Scientia Horticulturae 164 (2013) 340–347

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Effects of irrigation and fruit position on size, colour, firmness and sugar contents of fruits in a mid-late maturing peach cultivar

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ARTICLE INFO

Article history:
Received 31 January 2013
Received in revised form
24 September 2013
Accepted 26 September 2013

Keywords:
Fruit size
Fruit-quality attributes
Prunus persica
Regulated deficit irrigation
Sugar content

ABSTRACT

Experiments were conducted on a mid-late maturing peach (*Prunus persica*) cv. 'Catherine' in 2008 in order to study the influences of irrigation and fruit location within the canopy, on fruit growth and several fruit-quality attributes, including sugar and acid contents. Trees were subjected to full irrigation (FI) and regulated deficit irrigation (RDI). Fruit height in the crown, exposure to sunlight and orientation were recorded. Fruit diameter, fresh weight, firmness, flesh and skin colour attributes, soluble solids content, pH and sugar and acid contents were determined for each fruit at harvest. Water stress had a high impact on most of the fruit-quality variables studied. Fruits from trees under RDI were firmer than those from FI trees but did not differ in weight and diameter, perhaps due to the low crop load supported by the studied trees. In contrast, fruits from RDI trees had more soluble solids, glucose, sorbitol, and malic, citric and tartaric acids. Height in the crown partially affected positively soluble solids content. Exposure to sunlight strongly influenced stone dry weight and soluble solid content. Finally, orientation did not have a significant influence on most of the fruit-quality attributes considered in this study. Our results suggested that leaving a low crop load on the tree maintaining fruits only in the most ideal parts of the canopy may improve fruit quality under water restriction conditions. In this way, the negative effects of water stress may be counteracted and fruit quality for this mid-late maturing peach cultivar would be improved.

1. Introduction

Peach trees (*Prunus persica* L. Bastch) are widely cultivated in Mediterranean countries, with the Murcia Region being the third leading peach producer in Spain with an annual yield of 162,000 tonnes of peaches from a cultivation area of 11,151 ha in 2010 (Magrama, 2011); these figures represent approximately 21% and 25% of the Spanish total peach production and cultivation area of peaches, respectively. Peaches, as fleshy fruits, are valued for their colour and taste; therefore, management practices leading to good-quality fruits with a high marketable value should be sought.

Peach flavour depends on its sugar and acid content ratio (Souty and André, 1975). Sucrose is the dominant sugar in peaches but reducing sugars (glucose and fructose) are also abundant (Génard and Souty, 1996). These sugars influence peach flavour along with the dominant organic acids, malic and citric (Souty and André, 1975).

However, fruit size and quality varies considerably within the tree (Wu et al., 2005; Alcobendas et al., 2012), showing that tree management can probably still be improved. The variability of fruit performance is related to factors such as light interception (Génard and Baret, 1994), crop load (Marini and Sowers, 1994) and pruning (Kumar et al., 2010). A major factor affecting fruit yield and quality is irrigation management, that controls water stress, whose effects on peach fruit yield and quality have been widely reported (e.g. Crisosto et al., 1994; Besset et al., 2001; Mercier et al., 2009; Lopez et al., 2011). Some studies reported cultural practices aiming to counteract the negative effects of water stress on fruit yield (Marsal et al., 2006). However, early and late-maturing peach cultivars seem to respond differently to water shortage (Naor et al., 2001; Girona et al., 2005; Buendía et al., 2008).

Fruit growth is correlated with several components of fruit quality (Génard and Bruchou, 1992) and all practices affecting this growth may exert an influence on fruit quality, since sugar partitioning is affected by source and sink growth (Lo Bianco et al., 2000). However, in this regard, results reported are contradictory. For instance, Corelli-Grappadelli and Coston (1991) observed smaller

Abbreviations: FI, full irrigation; RDI, regulated deficit irrigation; ET_0, reference evapotranspiration; SSC, soluble solid content; FFW, fruit fresh weight; FW, flesh weight; FD, fruit diameter; SW, stone weight; SDW, stone dry weight; TCSA, trunk cross-sectional area.

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http://dx.doi.org/10.1016/j.scienta.2013.09.048

fruits at the distal end of fruiting shoots whereas Marini and Sowers (1994) did not detect differences in fruit size as a function of positions on the shoot. Bible and Singha (1993) observed redder and darker fruits in the upper side of the canopy than those in the lower side; showing the lack of uniformity and maturity in peach as a function of canopy position. Moreover, Lewallen and Marini (2003) observed that peach fruit firmness and colour were affected by light and fruit position within the canopy. In a previous study on an early-maturing peach cultivar, Alcobendas et al. (2012) found that fruit exposure to sunlight and position in the canopy affected fruits differently depending on the irrigation treatment.

However, these studies presented limitations such as considering only one or two factors, disregarding others, (Bible and Singha, 1993; Kumar et al., 2010) or they accounted only for fruits from the south side of the tree and the upper part of the canopy (Génard and Bruchou, 1992). In addition, fruit quality data in these studies was mainly centred on ground colour and total soluble solid content (Corelli-Grappadelli and Coston, 1991; Miranda Jiménez and Royo Díaz, 2002) and only a few studies reported data on sugar and acid concentration (Génard and Bruchou, 1992).

