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Characterization of Attributes Related to Fruit Size in Pomegranate

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Abstract. **Pomegranate fruit is valued for its juice-containing arils and is consumed and marketed as whole fresh fruit, extracted arils, juice, syrup (grenadine), wine, teas, seed oil, and other products. Recent consumption has rapidly increased attributable in part to reported health benefits that include efficacy against coronary heart disease, atherosclerosis, cancer, hypertension, and infectious diseases. Within commercial orchards, the size of fruits produced can be quite variable even with trees of the same genotype grown under similar cultivation practices. Although pomegranates have been cultivated since antiquity, fruit attributes, particularly those related to size, are poorly defined. In this study, compositional changes in pomegranate fruits of the Wonderful cultivar, including volume and weight, aril weight and number, pericarp weight, seed weight, and juice/pulp content, were evaluated in fruits of variable sizes. Correlations between fruit characteristics were determined, and factor analysis established fruit and aril indices. Results indicated that because fruit volume, fruit weight, and total aril weight are closely correlated, any of these characteristics can be used as an indicator of fruit size. The number of arils per fruit was highly correlated with fruit size with larger fruit containing greater numbers of arils. This is in contrast to individual average aril weight, which showed no significant relationship to fruit size. Crop production strategies aimed at increasing aril numbers may be a means for obtaining larger fruit in pomegranate.**

The pomegranate, *Punica granatum*, has been cultivated as a fruit crop since antiquity. Native to central Asia, the pomegranate and its use are deeply embedded in human history with references in many ancient cultures of its use in food and medicine (Holland et al., 2009). Pomegranate produces fruit that is valued for its juice-containing arils, health benefits, and decoration and is consumed and marketed as whole fresh fruit, extracted arils, juice, syrup (grenadine), wine, teas, seed oil, and other products. In addition, it is used as an ingredient in an array of products ranging from cosmetics to nutritional supplements. Recent consumption of pomegranates has rapidly increased attributable in part to its reported health benefits that include efficacy against a wide range of conditions, including coronary heart disease, atherosclerosis, prostate cancer, hypertension, and infectious diseases (Basu and Penugonda, 2008; Holland et al., 2009; Lansky and Newman, 2007; Seeram et al., 2006).

The pomegranate fruit is spherical, crowned with a persistent calyx, and covered with a leathery pericarp derived from sepals and adhering floral tissue. Developing from a flower with showy crenulated petals, the hypogenous ovary contains a large number of ovules. Wetzstein et al. (2011) described the morphology and anatomy of the flower types in pomegranate, which consist of both hermaphrodite and functionally male flowers. Fruit are derived from hermaphrodite flowers, which have a discoid stigma covered with copious exudate, an elongated style, and an ovary with many ovules, which on fertilization develop into the hundreds of succulent juice-containing arils that make up the edible portion of the fruit. Male flowers fail to set fruit and have reduced female parts characterized by shortened pistils containing rudimentary, degenerated ovules (Shulman et al., 1984; Wetzstein et al., 2011).

Within commercial orchards, the size of fruits produced can be quite variable, even with trees of the same genotype grown under similar cultivation practices (N. Ravid, personal communication). Although pomegranates have been cultivated since antiquity, fruit attributes, particularly those related to size, are poorly defined. With market premiums for large-sized fruits and producer-targeted traits including high total aril weight and juice content, understanding fruit attributes is essential. Recent research has addressed quantitative evaluations of pomegranate fruit characteristics, but generally, objectives have been to compare genotypes for selection and breeding programs or to evaluate growth under different climatic conditions (Barone et al., 2001; Dafny-Yalin et al., 2010; Drogoudi et al., 2005; Mars and Marrakchi, 1999; Martinez et al., 2006).

