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Physico-chemical and nutritional characteristics of main pomegranate (*Punica granatum* L.) cultivars grown in Deccan Plateau of India

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Summary. – A comparative study of physico-chemical and nutritional characteristics of main pomegranate cultivars (Bhagawa, Ganesh, Arakta and Mridula) widely grown in India was conducted. Cultivar 'Ganesh' produced the biggest fruit (average fruit weight 280.42 g) followed by Bhagawa, Mridula and Arakta. However, fruits of Bhagawa appeared to be attractive red in colour than 'Ganesh' and had bold arils. Its arils exhibited good flavour with high acidity (0.50%) and were also rich in micronutrients (Fe, Mn and Zn). Arakta was characterized by a high phenol (177 mg GAE/100 mL), anthocyanin (79.19 mg/100 mL) and macro-nutrients concentrations and for a dark red colour. Cultivars Arakta and Mridula showed high juice percentage (45.67%) and juice recovery (45.90-46.45%), and hence were a better choice for processing. A significant positive correlation was observed among P concentration of fruits and total soluble solids and ascorbic acid, and between Ca concentration and phenol, anthocyanin and sugar, Zn concentration and fruit acidity.

Introduction. – Pomegranate (*Punica granatum* L.) is an ancient edible fruit of tropical and sub-tropical regions of the world. In India, it is traditionally grown in the Deccan Plateau located between two mountain ranges viz. the Western Ghats and the Eastern Ghats, and it is traditionally consumed as fresh fruit and also processed as juice. The edible parts of the fruit commonly known as 'arils' contain remarkable amounts of polyphenols, vitamins, proteins, sugars, polysaccharides and minerals (Ozgen *et al.*, 2008). The phytochemical and pharmacological actions of pomegranate components suggest a wide range of chemical applications for the treatment and prevention of cancer as well as other diseases, where chronic inflammation is believed to play an important etiologic role (Lansky and Newman, 2007). More recently, the fruits have drawn special interest for their antioxidant and

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nutritional values which are important for human health (Tehranifar *et al.*, 2010).

Increasing awareness on the use of pomegranate fruits as a medicinal food and dietary supplement caused a huge demand for fruits not only in India, but also in other countries. This has led to extension of pomegranate cultivation in the country. In the era of commercialization, the quality of the pomegranate fruit is of paramount importance. It depends largely on the inherent genetics (i.e. cultivars), growing regions, climate and cultural practices (Poyrazaglu *et al.*, 2002; Tehranifar *et al.*, 2010). In addition, several reports showed significant variations in phenolic, sugar and water soluble vitamin composition of pomegranate during the years (Opara *et al.*, 2009; Tehranifar *et al.*, 2010; Fawole *et al.*, 2011). Due to the inherent genetic variability among pomegranate cultivars and the influence of climatic conditions on the physico-chemical, nutritional and antioxidant values of this fruit (Opara *et al.*, 2009), scientific assessment of commercially important cultivars grown in different countries is essential for proper selection by the breeders, post-harvest handling and marketing of fruits with desirable quality attributes (Opara *et al.*, 2009) for fresh consumption or processed products. Furthermore, appearance of fruits as indicated by fruit colour and size also affect consumers' preference and hence its market price. Only few works on the physical properties of pomegranate cultivars have been reported (Khodade *et al.*, 1990; Chandra *et al.*, 2012). To our knowledge, no published data are present on their chemical and nutritional properties related to human health benefits. In addition, right nutrient balance is also essential to maintain fruit quality (Dris *et al.*, 1999). Thus, it is useful to correlate nutrient content/concentration with fruit quality to explore the implicit role of nutrients on fruit quality.

The goal of the present study was to investigate the physico-chemical and nutritional properties of four commercially pomegranate cultivars (Bhagawa, Ganesh, Arakta and Mridula) grown in India, and to relate nutrient levels with fruit quality attributes.

Materials and Methods. – *Soil and plant material.* – The study was conducted at the Pomegranate Research Farm, ICAR-National Research Centre on Pomegranate (NRCP), Solapur, Maharashtra, India located at 17°48´N latitude and 75°91´E longitude, at an altitude of 457 m above mean sea level for two cropping season during 2014-16. The climate of the study area is semi-arid, showing hot summers and moderate winters with a mean annual maximum and minimum temperature of 40.4 and 14.9°C, respectively, and an average annual rainfall of about 694 mm, occurring mostly during the months of July–September. The orchard soil was a loamy-skeletal Typic Ustorthents with the following characteristics: sand 27%, silt 25%, clay 48%; organic carbon 0.62%; calcium carbonate 10.7%; pH 8.2 (1:2.5 soil:water) and cation exchange capacity 56.9 cmol (p^+) kg^{-1} soil. The experimental material consisted of four commercial cultivars viz. Bhagawa, Ganesh, Arakta and Mridula coming from a four-year-old pomegranate (*Punica granatum* L.) plantation. The trees were spaced by 4.5 and 3.0 m between and within rows. All cultivars were grown under the same environmental conditions and received similar agronomic and cultural practices for Mrig bahar crop (i.e. June-July flowering). The fruit maturity periods for these four commercial cultivars (Bhagawa, Ganesh, Arakta, and Mridula) were 180, 150, 140 and 140 days after anthesis, respectively, based on maturity indices (total soluble solid/acid ratio). The hermaphrodite flowers were tagged at the time of anthesis. The fruits were harvested at the commercially ripe stage from the four pomegranate cultivars. After harvest, fruits were quickly transported in a cold chain to the research laboratory at ICAR-NRCP. Eighteen pomegranate fruits were sampled from each cultivar. Six replicates were used for each analysis, and each replicate included three fruits.

