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Research Article

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Characterization Based on Colorimetry Physiology and Sensory Attributes Among Traditional Jujube Cultivars of Sindh, Pakistan

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Abstract

Jujube (*Ziziphus* spp.) fruit is attaining incredible attention in current global climatic changing scenario as the fruit has significant nutritional value but remained unexplored in past. Fifteen Jujube cultivars were selected at Jujube Research Station Tandojam, Sindh Pakistan, to exploit their morphological, physiochemical, color and sensory attributes. Measured traits like tee shape diverged as semi erect, erect and spreading whereas leaf shape was also found highly variable. Thorn attachment differed as cadoucous, partial and persistent and fruit shape was set as round, oblong, oval and ovate. Maximum leaf blade length was counted by Soofi sanghar (9.0cm) while lowest was found in Gola soghat (5.1cm). Maximum fruit mass was recorded in cultivar Late gola (31.57 g) whereas least was observed in Khirol mukkhri (5.63 g). Maximum stone weight was estimated in Early gola (10.55 g) whereas minimum was recorded in Khirol desi (6.4 g). Highest glucose level was observed in Soofi local (4.46 g 100 mL^{-1}) while lowest glucose level was recorded in Khirol desi and Khirol Ratam (3.53g 100 mL^{-1}). Best cultivars by appearance were Late gola and Early gola followed by Gola saffina, Gola soghat, Soofi sanghar and Soofi local. Findings of this study are useful for varietal improvement and to run successful breeding programmes. Commercially relevant features evaluated in this study are highly beneficial for jujube varietal identification and germplasm conservation.

Keywords; *Ziziphus*, breeding, conservation, colorimeter, sugars, gola, ber, Tandojam

Introduction

Jujubes/ber is lesser known fruits, growing in tropical to subtropical zones of the world. It (*Ziziphus mauritiana* Lamk.) belongs to the family Rhamnaceae i.e. a gigantic family of angiospermic plants encompassing many shrubs, trees and vines (Midha *et al.*, 2017). Rhamanaceae family has worldwide distribution comprised of about 55 genera and 950 species. Genus *Ziziphus* is predominant and contained 135 to 170 species (Jackson *et al.*, 2011; Christenhusz and Byng, 2016). Jujubes were in use since chalcolithic age (i.e.1500-1000 B.C.) and fruits are cultivated for over 400 years in Indian sub-continent and China. Jujubes have been mentioned in Ayurveda, Epics, Sutras and in other literatures.

Pakistan is massive treasure of wild jujube germplasm. Prominently jujube family is mainly represented in Pakistan by three species i.e. *Ziziphus mauritiana*, *Ziziphus rotundifolia* and *Ziziphus nummularia*. *Ziziphus mauritiana* is commercially cultivated Jujube or Ber in Pakistan. Promising characters which make fit its cultivation in subtropical to semiarid zone include its xerophytic behavior, deep tap root system, early fruiting and deciduous behavior in extreme summer temperatures (Anjum *et al.*, 2018). Jujube has the capability to grow on marginal soils with diverse kind of waste lands like saline, sodic and sodic-saline (Pathare *et al.*, 2016). Regarding its distribution in Pakistan it grows well in Karachi, Hyderabad, Tandojam, Sukkhur, Nawabshah, Rahim Yar Khan, Bahawalpur, Multan, Layyah, Bhakkar and Faisalabad zones. Although with the introduction of new improved germplasm, area under Jujube cultivation is increasing but still it is categorized as underutilized fruit in Pakistan (Pareek, 2001).

Ziziphus mauritiana Lamk is evergreen, spiny shrub or tree with 40-50 cm trunk diameter having spreading crown with stipular spines and drooping branches. Tree bark is irregularly fissured and dark grey to dull black in colour. Leaves are alternate and variable oblong to elliptic and wavy-toothed on edges. Inflorescence is axillary cymes with greenish yellow and faintly fragrant flowers. Jujube fruits are excellent source of vitamin C, suitable against asthma as well as

naturally equipped with anticancer properties, fantastic wound healer and have sedative characteristics. Also, Jujube has valuable amount of antioxidants that are able to neuter free radical's activity (Li *et al.,* 2005). They are equipped with bioactive compounds such as phenolic acids, anthocyanins and nutritive compounds like essential oils, sugars, vitamins, carotenoids, and minerals. Jujube is cross pollinated fruit and has remarkable variations in its germplasm, which need characterization for commercial exploitation and to facilitate breeding programs (Devanshi *et al.,* 2007). High nutritional value and introduction of improved germplasm has contributed significantly in Jujube cultivation (Hossain, 2019). Numerous studies have been carried out to assess genetic diversity in various plant species to facilitate breeding and conservation using morphological markers (Hosseinpour *et al.,* 2020).

Alarming increase in world population and insensitive use of plant resources to fulfill human needs is destroying the natural crop cover. Rapid land development, industrialization and urbanization causing loss to plant genetic resources (Corlett, 2016). First step to protect and conserve genetic resources is detection of genetic diversity existing in a gene pool (Koornneef *et al.,* 2004; Ali et *al.,* 2020). Jujube germplasm evaluation has been already done in China, (Gao *et al.,* 2009; Dong *et al.,* 2009), India (Shiwanand and Bhagwan, 2018), Iran (Tatari *et al.,* 2016) and in Pakistan (Ahmad *et al.,* 2016) and identified wonderful cultivars for future commercial uses. Measurement of morphological traits is of great significance as they are valuable for identification of differences among various varieties. As being neglected fruit crop and cultivation on a limited area in Pakistan, there is a severe threat of Jujube extinction. Conventional Jujube germplasm is largely unexploited source of diversity, for exploring plant science and breeding. Morphological distinction is a foundation of plant evolution and new cultivar formation. The present investigations were therefore, aimed to gather basic knowledge for characterization on fifteen Jujube varieties available in research repository of Jujube Research Station, Tandojam, Sindh, Pakistan.