Despite the long history of pomegranate culture as a fruit crop, literature is lacking on how fruit characteristics and components relate to changes in fruit size. Pomegranate exhibits considerable phenotypic diversity in fruit size among different genotypes (Drogoudi et al., 2005; Mars and Marrakchi, 1999; Martinez et al., 2006). However, the literature lacks evaluations of within-genotype fruit attributes and how fruits change in relation to size. A number of fundamental questions related to pomegranate fruit development remain unanswered. Unclear is how fruit composition changes with fruit size. What characteristics are associated with larger fruit? Do fruit components such as the proportion of aril to pericarp and membrane content stay constant or do they change with varying fruit size? Does juice content change with fruit size? What is more important to fruit size: increasing aril numbers per fruit or promoting more extensive aril enlargement?

Production strategies addressing these alternative circumstances would be quite different. Understanding the fundamental aspects of fruit development that determine size would indicate how and when size could be affected and specify which components can be environmentally manipulated versus which are fixed and under genetic control (Webb et al., 1974). Additionally, such knowledge would be useful to breeding programs that require awareness of fruit qualities in the selection of traits for improvement (Leon et al., 2004).

The objectives of this study are to evaluate fruit characteristics in pomegranate and to identify which attributes are related to size. Fruit attributes, including fruit volume and weight, aril weight and number, pericarp weight, seed weight, and juice/pulp content, were evaluated in a collection of 'Wonderful' pomegranate fruits of variable sizes. Correlations between fruit characteristics were determined. In addition, factor analysis was used to establish a fruit index that can be used to select and rate fruit.

Materials and Methods

Plant materials. Pomegranate fruits (*Punica granatum*, Punicaceae) were harvested from 8-year-old 'Wonderful' trees grown in

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commercial orchards located near Delano, CA, and managed under conventional commercial conditions. Pomegranate trees produce flowers over a several-week period. To ensure that fruit used in the study were of the same age, 100 hermaphroditic flowers of the same developmental stage, (i.e., 1 d before opening) were tagged on the same day (9 May) during the early wave of bloom. Petals were red–orange and extended beyond the sepal tips, but petals were not reflexed and stigmas and stamens were not visible. Fruit were not thinned. The 48 fruit that set from these tagged flowers were harvested at maturity (11 Oct.), which corresponded to standard commercial maturity criteria and harvest time. Fruit were then next-day shipped in coolers with blue ice to the University of Georgia for analysis.

Fruit characteristics. On arrival of the shipment, whole fruit weight, width (as an average of two perpendicular measurements), and height were measured. Fruit volume was estimated using the equation for a sphere ($V = 4/3\ \pi\ r^3$). Fruits were carefully opened to avoid damaging arils. The arils were separated from pericarp/membrane fractions, the total number of arils for each fruit was determined, and total aril weight per fruit obtained. Total non-aril weight, consisting of the pericarp and membranes, was calculated by subtracting aril weight from total fruit weight. Average weight per aril was calculated by dividing total aril weight by the total number of arils.

To determine aril seed and juice characteristics, 30 arils were randomly selected from each of 48 fruits and aril fresh weights were measured. Arils were then manually juiced and residual pulp carefully cleaned from the seeds using cheesecloth. Seeds were immediately weighed to obtain seed fresh weight. Juice and pulp weight were calculated by subtracting seed fresh weight from whole aril fresh weight. The percentage juice and pulp weight was calculated using: (juice + pulp)% = [(juice + pulp) weight/whole aril weight] × 100. Seeds were oven-dried to constant weight to obtain seed dry weights.

Correlation analysis. Pearson's correlation coefficients (Steel et al., 1996) were used to determine the degree of linear pairwise relations among fruit characteristics. Correlation coefficients measure the interdependence of two variables and indicate the strength and direction of a linear relationship between the two variables. The 11 fruit characteristics evaluated were: fruit volume, total fruit weight, total aril weight per fruit, total number of arils per fruit, total non-aril weight, percent aril weight, average aril weight, average seed fresh weight, average seed dry weight, average juice and pulp weight, and percent juice and pulp weight. A fruit characteristic correlation matrix was constructed.

