Physical and Chemical Attributes of Pomegranate (Punica granatum L.) Cultivars Grown in Humid Conditions in Georgia

Juan C. Díaz-Pérez and Dan MacLean
Department of Horticulture, University of Georgia, 2360 Rainwater Road, Tifton, GA 31793-5766

Smiljana Goreta
Institute of Agriculture and Tourism, Karla Huguesa 8, 52440 Poreč, Croatia

Sarah Workman
Center for Agribusiness and Economic Development, University of Georgia, Athens, GA 30602-7509

Erick Smith, Harwinder Singh Sidhu, Gunawati Gunawan, Anthony Bateman, and Jesús Bautista
Department of Horticulture, University of Georgia, 2360 Rainwater Road, Tifton, GA 31793-5766

William Lovett
University of Georgia Extension Service, Bacon County, Alma, GA 31510

Maja Jukić Spika, Gvozden Dumičić, and Mira Radunić
Institute of Adriatic Crops and Karst Reclamation, Put Duilova 11, 21000 Split, Croatia

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Abstract. Pomegranate (Punica granatum L.) is a nonclimacteric fruit sold fresh as whole fruit or arils (fleshy seeds). It is also used for the production of juice, wine, and syrup. Pomegranate is popular due to its numerous health benefits. In the United States, it is grown primarily in California and other semi-arid regions, with Wonderful being the most widely grown cultivar. However, preliminary research has shown that ‘Wonderful’ produces low yields in Georgia, thus indicating the need to identify cultivars better suited for warm and humid conditions, such as those of the southeastern United States. The objective of this study was to determine the physical and chemical quality attributes of pomegranate cultivars grown in Georgia. Pomegranate fruit from 40 cultivars were harvested during 2012 to 2017. Individual fruit weight varied from 124 g for ‘Utah Sweet’ to 631 g for ‘C1’. The total fruit weight percentage accounted for by fresh aril weight (aril fraction) ranged from 22% for ‘C8’ to 70% for ‘JC’. Individual aril weight ranged from 174 mg for ‘Utah Sweet’ to 638 mg for ‘Cloud’. Across cultivars, individual fruit weight increased linearly with the increasing number of arils. Aril color varied from white to deep red. The arils L* value ranged from 15.7 (dark arils) for ‘Crown Jewel’ to 46.1 (light arils) for ‘Utah Sweet’. The a* values ranged from 0.6 (white arils) for ‘Cloud’ to 20.5 (red arils) for ‘Crab’. The b* values ranged from 8.7 for ‘DJ Forry’ (from a store) to 62.5 for ‘R9’. The Chroma* values ranged from 13.4 for ‘Cloud’ to 24.3 for ‘Crač’. The hue* values ranged from 29.7 for ‘Wonderful’ (from a store) to 87.1 for ‘Cloud’. Rind color was related to the color of the arils; high a* values in the rind and arils were associated with the red color. The fruit juice content ranged from 174 mL kg−1 fruit for ‘Utah Sweet’ to 638 mL kg−1 fruit for ‘Cloud’. Cultivars varied from tart to sweet. The fruit soluble solids concentration (SSC) ranged from 10.8% for ‘Sin Pepe’ to 16.4% for ‘Crown Jewel’. Fruit titratable acid (TA) ranged from 0.27% for ‘Sin Pepe’ to 6.20% for ‘Utah Sweet’. The juice maturity index measured as the SSC/TA ratio ranged from 1.9 for ‘Utah Sweet’ to 39.5 for ‘Sin Pepe’. The juice total phenols (measured as gallic acid equivalents) ranged from 463 mg L−1 for ‘JC’ to 2468 mg L−1 for ‘Wonderful’ (Georgia). Trolax equivalent antioxidant capacity values of juice ranged from 10,001 μM for ‘King’ to 59,821 μM for ‘I11’. Cupric reducing antioxidant capacity values in juice ranged from 7471 μM for ‘Azadi’ to 20,576 μM for ‘Wonderful’ (Georgia). Juice total anthocyanins varied from 1.7 mg L−1 for ‘R19’ to 50.0 mg L−1 for ‘Wonderful’ (Georgia). Pomegranate cultivars showed large variability in physical and chemical attributes. Such pomegranate variability represents opportunities for breeding, for the retail market, and for the development of different products by the food industry.
Table 1. Pomegranate cultivars and locations where they were grown in Georgia.