Materials and Methods

Germplasm collection: The study was conducted on fifteen Jujube varieties (Early gola, Late gola, Gola kararri, Gola saffina, Gola soghat, Soofi sanghar, Soofi local, Soofi sialkoti, Soofi gilli, Soofi umran, Khirol mukkhri, Khirol white chambeli, Khirol desi, Khirol Ratam and Khirol Nayab) selected from Jujube Research Station, Tandojam Sindh (25°25′37″ N, 68°32′10″ E, altitude 29m) (Figure 1). Tandojam is town of District Hyderabad, in the Sindh province of Pakistan with arid to subtropical climate. Healthy and disease-free fruits and leaves were collected for characterization.

Fruit color and sugar assessment: Fruit color of selected accessions was measured by using the colorimeter (CR-400 Minolta). It was made by using the head 15mm in diameter of the Hunter Color lab and recorded in CIELAB units of L*, a* and b*. Glucose, fructose and sucrose were measured from Jujube juice by using high performance liquid chromatography (HPLC).

Morphological and physiochemical characterization: Morphological data was recorded by following the descriptor National Bureau of Plant Genetic Resources (NBPGR, 2002). Physical traits (including length and width) relevant to leaf, thorn, fruit and stone were measured by using the digital vernier caliper (Model: HT0403-A1, Cingda Industry Co., Ltd. China) with an accuracy of 0.10mm. All characters interrelated to the weight were measured by using digital weight balance (0.001 g sensitivity). Pulp yield was calculated by following formula. Pulp yield % = Pulp weight (g)/Fruit weight (g) × 100. The total soluble solids (TSS%) of Jujube juice were estimated by using a digital refractometer (RX 5000, ATAGO, Japan). Vitamin C (VITC mg/100 g) contents in fruit flesh were determined by following Ruck, (1969). Titratable acidity (TA) and pH were determined using an acid–base potentiometer (877 Titrinoplus, Metrohm ion analyses CH9101; Herisau, Switzerland).

Sensory evaluation: It was carried out by using Hedonic scale (1-5) to rate the selections for color, taste, flavor, and texture (Peryam and Pilgrim, 1957). Fruits were arranged according to replication for analysis. A panel of ten judges evaluated sensory assessment using the Hedonic scales as given below. For each replication, average score was recorded as

1: Hedonic scale rating product, 2: Variety, 3: Date, 4: Name of Judge and 5: Signature.

Instructions: (Please read the instructions carefully before filling blanks)

1. This is an organoleptic analysis form for the evaluation of Jujube fruit.
2. Please follow the numerical system for scoring the samples.
3. Please do not disturb the sequence of the samples provided.
4. Please wash the tongue before testing next sample with water provided.

1. Dislike extremely
2. Dislike slightly
3. Like slightly
4. Like moderately
5. Like extremely

Statistical analysis: Color meter, morphology, physiochemical, sugars and sensory traits were analyzed following completely randomized design by considering each cultivar as a treatment. The analysis of variance (ANOVA) was conducted by using software Statistix 8.1 to test the significance of variation between cultivars. Significant differences ($p < 0.05$) were counted according to Tukey's test.

Results

Diversity in fruit color of Sindh Jujube germplasm: Diversity estimation regarding color variation was recorded in Figure 1. Highest L value was recorded for Gola saffina i.e. 60.76 followed by Early gola i.e. 58.99 and Late gola i.e. 58.62. Lowest value of L was found in Soofi umran i.e. 41.71. Highest value for a* was recorded for Late gola i.e. 9.11 followed by Gola saffina and Soofi local i.e. 8.08 whereas lowest value was recorded by Khirol desi i.e. 1.02. Highest value for b* was recorded by Soofi local i.e. 52.13 followed by Late gola i.e. 51.81 and Soofi silakoti 50.99. Lowest value was recorded in Khirol desi i.e. 11.48. Highest Hue value was recorded by Gola kararri and Soofi gilli i.e. 89.95 followed by Khirol mukkhri i.e. 89.79 and Early gola 89.63. Lowest Hue value was noted by Khirol nyab i.e. 86.16. Highest C value was noted for Soofi local i.e. 52.84 followed by Late gola 52.6 whereas the lowest value was noted for Khirol desi i.e. 11.52.

