

MORPHOLOGICAL CHARACTERIZATION OF LEAVES AND FRUIT OF JUJUBE (*Ziziphus mauritiana* Lamk.) GERMPLASM IN FAISALABAD, PAKISTAN

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The genus *Ziziphus* (Jujube) with more than 100 species of deciduous or evergreen trees and shrubs distributed in the tropical and subtropical regions of the world offers sufficient plants genetic resources suitable for arid and semi arid climates to enhance food security. Some of the species, like *Z. mauritiana* occur in nearly every continent and is thought to possess great genetic diversity. The traditional selection and cultivation of *Ziziphus* varieties in China and India resulted in better known and more widely researched varieties than those in other regions. Several local and exotic ber varieties are cultivated for fruit production in Pakistan with the least research work regarding different aspects including morphological characterization of the available germplasm resources. In this study, existing gene pool was characterized for physical and morphological diversity to develop a reliable identification key which would lead to characterization, selection and approval of better germplasm for further cultivation. Eleven commercial varieties (Desi, Selection-13, Gola, Selection 11, Karnal Local, Gourh, Karela, Umran-9, Mirpuri, Khati Mithi, and Badam) and two unknown strains (Anonymous-1 and Anonymous-2) of ber were studied for qualitative and quantitative characters. The quantitative studies included leaf area, petiole length and fruit diameter, weight and volume while, qualitative studies comprised of leaf shape, apex, base, margins and characteristics of leaf dorsal and ventral surface. Fruits from the selected strains were also subjected to morphological studies including shape, type of stem-end and cavity, form of styler-end and skin appearance. Results showed great physico-morphological diversity suggesting division of all the 13 cultivars into 4 sections.

Keywords: Leaf and fruit morphology, cultivar characterization, Jujube, ber germplasm, underutilized fruits.

INTRODUCTION

The genus *Ziziphus* (Jujube) belongs to Buckthorn family (Rhamnaceae). It is a genus of about 100 species of deciduous or evergreen trees and shrubs distributed in the tropical and subtropical regions of the world between 34°S & 51°N latitude and up to 2800 m above sea level. Some species, like *Z. mauritiana* occur in nearly every continent. It is an example of an extremely drought-hardy species and is a dominant component of the natural vegetation of the Indo-Pak deserts. Both leaves and fruits of ber are very important from nutritional point of view for being richer in mineral contents (Ivanova, 1982) vitamin C (Wang *et al.*, 1992) and other important nutritional contents. In both China and India, *Ziziphus* varieties have a long tradition of selection and cultivation which resulted in better known and more widely researched varieties than those in other regions (Cherry, 1985). Various scientists have reported variation among ber cultivars. For example, in response to different pruning treatments and plant-to-plant spacing, Bisla *et al.* (1988) stated maximum and minimum leaf area of ber to be 25.87

cm² to 32.40 cm². Pareek (2001) narrated difference in leaf physical and morphological characteristics in several ber cultivars and reported the leaf length 4.9-12.0 cm; petiole length 1.1-3.2 cm; leaf width 3.6-6.5 cm; leaf area 15-60 cm²; leaf color from light green to dark green; leaf shape as oblong, oval-elliptic, round; leaf base as obtuse, broad, round, oblique, tapering, narrow, acute; leaf apex as round-obtuse, flat-obtuse, cupped-acute and curved-acute. He also summarized fruit physical characteristics of ber cultivars in India showing wide variations. Fruit shape varied from round, oval, ovate, obovate, oblong to oblate whereas fruit length ranged from 1.1 to 4.7 cm, size (length x breadth) from 1.7-2.2 x 3.5-5.7 and weight from 3.8 to 39.5 g. Kundu *et al.* (1995) noted the highest fruit weight (29.34 g) in cv. Cantonment whereas cv. Lal Wali had lowest fruit weight of 9.54 g only. Kundi *et al.* (1989) recorded fruit weight from 18.38 to 24.91 g in cv. Umran. Saini *et al.* (1994) estimated the fruit length x breadth to be the highest (4.2 x 1.6 cm) in severely pruned trees and lowest (3.6 x 1.6 cm) in un-pruned control. Botanical characterization of local gene pool in Pakistan has not been seriously taken up and records of local

cultivars are mostly missing, whereas, its care-free production demands identification of better yielding varieties for low income masses. Thus, exploitation of such varieties may boost commercial production of ber in Pakistan with lower inputs, better yield and improved nutrition.

In this research work, ampelographical studies were conducted on existing gene pool for physical and morphological characterization to develop a reliable identification key for these varieties which would further lead towards local patent varieties of Pakistan.

