

on lemons, the fruit were pressure washed with water and immersed in 0, 93, 160, or 405 $\mu\text{g}\cdot\text{ml}^{-1}$ imazalil heated to 32.2, 37.8, or 43.3°C for 15, 30, or 60 s. After treatment, the lemons were dried in the first stage of the packing line dryer as previously described, waxed with a water-emulsion lemon storage wax, and dried in air on wire screens. Fruit were stored at 10°C and the imazalil content of the fruit analyzed within 7 days as previously described.

Comparison of imazalil efficacy when applied in wax or in water heated to 37.8°C. To compare the influence of imazalil (Fungaflor 500EC) applied in wax or in water heated to 37.8°C on control of the incidence and sporulation of *P. digitatum* using oranges and lemons, all fruit were inoculated with isolate M6R 24 h before treatment. Fruit were pressure washed with water, then treated with imazalil by: 1) immersion in 136, 240, 350, or 490 $\mu\text{g}\cdot\text{ml}^{-1}$ imazalil at 37.8°C for 15 s, dried in the first stage of the packing line dryer, waxed, and dried in the second stage of the packing line dryer as previously described; or 2) after drying in the first stage of the packing line dryer, they were sprayed with a high solids content, shellac-based organic finishing wax containing 1,100, 2,200, 3,400, or 4,200 $\mu\text{g}\cdot\text{ml}^{-1}$ imazalil, and dried in the second stage of the packing line dryer as previously described. Fruit were stored at 10°C and the imazalil content of the fruit analyzed within 7 days as previously described. Green mold incidence and sporulation of *P. digitatum* was determined as previously described.

Preliminary tests showed fruit immersed in heated aqueous solutions of imazalil for 15 s or less often had imazalil residues too low to control sporulation of *P. digitatum*, therefore, the heated imazalil treatments were followed by a spray of imazalil in wax to increase imazalil residues. Lemons were treated by immersing in 0, 93, 160, or 405 $\mu\text{g}\cdot\text{ml}^{-1}$ imazalil heated to 32.2, 37.8, or 43.3°C for 15 s, dried in the first stage packing line dryer as previously described, waxed with water-emulsion lemon storage wax alone or storage wax containing 1,070 or 1,910 $\mu\text{g}\cdot\text{ml}^{-1}$ imazalil, and dried in air on wire screens. Fruit were stored at 10°C and the imazalil content of the fruit analyzed within 7 days as previously described.

Control of imazalil-sensitive or imazalil-resistant *P. digitatum* isolates. Navel oranges were inoculated using two *P. digitatum* isolates, imazalil-sensitive isolate M6R or imazalil-resistant isolate 151, incubated 24 h at 20°C, and immersed in 247 or 410 $\mu\text{g}\cdot\text{ml}^{-1}$ imazalil (Magnate Sulfate 750 WP, 75% a.i.; Makhteshim Agan, Republic of South Africa) heated to 21.1 or 40.6°C for 90 s; dried in the first stage of the packing line dryer as previously described, waxed with a high solids content, shellac-based organic finishing

wax; and dried in the last stage of the packing line dryer as previously described. Fruit were stored at 10°C and the imazalil content of the fruit analyzed within 7 days as previously described. Green mold incidence and sporulation of *P. digitatum* were determined as previously described.

Statistical analyses. Imazalil residues, the incidence of green mold, and sporulation of *P. digitatum* were analyzed by two- or three-way analysis of variance. An arcsin transformation of the square root of the proportion of decayed fruit was applied before analysis of the incidence of green mold. Duncan's new multiple range test ($P = 0.05$) to separate means or orthogonal contrasts were applied to compare treatments. A second order response surface model was fitted using SAS PROC GLM (SAS/STAT, Vers. 6, 4th Ed., Cary, NC) to predict the residues and 95% confidence intervals (CI). Regression expressions

describing the relationship between sporulation indices and imazalil residues were fitted using Cricket Graph III (1).

RESULTS

Influence of fungicide concentration, temperature, and immersion period on imazalil residues. Increasing the temperature, immersion time, or imazalil concentration increased imazalil residues on Valencia oranges (Table 1) and Eureka lemons (Table 2). Doubling the imazalil concentration, doubling the immersion time, or increasing the solution temperature by 5.6°C increased imazalil residues approximately one and one-half to two times on the fruit. Separate second order models describing imazalil residues for oranges and lemons were prepared that can be used to predict residues. Residues predicted by both models were similar to those measured (Tables 1 and 2).

Table 2. Influence of imazalil concentration, temperature, and immersion period on imazalil residues ($\mu\text{g}\cdot\text{g}^{-1}$) on Eureka lemons

Imazalil ($\mu\text{g}\cdot\text{ml}^{-1}$)	Temperature (°C)	Immersion time (s)		
		15	30	60
93	32.2	0.22 (0.25) ^a	0.33 (0.36)	0.46 (0.43)
93	37.8	0.34 (0.36)	0.57 (0.47)	0.60 (0.64)
93	43.3	0.50 (0.44)	0.61 (0.62)	0.94 (0.96)
160	32.2	0.54 (0.50)	0.58 (0.64)	0.84 (0.84)
160	37.8	0.68 (0.67)	1.07 (0.92)	1.58 (1.37)
160	43.3	0.79 (0.88)	1.18 (1.30)	2.11 (2.21)
405	32.2	0.92 (0.91)	1.42 (1.27)	1.75 (1.94)
405	37.8	1.42 (1.39)	1.77 (2.07)	3.88 (3.62)
405	43.3	2.06 (2.09)	3.70 (3.34)	6.65 (6.67)

