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Sensitivity of root pruned 'Conference' pear to water deficit in a temperate climate

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ABSTRACT

The present study examines the need for irrigation in pear trees (*Pyrus Communis*, cv. 'Conference') under low evaporative demand conditions, like in Belgium, in order to maintain a consistent fruit yield and high fruit size. To determine the sensitivity of the pear yield under low evaporative demand conditions three different orchards were monitored. The study shows that a Ψ_{soil} of −60 kPa during shoot growth has no effect on fruit yield but lower Ψ_{soil} values induced a decline in both fruit size and total yield. Just as for arid environments a Ψ_{stem} of −1.5 MPa is related to negative yield responses. In dry conditions lower Ψ_{soil} and Ψ_{stem} values were observed in root pruned trees compared to not root pruned trees in the same irrigation treatment, however without yield decline. In one orchard a biannual bearing tendency was observed after root pruning. Furthermore intensive Ψ_{soil} measurements show a high variation in Ψ_{soil} between orchards, and within an orchard. This underlines the need for irrigation management on a parcel level and the need for new irrigation scheduling techniques which take the spatial variation in the orchard into account.

1. Introduction

Over the past years pear fruit (*Pyrus communis* cv. 'Conference') has become an important part of fruit growing in Belgium and the Netherlands. Belgium is situated in the temperate climate zone with a relatively low average evapotranspiration and a high but variable rainfall from bloom (first half of April) to harvest (first half of September). Since the ban of growth inhibitors based on hormonal applications, for example Paclobutrazol, trees are subjected to different management practises such as root pruning to control the vigour of the tree (Maas, 2007; Vercammen et al., 2005). Root pruning is an effective tool to control the vegetative growth because tree transpiration is reduced (Asín et al., 2007; Rodriguez-Gamir et al., 2010; Schupp et al., 1992). Root pruning reduces the root volume of the tree in the upper soil layer, where the most significant water extraction by the tree occurs (Gong et al., 2006; Green and Clothier, 1999; Green et al., 2003; Ma et al., 2007). As a consequence, it possibly makes the trees more sensitive to water stress.

Market price of fruits having a diameter of >60 mm is twice the price of smaller sized fruits (<55 mm). During summer in Belgium in 30% of the years a rain deficit of at least 10 mm per ten days occurs (Fig. 1a). In those years the price difference between large and small fruits increases significantly. The high market price for large fruit sizes and the higher water stress sensitivity due to root pruning (Marsal et al., 2008; Schupp et al., 1992) has pushed the fruit growers to the implementation of irrigation systems.

In arid and mediterranean environments it has been demonstrated for pear fruit that during fruit maturing, a water deficit is strongly related to a poorer fruit tissue growth but that irrigation can prevent the decline in fruit yield and size (Cui et al., 2008; Marsal et al., 2000, 2002; Naor, 2001). Naor (2001) observed yield decline when Ψ_{soil} dropped below −20 kPa. During the shoot growth, which starts immediately after full bloom and ends one month before harvest, a deficit irrigation scheme can control the vigour of the pear tree (Asín et al., 2007; Cui et al., 2009; Marsal et al., 2000, 2002). However the main focus for the fruit grower is the total yield and fruit size which should not be affected negatively. For jujube pear tree a reduced water supply during shoot growth had no effect on the total yield (Cui et al., 2009). Anconelli and Mannini (2002) even showed that the total yield can increase when the irrigation supply is lowered during shoot growth. In relation to pear fruit size however Marsal et al. (2000, 2002) reported smaller fruit size during deficit irrigation when the stem water potential dropped (Ψ_{stem}) below −1.5 MPa, even during shoot growth. On the other hand excessive irrigation reduced the total number of

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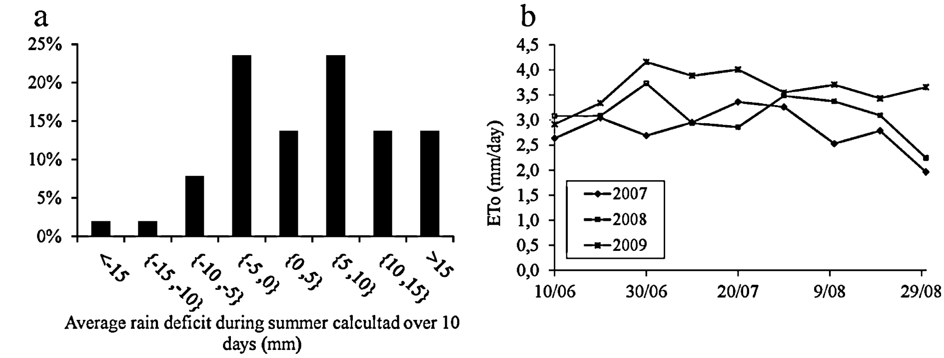

Fig. 1. Distribution of average rain deficit per 10 days during summer in Belgium the last 51 years (a) and average evapotranspiration calculated over 10 days 2007–2009 (b).

fruits and had a negative effect on total yield, which indicates the delicate optimal equilibrium between deficit irrigation and excessive irrigation. An irrigation threshold of a Ψ_{stem} of −1.5 MPa for pear tree in an arid and mediterranean climate has been confirmed by others (Naor, 2001; O'Connell and Goodwin, 2007; Ramos et al., 1994).