| Cultivar          | Almaa | Tiffoeb | Ty Tyb |
|-------------------|-------|---------|--------|
| Afganski (R26)    | +     | ++      | +      |
| Al sirin-nar (R6) | +     |         |        |
| Azadi             | +     |         |        |
| Bala Miursal (R25) | +    |         | +      |
| Barskislatki (C5) | +     | +       |        |
| Ciparski (C8)     | +     | +       |        |
| Cloud             | +     |         |        |
| Crab              | +     |         |        |
| Cranberry         | +     | +       |        |
| Crown Jewel       | +     |         |        |
| Domaci kiseli (C6)| +     |         |        |
| Don Sumner North  | +     | +       |        |
| Don Sumner South  | +     |         |        |
| Dorosht 5 hahanshahi | + |         |        |
| Khoramabad (I7)   | +     |         |        |
| Entek habi saveh  | +     |         |        |
| Eve               | +     |         |        |
| Fleshman          | +     |         |        |
| Gissarski Rozovyi | +     |         |        |
| Granada           | +     |         |        |
| Jimmy             | +     |         |        |
| Kaic-ak-anor (R9) | +     | +       |        |
| King              | +     |         |        |
| Lester            | +     | +       |        |
| Medovyov          | +     | +       |        |
| Mehjous (R2)      | +     | +       |        |
| Nikitski ranni (R19) | +   | +      |        |
| Pink              | +     |         |        |
| Rose              | +     |         |        |
| Sakerdze (R5)     | +     |         |        |
| Salavatski (R8)   | +     | +       |        |
| Shirin Pust Ghermez |     |         |        |
| Saveh (I11)       | +     |         |        |
| Sin Pepe          | +     |         |        |
| Sirenevny         | +     |         |        |
| Surr-anor (R33)   | +     | +       |        |
| Sweet             | +     |         |        |
| Thomson           | +     |         |        |
| Utah Sweet        | +     |         |        |
| Wonderful         | +     |         |        |
| x 305 ± 35 8.7 ± 0.4 51 ± 1.1 49 ± 1.1 310 ± 5 466 ± 45 |
| x 498 ± 10 10.0 ± 0.3 48 ± 0.7 51 ± 0.7 387 ± 5 662 ± 18 |
| x 42 ± 42 21.2 ± 1.7 55 ± 0.7 38 ± 0.7 383 ± 0 412 ± 66 |
| x 70 ± 70 140 ± 1.1 56 ± 0.1 70 ± 0.1 360 ± 7 467 ± 68 |
| x 94 ± 94 158 ± 1.1 60 ± 0.1 94 ± 0.1 366 ± 9 440 ± 90 |
| x 112 ± 112 224 ± 1.1 110 ± 0.1 112 ± 0.1 365 ± 2 520 ± 52 |
| x 128 ± 128 256 ± 1.1 120 ± 0.1 128 ± 0.1 364 ± 1 453 ± 45 |
| x 164 ± 164 328 ± 1.1 160 ± 0.1 164 ± 0.1 363 ± 1 512 ± 51 |
| x 192 ± 192 384 ± 1.1 180 ± 0.1 192 ± 0.1 362 ± 1 570 ± 57 |
| x 220 ± 220 440 ± 1.1 200 ± 0.1 220 ± 0.1 361 ± 1 628 ± 62 |
| x 248 ± 248 496 ± 1.1 224 ± 0.1 248 ± 0.1 360 ± 1 685 ± 68 |
| x 276 ± 276 552 ± 1.1 252 ± 0.1 276 ± 0.1 359 ± 1 743 ± 74 |
| x 304 ± 304 608 ± 1.1 280 ± 0.1 304 ± 0.1 358 ± 1 801 ± 80 |
| x 332 ± 332 664 ± 1.1 300 ± 0.1 332 ± 0.1 357 ± 1 859 ± 86 |
| x 360 ± 360 720 ± 1.1 320 ± 0.1 360 ± 0.1 356 ± 1 917 ± 91 |
| CR-400 (8-mm aperture, D65 illuminant) handheld colorimeter (Konica Minolta, Ramsey, NJ) was used to measure the fruit color and aril color. Three color readings were performed per fruit and fruit aril. Color was measured as L* (red), a* (green to yellow), and b* (blue to yellow). Chroma (C*) [(a*2 + b*2)1/2] and the hue angle (h°) values (0° = red-purple; 90° = yellow; 180° = blue-green; 270° = blue) were calculated from the a* and b* values (McGuire, 1992). Physical attributes. Individual fruit weight and diameter were determined. Fruit were peeled to determine the rind and aril weights, and their respective weight fractions (relative to total fruit weight) were calculated. For each fruit, a sample of 50 arils was weighed and the mean aril weight was determined. A more, CA) that was calibrated with distilled water. Titratable acidity (TA) was determined using an automatic titrator (DL-15; Mettler Toledo, Switzerland) and 500 mL of juice diluted with 25 mL of water. The juice sample was titrated to pH 8.2 using 0.1 M NaOH after recording the initial pH. Titratable acidity was expressed as the percentage of malic acid present in juice. Total phenols were determined as a measure of the total antioxidant capacity following the Folin-Ciocalteau method (Singleton et al., 1999), and data were expressed as gallic acid equivalents. The antioxidant capacity was determined by the Trolox equivalent antioxidant capacity (TEAC) and the Cupric reducing antioxidant capacity (CUPRAC) methods (Barros et al., 2007; Castro-Concha et al., 2014). The total anthocyanins in juice (dilution 1:5 with water) were calculated from the absorbance at 513 nm (Kong et al., 2003).
Statistical design and analysis. The MEANS procedure of SAS (SAS version 9.4; SAS Institute Inc., Cary, NC) was used to perform statistical analyses (mean and se) for all response variables. The CORR procedure was used to calculate the Pearson correlation coefficient of color values in the rind and arils of pomegranate fruit and of antioxidant concentrations and aril color values. The REG procedure was used for the regression of fruit weight as a function of the number of arils per fruit and individual aril weight. Data regarding the years and farms were pooled for statistical analyses.

