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Full Length Research Paper

Screening of various pomegranate (*Punica granatum* L.) selections of Kashmir valley

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The present investigation was carried out in order to document the available genetic variability of several morphological quantitative and qualitative characters, and to select elite pomegranate genotypes which have superior yield and quality traits. Intensive survey was conducted in different areas of district Srinagar between 2009 and 2010. Observations were recorded on morphological, physical and chemical characters, as per the standard procedure. Sizeable variability among the genotypes for different traits was observed. Plant height ranged from 2.34 to 4.78 m, plant spread was 1.24 to 2.47 m, suckering capacity was 4 to 42, yield per tree was 7.2 to 59.02 kg, yield efficiency was 0.20 to 2.21 kg cm^{-2}, fruit length was 5.90 to 9.24 cm, fruit diameter was 6.54 to 9.84 cm, fruit weight was 133.80 to 463.75 g, total aril weight was 62 to 250 g, rind thickness was 1.81 to 3.64 mm, total soluble solids (TSS) was 11.50 to 16.00%, juice content was 25.59 to 62.37%, acidity was 0.30 to 0.57 %, ascorbic acid was 7.96 to 20.68 mg/100 g fruit, reducing sugar was 6.00 to 10.12%, total sugar was 7.24 to 12.92% and anthocyanin content was 9.14 to 19.30 mg/100 g fruit. This variability can act as a source for further improvement and development of high yielding varieties of pomegranate which suits the Kashmir condition.

Key words: Pomegranate, survey, selection, genotypes, variability.

INTRODUCTION

Pomegranate (*Punica granatum* L.) is an important commercial fruit crop that is extensively cultivated in parts of Asia, North Africa, the Mediterranean and the Middle East (Sarkhosh et al., 2006). Iran is one of the most important pomegranate producers and exporters in the world, and its total production in 2005 was 670,000 tons (Anonymous, 2005). In its centre of origin, pomegranate is encountered as wild types and cultivated varieties/ accessions (Al-Said et al., 2009; Narzary et al., 2009). However, in Mediterranean basin, only cultivated varieties have been reported (Martinez et al., 2006; Jbir et al., 2008; Durgac et al., 2008). Different parts of this tree (leaves, fruits and bark skin) have traditionally been used for medicinal and other properties (Rania et al., 2007). These beneficial effects may be related to its high antioxidant activity resulting from the presence of a variety of biologically active compounds (Aviram, 2002; Halvorsen et al., 2002). The edible part of the fruit contains considerable amount of acids, sugar, vitamins, polysaccharides, polyphenols and minerals (Gil et al., 2001 and Kulkarni et al., 2004). The composition of pomegranate fruit is strongly dependent on the cultivar type, growing region, climate, maturity and cultural practice (Heshi et al., 2001; Ozkan, 2002). In addition, various reports have shown significant variations in organic acids, phenolic compounds, sugars and water-soluble vitamins composition of pomegranates during the years (Kulkarni and Aradhya, 2005; Ozgen et al., 2008; Tezcan et al., 2009). These parameters may supply important information to the consumer in terms of

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recognizing a more nutritional fruit. In India, pomegranate grows wild in Western Himalayan regions that include states like Himachal Pradesh, Jammu and Kashmir and Uttarakhand (Pandey et al., 2008). In spite of various pomegranate cultivars grown in different regions of India, there is no known cultivar for Kashmir conditions. Studies to determine whether wide variability exists in the antioxidant activity and other physical and chemical properties among different pomegranate cultivars allow the fruit breeders to select and breed genotypes with higher level of antioxidants. The present investigation was aimed to study variation within vegetative and physico-chemical attributes of pomegranate of district Srinagar in Jammu and Kashmir, India.

MATERIALS AND METHODS

Survey of pomegranate trees was conducted in Srinagar districts of Kashmir valley between 2009 and 2010. Seventeen bearing trees of pomegranate were selected across the district and individual trees was assigned separate accession number. Every accession was evaluated for different morphological parameters of tree as per the standard procedures.

