Available online at www.sciencedirect.com
SCIENCE DIRECT®
Postharvest Biology and Technology 37 (2005) 31–36
Postharvest Biology and Technology
www.elsevier.com/locate/postharvbio

Integration of pre- and postharvest treatments to minimize *Penicillium* decay of Satsuma mandarins

Pervin Kinay [a,*], Figen Yildiz [a], Fatih Sen [b], Mehmet Yildiz [a], Ismail Karacali [b]

[a] *Ege University, Faculty of Agriculture, Department of Plant Protection, 35100 Bornova, Izmir, Turkey*
[b] *Ege University, Faculty of Agriculture, Department of Horticulture, 35100 Bornova, Izmir, Turkey*

Received 25 June 2004; accepted 16 February 2005

Abstract

Green and blue mold, caused by *Penicillium digitatum* (Pers.) Sacc. and *P. italicum* Wehmer, respectively, cause significant losses of Satsuma mandarins (*Citrus unshiu* Marc.) after harvest. The effects of some pre- and postharvest treatments on development of these diseases and on the wound healing processes of Satsuma mandarin fruit were determined. Trees were treated with $CaCl_2$ in combination with growth regulators (2,4-D and GA_3) and benomyl before harvest. Fruit were harvested from each treatment and wounded at three sites. One group was inoculated with the pathogens immediately while another group was inoculated 3 days later. Of these, one group was held at 30 °C with high humidity (90–95%) for 72 h, which is a thermal curing regime, and another was exposed to UV-C light for 10 min. Green and blue mold incidence after harvest during storage was inhibited by preharvest treatments containing benomyl. UV light treatments also reduced green mold, but caused some injury to the fruit. The disease incidence was very low among fruit that were held at 30 °C with high humidity (90–95%) for 72 h compared to the other treatments. Combinations of these treatments were additive in efficacy.

Keywords: Satsuma mandarin; Postharvest; Preharvest; *Penicillium* decays; Wound healing; Curing

1. Introduction

The Satsuma mandarin is important export crop for Ege Region of Turkey, especially in the Izmir province. Postharvest penicillium (*Penicillium digitatum* and *P. italicum*) decay is the main problem during transportation and the typically brief period of storage. This has been generally controlled by postharvest fungicide treatments. However, decay can be a significant problem during ethylene degreening, a practice conducted after harvest to improve fruit color and done before packing line processing, so there is no fungicide present during this process to protect the fruit. Some physiological control methods, such as thermal curing to induce wound healing and enhance host resistance

* Corresponding author. Tel.: +90 232 388 40 00/1411; fax: +90 232 374 48 48.
E-mail addresses: kinay@ziraat.ege.edu.tr, pkinay@yahoo.com (P. Kinay).

0925-5214/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.postharvbio.2005.02.008

of citrus fruit, have recently emerged as promising alternatives to the postharvest use of fungicides. Other treatments, such as low temperature and growth regulators (2,4-D and gibberellic acid), that delay fruit senescence also suppress the development of postharvest diseases, as can the application of fungicides to the fruit before harvest (Ferguson et al., 1982; Eckert et al., 1990). The application of calcium before and after harvest has been reported to play an important role in reducing physiological disorders, delaying fruit senescence, and inhibiting postharvest decay (Sommer, 1992). The degreening of citrus fruit with ethylene at high humidity (90–95% RH) and 30 °C has been reported to reduce the incidence of green mold in Florida (Ismail and Brown, 1979), although degreening in most other parts of the world is done at lower temperatures to avoid ethylene-associated rind injuries (Eckert and Eaks, 1989). Wound healing, due to the formation of lignin and the induction of the antifungal compounds such as scoparone and scopoletin (Brown, 1973; Ismail and Brown, 1975; Ben-Yehoshua et al., 1988, 1989; Stange et al., 1993; Ben-Yehoshua, 2003) is accelerated during high humidity storage at 30 °C, and impedes hyphal penetration of the fruit by *P. digitatum* (Stange and Eckert, 1994). Temperatures of 30 °C or higher inhibit growth of these pathogens (Plaza et al., 2003a). The reduction in postharvest decay accomplished by curing of fruit at these temperatures is a combination of resistance to infection and thermal inhibition of the pathogens.

Curing at 33 °C for 65 h prevented mold development on artificially inoculated and naturally infected orange fruit (Plaza et al., 2003b). Also, curing at 36 °C for 3 days reduced chilling injury on 'Star Ruby' grapefruit (Porat et al., 2000). High humidity and temperature (30 °C) accelerate the healing process and retard decay apparently by enhanced lignin formation observed through histological staining (Mulas et al., 1996). The objective of this study was to increase the host resistance to pathogens by the combination of preharvest treatments with calcium, 2,4-D, gibberellic acid (GA_3), and fungicides, with postharvest curing treatments to minimize decay of Satsuma mandarin peel after harvest. This is the first report where the combined effects of preharvest and postharvest treatments of these kinds on postharvest green mold have been assessed.

2. Materials and methods

2.1. Preharvest treatments

All experiments were conducted on Satsuma mandarins (*Citrus unshiu* Marc.) at the orchard of the Ege University, Faculty of Agriculture with 25-year-old trees. For each application, three trees were selected for uniform size and treated in the orchard.

Calcium chloride ($CaCl_2{\cdot}2H_2O$) was applied at the rate of 2% (w/v) three times at an interval of 10 days beginning 1 month before harvest. Benomyl was used as a control for preharvest applications. Benomyl (Benlate 50% WP, Du Pont) at the dose of 60 g/100 l, 2,4-D (dichloro-phenyl acetic acid; Citrofix 1.6%, 2,4-D v/v, Inapra, Spain) and gibberellic acid (Berelex, 1 g technical gibberellic acid Tablet/Hektas) at the rate of 10 μg/ml were applied on the selected trees 10 days before harvest. An adhesive and spreading material Agral (Zeneca) was used at a rate of 0.25% per liter of solution in all the treatments. Control trees were sprayed with water containing Agral. Fruit were harvested at commercial maturity.

In the first year, the preharvest applications were: (1) control; (2) $CaCl_2$; (3) $CaCl_2$ + 2,4-D; (4) $CaCl_2 + GA_3$; (5) $CaCl_2$ + benomyl; (6) $CaCl_2$ + 2,4-D + GA_3; (7) $CaCl_2$ + 2,4-D + benomyl; and in second year, (8) $CaCl_2 + GA_3$ + benomyl treatment was added. In the final year, the treatments were: (1) control, (2) $CaCl_2$ + 2,4-D + GA_3, and (3) $CaCl_2 + GA_3$ + benomyl.

2.2. Curing applications

Fruit treated before harvest were taken from the orchard and exposed to some curing treatments at 30 °C for 72 h and UV-C light (10 min) to determine the influence of preharvest applications on wound healing.

Fruit were harvested from each treatment and washed, air-dried, and injured at three points (2 mm diameter × 2 mm deep). These fruit were divided into two groups. *P. digitatum* and *P. italicum* cultures were maintained on potato dextrose agar medium for 7–10 days. Spore suspensions of pathogens were adjusted to 1×10^4 spores ml^{-1}. The first group were inoculated with *P. digitatum* and *P. italicum* (1×10^4 spores ml^{-1}) by spraying, then immediately placed in moist plastic trays and kept at 25 °C. After wounding, the sec-