit weight and size. The pulp/ stone ratio was highest in Bhadurgarhia (17.61) genotype. The germplam also differed significantly for various biochemical characters such as pulp total soluble solids (TSS), pulp acidity and ascorbic acid. The highest pulp TSS was recorded Illaichi (22.13°B), whereas it was minimum in Hsaianaul (12.68°B). The lowest pulp acidity was recorded in Katha Bombay (0.26%). Genotype Kathaphal tended to show the highest ascorbic acid content (84.32 mg 100 g^{-1} fruit weight), while it was lowest in Katha Bombay (65.57 mg 100 g^{-1} fruit weight). The study shows the potential for utilization of these genotypes in commercial production, and various crop improvement programmes.

Key words: *Ziziphus mauritiana* Lamk., genotypes, crop improvement, fruit, seed.

INTRODUCTION

The Indian jujube or ber (*Ziziphus mauritiana* Lamk.) is one of the finest fruits growing in the arid and semi-arid region of the country. The tree illustrates a plant that is exceptionally tolerant of drought and may be grown in dry locations and marginal edaphoclimatic conditions. The fruits are rich in carotene, vitamin C, protein, calcium, and phosphorus than apple (Azam-Ali *et al*., 7; Krishna *et al*., 13; Krishna and Parashar, 12). Most common cultivars are the outcome of selection in various geographic areas. Additionally, to preserve their genetic integrity, farmers choose seedlings already growing in nature, based on their economic characteristics, and continued to multiply them vegetatively. A wide range of variability exists throughout the Indian subcontinent in term of plant and fruit quality, suggesting ample scope for the ber improvement and systematic breeding programme. However, several cultivars have ambiguous morphological descriptors.

Furthermore, many indigenous genotypes have been left uncharacterized, and systematic documentation of available variability needs attention for their future improvement. Evaluation of genetic variation within natural populations is pivotal for effectively conserving and exploiting genetic resources for crop improvement programmes. Besides, ber provides nutritional security to the local population, which can also help to design future breeding strategies for developing nutrients fortified varieties with enhanced health properties. Therefore, the present study was undertaken to characterize and evaluate 25 ber genotypes, based on morphological and biochemical characteristics and to establish the distinctness of the variety from other varieties available in India for eliminating duplicity in available accessions.

MATERIALS AND METHODS

The present study was conducted at RRS, Bawal, located at latitude 28.1°N, longitude 76.5°E, and 266 m above mean sea level in the southwest zone of Haryana. The typical semi-arid climate of this region is distinguished by scorching, dry summers and very cold winters. The experiment was laid out in Randomized Block design with three replications. In the present study, 25 ber genotypes were selected for evaluation in 2020-2021 and 2021-2022. The fully mature ber trees were earmarked during the fruiting season, and mature fruits were randomly plucked from the tagged trees to record the data on fruit quality traits. These fruits were washed thoroughly with water to remove the dirt and dust adhering to the fruit. The observations were recorded on several morphological parameters *viz*., mature fruit weight (g), mature fruit length (mm), mature fruit width (mm), stone weight (g), stone length (cm), stone width (mm), pulp: stone ratio, were recorded as per DUS guidelines (Anonymous, 2). The digital refractometer was used to directly quantify biochemical parameters, such as the TSS content of fruit pulp

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(Brix: 0.0 to 53.0%) at 20°C. The titratable acidity (TA) of pulp was determined using titration against 0.1 N NaOH, and ascorbic acid content was estimated with 2,6-dichlorophenolindophenol dye (AOAC, 1).

All the observations were triplicated and subjected to ANOVA (analysis of variance) and the mean separation between treatments was considered significant using LSD value at *p≤0.05*. Pearson's correlation and Cluster analysis (HCA) were performed using the average of studied physico-chemical traits, to highlight the association between traits and distances between genotypes, using RStudio (RStudio, PBC, Version 2022.07.1-554).