MATERIALS AND METHODS

Eleven commercial varieties (Desi, Selection-13, Gola, Selection 11, Karnal Local, Gourh, Karela, Umran-9, Mirpuri, Khati Mithi, and Badam) and two unidentified strains (Anonymous-I and Anonymous-II) of ber in University of Agriculture, Faisalabad were studied for qualitative and quantitative characters where each variety was considered as treatment. Exact age of the studied plants is not known, however, it is believed that the trees were planted between the years 1950 and 1960. The quantitative studies included leaf length (cm), leaf area (cm²), petiole length (cm), fruit diameter, weight and volume while, qualitative studies comprised of leaf shape, apex, base, margins and characteristics of leaf dorsal and ventral surface. Fruits were also studied for morphological characteristics including shape, type of stem-end and cavity, form of styler-end and skin roughness.

For the required measurements, 40 healthy leaves were taken at random from each variety and subjected to study the parameters mentioned above. Leaf area and length were measured with the help of digital leaf area meter (model MK2; Delta-T Devices, Cambridge, UK) and graduated scale, respectively. For qualitative studies, 50 leaves were collected randomly from each variety and visually analyzed for different parameters according to the key for identification, described previously (Anonymous, 1976). To record fruit physical and morphological characteristics, 90 fruit were harvested from each variety and randomly distributed into three equal replications. Morphological characteristics of fruit (shape, type of stem-end cavity, appearance of styler end and skin smoothness and/or roughness) were studied on visual basis and according to the key provided earlier (Anonymous, 1976), whereas, fruit length and diameter, weight and volume were recorded using digital Vernier's caliper (Model: HT0403-A1, Cingda Industry Co., Ltd. China) and electric weight balance and 500 ml volumetric cylinder, respectively. Length and width were recorded for single fruits, whereas, weight and volume were recorded for groups of five randomly selected fruits in such a way that graduated cylinder was half filled with water, initial reading was noted fruit were gently put

into the graduated cylinder, raising the water level. The final readings were carefully taken and mean fruit volume calculated using the formula:

$$\text{Mean Volume} = \text{Final reading} - \text{Initial reading} / 5$$

The data obtained from physical parameters was subjected to statistical analysis using completely randomized design (CRD) after Steel *et al.* (1997).

RESULTS

Leaf Quantitative Characteristics: Among various leaf physical parameters, leaf area varied significantly at $p < 0.05$ among cultivars. The maximum (41.80 cm²) leaf area was recorded in cv Karela followed by cv Umran 9 (33.47 cm²) with a significant difference from other cultivars and strains including Anonymous II and cv Ghor which produced the smallest (15.38 cm²) sized leaves (Fig.1). Petiole length also varied significantly among different cultivars. Maximum petiole length (2.405 cm) in cv Badam significantly varied from cv Karela (2.139 cm). Other varieties i.e. cv Mirpuri, Selection 11, Anonymous II and cv Karnal Local, were statistically at par with each other. Similarly cv Desi, Selection 13, cv Khati Mithi and Ghor were statistically at par with each other showing a significant difference ($P < 0.05$) from the strain Anonymous I; which showed the lowest petiole length (1.011 cm) in the germplasm. The leaf length varied significantly among all the cultivars at $P < 0.05$. V₂ showed the highest (9.872 cm) leaf length differing significantly from all other cultivars similarly; V₁₃ with the smallest leaf length (5.301 cm) differed significantly from other cultivars. Leaf breadth (cm) was found to be the highest (5.49 cm) in V₂ and the lowest (3.641 cm) in Anonymous I (Data not shown).

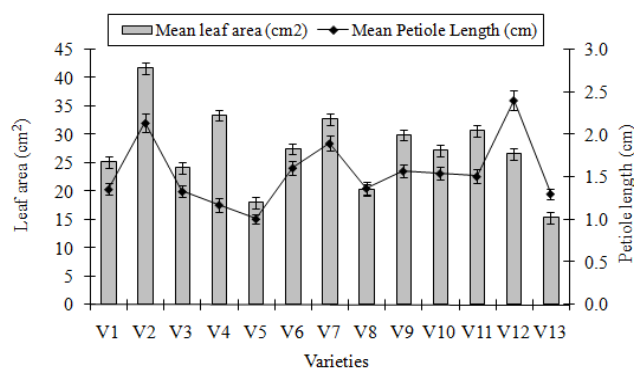


Figure 1. Mean leaf area and petiole length (\pm standard error) of ber cultivars and strains including V₁ (Desi), V₂ (Karela), V₃ (Selection 13), V₄ (Umran 9), V₅ (Anonymous I), V₆ (Mirpuri), V₇ (Gola), V₈ (Khati Mithi), V₉ (Selection 11), V₁₀ (Anonymous II), V₁₁ (Karnal Local), V₁₂ (Badam) and V₁₃ (Ghor). Standard error bars are indicated.

