Acta Sci. Pol. Hortorum Cultus, 17(4) 2018, 39–52

www.acta.media.pl ISSN 1644-0692 e-ISSN 2545-1405 DOI: 10.24326/asphc.2018.4.4

ORIGINAL PAPER

Accepted: 2.01.2018

THE EVALUATION OF BIODIVERSITY IN SOME INDIGENOUS INDIAN JUJUBE (*Zizyphus mauritiana*) GERMPLASM THROUGH PHYSICO-CHEMICAL ANALYSIS

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ABSTRACT

Indian jujube (*Zizyphus mauritiana* Lamk.) is mostly cultivated in tropical and sub-tropical regions of the world. Many native and exotic jujube cultivars are grown for fruit production in Pakistan. However, little research work has been conducted on various aspects of jujube i.e. morphological and biochemical characterization of available germplasm. Therefore, fruits of thirteen genotypes were collected to study the biodiversity through physico-chemical analysis during the years 2015 and 2016. The aim of the present study was to investigate the relationship among various physico-chemical attributes of the jujube through Pearson's correlation that may have greater importance for breeders during the selection of desirable genotype. The cultivar Foladi had the maximum fruit weight (30.49 g), pulp weight (28.42 g) and fruit diameter (36.75 mm) among all the cultivars. The maximum fruit length was recorded in Umran-13 (45.16 mm), while the maximum seed weight (2.70 g) was found in Dilbahar. Khobani had the maximum TSS (14.92 ºBrix). The highest level of acidity (0.74%) was recorded in Gorh. Akasha had highest vitamin C content (72.53 mg 100 mL^{-1} juice). The cultivars Sadqia, Umran-13, Mehmood wali, Yazman local and Gorh were much sweeter due to the maximum total sugars content (9.74–10.09%). The maximum antioxidant capacity was measured in Mahmood wali (616.13 mM Trolox 100 mL^{-1}), Pak white (615.02 mM Trolox 100 mL^{-1}) and Seedless (600.46 mM Trolox 100 mL^{-1}), while antioxidant activity was significantly higher in Sadqia (40.604%). The maximum amount of total phenolic content was determined in Umran-13 and Sadqia (243.06 and 239.25 µg GAE mL^{-1} juice, respectively). The highly significant correlation (0.99) was observed between the fruit weight and pulp weight. Antioxidant activity and total phenolic content were also strongly correlated (0.70). Principal component analysis was made to determine the relationship among the genotypes and their variables. Dendrogram constructed on the basis of morphological attributes, divided 13 genotypes into four main clusters. Among the cultivars, Khobani and Mehmood wali share the maximum similarity (78%). Biochemical characteristics also divided the genotypes into three main clusters. The cultivars Pak white and Seedless had the maximum similarity (75%) among all the cultivars.

Key words: antioxidant activity, biochemical attributes, biplot analysis, genetic diversity, morphological characteristics

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INTRODUCTION

Ber or Indian jujube (*Zizyphus mauritiana* Lamk.) belongs to the family *Rhamnaceae*. This species is indigenous to China and Indo-Pak subcontinent and now widely dispersed in Afghanistan, Syria, Burma, Kazakhstan, Nepal, Bangladesh, Indonesia, Malaysia, Iran, Iraq, Kuwait, Qatar, Saudi Arabia, United Arab Emirates, Western Sahara, Sri Lanka, Queensland in Australia and North Africa [Liu and Cheng 1995]. In Punjab (Pakistan), it is grown in Faisalabad, Sargodha, Bahawalpur, Multan and Dera Ghazi Khan divisions.

The genus *Zizyphus* consists of 135 to 170 species. Several species grow as wild which include *Z. rotundifolia*, *Z. xylocarpa* and *Z. ocenoplia* [Jackson et al. 2011]. Z. *mauritiana* and Z. *jujuba* are two well-known species, which are mostly cultivated for edible fruits [Memon et al. 2012]. Cultivation of *Z. mauritiana* spread due to its wide adaptation, easiest to grow, xerophytic properties, early age bearing, survival under harsh environments, resistance to drought and salinity stress, minimum inputs required, high nutritional value and fetch quite higher prices as compared to many other fruits. Therefore, it is known as king of arid fruits [Bhatt et al. 2008].

Z. *mauritiana* had more than fifty varieties grown in Pakistan. The shape of fruit may be round, ovate, oval and oblong with smooth or rough skin. The fruit has climacteric behavior therefore: fruit ripening is based on ethylene production and respiration rate [Abbas and Fandi 2002]. The fruit is very delicious, rich source of nutrition and economically good for rural people in the developed and developing countries therefore, it is famous as poor man's apple [Saka et al. 2007]. Annual yield of a mature tree is about 50–250 kg [Meena et al. 2014].

The fruit is an excellent source of carbohydrates, proteins, fats, fiber, TSS, ascorbic acid, total phenolics, antioxidants, carotenes, flavonoids and reducing, non-reducing and total sugars [Obeed et al. 2008, Koley et al. 2011, Krishna and Parashar 2012, Zozio et al. 2014, Kumari et al. 2015]. Among the minerals: calcium, phosphorus and iron are present in the fruit [Pareek et al. 2009]. The fruit and leaves are good source of vitamin A, B and C, and minerals like calcium and potassium [Choi et al. 2011]. Mostly, the fruit is eaten as fresh, but could be used in dried and processed forms [Abbas et al. 2012]. It is also used for reparation of beverages, pickles, juice, candies, murrabbah and jams. In this scenario current study was planned to find out the relationship among various quality traits as well as to investigate the physico-chemical data for promising Indian jujube cultivars for future crop improvement programs.

MATERIALS AND METHODS

The present work was conducted at the Postgraduate Lab., Department of Horticulture, Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University, Multan (Pakistan) during 2015 and 2016. Fruits of the following Indian jujube cultivars were collected from Horticultural Research Station, Bahawalpur (Pakistan) i.e. Ajooba, Akasha, Meh- mood wali, Dilbahar, Umran-13, Sadqia, Foladi, Seedless, Khobani, Karella, Yazman local, Gorh and Pak white.

