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Orchard establishment, precocity, and eco-physiological traits of several pomegranate cultivars

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ABSTRACT

California faces many threats to food security, ranging from water limitations resulting from long-term drought to invasive pests and diseases. Major tree crops, such as citrus and avocado, are threatened by Citrus Greening and Fusarium Dieback, respectively, posing significant economic losses to growers and farm sustainability. Pomegranate (*Punica granatum* L.) was previously a minor tree crop in California, but has become an important specialty crop, with planted area increased by 10-fold during the last twenty years, and is currently a $200 million annual industry. Pomegranate is not threatened so far by any pest or disease and is a drought- and salt-tolerant crop that can be cultivated on marginal land, which makes it an attractive alternative crop for the growers facing water and disease issues. For this investigation, two pomegranate field trials were initiated and followed over four years to evaluate site effects on establishment, precocity, photosynthesis and water relations to assist in determining appropriate cultivars for coastal versus inland climates. Traits measured included orchard establishment, photosynthesis, water potential, and flowering and yield traits. There were significant site and cultivar effects on many traits as well as site-cultivar interactions. The coastal trial grew significantly faster than the semi-arid inland site, however, the inland site was more productive than the coastal site for the first three years. Production during year four of establishment was similar at both sites.

1. Introduction

Global food security is threatened by climate change, which includes increasing temperatures and other unpredictable changes in weather patterns potentially damaging to agricultural systems (Altieri and Nicholls, 2017). For example, long-term drought in California has caused significant economic losses to farmers (Medellín-Azuara et al., 2016), with extreme and exceptional drought affecting significant percentages of California land from 2013 until early 2017. Drought in California has driven farmers to engage in crop abandonment, stress irrigation, the replacement of water-intensive crops with alternative crops (Medellín-Azuara et al., 2016), and most recently, using secondary water resources often available from urban or suburban wastewater systems. To lessen the impacts of climate change, it has been proposed that crop diversification may reduce the risk of food system vulnerability (Altieri and Nicholls, 2017).

Challenges posed by drought and water scarcity issues have led physiologists and breeders to focus on water-use efficiency in agriculture (Wallace, 2000). Improving production efficiency and drought tolerance through cultivar selection has been proposed in citrus (Savé et al., 1995) *Prunus* species (Rieger and Duemmel, 1992), dates (Djibril et al., 2005), and coffee (DaMatta, 2004). Because tree crops have some degree of variability of physiological traits among genotypes in the same species, it is useful to study diversity within crop species to determine if there are cultivars that use water more efficiently or are as productive in cropping system conditions of high abiotic stress. Pomegranate is touted as a drought tolerant crop, especially once established (Stover and Mercure, 2007), and it is being evaluated in California as an alternative tree crop species to replace or supplement more water-intensive species, such as avocado, citrus and almond (McClurg, 2015), all three of which face pest and disease threats of their own.

Historically, pomegranate has been growing in California for hundreds of years, even before statehood, starting with the Spanish missionaries who arrived in the 1700s (Day and Wilkins, 2009) and allegedly planted mongrel seed from Spain in their gardens. Pomegranate is a minor crop in California with a market value of approximately $200 million annually for juice and fresh market. The body of knowledge regarding differences in pomegranate physiology, establishment, and

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site/climate effects among cultivars conserved in germplasm is limited. Even less is known about how climate affects precocity, the reproductive biology, flowering, and fruiting of young pomegranate trees. This limitation is a barrier to commercial growers and nurseries adopting new or flouted cultivars that have traits with the potential to decrease water use and increase consumer demand for the fruit. Breeders also benefit from having germplasm phenotyped so that efforts to utilize molecular tools to map quantitative trait loci within breeding populations can be pursued for crop improvement.

The National Clonal Germplasm Repository (NCGR) of the United States Department of Agriculture - Agricultural Research Service (USDA-ARS) in Davis, CA, has conserved about 200 genotypes of pomegranate in their Winters, CA experimental orchard. Many of them have consumer-friendly phenotypic characteristics, not perceived in the industry standard cultivar 'Wonderful' (Stover and Mercure, 2007). Previous investigations from our laboratories have demonstrated differences in morphology and vegetative growth traits during the propagation phase of the present study (Chater et al., 2017). Studies have shown that there can be differences among cultivars for many agriculturally-relevant physiological traits of pomegranate in other collections, including transpiration rate, stomatal conductance, water-use efficiency, photosynthetic rate and chlorophyll content (Drogoudi et al., 2012; Hepaksoy et al., 2000). The objectives of this research were: 1) to evaluate eleven unique pomegranate cultivars for field performance in semi-arid and coastal Mediterranean climates to determine plant establishment rates and site effects on reproductive biology; and 2) to evaluate four pomegranate cultivars for field performance in coastal versus inland agroecosystems to determine if there are differences among the genotypes for physiological traits that would be conducive to commercial crop production in drought conditions.