Physical analysis

Height of each plant was measured from the ground level to the top of the main branch or leader with the help of measuring tape and expressed in metres, whereas plant spread was measured in terms of the extent of the canopy in two different directions, that is, N-S and E-W, and means of two sides was expressed in metres. Yield efficiency of tree was calculated as per the formula suggested by Westwood and Robert (1970) and expressed in kg cm^{-2}. Twenty fruits of each cultivar were individually analyzed for physical characteristics. Fruits were weighed in the air on a balance of accuracy of 0.001 g. Fruit volume was calculated by a liquid displacement method. The length and diameter of the fruit was measured with a digital vernier caliper. The measurement of fruit length was made on the polar axis, that is, between the apex and the end of stem. The maximum width of the fruit, as measured in the direction perpendicular to the polar axis, is defined as the diameter. After measuring the whole fruit size, the arils were manually separated from the fruits, and total arils and peel per fruit were measured as afore described. The measurements of the peel thickness were made using the digital vernier caliper.

Chemical analysis

The total soluble solids (TSS) were estimated in terms of °Brix by using Atago hand refractometer and expressed °Brix values were corrected at 20°C with the help of temperature coefficient chart (A.O.A.C, 1998). Vitamin C, reducing sugar, total sugars and anthocyanin content were determined by following the methods of Ranganna (2001). The acidity was determined by titrating the known volume of juice with 0.1 N NaOH, using phenolphthalein as indicator (A.O.A.C, 1998). Sensory evaluation were carried by panel of 10 semi-trained judges for general appearance, fruit shape, fruit rind colour, fruit size and aril colour by using pomegranate descriptor and the attributes were rated on a 4-point scale (Table 1) and was analyzed in R-software as suggested by Gomez and Gomez (1985).

RESULTS AND DISCUSSION

The data revealed that accessions showed significant variations in most of the vegetative characters (Table 2). Plant height ranged from 2.34 m in accession SKAU-Pg-Sr-001 to 4.78 m in accession SKAU-Pg-Sr-012 with mean of 3.54 m and coefficient of variation of 23.73. Plant spread was maximum in accession SKAU-Pg-Sr-005 (2.47 m) and minimum in accession SKAU-Pg-Sr-010 (1.24 m) with coefficient of variation of 23.35. Suckering capacity showed coefficient variation of 55.40, while as number of fruits per plant showed coefficient variation of 42.98. Yield was highest in accession SKAU-Pg-Sr-012 (59.02 kg) followed by accession SKAU-Pg-Sr-004 (56.75 kg) with coefficient of variation of 49.42. Yield efficiency showed coefficient of variation of 69.66 with average efficiency of 0.89 kg cm^{-2}. Highest leaf area was recorded in accession SKAU-Pg-Sr-002 (12.60 cm^2) while lowest in accession SKAU-Pg-Sr-011 (7.48 cm^2). Similar type of variation in plant height, plant spread, yield, and leaf area has been reported in pomegranate (Sharma and Bist, 2005). These variations may also be contributed by genetic makeup of accessions and agro-climatic conditions (altitude, nutritional status of soil, cultural practices and environment).

It is evident from Table 3 that fruit length was maximum at 9.24 cm (SKAU-Pg-Sr-001) and minimum at 5.90 cm (SKAU-Pg-Sr-013). Fruit diameter showed coefficient of variation of 11.57 whereas fruit weight showed coefficient of variation of 37.37. Fruit volume ranged from 146.50 to 401.99 cm^3 with a mean value of 247.70 cm^3 and coefficient of variation of 38.72. Total aril weight exhibited a coefficient of variation of 37.05 while aril number exhibited coefficient of variation of 29.82. Maximum weight per aril was recorded in accession SKAU-Pg-Sr-001 (0.33 g) and minimum in accession SKAU-Pg-Sr-013 (0.22 g). Rind thickness varied from 1.81 mm (SKAU-Pg-Sr-015) to 3.64 mm (SKAU-Pg-Sr-008) whereas rind weight varied from 60 g (SKAU-Pg-Sr-006) to 217.75 g (SKAU-Pg-Sr-001). Rind proportion was highest in accession SKAU-Pg-Sr-013 (56.05%) and lowest in accession SKAU-Pg-Sr-012 (32.60%). According to the current study, the aril percentage was inversely correlated to skin percentage. Fruit weight of pomegranate cultivars was found between 150 and 568 g (Al-Maiman and Ahmad, 2002; Kazankay et al., 2003; Ozkan, 2005). Cracking ranged from 6.31% (SKAU-Pg-Sr-017) to 31.40% (SKAU-Pg-Sr-004) with mean of 15.14% and coefficient of variation of 56.34, whereas anar butterfly incidence ranged from 9.52% (SKAU-Pg-Sr-017) to 38.62% (SKAU-Pg-Sr-013) with mean of 20.91% and coefficient of variation of 34.67 (Figure 1). Fruit length, fruit diameter and fruit volume recorded in pomegranate support our findings (Kazankaya et al., 2003). Similar type of variation for fruit length, fruit diameter, fruit weight, fruit volume, total aril weight, number of arils per fruit, weight per aril, rind thickness,

Table 1. Four point scale.

