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Evaluation of fruit quality traits on inter-varietal F₁ hybrids of pomegranate

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Abstract

Sixty F₁ hybrids were selected for recording observations on different fruit quality parameters. The present investigation was carried out in the experimental block of the Department of Fruit Science during the year 2017-18. These F₁ hybrid progeny developed during the year 2011-12 from the inter-varietal crosses of six soft-seeded (Ganesh, G-137, Dholka, Nabha, Jodhpur Red, Mridula) and three hard-seeded (Kandhari Hansi, China Seedling, Bush Large). The results showed that maximum fruit weight (531.50 g), maximum fruit length (91.54 mm) and fruit diameter (98.51 mm) was recorded in Plant No.2 of Bush Large × Mridula. A higher number of arils per fruit (700.50) was recorded in Plant No.1 of Dholka × Kandhari Hansi and a minimum (258.25) in Plant No.3 of China Seedling × Dholka and a higher Aril weight (269.00 g) was in Plant No.2 of Bush Large × Mridula F₁ hybrids. Plant No.4 of Kandhari Hansi × China Seedling had the thickest rind (3.73 mm) and Plant No.4 of Kandhari Hansi × Ganesh had the thinnest rind (1.46 mm) among all 60 hybrid plants. The total soluble solids content was highest (15.97 °B) in Plant No.1 of Dholka × Kandhari Hansi and total sugars (12.68%) were highest in Plant No.1 of Bush Large × Mridula. The minimum acidity value (0.67%) was recorded in Plant No.5 of Mridula × Kandhari Hansi and the highest (2.50%) in Plant No.1 of Bush Large × G-137. Reducing sugars varied from (4.31) per cent in Plant No.3 of China Seedling × Dholka to (10.54) per cent in Plant No.1 of Bush Large × Mridula. TSS/acidity ratio was maximum (19.77) in Plant No.1 of Bush Large × Mridula and minimum (4.45) in Plant No.1 of Kandhari Hansi × Dholka.

Keywords: F₁ hybrids, pomegranate, fruit size, chemical characteristics

Introduction

Pomegranate (*Punica granatum* L.) belongs to the family Punicaceae and is a well-known table fruit of tropical and subtropical regions of the world. The pomegranate is an ancient fruit with a wealthy history. It is considered to be a native of Iran and has spread in the regions of Afghanistan and the Western parts of the Himalayas. It is grown mainly in Mediterranean and Asian countries. India, Iran, China, and Turkey are the main producer countries (Sarkar, 2016) [30].

The growing interest in this fruit is not only because it is pleasant to eat, but also because it is a functional product that is beneficial to human health, as it contains several types of substances that are useful in disease prevention (Martinez-Nicolas *et al.* 2016) [20].

The fruit has a wide consumer preference for its attractive, juicy, sweet, acidic, and refreshing arils. Pomegranate fruits are a good source of protein, carbohydrates, minerals, antioxidants, and vitamins A, B and C, and are also used in controlling diarrhea, hyperacidity, tuberculosis, leprosy, abdominal pain, and fever (Aseri *et al.* 2008) [4]. Due to its multipurpose medicinal uses, it is also known as “Super fruit” in the global functional food industry (Martinez *et al.* 2016) [20]. The arils are the edible part of the fruit, which contain around 80% juice and 20% seed. The juice is rich in sugars, organic acids, vitamins, polysaccharides, and essential minerals (Al-Maiman and Ahmad, 2002) [5].

Due to its versatile adaptability to a wider range of climatic conditions, the fruit has shown great potential for diversification and commercial cultivation in Himachal Pradesh in recent years. The cultivars like Kandhari, Bedana, Dholka and Spain Dander have been recommended for cultivation in Himachal Pradesh. Although Ganesh, G-137 and Bhagwa have also been recommended (Anonymous, 2000) [2], but increase in the area under commercial pomegranate cultivation is very low.

The varietal array favouring cooler climates is narrow.

Moreover, the degeneration of clones of the adapted varietal lot, the absence of cultivars suitable to local conditions and preference of consumers towards soft-seeded cultivars with deep red aril colour over hard-seeded ones necessitates the breeding of cultivars with wider adaptability. The acceptability of a cultivar by consumers depends largely on its fruit quality. Some of the well-adapted popular cultivars *viz.* Ganesh, G-137, and Dholka are lacking in desired aril colour. Therefore, present studies on the evaluation of sixty F₁ hybrids of pomegranate were selected to assess the physicochemical fruit characteristics of F₁ Hybrids of pomegranate.

Materials and Methods

The present investigation was carried out in the experimental block of the Department of Fruit Science, Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during 2018-19. The experimental area is located at an altitude of 1220 m above mean sea level between 31°N latitude and 77°E longitudes. The climate is mild temperate. The experimental material included 6-7 years old F₁ hybrid progenies developed during the year 2011-12 from the inter-varietal cross combination of six soft-seeded (Ganesh, G-137, Dholka, Nabha, Jodhpur Red, Mridula) and three hard-seeded (Kandhari Hansi, China Seedling and Bush Large). Based on visual observation, vigour and health 60 individual plants belonging to 12 cross combinations (5 plants from each F₁ hybrid) were taken up to assess the fruit quality. The observations on various Physico-chemical parameters like fruit weight, fruit size, fruit colour, fruit shape, rind thickness, aril colour, no of arils/fruit, the weight of arils/ fruit, aril: rind ratio, aril taste mellowness of seeds fruit base, TSS, acidity, total sugars, non-reducing sugars and TSS: acidity ratio were recorded.

