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CHANGE IN COLOUR DEVELOPMENT, ANTHOCYANIN CONTENTS AND ORGANOLEPTIC RATING DURING FRUIT DEVELOPMENTS OF POMEGRANATE CV. MRIDULA

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ABSTRACT
Change in rind colour, aril colour, organoleptic rating and anthocyanin contents of the juice of pomegranate fruit cultivar 'Mridula' at different developmental stages were investigated to provide useful information regarding maturity. The maximum value of *L**, *a**, b*, *C** and h° recorded as 44.75 (130 DAFB), 23.48 (150 DAFB), 21.50 (120 DAFB), 28.90 (130 DAFB) and 49.20 (110 DAFB) respectively. Similarly, the maximum value of *L**, *a**, b*, *C** and h° recorded as 62.85 (30 DAFB), 29.89 (150 DAFB), 24.57 (30 DAFB), 30.82 (150 DAFB) and 30.82 (150 DAFB). The rate of change in anthocyanin content in the aril juice was recorded maximum between 9.06 mg/100 ml (110 DAFB) to 14.69 mg/100 ml (120 DAFB). Rind a* showed strong relation with organoleptic rating (r^2 = 0.914), anthocyanin contents of juice (r^2 = 0.932), aril a* (r^2 = 0.917) rind *C** (r^2 = 0.890) and aril *C** (r^2 = 0.830). Significant increase in a* and C* value of rind and aril as well as organoleptic ranting and anthocyanin content of the juice characterized rind and aril pigmentation and superior juice quality. This information provided could assist pomegranate growers to access the maturity of 'Mridula' cultivars of pomegranate.

INTRODUCTION

The pomegranate (*Punica granatum* L.) has been cultivated as a fruit crop since antiquity. Pomegranate fruits are vital for human health because of their high antioxidant capacity and high polyphenols and anthocyanin contents (Gil *et al.*, 2000).The quality of pomegranate fruits is strongly reliant on the cultivars. The physical and chemical properties of pomegranate is an imperative factor to determine fruit quality (Gadze *et al.*, 2012). There are six identical anthocyanins compounds, namely the 3-glucosides and 3,5-diglucosides of cyanidin, delphinidin and pelargonidin were identiûed as the key compounds accountable for the colour of the pomegranate juice. In combination, organic acids, anthocyanins and sugarsare imperative for the sensory attributes and authenticity of fruit products. The types and quantity of organic acids, anthocyanin and sugars also add to the nutritional quality of both fresh fruits and juices (Hasnaoui *et al.*, 2011). The anthocyanin composition is an important quality parameter of pomegranate fruit due to the importance of these compounds in the colour of the respective juices (Gil *et al.,* 1995) whereas, flavour is the significant parameter for determined the maturity of pomegranate (Kumar and Khosla, 2009). Pomegranate fruit maturity eminence is commonly assessed based on peripheral skin colour, aril, juice colour and juice acidity (Cristosto *et al.,* 2000). Likewise, the acceptability of pomegranate to the user and processor depends on the aggregate of certain quality attributes that are associated to the physico-chemical properties inclusive of size, skin colour, sugar content, TA and flavour (Al-Said *et al.*, 2009). The timing of harvest is of outmost important if fruit, either for immediate fresh market or for storage and to reach the customer in prime condition. In pomegranate fruit, early harvesting of fruit caused the diminution of organoleptic properties and browning of internal husk. Furthermore, over-ripen fruits were susceptible to physiological disorders and fungal infections during storage (Shaybani and Sharifi, 1973). Despite the long history of pomegranate culture as a fruit crop, literature is inadequate on how fruit peculiarity and components relate to changes in fruit size in cv. 'Mridula'. Pomegranate exhibits extensive phenotypic diversity in fruit size among different genotypes (Martinez *et al.,* 2006). There is an increased concern about the quality of fruit during development and proceeding to harvest aimed at curtail post-harvest devaluation. The present study was undertaken to investigate the change in colour development, anthocyanin contents and organoleptic rating during fruit developments of pomegranate cv. Mridula.

