Control of Postharvest Disease in Cantaloups by Treatment with Guazatine and Benomyl

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ABSTRACT

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Postharvest treatment of mature ripening cantaloups (*Cucumis melo* var. *reticulatus*) with a dip containing both benomyl and guazatine controlled the disease complex responsible for market wastage in Australia. Naturally inoculated melons treated with 250 mg/L of benomyl and 500 mg/L of guazatine were still marketable after holding at 25 C for 1 wk after harvest.

Wastage of cantaloup melons from disease under Australian conditions is caused by *Fusarium* spp., *Geotrichum candidum, Rhizopus* spp., *Alternaria* spp., and *Cladosporium* spp. (10,11). The relative importance of the various organisms varies with weather and handling conditions. Hot wet weather favors development of soft rots incited by *G. candidum* and *Rhizopus* spp., whereas Fusarium rot occurs under dry or wet conditions. *Alternaria* spp. and *Cladosporium* spp. cause an unsightly surface blemish on the rind and stem scar and are especially troublesome in cool-stored fruit (12) or in netted cultivars at ambient temperatures.

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The best current treatments for wastage control in cantaloups are dips of captan (9) or sodium dimethyldithiocarbamate (1,2), both at 57 C, or dips of imazalil at either 24 or 57 C (2). The benzimidazole derivatives thiabendazole (12) and benomyl (4) have also proved useful in the control of cantaloup wastage. Recently, we reported (10) that benomyl specifically controls cantaloup wastage caused by *F. solani* but is ineffective against the other important pathogens, whereas guazatine gives at least some control of wastage caused by *F. solani, G. candidum, R. oryzae, Alternaria* spp., and *Cladosporium* spp. In this paper, we examine in more detail the use of benomyl and guazatine for reducing cantaloup wastage.

MATERIALS AND METHODS

Fruit. All trials used GoldPak

cantaloups harvested from commercial crops at "full-slip" maturity (ie, an abscission crack had formed between the fruit and pedicel) and "eastern choice" ripeness (ie, the fruit were greenish yellow to light yellow). These descriptive terms for maturity and ripeness were discussed by Ryall and Lipton (6).

Surface-inoculation trial. Melons were taken to the laboratory within 24 hr of harvest and dipped for 1 min in a suspension containing 10^4 spores per milliliter of *Fusarium* spp. (mixed isolates grown on potato-dextrose agar [PDA] for 7 days). The stem scar of each melon was swabbed immediately with a sodium hypochlorite solution containing 0.1% (w/v) available chlorine. Seven-day-old cultures of *G. candidum* on PDA were cut into slabs (5 mm^2) and one slab was applied to each stem scar. The melons were incubated for 24 hr at 20 C and ambient relative humidity (RH). Units of 15 melons were then dipped for 1 min in aqueous suspensions or solutions of benomyl or guazatine. Benomyl was formulated as Benlate 50% wettable powder and guazatine as Panoctine 400 liquid fungicide (Kenogard, Stockholm, Sweden). Each fungicide was tested at concentrations of 0, 30, 100, 200, 300, 400, 500, 600, 1,000, 3,000, and 10,000 mg/L. A nonionic ethylene oxide condensate wetter, Agral 60, was added at 0.01% (v/v) to each dip. The treated melons were packed in cartons and stored at 20 C and ambient RH before assessment for disease 9 days after harvest.

Wound-inoculation trial. Punctures 4 ± 1 mm deep were made with nail tips at four points around the equator. Two punctures per fruit were each inoculated with conidia of *Fusarium* spp. (mixed isolates grown on PDA for 7 days), and the remaining two punctures were each inoculated with arthrospores of *G. candidum* (7-day-old culture on PDA). A 40-μl spore suspension containing 10^5 spores per milliliter was injected into each puncture by syringe, and the melons were incubated for 4 hr at ambient temperature and RH with the punctures open to the air.

The melons were then dipped for 1 min in aqueous suspensions or solutions of benomyl and guazatine. The fungicides were tested at 0, 500, 1,000, and 2,000 mg/L in a factorial experiment. All dips contained 0.01% (v/v) Agral 60 to prevent flocculation of benomyl in the presence of the Panoctine formulation. Each treatment was applied to four replicate units made up of 15 melons each.

Treated melons were air-dried and packed in cartons with shredded paper, which prevented bruising and maintained high RH. The melons were transported 700 km to the laboratory by rail at ambient temperature and stored at 25 C. Disease incidence was assessed 8 days after harvest.