The following morphological attributes were recorded during the study i.e. fruit weight (g), pulp weight (g), juice weight (g) and seed weight (g) were recorded through digital weighing balance. Fruit length (mm), fruit width (mm), seed length (mm) and seed width (mm) were measured through digital vernier caliper.

During biochemical analysis; total soluble solids (˚Brix) were determined with hand refractometer, juice acidity (%) as explained by Hortwitz [1980], ripening index according to Hardy and Sanderson [2010], vitamin C (mg 100 mL^{-1}) by the method given by Ruck [1963] and sugars (%) were determined through the method of Hortwitz [1980]. For determination of antioxidant capacity (mM Trolox 100 mL^{-1}), antioxidant activity (%) and total phenolic content (µg GAE mL^{-1}), same sample extraction method was used as described by Ozgen et al. [2010] with little modifications.

Data analysis

The statistical software, Statistix 8.1 (Tallahassee Florida, USA) was used to analyze the collected data.

Due to two factors; years and cultivars, two-way analysis of variance were applied. The treatment means were separated by using least significant difference (LSD) test at 5% level of probability. However, effect of years and their interaction with cultivars was found statistically non-significant; hence, these are not discussed in the following section. Pearson's correlation and biplot were constructed through a software XLSTAT 2017, while dendrograms were constructed through a software, Minitab 2017.

RESULTS AND DISCUSSION

The cultivar Foladi had significantly greater fruit weight (30.49 g), fruit width (36.75 mm) and pulp weight (28.42 g). The highest fruit length (45.16 mm) was recorded in Umran-13 cultivar and seed length in Karella (24.03 mm) and Umran-13 (23.64 mm). The maximum juice weight (8.20 g) was found in the fruits of Akasha cultivar, which was statistically similar with Foladi, Sadqia, Dilbahar and Khobani cultivars. The cultivar Dilbahar had the maximum seed weight (2.70 g) and seed width (11.73 mm). The cultivar Gorh had the minimum fruit weight (9.44 g), fruit length (27.55 mm), fruit width (25.78 mm), pulp weight (8.23 g) and juice weight (2.26 g). The cultivar Seedless had very little amount of seed weight (0.22 g) among all the other cultivars, while seed length and seed width could not be measured due to its littleness. After Seedless cultivar, the minimum seed length was measured in Gorh and seed width in Karella among all the studied cultivars. Further details regarding the morphological attributes are presented in Table 1, which indicate wide differences in morphological attributes of jujube cultivars. Obeed et al. [2008], Abbas et al. [2012], Singh and Misra [2012], Raziet al. [2013] and Godi et al. [2016] also reported wide variations in fruit weight, fruit length, fruit width, pulp weight, stone weight, stone length, and stone width in Indian jujube cultivars. Genetic make-up, agronomic practices, plant nutrition and fruit orientation are the possible causes of variations in these morphological traits.

Table 1. Morphological attributes of 13 jujube cultivars

Genotypes	Fruit weight (g)	Fruit length (mm)	Fruit width (mm)	Pulp weight (g)	Juice weight (g)	Seed weight (g)	Seed length (mm)	Seed width (mm)
Ajooba	13.13 f	30.3 h	27.02 hi	11.80 h	4.88 c	1.33 ef	14.83 g	10.12 c
Akasha	20.47 d	37.12 ef	32.38 c	19.09 de	8.20 a	1.38 de	17.91 e	9.55 d
Mehmood wali	19.54 de	33.29 g	31.99 cd	18.38 ef	7.37 b	1.17 fg	16.05 f	9.14 d-f
Dilbahar	27.23 b	43.75 b	34.37 b	24.53 b	7.66 ab	2.70 a	22.38 b	11.73 a
Umran-13	20.66 d	45.16 a	29.29 ef	19.70 c	7.33 b	0.96 h	23.64 a	7.39 g
Sadqia	18.13 e	38.13 de	29.39 ef	16.82 f	7.90 ab	1.31 ef	20.33 d	9.33 de
Foladi	30.49 a	39.05 d	36.75 a	28.42 a	7.96 ab	2.06 b	20.99 cd	11.00 b
Seedless	13.31 f	31.04 h	29.04 fg	13.09 g	4.99 c	0.22 i	0.00 i	0.00 i
Khobani	18.14 e	33.94 g	29.48 ef	16.89 ef	7.63 ab	1.25 ef	15.53 fg	8.75 f
Karella	18.97 e	43.32 b	27.77 gh	17.95 ef	5.18 c	1.01 gh	24.03 a	6.89 h
Yazman local	20.99 d	40.68 c	30.66 de	19.46 cd	5.30 c	1.53 d	21.14 c	9.01 ef
Gorh	9.44 g	27.55 i	25.78 i	8.23 i	2.27 e	1.21 ef	13.69 h	9.49 d
Pak white	24.08 c	36.44 f	34.46 b	22.32 b	3.72 d	1.76 c	21.18 c	10.32 c

Mean values sharing similar letter(s) in a column are statistically non-significant at $p = 0.05$ (LSD test)

Table 2. Pearson's correlation of 13 jujube cultivars for morphological attributes

	Fruit weight	Fruit length	Fruit width	Pulp weight	Juice weight	Stone weight	Stone length	Stone width
Fruit weight	**1**							
Fruit length	**0.69**	**1**						
Fruit width	**0.91**	0.39	**1**					
Pulp weight	**0.99**	**0.70**	**0.91**	**1**				
Juice weight	**0.56**	0.48	0.48	**0.57**	**1**			
Stone weight	**0.72**	0.38	**0.67**	**0.66**	0.26	**1**		
Stone length	**0.61**	**0.75**	0.33	**0.59**	0.29	**0.61**	**1**	
Stone width	0.46	0.19	0.40	0.41	0.20	**0.84**	**0.71**	**1**