RESULTS AND DISCUSSION

The results of the present study showed the significant variations for the morphological traits of various genotypes as shown in Table 1 and Fig. 1. The average fruit weight of ber genotypes ranged between 7.33 - 31.14 g. The heaviest fruit was noticed in Narendra Ber Sel. 1 (31.14 g), which was followed by Umran, Narendra Ber Sel. 2 and Bhadurgarhia, while Illaichi had the lightest fruit weight (7.33 g). The longest fruit was recorded in Chuharra (44.06 mm), which was statistically at par with the genotypes Umran, Kaithali, Jhajjar Special and Thornless, and the highest fruit width was recorded in Bhadurgarhia (34.86 mm) genotype, which was statistically at par with Narendra Ber Sel. 1. Whereas, the Illaichi genotype registered the lowest fruit size having 19.44 mm and 19.90 mm, fruit length and width, respectively, among the studied genotype. Furthermore, the stone weight varied from 0.70 to 1.84 g. The lowest stone weight

Table 1. Fruit physical traits of ber genotypes grown under semi-arid condition (Pooled means for two seasons).

Genotype	Fruit weight (g)	Fruit length (mm)	Fruit width (mm)	Stone weight (g)	Stone length (mm)	Stone width (mm)	Pulp: stone ratio
Dandan	16.08^{i}	37.02^{fgh}	27.51^{efghi}	1.24^{hi}	23.46^{hijk}	10.02^{cdef}	11.97^{q}
Gola	15.32^{ij}	33.85^{hij}	26.46^{fghij}	1.12^{ij}	22.53^{jkl}	12.81^{a}	12.70^{k}
Govindgarh Sel. 3	22.97^{de}	43.89^{a}	27.86^{defgh}	1.61^{cde}	27.89^{abcde}	8.54^{hij}	13.27^{i}
Kathaphal	14.90^{ij}	27.85^{l}	23.71^{j}	0.94^{k}	22.87^{ijkl}	10.21^{cde}	15.07^{d}
Katha Rajasthan	18.75^{h}	29.21^{kl}	27.12^{efghi}	1.46^{f}	25.91^{defgh}	10.72^{bcd}	11.85^{r}
Katha Bombay	13.51^{j}	31.54^{jkl}	24.6^{ij}	0.96^{k}	20.73^{l}	9.90^{cdef}	13.08^{j}
Seo	16.53^{i}	32.79^{ijk}	25.28^{hij}	1.08^{jk}	21.19^{kl}	9.70^{defg}	14.32^{e}
Illaichi	7.33^{k}	19.44^{m}	19.90^{k}	0.70^{l}	15.53^{m}	7.64^{j}	9.47^{u}
Jhajjar Special	22.38^{def}	41.77^{abcd}	28.18^{defgh}	1.50^{ef}	27.18^{bcdef}	8.48^{ij}	13.92^{h}
Hsaianaul	15.70^{i}	36.56^{fghi}	26.86^{fghi}	1.17^{hij}	23.09^{ijkl}	9.64^{efg}	12.44^{n}
Bhadurgarhia	23.96^{bcd}	38.01^{def}	34.86^{a}	1.29^{gh}	23.98^{ghij}	11.48^{b}	17.61^{a}
Sanori	20.68^{fgh}	39.41^{bcdef}	29.01^{cdef}	1.45^{f}	25.28^{efghi}	10.89^{bc}	13.28^{i}
Safeda Rohtak	20.07^{gh}	39.88^{bcdef}	28.18^{defgh}	1.48^{ef}	26.32^{cdefg}	10.08^{cdef}	12.59^{l}
Safeda selection	15.53^{ij}	34.15^{ghij}	28.42^{cdefg}	1.15^{hij}	22.84^{ijkl}	9.33^{efghi}	12.51^{m}
Tasbtso	22.63^{def}	36.70^{fgh}	29.92^{cde}	1.70^{abc}	28.63^{abc}	9.74^{defg}	12.31^{o}
Thornless	23.70^{cd}	41.47^{abcde}	30.71^{bcd}	1.69^{bcd}	28.40^{abcd}	9.15^{fghi}	13.02^{j}
BS 1	16.44^{i}	37.82^{efg}	27.09^{efghi}	1.26^{hi}	24.16^{ghij}	9.56^{efgh}	12.05^{p}
BS 2	16.56^{i}	37.16^{fgh}	28.11^{defgh}	1.22^{hij}	24.42^{ghij}	9.21^{efghi}	12.59^{l}
Umran	26.02^{b}	42.80^{ab}	31.22^{bc}	1.73^{abc}	28.16^{abcd}	9.71^{defg}	14.05^{g}
Kaithali	19.53^{gh}	41.86^{abc}	25.86^{ghij}	1.61^{cde}	29.01^{ab}	8.85^{ghi}	11.13^{t}
Chuharra	21.12^{efg}	44.06^{a}	26.87^{fghi}	1.68^{bcd}	30.28^{a}	9.46^{efghi}	11.57^{s}
Thar Sevika	23.45^{cd}	39.32^{bcdef}	27.42^{efghi}	1.55^{def}	27.65^{abcde}	9.98^{cdef}	14.13^{f}
Thar Bhubhraj	22.76^{def}	38.33^{cdef}	28.61^{cdefg}	1.78^{ab}	26.17^{cdefg}	9.66^{efg}	11.79^{r}
Narendra Ber Sel. 1	31.14^{a}	38.42^{cdef}	33.65^{ab}	1.84^{a}	27.14^{bcdef}	10.18^{cdef}	15.93^{c}
Narendra Ber Sel.2	25.46^{bc}	39.12^{bcdef}	30.78^{bcd}	1.41^{fg}	24.88^{fghij}	9.88^{cdefg}	17.06^{b}
LSD (p≤0.05)	2.08	3.79	2.95	0.14	2.63	1.05	0.06

