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Fruit yield and quality response of a late season peach orchard to different irrigation regimes in a semi-arid environment

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ABSTRACT

Some degree of deficit irrigation is normally applied to orchards in semi-arid environments in order to reduce unwanted vegetative growth and to increase water productivity. In this study the effect of three irrigation treatments on the yield and quality of the fruit production was evaluated during five consecutive years (2008–2012) in a commercial drip irrigated late season peach (*Prunus persica* (L). Batsch cv 'Calrico') orchard. Irrigation treatments consisted in a full irrigation (FULL) with irrigation applications covering the crop water requirements, a sustained deficit irrigation during the whole irrigation season (SDI) with irrigation applications of 62.5% of the FULL treatment and a regulated deficit irrigation (RDI) with a reduction of water applied to 50% of the FULL treatment in the stone hardening period. The differential irrigation treatments created negligible differences in the stem water potential of the trees. Results showed that fruit production was only significantly higher in the FULL treatment than in the other two treatments in 2008 but in the rest of the years no significant differences were found between treatments. The average fruit weight was significantly smaller in the SDI treatment than in the FULL and RDI treatments. Firmness of the fruits in the SDI treatment was significantly lower than that of the FULL and RDI treatments and the total soluble solids of the SDI was significantly higher than the FULL and RDI treatments. Color parameters of the fruit skin and flesh were also affected by the irrigation treatments. The higher values of the soluble solids content (SSC) and the relation SSC/TA (total acidity) and the slight decrease in fruit diameter found in the SDI treatment suggest that irrigation water saving can be achieved without affecting the commercial profitability in the semi-arid conditions of the Lower Ebro Valley in Northeast of Spain.

1. Introduction

In 2009 the peach and nectarine orchard area in the world was around 1.5 million ha; China is the country with the highest peach production which represents over half of the world peach production. Another important peach production area is located in southern Europe which includes the countries of Spain, France and Greece (FAO, 2011). The peach orchards in Spain covered an area of 50,000 ha in 2010 (MAGRAMA, 2011). Around 50% of the peach and nectarine orchard area is cultivated in the regions of Aragón and Cataluña in Northeast of Spain. Most of these orchards have early season cultivars in order to put the fruit production in the markets as soon as possible at the beginning of the summer season and obtain high economic profit. However in recent years the late season peach orchards which are harvested at the end of the summer and early fall are getting a higher relevance since this kind of peach characterized by its very firm flesh and sweetness is highly appreciated by the consumers. In an area of Aragón of around 5000 km^2 in the Northeast of Spain, a group of late season peach cultivars has been grown for a long time with a great acceptance by the consumers because of their excellent aspect and organoleptic characteristics. Peaches of these late season cultivars grown in this area have a unique and special denomination named "Calanda peach". These peaches reach significant higher prices than

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the regular peaches and nectarines. The most important cultivars included in the "Calanda peach" denomination are 'Jesca', 'Calante' and 'Evaisa' (Espada et al., 2009). The fruit of these clingstone cultivars has round shape; the skin is light yellow without red spots and very low pubescence. The fruit flesh is yellow, non-melting and firm with high sugar content. Maturation is between middle of September and the beginning of November. At present new cultivars have been added to the denomination of "Calanda peach" and the demand of this type of peaches is increasing.

One of the most characteristic agronomic practices of "Calanda peach" is introducing the fruit into a paper bag during the stone hardening phase in order to protect the fruit against the Mediterranean fly (*Ceratitis capitata*), contact with pesticides, climatic incidences and other external physical damages (Sharma et al., 2014). The paper bag remains on the fruit until the harvest. The fruit acquires a homogeneous yellow color very appreciated by the consumers.

The production areas of the "Calanda peach" are semi-arid with low and irregular precipitation. Usually these orchards are located in flat areas with calcareous soils and high carbonate and gypsum content and drip irrigation is used in the modern peach orchards. Under this high frequency irrigation a high plant water status is maintained and the orchard does not suffer any water stress.

At present some problems of lack of quality in the "Calanda peach" have been reported. The farmers consider that this lack of quality can be due to inadequate agronomic practices such as excessive irrigation and nitrogen application and imbalance of nutrients in the fertilization. One of the most important problems that has been identified in peaches and other deciduous fruits is the appearance of the vitrescent dark spot. This physiological disorder affect the flesh of the peach and it is not visible in the fruit skin. According to the findings of Fernández et al. (2009) this disorder seems to be related to calcium (Ca)-nutrition imbalances.