Results

Fruit physical attributes. Individual fruit weight showed a wide range from 124 g for ‘Utah Sweet’ to 631 g for ‘C1’ (Table 2). The fruit diameter ranged from 4.6 cm for ‘Utah Sweet’ to 11.3 cm for ‘C1’. Fruit weight and diameter were highly correlated ($r^2 = 0.818; P < 0.0001$). The percentage of weight accounted for by the rind weight (rind fraction) ranged from 30% for ‘JC’ to 78% for ‘C8’. The percentage of fruit weight accounted for by the fresh aril weight (aril fraction) ranged from 22% for ‘C8’ to 70% for ‘JC’. Neither the rind fraction nor the aril fraction was related to fruit weight across cultivars. Individual aril weight ranged from 174 mg for ‘Utah Sweet’ to 638 mg for ‘Cloud’. Across cultivars, individual fruit weight increased linearly with the increasing number of arils, but the fruit weight was unrelated to the individual aril weight (Fig. 1).

Fruit color. Across cultivars, aril color varied from white to deep red. Aril L* values ranged from 15.7 (i.e., dark arils) for ‘Crown Jewel’ to 46.1 (light arils) for ‘Utah Sweet’. The a* value ranged from 0.6 for ‘Cloud’ (white arils) to 20.5 (red arils) for ‘Crab’. The b* value ranged from 8.7 for ‘DJ Forry’ to 62.5 for ‘R9’. The C* value ranged from 13.4 for ‘Cloud’ to 24.3 for ‘Crab’. The $h/C_{176}$ value ranged from 29.7 for ‘Wonderful’ to 87.1 for ‘Cloud’ (Table 3).

The fruit rind color included green, yellow, pink, and red. The rind L* value ranged from 39.4 for ‘R26’ to 55.0 for ‘DSN’. The a* value ranged from 7.8 for ‘Utah Sweet’ to 31.9 for ‘Cranberry’. The b* value ranged from 18.2 for ‘Crab’ to 31.1 for ‘R8’. The C* value ranged from 1.0 for ‘Rose’ to 5.7 for ‘Eve’. The $h/C_{176}$ value ranged from 0.6 for ‘Eve’ to 7.0 for ‘Cloud’.

The color of the rind was related to the color of the arils (Table 4). Aril L* values were negatively correlated with aril a* values and rind a* and C* values, and they were positively correlated with aril b* and h* and rind C* values. Aril a* values were negatively correlated with aril b* and h* and rind h* and C* values. Aril b* values were negatively correlated with aril a* and C* values, and they were positively correlated with aril h* and rind C* values. Aril b* values were positively correlated with aril C* and aril h* values. Aril C* values were negatively correlated with aril h* and rind h* values, and they were positively correlated with rind a* and C* values. Aril h* values were negatively correlated with rind a* and C* values, and they were positively correlated with rind h* values. Rind a* values were negatively correlated with rind h* values, and they were negatively correlated with rind C* values. Rind b* values were positively correlated with C* and h* values. Rind C* values were positively correlated with rind h* values. The highest correlation coefficient for aril and rind color attributes was for aril a* and rind a* values; high a* values were associated with a red rind and arils.

Fruit chemical attributes. Fruit juice content ranged from 174 mg·L⁻¹ fruit for ‘Utah Sweet’ to 638 mg·L⁻¹ fruit for ‘Cloud’ (Table 5). The fruit juice content was positively correlated with the number of arils per fruit and the individual aril weight. The highest correlation coefficient for aril and rind color attributes was for aril a* and rind a* values; high a* values were associated with a red rind and arils.

Fig. 1. Relationships between the number of arils and individual aril weight with pomegranate fruit weight for 40 cultivars grown in Georgia. Symbols represent individual fruits.
Table 3. Fruit color values of pomegranate fruit from cultivars grown in Georgia. 