Physical properties. – Fruits were weighed individually on a balance with an accuracy of 0.001 g. Length and diameter of fruit and calyx were measured with a digital Vernier calliper. The measurement of fruit length was made on the polar axis of the fruit, i.e. between the apex and the end of the stem. The maximum width of the fruit, as measured in the direction perpendicular to the polar axis, is defined as the diameter. Arils were manually separated from the fruits, and then weighed. Replicate measurements of the peel thickness on the opposite sides were made using a digital Vernier calliper (Tehranifar *et al.*, 2010). Fruit juice yield was determined by extracting 100 g of arils per fruit using a juice extractor. Then the juices were analysed for their chemical properties.

Fruit peel and aril colour. – Fruit peel and aril colour of pomegranate was measured on each fruit computed as means of three measurements taken from opposite sides at the equatorial region of the fruit by using a LabScan XE colorimeter (Hunter Lab, USA) and result were represented as L*, a* and b* values. The chroma (C) value was calculated as $C = (a^{*2} + b^{*2})^{1/2}$ and indicates the colour intensity or saturation. Hue angle (H°) is a parameter that is effective in evaluating visual colour appearance and was calculated as $H° = \tan^{-1}(b^*/a^*)$. The colour index was calculated as (180 – H°)/(L* + C) (Carreno *et al.*, 1995).

Total soluble solids, acidity and ascorbic acid. – The total soluble solids (TSS) were determined using a digital refractometer (model SMART-1, ATAGO, Tokyo, Japan) and reported as °Brix at 21°C. Acidity was measured according to the AOAC method (AOAC, 1995) and expressed in terms of g citric acid/100 mL of juice (Ranganna, 2001). Ascorbic acid (AA) was determined by the 2,6-dichloroindophenol titrimetric method according to the standard method (AOAC, 2005).

Total phenols and anthocyanins. – Total phenolics were determined using the Folin-Ciocalteu colorimetric method (Makkar *et al.*, 2007). Total phenolics were extracted from 10 g of fresh samples using 40 mL of 80% (by volume) aqueous ethanol. The mixture was extracted (in water bath at 80°C), kept for 20 min in inert atmosphere, and filtered through a Whatman filter paper using a Buchner funnel. Extraction of the residue was repeated under the same conditions. The filtrates were combined and diluted to 100 mL in a volumetric flask with 80% aqueous ethanol, and the obtained extract was used for the determination of total phenolics and was expressed as mg of gallic acid equivalents (GAE)/100 mL of fresh juice. Total anthocyanin concentration in the fruit extracts was determined following the method suggested by Wrolstad (1993). Fruit anthocyanins were extracted from 2 g of fresh samples using 2 mL of 0.1% HCl (by volume) in 96% ethanol and 40 mL of 2% aqueous HCl (by volume). The mixture was centrifuged at 1,863 *g* for 15 min. The obtained supernatant was used for the determination of total anthocyanins. The absorbance was measured at 520 nm. The molar absorbance value of cyanidin-3,5-diglucoside was used as a standard value. Results were expressed as mg of cyanidin-3,5-diglucoside equivalents/100 mL fresh juice.

Free radical scavenging activity. – Fruit juice samples were tested against stable 2,2-diphenyl-1-picrylhydrazyl (DPPH) according to Karioti *et al.* (2004). Briefly, under dim light a juice sample (15 μL) was diluted with methanol (735 μL) followed by the addition of a methanolic DPPH solution (0.1 mM, 750 μL). The mixtures were incubated in the dark at room temperature for 30 min before the absorbance was measured at 517 nm. The free radical-scavenging activity of fruit juice was expressed as ascorbic acid (milligrams) equivalent/100 mL of crude juice.

Sugars – The reducing sugars in the fruits were determined by the titration method in which the clarified fruit solution was titrated against mixed Fehling's solution using methylene blue as an indicator. Total sugars were also determined by titration after addition of citric acid followed by boiling of the solution in order to complete the inversion of sucrose. Total sugar, reducing and no-reducing sugar concentrations in the pomegranate fruits were determined following the method described by AOAC (2005).

