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Water stress for a short period before harvest in nectarine: Yield, fruit composition, sensory quality, and consumer acceptance of fruit

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ABSTRACT

This study addressed the possibility of increasing consumer acceptance of nectarine fruit by reducing irrigation for a short period during the late phase of fruit growth. Deficit irrigation (DI) was applied for 15 days before harvest in 2011 and for nine days in 2012 to the early-maturing 'Gardeta' nectarine. Fruit diameter, pulp dry matter concentration, firmness, titratable acidity, soluble solids concentration, skin and pulp colour, several sensory traits and consumer acceptance of fruit were evaluated twice at harvest. In 2011 and 2012 mean midday stem water potential (SWP) during the experimental period was −1.25 MPa and −1.05 MPa in the DI treatment, respectively. Control trees had always midday SWP values higher than −0.85 MPa. Less yield and lower mean fruit weight at harvest was observed only in 2011. In 2011, DI increased pulp dry matter and soluble solids concentrations, and pulp and skin colour. In 2012, DI did not affect fruit composition. Sensory quality was relatively unaffected by DI in both experimental years but DI consistently increased consumer acceptance of fruit by 27% in 2011 and by 25% in 2012. Consumers apparently perceived modest changes in fruit chemical composition and more advanced maturity in response to water stress that was not reflected by fruit composition and sensory analysis. The consumer panels appeared to be more sensitive than sensory panels and analytical instruments used for fruit composition determination. The inclusion of consumer panels in future DI studies is recommended. Consumer acceptance increased with modest decreases in tree water status as indicated by SWP at the cost of significant reductions in fruit size. However, an improvement of consumer acceptance was possible with minimum impact on fruit size and yield when dealing with very mild levels of water stress.

1. Introduction

Irrigation in peach and nectarine (*Prunus persica*) is essential for commercial production in many regions of the world (Girona et al., 2012). However, in semi-arid regions water supplied may be lower than tree's requirements. Water shortages are most critical when they occur during the final stage of fruit growth (Stage III of fruit development in *Prunus persica*). Fruit growth during Stage III is very sensitive to water stress because cell expansion is mainly explained by an accumulation of water (Berman and DeJong, 1996). Reduction of fruit size during Stage III because of water stress has been accompanied with an increase in soluble solids concentration (SSC) (Behboudian et al., 2011). Increases in SSC have been often related with improvements in peach and nectarine quality. However, increases in SSC may not always relate to improvements in fruit organoleptic quality and/or increases in consumer acceptance. For example, severe water stress before harvest in 'Ryan Sun' peach reduced consumer acceptance despite a 5% increase in SSC (Lopez et al., 2011a). The reduction in consumer acceptance was explained by increases in fruit sourness and firmness and reductions in sweetness, juiciness and intensity of flavour. Sensory properties such as sweetness, texture, flavour, and juiciness therefore play a significant role in consumer preference (Infante et al., 2008; Delgado et al., 2013).

There are few reports on the effect of deficit irrigation (DI) on the sensory properties and consumer acceptance of *Prunus persica* fruit. One involved water stress for a long period before harvest (Lopez et al., 2011a) and another focussed on regulated deficit irrigation during Stage II of fruit development (Vallverdu et al., 2012). Other studies have emphasised fruit composition changes (Behboudian

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et al., 2011). The effects of water stress for a short period before harvest on nectarine consumer acceptance are not clear. Although improvements in fruit composition are expected under moderate levels of water stress before harvest (Behboudian et al., 2011), it is not known if consumers could increase their preference for DI fruit at mild levels of water stress. Increasing consumer acceptance with a minimum impact on fruit size and yield would be relevant for the fruit industry. Considering the above issues, DI was applied for a short period before harvest on 'Gardeta' nectarine in a commercial orchard during 2011 and 2012. The levels of DI were decided on the basis of developing moderate levels of water stress levels in 2011 and very mild levels of water stress in 2012. The specific objective of the study was to determine the effect of a short period of water stress before harvest on fruit weight, marketable yield, fruit composition, sensory attributes, and consumer acceptance of nectarine fruit.

2. Materials and methods

2.1. Experimental orchard

The experiment was conducted during 2011 and 2012 in a commercial nectarine (*Prunus persica* L. Batsch cv. R-28 'Gardeta') orchard located in Aitona (41° 21′ N, 0° 27′ E, 110 m elevation), Lleida, Spain. The orchard had silty-loam textured shallow soil. The trees were six years old at the beginning of the experiment. They were grafted onto 'Guardian' x 'Nemaguard' (GxN) rootstock and trained to an open vase system. Spacing between rows was 5.0 m. For a given row, spacing between trees was 2.5 m. Trees were managed according to commercial practices. Fruit thinning intensity was low and spacing between fruits ranged between 5 and 10 cm.