Since sap flow, and also water status (Ψ_{stem}), in plants is driven by the difference between Ψ_{air} (evaporative demand) and Ψ_{soil} (Van den Hornert, 1948) the optimal irrigation equilibriums discussed by Anconelli and Mannini (2002), Cui et al. (2008), Marsal et al. (2000, 2002) and Naor (2001) all depend on the local evaporative conditions (Doorenbos and Kassam, 1986). Although more than 30% of the world pear production is situated in the temperate climate zone (WAPA, 2008), the number of irrigation studies on pear tree in a temperate climate is limited. The introduction of root pruning in combination with the market demand for large fruit sizes has only recently increased the interest for irrigation in pear tree in the temperate climate zone. The question which remains is how the pear fruit yield of the trees is affected when deficit irrigation is applied during shoot growth under conditions with low evaporative demand. Also secondly, the relation between deficit irrigation and root pruning for pear has so far only been described by Marsal et al. (2008) in more arid conditions.

The first objective of this study is to examine the impact of a low soil water potential (Ψ_{soil}) on the fruit yield and the fruit size and the tree water status quantified by stem water potential (Ψ_{stem}) in a temperate climate. Can the thresholds proposed for irrigation scheduling in arid conditions be maintained in a temperate climate? The second objective is to analyse the impact of root pruning on the fruit yield and the tree water status in a deficit irrigation regime. For this purpose an irrigation experiment and a root pruning experiment were set up.

2. Materials and methods

In Belgium in the pear trees (*Pyrus Communis*, cv. 'Conference') full bloom takes place mid April, followed by a period of intensive cell multiplication until the end of May. June and July are characterised by a period of extensive shoot growth. In August the fruits start to mature with a period of cell elongation, until harvest at the end of August or the beginning of September.

Given the variety in soil profiles and planting regimes in Belgium, three different orchards were selected for this study: an intensively planted orchard on a dry profile on a slope situated in Bierbeek, and two older less intensively planted orchards in Meensel and in Sint-Truiden. In these orchards an irrigation experiment and a root pruning experiment were set up during 2007, 2008 and 2009. In the irrigation experiment a full irrigation regime (FI) was compared to a deficit irrigation regime (DI). In the root pruning experiment a comparison was made between root pruned trees (RP) and not root pruned trees (NRP).

2.1. Experimental sites and plant material

2.1.1. Bierbeek

The first orchard is situated in Bierbeek (50°49′36.35″N, 4°47′40.35″E). The orchard was planted with pear tree cv. 'Conference' on Quince C rootstock. The trees were planted in 2000 with a planting distance of 3.3 m by 1 m. Trees were trained in an intensive V system with four fruiting branches on one central stem. Average tree height was 2.5 m. The orchard was situated on a slope. Soil texture in the upper soil layer was loam; in the deeper soil layer texture was sandy loam. The soil had an organic carbon content of 1% in the upper soil layer (0–30 cm). The water retention curve (WRC) was fitted through 8 measurements on pressure plates. Volumetric water content was 38%, 30% and 12% at −10 kPa, −30 kPa and −1600 kPa, respectively. The bulk density in the upper soil layer (0–30 cm) was 1.4 g m^{-3} and 1.5 g m^{-3} in the deeper soil layer (30–60 cm). Irrigation water had a low salinity risk with a electric conductivity (EC) of 0.76 dS/m at 25 °C.

2.1.2. Meensel

The second orchard is located in Meensel (50°53′40.20″N, 4°55′38.12″E). The orchard was composed of pear tree 'Conference' on a Quince Adams rootstock. The trees were planted in 1996 with a planting distance of 3.5 m by 1.5 m, trained in a free spindle system. The soil texture was sandy loam. A shallow ground water table was present in the soil profile at a depth between 1.5 m and 2 m. The orchard was situated on a small slope and the organic carbon content of the upper soil layer was 1%. Volumetric soil water content was 36%, 29% and 13% at −10 kPa, −30 kPa and −1600 kPa, respectively. The bulk density was 1.4 g m^{-3} in the upper soil layer (0–30 cm) and 1.5 g m^{-3} in the deeper soil layer (30–60 cm). Irrigation water had a low salinity risk with a EC of 0.58 dS/m at 25 °C.

2.1.3. Sint-Truiden

The third orchard is situated in Sint-Truiden (50°45′59.46″N, 5°9′24.68″E) and was planted with Conference trees on a Quince Adams rootstock. The trees were planted in 1996 with a planting distance of 3.5 m by 1.5 m. The average tree height was 3.5 m. The trees were never root pruned and were trained in a free spindle system. The orchard was situated on a loamy textured soil. The organic carbon content in the upper soil layer was 1.1%. The volumetric soil water content was 36%, 25% and 11% at −10 kPa, −30 kPa and −1600 kPa, respectively. The bulk density was 1.4 g m^{-3} for the upper soil layer and 1.5 g m^{-3} for the lower soil layer. The EC of the irrigation water was 0.87 dS/m at 25 °C.