Fruit mineral analysis. – Fruits were washed thoroughly in consecutive volumes of deionized water, containing a few drops of domestic detergent and acidified with a few millilitres of concentrated HNO_3 and finally rinsed in deionized water. Arils and rinds were separated manually, and dried in an oven at 50°C and then ground. The moisture contents of arils and rinds were determined gravimetrically. The powder samples were subjected to mineral nutrient determination following ashing in a muffle furnace; samples were then dissolved in 10 mL of 2 N HCl and adjusted to a volume of 100 mL for determination of macro and micronutrients. Fe, Mn, Zn and Cu concentrations were measured using a Perkin-Elmer atomic absorption spectrophotometer (model 3110). Potassium concentration was determined by a flame photometer. The spectrophotometric method was used for phosphorus (Chapman and Pratt, 1961) and sulphur (turbidimetrically) determinations after wet digestion. For nitrogen analysis, samples were digested according to the method of Chapman and Pratt (1961), and total nitrogen concentration was determined using the Kjeldhal method (Buresh *et al.*, 1982). Mineral concentrations in arils and rinds were expressed as mg/100 g fresh weight and mg/100 g dry weight, respectively. Nutrient removal was calculated as the amount of each nutrient in dry matter.

Sensory evaluations. – The sensory quality of separated arils was evaluated by acceptance and descriptive tests (Mayuoni-Kirshenbaum *et al.*, 2013). In all cases, separated arils were extracted from at least five different fruits and placed in plastic cups identified by randomly assigned three digit codes. Consumer sensory acceptance tests were evaluated according to a 9-point hedonic scale ranging from "very strong dislike" to "very strong like".

Statistical analysis. – Data were analysed according to a completely randomized design, with six replications for each cultivar at a particular location. A replication consisted of a composite fruit sample from an individual plant. Data were subjected to analysis of variance (ANOVA) using the general linear model (GLM) procedure of SAS (1999). Pearson correlation coefficients were determined using SAS to describe the relationship between nutrient concentration of fruit and fruit quality parameters.

Results and Discussion. – *Physical properties.* – The physical properties of the four pomegranate cultivars grown in the Deccan Plateau region of India are shown in Table 1. Significant differences ($P < 0.05$) were detected in all measured parameters except for the length/diameter ratio of fruits. Average fruit weight of pomegranate cultivars ranged from 265.08 g (Arakta) to 280.42 g (Ganesh). The fruit length and diameter values were between 7.27 (Mridula) and 7.93 cm (Ganesh), and 7.80 (Bhagawa) and 8.20 cm (Ganesh), respectively. Among the cultivars, Ganesh had a significantly higher fruit weight and fruit length, while Bhagawa showed a significantly lower fruit diameter than the other cultivars. In several previous studies a wide variation of fruit weight was found, varying between 150 and 568 g (Kazankaya *et al.*, 2003; Gadze *et al.*, 2012). Under semi-arid agro-climatic conditions of India, pomegranate fruit weight was reported to range from 96 to 288 g (Chandra *et al.*, (2012). Our fruit weight data are very much within these limits. In some studies fruit length and diameter of pomegranate cultivars ranged from 61 to 91 and from 36 to 104 mm (Kazankaya *et al.*, 2003),respectively, which also supports our findings. Chandra *et al.* (2012) reported that variation of fruit weight and shape depends on the cultivars and ecological conditions. Since all the four cultivars were grown under the same ecological conditions, the variation in fruit weight and shape might have arisen from cultivars. Calyx length and diameter values ranged from 33.34 (Mridula) to 36.23 mm (Bhagawa), and from 12.55 (Arakta) to 15.70 mm (Mridula), respectively. It was previously shown that calyx length and diameter of pomegranate fruits grown in Iran are between 16.7-29.9 mm and 13.9-25.0 mm, respectively (Sarkhosh *et al.*, 2009). This knowledge is particularly relevant in the discrimination of cultivars among each other, and also in the design or selection of the appropriate packaging for fruit handling and storage.

TABLE 1. – *Physical properties of four pomegranate cultivars grown in India.*

	Cultivars			
	Bhagawa	**Ganesh**	**Arakta**	**Mridula**
Fruit mass (g)	274.23[b]	280.42[a]	265.08[c]	265.37[c]
Fruit length (cm)	7.62[b]	7.93[a]	7.31[c]	7.27[c]
Fruit diameter (cm)	7.80[b]	8.20[a]	7.50[a]	7.60[a]
Fruit length/diameter	0.98[NS]	0.97	0.97	0.96
Calyx length (mm)	36.23[a]	35.58[ab]	34.48[bc]	33.34[c]
Calyx diameter (mm)	14.02[b]	12.97[bc]	12.55[c]	15.70[a]
Calyx length/diameter	2.59[a]	2.76[a]	2.75[a]	2.14[b]
Peel thickness (mm)	3.30[a]	2.00[c]	2.42[b]	2.30[b]
Aril test weight (g)	35.20[a]	26.40[c]	30.50[b]	30.60[b]
Aril (%)	59.17[c]	66.17[a]	64.17[b]	65.17[ab]
Juice (%)	39.67[b]	44.50[a]	45.67[a]	45.67[a]
Juice recovery (%)	39.67[c]	42.49[b]	46.45[a]	45.90[a]
Taste	Sweet	Sweet	Sweet	Sweet

Data are expressed as average value of four replicates. Different letters in the same row indicate significant differences at 5% level by LSD test. NS, not significant.

