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Reduction of Chilling Injury in Grapefruit by Thiabendazole and Benomyl during Long-Term Storage[1]

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Abstract. Postharvest treatments with thiabendazole (TBZ) and benomyl reduced the incidence of chilling injury (CI) in grapefruit (*Citrus paradisi*, MacFadyen) as expressed by peel pitting. The effect persisted during prolonged storage at 2, 5 and 8°C. Thiabendazole was more effective than benomyl. The effectiveness of both TBZ and benomyl in water suspension increased when followed by waxing, but the greatest reduction in CI was obtained with the chemicals incorporated in the wax coating. The effect of TBZ was enhanced by increasing concentration and residues, while the effect of benomyl did not change with concentration. Both chemicals were effective in reducing rots during cold storage. There was a marked increase in the incidence of rots during shelf-life. These rots, primarily of the mold type—*Penicillium digitatum* Sacc. and *P. italicum Wehmer*, developed mostly in pits induced by the low storage temperatures.

Besides their fungicidal action, TBZ and benomyl have been reported to produce various physiological effects on a wide range of plants. These effects include delay of leaf senescence in a number of crop plants (1, 5, 7, 15), promotion of postharvest breakdown in pears (2), as well as stimulation of respiration and ethylene production in this fruit (Ruth Ben-Arie, personal communication). Thiabendazole and benomyl were found to reduce ozone injury to leaves (6, 10), while postharvest applications of TBZ reduced peel pitting of citrus fruit caused by ethylene dibromide fumigation (3).

Chilling injury (CI) and rots are primarily responsible for limiting the postharvest life of grapefruit. In view of the susceptibility of grapefruit to CI at low temperatures, a relatively high storage temp. of 12°C is recommended (12). We found earlier (11) that TBZ reduced CI and other forms of peel pitting in grapefruit at low storage temp. Similar results were obtained by Wardowski et al. (14).

Our purpose was to compare the effects of benomyl and TBZ on CI. To elucidate the mode of action of these 2 benzimidazole derivatives in reducing CI, we studied the relationships among their concns, residues and modes of application.

Materials and Methods

'Marsh Seedless' grapefruit picked from the same grove several times during 2 seasons was used in both laboratory and large-scale, semi-commercial experiments.

Laboratory experiments. To determine the effect of concn and mode of application of TBZ and benomyl on CI, fruits were treated with 0.02 to 2.0% active ingredient (a.i.) of each chemical. The modes of application were: a) water suspension of TBZ or benomyl, b) water suspension treatment followed by wax coating, c) wax coating containing TBZ or benomyl incorporated into the wax shortly prior to treatment, d) plain wax coating, and e) untreated control. All the treatments were made one day after harvest by dipping the fruit and then drying. Following treatment, the fruit were packed unwrapped in cartons, stored at 5, 8 or 12°C for up to 16 weeks, and then transferred to 17°C for 2 additional weeks to simulate shelf-life. Each experimental lot consisted of 50–80 fruits. The experiment was conducted twice.

Large-scale experiments. The effect of TBZ and benomyl on CI was tested on fruit treated in a commercial packinghouse. Fruit from the same grove was divided into 3 equal lots. One lot was coated with a water emulsion wax containing 0.4% a.i. TBZ; another lot was coated with the same wax containing 0.2% a.i. benomyl (current commercial practice). The third lot was treated with plain wax as a control. All fruit were packed unwrapped in cartons, each with 2 diphenyl-impregnated pads (3 g diphenyl/carton). The fruit were stored at 2, 5, 8, 12, or 17°C for 4, 8, 12, 16, or 20 weeks. Each storage period was followed by 2 weeks simulated shelf-life at 17°C. The relative humidity in storage rooms was 90 ± 4% with 1½ fresh air changes/hr based on empty room volume. Each lot for every storage period and temp. combination comprised 10 cartons, with an average of 56 fruits per carton.

In all experiments, the incidence and severity of CI were evaluated during storage and after simulated shelf-life. Fruit showing sunken surface lesions or brown discoloration covering more than 0.5 cm^2 was classified as pitted. Rot incidence, wt loss, and changes in fruit color were recorded. Thiabendazole and benomyl residues were analyzed by the method of Rajzman (8, 9).

Results

Thiabendazole as well as benomyl consistently reduced the incidence of CI during prolonged storage at low temp in both laboratory and large-scale experiments. Thiabendazole was more effective than benomyl at all concns tested, irrespective of mode of application (Fig.

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I). Even with benomyl at a higher concn and with higher residues, the superiority of TBZ was still evident. For example, with TBZ at 0.4% and benomyl at 1.0%, with residues in the peel of 23.0 and 46.2 ppm, respectively, CI was 17.5% in TBZ-treated fruit and 40.0% in benomyl-treated fruit (data not shown).