| Cultivar | L* | a* | b* | C | Hue |
|---------|----|----|----|---|-----|
| Azadi   | 38.9±1.3 | 1.5±0.3 | 14.9±0.4 | 15.0±0.4 | 84.3±1.2 |
| C1      | 39.6±1.2 | 1.0±0.5 | 17.4±0.4 | 17.5±0.4 | 86.9±1.8 |
| C5      | 35.3±2.1 | 10.0±1.0 | 13.5±0.5 | 17.0±0.4 | 53.7±3.5 |
| C6      | 41.6±1.0 | 1.4±0.5 | 18.3±0.5 | 18.4±0.5 | 85.7±1.5 |
| C8      | 35.1±0.6 | 5.9±0.4 | 14.5±0.4 | 14.7±0.4 | 67.8±0.7 |
| Cloud   | 31.3±1.9 | 0.6±0.6 | 13.4±0.9 | 13.4±0.9 | 87.1±2.7 |
| Crab    | 25.3±1.6 | 20.5±1.0 | 13.0±0.6 | 24.3±1.0 | 32.6±0.9 |
| Cranberry | 25.2±1.6 | 17.3±1.2 | 12.5±0.5 | 21.8±0.9 | 35.7±2.4 |
| Crown Jewel | 15.7±3.4 | 15.0±1.4 | 9.1±1.2 | 17.8±1.0 | 31.5±5.0 |
| DJ Forry | 20.0±2.4 | 14.1±0.9 | 8.7±0.5 | 16.8±0.6 | 32.6±2.8 |
| DSN     | 35.5±2.4 | 5.8±0.4 | 13.8±0.3 | 15.0±0.4 | 67.2±1.1 |
| DSS     | 45.2±3.4 | 3.9±1.0 | 14.9±0.4 | 15.6±0.3 | 75.2±3.9 |
| Eve     | 26.0±2.0 | 16.1±1.0 | 12.4±0.5 | 20.9±1.2 | 37.8±2.2 |
| Fleshman | 34.1±1.7 | 10.3±0.8 | 13.4±0.4 | 17.1±0.6 | 53.2±2.3 |
| Gissark | 24.5±1.0 | 19.2±0.6 | 12.8±0.4 | 21.3±0.6 | 33.7±0.7 |
| Granada | 28.0±1.8 | 16.3±1.3 | 11.9±0.9 | 20.5±1.0 | 37.9±2.6 |
| I11     | 41.2±0.5 | 3.3±0.0 | 15.0±0.2 | 15.4±0.1 | 77.5±0.2 |
| I7      | 32.9±1.0 | 17.8±1.3 | 13.8±0.3 | 22.6±1.2 | 83.3±1.5 |
| I8      | 32.9±1.6 | 14.5±1.4 | 13.9±0.4 | 20.7±1.0 | 46.4±3.0 |
| JC      | 27.7±1.5 | 3.5±0.3 | 15.7±0.5 | 16.1±0.5 | 77.6±0.8 |
| Jimmy   | 32.4±2.5 | 3.8±0.3 | 14.5±0.7 | 15.0±0.7 | 75.3±0.8 |
| King    | 28.5±3.0 | 10.5±1.3 | 12.0±0.9 | 16.2±1.0 | 49.2±4.2 |
| Lester  | 29.7±1.4 | 9.0±1.4 | 13.7±0.5 | 17.4±0.9 | 60.0±3.9 |
| Medovyi | 28.1±1.8 | 16.6±1.1 | 12.1±0.5 | 20.7±1.0 | 36.4±1.8 |
| Pink    | 37.4±3.9 | 9.6±2.0 | 13.4±0.5 | 16.7±2.2 | 55.9±3.9 |
| R2      | 32.1±1.8 | 14.6±1.0 | 12.5±0.4 | 19.7±0.7 | 41.8±2.6 |
| R5      | 38.0±2.9 | 5.2±1.8 | 15.4±1.3 | 17.0±0.7 | 70.3±7.3 |
| R6      | 29.7±1.6 | 11.9±1.3 | 13.0±0.6 | 18.4±1.0 | 49.5±3.3 |
| R8      | 34.7±1.5 | 9.1±0.8 | 13.2±0.6 | 16.5±0.5 | 57.2±2.2 |
| R9      | 28.8±1.2 | 16.8±0.9 | 11.8±0.5 | 16.7±2.2 | 57.0±2.6 |
| R19     | 27.8±1.5 | 13.4±1.2 | 12.7±0.5 | 19.1±1.1 | 46.5±1.9 |
| R25     | 26.0±1.1 | 12.4±0.9 | 12.3±0.5 | 17.7±0.7 | 45.4±1.8 |
| R26     | 27.1±1.8 | 13.7±1.0 | 12.5±0.6 | 21.3±0.8 | 38.9±2.1 |
| R33     | 33.9±1.6 | 5.6±0.5 | 13.2±0.4 | 14.6±0.4 | 66.4±2.2 |
| Rose    | 26.4±1.5 | 18.3±1.0 | 11.4±0.6 | 21.7±1.0 | 32.5±1.5 |
| Sin Pepe | 37.4±0.7 | 2.6±0.2 | 14.8±0.3 | 15.0±0.3 | 80.0±0.5 |
| Sirnevey | 26.7±0.0 | 14.1±0.0 | 12.4±0.0 | 18.8±0.0 | 41.4±0.0 |
| Sweet   | 32.2±5.7 | 11.3±2.4 | 14.7±2.5 | 19.3±1.5 | 51.6±8.8 |
| Thomson | 32.6±4.5 | 12.4±3.0 | 12.8±1.6 | 18.6±1.9 | 48.8±7.6 |
| Utah Sweet | 46.1±3.3 | 1.9±0.5 | 17.2±0.8 | 17.3±0.8 | 83.4±1.8 |
| Wonderful | 20.8±1.1 | 17.1±0.7 | 9.7±0.4 | 19.7±0.7 | 29.7±0.9 |
| Wonderful | 32.4±2.0 | 18.0±1.9 | 13.1±0.4 | 22.5±1.5 | 37.0±3.4 |