There was a significant difference observed in aril percentage among the cultivars, Ganesh having the highest aril per cent (66.17%) and Bhagawa the lowest (59.17%). However, cultivar Bhagawa had bold arils (as indicated by 100 aril weight) compared to the other cultivars. A significant difference among the cultivars was also noticed in juice percentage and its recovery. Ganesh, Arakta and Mridula showed a higher juice percentage (44.50-45.67%) and juice recovery than Bhagawa (39.67%). TEHRANIFER *et al.* (2010) reported considerable variations in aril (37.59 to 65.00) and juice percentages (32.28 to 59.82) in Iranian pomegranate cultivars, which are in agreement with our findings. Mridula presented a high juice recovery, which also confirms our results. The cultivars with high juice percentage and high juice recovery have potential for utilization in the processing and beverage industry.

Peel thickness is an important characteristic of fruits from a physical strength point of view. There were significant differences in fruit peel thickness among the cultivars. Bhagawa had a higher peel thickness (3.30 mm) than other cultivars (ranging from 2.00 to 2.42 mm). Thick-peel type Iranian cultivar Pust Siah was reported to have longer shelf life and less fruit cracking problem (SARKHOSH *et al.*, 2009). Thus, Bhagawa with thick peel can be used in breeding programme for developing varieties with longer shelf life and less fruit cracking. This cultivar can also be used by the processing industry for preparing peel powder rich in medicinal ingredients and nutrients and for extracting tannins.

Fruit peel and aril colour. – Colour is an important quality attribute in food and bioprocess industries and it influences consumer's choice and preferences. Fruit peel and aril colour of pomegranate cultivars are shown in Table 2. Bhagawa had the highest red coloration (a value) on its peel, while Ganesh had the lowest red coloration among the cultivars. In other way, Ganesh had significantly more light peel colour (L value), while Arakta and Mridula had the lowest lightness. The chroma value (C), which represents colour intensity, was highest in peel of Bhagawa, while Ganesh showed the lowest chroma value. Hue angle is a parameter that is effective in evaluating visual colour appearance. In our study the peel colour of Ganesh was lighter (higher hue value) than Arakta and Mridula, which registered the lowest hue values. The data on colour index indicate that appearance of Mridula was darker and Ganesh appeared lighter in colour, while Bhagawa and Arakta secured the intermediate ranks. None the less, Arakta was darker than Bhagawa.

Fruit aril colour also varied in all measured parameters. Red colour intensity (a value) of arils was significantly higher in Bhagawa followed by Arkata and Mridula, while arils of Ganesh had the lowest intensity of red colour. Arils of cultivars Arakta and Mridula had lower yellowness (b value) and lightness (L-value) compared to Ganesh and Bhagawa.

TABLE 2. – Fruit peel and aril colours of four pomegranate cultivars grown in India.

	Peel colour					
Cultivars	L*	a*	b*	Chroma	Hue	Colour index
Bhagawa	15.98^{b}	42.31^{a}	23.62^{b}	48.47^{a}	32.32b	2.30^{c}
Ganesh	65.91^{a}	17.99^{c}	34.37^{a}	38.81^{c}	69.31a	1.06^{d}
Arakta	11.73^{c}	39.07^{b}	19.01^{c}	43.48^{b}	28.88c	2.74^{b}
Mridula	10.94^{c}	38.75^{b}	18.02^{c}	42.76^{b}	27.67c	2.84^{a}
	Aril colour					
Bhagawa	31.98^{b}	34.27^{a}	17.79^{a}	38.62^{a}	30.34b	2.12^{c}
Ganesh	45.53^{a}	16.96^{d}	16.75^{a}	23.84^{d}	49.63a	1.88^{d}
Arakta	28.42^{c}	28.20^{b}	14.87^{b}	31.89^{b}	30.99b	2.47^{b}
Mridula	25.31^{d}	25.74^{c}	12.48^{c}	28.62^{c}	28.63b	2.81^{a}

Data are expressed as average value of four replicates. Different letters in the same row indicate significant differences at 5% level by LSD test.