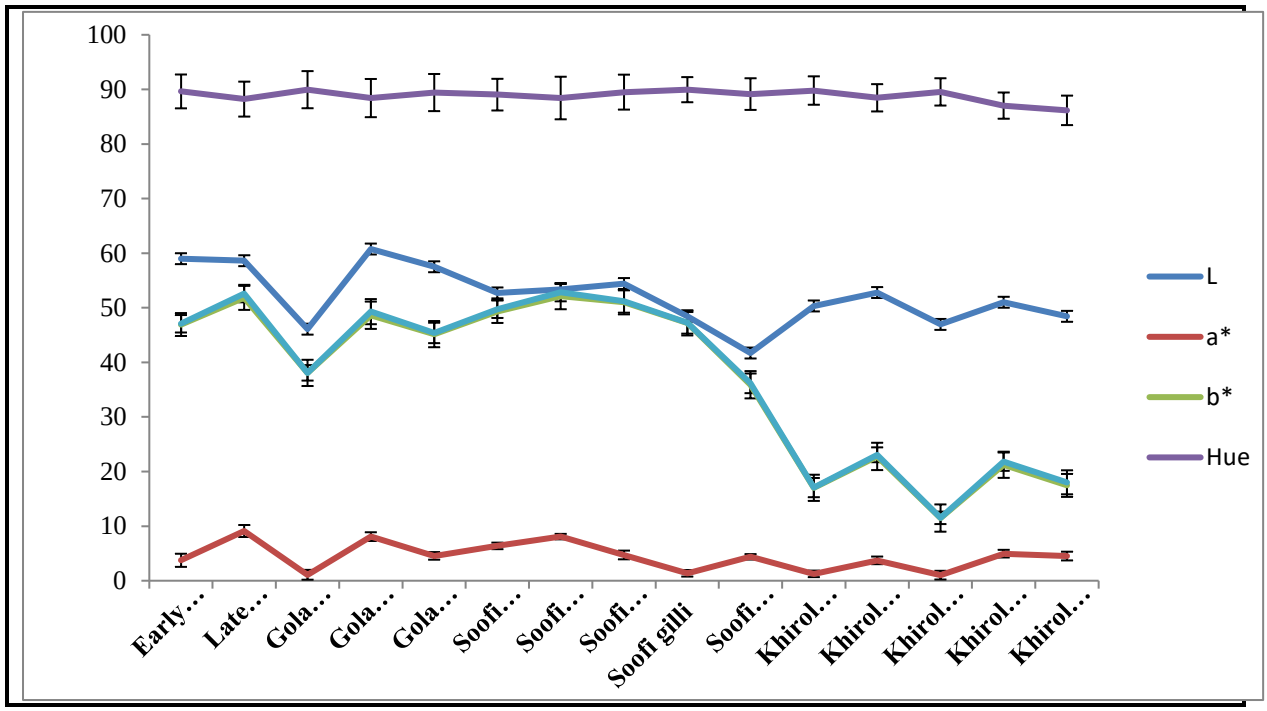

Figure 1. Diversity estimation regarding fruit color among fifteen jujube cutlivars of Sindh, Pakistan.

Diversity in morphological attributes of Sindh Jujube germplasm: Qualitative characters among fifteen investigated jujube varieties were found highly diverse and have been listed in Table 1. Tree shape diverged as semi erect, spreading and erect. Five cultivars i.e. Early gola, Late gola, Gola kararri, Gola saffina and Gola soghat were counted with semi erect tree shape whereas Soofi sangahr, Soofi local, Soofi sialkoti, Soofi gilli and Soofi umran were found with spreading tree shape. Erect tree shape was found in Khirol mukkhri, Khirol white chambeli, Khirol desi, Khirol ratam and in Khirol nayab. Branching shape was also found quite variable. Early gola, late gola, gola kararri and gola saffina were found with drooping branch shape. Gola soghat, Soofi sangahr, Soofi local, Soofi sialkoti, Soofi gilli and Soofi umran were governed with semi drooping branching shape. Erect branching shape was found in Khirol mukkhri, Khirol white chambeli, Khirol desi, Khirol ratam and Khirol nayab. Leaf shape was found highly variable in observed germplasm. Early gola, Khirol desi and Khirol nayab was found with oval shape leaves. Six cultivars including Late gola, Gola kararri, Gola saffina, Gola soghat, Soofi sangahr and Khirol mukkhri were found with ovate leaf shape. Soofi local, Soofi gilli and Soofi umran was found with oblong leaf shape. Soofi sialkoti, Khirol white chambeli and Khirol ratam had obovate leaf shape. Leaf apex was found as obtuse, acute and round. Early gola, Soofi Sialkoti, Khirol white chambeli, Khirol desi, Khirol ratam, Khirol nayab was found with obtuse leaf shape. Gola kararri and Soofi local exhibitedround leaf shape. Leaf base was governed as round, acute and oblique whereas leaf margin was found as crenate. Leaf petiole color was also variable. It was light yellow in Sooofi silakoti and Khirol white chambeli while in Khirol desi it was light green with red tinge whereas in all other varieties it was light green.Thorn attachment was found cdoucous, partial and persistent. Gola kararri, Soofi sanghar, Soofi gilli and Khirol mukhrri were found partial whereas in other varieties it was found as persistent or caducous. Thorn shape was documented as alternate curved, all curved or straight. Fruit shape was found as round, oblong, oval and ovate. It was found round in Early gola, Late gola, Gola kararri, Gola saffina and Gola soghat. Soofi sanghar, soofi sialkoti and khirol mukkhri was governed with oblong fruit shape. In

Soofi local and Soofi umran it was found oval shape. Soofi gilli and Soofi mukkhri were governed with pointed fruit apex whereas all other varieties were governed with round fruit apex. Fruit base was documented as round or round with depression. In Khirol mukkhri, Khirol white chambeli, Khirol desi, Khirol ratam and Khirol nayab it was noted as round while in other ten varieties it was noted as round with depression. Fruit surface was found plain in all examined varieties. Stone shape was governed as oval, oblong and spindle. Oval shape was governed as Early gola, Khirol mukkhri, Khirol White chambeli, Khirol ratam and in Khirol nayab. Stone apex as obtuse or acute. Stone surface was recorded as smooth in Early gola, Khirol mukkhri, Khirol white chambeli, Khirol desi and in Khirol ratam.