Values in bold are different from 0 with a significance level $\alpha = 0.05$

Pearson's correlation was estimated for morphological attributes on the basis of available averaged data (tab. 2). Fruit weight had significant correlation with pulp weight (0.99), fruit length, (0.69), fruit width (0.91), stone weight (0.72), stone length (0.61) and juice weight (0.56). Fruit length showed significant correlation with pulp weight (0.70) and stone length (0.75). Significant correlation was found between fruit width and pulp weight (0.91) and between fruit width and stone weight (0.67). Pulp weight exhibited significant correlation with juice weight (0.57), stone weight (0.66) and stone length (0.59). Significant correlation was observed between stone weight and stone width (0.84) and between stone weight and stone length (0.61), while stone length also exhibited significant correlation with stone width (0.71). Correlation study is a very necessary tool for plant breeders. This correlation among different traits is due to pleiotropic effect of various genes [Anwar et al. 2009]. Environmental factors play a significant role in the influence of phenotypic relationship [Ali et al. 2009]. Fruit weight had a direct correlation with pulp weight, fruit length, fruit width and stone weight which indicated that when fruit weight increased it also increased the respective traits. Fruit weight, fruit length, fruit width, pulp weight and juice weight are the major yield contributing traits. The similar correlation studies have already been carried out in grapes and mango [Patil and Patil 1995, Attri et al. 1999].

Principal component analysis was carried out to detect the traits that were the main cause of variability in jujube cultivars. Biplot is an important and useful method to determine the maximum possible amount of information in multivariate data. Biplot has been divided into four quadrants or components. The vectors represent the relationship among the variables, while dots represent the performance of various cultivars. In the present study, findings through biplot were similar to Pearson's correlation coefficient. Fruit weight had strong correlation with pulp weight, fruit length and fruit width, while stone weight had strong correlation with stone length and moderately with stone width (fig. 1). The cultivars Pak white, Yazman local, Dilbahar, Sadqia, Akasha, Umram-13 and Foladi had good performance while, Gorh and Ajooba had moderate performance among all the genotypes. The genotype Seedless had very poor performance regarding the morphological traits (fig. 1). The genotypes sharing excellent performance can be used in parent selection for further breeding purposes. The interpretation of present study results through biplot are in accordance with previous studies [Abdi and Williams 2010].