Leaf Qualitative Characteristics: The leaf qualitative characters were studied on visual appearance showing significant variations among different cultivars and strains. Overall leaf shapes in different cultivars and strains were noted to be Elliptic, Oblanceolate, Oval, Ovate and/or oblong as shown in Table 1. Leaf apex was noted to be obtuse in cultivars Desi, Karela, Anonymous I, cv Gola, cv Khati Mithi and cv Kernal Local, whereas, leaf apex shapes were noted to be cuspidate, acute or sub-acute in all of the other cultivars. Similarly, leaf base was found to be obtuse in most of the cultivars except Anonymous I, cv Selection 11 and cv Badam in which the leaf base turned to be Cuneate and cv Ghor, which was only one to exhibit a cordate shaped leaf base. Leaf margins and upper/lower surface types were also studied and are given in Table 1.

Fruit Quantitative Characteristics: Fruit physical characteristics consisted of fruit length, diameter, weight and volume. Fruit length and diameter showed significant statistical difference ($p < 0.05$) among different cultivars. The highest fruit length was observed in cv. Karela (4.69 cm) which was non-significant from cv. Selection 13 (4.60 cm), whereas, cv Ghor with the lowest fruit length (2.38 cm) was significantly different from all other cultivars. Similarly, fruit diameter was found to be the highest (3.274 cm) in cv. Umran 9, with non-significant difference from cv. Selection 13 (3.105 cm; Fig. 2). However, the unknown strain "Anonymous I" with the lowest fruit diameter (1.961 cm) was significantly different from all the other cultivars. The Pearson correlation among fruit length and diameter indicated a highly positive correlation ($r = 0.7333$; data not shown) showing spontaneously simultaneous increase or decrease in fruit length and diameter. Fruit weight was as high as 23.4 g in cv. Umran 9 and as low as 5.854 g in cv. Ghor, whereas, fruit volume was the maximum (24.75 cm³) in cv. Umran 9 and the minimum (10.7 cm³) in cv. Ghor (Fig. 3). Fruit gravity was recorded to be as high as

1.408 in cv. Selection 11 and as low as 0.574 g per cubic centimeters in cv. Ghor, indicating presence of higher variations in different fruit quality traits such as juiciness, fruit texture, water contents and chemical composition.

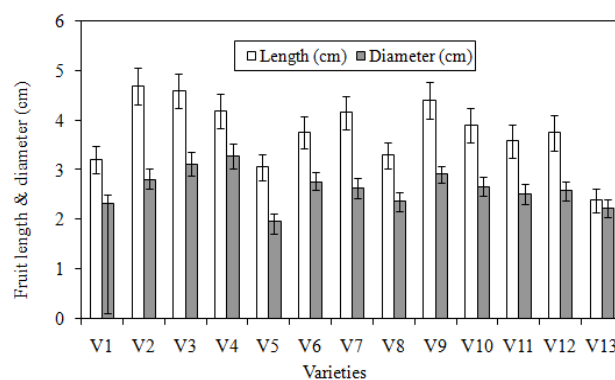


Figure 2. Variety-dependent variation in fruit length and diameter in ber cultivars and strains including V₁ (Desi), V₂ (Karela), V₃ (Selection 13), V₄ (Umran 9), V₅ (Anonymous I), V₆ (Mirpuri), V₇ (Gola), V₈ (Khati Mithi), V₉ (Selection 11), V₁₀ (Anonymous II), V₁₁ (Kernal Local), V₁₂ (Badam) and V₁₃ (Ghor). Standard error bars are indicated.

Fruit Qualitative Characteristics: Different morphological characteristics like fruit shape, apex, base and skin studies showed considerable similarities and dissimilarities among different cultivars (Table 2). Fruit shape varied from oval, oblong, ovate to round in different cultivars and strains, whereas, stem end cavity was small, medium or large in size on visual basis. Fruit styler end was either round, depressed, pointed or beaked with or without styler scars in different cultivars. The fruit skin was found to be either smooth with

Table 1. Leaf morphological characteristics of Jujube (ber) germplasm in Faisalabad