**Discussion**

**Physical attributes.** Pomegranate is an ancient crop that is grown in many countries, particularly those with a Mediterranean climate (Preece and Moersfelder, 2016). Pomegranate fruit may vary widely in physical and chemical properties (Chater et al., 2018; Radunich et al., 2015). In our study, fruit showed a large variation in fruit weight and fruit color (both rind and arils). Fruit weight differences among cultivars may be attributed to genetics as well as to differences in...
the time of flower pollination and fruit set. In Georgia, pomegranate cultivars produce various flushes of blooming that start in April and continue to the fall, which can result in variations in fruit size and maturity stage. The time from flowering to fruit maturity in Georgia is ≈4 to 5 months, depending on the cultivar.

The mean fruit size across cultivars at the UGA Tifton Campus Farm (mean, 357 g) was similar to that at the Alma commercial farm (mean, 348 g) and higher than that at the Ponder Farm (mean, 256 g). Reduced fruit size could be at least partially attributed to the nonideal production practices at the University of Georgia farms (e.g., reduced pesticide applications). A study of ‘Wonderful’ grown in California indicated that the number of arils per fruit was found to be correlated with fruit size, but no relationship was found between individual aril weight and fruit size (Wetzstein et al., 2011). In our study, we found that such a relationship occurs not only for ‘Wonderful’ but also across a range of cultivars. Wetzstein et al. (2011) proposed that production strategies directed at increasing aril number may help to increase pomegranate fruit size.

**Chemical attributes.** Regarding physical properties, pomegranate fruit showed a wide range of juice yield and chemical properties, such as TA and SSC, resulting in a high range of flavor from very sweet to very acidic. Unexpectedly, ‘Utah Sweet’ was very acidic in this study, possibly because the fruit was still immature when sampled or because the accession in our collection was more acidic than other accessions of ‘Utah Sweet’.

In another study, the ‘Wonderful’ fruit juice content was found to be ≈375 mL·kg⁻¹ fruit and had a TA of 1.85% (Chace et al., 1930). In ‘Baghwa’ pomegranate, the sugar content, SSC/TA ratio, ascorbic acid, and total anthocyanins increased during fruit maturation, whereas TA, organic acids, and phenolics significantly decreased (Fawole and Opara, 2013b). In ‘Ruby’ pomegranate, the SSC (sugar and fructose), and anthocyanin composition increased, whereas TA, organic acids, and total phenolics decreased with advancing maturity (Fawole and Opara, 2013a).

Fruit maturity was not determined in our study; therefore, harvested fruit likely differed in maturity stage among cultivars. Fruit were selected to be visually “mature” or “ready for harvest.” Therefore, differences in fruit maturity may have influenced fruit chemical properties. In our study, we sampled fruits over the course of several years to reduce the effects of possible differences in fruit maturity among cultivars on the comparisons of chemical properties among cultivars.

Juice total phenolics (measured as gallic acid equivalents) were among the highest for ‘Wonderful’ (grown in Georgia) (2468 mg·L⁻¹). It is unclear why the majority of cultivars in our study had reduced levels of total phenolics. It is also noteworthy that ‘Wonderful’ (stored) had reduced total phenolics (800 mg·L⁻¹), suggesting that the total phenol concentration of pomegranate may be affected by fruit maturity and production practices as well as by environmental conditions before and after harvest. In Spain, the cultivar Mollar de Elche was found to have total phenols ranging from 2285 to 2457 mg·L⁻¹ (Nuncio-Jauregui et al., 2015).

In some Tunisian pomegranate cultivars, the total amount of anthocyanin pigmentation of pomegranate juice was found to be largely affected by the cultivar, fruit maturation stage, and geographical location (Gil et al., 1995). In our study, the total anthocyanin concentration varied widely among cultivars, with ‘Wonderful’ (grown in Georgia) having one of the highest anthocyanin concentrations. Monoglicosylated and diglicosylated delphinidins and cyanidins were the major anthocyanins, with cyaniding being more abundant and the delphinidin concentration being increased in cool conditions; in general, anthocyanin accumulation increased with decreasing temperatures during the season (Borochov-Neori et al., 2011).

Studies performed in California showed that as pomegranate fruit mature, TA decreases and SSC increases, resulting in increased sweetness (Chater et al., 2018). In Georgia, however, fruit have high incidences of fruit decay as they mature on the tree. Therefore, early harvesting (≥1 weeks before the full maturity stage) may be a strategy to reduce postharvest fruit decay under the conditions in Georgia.

The variability in physical attributes and chemical composition of pomegranate fruit from the cultivars used in the present study may be useful for breeding efforts. Furthermore, it may be of interest to the food industry for the development of different products. Consumers may prefer pomegranate fruit and derived products with a range of colors, acidity, and sweetness.

