Scientia Horticulturae 213 (2016) 173–178

Contents lists available at ScienceDirect

Scientia Horticulturae

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

The effects of aminoethoxyvinylglycine and foliar zinc treatments on pre-harvest drops and fruit quality attributes of Jersey Mac apples

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ARTICLE INFO

Article history:
Received 12 June 2016
Received in revised form 1 October 2016
Accepted 21 October 2016

Keywords:
Antioxidant
Color
Flesh firmness
Internal ethylene concentration
Micro and macro elements
Phenolics

ABSTRACT

The present study was carried out to investigate the effects of pre-harvest aminoethoxyvinylglycine (AVG, 250 mgL^{-1}) and zinc (0.3% $ZnSO_4$) treatments on pre-harvest fruit drops, internal ethylene concentration (IEC), fruit weight, color characteristics, fruit firmness, soluble solids content (SSC), titratable acidity-like quality attributes and antioxidant activity, total phenolics, micro and macro elements of Jersey Mac apples (*Malus x domestica*). Compared to control treatment, except for 22 July, pre-harvest drops were significantly reduced with all treatments in all measurement times. Zn + AVG treatment was found to be more effective in reducing pre-harvest fruit drops. IEC decreased with AVG, Zn and Zn + AVG treatments. Single AVG treatment was more effective on IEC decreases. While flesh softening was retarded with AVG treatments, Zn treatments stimulated flesh softening. Fruit weights increased with Zn treatments, but decreased with AVG and Zn + AVG treatments. Red color development was retarded with both AVG and Zn + AVG treatments, but stimulated with Zn treatment. SSC significantly decreased in the last measurement date (12 August) with AVG treatment. Compared to control fruits, AVG and Zn + AVG-treated fruits had higher titratable acidity, total phenolics and total antioxidant capacity, but Zn-treated fruits had lower values. All micro element and nitrogen and phosphorus-like macro element contents of single Zn and AVG or Zn + AVG-treated fruits were higher than the control fruits. It was concluded that beside AVG, Zn could also play an active role in retarding pre-harvest fruit drops.

1. Introduction

Pre-harvest fruit drops are among the most significant problems in apple culture. The severity of pre-harvest drops may vary based on the cultivar, ecological factors and cultural practices and drop rates may reach to 50% in some cultivars. Such a case then results in significant yield and quality losses and ultimately serious economic losses (Ward, 2004; Greene, 2006).

Internal hormone balance plays important roles in pre-harvest fruit drops. Previous researchers reported that external growth regulator treatments retarded fruit drops in many apple cultivars (Amarante et al., 2002; Greene and Schupp, 2004; Kang et al., 2007). Among the auxin-type growth regulators, naphthalene acetic acid (NAA) has long been used to prevent fruit drops (Yuan and Carbaugh, 2007; Dal Cin et al., 2008). Following the invention of AVG, an ethylene inhibitor, it was found to be more effective in preventing pre-harvest fruit drops than NAA (Byers, 1997; Greene and Schupp, 2004; Dal Cin et al., 2008). Contrary to NAA, AVG also retards fruit ripening process (Amarante et al., 2002; Argenta et al., 2006; Petri et al., 2006).

Nutrient deficiency or competition for nutrients was also indicated as a significant factor influencing fruit drops in apples (Luckwill, 1970; Boyton and Burrell, 1994). Various researchers recommended combined application of growth regulators and plant nutrients to prevent or control pre-harvest fruit drops in citruses (Doberman and Fairhurst, 2000; Rodriguez et al., 2005; Saleem et al., 2005; Razi et al., 2011; Ashraf et al., 2012).

Nutrient deficiencies may also alter internal hormone balance controlling fruit drops (Razi et al., 2011; Ashraf et al., 2012). Zn was reported to play a significant role in auxin metabolism and Zn deficiency significantly reduced auxin synthesis (Cakmak et al., 1989; Alloway, 2004; Kramer and Clemens, 2006).

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http://dx.doi.org/10.1016/j.scienta.2016.10.026
0304-4238/

It was reported that combined treatments of growth regulators and Zn-containing nutrients reduced per-harvest fruit drops in citrus cultivars (Ashraf et al., 2012, 2013; Razzaq et al., 2013). Although there are several studies carried out to elucidate the effects of growth regulators, especially of AVG and NAA, on pre-harvest fruit drops in apples, the studies considering combined applications of these growth regulators and plant nutrients are quite limited. There is also limited information available about the effects of pre-harvest AVG and Zn treatments on total phenolics and antioxidant capacity of apples with a great place in daily food consumption. Therefore, the present study was conducted to investigate potential additional effects of combined Zn and AVG treatments over single AVG treatments in controlling pre-harvest fruit drops in apples and to elucidate the effects of combined treatments on fruit quality attributes and mineral nutrient contents of apples.