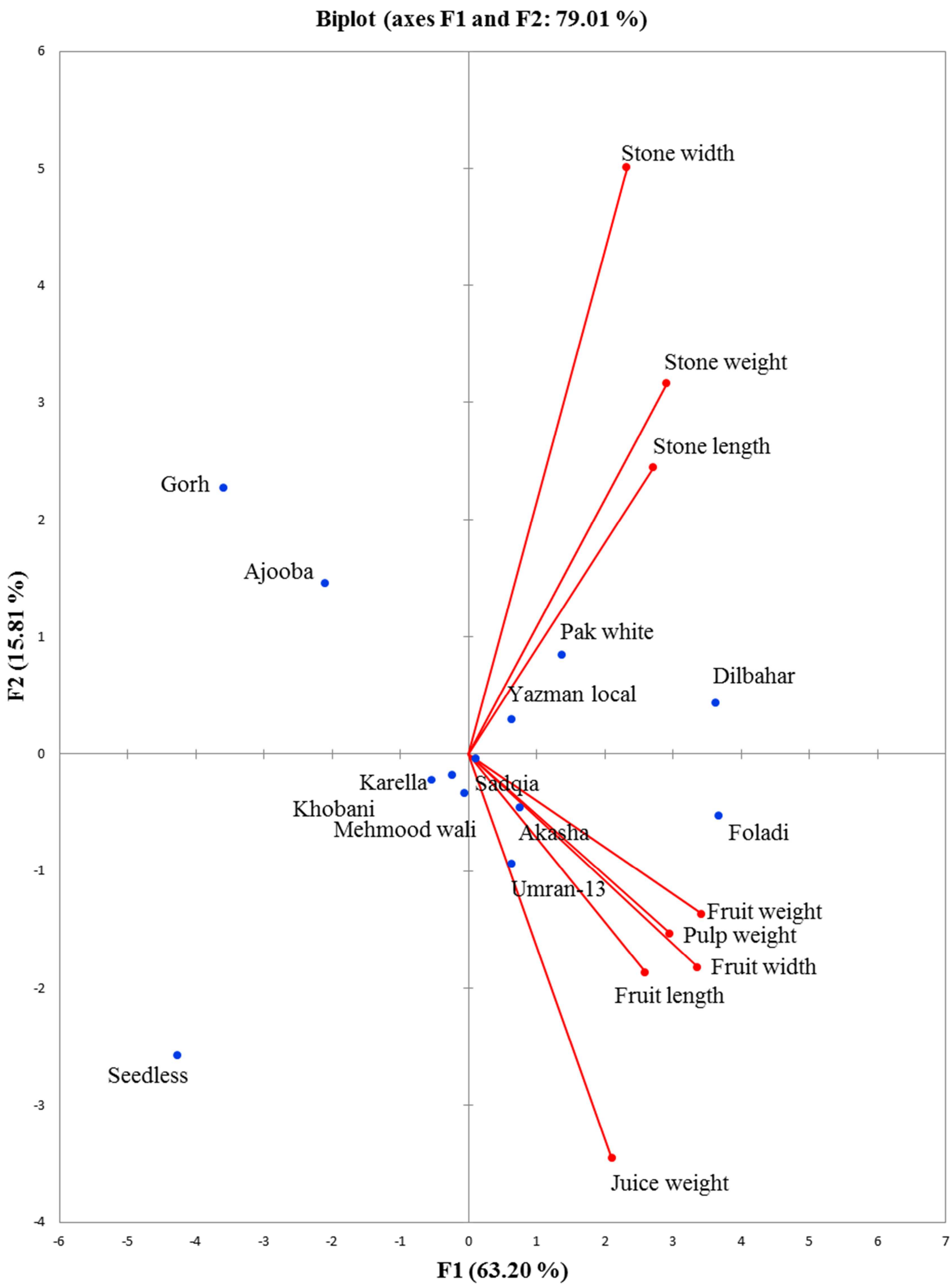

Fig. 1. Biplot analysis of morphological attributes of 13 jujube cultivars

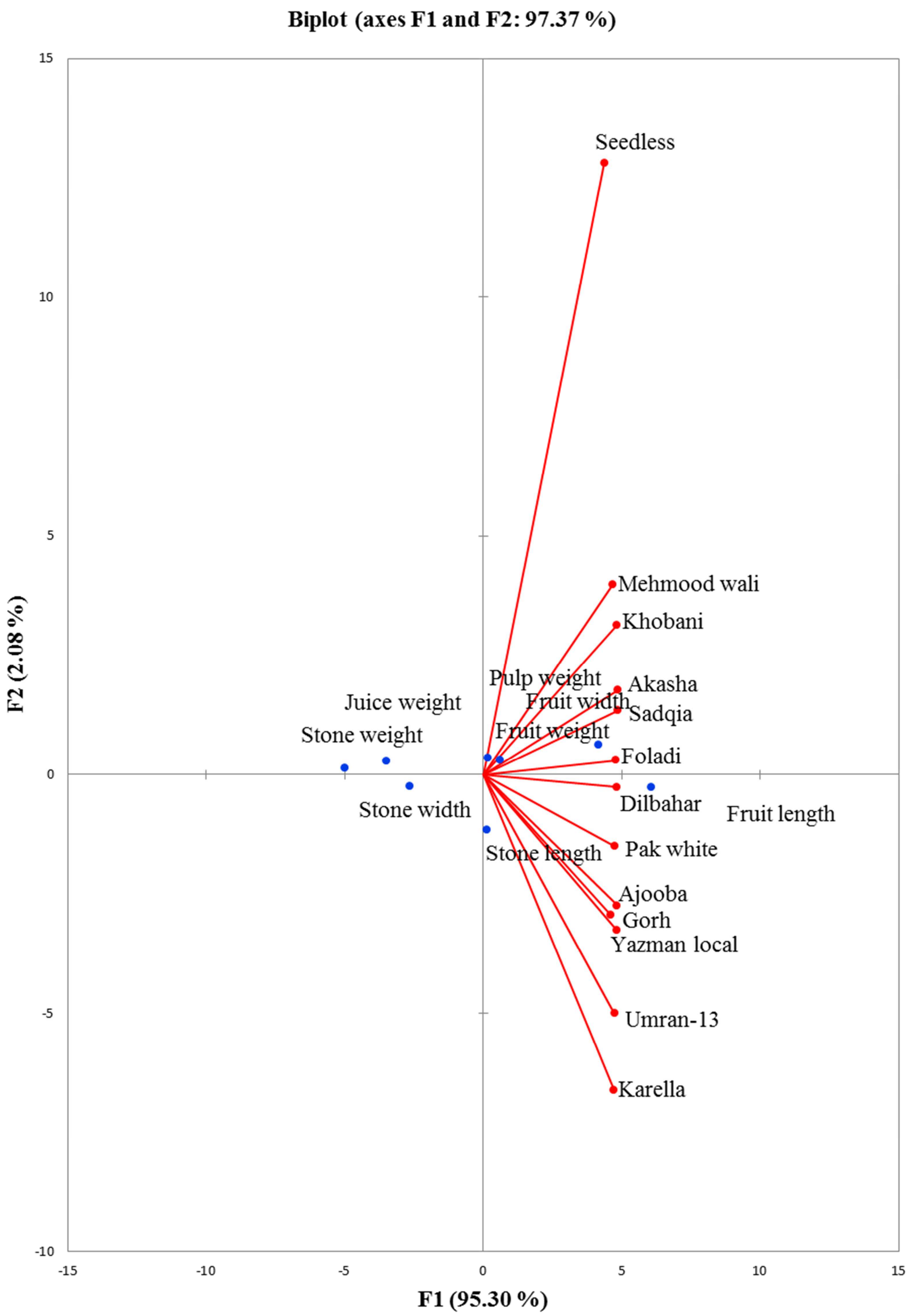

Fig. 2. Relationship among 13 jujube cultivars on the basis of morphological attributes through biplot analysis

