



Effects of harvest date and low-temperature conditioning on chilling tolerance of ‘Wonderful’ pomegranate fruit



Yael Kashash^{a,c}, Lina Mayuoni-Kirshenbaum^a, Livnat Goldenberg^a, Hyun Jin Choi^b, Ron Porat^{a,*}

^a Dept. of Postharvest Science of Fresh Produce, ARO, the Volcani Center, P.O. Box 6, Bet Dagan 50250, Israel

^b Postharvest Research Team, National Institute of Horticultural and Herbal Science, Wanju-gun, Jeollabuk-do, South Korea

^c The Robert H. Smith Faculty of Agricultural, Food and Environment Sciences, the Hebrew University of Jerusalem, Rehovot 76100, Israel

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ABSTRACT

The optimal storage temperatures for ‘Wonderful’ pomegranates are between 5 and 7.5 °C. However, application of a cold-quarantine disinfestation treatment against the Mediterranean fruit fly (*Ceratitis capitata*) requires exposure to a much lower temperature – below 1 °C – for at least 14 days; conditions that often cause chilling injury (CI) symptoms, manifested in surface pitting and internal browning of the white spongy tissue and inner membranes. We demonstrated that harvest time had a remarkable effect on fruit chilling tolerance: early-harvested fruits were very susceptible to CI and were severely damaged after 4 weeks of exposure to 1 °C followed by an additional week at a shelf-life temperature of 20 °C, whereas late-harvested fruits were rather chilling tolerant and showed hardly any CI symptoms after similar exposure. In addition, we developed a postharvest low-temperature-conditioning (LTC) treatment for ‘Wonderful’ pomegranate fruits; it involves exposure to a moderate temperature of 15 °C for 10 days before transfer to the cold-quarantine treatment. When this proposed LTC treatment was applied to mid-season fruits, it entirely prevented the appearance of CI symptoms after 4 weeks storage at 1 °C followed by one additional week at 20 °C, without impairment of fruit-quality parameters, as manifested in loss of weight, flavor, juice total soluble solids and acid contents, and total antioxidant activity. Overall, these findings demonstrate that harvesting mid- and, preferably, late-season fruits, and applying a pre-storage LTC treatment at 15 °C for 10 days, enables export of ‘Wonderful’ pomegranates to new markets that require cold-quarantine disinfestation treatments against the Mediterranean fruit fly.

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1. Introduction

Pomegranate (*Punica granatum* L.) fruits and juice form a rich and unique source of bioactive phytochemicals, and their consumption confers proven medicinal benefits in preventing various chronic diseases, such as cardiovascular diseases, diabetes, and cancer (Heber et al., 2006; Newman and Lansky, 2012). Accordingly, these findings led to dramatic increases in demand for and world trading of pomegranate fruits and juices (Rymon, 2011). The main pomegranate variety grown in several major pomegranate-producing countries, such as California and Israel, is ‘Wonderful’, which bears large, late-season fruits that ripen in October and are “sweet-sour” in taste (Holland et al., 2009). On account of its

appearance, attractive taste, and late ripening, ‘Wonderful’ also is one of the main varieties that are stored for long periods in order to extend the marketing season (Hess-Pierce and Kader, 2003; Porat et al., 2009; Mayuoni et al., 2013). In this respect, the main problems associated with prolonged storage of pomegranate fruits are weight loss and shrinkage, decay development, appearance of physiological disorders, i.e., scald and chilling damage, and impaired internal quality and flavor (Elyatem and Kader, 1984; Kader, 2006; Koksall, 1989; Opara et al., 2015; Pareek et al., 2015).

Pomegranate fruits are chilling sensitive, and are prone to develop chilling injury (CI), manifested as surface pitting on the peel and internal brown discoloration of the white spongy tissue surrounding the arils and the inner membranes, when exposed to unfavorably low temperatures (Elyatem and Kader, 1984; Paull, 1990). In the case of ‘Wonderful’ pomegranates, the recommended safe storage temperatures for avoiding CI are 5 °C for up to 2

* Corresponding author.

E-mail address: rporat@volcani.agri.gov.il (R. Porat).

months, and 7.2 °C for longer storage periods (Crisosto et al., 1996; Elyatem and Kader, 1984).

This sensitivity of pomegranate fruits to low storage temperatures raises serious economic concerns, because cold storage provides an important quarantine treatment that is required for exporting fruit to fly-free zones in many countries. According to the US Animal and Plant Health Inspection Service (APHIS), the approved cold-quarantine treatment against the Mediterranean fruit fly (*Ceratitus capitata*) involves exposure of the fruits to an internal temperature below 1.1 °C for at least 14 days (USDA, 1976; Powell, 2003). This temperature is lower than the recommended safe storage temperature therefore this treatment might cause substantial CI damage.

Several postharvest treatments can reduce development of CI symptoms during cold storage (Hatton, 1990; Wang, 1993). In pomegranates, it was reported that various treatments, including application of the polyamines spermidine and putrescine (Barmann et al., 2011; Mirdehghan et al., 2007; Ramezaniani et al., 2010; Ramezaniani and Rahemi, 2011), and the plant growth regulators jasmonic acid and salicylic acid and their derivatives (Sayyari et al., 2009, 2011) enhanced fruit chilling tolerance. Similarly, it was reported that heat treatments, including either hot air at 38 °C or hot water at 45–55 °C, also enhanced pomegranate fruit chilling tolerance (Mirdehghan and Rahemi, 2004; Rahemi and Mirdehghan, 2004). Nonetheless, these treatments were only partially effective, and could not entirely prevent the appearance of CI symptoms.