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Table 5. Fruit juice content and juice soluble solids content (SSC), titratable acidity (TA), pH, and maturity index (SSC/TA) of pomegranate fruit of cultivars grown in Georgia. 

| Cultivar | Juice content (mL·kg⁻¹ fruit) | SSC (%) | TA (% malic acid) | pH | Maturity index
|----------|-------------------------------|---------|------------------|----|-------------
| Azadi    | 35i ± 15                      | 12.4 ± 0.3 | 0.45 ± 0.05 | 3.83 ± 0.01 | 27.7 ± 2.6 |
| C1       | 466 ± 20                      | 14.7 ± 0.2 | 1.19 ± 0.11 | 3.67 ± 0.04 | 12.3 ± 1.0 |
| C5       | 445 ± 25                      | 14.0 ± 0.3 | 0.59 ± 0.03 | 3.79 ± 0.04 | 23.9 ± 0.9 |
| C6       | 360 ± 26                      | 13.0 ± 0.4 | 1.30 ± 0.07 | 3.71 ± 0.02 | 10.0 ± 0.7 |
| C8       | 433 ± 34                      | 14.0 ± 0.2 | 0.46 ± 0.02 | 3.90 ± 0.03 | 30.7 ± 2.3 |
| Cloud    | 638 ± 1                       | 14.2 ± 0.1 | 0.56 ± 0.04 | 3.84 ± 0.15 | 25.1 ± 1.9 |
| Crab     | 468 ± 1                       | 14.0 ± 0.1 | 2.60 ± 0.13 | 3.45 ± 0.06 | 5.4 ± 0.3 |
| Cranberry| 523 ± 27                      | 13.8 ± 0.1 | 1.80 ± 0.12 | 3.36 ± 0.05 | 7.7 ± 0.5 |
| Crown Jewel | 393 ± 31                    | 16.4 ± 1.5 | 1.84 ± 0.17 | 3.53 ± 0.05 | 8.9 ± 1.7 |
| DJ Forry, w | 310 ± 10                     | 14.7 ± 0.3 | 1.29 ± 0.20 | 3.68 ± 0.04 | 11.4 ± 2.2 |
| DSN      | 368 ± 62                      | 11.9 ± 0.5 | 0.62 ± 0.09 | 3.52 ± 0.09 | 19.1 ± 3.0 |
| DSS      | 310 ± 10                      | 12.7 ± 0.3 | 1.09 ± 0.30 | 3.75 ± 0.11 | 11.7 ± 1.9 |
| Eve      | 508 ± 1                       | 14.0 ± 0.2 | 1.64 ± 0.07 | 3.27 ± 0.06 | 8.5 ± 0.4 |
| Fleshman | 386 ± 1                       | 14.0 ± 0.7 | 0.50 ± 0.04 | 3.70 ± 0.05 | 28.0 ± 2.7 |
| Gissarsk | 414 ± 28                      | 13.8 ± 0.2 | 1.49 ± 0.13 | 3.61 ± 0.03 | 9.3 ± 0.8 |
| Granada  | 369 ± 33                      | 14.6 ± 0.3 | 2.11 ± 0.35 | 3.53 ± 0.06 | 6.9 ± 1.3 |
| I7       | 375 ± 15                      | 14.1 ± 0.2 | 1.66 ± 0.08 | 3.57 ± 0.02 | 8.5 ± 0.4 |
| I8       | 325 ± 26                      | 13.5 ± 0.1 | 3.13 ± 0.13 | 3.30 ± 0.04 | 4.3 ± 0.3 |
| I11      | 354 ± 23                      | 13.8 ± 0.1 | 2.33 ± 0.13 | 3.62 ± 0.02 | 5.9 ± 0.3 |