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Variation in physiochemical traits of Sindh Jujube germplasm: Results showed that maximum leaf blade length was counted by Jujube cultivar Soofi sanghar (9.0cm) followed by Soofi umran (8.7cm), Soofi gilli (8.5cm) and Soofi local (8.3cm) while lowest leaf blade length was observed in Soofi soghat (5.1cm). Highest leaf blade width was recorded for Early gola (5.7cm) followed by Gola kararri (5.6 cm) and Soofi umran (5.0) whereas minimum leaf blade width was in Khirol white chambeli (3.5 cm). Maximum leaf petiole length was recorded by Gola saffina (2.3 cm) followed by Khirol nayab (2.2 cm) and Soofi sialkoti (2.1cm). Smallest leaf petiole length was gained by Khirol desi (1.14cm) (Figure 2)

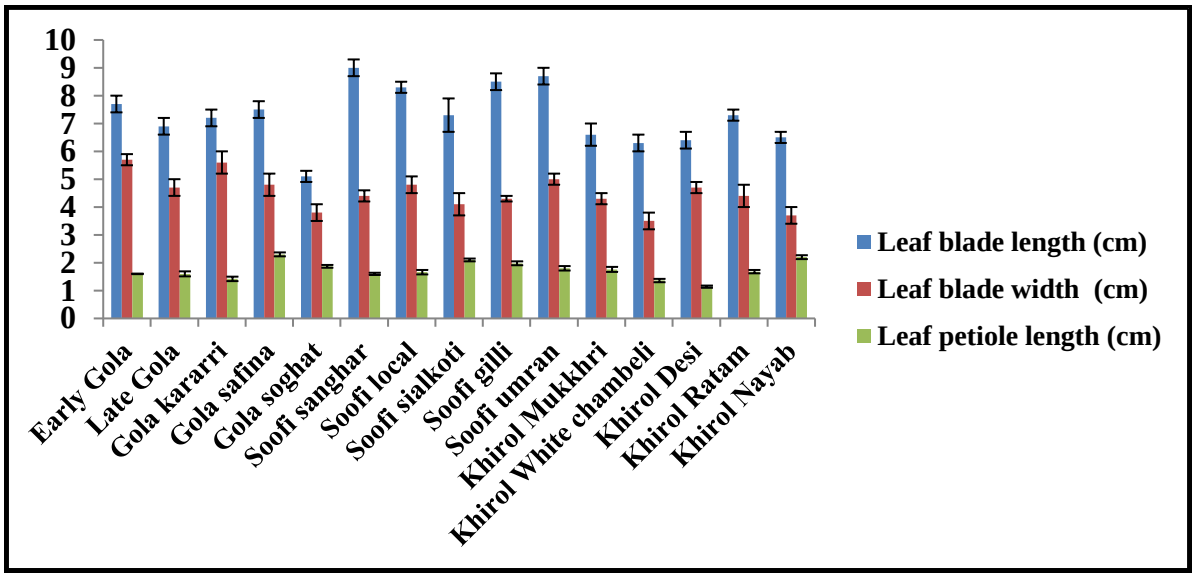

Figure 2. Diversity estimation regarding physiological parameters (leaf blade length, leaf blade width and leaf petiole length) among fifteen jujube cutlivars of Sindh, Pakistan.

Maximum fruit mass value was recorded in Late Gola variety (31.57 g) followed by Early Gola (29.8 g), Soofi umran (27.48 g), Gola soghat (23.87g) and Gola kararri (23.3g) whereas least fruit mass was observed in Khirol mukkhri (5.63 g) followed by Khirol white chambeli (5.79 g), Khirol desi (5.93 g) and Khirol Ratam (7.34 g). Maximum stone weight was estimated in Early Gola (10.55 g) followed by Gola soghat (10.45 g), Late gola (10.43 g), Gola saffina (9.8 g) and Khirol nayab (9.5 g), whereas, minimum stone weight was recorded in Khirol desi (6.4 g) followed by Soofi sanghar (7.1 g), Gola kararri (8.54 g), Soofi local (8.2 g), Khirol white chambeli (8.18 g), and Soofi sialkoti (8.09 g). Maximum pulp weight was recorded in Late gola (29.79 g) followed by Early gola (28.12 g), Soofi umran 26.2), Gola soghat (22.85 g), Gola kararri (21.83 g) and Soofi sanghar (20.93 g) whereas, minimum pulp weight was recorded in Khirol mukkhri (4.89 g) followed by Khirol white chambeli (4.95 g), Khirol desi (5.41 g) and Khirol ratam (6.67 g). Maximum pulp yield % was recorded in Soofi sanghar (95.79 %) followed by Gola soghat (95.73 %), Soofi umran (95.34 %), Late gola (94.36 %) and Early gola (94.36 %) whereas minimum pulp yield % was estimated in Khirol white chambeli (85.49 %) followed by Khirol mukhrri (86.86 %), Khirol ratam (90.87 %), Khirol nayab (90.75%) and Soofi local (91.99 %) (Figure 3).