MATERIALS AND METHODS

Monitoring and sample collection

Fresh fruits of eight years old plants of pomegranate cv. 'Mridula' were picked manually in the morning from Fruit Research Farm, Department of Fruit Science, Punjab Agricultural University, Ludhiana, India at different developments stages, viz. 30 to 150 DAFB at ten days interval. All plants grown under the same geographical conditions and received the similar agronomic and cultural practices. Nine

pomegranate fruits sampled and three replicates were maintained for each analysis and each replicate includes three fruits and each replicate indicating a single pomegranate fruit. Fruits were harvested, then transport to the laboratory in a plastic bag. Colour changes were observed on same days of harvesting of the sample.

Colour dynamics

The fruit rindand aril colour of fruits were recorded along the equatorial axis of each fruit at two opposite spots in CIE coordinates (L^*, a^* and b^*) using (Hunter Lab, Colour Flex, Hunter Associated Inc., Restor, VA, USA) after calibration with a white tile background. Correspondingly, duplicate colour measurements (L^*, a^* and b^*) were made on the arils placed in a colour-less glass petri dish. The colour parameter Chroma (C^*) whichdescribes the length of the colour vector in the plane formed by $a^*$and b^* and the hue angle ($h°$) that determines the position of suchvector where calculated in consonance with the following equations:

$C^* = (a^*2 + b^*2)1/2$

$h° = \arctan (b^*/a^*)$

Anthocyanin contents of juice

Total anthocyanin content of aril juice was determined as described by *Ranganna* (1986) with the extraction solvent ethanolic HCl and absorbance were noted at 535 nm wavelength by spectrophotometer (Spectronic 200$^+$ Thermo Scientific).

Organoleptic rating

The fruits were rated by the panel of 30 judges on the basis of colour, flavour, texture and overall acceptability. A nine point hedonic scale (9 = extremely desirable, 8 = very much desirable, 7 = moderately desirable, 6 = slightly desirable, 5 = neither desirable nor undesirable, 4 = slightly undesirable, 3 = moderately undesirable, 2 = very much undesirable and 1 = extremely undesirable) described by *Amerian, Pangborn and Roessler* (1965) was used for its inference.

Statistical analysis

The data for nine replication was analyzed analysis of variance (ANOVA) and significance difference among the mean were determined at P Â 0.05 by LSD using the SAS version 9.3 (SAS Institute Inc., Cary, NC, USA).

RESULTS AND DISCUSSION

Colour dynamics

Fruit rind and aril pigmentation is an important fruit quality indicator for pomegranate. Significant differences ($p < 0.05$) were found among the developmental stages in the colour of fruit rind and arils (Fig. 1-6). The CIE L^* value indicates the lightness of the fruit rind and aril. The mean minimum value of L^* of rind during fruit development was recorded as 25.90 (30 DAFB) and mean maximum value recorded as 44.75 (130 DAFB). The L^* value of fruit skin increased continuously from 25.90 (30 DAFB) to 44.75 (130 DAFB) and then value gradually decline toward the maturity i.e 36.33 (150 DAFB)(Fig. 1).The rate of change in the lightness of fruit skin was maximum from 25.9 (30 DAFB) to 36.27 (40 DAFB) (Fig 1). The parameter positive a^* indicates the intensity of redness of fruit skin. The mean minimum a^* value was recorded as 8.57 at 30 DAFB and mean maximum a^* value for fruit skin was 23.48 at 150 DAFB. The a^* value increased continuously with advancement toward maturity but the rate of change in intensity of redness of fruit skin was maximum from 18.98 (120 DAFB) to 23.35 at 140 DAFB (Fig 1). The b* value increase continuously from 7.19 (30 DAFB) to 21.50 (120 DAFB) and then sharply decline from 21.50 (120 DAFB) to 13.87 (150 DAFB). The chroma C* value constantly increased from minimum 11.20 (30 DAFB) to maximum 28.90 (130 DAFB) and then declined from 120 DAFB to 150 DAFB (27.31). Furthermore, the h° first showed an increasing trend from 40.07 (30 DAFB) to 49.20 (110 DAFB) then declining trend with advancing maturity and reached to minimum value 30.72 at 150 DAFB (Fig. 2).