Cultivars	Leaf shape	Apex	Base	Margins	Surface (lower)	Surface (upper)
Desi	Elliptic	Obtuse	Obtuse	Serrulate	Glaucous: with whitish waxy covering)	Glabrous, dark green
Karela	Oblanceolate	Obtuse	Obtuse	Serrulate	Glabrous, light yellow	Glabrous, light green
Selection 13	Elliptic	Cuspidate	Obtuse	Serrate	Glabrous	Glaucous, whitish green
Umran 9	Oval	Sub acute	Obtuse	Crenate	Glabrous	Glaucous, whitish green
Anonymous I	Oblanceolate	Obtuse	Cuneate	Crenate	Glabrous, light green	Glaucous, light green
Mirpuri	Ovate	Acute	Obtuse	Crenate	Glabrous, light green	Glaucous, light yellow
Gola	Oblong	Obtuse	Obtuse	Serrulate	Glabrous, light green	Glaucous, light yellow
Khati Mithi	Ovate	Obtuse	Obtuse	Serrulate	Glabrous, dark green	Glaucous, light yellow
Selection 11	Oblanceolate	Cuspidate	Cuneate	Crenate	Glabrous, light green	Glaucous, light yellow
Anonymous 2	Ovate	Cuspidate	Obtuse	Sinuate	Glabrous, light green	Glaucous, light yellow
Kernal Local	Elliptic	Obtuse	Obtuse	Crenate	Glabrous, light green	Glaucous, light yellow
Badam	Oblanceolate	Cuspidate	Cuneate	Serrulate	Glabrous, dark green	Glaucous yellowish green
Ghor	Ovate	Sub acute	Cordate	Entire	Papery, dark green	Smooth, Light green

Table 2. Fruit morphological characteristics studied in different Jujube (ber) cultivars and strains in Faisalabad

Cultivars	Shape	Stem end cavity	Style end	Skin
Desi	Oval	Round with small cavity	Round	Smooth
Karela	Oblong wrinkled	Shoulders unequal with small cavity	Slightly beaked	Wrinkled, fruit is dented
Selection 13	Oblong	Large	Slightly beaked	Smooth
Umran 9	Oblong	Larger	Depressed	Wringed
Anonymous I	Elongated	Ascent	Pointed	Doted scantily & smooth
Mirpuri	Ovate	Medium	Pointed & beaked	Doted scantily & smooth
Gola	Oval	Medium	Slightly pointed	Smooth occasionally Scratching or splitting
Khati Mithi	Oval	Large	Slightly Pointed	Smooth occasionally splitted
Selection 11	Oblong	Medium	Pointed	Smooth
Anonymous 2	Oval(shoulders unequal)	Medium	Pointed	Smooth
Kernal Local	Oval	Medium	Slightly pointed	Smooth, parallel lines like sutures even in pulp
Badam	Chordate	Small	Beaked	Smooth
Ghor	Round	Small	Round & depressed	Smooth

or without dots on it or may be wrinkled as in cv. Karela, whereas, the skin was wringed in cv. Umran 9 and with parallel suture like lines which could be seen throughout the fleshy parts of the fruit (Table 2).

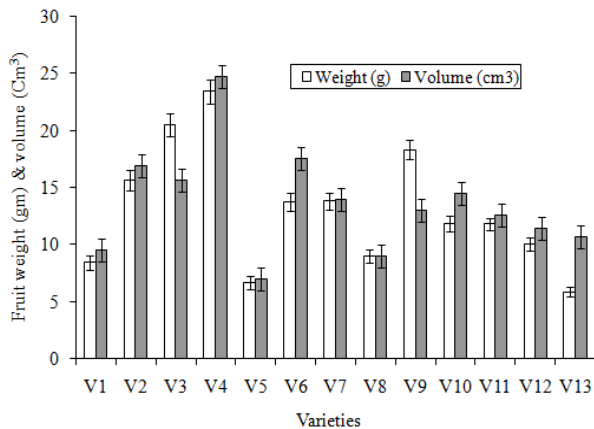


Figure 3. Variety-dependent variation in fruit weight (g) and volume (cm³) in of ber cultivars and strains including V₁ (Desi), V₂ (Karela), V₃ (Selection 13), V₄ (Umran 9), V₅ (Anonymous I), V₆ (Mirpuri), V₇ (Gola), V₈ (Khati Mithi), V₉ (Selection 11), V₁₀ (Anonymous II), V₁₁ (Kernal Local), V₁₂ (Badam) and V₁₃ (Ghor). Standard error bars are indicated.

