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Fruit quality traits of ten California-grown pomegranate cultivars harvested over three months

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ABSTRACT

Pomegranate (*Punica granatum* L.) is a deciduous tree crop. Its fruit are known to have relatively high concentrations of polyphenolic compounds and antioxidant properties. The USDA-ARS pomegranate germplasm collection maintains over 250 cultivars, but most have not been evaluated for optimal harvest dates or fruit quality. In the following investigation, pomegranate germplasm was evaluated to determine optimal harvest windows, identify cultivars with consumer-friendly traits, and to compare fruit quality with the industry standard, 'Wonderful.' Fruit from ten cultivars were analyzed for the following traits: fruit weight, fruit diameter, fruit length, calyx diameter, calyx length, weight of 100 arils, weight of all arils, edible portion of fruit, ºBrix, titratable acidity (TA) (% in citric acid equivalents), maturity index (MI) (sugar to acid ratio), antioxidant activity (AA) (% inhibition of DPPH), and total phenolics (mg/L in gallic acid equivalents). Cultivars selected from the germplasm included those similar to 'Wonderful' as well as cultivars with other traits, such as softer seeds, which could meet wider consumer demand. Many trait values increased over time (ºBrix, MI, etc.), while some decreased over time (AA, TA). Sugar to acid ratio was used as the MI and there were significant differences among cultivars. Lower acid, sweet cultivars had higher MI than sweet-tart, tart, and sour cultivars. For cultivars with high sugar to acid ratios, growers may need a different MI from 'Wonderful' to determine fruit maturity for commercial production.

1. Introduction

Pomegranate is a deciduous tree crop that has been domesticated for thousands of years for its fruit, flowers, bark, and leaves (Levin, 2006, Preece and Moersfelder, 2016), all of which have been believed to possess medicinal properties (Holland et al., 2009; Lansky and Newman, 2007). Despite its long history of cultivation, limited horticultural information is available for growers, breeders, and the food and beverage industries about when fruit of a given cultivar is ready for harvest, processing and consumption (Fawole and Opara, 2013). In the United States, 'Wonderful,' the industry standard (Brooks and Olmo, 1997), is a sweet-tart, moderately hard-seeded fruit that has been reported to have astringent and bitter juice compared to other cultivars previously analyzed from the collection at the United States Department of Agriculture - Agricultural Research Service (USDA-ARS) National Clonal Germplasm Repository (NCGR), Davis, CA (Beaulieu et al., 2015). Despite these negative fruit quality traits, pomegranate cultivation in the United States remains predominantly a monoculture of 'Wonderful.' It is believed that cultivars in the national germplasm with desirable traits, such as soft seededness and low acidity, may be candidates for commercial production (Stover and Mercure, 2007).

Studies have demonstrated a large variation in mature fruit size within commercial orchards of 'Wonderful,' which poses a problem for fresh market growers and packers. Wetzstein et al. (2011) reported a greater than five-fold range in mature fruit volume and weight in commercial 'Wonderful' pomegranates. Factors that influence fruit size and yield include aril number (Wetzstein et al., 2011), cultivar (Levin, 2006), cultural practices (Glozer and Ferguson, 2008), and plant maturity (Glozer and Ferguson, 2008). Finding cultivars with better uniformity than 'Wonderful' would be beneficial to the industry.

In addition to variable fruit size, dates of fruit maturity can play a major role in fruit quality. Late season harvests run the risk of fall rains, which have been associated with greater numbers of split fruit (Holland et al., 2009). Typical commercial harvest windows for 'Wonderful' range from late September to early November, but fruit in the Central Valley of California, USA, where the most pomegranates are grown in America, are typically ready to harvest starting in late October. Usually by November, weather, especially rains, and pests will begin to damage

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Table 1
Descriptions of ten pomegranate cultivars from the USDA-ARS National Clonal Germplasm Repository used in this investigation. Parameters known include country of origin, acidity, flavor, peel color, aril color, and seed hardness. All fruits were picked at maturity from the national pomegranate germplasm collection in Winters, CA.

Cultivar	Country of origin	Acidity	Flavor	Peel color	Aril color	Seed hardness
Ambrosia	USA	Low	Sweet	Pink	Pink	Hard
Desertnyi	Turkmenistan	Medium	Sweet-tart	Red	Red	Soft
Eversweet	USA	Very Low	Sweet	Pink and yellow	Pink	Soft
Golden Globe	USA	Low	Sweet	Yellow and pink	Pink	Hard
Green Globe	USA	Low	Sweet	Greenish yellow	Pink	Hard
Haku Botan	Japan	Very High	Sour	White/yellow	White	Hard
Loffani	USA	Low	Sweet	Pink	Pink	Hard
Parfianka	Turkmenistan	High	Sweet-tart	Red	Red	Soft
Phoenicia	USA	High	Tart	Yellow, Green, pink	Red	Hard
Wonderful	USA	Medium-high	Sweet-tart	Red	Red	Medium hard

the fruit. Therefore, harvest date can determine whether a cultivar is a good candidate for commercial production. Cultivars with an earlier fruit maturity date than 'Wonderful' have more commercial potential than later ones.