Factor analysis. Factor analysis (Jolliffe, 2002) was used for the development of fruit and aril indices and used to describe variability within fruit characteristics. The 11 characteristics mentioned were used to establish a weighted measure of fruit attributes.

Results

Mature pomegranate fruit were spherical and had a glossy leathery pericarp and persistent calyx (Fig. 1A). Opened fruit revealed numerous juice-containing arils enclosed within a leathery pericarp (Fig. 1B). Arils were tightly packed and had polygonal, angular surfaces resulting from the crowding of arils during development (Fig. 1C). Pigmentation in the rind was restricted to the outer surface layers. In addition to the arils, the fruit interior contained white spongy tissue (pulp or rag) and membranous septal walls that separated the fruit into locules. Each aril (Fig. 1D) was composed of an outer layer of translucent juice-containing cells that surrounded an angular central seed (Fig. 1D, inset). Aril color was deep red.

The summary statistics showing mean, minimum, and maximum values for the fruit and aril characteristics obtained in this study are listed in Table 1. Fruits exhibited a wide range of sizes with the smallest and largest fruit having 62 and 112 mm diameters, respectively. Fruits ranged widely in volume and weight with these characteristics exhibiting a 5.8- and 5.5-fold increase between the smallest and largest fruits. A range of fruit sizes was highly desirable for this study because it allowed comparisons of fruit characteristics over fruits ranging from small to large.

Fruit separated into component parts similarly showed wide ranges in the proportion of edible and non-edible portions (Table 1). Total aril weight per fruit, total non-aril weight per fruit, and total number of arils per fruit exhibited 5.7-, 5.6-, and 4.9-fold differences, respectively, among all the fruit sampled. Aril characteristics varied somewhat among fruits (Table 1) but exhibited less variation than whole fruit characteristics. Average weight per aril, seed weight (fresh and dry), juice/pulp weight, and percent juice/pulp were relatively stable and varied 1.1- to 2.2-fold in all fruits. The mean percent aril weight for all fruit was 50% of the total fruit weight. Notable is that the percent aril weight was relatively consistent and ranged up to a 1.4 times difference among fruits of all sizes.

Fruit character correlations. The correlation matrix relating the different pomegranate fruit characteristics is presented in Table 2. Five fruit characteristics were strongly correlated: fruit volume, total fruit weight, total aril weight per fruit, total number of arils per fruit, and total non-aril weight per fruit. The relationship between six fruit characteristics is shown in Figure 2. Fruit weight and volume (Fig. 2A) and fruit weight and total aril weight per fruit (Fig. 2B) indicate strong positive relationships (significant at the 0.05 level) indicating that larger fruit are heavier and have greater total aril weight. The strong linearity of the relationships is evident in the strong correlation coefficients of 0.983 and 0.975, respectively (Table 2).

Fruit weight and volume were also strongly correlated with the number of arils in a given fruit ($r = 0.86$ and 0.83, respectively) (Table 2). The total number of arils per fruit increased as fruit weight increased and was significant at the 0.05 level (Fig. 2C). Small-sized fruits had fewer than 300 arils per fruit; larger fruits had over 600 arils per fruit, and up to 985 in the largest fruit. In contrast, the percent aril weight per fruit was poorly correlated with fruit size ($r = 0.175$), and no significant relationship was found at the 0.05 level (Fig. 2D).