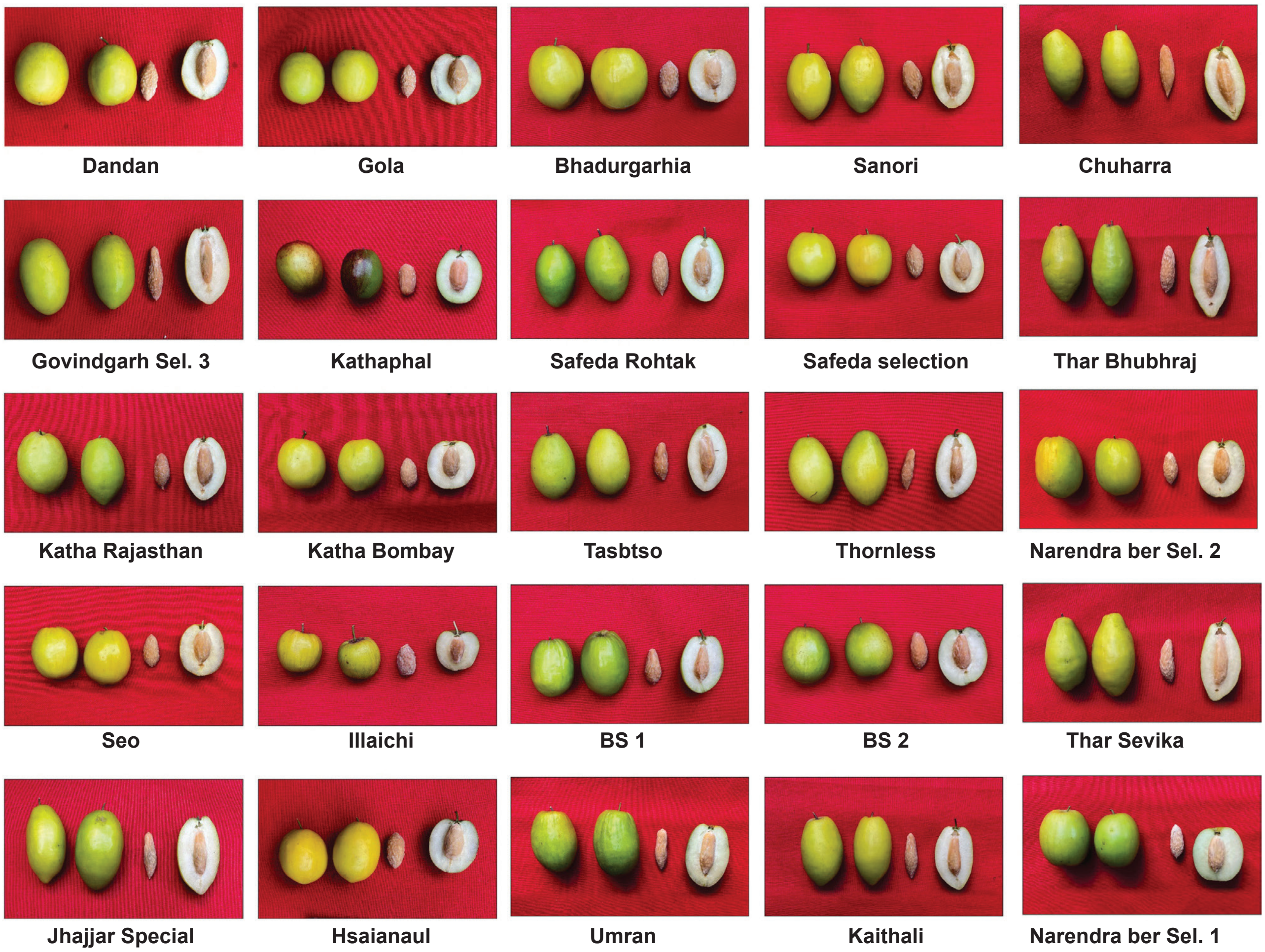

Fig. 1. Mature fruit of different ber genotypes.

was recorded in the genotype Illaichi, while it was highest in Narendra Ber Sel. 1. The stone length ranged from 15.53 mm to 30.28 mm, and it was observed minimum in Illaichi (15.33 mm), whereas the highest stone length (30.28 mm) was recorded for genotype Chuharra. The lowest stone width (7.64 mm) was recorded in Illaichi, which was statistically at par with Govindgarh Sel. 3, while the highest stone width was found in Gola (12.81 mm). The pulp/stone ratio of the evaluated ber genotype ranged from 9.47 to 17.61. The highest pulp/stone ratio was noted in the Bhadurgarhia, while the lowest pulp/stone ratio was registered in Illaichi (9.47).

The results obtained for physical traits in the present study align with the findings of Singh *et al.* (20), stating that the genotype exhibited a wide range of diversity for different morphological characters. The extensive variability in fruit and stone morphological parameters among Indian jujube cultivars has also been documented by various researchers (Singh and Misra, 18; Godi *et al.*, 8). The differences in the physical parameters of the fruits among the studied ber genotypes are attributed to the high heterozygosity of genotypes. The individual genotypes have unique fruit size at fruit maturity, resulting from their genetic makeup, leading to differential ovarian tissue development rates, further affected by agronomic practices, plant nutrition, and prevailing agroclimatic conditions (Singh *et al.*, 17). The physical attributes of fruits are an important criterion for selecting a new suitable genotype and selection of parentage(s) during the hybridization programme.

