Scientia Horticulturae 176 (2014) 162–169

Contents lists available at ScienceDirect

Scientia Horticulturae

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

# Pre-harvest spray application of methyl jasmonate plays an important role in fruit ripening, fruit quality and bioactive compounds of Japanese plums

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ARTICLE INFO

*Article history:*
Received 30 April 2014
Received in revised form 2 July 2014
Accepted 4 July 2014
Available online 26 July 2014

*Keywords:*
Antioxidant
Chlorogenic acid
Colour
Ethylene production
Firmness
Phenolics

ABSTRACT

The effects of pre-harvest methyl jasmonate (MeJA) treatment on ethylene production, respiration rate, bioactive compounds and physico-chemical parameters of plum fruits (*Prunus salicina* Lindell cvs. 'Black Beauty' and 'Black Amber') were investigated in this study. Whole trees were sprayed once with an aqueous solution containing MeJA (0 and 2240 mg $L^{-1}$) two weeks before the anticipated commercial harvest for each cultivar separately. Compared to control treatment, MeJA-treated trees had higher yields. However, fruit mass and geometric mean diameters of MeJA-treated fruits were lower than the fruits of control. Ethylene production and respiration rate were significantly increased with MeJA. MeJA-treated fruits significantly maintained higher flesh firmness, except for initial harvest date. MeJA treatment significantly decreased $L^*$ and hue angle of plum fruits. Soluble solids content significantly increased with MeJA treatment and but MeJA treatment reduced titratable acidity. MeJA-treated fruits exhibited higher levels of total antioxidant activity and total phenolics. In all harvest dates, MeJA treatment resulted in significant increases in chlorogenic acid, caffeic acid, rutin, naringenin and kaempferol of 'Black Beauty' and chlorogenic acid, caffeic acid, *p*-coumaric acid, ferulic acid, quercetin and kaempferol of 'Black Amber' plums.



## 1. Introduction

Beside low calorie content, plums are highly rich in vitamins A, C and E, fibre, mineral nutrients (potassium, fluoride and iron), flavonoids and phenolic acids, which may function as an effective natural antioxidant in our daily diet. Phytochemical compounds have great contributions to colour, taste and flavour of plums. Most of them also have antioxidative, anticarcinogenic, antimicrobial, antiallergic, antimutagenic and antiinflammatory impacts (Stacewicz-Sapuntzakis et al., 2001; Kim et al., 2003). Therefore, consumers should prefer the foods with high phytochemical contents in their daily diets.

Phytochemical contents of fruits vary based on fruit ripening level, fruit species, growth period, production area, surrounding environmental conditions, type of production (organic or inorganic), time of harvest and other horticultural practices (pruning, training, irrigation, nutrition and plant growth regulators) implemented during the growth of fruits (Kim et al., 2003; Lara, 2013).

In recent years, phytochemical contents and other quality parameters have been improved with pre- and post-harvest plant growth regulator treatments (Khan and Singh, 2007; Lara, 2013). Methyl jasmonate (MeJA) is among the most common ones of such plant growth regulators. Since it has a regulatory role in fruit growth and ripening, it can easily affect the ripening processes of both climacteric and non-climacteric fruits (Lalel et al., 2003; Pena-Cortes et al., 2005). It was reported in previous researches that MeJA had significant impacts on fruit peel colour development, anthocyanin accumulation, phenolics compounds and antioxidant activity of the fruits (Rudell et al., 2005; Shafiq et al., 2013). Wang and Zheng (2005) reported increased flavonoids, total phenolics and antioxidant activity of raspberry with MeJA treatments. Similarly, significant increases were reported with pre-harvest MeJA treatments in phytochemical contents of blueberries (Percival and MacKenzie, 2007), blackberries (Wang et al., 2008), apples

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http://dx.doi.org/10.1016/j.scienta.2014.07.007

(Shafiq et al., 2011) and grapes (Ruiz-Garcia et al., 2012). Khan and Singh (2007) on the other hand reported increased phytochemical contents of Japanese plums ('Black Amber', 'Amber Jewel' and 'Angelino') with post-harvest MeJA treatments. Although there are several studies about the effects of MeJA treatments on ripening of various fruits, effects of pre-harvest MeJA treatments on ripening and phytochemical composition of plum fruits have not been studied, yet.

The main objective of this study was to elucidate the impacts of pre-harvest MeJA treatment on colour characteristics, fruit mass, geometric mean diameter, flesh firmness, soluble solids content, titratable acidity, ethylene production, respiration rate, total antioxidant activity, total phenolics and individual phenolics of 'Black Beauty' and 'Black Amber' fruits during fruit ripening.

## 2. Materials and methods

### 2.1. Plant materials

Five-years old uniform Japanese plum trees (*Prunus salicina* Lindell cvs. 'Black Beauty' and 'Black Amber') grafted on Myrobalan (*Prunus ceresifera* Ehrh.) rootstock at Research Station of Horticulture Department of Gaziosmanpaşa University Agricultural Faculty (40°20′02.19″N latitude, 36°28′30.11″E longitude and 623 m altitude) in the Middle Black Sea Region of Turkey were selected for the experiments. The trees were planted at 4 m × 4 m spacing and trained by modified leader system.

The experiments were laid out in a randomized complete-block design with three replicates. For each plum cultivar, 6 trees with homogeneous fruit load were selected and trees were grouped into 3 blocks with 2 trees per block based on proximity in orchard and crop load. Each MeJA (Sigma-Aldrich, Taufkirchen, Germany) dose (0 and 2240 mg $L^{-1}$) was applied to a tree in each block and one tree in each block was selected as the control treatment (with 0 mg $L^{-1}$ MeJA).