In addition to the fresh fruit market, pomegranates are also utilized for juice. The beverage and wine industries utilize different fruit juices that have sufficient quantities of organic acids, carbohydrates, and phenolic compounds. Generally, citric acid is the most abundant organic acid in pomegranate juice, so TA is generally expressed in citric acid equivalents. Concentrations of total soluble solids (TSS), often expressed in ºBrix, for commercial pomegranates range from 12% to 16% at maturity. It is recommended that 'Wonderful' have at least 15% TSS at harvest (Fawole and Opara, 2013), but above 17% is preferable (Crisosto et al., 2013). Hasnaoui et al. (2011) reported that citric acid is the determinant of sour flavor in pomegranate juice, despite sugar concentration. Sweet (or low acid) pomegranates typically have been reported to have citric acid concentrations less than 0.50% (Beaulieu et al., 2015; Hasnaoui et al., 2011). Standards for fruit maturity of sweet cultivars are being investigated because growers often pick early-season cultivars too early (before maturity) in order to increase profits (Mayuoni-Kirshinbaum and Porat, 2014). There are no known imposed regulations on growers in any country, meaning they can harvest early before fruit maturity without short-term consequence. The effect of picking early on consumer perception and acceptance of pomegranate fresh fruit has been shown to be associated with astringency and a low flavor preference score (Mayuoni-Kirshinbaum and Porat, 2014).

Standards have been proposed for titratable acidity (TA) and TSS for 'Wonderful' pomegranate (Kader, 2006). 'Wonderful' pomegranate fruit is considered mature when juice is lower than 1.85% TA (Kader, 2006), so fruit are picked when fruit measure below that threshold.

Maturity index (MI) is a standardized measure of maturity in many fruit crops. For pomegranate, a commonly used MI is the ratio of °Brix to TA, also known as the sugar to acid ratio. This ratio is often used to determine fruit maturity, but it has been found not to be uniform for all cultivars, especially sweet, low-acid ones. Instead, is was proposed that fresh aril weight be used as the indicator of fruit maturity and consumer acceptance in the sweet cultivars (Mayuoni-Kirshinbaum and Porat, 2014). The optimum MI for 'Wonderful' has been calculated to be greater than 8.1, at which point the fruit is ready for harvest. Other cultivars may have significantly different quantities of organic sugars and acids, so optimum MI may be different for different types of pomegranates (insipid, sweet, sweet-tart, tart, sour, bitter, etc.) (Lina et al., 2014).

Fruit quality is not only related to sugar content, TA and spoilage, but also to phenolic compounds that contribute to the fruit's flavors, antioxidant activity, and color (Gil et al., 2000). Cultivar is more influential in determining fruit juice composition than site of cultivation, year of harvest, or length of storage (Belton et al., 1998), so it is important to investigate differences in traits among cultivars to identify superior cultivars in germplasm resources and make them available to growers and consumers. Determining quantities of phenolics and the antioxidant activity of a cultivar's juice is important to the beverage industry and consumers because advertisements promote high antioxidant activity as the main selling point of juice products. If any cultivar were to demonstrate similar antioxidant activity to 'Wonderful,' it would possibly be competitive in the pomegranate market were it to meet other consumer preferences. Having lower antioxidant activity than 'Wonderful' could make for an undesirable candidate for commercial production, although the public is unlikely to be able to detect flavor differences in antioxidant activities among differnt cultivars.

The objectives of this research were: 1) to evaluate fruit and juice quality traits of NCGR germplasm by comparing commercial quality parameters to the industry standard, Wonderful; and 2) to determine potential harvest windows of ten preselected pomegranate cultivars, based on seasonal trends of potential maturity indices for different harvest dates.

2. Materials and methods

2.1. Plant materials

Fruit were harvested from the USDA-ARS National Clonal Germplasm Repository for Tree Fruit and Nut Crops and Grapes in Davis, CA, USA for two seasons. The trees were all over nine-years-old and at full maturity. The pomegranate cultivars analyzed included: 'Ambrosia,' 'Desertnyi,' 'Eversweet,' 'Golden Globe', 'Green Globe,' 'Haku Botan,' 'Loffani,' 'Parfianka,' 'Phoenicia,' and 'Wonderful' (Table 1). The cultivars in this investigation with softseeds included 'Desertnyi,' 'Eversweet' and 'Parfianka.' Low acid (sweet) cultivars included 'Ambrosia,' 'Desertnyi,' 'Eversweet,' 'Golden Globe,' 'Green Globe,' and 'Loffani.' 'Wonderful' fresh fruit was included as a control and as the standard to compare the other cultivars in this study. All cultivars are of American origin except for 'Haku Botan' (from Japan), 'Desertnyi' and 'Parfianka' (both from Turkmenistan).

Up to twelve fruit of each cultivar were hand-harvested in mid-September, mid-October, and mid-November in 2014. This was repeated in 2015. Fruit were ground shipped, and then stored at 6 °C and 98% relative humidity for 3-4 weeks until processing. Fresh market quality fruit, as defined by being well-filled, mature, and unblemished, were chosen for juice analysis from each of the 10 cultivars. Three cultivars, 'Golden Globe,' 'Green Globe' and 'Parfianka,' had insect or physical fruit damage in November, so less fruit were available for these cultivars during November harvest dates. 'Golden Globe' and 'Parfianka' had no fresh market quality fruit available in November 2015 and 'Green Globe' had no fresh market fruit available for 2014 and 2015. At this end of season harvest date, the trees of these cultivars had fruit that were either cracked, sunburned, rotted, or damaged by insect pests, especially leaf-footed bug (*Leptoglossus* sp.).