The weight of 4 fruits from each plant of the F₁ hybrid was determined with the help of a weighing pan and the average fruit weight was calculated and expressed as weight per fruit in grams. The length and diameter were measured with help of digital Vernier Callipers (Model No. CD-6" CS, Mitutoyo Corp. Japan). The different types of shapes noted in the representative samples of the fruits were observed visually, following the descriptors (Anonymous, 2015) [1]. The surface colour and blush colour of the fruit were observed by comparing them with the colour chart of the Royal Horticultural Society, London. The rind was separated from the fruit and its thickness was measured at four to five different places with Vernier Calipers (Model No. CD-6" CS, Mitutoyo Corp. Japan). The average rind thickness was calculated for the F₁ hybrid. The acidity, reducing sugars and total sugars were estimated as per the method suggested by AOAC (1980) [3]. The experiment was laid out in RBD with four replications (four fruits from each plant).

Results and Discussion

Physical characteristics

Significant variations in different fruit characteristics such as size, weight, colour, number of arils, aril taste, the colour of aril and mellowness of seeds were recorded in F₁ hybrids of pomegranate (Table 1). Average fruit weight varied from 143.50 g to 521.50 g in different pomegranate hybrids under study.

Among 60 individual F₁ hybrids, Plant No.2 of Bush Large × Mridula had a maximum average fruit weight (521.50 g) which was significantly higher than the other hybrids and Plant No.4 of China Seedling × Dholka had a minimum fruit

weight (143.50 g). Maximum fruit length (91.54 mm) and diameter (98.51 mm) were recorded in Plant No.2 of Bush Large × Mridula, minimum fruit length (55.65 mm) in Plant No.5 of China Seedling × Dholka and minimum fruit diameter (59.40 mm) was recorded in Plant No.2 of Kandhari Hansi × China Seedling (Table 1). Similar studies were done by Sharma and Dhillon (2002) [31] where the maximum fruit weight of 450.00 g was recorded in Ganesh followed by 400.00 g in PS-77 and 330.50 g in Bassein-Seedless and the minimum (200.00 g) fruit weight was noted in Jodhpur White. Celik and Erasl (2009) [7] studied the physical characteristics of pomegranate cv. Eksinar found fruit weight between 154.40 to 289.50 g. Ozguven *et al.* (2011) [26] recorded the highest fruit weight and fruit diameter in Izmir 1264 (369.40 g) and (89.77 mm), while the lowest fruit weight (146.90 g) and fruit diameter (65.12 mm) were recorded in cultivar Izmir 1445. Whereas the longest fruits have been observed in cultivar Izmir 1264 (80.57 mm) and Izmir 1483 has the smallest fruits (51.87 mm). Singh *et al.* (2011) [32] have also observed differences among parameters of average fruit weight, fruit length and fruit width which varied between 16.90 g to 51.72 g, 3.07 cm to 4.70 cm and 2.82 cm to 4.45 cm respectively in 14 different pomegranate germplasm accessions. Such variation in fruit size has also been reported by Hamouda *et al.* (2014) [11].

The fruit ground colour was observed to be Yellow Green Group (144 A- 143 B) in all plants of Bush Large × G-137, Yellow Green Group (142 A) and Green Group (38 C) in Mridula × Kandhari Hansi, Yellow Green Group (150 A) in Mridula × Bush Large, Yellow Green Group (144 B-143 B) in Dholka × Kandhari Hansi; Yellow Green Group (149 A-144 B-145 A) in Kandhari Hansi × Dholka; Yellow Green Group (145 A-144 B) in China Seedling × Kandhari Hansi; Yellow Green Group (150 B-142 A) in Kandhari Hansi × China Seedling; Yellow Green Group (144 C-150 B-145 A) in Bush Large × Mridula; Yellow Green Group (142 A) in China Seedling × Dholka; Yellow Green Group (150 C) in Kandhari Hansi × Mridula; Yellow Green Group (150 B- 150 C-144 B) in Kandhari Hansi × Ganesh and Green Group (143 C) in Nabha × Jodhpur Red. Several workers have worked on the physical aspects of pomegranate fruits (Mir *et al.* 2007; Sarkhosh *et al.* 2009; Wani *et al.* 2012) [21, 33, 41] in the past and have reported considerable variation in the fruit colour of different pomegranate cultivars. Fruit blush colour under the present study was observed to be Yellow Green Group (153 D) in all plants of Bush Large × G-137 and Bush Large × Mridula; Green Group (38 C) in Mridula × Bush Large; Red Yellow (17 B) in Dholka × Kandhari Hansi and Kandhari Hansi × Dholka; Red Green Group (49 A) in China Seedling × Kandhari Hansi and China Seedling × Dholka; Green Group (52 A) in Kandhari Hansi × China Seedling and Nabha × Jodhpur Red and Yellow Green (150 C) in Kandhari Hansi × Mridula and Kandhari Hansi × Ganesh. Similar differences in blush colour have also been reported by Ozkan (2003) [25]. Thakur *et al.* (2011) [39] observed greenish-yellow colour fruit with a red-purple colour aril which is in contradiction with the present findings. These fruit characteristics are determinantal in making any pomegranate variety acceptable to the end user i.e., the consumer. In general, the domestic market and consumers prefer pomegranate fruits having deep red and soft arils.

