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Cracking and quality attributes of jujube fruits as affected by covering and pre-harvest Parka and GA_3 treatments

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ABSTRACT

This study was carried out to investigate the effects of rain protective covering (RPC) together with Parka and gibberellic acid (GA_3) treatments on cracking rates and quality attributes of jujube fruits. RPC was mounted 5 weeks before the commercial harvest date. 1% Parka (containing 7.5% stearic acid, 5% cellulose and 1% calcium) and GA_3 (15 mg L^{-1}) were sprayed to experimental trees 3 and 2 weeks before the commercial harvest date. As compared to the control, all treatments (Parka, GA_3 and GA_3 + Parka) yielded lower cracking rates. Cracking rates were also significantly lower in covered trees than in uncovered trees. However, GA_3 + Parka treated fruit had significantly lower cracking rates than both the control and the other treatments. GA_3 treated fruits had significantly higher weight, width, hue angle and firmness values, but significantly lower L* values than the control fruits. As compared to the control, all treatments yielded a significantly lower respiration rate and soluble solids content, but higher titratable acidity, vitamin C and total phenolics. The covered fruits had significantly higher hue angle, respiration rate, vitamin C, total phenolics, total flavonoids and antioxidant activity (free radical scavenging activity on DPPH and FRAP) than the uncovered ones. It was concluded based on the present findings that rain-protective covering could be used as an efficient tool to reduce cracking rates in jujube fruits without any negative effects on the other quality attributes. It was also concluded that Parka and GA_3 treatments reduced cracking rates significantly and such a reduction was more remarkable with combined GA_3 + Parka treatments.

1. Introduction

Jujube fruits are used to treat several diseases such as cancer, heart diseases and anemia (Gao et al., 2013). Fruits are also used as anti-inflammatory and immune system booster (Yu et al., 2012). They play a significant role in prevention of oxidative stress (Wu et al., 2013). Jujube fruit are quite rich in vitamin C. Due to its attractive taste and flavor, fruits are appreciated by the consumers. Jujube fruits have long been used in traditional medicine in China and recently have been used in pharmaceutical industry (Yao, 2013). While dried fruits have been used in China, usually fresh forms are preferred in Turkey.

For fresh consumption, consumers commonly prefer juicy, crispy, tasty, hard and large size jujube fruits. Cracks over the fruit skin reduce the quality, influence consumer preferences and decrease cold storage and shelf life of the fruits. Cracking is a serious problem for various fruits (sweet cherry, apple, peach, grape, pomegranate, persimmon, plum and orange) including jujube fruits (Kader et al., 1982; Balbontin et al., 2013; Hua et al., 2015; Khadivi-Khub, 2015). It was reported that cracking rates varied with the cultivars and the precipitations during the fruit growth stages and fruits were totally lost in some years in the USA (Yao, 2013). Guo and Shan (2010) indicated about 40% cracking-induced fruit loss in every 5 years in Shandong Province of China. Although there aren't any studies on cracking rates in Turkey, producers indicated significant losses in some years.

Although cracking is influenced by several factors including growth stage, ambient temperature, fruit load, structure of cuticle layer, osmotic potential, fruit size, rootstock and cultivar; researchers mostly indicated the primary reason of cracking as the pre-harvest precipitations (Measham, 2011; Meland et al., 2014; Hua et al., 2015). Measham (2011) indicated that pre-harvest precipitations were absorbed by roots and directly by the fruits, and such precipitations increased fruit turgor pressure and ultimately resulted in cracking over the fruit skin.

The use of protective coverings throughout the fruit ripening are one of the most effective methods to prevent cracking in fruit. Rain protective coverings (RPCs) prevent the contact of fruit with rain drops and ultimately prevent or reduce cracking over fruit skins. Besides, external solutions may also regulate osmotic potential or improve the strength of fruit skin, thus may be effective in reducing cracking

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(Meland et al., 2014). For instance, salt or sugar treatments balanced osmotic potential of sweet cherry and reduced water intake through cuticle in rainy seasons (Lang et al., 1997). Calcium-based chemicals were also reported to reduce water intake through cuticle, thus effective in reducing cracking rates (Lang et al., 1997). Growth regulators are also applied to prevent cracking over the fruit skins. Especially gibberellic acid (GA_3) has been used by the growers in several fruit species to prevent cracking and positive outcomes have been reported by all (Yildirim and Koyuncu, 2010; Zhang and Whitting, 2011). A lipophilic hydrophobic compound, commercially produced under the brand of Parka (7.5% stearic acid, 5% cellulose and %1 calcium based bio film provided by Cultiva) was also used in sweet cherry to create a cover over the fruit skins and thus to prevent water intake, to increase skin elasticity and ultimately to reduce cracking rates over the fruit skins (Meland et al., 2014).

The present study was conducted to investigate the effects of GA_3 and Parka treatments supplemented with RPC on cumulative cracking, cracking index and fruit quality characteristics of jujube fruits.

2. Materials and methods

2.1. Plant material

Experiments were conducted with 5-year old jujube (*Ziziphus jujuba* Mill. cv 'Li') trees propagated from the cutting (40°44′00.18″N latitude, 35° 45′ 23.44″E longitude and 432 m altitude). 'Li' cultivar has spread to the world from the Shanxi region of China. It is mainly grown in China and the USA. 'Li' jujube has large and oval shape, and is to eat fresh. The fruit is thin ochre-red with white flesh that is sweet, crisp and juicy.