The biochemical characteristics in terms of pulp TSS, TA (citric acid equivalent) and ascorbic acid of ber genotype varied significantly among the evaluated ber genotypes (Table 2). The pulp TSS and TA of fruit ranged from 12.68-22.13°B and 0.26-0.49%, respectively. The highest TSS content 22.13°B was recorded in Illaichi, which was statistically at par with Kathaphal (20.40°B), while the Hsaianual genotype had the minimum TSS (12.68°B).

Table 2. Fruit biochemical traits of ber genotypes grown under semi-arid condition (Pooled means for two seasons).

Genotype	TSS (ºBrix)	Titratable acidity (%)	Ascorbic acid (mg/100g FW)
Dandan	16.10^{fg}	0.33^{hi}	69.91^{ghij}
Gola	19.95^{bc}	0.41^{cde}	79.42^{abcde}
Govindgarh Sel. 3	12.79^{ij}	0.30^{i}	69.11^{hij}
Kathaphal	20.40^{ab}	0.49^{a}	84.32^{a}
Katha Rajasthan	15.40^{gh}	0.35^{fgh}	71.02^{fghij}
Katha Bombay	12.75^{j}	0.26^{j}	65.57^{j}
Seo	18.15^{cde}	0.36^{fgh}	71.82^{efghij}
Illaichi	22.13^{a}	0.39^{defg}	75.86^{bcdefghi}
Jhajjar Special	15.19^{gh}	0.35^{gh}	70.52^{fghij}
Hsaianaul	12.68^{j}	0.39^{def}	77.26^{abcdefg}
Bhadurgarhia	15.65^{gh}	0.42^{cd}	80.03^{abcd}
Sanori	17.74^{def}	0.36^{fgh}	72.16^{defghij}
Safeda Rohtak	18.25^{cd}	0.39^{def}	76.73^{abcdefgh}
Safeda selection	20.13^{b}	0.45^{bc}	82.16^{abc}
Tasbtso	14.05^{hij}	0.39^{defg}	76.32^{abcdefghi}
Thornless	13.23^{ij}	0.36^{fgh}	71.68^{efghij}
BS 1	14.66^{ghi}	0.33^{hi}	69.45^{ghij}
BS 2	13.95^{hij}	0.30^{i}	68.26^{ij}
Umran	17.82^{def}	0.36^{fgh}	73.98^{defghi}
Kaithali	17.72^{def}	0.48^{ab}	83.10^{ab}
Chuharra	18.06^{de}	0.36^{fgh}	73.41^{defghij}
Thar Sevika	18.57^{bcd}	0.40^{de}	78.14^{abcdef}
Thar Bhubhraj	19.06^{bcd}	0.38^{defg}	75.20^{bcdefghi}
Narendra Ber Sel. 1	17.85^{def}	0.37^{efgh}	74.69^{cdefghi}
Narendra Ber Sel.2	16.37^{efg}	0.35^{fgh}	70.63^{fghij}
LSD (p≤0.05)	1.88	0.04	8.14