Fruit shape was found to be rounded in all F₁ hybrids except all plants of Kandhari Hansi × China Seedling and Kandhari Hansi × Ganesh which had elliptical and oval shapes respectively. Malhotra *et al.* (1983) [23] found that fruits of

pomegranate were either round or oblate at the time of maturity. Elongated oval and round fruit shapes were also reported in Kandhari, Ganesh and Nabha. Kumar (2000) [18] also reported rounded fruit shapes of different cultivars grown in the valley of the river Neretva.

The Thickest rind was recorded (3.73 mm) in Kandhari Hansi × China Seedling (Plant No.4) which was statistically at par with (Plant No.1) of Bush Large × G-137, (Plant No.4) of Mridula × Bush Large, (Plant No.1 and 5) of Dholka × Kandhari

Hansi, (Plant No.1 and 2) of China Seedling × Kandhari Hansi, (Plant No.1 and 2) of Kandhari Hansi × China Seedling, (Plant No.1 and 5) of China Seedling × Dholka, (Plant No.1 and 5) of Kandhari Hansi × Mridula and (Plant No.1, 2 and 5) of Nabha × Jodhpur Red and lowest (1.46 mm) in Kandhari Hansi × Ganesh (Plant No.4). Several workers (Mir *et al.* 2007; Zaouay *et al.* 2012 [43]; Ismail *et al.* 2014) [21] have also reported similar variation in rind thickness in different pomegranate accessions in the past. Bakshi *et al.* (2014) [6] studied the wild pomegranate in Jammu and showed that the rind thickness varied from 3.18 to 3.67 mm.

The number of arils per fruit was observed to be highest (700.50) in Plant No.1 of Dholka × Kandhari Hansi which was statistically at par with Plant No.1 of Bush Large × G-137 and a minimum (258.25) aril per fruit was observed in Plant No.3 of China Seedling × Dholka under present study (Table 1). Islam *et al.* (2009) [15] reported seed numbers per fruit varied from 103 to 597 in pomegranate fruits grown in the eastern Black Sea Region of Turkey. Wetzstein *et al.* (2011) [42] have also reported the total number of arils per fruit between 201 to 985 for different pomegranate cultivars. Considerable variation in the weight of arils per fruit has been recorded for different pomegranate hybrids in the present study. The weight of arils per fruit varied from 82.50 g in Plant No.4 of China Seedling × Dholka to 269.00 g in Plant No.2 of Bush Large × Mridula. Tehranifar *et al.* (2010) [40] also recorded 83.90 g to 166.20 g arils weight per fruit in fifteen Iranian pomegranate cultivars.

Aril/rind ratio varied from (1.43) in Nabha × Jodhpur Red (Plant No.4) to (3.05) in Kandhari Hansi × Ganesh (Plant No.4) which was statistically at par with (Plant No.1 and 2) of Bush Large × G-137, (Plant No.1) of Mridula × Kandhari Hansi, (Plant No.1) of Mridula × Bush Large, (Plant No.1) of Dholka × Kandhari Hansi, (Plant No.1 and 2) of Kandhari Hansi × Dholka, (Plant No.1 and 3) of China Seedling × Kandhari Hansi, (Plant No.5) of Kandhari Hansi × China Seedling, (Plant No.2 and 5) of Bush Large × Mridula, (Plant No.1) of China Seedling × Dholka and (Plant No.3 and 5) of Nabha × Jodhpur Red. Sinha (2014) [38] reported the highest aril: rind ratio (3.30) in accession "20090265" whereas the lowest (1.12) was recorded in Purple Heart.

Aril colour in all 60 F₁ hybrids studied belongs to the Red Group with the variation of intensity. Sinha (2014) [38] reported red aril colour in all 20 pomegranate accessions

under study belonged to the Red Group except Haku-Botan in which the aril colour belonged to the Yellow Group. Hepaksoy *et al.* (2009) [12] studied 13 Turkish pomegranate varieties representing Bordeaux, dark red, light pink, light red, pink and red berry colours. Kumar (2000) [18] also reported aril colour variation in Kandhari and Ganesh. Similarly, Malhotra *et al.* (1983) [23] and Khodade *et al.* (1990) [19] discussed varied aril colours in pomegranate genotypes.

Fruit base was absent in all hybrid plants of Bush Large × G-137, Kandhari Hansi × China Seedling, China Seedling × Dholka and Nabha × Jodhpur Red and fruit base was present in all plants of Mridula × Kandhari Hansi, in Mridula × Bush Large, Dholka × Kandhari Hansi, Kandhari Hansi × Dholka and Kandhari Hansi × Mridula. However, the hybrid China Seedling × Kandhari Hansi and Kandhari Hansi × Ganesh were slightly shouldered concerning fruit base. Sinha (2014) [38] observed fruit base in 20 pomegranate accessions and reported it to be absent in most accessions except Nausi, and accession Ovadan was recorded to be slightly shouldered.