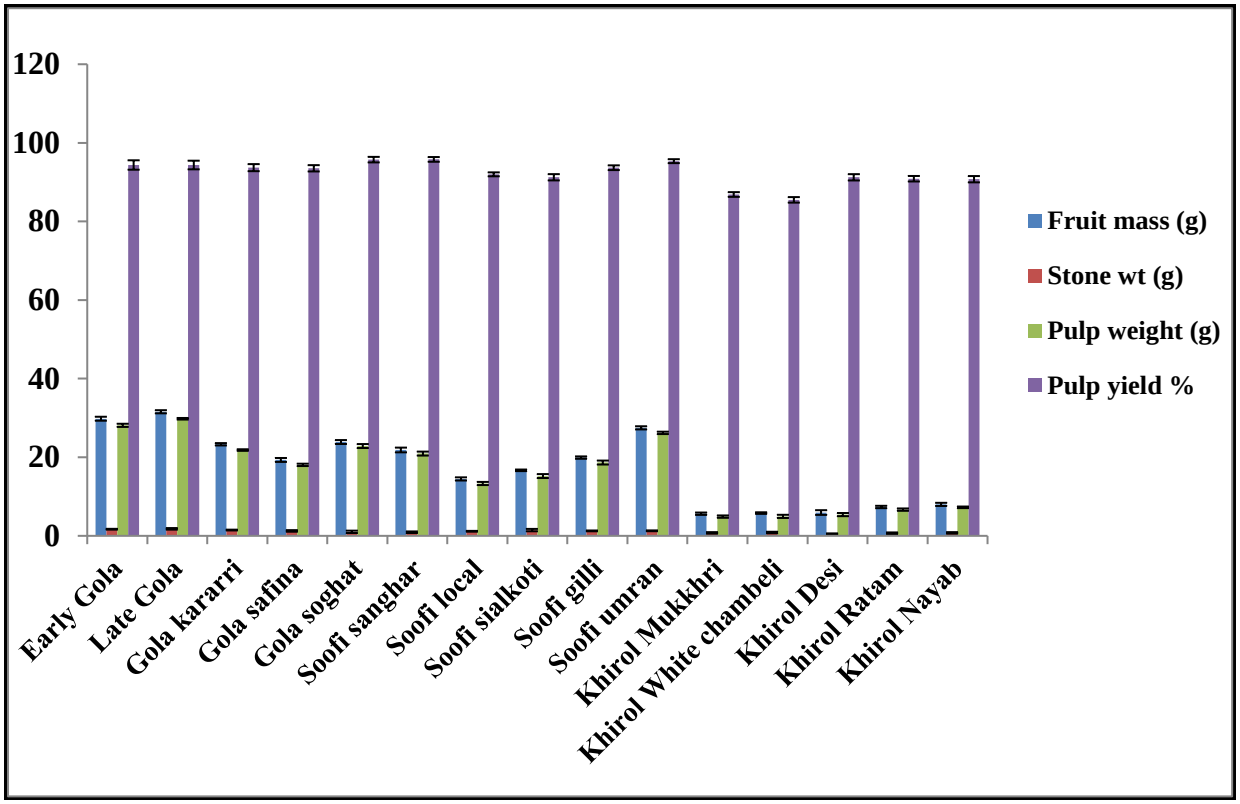

Figure 3. Diversity estimation regarding physiological parameters (fruit mass, stone weight and pulp weight and pulp yield %) among fifteen jujube cultivars of Sindh, Pakistan**.**

Highest fruit pH was recorded in Early gola (7.3) followed by Late gola (6.9), Soofi local (6.9) and soofi sanghar (6.8), whereas lowest fruit pH was estimated in Khirol ratam (4.9). Maximum TSS was recorded in Early gola (16.5 Brix) followed by Late gola (14.93 Brix), Gola kararri (13.38 Brix), Soofi gilli (13.76 Brix) and Soofi umran (13.6) while minimum TSS value was estimated in Khirol nayab (8.5 Brix) followed by Khirol Ratam (9.44 Brix), Soofi sanghar (10.87 Brix), Khirol desi (11.83) and Khirol white (10.66 Brix). Maximum vitamin C value was recorded in Khirol desi (160.26 mg/100 g) followed by Khirol white (133.86 mg/100 g), Gola saffina (133.74 mg/100 g) and Gola soghat (133.01 mg/100 g) while minimum ascorbic acid value was recorded in Gola kararri (107.81 mg/100 g), Early Gola (112.88 mg/100 g), Soofi gilli(113.9 mg/100 g) and Soofi sialkoti (115.14 mg/100 g) (Figure 4).

Variation in sugars profile of Sindh Jujube germplasm: Highest glucose level was observed in Soofi local (4.46 g 100 mL^{-1}) followed Gola saffina (4.36 g 100 mL^{-1}), Soofi sanghar (4.33g 100 mL^{-1}) and Gola soghat (4.30g 100 mL^{-1}) while lowest glucose level was recorded in Khirol desi and Khirl ratam (3.53g 100 mL^{-1}) followed by Soofi gilli (3.60g 100 mL^{-1}) and Khirol nayab (3.63g 100 mL^{-1}) Table 2. Highest fructose level was estimated in Early gola (6.16g 100 mL^{-1}) followed by Soofi local (5.96 g 100 mL^{-1}), Late gola (5.93 g 100 mL^{-1}), Gola kararri (5.83 g 100 mL^{-1}) and Gola soghat (5.76 g 100 mL^{-1}) while lowest fructose level was recorded in Khirol nayab (4.33 g 100 mL^{-1}) Significant sucrose level value was recorded in Gola soghat (8.36 g 100 mL^{-1}) followed by Late Gola and Gola kararri (8.30 g 100 mL^{-1}),Soofi sanghar (8.06 g 100 mL^{-1}), Soofi local (8.03 g 100 mL^{-1}) and Soofi sialkoti (7.83 g 100 mL^{-1}), whereas, least significant values was recorded in Khirol ratam (5.86 g 100 mL^{-1})