The efficacy of both chemicals in reducing CI was dependent on the mode of application to the fruit, decreasing in the following order: (i) chemicals in wax; (ii) water dip + wax; (iii) water dip only; and (iv) plain waxing, no chemical (Fig. 2).

The efficacy of TBZ in reducing the incidence of CI was found to be a function of concn. This was evident in the case of TBZ applied in the water suspension (Fig. 3) as well as in other modes of application. On

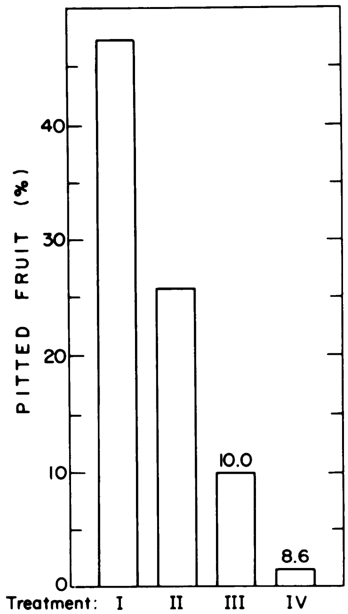

Fig. 1. Reduction of chilling injury in grapefruit by benomyl or TBZ. Concentration of chemicals in the wax was 0.4%, storage period 8 weeks at 8°C. Treatments: I, non-treated control; II, plain coating; III, wax containing benomyl; IV, wax containing TBZ. All treatments were applied by dipping. Numbers on columns indicate residues of the chemical in the peel (ppm).

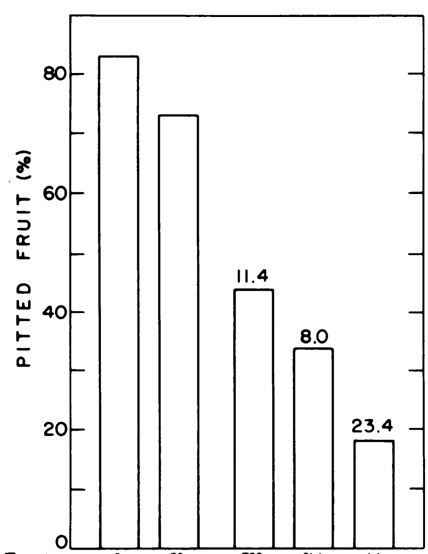

Fig. 2. Effect of mode of application of TBZ on chilling injury in grapefruit during cold storage. Storage period 14 weeks at 5°C. Concentration of TBZ, 0.4%. Treatments: I, non-treated control; II, plain coating; III, water suspension of TBZ; IV, as in III, followed by wax coating; V, wax coating containing TBZ. All treatments were applied by dipping. Numbers on columns indicate residues of TBZ in the peel (ppm).

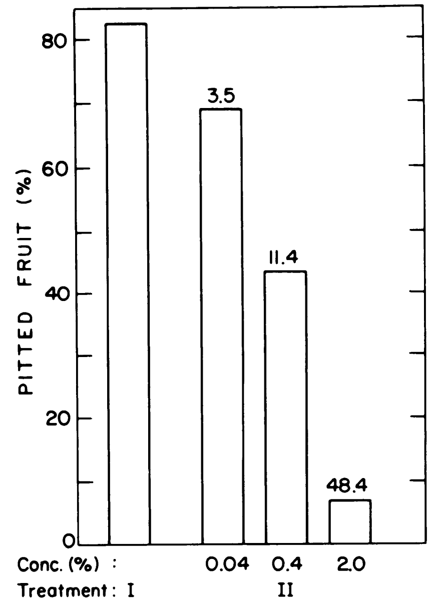

Fig. 3. Reduction of chilling injury in grapefruit by TBZ, as affected by the concentration of the chemical. Storage period 14 weeks at 5°C. Treatments: I, non-treated control; II, water suspension of TBZ. All treatments were applied by dipping. Numbers on columns indicate TBZ residue in the peel (ppm).

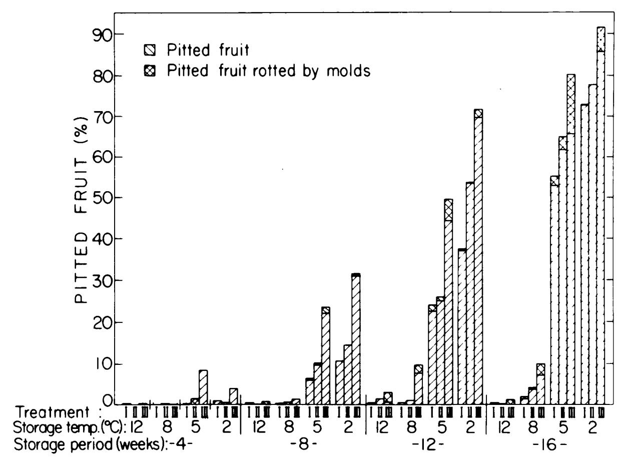

Fig. 4. Reduction of chilling injury in grapefruit by TBZ or benomyl applied in the wax coating, as recorded for different temperatures and storage periods. Treatments: I, wax containing 0.4% TBZ; II, wax containing 0.2% benomyl; III, plain wax coating. All treatments were sprays applied in the packinghouse.

the other hand, there was no evidence that reduction of CI by benomyl was affected by its concn or by the amount of residue in the peel.