The L^* value of aril continuously declined with progress in the season (Fig. 4). The maximum L* value for aril was recorded as 62.85 (30 DAFB) and minimum L^* value recorded 28.95 at150 DAFB (Fig. 4). Thus first dynamics in L^* value shows that lightness of aril colour decreased gradually with advancement toward the maturity. The rate of the lightness of aril colour was recorded maximum from 42.60 (100 DAFB) to 33.17 (120 DAFB). The a^* value ranged between 1.29 (30 DAFB) to 29.89 (150 DAFB). The change in intensity of redness of aril colour was recorded maximum from 3.91 (60 DAFB) to 21.05 (100 DAFB). The b^* value was recorded maximum 24.57 at 30 DAFB and lowest 7.48 at 150 DAFB (Fig. 4). The aril C* value shows increasing trends where as aril h° shows decreasing trends during the fruit developmental studies. The value of aril C* and aril h° recorded maximum as 30.82 (150 DAFB) and 86.99 (30 DAFB) respectively (Fig. 5). Interestingly, fruit aril had highest C* and lowest h° value during the maturity stage, showing the disparity in fruit parts colour dynamics during fruit development of pomegranate.

The characteristic red colouration in some pomegranate fruit cultivar has been attributed to increasing in biosynthesis and accumulation of red anthocyanin in fruit (Shulman *et al.,* 1984). Fruit peel colour in terms of L*, a* and b* values increased significantly with the advancement of fruit development (Mukhim *et al* 2015) Studies on different accessions of 'Wonderful' cultivar of pomegranate showed that red pigmentation increased significantly in fruit parts during ripening (Shwartz *et al.,* 2009). The a^* value was recorded between 15.16 and 31.42 (Ercisli *et al.,* 2007) in pomegranate.

Organoleptic rating

Organoleptic rating increased linearly as fruit progressed toward the maturity. The minimum organoleptic rating for the aril was 3.58 at 30 DAFB (Fig. 7). During this stage the acceptability was between moderately undesirable and slightly undesirable whereas maximum was 8.33 at 150 DAFB. During 150 DAFB acceptability of the aril was between very much desirable and extremely desirable. Organoleptic rating of fruit increased significantly at successive intervals from 30 DAFB to 130 DAFB then non-significantly increased at consecutive sampling period till the end (150 DAFB). The increased in organoleptic rating of fruit may be attributed to increasing in TSS, Juice, vitamin C, total sugars, anthocyanin and decrease in the acidity of juice. Shwartz *et al.* (2009) recorded cv. 'Rosh-Hapered' as strong sweet taste but pomegranate cv.

Table 1: Pearson correlation between rind colour, aril colour, organoleptic rating and anthocyanin during fruit development

Variables	1	2	3	4	5	6	7	8	9	10	11	12
1. Rind *L**	1											
2. Rind *a**	0.479*	1										
3. Rind *b**	0.917*	0.442*	1									
4. Rind *C**	0.783*	0.890*	0.801*	1								
5. Rind *h*°	0.369[k]	-0.590*	0.448*	-0.162	1							
6. Aril *L**	-0.576*	-0.935*	-0.594*	-0.921*	0.417*	1						
7. Aril *a**	0.559*	0.917*	0.602*	0.914*	-0.398[k]	-0.973*	1					
8. Aril *b**	-0.589*	-0.940*	-0.608*	-0.931*	0.411*	0.982*	-0.980*	1				
9. Aril *C**	0.093	0.839	0.108	0.609*	-0.768*	-0.812*	0.832*	-0.806*	1			
10. Aril *h*°	-0.590*	-0.906*	-0.639*	-0.924*	0.358[k]	0.972*	-0.997*	0.984*	-0.801*	1		
11. Organolepticrating	0.650*	0.914*	0.683*	0.954*	-0.314	-0.981*	0.985*	-0.980*	0.763*	-0.987*	1	
12. Anthocyanin	0.365[k]	0.932*	0.338[k]	0.788*	-0.632*	-0.928*	0.889*	-0.916*	0.893*	-0.875*	0.878*	1

*$P < 0.01$ (2-tailed); [k] $P < 0.05$ (2-tailed)