The Katha Bombay genotype exhibited the lowest TA (0.26%) which was followed by Govindgarh Sel. 3, BS 2, Dandan, BS 1. The highest pulp acidity of fruit pulp was noted in the genotype Kathaphal (0.49 %), while remaining genotypes had the intermediate acidity. The results of present study are consistent with those of Pareek *et al.* (14), who also reported that similar range of variation among ber genotype for biochemical traits. The variations observed in TSS values can be ascribed to the seasonal and climatic fluctuations within the region. In general, the prevailing dry weather conditions tend to promote higher TSS content in majority of cultivars (Singh and Misra, 18). The ascorbic acid content varied from 65.57 to 84.32 mg 100 g^{-1} fruit weight among the ber genotypes. The highest ascorbic acid (84.32 mg 100 g^{-1} fruit weight) was noticed in Kathaphal, which was statistically at par with Kaithali, Safeda Selection, Bhadurgarhia, Gola, Thar Sevika, Hsaianual, Safeda Rohtak and Tasbtso. However, the minimum ascorbic acid content was recorded in Katha Bombay (65.57 mg 100 g^{-1} fruit weight). The range of ascorbic acid in our study is in agreement with the previous research findings (Pareek *et al.*, 14; Koley *et al.*, 11). The results pertaining to the biochemical fruit quality attributes observed for each ber genotype provide valuable information for selecting genotypes with desirable fruit quality traits, potentially influencing decisions in cultivation and breeding programs of potential underutilized fruit crop i.e. ber.

The results of the present study indicated a significant correlation between the physical and biochemical attributes of different fruits (Fig. 2). The ascorbic acid content had a significant positive association with the TSS and TA (R^2=0.59 and 0.97, respectively). The TSS and TA also had a significant positive correlation. Among the fruit physical traits, fruit weight, length, and width positively correlated with seed weight and length. Furthermore, the pulp-to-stone ratio positively was correlated with fruit weight and fruit width. Ahmad *et al.* (3) and Anjum *et al.* (5) also noticed a significant correlation between fruit physico-chemical traits. These results substantiate

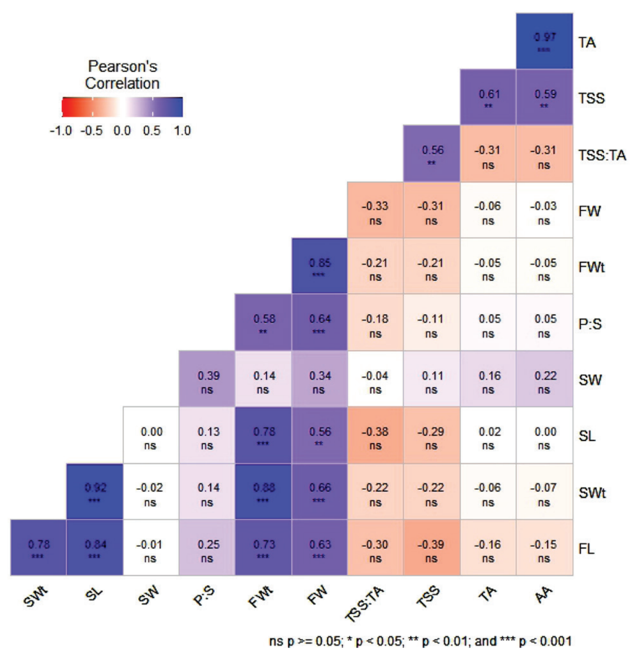

Fig. 2. Pearson's correlation for fruit physico-chemical fruit quality traits. TA=titratable acidity; TSS= total soluble solids; TSS:TA = TSS to TA ratio, FW=fruit width; FWt= fruit weight; P:S = pulp to stone ratio; SW = seed width; SL= seed length; FL= fruit length