Consequently, a lack of knowledge on the effects on fruit quality and the interactions between irrigation and fruit position within the tree canopy still exists. Fruit distribution within the canopy may compensate for the negative effects of water stress on fruit size and quality (Alcobendas et al., 2012). This may have implications in horticultural practices since growers may be able to optimize fruit distribution within the canopy to obtain high peach quality and marketable yields.

Our objective was to investigate the effects of two types of irrigation (full and regulated deficit irrigation) and fruit position in the canopy (height in the crown, exposure to sunlight and orientation) on fruit growth (diameter, fresh weight, flesh weight and stone weight) and a number of quality attributes (colour, firmness, soluble solid content, pH and sugar and acid contents). Fruit quality is increasingly important (Crisosto and Costa, 2008), since it is emphasized by the new Common Organization of the Market (COM) of the European Union for fruit and vegetables. Thus, a low crop load was left in the studied trees in order to attain the maximum fruit-quality potential in the different locations within the canopy for this mid-late maturing peach cultivar. This was combined, with the use of an RDI strategy to determine its influence on fruit-quality attributes. RDI is often used for peach-tree culture in southeastern Spain due to water shortage.

2. Materials and methods

2.1. Plant and fruit materials, irrigation treatments and experimental conditions

The study was carried out in 2008 on a 0.5 ha plot at a commercial orchard in Fuente Librilla, Murcia, Spain (37°55′ N, 1°25′ W, 360 m above sea level). The soil is sandy-loam textured (54.6% sand, 29.4% silt and 16% clay) and was classified as a Xeric Torriorthent (Soil Survey Staff, 2006). It is highly calcareous and possesses low organic matter (<1%) content and a pH of 8. The available water capacity is 0.31 $m^3 m^{-3}$. The climate of the region is semi-arid Mediterranean with hot and dry summers.

The plant material consisted of nine-year old peach trees (*Prunus persica* (L.) Batsch.), cv. Catherine, grafted on GF-677 peach rootstock and trained to an open-centre canopy and spaced 4 m × 6 m, with a mean ground cover of about 54%. Catherine is a mid-late maturing peach tree cultivar and is harvested by the beginning of July. Pest control and fertilization practices were those commonly used by the growers, and no weeds were allowed to develop within the orchard.

Trees were hand-thinned 30 days after full-bloom (DAFB), which occurred on March 18. Fruits were separated 40 cm (Nicolás et al., 2006). Therefore, the number of fruits left in the trees after thinning was low in order to avoid excessive intra-tree competition among fruits and to obtain a similar fruit size distribution in both fully and deficit irrigated trees, and thus achieving the maximum in fruit quality. Harvest date was July 1, it was defined by fruits attaining commercial size and also by fruit colour. Two different irrigation treatments were considered in this study. A full irrigation treatment (FI) where trees were irrigated with enough water to replace 100% of crop evapotranspiration (ET_c) requirements and a regulated deficit irrigation treatment (RDI) established to adjust a pre-defined threshold of stem water potential (ψ_s) of −1.8 MPa, where a severe water deficit is applied in a closely controlled way in low stress sensitivity periods (stage II of fruit development; Girona et al., 2005). Applied irrigation doses and frequency were continuously adjusted to match the average ψ_s value with the pre-defined RDI threshold. Crop irrigation requirements were determined according to daily crop reference evapotranspiration (ET_0), calculated with the Penman–Monteith equation, a crop factor based on the time of the year (FAO 56, Allen et al., 1998) and the percentage of ground area shaded by the tree canopy (Fereres and Goldhamer, 1990).

All irrigation treatments were carried out using a drip irrigation system with one lateral pipe per tree row and three emitters (each delivering 4 $L\,h^{-1}$) per plant. The cumulative amount of irrigation water until harvest for FI and RDI was 412 and 318 mm, respectively.

Irrigation treatments were distributed in a completely randomized design with four repetitions, each consisting of three rows of 4 trees. Two trees from the centre of the central rows were used, and the others served as guard trees. Therefore, fruit sampling was done on 16 selected trees, eight under RDI and eight under FI. The number of fruits per tree was counted and the average number of fruits per plant was calculated for each irrigation treatment. All fruits were harvested. For the analysis, we used 36 fruit per plant (1 fruit per cardinal point by 3 heights and by 3 exposures), we used fruits from 8 trees per treatment, yielding 288 fruits for data analysis.

Several measurements concerning tree size were carried out to assess the homogeneity of the control trees. These measurements included trunk cross-sectional areas (TCSA), tree height, tree diameter and canopy volume (according to Westwood, 1988).

In the tree, different height from the ground (top = height upper 1.2 m; middle = between 0.6 and 1.2 m; bottom = lesser than 0.6 m), different exposures to sunlight (fully exposed, medium exposed and shadowed), different orientations (north, south, east and west) were considered in order to account for fruit distribution in the canopy.

A visual assessment was made of the fractional area of the tree canopies that was illuminated by the sun's direct beam. This estimate was made by observing sixteen sections per tree (four per branch) of the outer part of the canopy, at two hourly intervals between the hours of sunrise and sunset. Four different observers determined every sunlit fraction, as described by Alarcón et al. (2003).

2.2. Measurements

Tree water status was assessed by means of midday stem water potential, a sensitive indicator of water stress (Choné et al., 2001). Measurements were performed using a pressure chamber (Soil Moisture Equip. Corp. Model 3000, Santa Barbara, CA, USA) on mature leaves from the north face of the tree near the trunk. Leaves were placed in plastic bags covered with aluminium foil at least 2 h prior to the measurements, which were carried out at midday every 7–15 days.