2.2. Irrigation management, treatments, and experimental design

Trees were irrigated daily using a drip irrigation system with 5 drippers per tree (3.8 l h^{-1} per dripper). Irrigation started on March 22 in 2011 and on March 1 in 2012. Tree water requirements were calculated using a water balance technique for replacing crop evapotranspiration (ETc) as follows: ETc = (ETo × Kc)−effective rainfall. ETo and Kc represent the reference evapotranspiration and crop coefficient, respectively. The Penman-Monteith method was used to determine ETo (Allen et al., 1998) and Kc values were derived from the empirical relationship between Kc and midday canopy light interception (Ayars et al., 2003). Two irrigation treatments were applied: (i) conventional irrigation (CI) receiving 100% of ETc during the whole irrigation season, and (ii) deficit irrigation (DI) before harvest. In 2011, the DI trees received 100% of ETc during the whole irrigation season except for 15 days before harvest. This was from 7 June to 21 June when DI trees received 15% of ETc. In 2012, the DI trees received 100% of ETc during the whole irrigation season except for nine days before harvest. This was from 18 June to 26 June when DI trees received no irrigation. The levels of DI were decided on the basis of developing water stress levels severe enough to limit nectarine growth which happens at a midday stem water potential (SWP) between −1.3 and −1.7 MPa (Naor et al., 2001). Midday SWP more negative than −1.8 MPa were avoided because leaf wilting occurs in peach when SWP is lower than that value (Lopez et al., 2006).

A randomised complete block design with four block replicates was used. Each block housed the two irrigation treatments in different experimental plots. Each experimental plot had three rows of six trees each. The four central trees of the middle rows were used as experimental and all the others as guard trees. There were therefore 32 experimental trees.

2.3. Applied water and tree water status

The amount of water applied to each plot was measured with digital water meters (CZ2000-3M, Contazara, Zaragoza, Spain). Midday stem water potential (SWP) was measured once or twice per week during the fruit-growing season. This was done with a pressure chamber (Model 3005; Soil Moisture Equipment Corp., Santa Barbara, CA, USA). Measurements were taken at solar noon (±30 min) from leaves located near the bases of two experimental trees per plot (one leaf per tree) as described by McCutchan and Shackel (1992).

2.4. Tree size

Individual tree crown surface area was determined at the end of each experimental year by using remotely sensed aerial imagery. In 2011, zenith angle images of the experimental orchard were taken from an aircraft (CESSNA C172S EC-JYN) equipped with a multispectral camera (DMSC) with 4-digital bands. The camera had a 2048 × 2048 pixel resolution with 14-bit digitization and optical focal length of 24–48 mm. The flight was conducted by RS Aviation (Lleida, Spain) under clear sky at 750 m altitude above ground level yielding images of 0.3 m spatial resolution, enabling identification of pure tree crown pixels. Radiometric calibrations and multispectral image processing was conducted by Specterra Services (Perth, WA, Australia). Surface area for each individual tree was extracted from the images using ArcMap (version 9.3; ESRI Inc. Redlands, CA, USA). Tree crown surface area was calculated from the visible image and by delineating the contour shape of each crown object and using ArcMap's 'calculate geometry' function. In 2012, tree crown surface area was calculated using the same procedures but the images of the experimental orchard were obtained from aerial orthophotos downloaded from the Institut Cartografic de Catalunya (www.icc.cat).

2.5. Harvest and yield components

Harvest was based on visual observation of fruit skin colour. Fruit were harvested when 90% of the skin reached a reddish colour. This approach required three harvest dates: 16, 20, and 23 June in 2011 and 22, 26, and 29 June in 2012. All fruit harvested per experimental tree were counted and weighed at each harvest. Physiological crop load for each tree was calculated as the number of fruits divided by the crown surface area.

2.6. Fruit quality

The following fruit quality attributes were measured: fruit diameter (FD), pulp dry matter concentration (DMC), firmness (FF), titratable acidity (TA), soluble solids concentration (SSC), SSC/TA ratio, and skin and pulp colour. Fruit samples were taken twice in 2011 (16 and 20 June) and thrice in 2012 (22, 26 and 29 June). In 2011, the sample taken on June 20 was evaluated after two weeks of cold storage as well as at harvest. In 2011, the fruit sample taken on June 16 consisted of two fruit per experimental tree (a total of 8 fruit per experimental plot and 32 fruit per irrigation treatment). In the second sample of 2011, the number of fruits was increased to four fruit per experimental tree (a total of 16 fruit per experimental plot and 64 fruit per irrigation treatment). In 2012 each sample consisted of five fruit per experimental tree (a total of 20 fruit per experimental plot and 80 per irrigation treatment).

FD was recorded for each fruit using a digital calliper (Mitutoyo, Tokyo, Japan). Skin and pulp colour and FF from two opposite fruit cheeks (most exposed and least exposed to light) were determined for each fruit. A photoelectric tri-stimulus colorimeter (CR-200, Minolta Co., Osaka, Japan) was used for measuring skin and pulp