the existence of a wide-ranging genetic diversity within the assemblage of 25 genotypes concerning various commercially significant traits such as fruit weight, pulp weight, and seed length. Furthermore, these traits displayed a strong interrelationship among themselves. A correlation analysis is an indispensable tool for plant breeders, facilitating the examination of associations between various traits and the simultaneous improvement of traits associated positively (Anwar *et al.*, 6; Ali *et al.*, 4). Specifically, the investigation revealed a positive direct correlation between ascorbic acid, TSS, and pulp acidity, which signifies that the traits can be improved simultaneously, and enhancing the ascorbic acid content along with TSS is helpful for breeding programmes. Furthermore, the fruit weight and traits include fruit length, width, and stone weight. This observation implies that as fruit weight increases, there is a concomitant increase in these respective traits. Relationships between different fruit quality attributes in the present study suggest that the selection for one could negatively or positively influence the other. The association between fruit attributes indicates their possibilities for simultaneous improvement in breeding programs and selecting the desirable fruits (Karimi *et al.*, 9).

Based on the studied fruit and seed traits, hierarchical cluster analysis (ward D2 method) was performed to estimate the interrelation among the genotypes under the present study. The 25 genotypes were grouped into five clusters based on the degree of genetic divergence among them (Fig. 3), and compared for each trait's cluster mean value (Table 3). Cluster II showed the highest number of genotypes (9 entries namely, Chuharra, Sanori, Thar Bhubhraj, Safeda Rohtak, Thar Sevika, Bhadurgarhia, Narendra Ber Sel.2, Umran and Narendra Ber Sel. 1), followed by clusters I (Govindgarh Sel. 3, Jhajjar Special, Tasbtso, Thornless, Hsaianaul and Kaithali) and III (Katha Bombay, Seo, Katha Rajasthan, Dandan, BS 1 and BS 2), each containing six genotypes, while cluster V had only three genotypes (Gola, Kathaphal and Safeda Selection) and cluster IV having only one genotype (Illaichi). It is evident from hierarchical clustering analysis that genetically similar ber genotypes tend to cluster together. The results agree with the previous study on ber fruit and tree traits (Kaundun and Park, 10; Saran *et al.*, 15; Anjum *et al.*, 5). The clustering pattern could be utilized in choosing parents for cross combinations likely to generate the highest possible variability for various economic characters in different sources were grouped in the same cluster, thus suggesting that

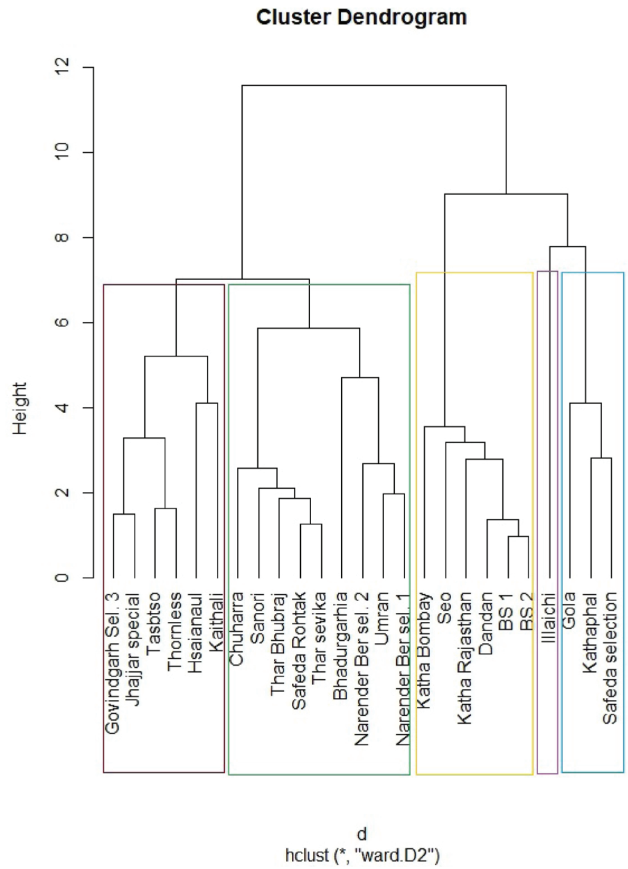

Fig. 3. Hierarchical clustering (ward D2) for ber genotypes based on studied fruit quality traits

Table 3. Cluster means for different physico-chemical fruit quality traits studied in ber genotypes (Pooled means for two seasons).