However, the hue value (h) was significantly higher in Ganesh than in all other cultivars. Colour intensity (C) was lowest in Ganesh, while arils of Bhagawa showed the highest colour intensity value. The visible aril colour of Mridula and Arakta was dark-red and that of Bhagawa was attractive red, while arils of Ganesh appeared light pink in colour.

Peel and aril colour development is not only governed by the cultivars but also influenced by the prevailing temperature at fruit maturity and ripening stages; a mild temperature during ripening helps colour development in pomegranate (MANERA *et al.*, 2012).

Chemical properties – The results of the qualitative fruit traits obtained from juice of pomegranate cultivars are shown in Table 3. TSS of fruit juice varied from 15.50 to 16.10°Brix. The juice of Ganesh had the highest TSS, while that of Arakta showed the lowest. The juice of Bhagawa was more acidic than the other three cultivars, which had an almost similar acidity. TSS and acidity play significant roles in the taste and flavour perceived in eating a pomegranate and as such help in characterizing pomegranate quality. It seems that there was a moderate variation in TSS and acidity. A similar finding on TSS was reported by GADZE *et al.* (2012) in pomegranate, but they could observe substantial variation on acidity. The cultivars under study are genetically related to each other which might have resulted in a moderated variation in acidity. According to the acidity values, pomegranate are classified as sweet (< 1%), sour-

TABLE 3. – *Chemical properties of the fruit juices of four pomegranate cultivars grown in India.*

	Cultivars			
	Bhagawa	**Ganesh**	**Arakta**	**Mridula**
Total soluble solid (°Brix)	15.95^{ab}	16.10^{a}	15.50^{c}	15.60^{bc}
Acidity (%)	0.50^{a}	0.42^{b}	0.45^{b}	0.45^{b}
Maturity index (TSS/TA)	30.01^{b}	38.43^{a}	34.58^{b}	34.72^{b}
Ascorbic acid (mg/100 mL)	18.75^{b}	20.42^{a}	18.75^{b}	17.50^{c}
Total anthocyanins (mg/100 mL)	78.15^{a}	26.31^{b}	79.19^{a}	78.47^{a}
Total phenolics (mg GAE/100 mL)	150.30^{b}	106.00^{c}	177.00^{a}	161.67^{ab}
Antioxidant capacity (mg AAE/100 mL)	32.56^{a}	30.58^{b}	33.07^{a}	32.55^{a}
Reducing sugars (%)	13.51^{c}	12.93^{b}	14.29^{a}	14.43^{a}
Non-reducing sugars (%)	0.11^{c}	0.09^{c}	0.13^{b}	0.21^{a}
Total sugars (%)	13.60^{c}	13.02^{b}	14.41^{a}	14.61^{a}

Data are expressed as average value of four replicates. Different letters in the same row indicate significant differences at 5% level by LSD test.

sweet (1-2%) and sour (> 2%) (Onur and Kaska, 1985). Therefore, all the four varieties under study belong to the sweet type and are used for table purpose. Ganesh had a significantly higher maturity index (TSS/TA 38.43) than the other cultivars, which were similar with each other. In contrast to our findings, Fawole *et al.* (2011) reported that the cultivar Arakta had a significantly higher maturity index than Bhagawa under South African conditions. This gives an indication that apart from cultivar, ecological condition also play an important role in influencing the quality parameters of pomegranate. Our finding is in agreement with a previous report by Chandra *et al.* (2012) who observed considerable variation in maturity index, ranging from 4.31 to 38.62 under tropical condition (India). Reducing sugars varied from 12.93 to 14.44%, while non-reducing sugars ranged from 0.10 to 0.21%. Reducing sugars and total sugars were significantly higher in Mridula and Arakta than Bhagawa and Ganesh. The lowest sugar concentration was noted in Ganesh. Mridula showed the highest non-reducing sugar concentration as well. Not much variation was noticed in the total sugar concentration (13.03 to 14.61%). Poyrazoglu *et al.* (2002) reported total sugar values of some pomegranate cultivars of Turkey to be between 13.9 and 16.06 (g/100 g). All the cultivars investigated are suitable for direct consumption and production of pomegranate juice because they had high levels of soluble solids.

Total phenol concentration of juice ranged from 1060.00 to 1770.00 mg GAE/L. Arakta registered the highest phenol concentration, followed by Mridula (1616.67 mg GAE/L) and Bhagawa (1503.33 mg GAE/L). The lowest phenol concentration in juice was recorded in Ganesh (1060.00 mg GAE/L). The anthocyanin concentration of arils was similar in Bhagawa, Arakta and Mridula, while Ganesh recorded the lowest anthocyanin value (26.32 mg/100 g arils). Our study indicates that Arakta had a significantly higher amount of bioactive healthy compounds than the other cultivars.