Climate data for experimental site is presented in Fig. 1. Experimental soils were sandy loam in texture with medium organic matter level. Jujube trees were planted along east-west direction with 3.5 m row spacing and 2 m on-row plant spacing.

The cultural practices such as pruning, irrigation and fertilization were performed regularly according to commercial standards. Trees were trained as central leader system. The jujube trees were irrigated by drip irrigation method during the experiment. This method consisted of 2 lateral lines per tree row (0.5 m apart) with in-line drippers (2 L h^{-1}) spaced at 0.50 m. Macro-micro nutrients were supplied in four aliquots on April 1, May 1, June 1 and July 1. A total of 12 g N (nitrogen), 15 g K_2O (60%, potassium oxide), 5 g $NH_4H_2PO_4$ (monoammonium phosphate) and 20 g K_2SO_4 (potassium sulphate) were supplied to trees. Additionally, 5 g calcium nitrate [Ca (NO_3)] was supplied once in August 1. Any symptoms of nutritional deficiency were not observed in leaf or fruits during the growing season.

2.2. Experimental design

Field experiments were carried out between September 3 - October 15 (one week after commercial harvest) of 2016. The trial was established in a split plot design with four replications for each treatment combination. Trees were planted in four rows with 32 trees in each row. Half of the trees in each row were covered with a cover (polyethylene), and the other half of the trees was left uncovered. In each row, both covered and uncovered plots were divided into four sub-plot with four trees. In each covered and uncovered plot, four trees were treated with Parka, four trees with GA_3, four trees with GA_3 + Parka, and four trees were used as the control. A tree was used as a buffer between the treatments.

2.3. Treatments

The covering method was mounted pitched cover with 0.5 m vertical distance from upper tree level to covers. The pitched cover was able to fully cover the tree. The framework was made of pine wood (4.5 × 6.5 m), supported with a wire over the wood frame posts (3.25 m) and the cover was trussed up to the trees of the next row. The cover material was made of 0.1 mm polyethylene and light transmittance was about 92% at 400 to 1100 nm and 0% at 300 to 350 nm [ultraviolet (UV)]. Cover material was placed on 8 October 2016 (5 weeks ahead of commercial harvest date, 3 September 2016) and removed on 15 October 2016.

The experimental trees were uniformly sprayed with an aqueous solution containing a certain concentration of GA_3 (15 mgL^{-1}, Berelex, Valentbioscience, USA) and/or 1% Parka (containing, 5% cellulose, 7.5% stearic acid and 1% calcium; Cultiva, USA) until run-off with a low pressure hand sprayer. The solutions (Parka, GA_3 and GA_3 + Parka) were sprayed 3 and 2 weeks before the commercial harvest date. All spray solutions included 'Sylgard-309' as surfactant [0.05%, v/v (Dow Corning, Canada Inc., Toronto)]. Only surfactant + water was sprayed to the control trees. All solutions were sprayed over trees early in the morning of a day without wind and precipitation. The rainfall was not forecasted for the following 24 h. The approximate temperature and relative humidity (RH) during spraying was 12 ± 1.0 °C and 80 ± 5% RH, respectively.

Fruit were hand-harvested (8 October 2016) at edible stages of maturity (when the skin color turned into 25–50% from yellow/green

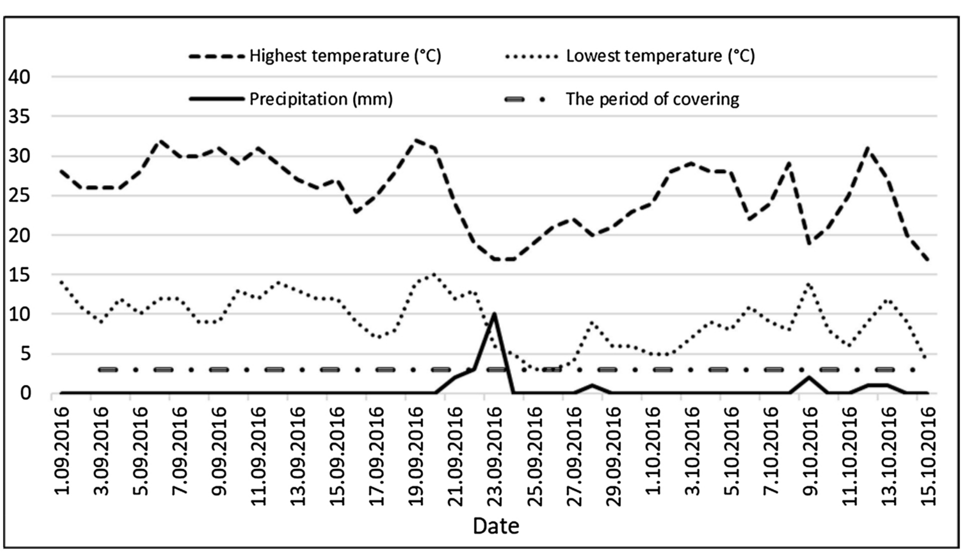

Fig. 1. Daily precipitation (mm), highest and lowest temperature (°C) from covering to last observation date of cumulative cracking rate.