Cluster	Mature fruit weight (g)	Mature fruit length (mm)	Mature fruit width (mm)	Stone weight (g)	Stone length (mm)	Stone width (mm)	Pulp: stone ratio	TSS (ºBrix)	Titratable acidity (%)	Ascorbic acid (mg/100g FW)
I	21.15	40.38	28.23	1.55	27.37	9.07	12.68	14.28	0.38	74.67
II	23.85	39.93	30.07	1.58	26.65	10.15	14.22	17.71	0.38	75.00
III	16.31	34.26	26.62	1.20	23.31	9.85	12.64	15.17	0.32	69.34
IV	7.33	19.44	19.90	0.70	15.53	7.64	9.47	22.13	0.39	75.86
V	15.25	31.95	26.20	1.07	22.75	10.78	13.43	20.16	0.45	81.97

geographical diversity does not necessarily represent genetic diversity. Genotypes from these diverse clusters can be used in a hybridization programme for better heterotic combinations. Sehrawat *et al*. (16) stated similar results with a broad genetic base in Indian jujube for various morphological traits, clustered all genotypes in different groups, and suggested for developing the useful breeding materials for jujube improvement from these clusters.

Furthermore, the result of the present study showed that the cluster II exhibited the highest cluster mean for mature fruit weight (23.85 g), mature fruit width (30.07 mm), stone weight (1.58 g), pulp: stone ratio (14.22), whereas cluster I exhibited the highest cluster means for mature fruit length (40.38 mm), stone length (27.37 mm) and cluster V having the highest value for stone width (10.78 mm), TA (0.45%) and ascorbic acid (81.97 mg/100 g pulp). The highest value of cluster mean for pulp TSS (22.13 °B) was found in cluster IV. Similarly, cluster IV exhibited the lowest cluster mean for mature fruit weight (7.33 g), mature fruit length (19.44 mm), mature fruit width (19.90 mm), stone weight (0.70 g), stone length (15.53 mm), stone width (7.64 mm), pulp: stone ratio (9.47), whereas cluster I exhibited the lowest cluster means for pulp TSS (14.28 °B) and cluster III having lowest value for pulp acidity (0.32%) and ascorbic acid (69.34 mg/100 g pulp). The cluster means pertaining to various traits reflected as indicators of the genetic disparities existing among these clusters. These clusters exhibited discernible distinctions in relation to one or more traits. These findings are in accordance with previous research findings in ber (Saran *et al*., 15).

The present study noticed a significant variation in the fruit and seed traits among the genotypes. However, none of the hybrids were superior for all the studied traits. The unique qualities of the genotypes point towards enormous diversity and high heterozygosity. The genotype studied in this investigation might help select the genotype for fresh consumption, processing, and varietal developmental programmes. Conservation of the ber genotypes repository for future use, utilization in crop improvement, precise identification, and characterization of ber cultivars are in extreme demand in the current scenario. Moreover, extensive genetic variations in genotype are significant for breeders to develop high-yielding varieties, premium quality fruits, and resistance or tolerance to various biotic/abiotic stresses. The study also revealed that this region's local genotype was superior in terms of fruit traits and can be utilized for local production and crop improvement programmes.

AUTHOR'S CONTRIBUTION

Conceptualization of research (JRS, MK); Designing of the experiments (MK, JRS, SK); Contribution of experimental materials (MK, JRS); Execution of field/lab experiments and data collection (JRS, MK, SK); Analysis of data and interpretation (SK, NS, MK, NK); Preparation of the manuscript (SK, MK, NS, NK).

DECLARATION

The authors declare that they do not have any conflict of interest.

ACKNOWLEDGEMENT

The authors are highly thankful to the Department of Horticulture, College of Agriculture and Regional Research Station, Bawal, CCS Haryana Agricultural University for providing research facility and valuable support.

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Received : March, 2024; Revised : December, 2024;
Accepted : December, 2024