Total phenol concentration of pomegranate cultivars from different countries varied between 14.4 and 1008 mg GAE/100 mL juice (Ozgen *et al.*, 2008; Tehranifar *et al.*, 2010; Fawole *et al.*, 2011). Tehranifar *et al.* (2010) and Fawole *et al.* (2011) reported that total anthocyanin in pomegranate cultivars grown in Iran, Turkey and South Africa varied between 9.9-20.9, 8.1-36.9 and 16.5-26.9 mg/100 g of juice, respectively. The studied cultivars (viz. Arakta, Bhagawa and Mridula) showed a higher concentration of total phenols and anthocyanins than those from Iran, Turkey and South Africa. A higher presence of anthocyanins might have led to the characteristic intense red coloration of arils in these cultivars. Moreover, the effects of phenolic compounds on low density lipoproteins and aggregation of platelets are beneficial as they reduce some of the major risk factors for coronary heart disease (Poyrazoglu *et al.*, 2002). The radical-scavenging power of the pomegranate polyphenolic juice samples ranged between 30.58 to 33.07 mg/100 mL of ascorbic acid equivalent. Bhagawa, Arakta and Mridula had significantly higher antioxidant potential than Ganesh. The varying degree of antioxidant capacity of juices could be due in part to differences in reaction kinetics and steady-state antioxidant potentials of various reductive substrates in the juice (Ozgen *et al.*, 2008).

Ascorbic acid in juice varied from 17.50 to 20.41 mg/100 mL juice. The highest ascorbic acid concentration was found in the juice of Ganesh (20.41 mg/100 mL juice), followed by Bhagawa and Arakta (18.75 mg/100 mL juice). Fruit juice of Mridula registered the lowest ascorbic acid concentration. Tehranifar *et al.* (2010) reported a vitamin C concentration in Iranian pomegranate genotypes between 9.9 to 20.9 mg/100 g. Our findings corroborate the earlier report.

Nutritional properties. – Pomegranate is a good source of Ca, Fe, Cu and Mn (Table 4). Ca concentration in arils varied from 129.73 to 394.32 mg/100 g, Fe varied from 3.54 to 36.98 mg/100 g, and Cu ranged from 0.66 to 3.57 mg/100 g, Mn varied from 0.39 to 1.47 mg/100 g. Consumption of 100 g of fresh arils would meet 100% of the dietary reference intake (DRI) for Fe and Cu, and provide 12.97 to 39.43% of DRI for Ca and 16.97 to 63.91% for Mn. The highest Ca concentration was found in Arakta (394.32 mg/100 g) followed by Bhagawa (184.08 mg/100 g), while the lowest Ca concentration was detected in Ganesh (129.73 mg/100 g). Cultivar Arakta was also recorded for significant higher concentration of K (982.92 mg/100 g). The highest Cu concentration was noticed in Mridula (3.57 mg/100 g). Mridula and Bhagawa had the highest concentration of Fe, while Bhagawa and Ganesh showed a higher concentration of Mn than the other cultivars. Phosphorus concentration in aril ranged from 47.31 to 232.76 mg/100 g. Ganesh had the highest concentrations of P (232.76 mg/100 g) and Mg (119.14 mg/100 g). Pomegranate arils may also provide 15-20% of DRI for P, K, Mg and Zn. Even its rind also contain cognizable amount of nutrients, particularly K, Ca, Mg and S (Table 5). Thus, the rind powder could be an important component for dietary supplements as it has been reported to

TABLE 4. – *Nutritional quality of arils of four pomegranate cultivars of grown in India.*

Nutrient (mg/100g fw)	DRI* (mg/day)	Cultivars				$CD_{\alpha 0.05}$
		Bhagwa	Ganesh	Arakta	Mridula	
Proteins	56000	5273.09[a]	5000.80[a]	5125.42[a]	3380.13[b]	900.64
Macro						
Phosphorus	700	143.44[b]	232.76[a]	47.31[d]	86.47[c]	13.80
Potassium	4700	636.59[b]	632.05[b]	982.92[a]	486.78[c]	104.93
Calcium	1000	184.08[b]	129.73[c]	394.32[a]	141.99[c]	32.79
Magnesium	320, 420	85.75[b]	119.14[a]	116.93[a]	77.90[b]	26.44
Sulphur	-	54.20	32.10	27.90	35.94	NS
Micro						
Iron	18, 8	34.46[a]	29.02[b]	3.54[c]	36.98[a]	4.85
Manganese	1.8, 2.3	1.47[a]	1.39[a]	0.39[c]	1.10[b]	0.21
Zinc	8, 11	2.34[a]	1.73[b]	1.18[c]	1.62[b]	0.13
Copper	0.90	1.12[c]	2.63[b]	0.66[d]	3.57[a]	0.27

*Dietary reference intakes (DRI) are the most recent set of dietary recommendations established by the Food and Nutrition Board of the Institute of Medicine. Values given are for adult females and males, ages 19-50 years.
Data are expressed as average value of six replicates. Different letters in the same row indicate significant differences at the 5% level by LSD test.

contain various bioactive compounds of pharmaceutical utility besides containing minerals (SHARMA and MAITY, 2010). The mineral concentrations of fruits are very much dependent on soil, fertilization, climatic conditions and cultivars (NOUR *et al.*, 2011). As regards the management practices (fertilization) and climate were the same for all of the cultivars under study, it may be suggested that such considerable differences in the mineral concentrations are related to the intrinsic characteristics of each cultivar. These results are therefore important in the choice of a cultivar with superior properties for consumption, and even for facilitating genetic improvement to obtain superior cultivars.