The soft seediness and deep red aril colour is the main consideration for selecting a variety of pomegranate. However, in the present study, none of the hybrids was found to be soft-seeded. Most of the hybrids had medium-soft seeds except China Seedling × Kandhari Hansi, Kandhari Hansi × China Seedling, Kandhari Hansi × Mridula and Nabha × Jodhpur Red which were observed to be hard seeded (Table 1). Jalikop and Kumar (1998) [16] reported 18 accessions representing soft, semi-soft and hard-seeded pomegranate accessions. Similar variation in the mellowness of arils has also been reported by Sepahvand *et al.* (2011) [35] in the Karaj region of Iran during 2007-2008. Also, similar observations have been reported by Martinez *et al.* (2012) [24]. Soft seediness or absence of seeds is a desirable economic trait which might be due to the genetic constitution of the cultivars (Jalikop, 2010) [17].

Aril taste of different hybrids evaluated under the present study is shown in (Table 1). The data revealed that the aril taste of pomegranate hybrids varied between sweet-sour to sour types. Hybrids like Bush Large × G-137, Mridula × Kandhari Hansi, Dholka × Kandhari Hansi, Mridula × Bush Large, Kandhari Hansi × Dholka and Bush Large × Mridula had sweet-sour arils, the sour taste was observed in China Seedling × Kandhari Hansi, China Seedling × Dholka, Kandhari Hansi × China Seedling, Kandhari Hansi × Mridula, Kandhari Hansi × Ganesh and Nabha × Jodhpur. No sweet aril taste was recorded among all F₁ hybrid plants studied under present investigations. This difference might be attributed to inherent differences that existed among different pomegranate genotypes. Pomegranate fruits have been reported to develop a sweeter taste in hotter climates as compared to cooler climates (Patil and Karale, 1992) [27]. The present findings also are in agreement with the observations noticed by Samadia and Pareek (2006) [36].

Table 1: Physical characteristics of fruits and arils of different F₁ hybrids of pomegranate

Hybrids	Plant No.	Fruit weight (g)	Fruit length (mm)	Fruit diameter (mm)	Fruit colour		Fruit shape	Rind thickness (mm)	Aril colour	Number of arils per fruit	Weight of arils per fruit (g)	Aril: rind ratio	Aril taste	Mellowness of seeds	Fruit base (shoulders)
					Ground colour	Blush colour									
Bush Large × G-137	1	295.75	80.60	84.17	Yellow Green Group 144 A	Yellow Group 153 D	Round	3.31	Red Group 37 A	692.75	169.25	2.78	Sweet-Sour	Medium-Soft	Absent
	2	184.5	66.29	78.39	Yellow Green Group 144 A	Yellow Group 153 D	Round	2.54	Red Group 41 A	584.00	115.00	2.56	Sweet-Sour	Medium-Soft	Absent
	3	200.13	67.68	70.98	Yellow Green Group 144 A	Yellow Orange Group 17 B	Round	2.08	Red Group 41 A	566.75	128.75	1.75	Sweet-Sour	Hard	Absent
	4	214.38	76.08	75.83	Yellow Green Group 143 B	Yellow Group 153 D	Round	2.05	Red Group 41 A	522.75	138.75	1.95	Sweet-Sour	Hard	Absent
	5	240.38	72.24	74.55	Yellow Green Group 143 B	Yellow Group 153 D	Round	2.24	Red Group 42 C	456.00	160.00	1.76	Sweet-Sour	Medium-Soft	Absent
Mridula × Kandhari Hansi	1	224.75	78.09	79.31	Yellow Green Group 142 A	Yellow Group 144 A	Round	3.12	Red Group 41 A	550.75	166.00	2.88	Sweet-Sour	Medium-Soft	Present
	2	222.38	73.02	78.80	Yellow Green Group 142 A	Yellow Group 144 A	Round	2.55	Red Group 41 A	435.00	169.75	2.35	Sweet-Sour	Medium-Soft	Present
	3	214.50	72.36	84.94	Yellow Green Group 142 A	Yellow Group 144 A	Round	2.28	Red Group 41 A	403.00	152.25	2.08	Sweet-Sour	Medium-Soft	Present
	4	179.25	69.40	85.96	Green Group 38 C	Green Group 52 A	Round	1.88	Red Group 38 A	409.50	129.50	1.85	Sweet-Sour	Medium-Soft	Present
	5	215.50	68.77	77.27	Green Group 38 C	Green Group 52 A	Round	1.72	Red Group 38 A	495.75	164.75	1.56	Sweet-Sour	Medium-Soft	Present
Mridula × Bush Large	1	291.25	84.74	87.33	Yellow Green Group 150 A	Yellow Group 150 C	Round	2.16	Red Group 38 A	574.50	175.00	2.75	Sweet-Sour	Medium-Soft	Present
	2	267.88	79.21	87.75	Yellow Green Group 150 A	Yellow Group 150 C	Round	1.77	Red Group 38 A	470.50	167.25	2.35	Sweet-Sour	Medium-Soft	Present
	3	168.13	69.65	85.54	Yellow Green Group 150 A	Yellow Group 150 C	Round	2.78	Red Group 38 A	477.00	114.50	2.07	Sweet-Sour	Medium-Soft	Present
	4	199.50	70.41	76.13	Yellow Green Group 150 A	Yellow Group 150 C	Round	3.56	Red Group 38 A	517.25	124.50	1.81	Sweet-Sour	Medium-Soft	Present
	5	186.50	68.59	67.03	Yellow Green Group 150 A	Yellow Group 150 C	Round	2.72	Red Group 38 A	531.00	114.00	1.80	Sweet-Sour	Medium-Soft	Present
Dholka × Kandhari Hansi	1	440.75	79.10	94.43	Yellow Green Group 144 B	Red Group 38 A	Round	3.42	Red Group 41 B	700.50	216.00	2.51	Sweet-Sour	Medium-Soft	Absent
	2	327.25	67.44	87.00	Yellow Green Group 144 B	Red Group 38 A	Round	2.57	Red Group 41 B	546.50	182.00	2.43	Sweet-Sour	Medium-Soft	Present
	3	200.88	71.25	83.73	Yellow Green Group 144 B	Red Group 38 A	Round	2.92	Red Group 41 B	543.00	163.75	1.52	Sweet-Sour	Medium-Soft	Present
	4	215.63	71.27	74.84	Yellow Green Group 143 B	Yellow Group 150 C	Round	2.76	Red Group 41 B	601.25	157.50	2.42	Sweet-Sour	Medium-Soft	Slightly Present
	5	314.50	74.62	85.17	Yellow Green Group 143 B	Yellow Group 150 C	Round	3.58	Red Group 42 C	476.00	189.00	1.93	Sweet-Sour	Medium-Soft	Present

