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Comparative study on postharvest performance of nectarines grown under regulated deficit irrigation

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ABSTRACT

A comparative study of fresh extra early 'VioWhite 5' nectarines, cultivated under long-term regulated deficit irrigation (RDI) strategies and stored under cold conditions, combined or not with a controlled atmosphere (CA; 3–4 kPa O_2 and 12–14 kPa CO_2) or 1-methylcyclopropene (1-MCP; 1.25 $\mu L L^{-1}$, 24 h, 0 °C), was performed. These strategies were: (i) non-deficit-irrigation (NDI), irrigated at 110% of maximum crop evapotranspiration (ET_C) during the whole season; (ii) RDI_1, irrigated at 110% ETc during critical periods of growth and at 85% of NDI during the rest of the growing season; (iii) RDI_2, irrigated at 110% ETc during critical periods of growth and at 80 and 60% NDI during the second fruit growth stage in March and late postharvest, respectively. Quality factors and biochemical parameters were monitored. In general, RDI_2 reached higher sensory evaluation scores mainly due to the higher soluble solids content. Weight loss was higher in air-stored nectarines with faster changes in firmness and color. The combination of cold storage with CA or 1-MCP better maintained the initial content of bioactive compounds. This fact highly correlated with soluble phenolic content, showing the involvement of phenolic compounds in the antioxidant activity of nectarines. A correlation between dehydroascorbic acid (DHA) concentration and stress were also found, resulting in the ability of using DHA concentration as a stress biomarker. The cultivation of extra early nectarines under RDI_2 combined with the 1-MCP postharvest treatment was the best method for improving and maintaining overall quality while saving a notable amount of water (2050 m^3/ha and year).

1. Introduction

Stone fruit is traditionally grown in the Mediterranean basin, although it needs a large amount of water (~6000 m^3/ha and year) for its cultivation, which is a limiting factor in these dry areas (averaging 200 mm of precipitation per year) (Riesco et al., 2014). The search for a sustainable technique for increasing the efficiency of the irrigation strategies has therefore become a high priority (Fereres and Soriano, 2007). One possibility is the application of water below the crop evapotranspiration requirements (ET_c) during certain phenological periods of tree development (Chalmers et al., 1981), commonly known as regulated deficit irrigation (RDI). In peach or apricot, quality attributes are not negatively-affected when appropriate deficit irrigation strategies are applied (Falagán et al., 2014, 2015; Pérez-Pastor et al., 2007) although other fruit characteristics may be affected (Peña et al., 2013; Pliakoni et al., 2010). Early studies by some authors have reported on improved fruit quality due to higher soluble solids or phenolic contents, lower acidity and hence, higher maturity index (Buendía et al., 2008; Girona et al., 2005) which is optimum for extra early cultivars (cvs.) with a short ripening time. In this work, an extra early nectarine was selected (*Prunus persica* var. Nectarina VioWhite 5), due to its proper size and organoleptic features, which make them very suitable for export. The export of Spanish nectarines and peaches in the 2000–2013 period has increased by 135% (Iglesias and Casals, 2014). Consumers demand high fruit quality, and cold storage is one of the most important tools used to preserve overall quality of stone fruits. The combination of chilling with controlled atmosphere (CA) and/or 1-methylcyclopropene

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(1-MCP) can help to preserve fruit and vegetable quality and extend their shelf life (Dal Cin et al., 2006). A delay in senescence and prevention of wooliness in stone fruit can be achieved by reducing O_2 concentrations below 8% and maintaining CO_2 above 1% (Lill and Van der Mespel, 1988), and 1-MCP is an inhibitor of ethylene action, delaying senescence and helping to postpone decay (Blankenship and Dole, 2003). Treatment with 1-MCP has been shown to maintain peach and nectarine flesh firmness and acidity among other characteristics (Fan et al., 2002). Presently, Spain is found in the top 10 exporter countries (FAOSTAT, 2015) and early peaches and nectarines are some of their exported products. The industrial applications of postharvest techniques, which are able to maintain the initial quality parameters until consumption by the consumer, are essential, as they allow for the marketing of the fruits to different foreign countries. However, there is no information on the response of RDI fruit to different storage atmospheres. The combination of water stress, which can increase the concentration of some bioactive compounds (Navarro et al., 2015) and proper postharvest treatments, which allow for better maintenance of those compounds (Sivakumar et al., 2012), may provide a healthier, high-quality product.

The main objective of this work was to study the effect of two long-term RDI strategies on extra early nectarines and their postharvest behavior when stored under CA or 1-MCP.