Organoleptic properties of pomegranate arils. – Sensory parameters viz. texture, flavour and taste of arils have strong influence on the eating quality of pomegranate fruits, while colour influences the consumers' preference. Table 6 shows the organoleptic profiles of the four commercial cultivars. In organoleptic evaluation of pomegranate arils, Bhagawa fetched the highest score for colour, texture and taste, while Ganesh scored the highest rating in texture, flavour and taste.

TABLE 5. – *Nutritional quality of peel in four pomegranate cultivars of grown in India.*

Nutrient (mg/100g dw)	**DRI* (mg/day)**	**Cultivars**				$\mathbf{CD_{\alpha 0.05}}$
		Bhagawa	**Ganesh**	**Arakta**	**Mridula**	
Macro						
Phosphorus	700	146.50^{b}	129.00^{b}	176.17^{a}	135.83^{b}	20.17
Potassium	4700	1748.33^{b}	1496.67^{c}	1953.33^{a}	1690.00^{b}	177.85
Calcium	1000	528.00^{a}	418.00^{b}	454.67^{ab}	496.00^{a}	74.92
Magnesium	320, 420	145.17	193.33	192.50	184.67	NS
Sulphur	-	33.83^{c}	68.33^{b}	102.17^{a}	$58.33b^{c}$	24.84
Micro						
Iron	18, 8	5.26	3.98	5.56	5.28	NS
Manganese	1.8, 2.3	1.68^{b}	1.97^{a}	1.87^{a}	1.74^{b}	0.13
Zinc	8, 11	1.62^{b}	0.81^{d}	2.25^{a}	1.25^{c}	0.15
Copper	0.90	0.86^{b}	0.97^{b}	1.19^{a}	0.95^{b}	0.19

*Dietary reference intakes (DRI) are the most recent set of dietary recommendations established by the Food and Nutrition Board of the Institute of Medicine. Values given are for adult females and males, ages 19-50 years.
Data are expressed as average value of six replicates. Different letters in the same row indicate significant differences at the 5% level by LSD test.

TABLE 6. – *Sensory evaluation (mean acceptance score, 1 = very strong dislike, 5 = neither like nor dislike, 9 = very strong like) based on colour, texture, flavour and taste of pomegranate arils of four cultivars grown in India.*

Cultivars	**Colour**	**Texture**	**Flavour**	**Taste**	**Overall acceptance**
Bhagawa	8.37^{a}	8.07^{ab}	7.73^{b}	8.57^{a}	8.18^{a}
Ganesh	5.73^{c}	8.27^{a}	8.07^{a}	8.43^{a}	7.63^{b}
Arakta	8.50^{a}	7.83^{bc}	6.50^{c}	7.20^{b}	7.51^{b}
Mridula	7.57^{b}	7.63^{c}	6.47^{c}	7.27^{b}	7.23^{c}
$LSD_{\alpha\ 0.05}$	0.26	0.36	0.25	0.28	0.17

Data are expressed as average value of six replicates. Different letters in the same row indicate significant differences at 5% level by LSD test.

Although Arakta scored high in colour, it fetched a low score value in other sensory parameters viz. texture, flavour and taste. Mridula fetched the lowest scoring in texture, flavour and taste which influence the eating quality. In comparing the overall acceptance, it was Bhagawa which scored the maximum value followed by Ganesh and Arakta. Mridula scored the lowest value for overall acceptance. This clearly shows that Bhagawa had excellent quality and must be intended for fresh consumption, while the other cultivars should be destined for processing. Our results corroborate the findings of SHIVA PRASAD *et al.* (2012) who also reported the outstanding quality of Bhagawa for fresh consumption.