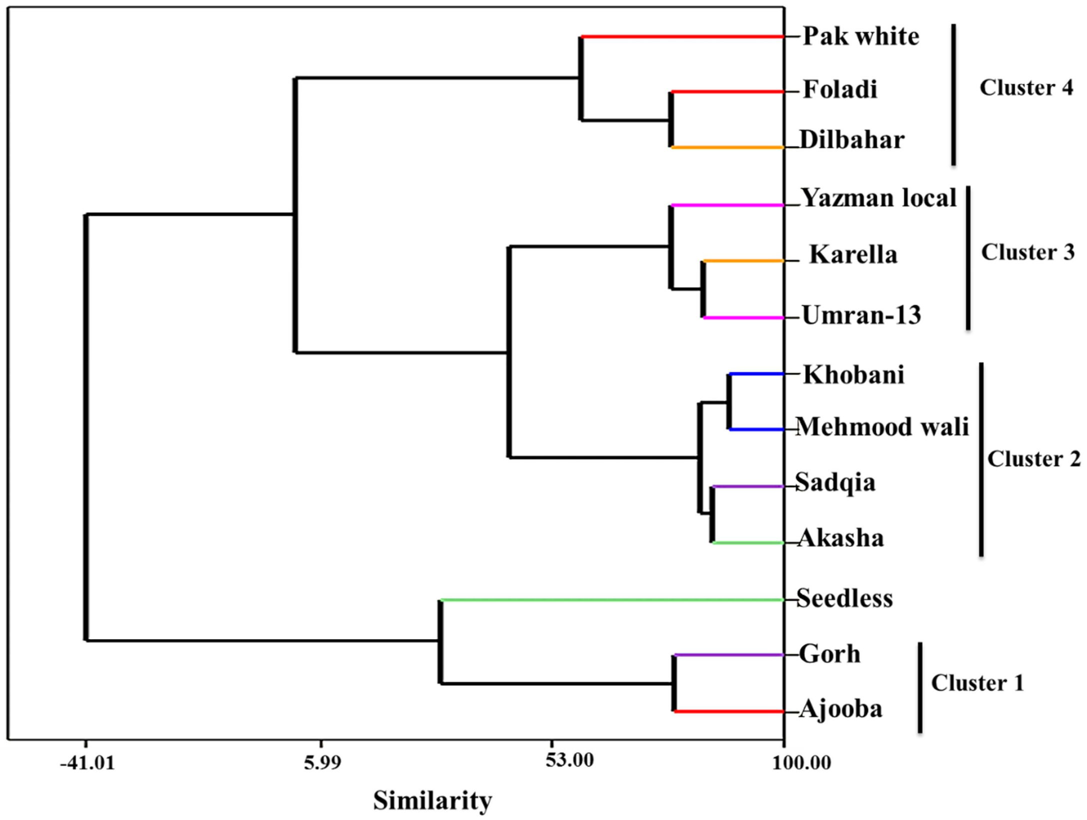

Fig. 3. Dendrogram showing relationship among 13 jujube cultivars based on morphological attributes

Biplot studies have already been carried out in different horticultural crops i.e. cucumber [Fan et al. 2006] and tomato [Jokanović et al. 2017]. Biplot also helped in determining the relationship among 13 different genotypes of Indian jujube on the basis of morphological attributes. The two cultivars Khobani and Mehmood wali had maximum similarity with each other, while seedless remained independent and did not group with other cultivars (fig. 2). This analysis could group cultivars and their variables by providing an opportunity for the selection of numerous genotypes for different traits.

Dendrogram (Ward linkage, Pearson distance) was constructed on the basis of morphological attributes which divided the 13 genotypes into four main clusters while truncated at 0.53 (53%) similarity level (fig. 3). Cluster 1 contained two cultivars (Gorh and Ajooba). Cluster 2 was the largest group, which comprised of 4 cultivars (Khobani, Mehmood wali, Sadqia and Akasha). Cluster 3 had three cultivars (Yazman local, Karella and Umran-13). Cluster 4 also contained three cultivars (Pak white, Foladi and Dilbahar). The two cultivars Khobani and Mehmood wali shared the maximum similarity in morphological characteristics therefore stood very close to each other in dendrogram among all the cultivars. The cultivar Seedless remained independent and did not group with any other cultivars in the dendrogram. Among the cultivars, this was the most diverse one.

Table 3. Biochemical attributes of 13 jujube cultivars

Genotypes	TSS (°Brix)	Acidity (%)	Ripening index	Vitamin C (mg 100 mL^{-1})	Reducing sugars (%)	Non-reducing sugars (%)	Total sugars (%)	Antioxidant capacity (mMTrolox 100 mL^{-1})	Antioxidant activity (%)	Total phenolic content (µg GAE mL^{-1})
Ajooba	13.58 c	0.55 b-d	24.65 cd	44.75 e	7.66 a	1.22 h	9.14 c–e	236.69 d–f	29.66 b–d	172.50 cd
Akasha	12.42 e	0.50 def	26.06 c	72.53 a	4.03 h	3.44 b	7.78 g	525.84 ab	22.04 fg	152.82 d–f
Mehmood wali	12.25 e	0.57 bc	26.15 c	48.15 d	5.13 g	4.52 a	10.03 a	616.13 a	19.66 g	160.38 c–f
Dilbahar	11.33 f	0.51 cde	25.71 c	55.86 c	6.69 c–e	1.99 fg	8.99 c–f	560.92 ab	21.11 fg	179.85 bc
Umran-13	12.33 e	0.46 efg	29.09 b	49.38 d	6.31 e	3.48 b	10.04 a	158.17 f	32.05 b	243.06 a
Sadqia	14.33 b	0.51 cde	32.60 a	39.20 f	7.16 b	2.56 cd	10.09 a	250.18 c–f	40.60 a	239.25 a
Foladi	13.00 d	0.61 b	22.88 de	27.47 g	6.42 de	1.87 fg	8.61 f	283.90 c–f	28.71 b–e	149.51 ef
Seedless	13.00 d	0.61 b	21.55 ef	40.74 f	6.78 b–d	2.18 ef	9.29 bc	600.46 a	20.07 g	163.33 c–e
Khobani	14.92 a	0.44 fg	33.80 a	63.89 b	6.39 de	2.04 e–g	8.70 ef	204.61 ef	30.51 bc	165.68 c–e
Karella	13.17 cd	0.41 g	33.44 a	27.47 g	5.70 f	2.81 c	8.82 def	338.92 c–e	26.97 c–e	196.31 b
Yazman local	13.25 cd	0.48 ef	30.25 b	24.07 h	7.78 a	1.78 g	9.88 a	393.77 b–d	25.52 d–f	140.18 f
Gorh	14.33 b	0.74 a	20.14 f	22.84 h	7.06 bc	2.37 de	9.74 ab	418.96 bc	24.99 ef	153.04 d–f
Pak white	13.50 c	0.59 b	25.25 c	22.22 h	6.94 bc	1.90 fg	9.18 cd	615.02 a	19.69 g	137.99 f

Mean values sharing similar letter(s) in a column are statistically non-significant at $p = 0.05$ (LSD test)

Table 4. Pearson's correlation of 13 jujube cultivars for biochemical attributes

	TSS	Acidity	Ripening index	Vitamin C	Reducing sugars	Total sugars	Non-reducing sugars	Antioxidant capacity	Antioxidant activity	Total phenolic content
TSS	**1**									
Acidity	0.13	**1**								
Ripening index	0.24	**–0.88**	**1**							
Vitamin C	–0.27	–0.40	0.20	**1**						
Reducing sugars	0.40	0.24	–0.07	**–0.57**	**1**					
Total sugars	0.11	0.17	0.06	–0.41	0.50	**1**				
Non-reducing sugars	–0.38	–0.15	0.13	0.34	**–0.76**	0.18	**1**			
Antioxidant capacity	–0.45	0.37	–0.48	–0.03	–0.28	–0.18	0.22	**1**		
Antioxidant activity	0.50	–0.32	0.54	–0.01	0.31	0.27	–0.14	**–0.87**	**1**	
Total phenolic content	–0.03	–0.44	0.48	0.19	0.03	0.39	0.28	–0.55	**0.71**	**1**