Natural-inoculation trial. Naturally inoculated melons were treated 24 hr after harvest with three concentrations of benomyl (0, 250, and 500 mg/L) and four concentrations of guazatine (0, 500, 1,000, and 1,500 mg/L) arranged factorially. Each treatment was applied to six replicate units made up of 15 melons each. The dips were prepared and the fruit dipped, packed, and transported to the laboratory as described in the wound-inoculation trial, except that no shredded paper was used. Disease was assessed 7 days after harvest.

Disease assessment and statistical analysis. The percentage of inoculation sites that became infected was recorded in the wound-inoculation trial and the data analyzed by multiple regression (8). In the other trials, disease was assessed using a subjective five-point score based on external and internal examination of each melon where 1 = no disease, 2 = trace, 3 = slight, 4 = moderate, and 5 = severe disease. Individual melons with a score of 2 are marketable without penalty but a score of 3 leads to downgrading in the market. Packages containing one or more melons with a score of ≥ 3 are also subject to downgrading. Disease scores were analyzed by multiple regression (8). Mean separation was by the Waller-Duncan k-ratio LSD test (3) using the k = 100 level.

RESULTS AND DISCUSSION

Surface-inoculation trial. Melons in this trial were affected by Fusarium and Geotrichum fruit rots and Alternaria surface blemish. Preliminary tests showed that dipping melons in 0.01% (v/v) Agral 60 solutions either had no effect on disease score or reduced it slightly with respect to undipped dry controls.

The relationships between disease score and fungicide concentration were best described by quadratic regressions. The coefficients of determination of these regressions are given in Table 1 and the dosage-response curves for all significant relationships are given in Figure 1. Benomyl was active against *Fusarium*, whereas guazatine was active against both *Geotrichum* and *Alternaria*. This result is consistent with our previous findings (10) except for the failure of guazatine to show activity against *Fusarium*. The estimated fungicide concentrations needed to give disease scores of 2 (trace of disease) are 20 mg/L for benomyl against *Fusarium*, 251 mg/L for guazatine against *Geotrichum*, and 23

Table 1. Correlations between fungicide concentration and disease score in surface-inoculation trial[a]

Disease	Fungicide	Coefficient of determination (r^2)
Fusarium rot	Benomyl	0.96[b]
	Guazatine	0.004
Geotrichum rot	Benomyl	0.36
	Guazatine	0.77[b]
Alternaria surface blemish	Benomyl	0.29
	Guazatine	0.79[b]

[a] $y = a + bx + cx^2$, where y is disease score (1–5 scale) and x is $\log_{10}$ fungicide concentration (mg/L).
[b] $P = 0.01$.

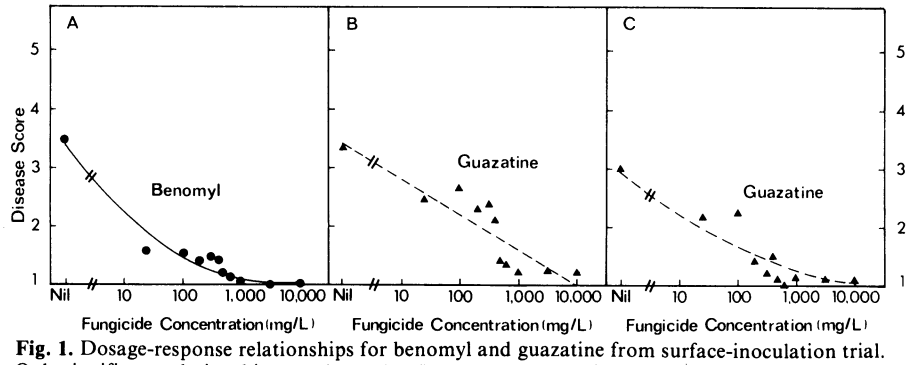

Fig. 1. Dosage-response relationships for benomyl and guazatine from surface-inoculation trial. Only significant relationships are shown (see Table 1). **(A)** Fusarium rot, **(B)** Geotrichum rot, and **(C)** Alternaria surface blemish. Disease score: 1 = no disease, 2 = trace, 3 = slight, 4 = moderate, and 5 = severe.