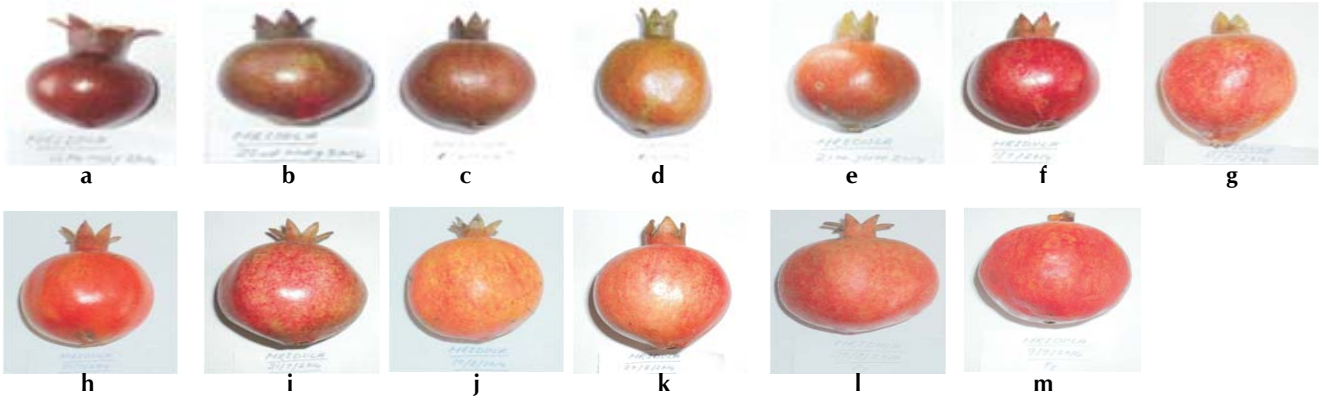

Figure 3: Changes in fruit rind colour during fruit development of pomegranate cv. Mridula at (a) 30 DAFB (b) 40 DAFB (c) 50 DAFB (d) 60 DAFB (e) 70 DAFB (f) 80 DAFB (g) 90 DAFB (h) 100 DAFB (i) 110 DAFB (j) 120 DAFB (k) 130 DAFB (l) 140 DAFB and (m) 150 DAFB

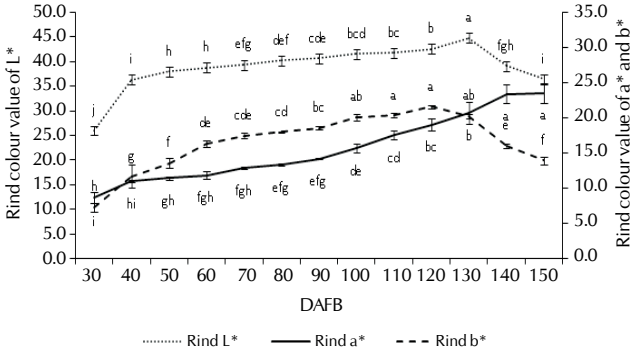

Figure 1: Stage progression changes in rind colour value of L*, a*and b* of pomegranate cv. Mridula. LSD (L* = 1.35, a* = 2.36 and b* = 1.75) indicates the least significant difference test at (p < 0.05) with CV (L* = 2.07, a* = 9.02 and b* = 6.35). Mean ± Standard error (SE), presented the same letter(s) on vertical bar indicate statistically non-significantly different compare to previous sample

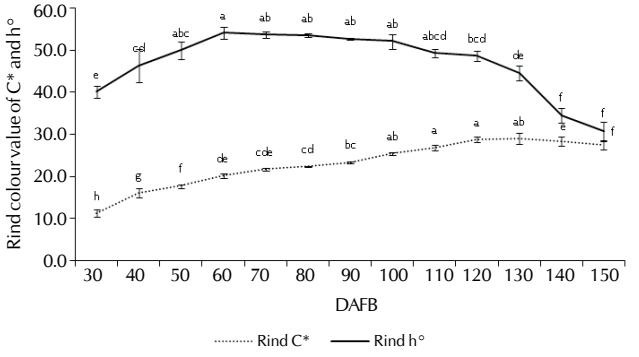

Figure 2: Stage progression changes in rind colour value of C* and h° of pomegranate cv. Mridula. LSD (C* = 2.18 and h° = 5.14) indicates the least significant difference test at (p < 0.05) with CV (C* = 5.68 and h° = 6.52). Mean ± SE, presented the same letter(s) on vertical bar indicate statistically non-significantly different compare to previous sample

'Wounderful' recorded as sour-sweet taste.