Values in bold are different from 0 with a significance level α = 0.05

The details regarding the biochemical characteristics are shown in Table 3. The maximum total soluble solids (14.92 °Brix) were found in Khobani, while the minimum in Dilbahar (11.33 °Brix). The TSS differed among the cultivars possibly due to genetic factors, cultural practices and ripening stage. These results are in agreement with the findings of Pareek et al. [2009], who found the maximum TSS in jujube cultivar Illaichi and the minimum in Karella. The cultivar Gorh had highest acidity level (0.74%) in juice and the lowest level was in Karella (0.41%), followed by Khobani (0.44%) and Umran-13 (0.46%). Pareek et al. [2009] estimated the maximum acidity level in Chhuhara cultivar. Thus, these results are in accordance with the previous findings. Higher ripening index was observed in the cultivar Khobani (33.80), Karella (33.44) and Sadqia (32.60%); while the minimum ripening index was in Gorh (20.14) and Seedless (21.55%).The cultivar Akasha had the maximum vitamin C content (72.53 mg 100 mL^{-1}), while the minimum (22.22 mg 100 mL^{-1}) in the cultivar Pak white, followed by Gorh (22.84 mg 100 mL^{-1}) and Yazman local (24.07 mg 100 mL^{-1}). Koley et al. [2011] also found differences in ascorbic acid content in jujube cultivars. The maximum reducing sugars content was found in Yazman local (7.78%) and Ajooba (7.66%), while the minimum reducing sugars content (4.03%) was in Akasha. Mehmood wali had the highest non-reducing sugars content (4.52%) and the lowest non-reducing content was in Ajooba (1.22%). However, total sugars content were higher in Sadqia (10.09%), followed by in Umran-13, Mehmood wali, Yazman local and Gorh; while the lower was in Akasha (7.78%). The variations among the cultivars for sugars content were probably due to genetic make-up, agronomic practices and position of fruits on the tree in respect to sunlight. Pareek et al. [2009] and Godi et al. [2016] also found variations in the sugar content among different jujube cultivars. So, our results are in accordance with the previous findings. The cultivar Mehmood wali showed the maximum value of antioxidant capacity (616.13 mM Trolox 100 mL^{-1}), followed by Pak white, Seedless, Dilbahar and Akasha. However, the minimum antioxidant capacity (158.17 mM Trolox 100 mL^{-1}) was in Umran-13, followed by Khobani, Ajooba, Sadqia and Foladi. The cultivar Sadqia showed the maximum value of antioxidant activity (40.60%) and significantly differed from rest of the cultivars. The minimum value was estimated in Mehmood wali (19.66%), followed by Pak white, Seedless, Dilbahar and Akasha. Koley et al. [2011] also recorded variations in antioxidant activity among 12 commercial jujube cultivars. The fruits of Umran-13 (243.06 µg GAE mL^{-1}) and Sadqia (239.25 µg GAE mL^{-1}) had the maximum phenolic content, while the minimum value was in Pak white (137.99 µg GAE mL^{-1}), followed by Yazman local, Foladi, Akasha, Gorh and Mehmood wali. Krishna and Parashar [2012] observed the maximum phenolic content (196.34 µg GAE mL^{-1}) in ZG-3 cultivar of jujube. The variations in phenolic content might be associated with the influence of different external factors such as soil, location, climatic factors and intensity of light.

Pearson's correlation was estimated for all the biochemical properties of jujube fruits on the basis of available averaged data as shown in Table 4. In the present study, total soluble solids content had no significant correlation with any other biochemical parameter. Acidity had significant but negative correlation (–0.88) with ripening index. Vitamin C had significant and negative (–0.57) correlation with reducing sugars. Reducing sugars also had highly significant but negative correlation (–0.76) with non-reducing sugars. Significant and negative correlation was observed between antioxidant capacity and antioxidant activity (–0.87), while antioxidant activity showed strong correlation (0.70) with total phenolic content. Positive correlation indicated that variables are directly proportional to each other, when one variable increased it also increased the other variable. The negative correlation showed that variables are inversely proportional to each other, when one variable increased than other variable decreased.

Biplot was constructed to identify the correlation among the biochemical attributes of 13 jujube cultivars. Reducing sugars, total sugars, TSS and antioxidant activity were found in quadrant 1 but their relationship was statistically non-significant. Total phenolic content and ripening index were in quadrant 2 but acidity in quadrant 3. Juice acidity had strong but