Table 2. Dosage-response regressions for guazatine and benomyl mixtures from wound-inoculation trial

Disease	Regression constants[a]			
	a	b	c	r^2
Fusarium rot	93.64	−0.0018 (F = 18.7)[b]	−0.0020 (F = 22.9)[b]	0.76[b]
Geotrichum rot	104.21	−0.0080 (F = 12.7)[b]	−0.0235 (F = 110.4)[b]	0.90[b]

[a] $y = a + bx + cz$, where y is percent inoculation sites infected, x is benomyl (mg/L), and z is guazatine (mg/L).
[b] $P = 0.01$.

Table 3. Control of wastage in naturally inoculated melons by mixtures of guazatine and benomyl

Guazatine (mg/L)	Disease score[y]			
	Benomyl (mg/L)			Mean response to guazatine
	0	250	500	
0	3.8 d[z]	3.1 bc	3.2 c	3.4 B[z]
500	3.2 c	2.1 a	1.9 a	2.4 A
1,000	3.0 bc	2.1 a	1.8 a	2.3 A
1,500	2.7 b	2.1 a	1.8 a	2.2 A
Mean response to benomyl	3.2 C[z]	2.4 B	2.2 A	

[y] A score of 1 = no disease, 2 = trace, 3 = slight, 4 = moderate, and 5 = severe disease.
[z] Results followed by the same lowercase or capital letter are not significantly different at $k = 100$. Linear regression: $y = 3.61 - 0.0020x - 0.00072z$, $r^2 = 0.78$, $P = 0.01$, where y is disease score (1–5 scale), x is benomyl (mg/L) ($F = 17.5$, $P = 0.01$), and z is guazatine (mg/L) ($F = 17.0$, $P = 0.01$).

mg/L for guazatine against *Alternaria*. Although low concentrations of benomyl can control fruit diseases in the laboratory (5), substantially higher concentrations (about 500 mg/L) are required in commercial dips (7,13). This fact along with the measured efficacy of guazatine against *Geotrichum* determined the fungicide concentrations used in the subsequent trials, which simulated commercial handling.

Wound-inoculation trial. The efficacies of mixtures of benomyl and guazatine were first studied using deep-wound-inoculated fruit. Highly significant linear regressions were obtained for the incidence of Fusarium and Geotrichum rots against fungicide concentration (Table 2). Benomyl and guazatine both contributed to the control of Fusarium rot, in contrast to the data of Table 1. Disease control was poor in this trial, probably because of the high RH in cartons packed with paper.

Natural-inoculation trial. A less severe test was conducted with naturally inoculated melons packed without shredded paper in accordance with normal commercial practice. Wastage in this trial was due to *Fusarium, Geotrichum, Alternaria, Cladosporium*, and a trace of *Rhizopus*. Assessment was based on disease from all causes and a single score for total disease was given to each melon. The linear regression of disease score on fungicide concentration was highly significant (Table 3), with both benomyl and guazatine contributing to disease control. All combinations of benomyl and guazatine gave better control of wastage than the highest concentrations tested of either benomyl or guazatine (Table 3). Neither fungicide when used alone gave a disease score of 2, although the concentrations were adequate to achieve this score for target diseases (Fig. 1). This result supports the contention that neither fungicide has a sufficiently wide spectrum of activity to control the disease complex.

The effect of guazatine on the incidence of Fusarium rot depends on the method of inoculation. Guazatine significantly controlled *Fusarium* in wound-inoculated melons when applied after incubation periods of 24 hr (10) or 4 hr (Table 2). Guazatine did not control *Fusarium* in surface-inoculated melons dipped after 24 hr of incubation or in naturally inoculated melons dipped 24 hr after harvest (Table 3). The cause of this phenomenon is unknown, although both the incubation period between inoculation and guazatine application and the method of inoculation are critical with regard to *Geotrichum* control in melons (10). It is desirable that a postharvest dip should be effective if applied within 24 hr of harvest, and guazatine does not satisfy this requirement.

A mixture of benomyl (250 mg/L) and guazatine (500 mg/L) gave the necessary spectrum of disease control in naturally inoculated melons. Treated melons had a marketable life at ambient temperature of 1 wk when picked at full-slip maturity and eastern choice ripeness. It is important to note that the commercial formulations used in this study are incompatible unless mixed in the presence of a suitable nonionic wetting agent. We conclude that the postharvest dip described in this paper is a promising treatment for improving the market quality of cantaloups.

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