Anthocyanin contents of juice

The red colour of the pomegranate aril juice is due to the presence of anthocyanin pigment. Anthocyanin content of aril juice followed an increasing trend as the fruit approached maturity stage (Fig 6-7). The minimum anthocyanin content in the aril juice was recorded as 0.52 mg/100 ml at 30 DAFB and maximum recorded as 22.78 mg/100 ml at 150 DAFB. The increment in anthocyanin content in aril juice was very slow in the initial stage of fruit development but as the fruit approached towards maturity anthocyanin content also improved. A non-significant increase at adjacent intervals of sampling in anthocyanin content of aril juice from 0.79 mg/100 ml (40 DAFB) to 5.77 mg/100 ml (100 DAFB) subsequently,

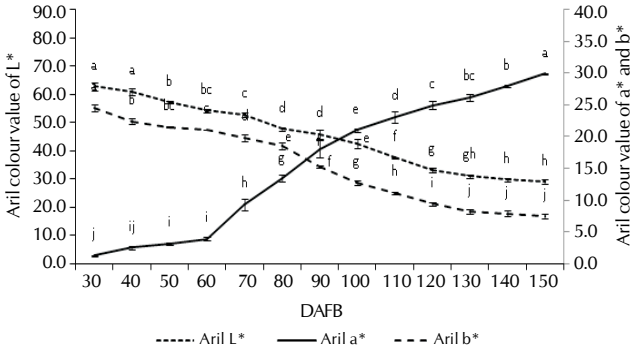

Figure 4: Stage progression changes in aril colour value of L*, a* and b* of pomegranate cv. Mridula. LSD (L* = 2.94, a* = 1.80 and b* = 1.12) indicates the least significant difference at (p < 0.05) with CV (L* = 3.89, a* = 6.82 and b* = 4.34). Mean ± SE, presented the same letter(s) on vertical bar indicate statistically non-significantly different compare to previous sample

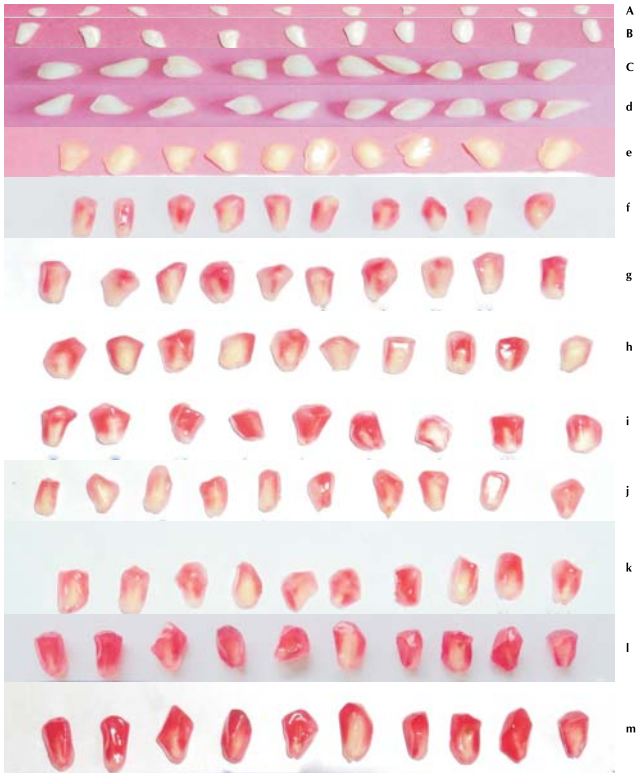

Figure 6: Changes in fruit aril colour during fruit development of pomegranate cv. Mridula at (a) 30 DAFB (b) 40 DAFB (c) 50 DAFB (d) 60 DAFB (e) 70 DAFB (f) 80 DAFB (g) 90 DAFB (h) 100 DAFB (i) 110 DAFB (j) 120 DAFB (k) 130 DAFB (l) 140 DAFB and (m) 150 DAFB

a significant increase was recorded till 130 DAFB at successive interval and again non-significant increment in anthocyanin content from 20.10 mg/100 ml at 130 DAFB to 22.78 mg/100 ml at 150 DAFB at consecutive interval of aril juice sampling. The rate of change in anthocyanin content in the aril juice was recorded minimum from 0.79 mg/100 ml (40 DAFB) to 1.22 mg/100 ml (50 DAFB) and recorded maximum between 9.06 mg/100 ml (110 DAFB) to 14.69 mg/100 ml (120 DAFB).