Disparity in sensory traits of Sindh Jujube germplasm: Best variety by appearance was Late Gola and Early Gola both with value (4.66) simultaneously followed by Gola saffina, Gola soghat, Soofi sanghar and Soofi local with same value (4.33) while least value by appearance was recorded in Khirol Ratam with (2.33) followed by Khirol nayab (2.66), Khirol mukhrri (3.00) and Khirol chambeli (3.66), Khirol desi (3.66) as shown in Table 3. Best flavor trait was recorded in Early Gola (5.00) followed by Late Gola, Gola saffina and Gola soghat with (4.66) simultaneously, while least flavor was assessed in Khirol nayab (1.66) Best taste was evaluated in Early Gola, Late Gola, Gola soghat and Gola kararri with same value (4.66) followed by Gola saffina, Soofi sanghar and Soofi local (4.33) while least taste value was assessed in Khirol nayab (2.33) Highest texture value was recorded in Early Gola, Late Gola and Gola soghat with (4.66) followed by Gola saffina and Gola kararri with (4.33) whereas lower texture value was observed in Khirol nayab (2.00).

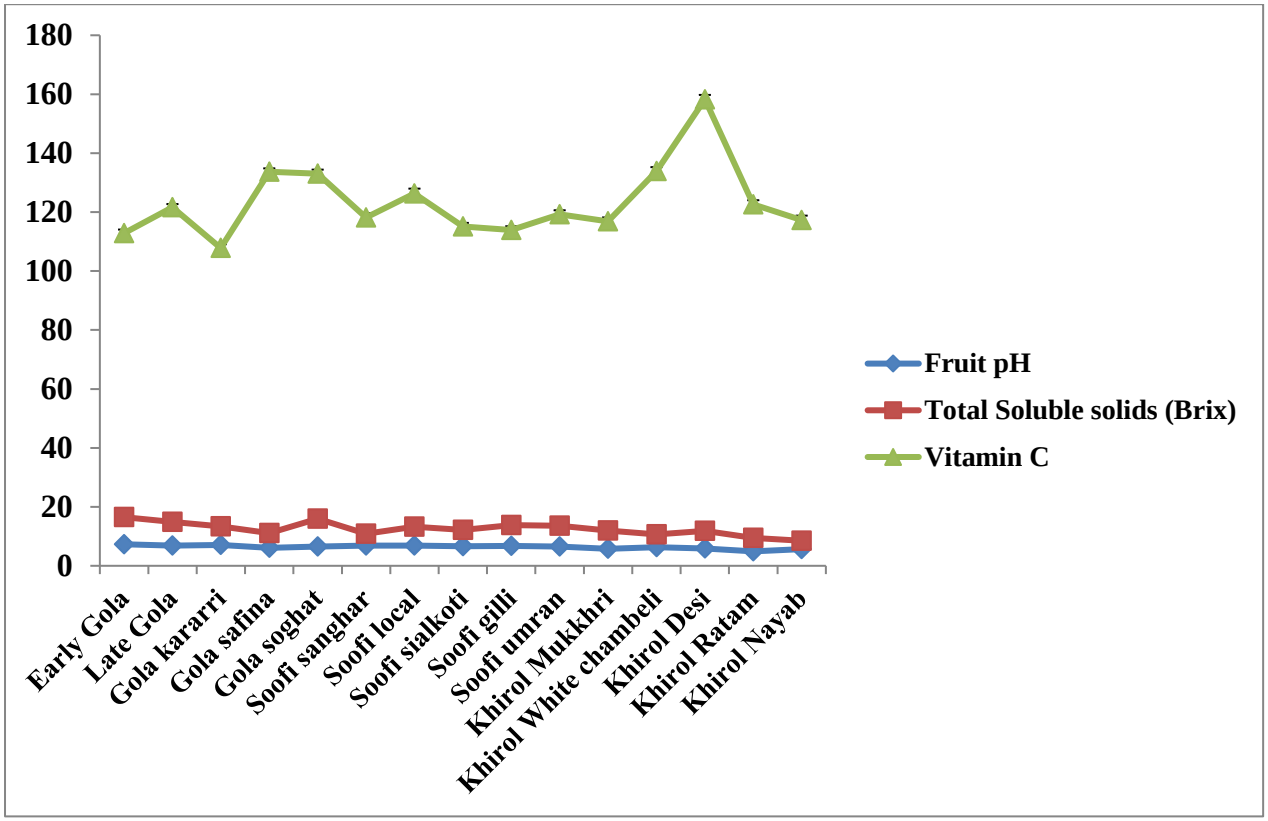

Figure 4. Diversity estimation regarding physiological parameters (Fruit pH, Total soluble solids and Vitamin C) among fifteen jujube cutlivars of Sindh, Pakistan**.**

Table 1. Diversity estimation regarding tree, leaf and thorn morphological parameters among fifteen Jujube cultivars of Sindh, Pakistan.