Relation between fruit nutrient concentration and fruit quality attributes. – Pearson correlation was also used to find out the interrelationship among fruit nutrient concentrations and fruit quality attributes viz. TSS, acidity, total phenols, anthocyanins, ascorbic acid, reducing and non-reducing sugars and total sugars (Table 7). There was a positive and significant correlation between phosphorus concentration of fruits and TSS (r = 0.574*) and ascorbic acid (r = 0.771**) concentrations. The mineral P participates in some of the vital metabolic processes by supplying energy, increasing acid neutralization and in sugar synthesis (KADER, 2008) and also stimulate the transport of sugars and hence could influence both TSS and ascorbic acid, a lactone of acid sugar concentration of fruit (MARSCHNER , 2012). Ca concentration of fruits correlated positively with phenol (r = 0.709*), anthocyanin (r = 0.557*) and sugar concentrations ($r_{reducing\ sugar}$ = 0.477* and $r_{total\ sugar}$ = 0.461*) of fruits. A similar relation between Ca and phenol and anthocyanin concentrations was reported by XU *et al.* (2014) who observed that foliar spray of $CaCl_2$ boosted fruit total phenolics concentration, and especially anthocyanins, by more than 20% in Seascape and Ruegen F 7-4 strawberry cultivars. They suggested that Ca can enhance accumulation of anthocyanins and total phenolics in fruit possibly via up-regulation of anthocyanin structural genes. The concentration of Zn correlated positively with fruit acidity (r = 0.665*). This positive relationship was in agreement with QIN (1996) who observed an increase in citrus fruit acidity upon application of Zn. The role of Zn could be traced out in the synthesis and degradation of carbohydrates and also its participation in biochemical reactions that involve sugar (MALAVOLTA, 2002). Cu concentration of fruits had a positive correlation with non-reducing sugars (r = 0.566*) of fruit juice. As Cu is necessary for the synthesis of chlorophyll and functions as an activator of photosynthetic enzymes and respiration (MALAVOLTA, 2002), it indirectly influences the formation of non-reducing sugars. There also exist negative correlations between mineral nutrient concentrations with fruit quality attributes which probably arise owing to interaction effect of mineral nutrients themselves.

TABLE 7. – *Pearson's correlation coefficients (r) among fruit parameters of four pomegranate cultivars grown in India.*

Variable	TSS	TA	TP	Acy	AA	RS	NRS	TS	N	P	Ca	Mn	Zn	Cu
TSS	1.000	-0.099^{ns}	-0.489*	-0.497*	0.453*	-0.398^{ns}	-0.454*	-0.611**	0.182^{ns}	0.556**	-0.312^{ns}	0.554**	0.399^{ns}	0.099^{ns}
TA		1.000	0.224^{ns}	0.531**	-0.349^{ns}	0.114^{ns}	0.028^{ns}	0.129^{ns}	0.041^{ns}	-0.259^{ns}	0.089^{ns}	0.031^{ns}	0.489*	-0.439*
TP			1.000	0.876**	-0.682**	0.747**	0.476*	0.708**	-0.272^{ns}	-0.872**	0.584**	-0.707**	-0.118^{ns}	-0.365^{ns}
Acy				1.000	0.0784**	0.715**	0.510*	0.701**	-0.350^{ns}	-0.859**	0.472**	-0.552**	0.121^{ns}	-0.373^{ns}
AA					1.000	-0.676**	-0.732**	-0.719**	0.554**	0.789**	-0.024^{ns}	0.394^{ns}	0.099^{ns}	-0.106^{ns}
RS						1.000	0.631**	0.664**	-0.332^{ns}	-0.756**	0.429*	-0.478*	-0.159^{ns}	0.017^{ns}
NRS							1.000	0.678**	-0.612**	-0.570**	-0.123^{ns}	-0.335^{ns}	-0.354^{ns}	0.456*
TS								1.000	-0.539**	-0.797**	0.324^{ns}	-0.594**	-0.247^{ns}	0.025^{ns}
N									1.000	0.515**	0.267^{ns}	0.330^{ns}	0.327^{ns}	-0.250^{ns}
P										1.000	-0.433*	0.802**	0.329^{ns}	0.332^{ns}
Ca											1.000	-0.549**	0.093^{ns}	-0.614**
Mn												1.000	0.568**	0.443*
Zn														-0.110^{ns}
Cu														1.000

Pearson's correlation coefficients using 95% confidence interval. TSS, total soluble solids; TA, titratable acidity; TP, total phenols; Acy, anthocyanins; AA, ascorbic acid; RS, reducing sugars; NRS, non-reducing sugars; TS, total sugars; N, nitrogen; P, phosphorous; Ca, calcium; Mn, manganese; Zn, zinc; Cu, copper; ns, not significant. *, $p < 0.01$; **, $p < 0.05$ (two-tailed).

Conclusions. – The quality of pomegranate fruits is strongly dependent on the cultivars. The study demonstrated that cv. Bhagawa has medium size fruit, attractive red peel colour with high red aril coloration, bold arils, high acidity and is rich in micronutrients. Hence, it is mostly preferred by the consumer for fresh consumption, while Arakta and Mridula are suitable for processing owing to a higher juice percentage and recovery. These three cultivars had a higher phenol concentration and exhibited higher antioxidant capacities than the cv. Ganesh. The study also identified the implicit role of nutrients on influencing fruit quality attributes. Thus, apart from cultivar effect, fruit quality attributes could be improved to a certain extent with the adoption of proper nutrient management practices.

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