^a Each value ($\mu\text{g}\cdot\text{g}^{-1}$) is the mean of two analyses. Values in parentheses are predicted by a second order surface model. The natural logarithm of imazalil residues in lemons = $-7.87 + 2.27 \cdot \text{Log}_e IC - 0.918 \cdot (T) + 0.0257 \cdot (\text{Log}_e IC \cdot T) - 0.0307 \cdot (t) + 0.00579 \cdot (\text{Log}_e IC \cdot t) + 0.000807 \cdot (T \cdot t) - 0.229 \cdot \text{Log}_e IC^2 - 0.00178 \cdot t^2$. IC = aqueous imazalil concentration ($\mu\text{g}\cdot\text{ml}^{-1}$); T = aqueous imazalil solution temperature (°C); and t = immersion time (s) in aqueous imazalil.

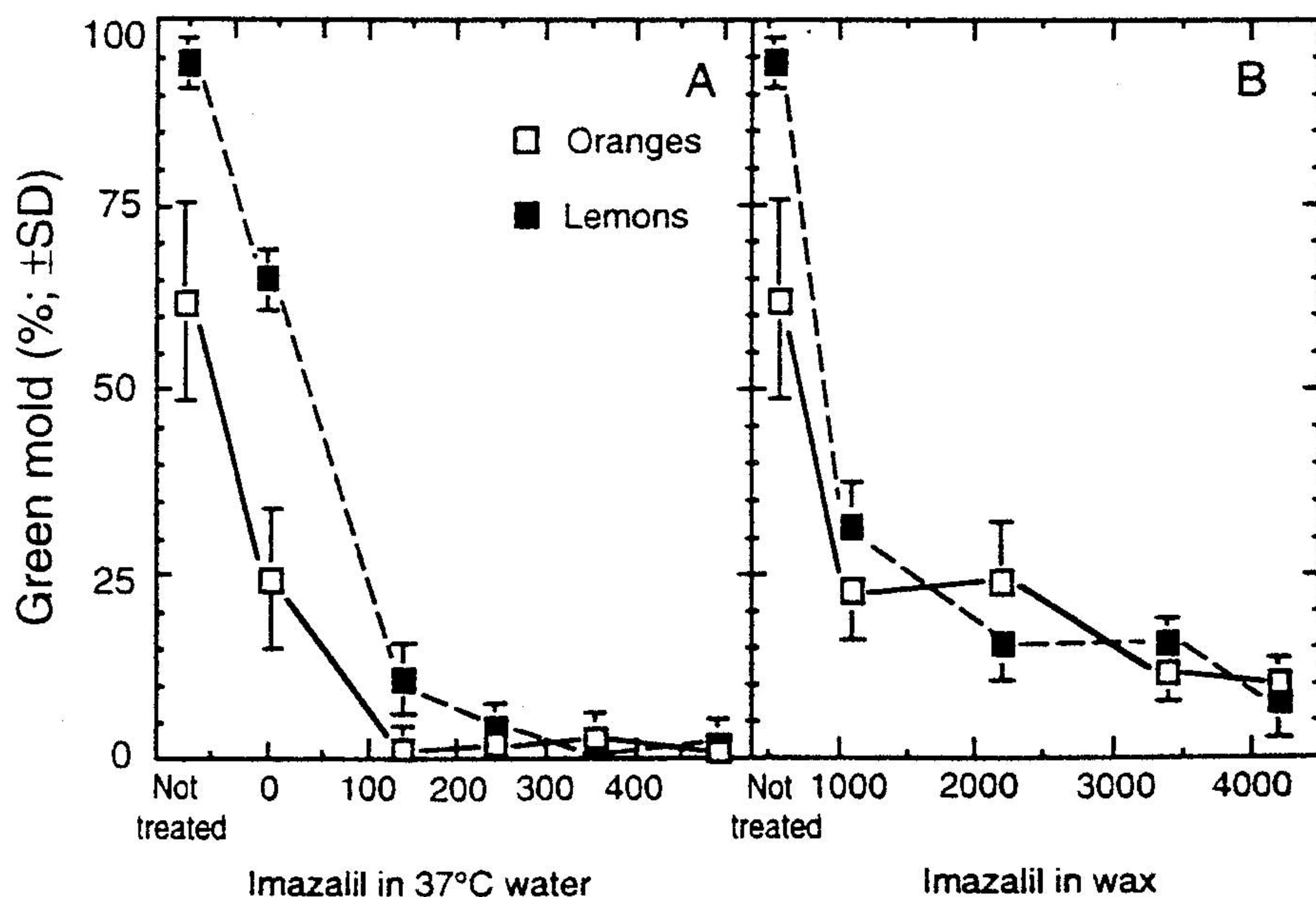


Fig. 1. Influence of imazalil concentration ($\mu\text{g}/\text{ml}$) and method of application on the incidence of postharvest green mold of oranges and lemons. The fruit were (A) immersed for 15 s in imazalil in water at 37°C or (B) sprayed with imazalil in wax over rotating brushes at 23°C. All fruit were inoculated 24 h before treatment with spores of *Penicillium digitatum*.