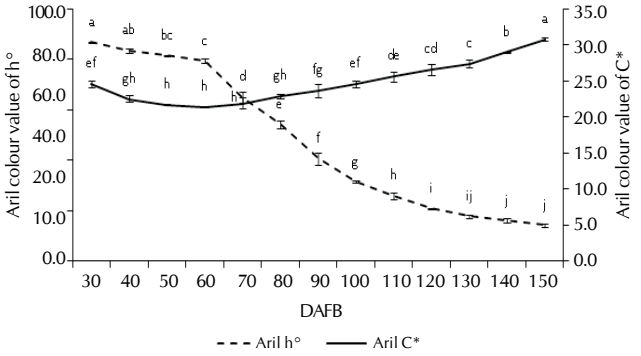

Figure 5: Stage progression changes in aril colour value of C* and h° of pomegranate cv. Mridula. LSD (C* = 1.56, and h° = 3.45) indicates the least significant difference test at (p < 0.05) with CV (C* = 3.74, and h° = 4.34). Mean ± Standard error, presented the same letter(s) on vertical bar indicate statistically non-significantly different compare to previous sample

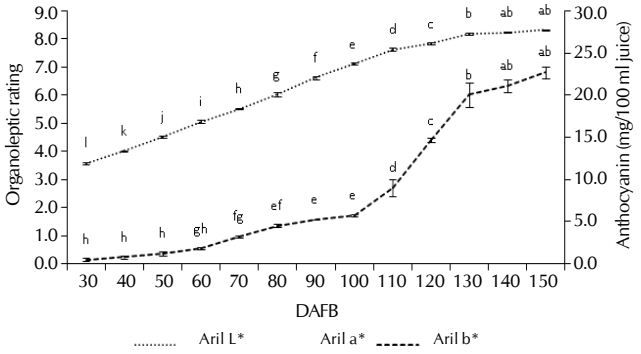

Figure 7: Stage progression changes in organoleptic rating and anthocyanin content of pomegranate juice cv. Mridula. LSD (Organoleptic rating = 0.12 and anthocyanin = 1.73) indicates the least significant difference test at (p < 0.05) with CV (Organoleptic rating = 1.15 and anthocyanin = 12.06). Mean ± Standard error, presented the same letter(s) on vertical bar indicate statistically non-significantly different compare to previous sample

Increase in anthocyanin was not observed in 'Ganesh' cultivar of pomegranate until the 80 DAFS, but the increase was significant with advancing maturation (Kulkarni and Aradhya, 2005).

Multivariate analysis of investigated fruit attributes

Pearson correlation (Table 1)was used to investigate the interrelationships among major maturity physical and chemical properties of 'Mridula' pomegranate. Significant ($P < 0.05$) strong relationships were revealed among the investigated parameters. Rind L^* showed significantly ($P < 0.01$) positive correlations with rind b^*($r^2 = 0.917$) and rind a^* showed strong relation with organoleptic rating ($r^2 = 0.914$), anthocyanin contents of juice ($r^2 = 0.932$),aril a^* ($r^2 = 0.917$) rind C^* ($r^2 = 0.890$) and aril C^* ($r^2 = 0.830$) but showed negative correlation with aril L^* ($r^2 = -0.935$), aril b^* ($r^2 = -0.940$) and aril $h°$ ($r^2 = -0.906$). Rind C^* showed significantly ($P < 0.01$) good relation with organoleptic rating ($r^2 = 0.954$) and anthocyanin contents of juice ($r^2 = 0.788$). Aril a^* also showed significantly ($P < 0.01$) strong relation with organoleptic rating ($r^2 = 0.985$) and anthocyanin content of

aril juice (r^2 = 0.889). Interestingly, strong negative relationships (P< 0.01) were observed between organoleptic rating (r^2 = - 0.987) and anthocyanin content of aril juice (r^2 = - 0.875). There were also positive relationships between organoleptic rating and anthocyanin (r^2 = 0.878).

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