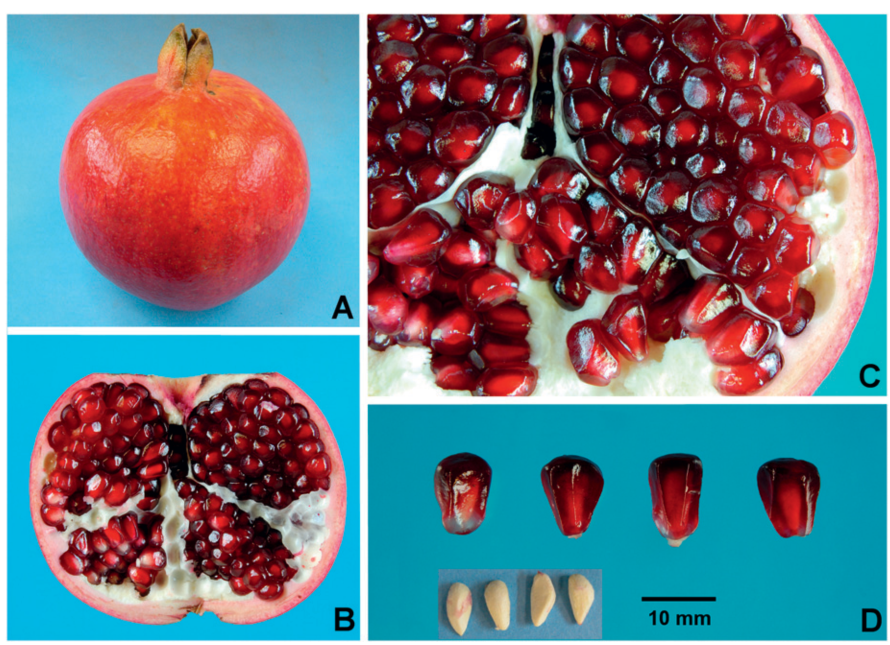

Fig. 1. Pomegranate fruit. (**A**) Whole fruit. (**B**) Longitudinal section of a fruit showing numerous arils within the leathery pericarp. (**C**) Closer view of an opened fruit showing pericarp, tightly packed arils, placenta, and inner membranes. (**D**) Whole arils showing the translucent juice sacs surrounding a central seed. Inset shows cleaned seed with juice and pulp removed.

Likewise, average aril weight was poorly correlated to fruit weight and volume (r = 0.452 and 0.474) (Table 2), indicating that heavier and bigger fruit are not composed of bigger arils. This was also the case for other aril characters including seed fresh and dry weights, average juice and pulp weight, and percent juice and pulp weight. No enhanced enlargement of aril tissues was observed in larger fruits. The relationship between fruit weight and average weight per aril (Fig. 2E) was also not significant at the 0.05 level. However, among arils of different sizes, a strong correlation was observed between aril weight and juice/pulp weight (r = 0.999) and aril weight and percentage juice/pulp (r = 0.881). The relationship between aril weight and percentage juice and pulp (Fig. 2F) was significant at the 0.05 level. It should be noted that the range for percent juice and pulp per aril was narrow (from ≈87% to 93%). Juice and pulp characteristics were not related to any other fruit characteristics.

Factor analysis. Eleven characteristics were used to establish fruit and aril indices (Table 3). Five characteristics (fruit volume, total fruit weight, total aril weight, total number of arils per fruit, and total non-aril weight per fruit) were highly related. This indicates that any one of these characteristics can be used as a measure to assess fruit size or used in fruit grading. Similar results occur for aril indices. Average weight per aril, average juice and pulp weight per aril, and percent of juice and pulp weight per aril are all major characteristics in explaining aril attributes. The lack of overlapping characteristics between the two indices indicates their independence. The characteristics associated with the aril index account for a very small amount of the variance explained in the fruit index. In terms of fruit size, it is not the average weight per aril but instead the number of arils that are associated with fruit volume and weight.

Discussion

Pomegranate fruits grown under normal commercial production methods exhibited a wide range of sizes. Fruits demonstrated more than a fivefold difference in both volume and weight between the smallest and largest fruits. This wide range in fruit size was observed even though fruits were from trees of the same genotype and age grown under identical cultural and environmental conditions. Fruits encompassed the full range of commercial grading classes: undersize fruits less than 71 mm diameter (size US) and those ranging from 71 to 127 mm diameter (size #42 to #16). Pomegranate trees produce flowers over a prolonged period. Flowering can occur from early May to November, although most flowering in the Central Valley of California occurs from mid-May to early June (Stover and Mercure, 2007). Fruit maturity can impact fruit size. However, the fruit evaluated in the current study were collected from same-aged flowers tagged on the same day to ensure that fruits were of an identical age. Fruit size can also vary with genotype. In the current study, all fruits were collected from ‘Wonderful’ trees, a dominant cultivar for the U.S. fresh and juice market.