Variety	Tree shape	Branching shape	Leaf shape	Leaf apex	Leaf base	Leaf margin	Leaf petiole color	Thorn attachment
Early Gola	Semi erect	Drooping	Oval	Obtuse	Round	Crenate	Light green	Caducous
Late Gola	Semi erect	Drooping	Ovate	Acute	Acute	Crenate	Light green	Caducous
Gola kararri	Semi erect	Drooping	Ovate	Round	Acute	Crenate	Light green	Partial
Gola safina	Semi erect	Drooping	Ovate	Acute	Acute	Crenate	Light green	Persistant
Gola soghat	Semi erect	Semi drooping	Ovate	Acute	Acute	Crenate	Light green	Caducous
Soofi sanghar	Spreading	Semi drooping	Ovate	Acute	Acute	Crenate	Light green	Partial
Soofi local	Spreading	Semi drooping	Oblong	Round	Acute	Crenate	Light green	Persistant
Soofi sialkoti	Spreading	Semi drooping	Obovate	Obtuse	Oblique	Crenate	Light yellow	Persistant
Soofi gilli	Spreading	Semi drooping	Oblong	Acute	Acute	Crenate	Light green	Partial
Soofi umran	Spreading	Semi drooping	Oblong	Acute	Oblique	Crenate	Light green	Caducous
Khirol Mukkhri	Erect	Erect	Ovate	Acute	Acute	Crenate	Light green	Partial
Khirol White Chambeli	Erect	Erect	Obovate	Obtuse	Acute	Crenate	Light yellow	Persistent
Khirol Desi	Erect	Erect	Oval	Obtuse	Acute	Crenate	Light green with red tinge	Persistent
Khirol Ratam	Erect	Erect	Obovate	Obtuse	Oblique	Crenate	Light green	Persistent
Khirol Nayab	Erect	Erect	Oval	Obtuse	Acute	Crenate	Light green	Persistent

Table 1. (continue). Diversity estimation regarding fruit morphological parameters among fifteen Jujube cutlivars of Sindh, Pakistan

Variety	Thorn shape	Fruit shape	Fruit apex	Fruit base	Fruit surface	Stone shape	Stone apex	Stone surface
Early Gola	Alternate curved	Round	Round	Round with depression	Plain	Oval	Obtuse	Rough
Late Gola	Alternate curved	Round	Round	Round with depression	Plain	Oblong	Acute	Rough
Gola kararri	All curved	Round	Round	Round with depression	Plain	Spindle	Acute	Rough
Gola safina	Alternate curved	Round	Round	Round with depression	Plain	Spindle	Obtuse	Rough
Gola soghat	Alternate curved	Round	Round	Round with depression	Plain	Spindle	Obtuse	Rough
Soofi sanghar	All curved	Oblong	Round	Round with depression	Plain	Oblong	Acute	Rough
Soofi local	All curved	Oval	Round	Round with depression	Plain	Spindle	Acute	Rough
Soofi sialkoti	All curved	Oblong	Round	Round with depression	Plain	Spindle	Acute	Rough
Soofi gilli	All curved	Ovate	Pointed	Round with depression	Plain	Oblong	Acute	Rough
Soofi umran	Alternate curved	Oval	Round	Round with depression	Plain	Oblong	Obtuse	Smooth
Khirol Mukkhri	Straight	Oblong	Pointed	Round	Plain	Oval	Acute	Smooth
Khirol White Chambeli	Straight	Round	Round	Round	Plain	Oval	Obtuse	Smooth
Khirol Desi	Straight	Round	Round	Round	Plain	Oblong	Acute	Smooth
Khirol Ratam	Straight	Round	Round	Round	Plain	Oval	Obtuse	Smooth
Khirol Nayab	Straight	Round	Round	Round	Plain	Oval	Obtuse	Rough

Table 2. Diversity estimation regarding sugar profile among fifteen Jujube cultivars of Sindh, Pakistan

Variety	Glucose (g 100 mL−1)	Fructose (g 100 mL−1)	Sucrose (g 100 mL−1)
Early Gola	3.80 a	6.16 a	7.53 abcd
Late Gola	3.93 a	5.93ab	8.30 ab
Gola kararri	4.13 a	5.83 ab	8.30 ab
Gola safina	4.36 a	5.13 ab	7.80abcd
Gola soghat	4.30 a	5.76 ab	8.36a
Soofi sanghar	4.33 a	5.16 ab	8.06 abc
Soofi local	4.46 a	5.96 ab	8.03 abc
Soofi sialkoti	3.96 a	5.43 ab	7.83 abcd
Soofi gilli	3.60 a	5.40 ab	7.10 abcd
Soofi umran	3.56 a	4.66 ab	6.30bcd
Khirol Mukkhri	3.70 a	5.30 ab	6.26cd
Khirol White Chambeli	3.76 a	5.46 ab	6.56 abcd
Khirol Desi	3.53 a	5.20 ab	6.43 abcd
Khirol Ratam	3.53 a	5.23 ab	5.86d
Khirol Nayab	3.63 a	4.33 b	6.33 bcd

Table 3. Diversity estimation regarding sensory evaluation among fifteen Jujube cultivars of Sindh, Pakistan

Variety	Appearance	Flavor	Taste	Texture
Early Gola	4.66 a	5.00 a	4.66 a	4.66 a
Late Gola	4.66 a	4.66 a	4.66 a	4.66 a
Gola kararri	4.00 abc	4.33 ab	4.66 a	4.33 ab
Gola safina	4.33 ab	4.66 a	4.33 ab	4.33 ab
Gola soghat	4.33 ab	4.66 a	4.66 a	4.66 a
Soofi sanghar	4.33 ab	4.33 ab	4.33 ab	4.00 abc
Soofi local	4.33 ab	4.33 ab	4.33 ab	3.66 abc
Soofi sialkoti	4.00 abc	4.33 ab	4.33 ab	3.66 abc
Soofi gilli	4.00 abc	3.66 abc	4.00 abc	3.33 abc
Soofi umran	4.00 abc	4.33 ab	3.66 abc	4.33 ab
Khirol Mukkhri	3.00 bcd	3.33 abc	3.33 abc	2.66 abc
Khirol White Chambeli	3.66 abcd	3.00 abc	3.66 abc	3.33 abc
Khirol Desi	3.66 abcd	2.33 bc	2.66 bc	2.33 bc
Khirol Ratam	2.33 d	2.00 c	2.66 bc	2.66 abc
Khirol Nayab	2.66 cd	1.66 c	2.33 c	2.00 c

Discussion

Estimation about available germplasm is mandatory to get basic information for better commercial adaptation and to initiate breeding programs for crop improvement. Understanding about economically linked traits is important for yield and quality enhancement. Varietal identification is an essential tool for guaranteed fruit quality. Pakistani Jujube germplasm is of different shapes i.e. varied in size from cherry to plum and in shape from round to oval and oblong. Due to these differences morphological parameters can be used to distinguish among them (Obeed *et al.*, 2008). Accounting to morphological variations, horticultural products are necessary for accurate estimation of physical descriptors and the properties such as length, breadth, volume and surface area are applicable to facilitate handling, processing, storage, drying, grading and to design equipment.