2. Materials and methods

2.1. Site conditions

Experiments were carried out in Horticultural Research Centre of Gaziosmanpaşa University located at 40° 20′02.19′N latitude and 36° 28′30.11′E longitude and 623 m above sea level, Tokat Province in middle Black Sea region of Turkey. Soil texture is clay loam with 22% sand, 50% clay and 28% silt and 0.7% organic matter. The soil pH is 8.16.

2.2. Plant material and experimental design

Twenty-four 6 year-old Jersey Mac apples (*Malus x domestica* Borkh)/M9 were selected and grouped (randomized block design) into three blocks of 8 trees based on proximity in orchard and crop load. The trees were spaced at 0.7 × 3.0 m and trained to 'Slender Spindle System'. Standard cultural practices (pruning, fertilization, irrigation and etc.) were regularly implemented. The experiments were laid out in a randomized complete-block design with three replications and two trees for each treatment in each replication.

2.3. Treatments

In each block, 2 trees were selected for control treatment, 2 trees for 250 mgL^{-1} AVG treatment [containing 150 mg aminoethoxyvinylglycine g^{-1}, (Valent BioScience Corp. Libertyville, USA)], 2 trees for Zn treatment (0.3% $ZnSO_4$) and 2 trees for Zn + AVG treatment (250 mgL^{-1} AVG + 0.3% $ZnSO_4$). AVG was sprayed 4 weeks (July 15, 2012) before anticipated harvest date (August 12, 2012). Zn was sprayed on tree after walnut size [fruit development stage (June 10, 2012)].

The experimental trees were uniformly sprayed with an aqueous solution containing AVG, Zn and 'Sylgard 309 [(0.05%, v/v), Dow Corning, Istanbul, Turkey] as a surfactant until run-off with a low pressure hand sprayer. Only water (pH = 6.48) + surfactant was used in control treatment. Sprays were completed in a non-windy day during favorable weather conditions where rainfall was not forecasted for the following 24 h. Amount of solution to be applied was calculated by using the equation developed by researchers (Anonymous, 2012) and 1000 mL solution was sprayed to each tree. Shape (conical or spherical), height and row spacing were taken into consideration to calculate the amount of solution.

One tree in each pair was designated to be the sample tree, from which fruits were collected for ethylene and quality analysis at certain dates. No fruit were harvested from the second tree until normal harvest time and this served to follow the progression of fruit drop.

20 fruits from the sample tree of each block were harvested randomly from the whole canopy to determine the quality attributes. Apple fruits with uniform shape, color and size and free from visual symptoms of any disease or blemishes were selected. The fruits were immediately transported to laboratory to determine the quality attributes and bioactive compounds.

2.4. Cumulative drop ratio (%)

To determine pre-harvest fruit drop ratio, beginning 30 day before anticipated harvest time, fruits fallen under tree were counted twice a week until harvest. Then, fruits remaining on the trees were harvested and cumulative drop ratio was calculated.

2.5. Internal ethylene concentration and flesh firmness

To evaluate internal ethylene concentration, 1-mL air sample from core cavity of each fruit was injected into a gas chromatograph equipped with an active alumina column and Flame Ionization Detector (Perkin Elmer-Clarus 500, USA), using the method of Bramlage et al. (1980). The resultant peaks were compared to that of 100 μLL^{-1} ethylene standard and the internal ethylene concentration was calculated. Flesh firmness was measured on three sides of equatorial line of each fruit using a press-mounted Effegi penetrometer (FT 327; McCormick Fruit Tech. Torino, Italy) with 11.1 mm tip.

2.6. Fruit weight and color characteristics

Fruit weight (g) was measured with a digital balance (±0.01 g) (Radvag PS 4500/C/1, Poland). Color characteristics (L*, chroma and hue angle) were measured at opposite sides of each fruit with a colorimeter (Minolta, model CR–400, 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 color space. The chroma value was calculated with the formula $C^* = (a^{*2} + b^{*2})^{1/2}$, and the hue angle with $h^\circ = \tan^{-1} b^*/a^*$.

2.7. SSC and titratable acidity

A sample of juice was taken from one piece of each of ten fruits per tree, and 3 different measurements were obtained from each replication. 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 distilled water was added and the value corresponding to consumed sodium hydroxide (NaOH) during the titration with 0.1 N NaOH to increase the pH of samples to 8.1 was expressed in malic acid (g malic acid 100 mL^{-1}).

2.8. Total phenolics and total antioxidant capacity

At the anticipated harvest date, flesh and skin samples of one piece of five fruits were homogenized and placed into 4 different tubes and measurements were taken from each tube in each replication. The fruit samples were kept in 50 mL tubes at −20 °C for bioactive analysis. Samples were thawed at room temperature (≈21 °C) and homogenized in a food grade blender. The resultant slurry was centrifuged (12,000 x *g*) for 30 min at 4 °C to separate the juice from the pulp. The freshly obtained juice materials were diluted with distilled water, divided into multiple sample aliquots, and refrozen at −20 °C until used in phenolics, antioxidant and anthocyanin assay procedures.