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Fruit thinning in 'Conference' pear grown under deficit irrigation: Implications for fruit quality at harvest and after cold storage

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ABSTRACT

Fruit thinning in pear is feasible for mitigation of water stress effects. However, it is not well known how fruit quality at harvest and after cold storage is affected by pre-harvest water stress. Even less is known about the effects of fruit thinning on quality under these circumstances. To elucidate these, we applied deficit irrigation (DI) and fruit thinning treatments to 'Conference' pear over the growing seasons of 2008 and 2009. At the onset of Stage II (80 and 67 days before harvest in 2008 and 2009, respectively), two irrigation treatments were applied: full irrigation (FI) and DI. FI trees received 100% of crop evapotranspiration (ETc). DI trees received no irrigation during the first three weeks of Stage II to induce water stress, but then received 20% of ETc to ensure tree survival. From bud-break until the onset of Stage II and during post-harvest, FI and DI trees received 100% of ETc. Each irrigation treatment received two thinning levels: no thinning leaving commercial crop load (~180 fruits $tree^{-1}$), and hand-thinning at the onset of Stage II leaving a light crop load (~85 fruits $tree^{-1}$). Under commercial crop loads, DI trees were moderately water-stressed and this had some positive effects on fruit quality. DI increased fruit firmness (FF), soluble solids concentrations (SSC) and acidity at harvest while no changes were observed in fruit maturity (based on ethylene production). Differences in FF and acidity at harvest between FI and DI fruit were maintained during cold storage. DI also reduced fruit weight loss during storage. But fruit size was reduced under DI. Fruit thinning under DI resulted in better fruit composition with no detrimental effect on fresh-market yield compared to un-thinned fruit. Fruit size at harvest and SSC values after five months of cold storage were higher in fruit from thinned trees than fruit from un-thinned trees. Fruit thinning increased fruit ethylene production, indicating advanced maturity. This may lead to earlier harvest which is desirable in years with impending drought. Fruit thinning is therefore a useful technique to enhance pear marketability under water shortage.

1. Introduction

Water shortage is becoming increasingly frequent in fruit producing areas with Mediterranean climates. The major pear-producing areas in Spain are not exempt from this problem and several restrictions on irrigation have been experienced in the past few years. These restrictions are usually imposed during mid-summer. Water stress therefore develops when pears are in their cell-expansion growth period (Stage II). Water stress in Stage II reduces the potential of achieving commercial fruit size at harvest (Marsal et al., 2008, 2010). Size is an important quality attribute for fresh-market pear. Fruit thinning has been proposed as a contingency plan for reducing water-stress, partially compensating for the negative effects on fruit size (Mpelasoka et al., 2001; Lopez et al., 2006; Marsal et al., 2008, 2010; Intrigliolo and Castel, 2010). The benefit of fruit thinning on pear growth was not solely related to a reduction in fruit competition for photoassimilates. It has been also associated with improvements in tree water status (Marsal et al., 2008).

Although pricing depends on fruit size, consumer acceptance depends on eating quality that should be maintained after a period of cold storage. It is not known how pear quality responds to fruit thinning under water limited conditions in Stage II. We hypothesised that fruit from trees with a lower crop load could have a better quality than fruit from trees with a normal crop load. Fruit thinning has generally resulted in higher firmness, soluble solids concentration (SSC) and acidity in apple (Wünsche and Ferguson, 2005) and in higher SSC in peach (Crisosto et al., 1994) and plum (Intrigliolo and Castel, 2010). Gaps of knowledge also exist in how pear quality responds to pre-harvest water stress, especially for

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fruit cold-stored after harvest. Although pear was one of the first fruit crops undergoing research on deficit irrigation, information on how fruit quality is affected is scant compared to other crops such as apple and peach (Behboudian et al., 2011; Gelly et al., 2003, 2004).

We therefore studied, over two growing seasons, the combined effects of pre-harvest water stress and fruit thinning on important fruit quality attributes in pear, both at harvest and after cold storage. We expected that our findings will enable growers to adopt suitable fruit thinning strategies for production of better quality fruit under water limited conditions. Besides being the most popular pear cultivar in Spain, 'Conference' was used because it is exposed to the increasingly frequent episodes of water shortage in midsummer and is kept in cold storage for several months.

2. Materials and methods

2.1. Pear orchard

The experiment was conducted over two years (2008–2009) in a 'Conference' pear (*Pyrus communis* L.) orchard located at the IRTA-Estaciò Experimental de Lleida (41°37′N; 0° 52′E; 260 m a.s.l.); Spain. The orchard was planted in 1999 with 4.0 m between rows and 1.6 m within rows. The trees were grafted onto dwarfing quince rootstock (M–A). The orchard was managed according to local commercial practices, including fruit thinning when commercial crop load exceeded 200 fruit per tree.