Fruit color assessment was also found highly variable. Color meter studies showing the values of L*, a*, b*, Hue and C were used to investigate differences among fifteen Jujube varieties. As it is reliable and simple approach this study can be used in future for identification and grading. In past, Cardenas-Perez *et al.*, (2017) and Itle and Kabelka, (2009) described variation in the color parameters L*, a*, and b*, and stated that they are affiliated with intensification in carotenoid intensities and lowering in chlorophyll level in the pericarp tissues. In another Jujube study Wang *et al.*, (2013) utilized the L*, a*, and b* parameters to identify Lingwu jujubes. Bahri *et al.*, (2017) and Çetin *et al.*, (2020) pointed in their studies that color features are significant in fruit identification. Fu *et al.*, (2016) used color meters to identify kiwifruit varieties along with other morphological features.

These results of present findings are in line with the finding of Saran *et al.*, (2006), who studied the broad genetic base in Indian Jujube for various morphological traits. These results confirmed variations in the earlier findings of Nanthakumar, (1991) and Pareek, (2001). Similar variations also recorded by Pathare *et al.*, (2016) in Jujube cultivars Mehrun-Khedi and Mehrun. Our findings match or

partially match with the earlier research work of Kundu *et al.,* (1995) and Pareek, (2001), due to genetic, cultural and climatic variations who studied Jujube germplasm in different zones of sub continent. Studied germplasm showed considerable variations in fruit related traits which are highly essential to conserve the valuable jujube germplasm in country. Such variations have also been found in morphological traits documented by researchers in past. Pareek, (2001) investigated that fruit shape diverse from round, oval, ovate, obovate, oblong to oblate.

Dhanumjaya Rao and Subramanyam, (2010); Jan Brindza *et al.,* (2011) and Mohsin Abbas *et al.,* (2012) recorded remarkable variations in fruit length, fruit width and fruit weight in Indian and Pakistani Jujube germplasm. Ganesh Shukla *et al.,* (2012) studied Indian Jujube varieties and found Kopargaon Selection has highest fruit length (5.56 cm), fruit width (4.89 cm) and Fruit weight(71.61g) while minimum fruit width was observed in Rahuri-3 (6.41 g)) and minimum weight was observed in Rahuri-3 (6.42 g). Results were also in line with Obeed *et al.,* (2008), who described that Komethery variety was with highest fruit width 5.87cm whereas lowest was Um-sulaem variety with 3.19cm fruit width.

Significant differences in stone related traits have been recorded in this study. These results have been supported by Singh and Misra, (2012) who revealed maximum stone length, stone breadth in Kadaka i.e. (2.79 cm) and (1.22 cm). Whereas minimum stone length were recorded in Rahuri-3i.e. 1.31 cm, minimum stone width Rahuri-3 (0.30 cm), and minimum stone weight in Chhuhara (0.50 g), respectively.

Characters relevant to pulp yield are considerable to promote the varieties with good pulp portion. Studies relevant to pulp yield have been documented previously by Pareek, (2001). These variations have been introduced due to changes in cultural practices, abiotic and genetic factors and prevailing climatic conditions.

Sugar contents in plants are considered to differ greatly even among cultivars according to their habitats and genetic constitution. In past, Jujube sweetness is considered due to fructose which makes them quite suitable for diabetic patients. Glucose, fructose and sucrose were the main sugars among all investigated jujube varieties. Gao *et al.,* (2012) in a study reported that glucose and sucrose are prominent sugars in jujube germplasm of Loess Plateau China.

A comprehensive study was performed in China on nutritional and sensory evaluation among winter Jujubes and Yuncheng was evaluated as best variety whereas Binzhou showed good antioxdanat activity along with good taste (Fan *et al.,* 2017). A comprehensive evaluation approach was adopted for the sensory evaluation of Jujube varieties grown in Sindh province based on appearance, flavors, taste and texture. Specific aim was to understand the quality and nutritional value of these jujube varieties, and explore export potential based on comprehensive evaluation criteria. Gola early, Gola late, Gola saffina, Soofi sanghar and Khirol mukkhri had good taste and highly appreciated by panel. Khirol ratam was another sweet and soft potential cultivar with red patch on fruit

Conclusion

Identification and characterization of traditionally cultivated Jujube cultivars is prerequisite for promoting commercial cultivation of Jujube in Pakistan. In this study, detailed characterization of fifteen Jujube cultivars from Sindh province of Pakistan was carried out. Study demonstrated that combination of morphological, physiological, color and sensory attributes is mandatory for exploiting potential of traditional cultivars. Study also demonstrated that Sindh province of Pakistan had a diverse collection of germplasm which can be exploited for export. The information presented here can be used to select the cultivars with desired attributes. In addition, the cultivars with superior traits can be utilized for improvement through selection to get desired traits.

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