The construction of a pomegranate fruit index using whole fruit characteristics (fruit volume, fruit weight, aril weight per fruit, skin and pericarp weight, and aril number) and individual aril characteristics (aril weight, seed weight, percent juice and pulp) identified key fruit characteristics that were highly related: fruit weight, fruit volume, total aril weight, total number of arils per fruit, and total non-aril weight. Larger fruits were heavier, had greater numbers of arils, and more total aril weight. The extremely high correlation between fruit volume and weight (r = 0.983) indicates that weight can be interchangeably used to indicate size. Also, aril number per fruit exhibited a strong linear relationship to fruit size. Thus, the development of a set of fruit characteristics for grading pomegranate fruit destined for different purposes (e.g., fresh fruit versus extracted arils) is probably not necessary. Instead, any of the characteristics loading high on the factor analysis fruit index (fruit volume, fruit weight, aril weight per fruit, skin and pericarp weight, and aril number) could serve as a measure. For example, crop breeders, farm managers, and marketing agents could use fruit weight, diameter, or volume as the index of size.

In terms of farm management practices, results indicate that methods with the objective of obtaining greater numbers of arils may be beneficial for enhancing fruit size. This is in contrast to managing the size or weight of individual arils. Mean aril weight was poorly correlated with fruit weight (r = 0.452) and aril weight remained relatively constant regardless of fruit size. Differences in average aril weight contributed little to fruit size. Larger fruit did not contain larger arils. Thus, increases in fruit size and weight do not appear to be a consequence of enhancement in aril development or enlargement.

Size is an important quality attribute in most fruit crops; thus, considerable work has been conducted to assess the underlying causes influencing fruit size. In many fruits, the major edible portions are derived from the ovary wall and floral parts where pericarp tissues, the receptacle, or floral tube are important contributors to the mature fruit. In a number of cases, fruit size variation has been correlated to differences in cell number

Table 1. Summary statistics of pomegranate fruit and aril characteristics.[z]

	Mean ± SD	Minimum	Maximum
Fruit characteristic			
Fruit diameter (mm)	90 ± 11	62	112
Fruit volume (cm^3)	391 ± 136	126	731
Total fruit wt (g)	345 ± 114	114	623
Total aril wt per fruit (g)	174 ± 62	55	313
Total non-aril wt per fruit (g)	170 ± 56	60	334
Total no. arils per fruit	488 ± 167	201	985
Percent aril wt to total fruit wt	50.4 ± 3.9	40.0	57.7
Aril characteristic			
Avg aril wt (mg)	357 ± 51	226	469
Avg seed fresh wt (mg)	33 ± 2.9	25	40
Avg seed dry wt (mg)	23 ± 1.7	18	26
Avg juice + pulp wt per aril (mg)	324 ± 49	196	436
Percent juice + pulp wt	90.5 ± 1.4	86.6	92.9

[z]Data are for 48 fruits.

Table 2. Pomegranate fruit characteristic correlation matrix.