| JC       | 347 ± 2                       | 12.7 ± 0.0 | 1.04 ± 0.02 | 4.38 ± 0.05 | 123 ± 2.0 |
| Jimmy    | 347 ± 3                       | 13.8 ± 0.0 | 1.48 ± 0.01 | 4.52 ± 0.01 | 9.3 ± 0.9 |
| King     | 385 ± 2                       | 13.9 ± 0.1 | 0.61 ± 0.09 | 3.70 ± 0.10 | 22.6 ± 5.4 |
| Lester   | 342 ± 11                      | 13.7 ± 0.3 | 0.63 ± 0.12 | 3.83 ± 0.03 | 21.7 ± 6.0 |
| Medoyvi  | 424 ± 36                      | 13.8 ± 0.2 | 0.46 ± 0.02 | 3.77 ± 0.03 | 29.9 ± 1.4 |
| Pink     | 400 ± 13                      | 11.7 ± 0.1 | 0.84 ± 0.08 | 3.55 ± 0.07 | 14.0 ± 1.5 |
| R2       | 367 ± 23                      | 13.8 ± 0.2 | 2.53 ± 0.25 | 3.41 ± 0.05 | 5.4 ± 0.8 |
| R5       | 406 ± 23                      | 13.3 ± 0.5 | 1.15 ± 0.16 | 3.66 ± 0.02 | 11.6 ± 1.3 |
| R6       | 482 ± 42                      | 13.8 ± 0.2 | 0.65 ± 0.04 | 3.30 ± 0.07 | 21.3 ± 1.3 |
| R8       | 354 ± 23                      | 13.7 ± 0.4 | 2.36 ± 0.88 | 3.15 ± 0.05 | 5.8 ± 1.4 |
| R9       | 371 ± 30                      | 14.1 ± 0.5 | 3.63 ± 0.82 | 3.32 ± 0.08 | 3.9 ± 0.6 |
| R19      | 529 ± 28                      | 13.8 ± 0.2 | 1.20 ± 0.18 | 3.47 ± 0.05 | 11.5 ± 3.1 |
| R25      | 410 ± 13                      | 12.9 ± 0.3 | 0.70 ± 0.08 | 3.31 ± 0.05 | 18.5 ± 2.2 |
| R33      | 459 ± 6                       | 14.6 ± 0.2 | 0.63 ± 0.08 | 3.55 ± 0.03 | 23.2 ± 2.8 |
| Rose     | 382 ± 1                       | 13.9 ± 0.2 | 1.32 ± 0.11 | 3.75 ± 0.16 | 10.5 ± 1.1 |
| Sin Pepe | 456 ± 46                      | 10.8 ± 0.5 | 0.27 ± 0.00 | 3.55 ± 0.05 | 39.5 ± 1.5 |
| Sireney  | 404 ± 0                      | 11.2 ± 0.0 | 0.46 ± 0.00 | 3.71 ± 0.00 | 245 ± 0.0 |
| Sweet    | 349 ± 7                       | 13.2 ± 0.6 | 1.09 ± 0.27 | 3.56 ± 0.17 | 12.2 ± 5.7 |
| Thomson  | 383 ± 2                       | 14.9 ± 0.3 | 1.10 ± 0.48 | 3.62 ± 0.14 | 13.6 ± 4.7 |
| Utah Sweet| 174 ± 4                      | 12.0 ± 0.6 | 6.20 ± 0.41 | 2.86 ± 0.14 | 1.9 ± 0.2 |
| Wonderful| 336 ± 6                       | 15.2 ± 0.3 | 1.23 ± 0.07 | 3.78 ± 0.03 | 12.5 ± 0.8 |
| Wonderful, w | 387 ± 27                    | 15.9 ± 0.1 | 1.53 ± 0.28 | 3.32 ± 0.05 | 10.4 ± 1.8 |
| Mean     | 398                           | 13.7     | 1.41             | 3.59             | 14.5     |