General appearance	Fruit shape	Rind colour	Fruit size	Arial colour	Points
Very attractive	Round	Primrose rose	Extra-large (>750 g)	Red	4
Attractive	Round oblong	Scarlet	Large (500-750 g)	Pink	3
Less attractive	Round flat	Scarlet with tinges	Medium (250-500 g)	Pinkish white	2
Least attractive	Elliptic	Lemon yellow	small (<250 g)	White	1

Table 2. Plant characteristics of various pomegranate genotypes.

Accession No.	Plant height (m)	Plant spread (m)	Suckering capacity	No. of fruits per tree	Yield/ tree (kg)	Yield efficiency (kg/cm^2)	Leaf area (cm^2)
SKAU-Pg-Sr -001	2.34	2.20	26	100	40.00	0.56	10.88
SKAU-Pg-Sr-002	2.74	1.28	4	90	13.04	0.73	10.86
SKAU-Pg-Sr-003	4.20	2.05	23	100	18.6	0.30	8.14
SKAU-Pg-Sr-004	4.76	1.92	37	200	56.75	1.90	8.62
SKAU-Pg-Sr-005	3.92	2.47	28	192	41.66	0.75	9.84
SKAU-Pg-Sr-006	2.64	1.61	20	184	28.34	0.58	12.60
SKAU-Pg-Sr-007	2.73	1.27	16	47	10.00	0.20	8.96
SKAU-Pg-Sr-008	3.86	1.28	10	209	36.00	0.50	10.84
SKAU-Pg-Sr-009	2.78	1.32	18	105	23.00	1.00	9.98
SKAU-Pg-Sr-010	2.47	1.24	6	60	7.20	0.39	11.22
SKAU-Pg-Sr-011	4.16	1.82	33	175	39.02	0.72	7.48
SKAU-Pg-Sr-012	4.78	1.80	42	215	59.02	2.18	9.76
SKAU-Pg-Sr-013	3.26	1.50	4	60	15.36	0.37	8.62
SKAU-Pg-Sr-014	3.94	2.14	23	225	55.35	0.88	9.48
SKAU-Pg-Sr-015	3.24	1.40	14	209	48.95	1.92	10.32
SKAU-Pg-Sr-016	3.56	1.33	22	126	53.07	2.21	11.56
SKAU-Pg-Sr-017	4.76	1.85	14	203	41.00	1.97	12.28
Mean	3.54	1.67	20.0	136.10	31.69	0.89	10.09
±SE	0.20	0.09	2.69	14.20	3.80	0.15	0.35
Range	2.34-4.78	1.24-2.47	4.00-42.00	47.00-225.00	7.20-59.02	0.20-2.21	7.48-12.60
CV (%)	23.73	23.35	55.40	42.98	49.42	69.66	14.27

rind weight and rind proportion was recorded in pomegranate (Mir et al., 2007). It was previously reported that the fruit weight, fruit length, fruit diameter, calyx length and calyx diameter of pomegranate fruits grown in Iran are between 164.89 and 375.76 g; 64 to 137.4 mm; 68 to 86.9 mm; 16.7 to 29.9 mm and 13.9 to 25 mm (Sarkhosh et al., 2009). The wide variation of the attack may be due to different genetic make-up and their resistance against the cracking and anar butter fly attack which may be due to variation in rind thickness. Cracking may be attributed to weather conditions during fruit development, particularly prevalence of high temperature and moisture stress condition of soil (Singh et al., 2003). Similar cracking reported in Jodhpur Red, supports our findings (Mali and Prasad 1999, Singh 2004). The difference in anar butterfly incidence of the genotypes might be due to different biological behaviour of the cultivar and their inherent capacity to tolerate the incidence. More rind thickness of genotype may be one of the causes of resistance against anar butterfly incidence. Similar results for anar butterfly incidence in Kashmir valley were reported, which supports our results (Tirathsing et al., 1992).