During the last few years, we evaluated the effects of harvest date on the quality and postharvest storage performance of pomegranate fruits, and noticed that it had a remarkable effect on chilling susceptibility. In addition, in previous studies in our laboratory we found that low-temperature conditioning (LTC) was very effective in reducing CI damage in citrus fruits (Maul et al.,

2011; Porat et al., 2003; Sapitnitskaya et al., 2006). However, we could not find any published information regarding the efficacy of LTC treatments for reduction of CI development in pomegranates. Therefore, the aims of the present study were: (1) to evaluate the effects of harvest date on susceptibility or tolerance of 'Wonderful' pomegranates to low temperatures; and (2) to develop a postharvest LTC treatment that would enhance chilling tolerance of 'Wonderful' pomegranates. Our general goal was to develop a protocol that would allow exposure of 'Wonderful' pomegranates to a cold-quarantine disinfestation treatment against the Mediterranean fruit fly, in order to enable the fruit to be exported to new markets. Because pomegranates may suffer from development of external peel damage for reasons other than CI – reasons such as scald (Defilippi et al., 2006) – in the present study we evaluated CI as manifested in internal browning symptoms, which result solely from exposure to chilling at low temperatures.

2. Materials and methods

2.1. Plant material and harvest dates

The experiments were conducted during the pomegranate-growing seasons of 2012 through 2015. To evaluate the effects of harvest dates on chilling susceptibility or tolerance of 'Wonderful' pomegranates, fruits were harvested in the 2012 and 2013 growing seasons at 2-week intervals from the beginning of the harvest season (early- to mid-October) till the end of the season (early- to mid-November); whereas in 2015 they were harvested only twice—at the beginning and end of the harvesting season. In 2012 fruits were harvested from the Hazera farm in the southern low-land area of Israel, and in 2013 and 2015 they were harvested from the Moshvey Hanegev farm in the Negev area in southern Israel.

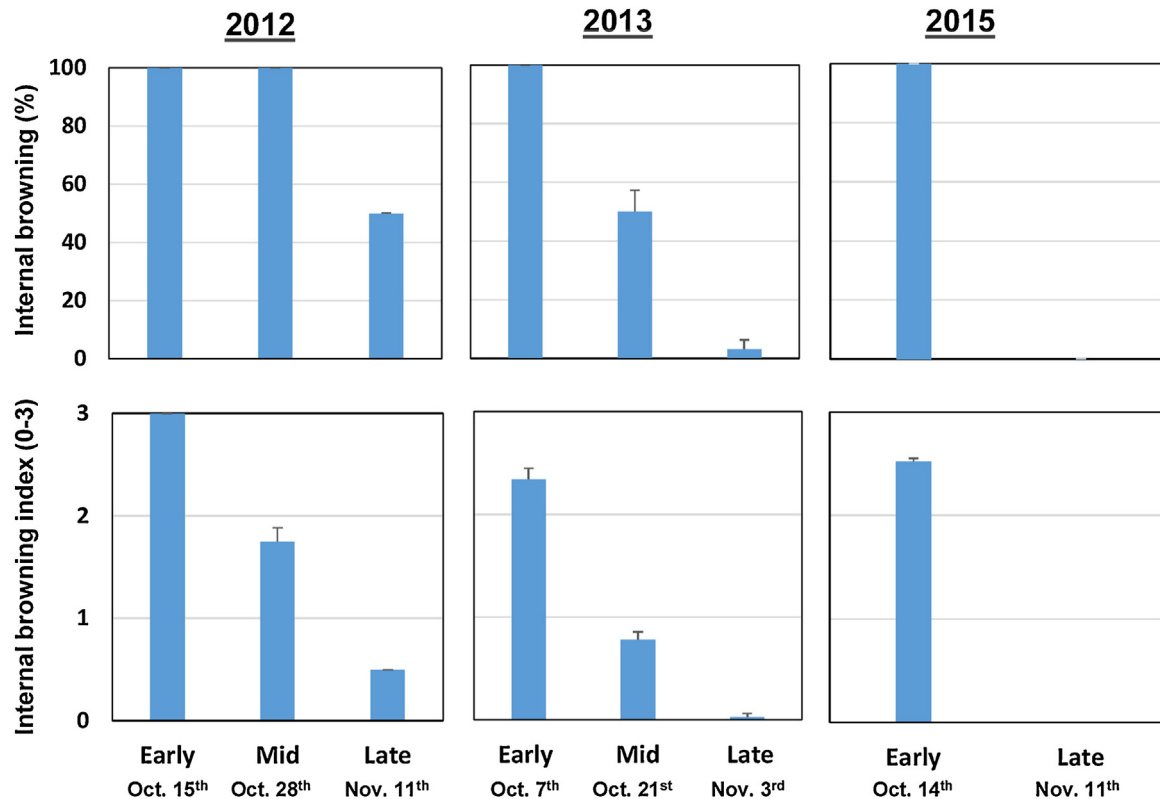


Fig. 1. Effects of harvest date on chilling susceptibility or tolerance of 'Wonderful' pomegranate fruits. Chilling injuries (manifested as internal browning) of fruits from different harvest times were determined during the 2012, 2013, and 2015 growing seasons, and evaluated after 4 weeks of storage at 1 °C and 1 week at a shelf-life temperature of 20 °C. Data are means $\pm$ S.E. of four cartons, each containing 9–11 fruits.

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