2. Materials and methods

2.1. Site conditions

The trials were conducted at the Agricultural Experiment Station of the University of California, Riverside, CA (33° 58′ 9.39″ N, 117° 20′ 46.93″ W, approximate elevation 340 m above the sea level) and on private land in Somis, CA (in proximity to 34° 15′ 26″ N 118° 59′ 43″ W, approximate elevation 98 m above the sea level) (Table 1). Riverside, CA (Riverside) is a semi-arid climate with hot, dry summers and cool winters whereas Somis, CA (Somis) is a coastal Mediterranean climate with warm, dry summers and wet, cool winters. Climate descriptions are based on Köppen climate classification. At Riverside, the mean annual precipitation of the area is 262 mm and mean high temperatures are 28 °C and 36 °C for June and August, respectively. Mean temperature lows are 13 °C and 18 °C for June and August, respectively and 5 °C, 6 °C, and 7 °C for December, January and February, respectively. The soil is a sandy loam with good drainage and was previously an established lemon grove. At Somis, mean annual precipitation of the area is 468 mm and mean high temperatures are 26 °C and 28 °C for June and August, respectively. Mean temperature lows are 13 °C and 14 °C for June and August, respectively and 5 °C, 5 °C, and 6 °C for December, January and February, respectively. The soil at Somis is a heavy sandy clay that was previously an established avocado grove. All trees were growing outside in field conditions with drip irrigation three times per week to replace water lost to soil evapotranspiration (ETo) as determined by California Irrigation Management Information System (CIMIS) weather stations in Riverside and Ventura counties. Trees were grown under conventional commercial management practices and fertilized in spring with urea and potassium sulfate, totaling 31.75 kg N, and 34 kg K per year, respectively, over approximately 0.81 ha (Approximately 39 kg/ha N and 42 kg/ha K). All experimental trees were followed during their first four years of development and were located on the inside of the grove, with at least one border tree acting as a buffer to reduce the edge effect.

2.2. Plant material

Two pomegranate cultivar trials were utilized for this study. The cultivars selected for the study were Ambrosia, Desertnyi, Eversweet, Golden Globe, Green Globe, Haku Botan, Loffani, Parfianka, Phoenicia, cv. 857 (an heirloom cultivar from Ventura County, USA) and Wonderful (Table 2). Cultivars were either cultivars bred for coastal sites or those that are typically grown in inland sites. Fruit acidity was the basis used for coastal versus inland cultivar categorization, with low acid cultivars considered for coastal and medium to high acid cultivars considered for inland applications. Coastal cultivars included Ambrosia, Eversweet, Golden Globe, Green Globe, and Loffani. Inland cultivars included Desertnyi, Haku Botan, Parfianka, Phoenicia, and Wonderful. For the heirloom cultivar included (cv. 857), it is unknown whether it is a coastal or inland cultivar. All genotypes were sourced from the National Clonal Germplasm Repository, Davis, CA, and propagated via dormant hardwood cutting at the same time in winter of 2012. All trees included were mature and most cultivars were bearing commercial loads of fruit by the fourth year. For physiological trait evaluations, three trees per cultivar were selected from a cultivar trial that consisted of a randomized complete block design with five blocks, three trees per cultivar per block, for a total of 15 trees per cultivar in the entire orchard. One tree was selected from three of the five blocks of the trial each day of measurement. Wonderful is the industry standard in many countries and was chosen as a control in the cultivar field trial. Wonderful is a widely-grown commercial cultivar that originated in Florida, it accounts for approximately 90–95% of production in the USA. It is a vigorous, thorny tree that has high yield with red fruit that have red arils with moderate seed hardness and a sweet-tart flavor. The growth habit is willowy, with a tendency to sucker at the base of the tree. There exists limited quantitative field establishment or physiology data for Wonderful and all other cultivars in this study.

2.3. Establishment measurements

Trunk diameter was measured in cm with a digital caliper in spring of each year, with the measurement taken approximately 15 cm above the soil level. Tree canopy diameter was measured in-row and between rows to determine how quickly trees were growing into each other and into the rows. Tree height and in- and between row spacing measurements were taken with a folding rule.

Equation 2.1 Equation for area of canopy.

$$S = \pi b x^2 + \frac{\pi a b}{e} \sin^{-1} e$$

Equation 2.2 Equation for eccentricity of ellipse.

Table 1
Site conditions after three years of growth of two cultivar field trials in Riverside, CA and Somis, CA planted with pomegranate cultivars sourced from the USDA-ARS National Clonal Germplasm Repository. Variables include soil mineral nutrient elements N, P, K (exchangeable), Ca (exchangeable), Mg (exchangeable), Na (exchangeable), S, B, Cu, Fe, Mn, Zn (in $g{\cdot}m^{-3}$). All mineral nutrients are reported in $g{\cdot}m^{-3}$. Soil analyses were conducted by a private laboratory.

Site	N	P	K	Ca	Mg	Na	S	B	Cu	Fe	Mn	Zn
Riverside, CA	12.7	13.6	240.5	4265.7	1338.6	99.3	86.8	0.4	1.5	24.0	22.8	10.0
Somis, CA	32.7	10.0	231.3	4228.9	1301.8	147.1	251.5	0.3	1.2	22.1	8.53	3.09