The data in Table 4 revealed that accessions exhibited significant variation for their chemical attributes. TSS varied from 11.50% (SKAU-Pg-Sr-013) to 16% (SKAU-Pg-Sr-005) with mean of 14.30% and coefficient of variation of 10.07 (Figure 2). Our results were in agreement with values of 10 to 16.5 °Brix (Fadavi et al., 2005). Maximum juice content of 62.37% was recorded in accession SKAU-Pg-Sr-017 followed by accession SKAU-Pg-Sr-015 (56.85%) with mean of 41.97 (Figure 2). The results of juice content reports correspond to those reported earlier (Prasad et al., 2000). Acidity varied from 0.30% (SKAU-Pg-Sr-017) to 0.57% (SKAU-Pg-Sr-013) with coefficient of variation of 15.90.

Table 3. Fruit physical characteristics of various pomegranate genotypes.

Accession No.	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Fruit volume (cm^3)	Total aril weight (g)	No. of arils per fruit	Weight per aril (g)	Rind thickness (mm)	Rind weight (g)	Rind proportion (%)
SKAU-Pg-Sr -001	9.24	9.51	463.75	450.47	250.00	736.00	0.33	3.55	217.75	46.09
SKAU-Pg-Sr-002	6.22	6.54	144.75	146.50	62.25	260.00	0.25	2.69	75.25	51.99
SKAU-Pg-Sr-003	6.63	7.14	185.75	190.64	109.25	392.00	0.27	2.38	76.50	41.18
SKAU-Pg-Sr-004	7.52	8.12	283.75	280.41	153.75	465.00	0.33	3.34	130.00	45.81
SKAU-Pg-Sr-005	6.79	7.92	217.50	260.19	137.00	424.00	0.32	2.63	80.50	37.01
SKAU-Pg-Sr-006	6.20	6.65	154.25	154.02	94.25	365.00	0.26	2.84	60.00	38.89
SKAU-Pg-Sr-007	7.27	7.71	233.75	240.04	128.00	452.00	0.28	2.20	105.75	45.24
SKAU-Pg-Sr-008	6.24	6.98	172.50	170.11	104.00	323.00	0.32	3.64	68.50	39.71
SKAU-Pg-Sr-009	6.78	7.45	219.00	224.51	128.50	470.00	0.27	3.22	90.50	41.32
SKAU-Pg-Sr-010	6.24	7.20	133.75	195.49	62.00	245.00	0.25	2.56	71.75	53.64
SKAU-Pg-Sr-011	7.13	7.70	223.75	239.11	135.25	484.00	0.28	3.01	91.00	40.67
SKAU-Pg-Sr-012	7.58	8.29	274.50	298.39	185.00	601.00	0.30	2.55	89.50	32.60
SKAU-Pg-Sr-013	5.90	7.25	256.00	199.59	110.00	505.00	0.22	2.53	143.50	56.05
SKAU-Pg-Sr-014	7.56	7.80	246.25	248.55	143.00	547.00	0.26	2.35	103.25	41.92
SKAU-Pg-Sr-015	7.31	7.66	234.25	235.40	139.50	485.00	0.29	1.81	94.75	40.44
SKAU-Pg-Sr-016	9.21	9.84	421.25	499.01	227.50	748.00	0.30	3.00	193.75	45.99
SKAU-Pg-Sr-017	6.52	6.98	180.00	178.11	115.25	433.00	0.27	2.09	64.75	37.59
Mean	7.08	7.69	237.90	247.70	134.40	466.80	0.28	2.73	103.40	43.30
±SE	0.24	0.22	21.60	23.30	12.10	33.80	0.01	0.12	10.80	1.50
Range	5.90-9.24	6.54-9.84	133.75-463.75	146.50-499.01	62.00-250.00	245.00-748.00	0.22-0.33	1.81-3.64	60-217.75	32.6-56.05
CV (%)	13.7	11.57	37.37	38.72	37.05	29.82	10.71	18.68	43.13	14.32