Kandhari Hansi × Dholka	1	254.13	75.93	86.22	Yellow Green Group 143 A	Red Yellow 17 B	Round	2.87	Red Group 41 A	519.25	149.25	2.78	Sweet-Sour	Medium-Soft	Present
	2	216.13	70.74	77.07	Yellow Green Group 144 B	Red Yellow 17 B	Round	2.18	Red Group 41 A	522.75	166.25	2.58	Sweet-Sour	Medium-Soft	Present
	3	189.88	68.73	79.52	Yellow Green Group 145 A	Red Yellow 17 B	Round	2.12	Red Group 41 A	401.50	107.00	2.29	Sweet-Sour	Medium-Soft	Present
	4	233.00	68.82	74.10	Yellow Green Group 145 A	Red Yellow 17 B	Round	2.00	Red Group 41 A	495.25	128.00	2.17	Sweet-Sour	Medium-Soft	Present
	5	174.63	68.37	75.17	Yellow Green Group 145 A	Red Yellow 17 B	Round	1.76	Red Group 41 A	393.25	105.25	1.75	Sweet-Sour	Medium-Soft	Present
China Seedling × Kandhari Hansi	1	187.13	67.65	62.65	Yellow Green Group 145 A	Red Group 49 A	Round	3.66	Red Group 38 A	411.75	114.25	3.02	Sour	Hard	Slightly Present
	2	243.13	79.78	91.16	Yellow Green Group 145 A	Red Group 49 A	Round	3.51	Red Group 38 A	533.75	134.00	2.34	Sour	Hard	Slightly Present
	3	260.88	71.62	79.22	Yellow Green Group 145 A	Red Group 49 A	Round	2.90	Red Group 38 A	410.50	160.50	2.60	Sour	Hard	Slightly Present
	4	187.50	65.72	72.12	Yellow Green Group 145 A	Red Yellow Group 43 C	Round	2.75	Red Group 38 A	424.75	123.75	1.99	Sour	Hard	Slightly Present
	5	324.50	84.39	86.80	Yellow Green Group 145 A	Red Yellow Group 43 C	Round	2.56	Red Group 38 A	571.25	178.25	1.60	Sour	Hard	Slightly Present
Kandhari Hansi × China Seedling	1	192.00	63.39	67.57	Green Group 142 A	Green Group 52 A	Elliptical	3.71	Red Group 41 A	300.50	121.50	2.09	Sour	Hard	Absent
	2	164.50	61.27	59.40	Green Group 142 A	Green Group 52 A	Elliptical	3.68	Red Group 41 A	280.75	90.50	1.52	Sour	Hard	Absent
	3	163.50	63.24	68.28	Yellow Green Group 150 B	Green Group 52 A	Elliptical	2.73	Red Group 41 A	301.25	86.25	1.48	Sour	Hard	Absent
	4	189.00	65.74	71.21	Yellow Green Group 150 B	Green Group 52 A	Elliptical	3.73	Red Group 41 A	317.25	109.00	1.53	Sour	Hard	Absent
	5	189.00	62.06	66.43	Green Group 142 A	Green Group 52 A	Elliptical	2.60	Red Group 41 A	329.75	121.25	2.49	Sour	Hard	Absent
Bush Large × Mridula	1	322.25	80.54	81.71	Yellow Green Group 144 C	Yellow Group 153 D	Round	1.71	Red Group 38 A	533.50	185.75	2.00	Sweet-Sour	Medium-Soft	Present
	2	531.50	91.54	98.51	Yellow Green Group 144 C	Yellow Group 153 D	Round	1.65	Red Group 38 A	659.00	269.00	2.65	Sweet-Sour	Medium-Soft	Present
	3	312.25	76.61	80.86	Yellow Green Group 144 C	Yellow Group 153 D	Round	1.60	Red Group 38 A	499.75	190.75	1.73	Sweet-Sour	Medium-Soft	Present
	4	220.00	72.78	80.01	Yellow Green Group 150 B	Yellow Group 153 D	Round	2.75	Red Group 38 A	424.00	139.00	1.49	Sweet-Sour	Medium-Soft	Present
	5	313.25	79.90	82.59	Yellow Green Group 150 B	Yellow Group 153 D	Round	2.50	Red Group 38 A	528.25	182.25	2.97	Sweet-Sour	Medium-Soft	Present