2. Materials and Methods

2.1. Experimental site and irrigation regimes

The field experiment was conducted on two consecutive seasons (2010–2011 and 2011–2012) in a commercial farm located in Murcia, Spain (38°8′N, 1°13′W). The experimental plot had an area of 2 ha and consisted of 11-year-old extra-early nectarine trees cv. VioWhite 5 grafted onto Puebla de Soto 101 plum rootstock at a spacing of 6 × 3.5 m. This cv. was chosen for its high commercial value as a result of its early picking date, high price, and suitable size for the European market. The soil had a clay loam texture with an average depth of 1.55 m, low-available K, low P and organic matter content in the main root zone of the soil. The electrical conductivity of the irrigation water was about 2 dS m^{-1}. Normal cultivation practices (e.g., weed control, fertilization, pruning, fruit thinning and banding) were carried out. The drip irrigation system had two lines per tree row and 9.33 pressure-compensated emitters (1.6 L h^{-1}) per tree, placed every 75 cm. Irrigation was scheduled weekly and applied with a frequency that varied from 1 to 2 times per day in spring-summer to 1–7 times per week for the rest of the year. The start time of any irrigation was the same for all the treatments, and it was done at night. During the experiment, three irrigation treatments were applied: (i) non-deficit-irrigation (NDI), irrigated at 110% of maximum crop evapotranspiration (ET_C) during the whole season in order to avoid limiting soil water conditions, determined from the crop ETc reference guidelines (ET_0 Penman–Monteith, Allen et al., 1998); (ii) RDI_1, irrigated at 110% ETc during the critical periods (third fruit growth stage and early postharvest) and at 85% of NDI during the rest of the growing season; (iii) RDI_2, irrigated at 110% ETc during the mentioned critical periods and at 80 and 60% NDI during the second fruit growth stage in March and late postharvest (from July until November), respectively. A total water volume of 6540; 5760 and 4490 m^3/ha and year were applied to NDI, RDI_1 and RDI_2, respectively. The treatments followed a randomized block design with three blocks, one replicate per block and 45 trees per replicate. Each replicate had three adjacent tree rows and 15 trees per row. The fruits were harvested in the 13 inner trees of the central row. Trees not used for measurements served as buffers.

2.2. Storage conditions

In two consecutive years nectarines were picked at the pre-climacteric stage (around April 26th) according to commercial criteria and also based on the maturity index (Table 1). The results presented here correspond to the second year as they represent the stress accumulated during both seasons (data not shown). Accumulated water stress was measured using stem water potential, and the integration of that data from each year provided the accumulate water stress (De la Rosa et al., 2015).

The postharvest results obtained in both years were similar, following the same trend and was therefore repeatable and accurate. At harvest, around 60 kg fruits per each irrigation treatment (20 kg per repetition × 3 repetitions) were sampled and immediately transported 45 km by car under refrigerated conditions to the Pilot Plant in the Technical University of Cartagena. Fruits were selected by eliminating those with external defects or bruises. Sound fruits were placed in plastic boxes which were then placed into air-tight polycarbonate-stainless-steel cells (0.42 m^3) under a continuous flow of humidified gas. The flow was controlled by an automatic gas mixing system (Tecnidex S.A., Valencia, Spain), which created the desired gas mixture from commercial cylinders (Air Liquide S.A., Cartagena, Spain). Samples were stored at 0 ± 0.5 °C and 95% RH for 10 days under three different postharvest treatments: normal air, controlled atmosphere (CA; 3–4 kPa O_2 and 12–14 kPa CO_2) or 1-MCP. For this last treatment, fruit was exposed to 1-MCP gas (1.25 μL L^{-1}) inside the hermetic cell for 24 h at 0 °C, after which the fruit was stored under normal air conditions at 0 °C (Blankenship and Dole, 2003). All these treatments were followed by 3 days at 15 °C and 70–75% RH in air, simulating a retail sale period. Each treatment (irrigation strategy/postharvest condition/days of storage) was composed of three repetitions (boxes) containing twelve uniform-size nectarines per each repetition. Each repetition from the irrigation treatments was used later for the postharvest treatment. Therefore, Control A fruits were used for 1-MCP A, CA A and Air A treatments, with the same done for the other (B, C) repetitions.

2.3. Weight losses

Fruits from each treatment were weighed on the initial and final day of cold storage and after the retail sale period, with the results reported as a percentage from the initial fresh weight (f.w.).

2.4. External ground color

Epidermal color was assessed in three different points in the equatorial area, by using the tristimulus color analyzer Minolta Chroma Meter CIE 1976 (model CR-200, Minolta Corp., Ramsey, NJ) calibrated with a white plate, and the measurements expressed as CIELAB ($L^*a^*b^*$) color space coordinates. Color indices used were a^* and Hue angle [$°h = \tan^{-1}(b^*/a^*)$]. Ten pieces per replicate were measured.

Table 1
Maturity characteristics at harvest (~April 26th) of 'Viowhite 5' extra early nectarines cultivated under three different regulated deficit irrigation (RDI) strategies [non-deficit-irrigation (NDI) as control, RDI_1 and RDI_2].

Samples	SSC (°Brix)	TA (g malic acid L^{-1})	Maturity index (SSC/TA)
NDI	9.67 ± 0.03	13.2 ± 0.1	6.99 ± 0.07
RDI_1	10.10 ± 0.20	12.3 ± 0.2	8.66 ± 0.20
RDI_2	10.63 ± 0.17	12.6 ± 0.6	8.24 ± 0.14

Data represents means (n = 3 ± SE).