	Fruit volume	Total fruit wt	Total aril wt per fruit	Total no. arils per fruit	Total non-aril wt	Percent aril wt	Avg aril wt	Avg seed fresh wt	Avg seed dry wt	Avg juice and pulp wt	Percent juice and pulp wt
Fruit volume (cm^3)	1.000										
Total fruit wt (g)	**0.983**	1.000									
Total aril wt per fruit (g)	**0.957**	**0.975**	1.000								
Total no. arils per fruit	**0.830**	**0.863**	**0.914**	1.000							
Total non-aril wt (g)	**0.955**	**0.970**	**0.891**	**0.756**	1.000						
Percent aril wt	0.170	0.175	0.379	0.453	–0.060	1.000					
Avg aril wt (g)	0.474	0.452	0.384	0.008	0.501	–0.167	1.000				
Avg seed fresh wt (g)	0.178	0.150	0.060	–0.083	0.240	–0.394	0.421	1.000			
Avg seed dry wt (g)	0.461	0.439	0.370	0.161	0.489	–0.241	**0.666**	**0.741**	1.000		
Avg juice and pulp wt (g)	0.475	0.454	0.389	0.013	0.498	–0.147	**0.999**	0.372	**0.638**	1.000	
Percent juice and pulp wt	0.396	0.394	0.380	0.066	0.386	0.084	**0.811**	–0.163	0.306	**0.839**	1.000

Numbers in bold represent high relative pairwise correlations.