Highest TSS/acid ratio of 53.34 was recorded in accession SKAU-Pg-Sr-017. Similar results have also been reported by Fadavi et al. (2005). As shown in Table 4, a great variation in terms of ascorbic acid content was observed among the pomegranate accessions with coefficient of variation of 25.51. Reducing sugars ranged from 6% (SKAU-Pg-Sr-013) to 10.12% (SKAU-Pg-Sr-007) while non-reducing sugars ranged from 0.66% (SKAU-Pg-Sr-004) to 3.06% (SKAU-Pg-Sr-017). Total sugar content was highest in accession SKAU-Pg-Sr-012 (12.92%) and lowest in accession SKAU-Pg-Sr-013 (7.24%) with mean of 9.58% and coefficient of variation of 14.40. Anthocyanin content varied from 9.14 mg/100 g fruit (SKAU-Pg-Sr-016) to 19.30 mg/100 g (SKAU-Pg-Sr-017) with mean of 13.36 mg/100 g fruit and coefficient of variation of 25.75 (Figure 2). Similar variation in ascorbic acid, reducing and total sugar was reported by Akbarpaur et al. (2009). Similar findings have been published for pomegranate of different cultivars (Mir et al., 2007). The extent and type of variation in vegetative plant and physico-chemical fruit characters is primarily due to genetic diffe-rence in the trees, which in the wild stand may have arisen as a result of influence of different evolutionary factors. These variations may also be contributed by agro-climatic conditions, altitude, and nutritional status of soil, cultural practices and environment. The evaluation suggests that superior strains hold promise for future cultivation of new high yielding varieties. Hence, there is an urgent need to collect and preserve these valuable wild forms which can act as a source for further improvement of pomegranate.

Scoring index of pomegranate accessions for general appearance, fruit shape, fruit rind colour, fruit size and aril colour of fruits are presented in

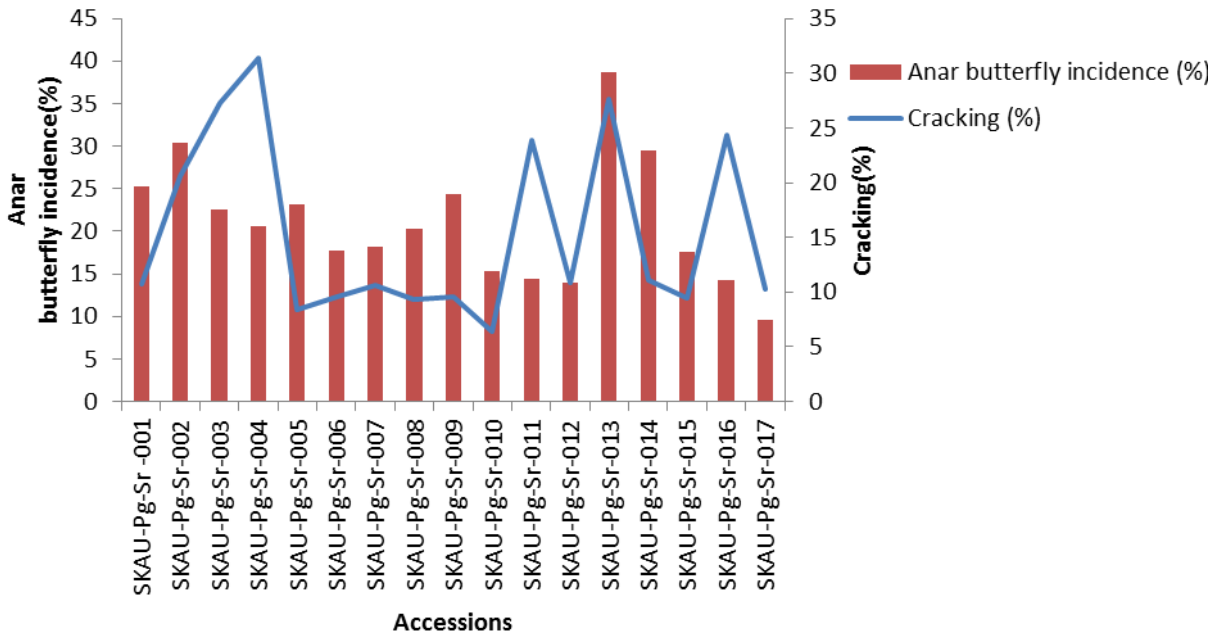

Figure 1. Anar butterfly incidence and cracking of various accessiona of pomegranate.

Table 4. Fruit chemical characteristics of various pomegranate genotypes.