Large-scale experiments. Packinghouse tests confirmed those from the laboratory. There was negligible CI pitting at the storage temp of 12°C and none at 17°C. At all temp tested, TBZ was significantly [Sign test $p < 0.01$] more effective than benomyl in reducing CI. The reduction by benomyl was in turn significantly greater than by wax alone (Fig. 4). The effect of TBZ and benomyl persisted up to 20 weeks. In prolonged storage, the effectiveness of TBZ and benomyl was more pronounced at the slightly suboptimal temp of 8°C than at 2° or 5°C, which are conducive to high incidence of CI.

TBZ and, to a lesser extent, benomyl reduced not only the incidence of CI pitting but also its severity, as expressed by the size of the affected area of the fruit surface (data not shown).

The incidence of rots in cold storage was generally low, although they increased slightly with duration (Fig. 4). There was, however, a marked increase in the incidence of rots during the shelf-life period at 17°C. These rots developed mostly in the pits induced by storage temp of 2° and 5°C (Fig. 5). Most prevalent were green mold (*Penicillium*

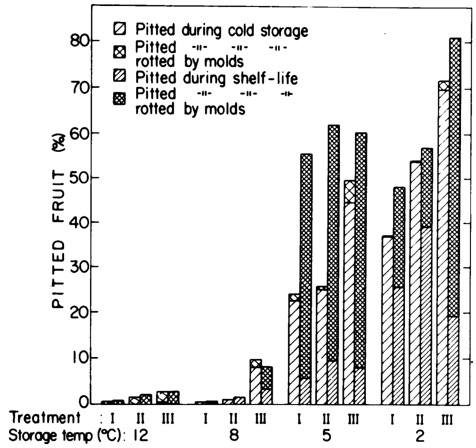

Fig. 5. Incidence of chilling injury and mold rots in grapefruit after 12 weeks of cold storage and 2 additional weeks of shelf-life at 17°C. Treatments: I, wax containing 0.4% TBZ; II, wax containing 0.2% benomyl; III, plain wax coating. All treatments were sprays applied in the packinghouse.

digitatum Sacc.) and, to a lesser extent, blue mold (*P. italicum* Whemer). The apparent reduction in the incidence of CI recorded after a fortnight of shelf-life (Fig. 5) is accounted for by the high percentage of rot that developed during shelf-life on pitted fruit and marked CI injury.

Results similar to those described above were obtained with fruit harvested throughout the season, but generally CI was more severe in fruit harvested toward the end of the season.

Weight loss of the whole fruit and peel was not affected by incorporation of TBZ or benomyl at any concn in the wax coating, nor did these chemicals significantly affect the rate of change in the chemical composition of the fruit during storage.

Fruit color changes during prolonged storage at all temp tested were significantly slowed down by TBZ applied in the wax coating. This effect was recorded for the transition from light green to yellow in fruit harvested early in the season as well as for the bronzing of yellow fruit. Benomyl did not affect fruit color.

Discussion

Our results show clearly that, besides their fungicidal action, TBZ and benomyl bring about a marked reduction in incidence of CI during prolonged storage of grapefruit at low temp. This effect may be related to a decrease in the rate of peel senescence. It also bears close resemblance to the inhibition of leaf senescence by benzimidazoles reported by a number of workers (1, 5, 7, 15). There may be a definite relationship between the 2 phenomena; it is possible that, in both instances, the underlying processes are similar to those involved in the inhibition of senescence by certain growth regulators (7, 13).

The greater effectiveness of TBZ in reducing CI, as compared with benomyl, suggests that the 2 chemicals may differ in their physiological activity. This assumption would seem to find support in the fact that only TBZ slowed down the color changes in grapefruit associated with peel senescence, and that the effectiveness of TBZ in reducing CI increased with concn while that of benomyl did not. These differences between the 2 benzimidazoles are perhaps associated with differences in mobility within the plant tissues. It is also possible that the 2 differ in chemical stability. Furthermore, these 2 compounds differ in their fungicidal action, benomyl being more effective than TBZ (4).

From the practical point of view, the effectiveness of TBZ, and to a lesser extent that of benomyl, in reducing CI, points to the possibility of lowering the optimum temp for long-term storage of grapefruit from 12° to 10° or 8°C, by making use of these chemicals. Such a change may improve fruit quality by reducing the rate of physiological deterioration of the fruit, and of rot development, thereby extending the storage life.

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