China Seedling × Dholka	1	240.00	73.87	82.94	Yellow Green Group 142 A	Red Group 49 A	Round	3.53	Red Group 38 A	326.75	136.00	2.96	Sour	Hard	Absent
	2	239.75	79.19	86.90	Yellow Green Group 142 A	Red Group 49 A	Round	2.72	Red Group 38 A	300.00	138.00	1.86	Sour	Hard	Absent
	3	154.00	62.97	69.83	Yellow Green Group 142 A	Red Group 49 A	Round	3.16	Red Group 38 A	258.25	92.00	2.02	Sour	Hard	Absent
	4	143.50	64.57	71.52	Yellow Green Group 142 A	Red Group 49 A	Round	2.52	Red Group 38 A	299.25	82.50	2.04	Sour	Medium-Soft	Absent
	5	174.25	55.65	70.26	Yellow Green Group 142 A	Red Group 49 A	Round	3.36	Red Group 38 A	285.75	100.25	1.53	Sour	Medium-Soft	Absent
Kandhari Hansi × Mridula	1	213.63	75.52	84.19	Yellow Green Group 150 C	Yellow Green Group 150 B	Round	3.18	Red Group 37A	397.75	129.75	1.59	Sour	Hard	Present
	2	230.50	74.76	80.44	Yellow Green Group 150 C	Yellow Green Group 150 B	Round	2.70	Red Group 37A	427.75	132.75	2.33	Sour	Hard	Present
	3	169.50	64.85	70.41	Yellow Green Group 150 C	Yellow Green Group 150 B	Round	2.51	Red Group 37A	292.50	92.50	1.77	Sour	Hard	Present
	4	215.25	74.61	79.61	Yellow Green Group 150 C	Yellow Green Group 150 B	Round	1.54	Red Group 37A	399.00	119.00	1.50	Sour	Hard	Present
	5	193.75	69.78	77.48	Yellow Green Group 150 C	Yellow Green Group 150 B	Round	3.37	Red Group 37A	395.75	109.25	1.65	Sour	Hard	Present
Kandhari Hansi × Ganesh	1	281.75	77.02	89.31	Yellow Green Group 150 B	Yellow Group 149 A	Oval	1.73	Red Group 42 C	487.75	146.25	2.37	Sour	Medium-Soft	Slightly Present
	2	384.50	86.54	91.88	Yellow Green Group 150 B	Yellow Group 149 A	Oval	2.26	Red Group 42 C	500.25	190.25	2.07	Sour	Medium-Soft	Slightly Present
	3	291.25	80.71	87.80	Yellow Green Group 150 C	Yellow Group 149 A	Oval	1.61	Red Group 42 C	459.00	156.75	2.12	Sour	Medium-Soft	Slightly Present
	4	327.75	84.98	84.47	Yellow Green Group 150 C	Yellow Group 149 A	Oval	1.46	Red Group 42 C	524.00	177.00	3.05	Sour	Medium-Soft	Slightly Present
	5	273.50	71.88	78.87	Yellow Green Group 150 C	Yellow Group 149 A	Oval	1.49	Red Group 42 C	413.25	141.00	2.34	Sour	Medium-Soft	Slightly Present
Nabha × Jodhpur Red	1	311.00	82.62	89.17	Green Group 143 C	Green Group 52 A	Round	3.34	Red Group 41 A	561.00	179.25	1.70	Sour	Hard	Absent
	2	259.50	74.50	82.15	Green Group 143 C	Green Group 52 A	Round	3.53	Red Group 41 A	440.25	141.50	2.14	Sour	Hard	Absent
	3	177.00	64.39	68.89	Green Group 143 C	Green Group 52 A	Round	2.71	Red Group 41 A	316.25	87.00	2.47	Sour	Hard	Absent
	4	165.25	62.33	70.22	Green Group 143 C	Green Group 52 A	Round	2.44	Red Group 41 A	306.25	93.25	1.43	Sour	Hard	Absent
	5	236.25	74.58	77.12	Green Group 143 C	Green Group 52 A	Round	3.43	Red Group 41 A	477.50	160.75	2.50	Sour	Hard	Absent
Mean		239.23	72.58	79.22				2.63		454.66	142.73	2.13			
CD _{0.05}		4.13	2.73	3.46				0.56		11.18	4.02	0.58			