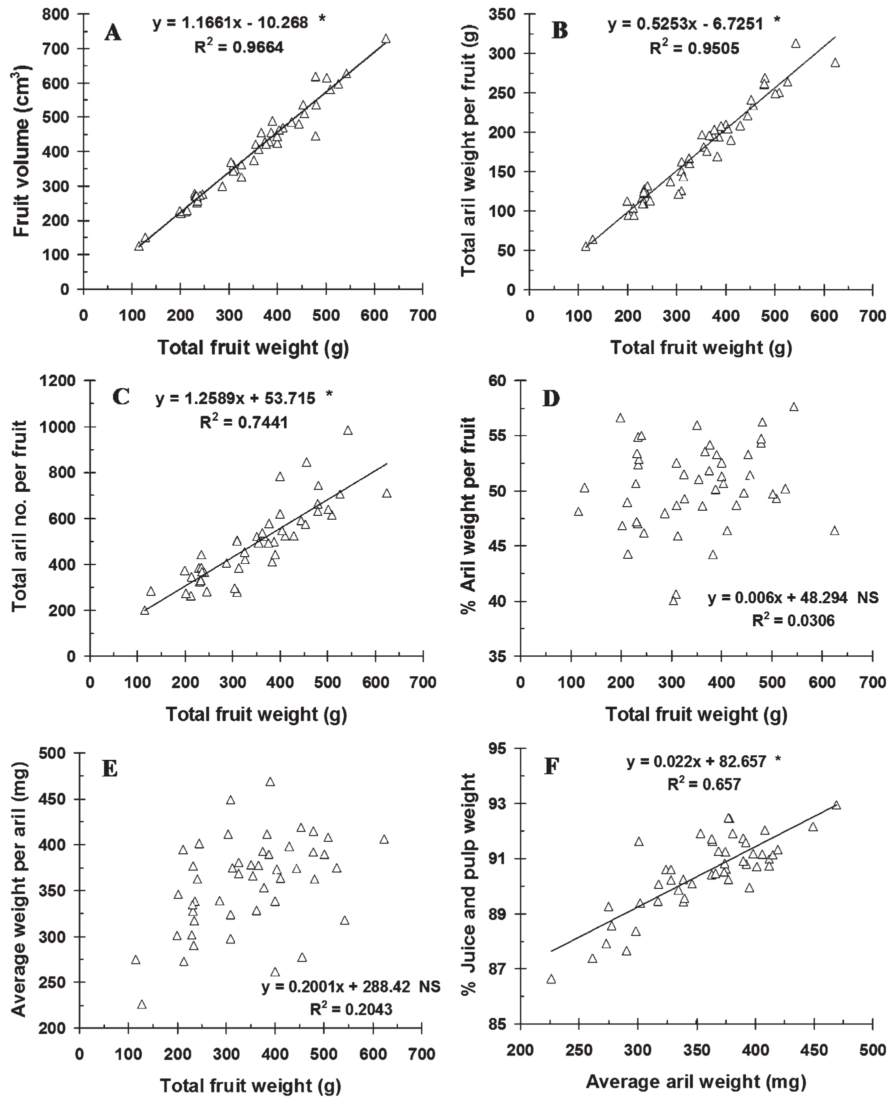

Fig. 2. Relationships between fruit characteristics in pomegranate. (**A**) Fruit weight and fruit volume. (**B**) Fruit weight and total aril weight per fruit. (**C**) Fruit weight and total aril number per fruit. (**D**) Fruit weight and percent aril weight. (**E**) Fruit weight and average weight per aril. (**F**) Aril weight and percent aril juice and pulp. Relationships are denoted as being significant (*) or non-significant (NS) at the 0.05 significance level.

Table 3. Fruit and aril indices for pomegranate using factor analysis.

Characteristic	Fruit index	Aril index
Fruit volume	**0.938**	0.266
Total fruit wt	**0.959**	0.250
Total aril wt per fruit	**0.940**	0.217
Total number of arils per fruit	**0.936**	–0.143
Total non-aril wt per fruit	**0.923**	0.271
Percent aril wt to total fruit wt	0.187	–0.043
Average wt per aril	0.191	**0.895**
Average seed fresh wt per aril	0.031	0.216
Average seed dry wt per aril	0.268	0.381
Average juice and pulp wt per aril	0.194	**0.915**
Percent of juice and pulp wt per aril	0.183	**0.959**

A bold number indicates the index is highly influenced by the associated characteristic.

of these tissues. Larger-sized fruits were associated with greater mesocarp cell numbers in peach, *Prunus persica* (Scorza et al., 1991), olive, *Olea europaea* (Rapoport et al., 2004), sweet cherry, *Prunus avium* (Olmstead et al., 2007), Saskatoon, *Amelanchier alnifolia* (McGarry et al., 2001), and rabbiteye blueberry, *Vaccinium ashei* (Johnson et al., 2011). In strawberry (*Fragaria ×ananassa*), fruit size was correlated with the number of receptacle cells (Cheng and Breen, 1992). In apple (*Malus* sp.), both a greater cell division capacity and enhanced cell elongation of perianth tissues were associated with large-sized fruits (Harada et al., 2005). Larger fruit size in mandarin (*Citrus aurantium*) was attributed to increases in juice sac development through an enhancement of cell size resulting from greater cell elongation (El-Otmani et al., 1993).

Understanding that aril number (and not aril size) dictates final fruit size has important implications on cultural practices. Pomegranate trees produce large, showy flowers with a single elongated style, over 100 anthers, and an inferior ovary that contains hundreds to thousands of ovules (Wetzstein et al., 2011). Each aril is the product of a fertilization event in which a pollen grain germinates on the stigma and fertilizes an ovule. Thus, a large fruit, which can have 1000 arils or more, requires an equivalent number of fertilization and seed development events to take place. A number of reproductive requirements must be met, which include a source of viable and compatible pollen, adequate deposition of pollen on the stigma, tube growth within the style, fertilization, and embryo development (Hiscock and Allen, 2008; Wetzstein et al., 2011). Pollination and fertilization events occur early during fruit development. That final fruit size may be determined so early in the season points out that careful crop management during this time period is critical for obtaining large fruit and high yields.

Flower quality may potentially be a factor influencing fruit size in pomegranate. The production of large fruits requires flowers with adequate numbers of both functional ovules and a source of viable pollen. Pomegranate is characterized as having hermaphrodite and functionally male flowers, a condition called andromonecy. Variation in flower quality can range from those having well-formed ovules to those with degenerated ovules (Holland et al., 2009; Wetzstein et al., 2011) implicating ovule number as a potential factor limiting fruit size. In pomegranate, ovule differentiation occurs in flower buds well before opening (Wetzstein and Ravid, 2008). Clearly defining the timing of flower initiation and development is warranted as well as studies to determine the effect of variables that affect flower strength and vigor (quality). Flower and/or ovary size have been shown to impact final fruit size in a number of other fruit crops, including peach (Scorza et al., 1991), blueberry (Johnson et al., 2011), and olive (Rosati et al., 2009).