Accession No.	Acidity (%)	TSS/acid ratio	Ascorbic acid (mg/100 g fruit)	Reducing sugar (%)	Total sugar (%)	Non-reducing sugars (%)
SKAU-Pg-Sr -001	0.48	32.81	13.40	8.40	9.25	0.85
SKAU-Pg-Sr-002	0.52	25.00	15.26	8.12	9.52	1.40
SKAU-Pg-Sr-003	0.38	41.76	13.74	9.23	10.57	1.34
SKAU-Pg-Sr-004	0.45	29.45	17.21	8.76	9.42	0.66
SKAU-Pg-Sr-005	0.37	43.24	17.96	9.27	10.82	1.55
SKAU-Pg-Sr-006	0.41	33.83	16.21	7.29	8.23	0.94
SKAU-Pg-Sr-007	0.39	40.05	9.18	10.12	11.32	1.20
SKAU-Pg-Sr-008	0.49	27.80	18.28	7.96	8.82	0.86
SKAU-Pg-Sr-009	0.43	32.84	16.64	8.21	9.54	1.33
SKAU-Pg-Sr-010	0.46	27.32	10.20	6.20	7.69	1.44
SKAU-Pg-Sr-011	0.48	27.60	18.86	7.56	8.98	1.42
SKAU-Pg-Sr-012	0.55	26.12	13.80	8.41	9.12	0.71
SKAU-Pg-Sr-013	0.57	20.17	7.96	6.00	7.24	1.24
SKAU-Pg-Sr-014	0.41	31.09	17.32	7.29	8.96	1.67
SKAU-Pg-Sr-015	0.36	44.08	14.98	8.27	9.82	1.55
SKAU-Pg-Sr-016	0.39	39.74	18.30	9.29	10.67	1.38
SKAU-Pg-Sr-017	0.30	53.34	20.68	9.86	12.92	3.06
Mean	0.44	33.90	14.70	8.26	9.58	1.33
±SE	0.02	2.08	0.91	0.28	0.34	0.132
Range	0.3-0.57	20.17-53.34	7.96-20.68	6-10.12	7.24-12.92	0.66-3.06
CV (%)	15.9	25.34	25.51	13.92	14.4	40.6

Table 5. It is evident that scoring index for general appearance ranged from 1.14 points (SKAU-Pg-Sr-002) to 4.00 points (SKAU-Pg-Sr-001), whereas for fruit shape, scoring points ranged from 2.00 points (SKAU-Pg-Sr-002) to 3.70 points (SKAU-Pg- Sr-011) with mean of 2.80 points and coefficient of variation of 17.50. As far as fruit rind colour is concerned, highest scoring index was observed in accession SKAU-Pg-Sr-014 (3.52) and lowest