Chemical characteristics

Data on total soluble solids content showed significant variation among the pomegranate hybrids (Table 2). The mean data revealed that TSS was maximum (15.97 °Brix) in Plant No.1 of Dholka × Kandhari Hansi which was statistically at par with Plant No.2 and 3 of the same hybrid, Plant No.5 of Kandhari Hansi × China Seedling, Plant No.2 of Bush Large × Mridula and Plant No.5 of Kandhari Hansi × Mridula and lowest (9.22 °Brix) in Plant No.5 of China Seedling × Dholka. The total soluble solids content in different varieties varied between (12.00 to 14.00 °Brix) with the highest (14.00 °Brix) in Moga-Local followed by (13.80 °Brix) in PS-77 and G-137 and (13.40 °Brix) in P-16 and the lowest (12.00 °Brix) in Panipat Selection and Co-1 (Sharma and Dhillon, 2002) [31]. Similar results were obtained by Gozlekci and Kaynak (2000) [10] in pomegranates. Prasad and Banker (2000) [28] reported that the TSS in the juice of different cultivars of pomegranate ranged from (16.20 °Brix) in Jodhpur Red to (18.80 °Brix) in Bassein Seedless under the arid climate of Jodhpur. Higher TSS content in a genotype is considered a good character while exercising selection for the table as well as processing purposes. The present findings are also in agreement with those obtained by Fadavi *et al.* (2005) [9]; Singh (2012) [37]; Hamouda *et al.* (2014) [11] and Hassan *et al.* (2012) [13].

It is evident from the data that great variability occurs among the different F₁ hybrids of pomegranate (Table 2). The Highest acid content (2.50%) was recorded in (Plant No.1) of Bush Large × Mridula which was statistically at par with Plant No.1 and 2 of Mridula × Bush Large, Plant No.4 and 5

of China Seedling × Mridula and Plant No.1 of Kandhari Hansi × Ganesh and lowest acidity value (0.67) was observed in hybrid Mridula × Kandhari Hansi (Plant No.5). The overall average of acid content was recorded (1.66%) among all the hybrids under study. Sharma and Dhillon (2002) [31] reported that acid content ranged from 0.44 to 0.62 per cent in different cultivars which were highest in Panipat Selection and lowest in G-137 and Bassein Seedless. (Fadavi *et al.* 2005; Singh 2012; Hamouda *et al.* 2014) [9, 37, 11] have reported considerable variation in the titratable acidity of different cultivars. Shulman *et al.* (1984) [34] reported that the acid content of pomegranate fruit is influenced by the harvesting stage and prevailing temperature at the time of fruit maturity. The total sugar content was found to be varied from 6.39 per cent in Nabha × Jodhpur Red (Plant No.4) to 12.68 per cent in Bush Large × Mridula (Plant No.1) (Table 2). The total sugar content of different pomegranate cultivars has been found to vary from 9.77 to 13.15 per cent under Rahuri conditions Meena *et al.* (2003) [22] reported total sugars of pomegranate accessions ranging between 9.24 per cent and 13.80 per cent. Sinha (2014) [38] also reported that total sugar content ranged from 7.55 per cent in Oবাদan to 14.13 per cent in Purple Heart. Reducing sugars for different pomegranate hybrids under the present stud ranged from 4.31 per cent in China Seedling × Dholka (Plant No.3) to 10.54 per cent in Bush Large × Mridula (Plant No.1) which was statistically at par with (Plant No. 4) of Kandhari Hansi × Mridula and (Plant No.5) of Kandhari Hansi × Ganesh. Chundawat (1995) [8] reported reducing the sugar content of different pomegranate cultivars to ranging from 7.80 per cent to 13.70 per cent.

Table 2: Biochemical characteristics and time of maturity of fruits of different F₁ hybrids of pomegranate

Hybrids	Plant No.	TSS (°Brix)	Acidity (%)	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)	TSS: Acidity ratio
Bush Large × G-137	1	14.59	2.50	11.42	9.60	1.73	5.87
	2	13.65	1.70	10.61	9.29	1.26	8.10
	3	12.34	1.62	10.16	8.29	1.78	7.64
	4	12.42	1.52	9.69	7.47	2.11	8.45
	5	11.65	1.41	9.24	7.67	1.50	8.26
Mridula × Kandhari Hansi	1	13.47	1.66	11.22	9.81	1.35	8.16
	2	13.18	1.49	10.66	8.35	2.19	8.97
	3	12.22	1.47	9.47	8.00	1.40	8.42
	4	11.66	1.47	9.50	7.86	1.55	7.98
	5	11.70	0.67	9.49	7.65	1.75	17.58
Mridula × Bush Large	1	14.96	2.31	10.57	9.36	1.14	6.51
	2	13.65	2.44	10.17	9.08	1.04	5.63
	3	13.19	1.29	11.68	9.39	2.18	10.33
	4	13.60	1.28	10.34	8.72	1.54	10.78
	5	12.61	1.40	10.41	8.17	2.12	9.12
Dholka × Kandhari Hansi	1	15.97	2.07	10.34	8.74	1.52	7.74
	2	15.61	2.03	10.84	8.58	2.15	7.72
	3	15.81	1.80	9.44	7.73	1.62	8.81
	4	13.71	1.38	9.24	7.63	1.53	8.81
	5	14.10	1.44	9.37	7.62	1.67	9.94
Kandhari Hansi × Dholka	1	9.55	2.15	7.37	5.37	1.91	4.45
	2	9.30	2.07	6.79	5.24	1.47	4.52
	3	10.67	1.29	7.51	5.22	2.18	8.35
	4	9.89	1.82	6.50	4.68	1.73	5.49
	5	9.23	1.55	6.70	4.98	1.64	6.02
China Seedling × Kandhari Hansi	1	12.36	2.08	8.92	6.71	2.10	5.98
	2	11.23	1.83	8.45	6.57	1.79	6.19
	3	9.53	1.15	7.36	5.47	1.80	8.31
	4	10.85	2.25	8.32	7.18	1.08	4.83
	5	11.36	1.11	8.64	6.98	1.58	10.22
Kandhari Hansi × China Seedling	1	14.89	2.14	9.47	7.79	1.59	7.64
	2	13.60	1.07	10.32	8.61	1.63	12.85