Adequate pollination is critical for fruit development and in pomegranate is required to produce large-sized fruits. Pomegranate flowers produce large amounts of pollen in anthers that can number from over 100 to more than 300 stamens per flower (Derin and Eti, 2001; Wetzstein et al., 2011). Reports suggest that pollen viability in pomegranate is high. Pollen viability assessed using in vitro germination assays varied from 97% to 65% in a comparison of three cultivars in India (Josan et al., 1979). Pollen germination in two cultivars, Hicaz and 33 N 26, grown in Turkey ranged from 57% to 69% (Derin and Eti, 2001). In our previous studies conducted with ‘Wonderful’ pollen, germination was strongly influenced by temperature with maximal germination (greater than 74%) obtained at 25 and 35 °C; lower temperatures significantly inhibited germination (Wetzstein et al., 2011). In the current study, flowers were tagged and allowed to open-pollinate. Results suggest that further studies on pollination biology and pollen dispersal in pomegranate may yield information for developing cultural practices that will significantly enhance fruit size.

In pomegranate, fruit size was highly correlated with both total aril and non-aril (pericarp and membrane) weights. Percentage aril weight remained ≈50% of the total fruit weight regardless of fruit size. An interest in understanding fruit attributes and how size relates to the percent of edible aril weight is pertinent, especially with the onset of mechanical extraction methods (Blasco et al., 2009) for marketing pomegranate arils in a ready-to-eat form. The results of this study indicate that although larger fruits contain more arils on a per fruit basis, selecting fruit for size will not improve the percentage of edible yield per fruit. This is in contrast to other fruits such as sweet cherry in which the proportion of pit to flesh changed with size; although both pit and flesh diameter increased in larger fruits, flesh increased proportionally more than pit (Olmstead et al., 2007). In saskatoons, the ratio of the mesocarp to endocarp–locular–ovular structure varied with fruit size (McGarry et al., 2001).

Fruit size is clearly influenced by genetic controls. In tomato (*Lycopersicon esculentum*), fruit inheritance studies indicated that significant positive correlations exist among fruit maturation period, fruit weight, and locule number (Kemble and Gardner, 1992). Pomegranate germplasm can exhibit considerable phenotypic diversity in physical and chemical characteristics, including fruit size, color, pericarp thickness, seed hardness, and juice biochemistry (Barone et al., 2001; Borochov-Neori et al., 2009; Dafny-Yalin et al., 2010; Drogoudi et al., 2005; Mars and Marrakchi, 1999; Martinez et al., 2006; Schwartz et al., 2009). Nonetheless, the current study shows that even within a single genotype, same-aged fruits grown under similar cultural conditions can show marked differences in size. This indicates that any studies evaluating pomegranate fruit characteristics such as size, volume, and weight should take precautions so that fruit samples are sufficiently large to compensate for large fruit-to-fruit variation. This is in contrast to characteristics such as percent juice, ratio of aril to whole fruit weight, and mean aril size, which exhibit less variability within a genotype and could thus be accurately assessed with smaller sample numbers.

In summary, fruit attributes and compositional changes were evaluated in 'Wonderful' pomegranate fruits of different sizes. Results indicated that because fruit volume, fruit weight, and total aril weight are closely correlated, any single character can be used as a common indicator of fruit size. The number of arils per fruit was highly correlated with fruit size with larger fruit containing greater numbers of arils. This is in contrast to average aril weight, which had no significant relationship to fruit size. Limitations in final fruit size could result from poor ovule development, insufficient pollination, or inadequate fertilization. Crop production strategies aimed at increasing aril numbers may be a means for obtaining larger fruit in pomegranate.

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