### 2.2. Treatments

The experimental trees were uniformly sprayed with an aqueous solution containing different concentrations of MeJA (0 and 2240 mg $L^{-1}$) and 'Triton X-100' [(0.077%, v/v), Alfa Aesar, Karslruhe, Germany] as a surfactant until run-off with a low pressure hand-sprayer two weeks before the anticipated commercial harvest date. Only the solution containing 'Triton X-100' was used in control trees (0 mg $L^{-1}$ MeJA). The anticipated commercial harvest date (8th, 15th and 22nd of July 2011 for 'Black Beauty' and 18th and 25th July and 1st of August 2011 for 'Black Amber') for each plum cultivar was determined based on the number of days after full bloom (the values were 75 and 105 days for 'Black Beauty' and 'Black Amber', respectively). Spray treatments were conducted during favourable weather conditions where rainfall was not forecasted for the following 24 h. MeJA dose was selected based on previous studies carried out under field conditions. Standard cultural practices (pruning, thinning, fertilization and irrigation) were carried out during the experiments.

The fruits of each plum cultivar were analysed at one week before anticipated commercial harvest, at anticipated commercial harvest and at one week after anticipated commercial harvest for all quality characteristics. Fifty fruits from each tree in each block were randomly harvested from the whole canopy on 8th, 15th and 22nd of July 2011 for 'Black Beauty', and 18th and 25th July and 1st of August 2011 for 'Black Amber'. Plums with uniform shape, colour and size and free from visual symptoms of any disease or blemishes were harvested. Harvested fruits were immediately transported to laboratory to determine the quality parameters.

### 2.3. Total fruit yield, fruit mass, geometric mean diameter and fruit flesh firmness

The yield per tree was obtained by weighing harvested fruit. Fifty fruits from each tree were used to determine the fruit mass and geometric mean diameter. Fruit mass (g) was measured with a digital balance (±0.01 g) (Radvag PS 4500/C/1, Poland). Fruit length ($L$), width ($W$) and thickness ($T$) were measured with a digital calliper (±0.01 mm) (Model CD-6CSX, Mitutoyo, Japan). Geometric mean diameter ($D_g$) was determined by using the relationship [$D_g = (LWT)^{1/3}$] described by Mohsenin (1970). Twenty fruits from each tree were used to determine the flesh firmness. The fruit skin was cut at two different points (on the cheeks) along the equatorial part of the fruit and the firmness was measured by using an Effegi penetrometer (model FT-327; McCormick Fruit Tech., Yakima, WA) with a 7.9 mm tip. The flesh firmness was expressed as Newton (N).

### 2.4. Ethylene production and respiration rate

To determine ethylene production and respiration rate, 30 fruits were selected among 50 fruits harvested from each tree and three measurements were obtained from each tree. For ethylene production, 10 fruits per chamber were sealed in a 1 L air-tight chamber fitted with a rubber septum for 1 h at 20 ± 1 °C and 90% relative humidity (RH), and then a 1 mL gas sample was collected into a syringe. Each sample was injected into a gas chromatograph (Clarus 500, PerkinElmer, USA) equipped with a flame ionization detector and an alumina column for ethylene determination. The respiration rate was determined by measuring the amount of carbon dioxide ($CO_2$) produced by plum fruits. For respiration rate, 10 fruits per chamber were sealed in a 1 L air-tight chamber fitted with a rubber septum for 1 h at 20 ± 1 °C and 90% RH, and then the effluent air was connected to an infrared gas analyser (Horiba PIR-2000R, USA). Results were expressed as μmol $kg^{-1}$ $h^{-1}$ for ethylene production and mmol $CO_2$ $kg^{-1}$ $h^{-1}$ for respiration rate.

### 2.5. Colour characteristics

Fifty fruits from each tree were used to determine the colour characteristics [$L^*$, $a^*$, $b^*$ chroma ($C^*$) and hue angle ($h°$)]. Changes in fruit colour characteristics were measured at opposite sides of each fruit with a colorimeter (Minolta, model CR-400, Tokyo, Japan). Chromatic analyses were conducted in accordance with the CIE (Commission Internationale de l'Eclairage) system of 1976. Values of $L^*$, $a^*$ and $b^*$ were used to define a three-dimensional colour space and interpreted as follows: $L^*$ indicates lightness with values ranging from 0 (completely opaque or 'black') to 100 (completely transparent or 'white'); a positive $a^*$ value indicates redness on the hue circle ($-a^*$ = greenness) and a positive $b^*$ value indicates yellowness ($-b^*$ = blueness). The hue angle ($h°$) expresses the colour nuance and values are defined as follows: red–purple: 0°; yellow: 90°; bluish green: 180°; blue: 270°. The chroma ($C^*$) is a measure of chromaticity, which defines the purity or saturation of the colour. The chroma value was calculated with the formula $C^* = (a^{*2} + b^{*2})^{1/2}$, and the hue angle with $h° = \tan^{-1} b^*/a^*$ (McGuire, 1992).

### 2.6. Soluble solids content (SSC) and titratable acidity

A sample of juice was taken from one piece of each of ten fruits per tree, and 4 different measurements were obtained from each tree. SSC was determined with a digital refractometer (PAL-1, McCormick Fruit Tech., Yakima, Wash). For titratable acidity (TA), 10 mL of extract was taken from each sample, 10 mL of distilled water was added and the value corresponding to consumed sodium hydroxide (NaOH) during the titration with 0.1 N NaOH to increase