	3	12.53	1.50	9.44	7.38	1.96	8.35
	4	14.95	1.68	10.46	8.61	1.76	8.95
	5	15.31	2.18	10.71	8.18	2.41	7.05
Bush Large × Mridula	1	14.77	0.75	12.68	10.54	2.04	19.77
	2	15.81	1.61	10.70	8.25	2.33	9.83
	3	15.17	0.95	11.37	9.53	1.75	16.08
	4	14.93	2.32	10.51	8.79	1.63	6.46
	5	14.03	2.41	10.53	8.33	2.09	5.84
China Seedling × Dholka	1	10.52	1.78	7.44	6.13	1.24	6.04
	2	10.61	2.15	6.46	5.06	1.32	4.98
	3	9.56	2.01	6.72	4.31	2.29	4.77
	4	10.11	1.97	7.49	5.53	1.86	5.20
	5	9.22	0.81	6.67	5.13	1.46	11.73
Kandhari Hansi × Mridula	1	14.75	1.65	11.46	9.60	1.77	9.00
	2	14.83	2.00	11.27	8.74	2.41	7.45
	3	14.04	1.88	10.79	8.50	2.18	7.49
	4	15.06	2.11	11.55	10.29	1.20	7.32
	5	15.20	0.84	10.30	8.32	1.89	18.11
Kandhari Hansi × Ganesh	1	12.81	2.42	10.11	8.72	1.32	5.41
	2	14.33	1.93	9.33	7.65	1.60	7.42
	3	13.46	1.91	10.57	8.30	2.16	7.05
	4	11.84	0.88	10.74	8.59	2.04	13.54
	5	15.18	0.95	12.20	10.47	1.65	16.04
Nabha × Jodhpur Red	1	10.12	2.16	7.32	6.64	0.65	4.70
	2	10.72	2.14	7.79	5.62	2.06	5.01
	3	9.27	0.93	8.40	5.57	2.69	9.98
	4	11.12	1.44	6.39	4.78	1.53	7.74
	5	9.37	0.92	7.29	5.51	1.69	10.15
Mean		12.70	1.66	9.45	7.61	1.74	8.52
CD _{0.05}		0.77	0.24	0.35	0.44	0.31	1.41

Poyrazoglu *et al.* (2002) ^[29] reported the reducing sugars in the juice of 13 pomegranate varieties in the range of 12.50 g/100ml to 16.02 g/100 ml. Wani *et al.* (2012) ^[41] reported reduced sugars per cent in some promising selections of wild pomegranate in Central Kashmir ranging from 6.00 per cent to 10.12 per cent. Non-reducing sugars were recorded to be maximum (2.69%) in Nabha × Jodhpur Red (Plant No.3) which was statistically at par with Plant No.5 of Kandhari Hansi × China Seedling and Plant No.2 of Kandhari Hansi × Mridula and minimum (0.65%) in Nabha × Jodhpur Red (Plant No.1). Similar results were recorded by Sinha (2014) ^[38] in a study conducted on 20 pomegranate accessions. Non-reducing sugars were maximum (2.34%) in Saharnyi and minimum (1.04%) in Haku-Botan.

TSS/acid ratio serves as an index of sweetness in different pomegranate cultivars. A higher TSS/acid ratio indicates that the cultivars are sweet as compared to those having a lower TSS/acidity ratio. The total soluble solids to acid ratio in different pomegranate hybrids in the present study varied from (4.45) to (19.77) (Table 2). Bush Large × Mridula (Plant No.1) recorded the maximum TSS/acidity ratio and minimum in Kandhari Hansi × Dholka (Plant No.1). Similar variations for TSS/acid ratio have also been reported by Mir *et al.* (2007) ^[21]; Tehranifar *et al.* (2010) ^[40]; Wani *et al.* (2012) ^[41]; Zaouay *et al.* (2012) ^[43]; Hamouda *et al.* (2014) ^[11] in different sets of cultivars. TSS/acidity ratio varied from 5.66 in Ovadan to 23.30 in Cloud Sinha (2014) ^[38].

Conclusion

The present investigation can be concluded that these F₁ hybrids do not possess all the desirable characteristics. However, Plant No.1 and 2 of Bush Large × Mridula showed maximum desirable traits. These two plants need further evaluation to study the breeding behaviour and the stability of the traits.

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