wValues represent means ± SE.

*Cultivars: Afganski (R26); Al sirin-nar (R6); Bala Miursal (R25); Barskislatki (C5); Ciparski (C8); Domaci kiseli (C6); Don Sumner North (DSN); Don Sumner South (DSS); Doroshi 5 hahanshahi Khoramabad (I7); Entek habi saveh (B); Gissarski Rozovyi (C1); Kaj-acik-anor (R9); Mejhos (R2); Nikitski ranni (R19); Sakerdze (R5); Salavatski (R8); Shirin Pust Ghermez Saveh (I11); and Surt-anor (R33).

*Maturity index = SSC/TA ratio.

*wWonderful, fruit purchased from a store in Tifton, GA.
Table 6. Pomegranate fruit juice total phenols (measured as gallic acid equivalents), antioxidant capacity [measured as Trolox equivalent antioxidant capacity (TEAC) and Cupric reducing antioxidant capacity (CUPRAC)], and total anthocyanin concentration from pomegranate cultivars grown in Georgia.

| Cultivar | Total phenols [gallic acid equiv. (mg·L⁻¹)] | TEAC (µM) | CUPRAC (µM) | Anthocyanins (mg·L⁻¹) |
|----------|---------------------------------------------|-----------|-------------|-----------------------|
| Azadi    | 858 ± 30°C | 19,487 ± 1,678 | 7,471 ± 555 | 11.9 ± 2.8 |
| C1       | 907 ± 87°C | 28,267 ± 6,994 | 8,447 ± 661 | 5.7 ± 1.5 |
| C5       | 989 ± 40°C | 51,817 ± 6,328 | 10,027 ± 231 | 4.6 ± 1.1 |
| C6       | 1,101 ± 47°C | 55,353 ± 5,323 | 11,814 ± 336 | 9.5 ± 1.9 |
| C8       | 865 ± 60°C | 46,506 ± 6,272 | 8,335 ± 441 | 18.0 ± 2.4 |
| Cloud    | 1,274 ± 225 | 12,458 ± 5,571 | 11,424 ± 837 | 31.3 ± 7.9 |
| Cranberry| 1,290 ± 124 | 38,904 ± 5,571 | 11,424 ± 837 | 31.3 ± 7.9 |
| Crown Jewel | 1,415 ± 111 | 33,351 ± 2,278 | 15,645 ± 958 | 9.8 ± 0.8 |
| DJ Forry | 2,016 ± 92°C | 37,607 ± 1,260 | 19,837 ± 1,149 | 13.0 ± 2.3 |
| DSN      | 1,305 ± 104 | 18,948 ± 2,063 | 11,998 ± 408 | 10.1 ± 1.7 |
| DSS      | 1,716 ± 114 | 17,158 ± 837 | 13,613 ± 861 | 20.4 ± 4.3 |
| Cloud    | 1,444 ± 240 | 23,648 ± 2,343 | 13,020 ± 1,357 | 37.7 ± 7.3 |
| R25      | 868 ± 69°C | 16,805 ± 930 | 9,916 ± 546 | 6.5 ± 3.4 |
| R26      | 674 ± 42°C | 16,805 ± 930 | 9,916 ± 546 | 6.5 ± 3.4 |
| R8       | 1,101 ± 47°C | 15,694 ± 1,046 | 9,172 ± 174 | 22.5 ± 8.2 |
| R9       | 1,998 ± 604 | 28,126 ± 3,728 | 10,115 ± 809 | 26.1 ± 4.6 |
| R19      | 636 ± 52°C | 16,815 ± 1,067 | 10,012 ± 345 | 1.7 ± 0.1 |
| R25      | 746 ± 23°C | 26,542 ± 3,040 | 9,243 ± 0 | 25.0 ± 2.1 |
| R26      | 820 ± 21°C | 30,597 ± 3,914 | 9,243 ± 0 | 25.0 ± 2.1 |
| R33      | 625 ± 35°C | 15,694 ± 1,046 | 9,172 ± 174 | 22.5 ± 8.2 |
| R5       | 1,452 ± 145 | 21,769 ± 951 | 13,922 ± 1,149 | 20.8 ± 4.3 |
| R6       | 868 ± 14°C | 17,399 ± 34 | 8,943 ± 571 | 4.1 ± 1.1 |
| Sakerdze | 908 ± 0°C | 20,791 ± 0 | 9,243 ± 0 | 25.0 ± 2.1 |
| Sweet    | 1,106 ± 38°C | 11,667 ± 271 | 11,879 ± 588 | 10.1 ± 1.2 |
| Thomson  | 1,214 ± 120 | 12,991 ± 679 | 11,053 ± 594 | 6.3 ± 0.5 |
| Utah Sweet | 1,418 ± 93°C | 14,686 ± 669 | 12,558 ± 410 | 7.7 ± 0.6 |
| Wonderful | 2,468 ± 240 | 30,890 ± 2,570 | 20,576 ± 1,010 | 50.0 ± 12.7 |
| Mean     | 1,163 ± 111 | 26,994 ± 11,820 | 16 |

| Cultivars: Afganski (R26); Al sirin-nar (R6); Bala Miursal (R25); Barskislatki (C5); Ciparski (C8); Domaci kiseli (C6); Don Sumner North (DSN); Don Sumner South (DSS); Dorosht 5 hahanshahi Khoramabad (I7); Entek habi saveh (I8); Gissarskii Rozovyi (C1); Kaj-acik-anor (R9); Mejhos (R2); Nikitski ranni (R19); Sakerdze (R5); Salavatski (R8); Shirin Pust Ghermez Saveh (I11); and Surh-anor (R33). |

yValues represent means ± SE.

Table 7. Pearson correlation coefficients between pomegranate juice color values (L*, a*, b*, Chroma*, and hue*) with juice total phenols (measured as gallic acid equivalents), antioxidant capacity [measured as Trolox equivalent antioxidant capacity (TEAC) and Cupric reducing antioxidant capacity (CUPRAC)], and total anthocyanin concentrations in fruit from cultivars grown in Georgia.

| TA | Total phenols | TEAC | CUPRAC | Anthocyanins | Aril L* | Aril a* | Aril b* | Aril C* | Aril h* |
|----|---------------|------|--------|--------------|---------|---------|---------|---------|---------|
| SSC | 0.02056x | 0.37827 | 0.04666 | 0.20753 | 0.21128 | -0.30402 | 0.30174 | -0.28859 | -0.37374 |
| TA | 0.5960x | 0.355 | 0.372 | 0.242 | 0.242 | 0.639 | 0.639 | 0.639 | 0.639 |
| SSC | 0.61847 | 0.36757 | 0.11025 | 0.12319 | 0.06198 | 0.33831 | 0.02444 | 0.36291 | -0.26876 |
| TAS | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 | 0.00001 |
| Total phenols | 0.14024 | 0.58204 | -0.11501 | 0.45236 | -0.20986 | 0.36439 | 0.04539 |
| TEAC | -0.0025 | 0.00303 | -0.00001 | -0.00001 | -0.00001 | -0.00001 | -0.00001 | -0.00001 | -0.00001 |
| CUPRAC | -0.00479 | 0.004372 | 0.02057 | 0.18972 | 0.01765 | 0.34398 | 0.02057 | 0.04372 | -0.04372 |
| Anthocyanins | 0.04035 | 0.4148 | -0.00001 | 0.00002 | 0.0380 | 0.00001 | 0.00002 | 0.0380 | 0.00001 |

xPearson correlation coefficient.

yP value.

zNumber of observations.