DISCUSSION

Ber possesses great potential to be a major choice as a fruit crop in arid and semi-arid zones of the country and looks to be the most important consideration for uncultured,

marginally fit and waste soils. This study revealed a wide range of variations in ber germplasm. Some of the leaf and fruit morphological characters were found to be cultivar specific as leaf area in association with petiole length, fruit size shape and texture. Although all such traits may change to some extent with change in cultural practices, climatic conditions and other biotic and abiotic factors; yet they provide a reliable basis for cultivar identification in jujube. These results confirmed variations in the earlier findings of Bisla *et al.* (1988), Nanthakumar (1991) and Pareek (2001). A wide range of similarities and dissimilarities were observed among different cultivars for example leaf base was found to be obtuse in most of the cases but leaf apex showed a noticeable difference in this regard (Table 1). Similarly, fruits of different cultivars and strains showed variations in stem and styler end shapes, skin roughness or smoothness, size, length and breadth. The fruit and leaf morphological similarities and variations suggested division and grouping of different cultivars and strains. All the 13 varieties were grouped into different sections, each containing the most closely related cultivars and strains together. Section 1 comprised of cv. Umran 9, Kernal Local, Mirpuri, Selection 13 and the strain “Anonymous II”, whereas, cultivars; Desi, Khati Mithi, Gola and Karela were easy to group together in section 2. In section 3, Anonymous 1, Selection 11 and cv. Badam showed morphological similarities, whereas, the only cv. Ghor in Section 4, showed an exceptional range of morphological charters leading to its separate placement in this study. The close resemblance of cv. Ghor with *Ziziphus rotundifolia* (not included in this study) growing as wild species in desert and semi-desert ecosystems of Pakistan suggest cv. Ghor to be either a chance seedling selection of *Z. rotundifolia* or a natural hybrid of *Z. mauritiana* and *Z. rotundifolia*.

Several researchers characterized a number of ber cultivars in neighboring India, where ber germplasm is more researched as compared to Pakistan. Singh *et al.* (1971) characterized 39 jujube varieties into 3 groups, whereas, Singh *et al.* (1972) divided 40 cultivars into 8 sections. Another group of 59 ber cultivars was divided into 3 groups and 28 sub-groups (Vashishtha and Pareek, 1989) on the basis of morphological characters. The earlier classifications indicate confusions because of different experimental and morphological standards followed while conducting such studies. As an instance; Vashishtha and Pareek (1989) gave abbreviation 'CC' to oblong leaf shape in cv. 'Khatti' and cordate leaf shape in cv. Bahadurgarh, however, Bal (1992) suggested the leaf area, branching habit and fruit shape and apex type to be the most important parameters to differentiate among 42 ber cultivars in India.

Self and cross incompatibility is a common and unique feature of the genus *Ziziphus* (Neeraja *et al.*, 1995; Vashishtha and Pareek, 1979; Zietsman and Botha, 1992; Chundawat and Srivastava, 1980; Singh and Vashishtha, 1993) which leads to higher genetic diversity apart from clonal and bud mutations. Further, vernacular nomenclatures are also important while classifying different germplasms. In mango; cv. Langra in Pakistan, is known as cv. 'Langra Banarasi', 'Langra Hajipur', 'Langarhi', 'Tikari' (Farrukhabad, UP), 'David Ford', 'Hardil-Aziz' (Bhopal), 'Langra Hardoi', 'Langra Patna', 'Sylhet' (Meerut, UP), 'Langra Faquirwala', 'Ruh-e-afza', 'Darbhanga' and 'Chhatpa' in most parts of India. Such citations cannot be ruled out in Ber cultivars as most of the germplasm of *Ziziphus* across Indo-Pak Subcontinent is of historical unanimity. Most of the ber cultivars in Pakistan are highly localized and restricted to limited areas either in cultivation or in wild and in the absence of traceability system cultivar characterization becomes more complicated.

Findings of this study partially match or mismatch with the earlier research works (Pareek, 2001) due to genetic, cultural and climatic variations in different zones of Subcontinent. However, several earlier studies (Kundu *et al.*, 1995; Kundi *et al.*, 1989; Saini *et al.*, 1994) support our findings as they also found a wide range of variations in fruit and leaf physical and morphological characters in different ber cultivars in India.

Conclusion: Considerable diversity was noted in 11 cultivars and 2 jujube strains of ber and all the 13 could be divided into 4 groups as per similarities and dissimilarities. Some of the varieties showed distinct characters useful for identification purposes; however, others showed only few recordable differences. In the same order of reference, self and cross-incompatibility should have led to undesirable characters in some of the cultivars, whereas, vernacular nomenclature and localized restriction of different varieties increases confusion in naming and identification of ber

cultivars. Conclusively, Pakistan possesses a wide range of jujube germplasm that can be further manipulated for gene pool conservation and cultivar improvement for future generations.

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