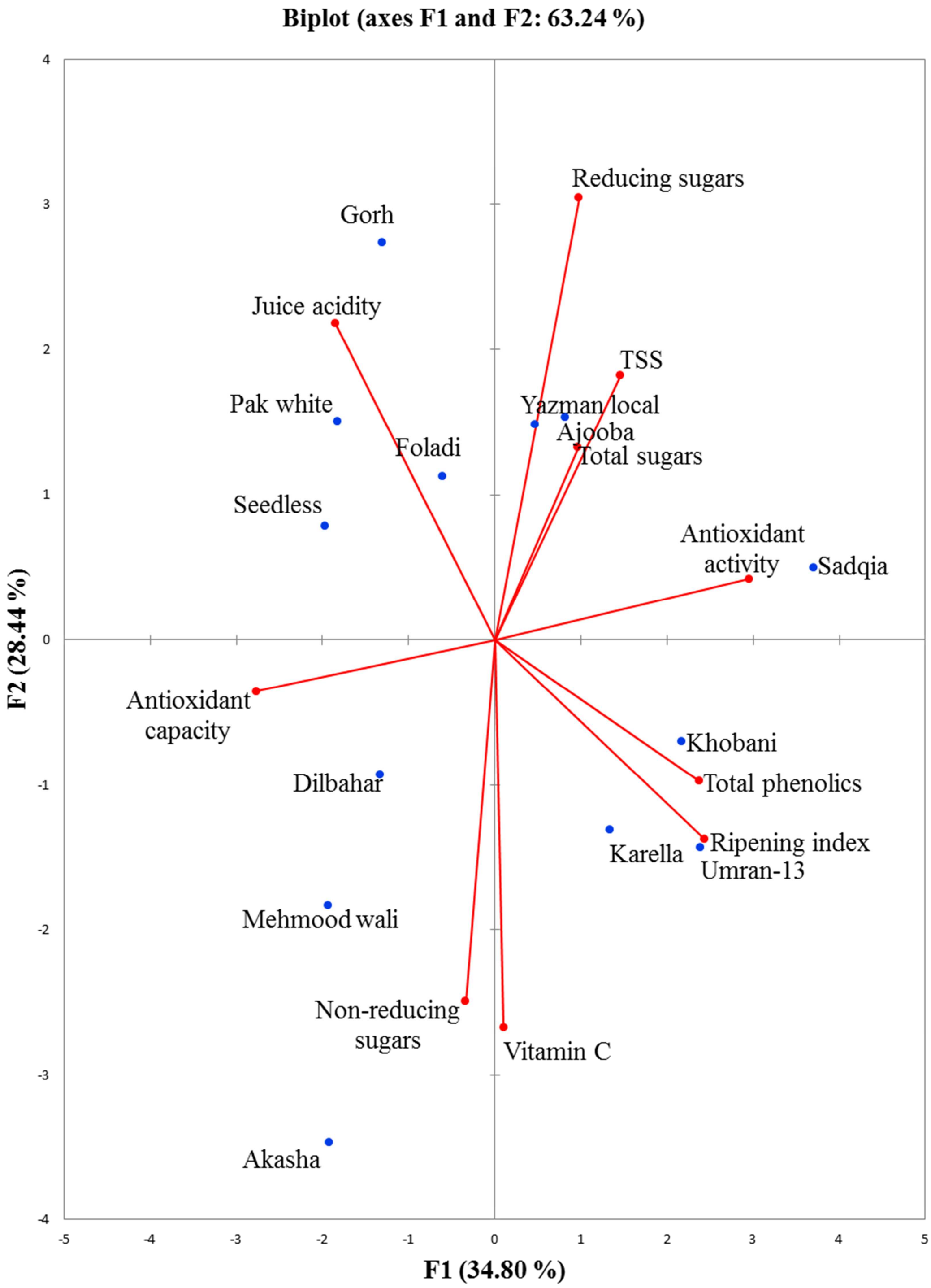

Fig. 4. Biplot analysis of biochemical attributes of 13 jujube genotypes

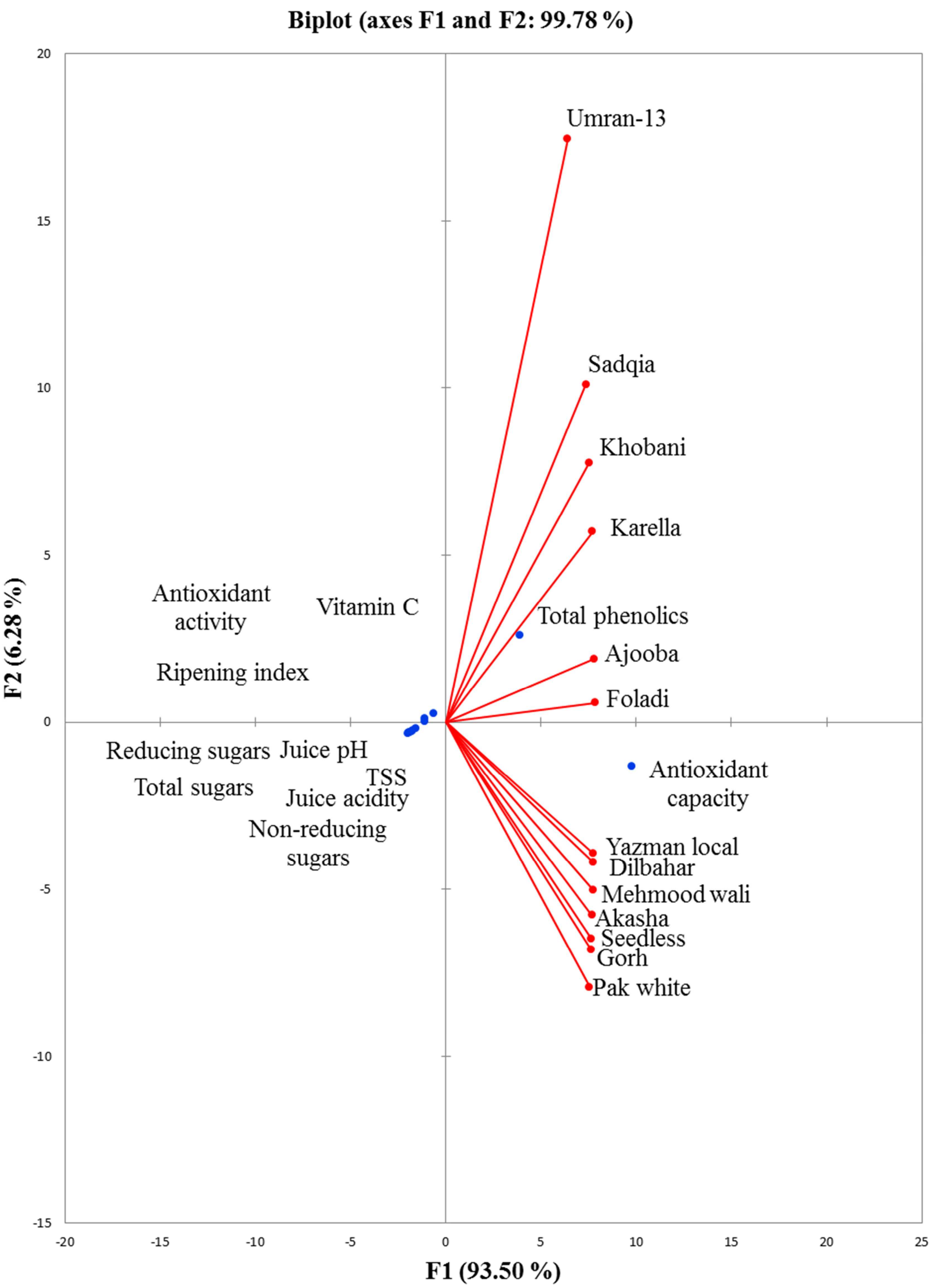

Fig. 5. Relationship among 13 jujube genotypes on the basis of biochemical attributes through biplot analysis