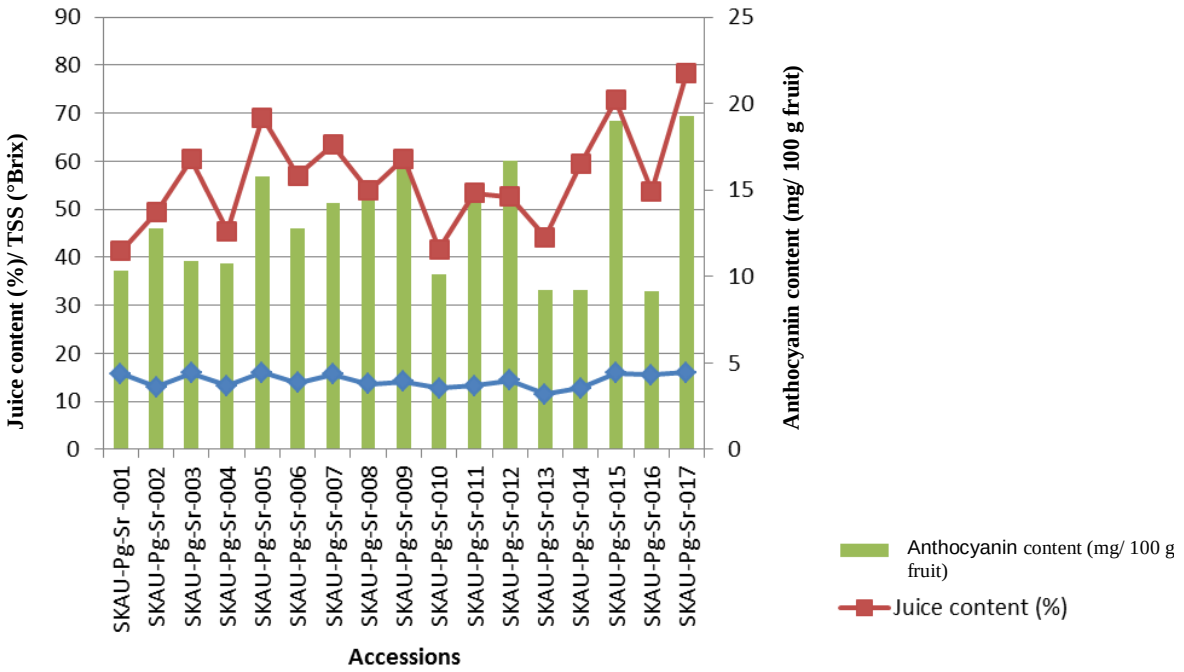

Figure 2. Variation in anthocyanin content, juice content and TSS of different accesssions of pomegranate.

Table 5. Sensory characteristics of pomegranate genotypes.

Accession No.	General appearance	Fruit shape	Fruit rind colour	Fruit size	Aril colour	Aril texture
SKAU-Pg-Sr -001	4.00	3.00	3.48	3.50	2.65	Hard
SKAU-Pg-Sr-002	1.14	3.00	1.28	1.00	3.50	Hard
SKAU-Pg-Sr-003	1.75	2.80	1.14	1.00	3.50	Hard
SKAU-Pg-Sr-004	3.00	3.14	2.43	2.36	3.42	Hard
SKAU-Pg-Sr-005	2.20	3.50	2.40	1.80	2.50	Semi-soft
SKAU-Pg-Sr-006	3.26	2.87	2.00	1.00	3.50	Hard
SKAU-Pg-Sr-007	2.00	2.20	2.60	1.00	3.00	Hard
SKAU-Pg-Sr-008	1.57	2.00	2.29	1.00	2.00	Hard
SKAU-Pg-Sr-009	2.00	2.72	2.00	1.00	4.00	Hard
SKAU-Pg-Sr-010	1.67	2.42	2.36	1.00	2.25	Hard
SKAU-Pg-Sr-011	2.70	3.70	2.57	1.00	3.00	Hard
SKAU-Pg-Sr-012	3.00	2.75	2.00	2.38	4.00	Hard
SKAU-Pg-Sr-013	2.00	2.26	1.00	2.00	2.00	Hard
SKAU-Pg-Sr-014	3.57	3.29	3.52	1.00	1.50	Hard
SKAU-Pg-Sr-015	3.47	2.00	3.00	1.00	4.00	Semi-soft
SKAU-Pg-Sr-016	3.75	3.00	3.00	2.68	2.27	Hard
SKAU-Pg-Sr-017	3.06	3.00	3.00	1.00	4.00	Soft
Mean	2.64	2.80	2.36	1.51	2.99	
±SE	0.22	0.12	0.18	0.19	0.20	
Range	1.14-4.00	2.00-3.70	1.00-3.52	1.00-3.50	1.50-4.00	
CV (%)	2.21	2.57	2	1.13	2.59	

in accession SKAU-Pg-Sr- 015 (1.00) with mean of 2.36 points and coefficient of variation of 31.36. For fruit size, scoring index in Srinagar was highest in accession SKAU-Pg-Sr-001 (3.50)followed by accession SKAU-Pg-Sr-16 (2.68) with mean of 1.51 and coefficient of variation of 52.32. For aril colour, scoring index in Srinagar ranged from 1.50 points (SKAU-Pg-Sr-014) to 4.00 points (SKAU-Pg-Sr-009, SKAU-Pg- Sr-012, SKAU-Pg-Sr-015

and SKAU-Pg-Sr-017) with mean of 2.99 points and coefficients of variations of 27.76. Aril texture was soft in accession SKAU-Pg-Sr-017, semi-soft in accessions SKAU-Pg-Sr-005 and SKAU-Pg-Sr-015, whereas the rest accessions were hard seeded. The high coefficient of variation for general appearance, fruit shape, fruit rind colour, fruit size and aril colour may be due to different genetic make-up of the plants and also affected by agroclimatic conditions. Similar findings have been published for pomegranate of different cultivars (Mir et al., 2007). On the basis of yield and quality, several accessions have been selected which are SKAU-Pg-Sr-012, SKAU-Pg-Sr-015 and SKAU-Pg-Sr-017. The evaluation suggests that the superior strains hold promise for future cultivation of new high yielding varieties and as a short term measure, these accessions can be used as mother plant for mass clonal multiplication of plant with better yield efficiency and quality.

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