Different irrigation strategies and agronomic practices can be used to optimize the yield and quality of peach fruit production. Reviews of literature have shown that reducing the irrigation applications below the crop water requirement can be an useful tool to reduce unwanted vegetative growth, improve fruit quality and increase water productivity in orchards (Fereres and Soriano, 2007; Geerts and Raes, 2009; Ruiz-Sanchez et al., 2010). These reductions can be applied during the crop cycle (i.e. sustained deficit irrigation, SDI) or they can be applied in specific phenological phases where the deficit irrigation does not affect the fruit production (i.e. regulated deficit irrigation, RDI). The response of fruit orchards to different deficit irrigation strategies has been widely studied in many fruit species and areas of the World (Girona et al., 2003; López et al., 2008; Moriana et al., 2003; Ruiz-Sanchez et al., 2010; Ramos and Santos, 2010). Different studies have showed that RDI saves irrigation water, increases water use efficiency and reduces tree vigor while the fruit yield remains constant or even increases (Chalmers et al., 1981; Boland et al., 2000; Geerts and Raes, 2009). Normally the RDI in peach orchard is applied in the stone hardening phase of the fruit development. In this phase the growth of the fruit is very slow and the shoots grow very fast. Most RDI studies have been made in early peach cultivars (Mounzer et al., 2008; Gelly et al., 2004) and very few results are available for late season peach cultivars.

The need to increase the water use efficiency in the irrigated areas of Spain and the vulnerability of the peach fruit quality to irrigation has moved the authors to study the effect of different irrigation regimes in the yield and quality of a late season peach orchard. Therefore the aim of the study is to ascertain the effect of different irrigation strategies including full irrigation (FULL), a sustained deficit irrigation during the whole irrigation season (SDI) and a regulated deficit irrigation (RDI) with a reduction of irrigation during the stone hardening period on the fruit production and quality of a late season peach orchard in northeast of Spain.

2. Material and methods

2.1. Experimental orchard

The experiment was started in 2008 in a 3-year old late season peach cultivar (*Prunus persica* (L.) Batsch cv 'Calrico') drip irrigated orchard located in the AFRUCCAS experimental farm in the county of Caspe in northeast of Spain (41.16°N, 0.01°W). The experiment was conducted from 2008 to 2012. The cultivar Calrico, included in the Calanda peach denomination, was grafted on GF-677 rootstock (*Prunus amygdalus* × *Prunus persica*). This rootstock is tolerant to Fe deficiency; it is well adapted to calcareous and arid soils but is sensitive to anaerobic conditions in the roots. The trees in the experimental orchard were planted at a spacing of 6 m by 2 m and pruned in Y formation system with two main branches starting at around 0.5 m from the soil surface. The soil of the plot has an average depth of 1.5 m and is a sandy-loam soil. It is classified as calcic haploxerept, fine loamy, mixed, thermic (Soil Survey Staff, 2006). The gravimetric average soil field capacity and permanent wilting percentage are 21% and 12%, respectively. Soil bulk density is 1600 mg m^{-3}.

The peach orchard was managed according to the normal cultural practices in the region: irrigations were applied daily with an automated drip system with two laterals per tree row located at 0.5 m from the rows with 1 m spaced self compensating emitters of 2, 3 and 4 L h^{-1}, depending on irrigation treatment. With this drip laterals disposition, each tree was in the center of 1 m^2 where the four emitters are located in the corners. Irrigation water is pumped directly from the Mequinenza reservoir in the Ebro River. The average value of the electrical conductivity of the irrigation water (EC_w) during the five study years was 1.1 dS m^{-1}. In general the EC_w was low at the beginning of the irrigation season with values around 0.7 dS m^{-1} and increased to about 1.6 dS m^{-1} by the end of the irrigation season with the exception of year 2012 where EC_w remained below 1.2 dS m^{-1} throughout the season. According to Ayers and Westcot (1985) the quality of the irrigation water does not affect the production of a peach orchard with a high-frequency drip irrigation system.

Soluble fertilizers were applied with the drip irrigation system along the irrigation season. The seasonal fertilizer amounts per year included 87 kg ha^{-1} of N, 47 kg ha^{-1} of P_2O_5 and 120 kg ha^{-1} of K_2O.

Fruits were thinned in early June to a target crop load of about 140 fruits per tree and then the fruits were covered with individual paper bags. Each tree of the experimental units was harvested individually in two harvesting events performed during the month of September.

2.2. Experimental design

The experiment design was a complete randomized block with five replicates and three differential irrigation treatments: (1) control or fully irrigated treatment (FULL) with 100% of the Gross Irrigation Requirements (I) estimated by the own farmer according to the irrigation recommendations from the Irrigation Advisory System of Aragón (http://servicios.aragon.es/oresa/) for the experimental orchard in the county of Caspe. This irrigation advisory system uses the FAO methodology (Allen et al., 1998) with data of agrometeorological stations of the SIAR network (National Network of Agrometeorological Stations for Irrigation of the Ministry of Agriculture, Food and Environment of Spain, http:www.magrama.gob.es/es/); (2) sustained deficit irrigation (SDI) with the irrigation application reduced to 62.5% of the FULL