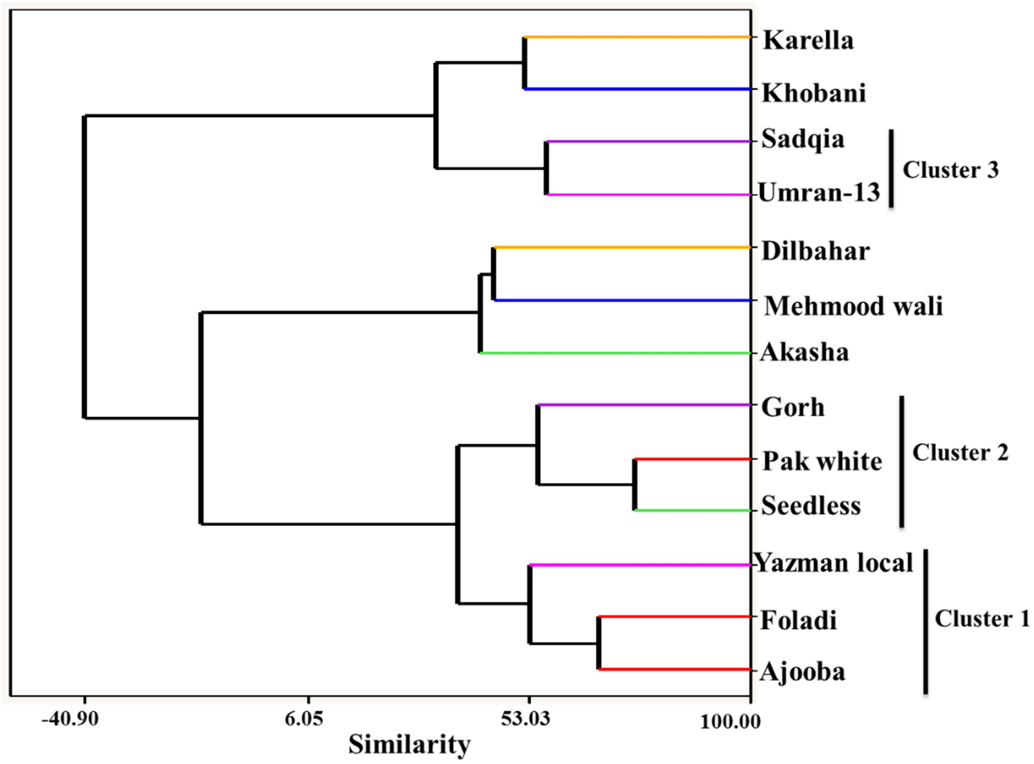

Fig. 6. Dendrogram showing relationship among 13 jujube cultivars based on biochemical attributes

negative correlation with the ripening index. Antioxidant capacity was in quadrant 4 exhibiting strong but negative correlation with antioxidant activity in quadrant 1 among all the variables. When antioxidant activity increased it decreased the efficiency of antioxidant capacity. These variables showed inverse relationship with one another. Non-reducing sugars were in quadrant 4 but had no relationship with any other variable. Yazman local, Ajooba and Sadqia were in quadrant 1 and Khobani, Karella and Umran-13 in quadrant 2 showing better performance for biochemical properties among all the cultivars. Gorh, Foladi, Seedless and Pak white having moderate performance. Poor performance was showed in biochemical attributes by three cultivars (Dilbahar, Mehmood wali and Akasha) in quadrant 4 (fig. 4). Biplot also helped to measure the similarity among 13 genotypes of jujube on the basis of their biochemical attributes. All 13 genotypes were grouped in two quadrants (quadrants 1 and 2). The six genotypes (Umran-13, Sadqia, Khobani, Karella, Ajooba and Foladi) were similar to each other in quadrant 1. However, Ajooba and Foladi had the maximum similarity among the genotypes of this quadrant. The remaining seven genotypes were in quadrant 2 exhibiting similarity with each other, while Seedless and Pak white showing the highest similarity with one another among all the genotypes (fig. 5).

Dendrogram (Ward linkage, Pearson distance) was also constructed on the basis of biochemical attributes which divided the cultivars into three main clusters when truncated at 0.53.03 (53.03%) similarity level (fig. 6). Cluster 1 contained three cultivars (Ajooba, Foladi and Yazman local). Cluster 2 comprised of three cultivars i.e. Pak white, Seedless and Gorh and former two cultivars were very close to each other. Cluster 3 had two cultivars (Sadqia and Umran-13) which shared the maximum similarity with each other. Two cultivars (Karellaand Khobani) showed the maximum similarity with each other but remained independent during clustering. The other three cultivars (Dilbahar, Mehmood wali and Akasha) also shared maximum similarity with each other but did not group with any other cultivars in the dendrogram (fig. 6). In the present study, dendrogram based on phenotypic characteristics as well as biochemical properties exhibited the variations in total number of clusters as well as position of cultivars within the clusters. Collection and maintenance of diverse germplasm is better than the collection of a few individuals from each population [Kaundun and Park 2002]. Thus, there is need that these genotypes should be conserved for future breeding programs.

CONCLUSION

Present study demonstrated that characterization of morphological and biochemical attributes is very important during the parent selection for evolving new commercial cultivars of jujube. Conclusively, Pakistan had a diverse germplasm of jujube that can be utilized in breeding purposes or further cultivar improvement programs in the future.

ACKNOWLEDGEMENTS

The authors are highly grateful to the Horticulturist, Horticulture Research Station, Bahawalpur for providing the plant material, and Bahauddin Zakariya University, Multan for financial support to conduct the study.

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