2.2. Phenological stages of 'Conference' pear

Pear growth consists of two linear stages: Stage I and Stage II (Bain, 1961). Stage I is characterised by slow growth, lasting for approximately 30 days in 'Conference' pear. Fruit growth is faster in Stage II, being almost linear up to harvest. To confirm these growth stages in our experiment, throughout the season destructive fruit samples were taken from experimental trees, dried and weighed. In 2008 Stage II occurred between 2 June and 21 August. In 2009 it did between 12 June and 18 August. The experimental fruit were harvested in one pick, on 21 August in 2008 and on 18 August in 2009.

2.3. Irrigation and fruit thinning treatments

Irrigation season began at bud-break (late March) and finished before leaf fall was complete (late October). Trees were irrigated on a daily basis by drip irrigation system with two drippers per tree ($4\,l\,h^{-1}$ per dripper). There was a single pipeline per tree row which passed close to the trunks of the trees. Irrigation requirements were calculated on a weekly basis by a water balance technique to replace crop evapotranspiration (ETc). ETc was calculated as (ETo × Kc) – Rainfall (Allen et al., 1998), where ETo and Kc represent the reference evapotranspiration and crop coefficient, respectively. ETo was obtained from the Catalan Agrometeorological Network (XAC) for the 'El Poal' weather station, located 7 km away from the experimental orchard. Kc values were obtained from a weighting lysimeter located in the centre of the pear orchard (Girona et al., 2011).

All trees received full irrigation (100% of ETc) from bud-break until the onset of Stage II. At the onset of Stage II (80 and 67 days before harvest in 2008 and 2009, respectively), two irrigation treatments were applied: full irrigation (FI) and deficit irrigation (DI). FI trees received 100% of ETc. DI trees received no irrigation during the first three weeks of Stage II to induce some degree of water stress. However, after the first three weeks of Stage II, DI trees were irrigated with 20% of ETc to ensure tree survival. After harvest all trees received again 100% of ETc.

Each irrigation treatment received two fruit thinning levels: no thinning (NT) leaving commercial crop load, and hand-thinning (T) at the onset of Stage II leaving a light crop load (about 45% of the crop load of NT trees). Hereafter we use the treatment designation 'T' to refer to the fruit remained on the tree after fruit thinning of the tree.

2.4. Experimental design

To avoid carry-over effects of the irrigation and fruit thinning treatments, different trees were used in 2008 and 2009. A randomized complete block design was used in both experimental years. In 2008 the experiment had three block replicates and in 2009 it had two. Each block housed four plots each designated to one of the following treatments: FI–T, FI–NT, DI–T, and DI–NT. Each plot had three rows of six trees with the four central trees of the middle row being considered as experimental and all the others as guard trees.

2.5. Measurements of applied water and tree water status

The amount of water applied in each experimental plot was measured with digital water meters (CZ2000-3M, Contazara, Zaragoza, Spain). Midday stem water potential (SWP) was measured weekly during Stage II. This was done with a pressure chamber (Model 3005; Soil Moisture Equipment, Santa Barbara, CA, USA.). Measurements were taken at solar noon ± 30 min from leaves located near the bases of the two central trees in each plot (one leaf per tree). To ensure equilibrium between the leaf and the stem attached to it, selected leaves were bagged with aluminium foil 1 h before measurement (McCutchan and Shackel, 1992).

2.6. Determination of fruit quality

All fruit from each experimental tree were harvested, counted and weighed. Mean fruit fresh weight was then calculated. In 2008, fruits were graded immediately after harvest using an electronic fruit grader (Model S2010; SAMMO s.r.l., Cesena, Italy). The fresh-market yield for each tree was considered to be the weight of all fruit with a maximum cheek diameter equal to or higher than 65 mm.

In 2008, twenty fruit per plot were randomly selected for the following measurements: fruit firmness (FF), juice soluble solids concentration (SSC) and titratable acidity (TA). Firmness for each fruit was evaluated on two opposite peeled surfaces using a manual penetrometer with a tip of $0.5\,cm^2$ and fixed in a drill stand (Penefel, Copa-Technology, CTIFL, France). SSC and acidity were measured on a mixture of juice from 10 pears (2 replicates) from each plot. SSC was determined using a digital refractometer (PR-32α Palette Series, Atago Co. Ltd., Tokyo, Japan). Acidity was determined by titrating the juice with 0.1 N NaOH to an end-point of pH 8.2. In 2009, six fruit per tree were used for measurement of firmness, SSC and acidity. These determinations were carried out three times before harvest, at harvest, and twice during cold storage. The cold storage was at 0 °C and 90% relative humidity and lasted for either two months or five months after harvest depending on the experiment.

In 2009, eighteen fruit per experimental tree were selected, their total fresh weight measured, and cold-stored. Their total weight was measured again after two and five months of cold storage to determine weight loss. Results were expressed as weight loss per gram of fruit.