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TOLERANCE OF FLORIDA AVOCADO CULTIVARS TO METHYL BROMIDE FUMIGATION TREATMENTS EFFECTIVE AGAINST FRUIT FLIES[1]

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ABSTRACT

Thirty cultivars of Florida-grown avocados were subjected to 2 standard methyl bromide (MB) quarantine treatment schedules to evaluate phytotoxic effects. Of those tested, 21 cultivars (70%) successfully withstood MB at 32 g/m^3 for 2½ hr at 70°F or above, followed by 7 days storage at 45 F. Fourteen cultivars (46.7%) were tolerant to MB at 32 g/m^3 for 4 hr at 70°F or above, followed by 3 days storage at 45 F or 55 F. Ten cultivars (33.3%) tolerated either treatment, and 4 (13.3%) tolerated neither. Deleterious effects associated with the treatments varied by cultivar, and included surface scald, lenticel spotting, anthracnose, stem-end rot, and internal chilling injury, delayed or inhibited ripening, darkened vascular bundles, and tissue breakdown. Late season cultivars were generally among the most tolerant to treatment.

Avocado (*Persea Americana* Mill.) can serve as a host of certain fruit flies (family Tephritidae) and seed weevils (*Conotrachelus* spp., family Curculionidae), which are considered excludable pests. Thus, the importation of avocados into the USA, as well as the movement of these fruits from infested to uninfested areas, are governed by strict federal quarantine regulations (10, 11, 12). Many foreign countries also restrict the importation of avocados for the same reason. Commercial importation of avocados into the USA is prohibited from countries in which avocado seed weevils are known to exist, because there is apparently no effective procedure to kill the immature stages of these insects without harming the fruit.

The movement of avocados and other host fruits and vegetables from areas infested with Mediterranean fruit fly (*Ceratitis capitata* (Wied.)), or other exotic fruit fly species, is often permitted, pending supervised treatment and certification by appropriate officials. If these fruit flies should become established in Florida, the movement of host fruits and vegetables (including avocados) out of infested areas would require treatment to kill the eggs and larvae that might be present.

For avocados, there are two USDA-approved quarantine treatments, which involve methyl bromide (MB) fumigation, either alone, or combined with a period of cold storage. Avocado cultivars are known to vary greatly in their tolerance to MB treatments (1, 4, *5, 7, 8,* 9) and to other treatments (3). Although no comprehensive study of the

MB tolerances of all cultivars has ever been undertaken, the present study is concerned with the MB tolerances of 30 major and minor avocado cultivars presently in commercial production in Florida.

METHODS AND MATERIALS

There are two fumigation schedules in the USDA Plant Protection and Quarantine Treatment Manual (11) that have been approved for use on avocados:

T 102(a)(1): MB @ 32 g/m^3 (2 lb./1000 ft^3) for 21/2 hr at 21°C (70°F) or above, followed by 7 days storage at 7.22°C (45°F) or below. (Note: in our tests, this was followed by storage at 70°F, to induce ripening.)

T 105(c)(1): MB @ 32 g/m^3 (2 lb./1000 ft^3) for 4 hr at 21 °C (70°F) or above, with no subsequent cold storage requirement. (Note: in our tests, to simulate commercial practice, we held the fumigated fruits at either 45°F or 55°F for 3 days, followed by storage at 70°F, to induce ripening.) Using the above two schedules, we tested 30 cultivars of Florida-grown avocados for tolerance to treatment. Fruits were fumigated in ventilated, single-layer fiberboard cartons (flats). We used one flat of fruit for each test (8-24 fruits per flat, depending upon size), plus an equal number of controls. Control fruits were put through the same temperature regimen as the treated fruits, but were not fumigated. In some cases, we added a third flat of fruit for an additional control, which was kept at a constant 70°F, in order to distinguish deleterious effects caused by temperature from those caused by MB exposure.

Upon arrival of fruit from the packinghouse (South Florida Growers Assoc., Inc., Goulds, FL), we held them overnight in an air-conditioned room at the intended fumigation temperature. Any atypical or soft fruits were eliminated from the test at that time. We fumigated the following morning, using gas-tight fumigation chambers of 0.8 m^3 capacity, as described by Benschoter (2). The load factor was ca. 20-25%. Pulp temperatures of the fruit at the beginning of fumigation ranged from 71°F to 78°F (average, 74.5°F). Inasmuch as the various cultivars matured at different times of the year, we conducted a series of nine separate fumigations over a 6-month period, from July 29, 1981 to January 21, 1982.

Skin injury, decay, and chilling injury were ranked on a scale from 1 to 9, as follows:

1. *none* (0%)

3. *Trace* (barely noticeable) (<2%)

5. *Slight* (noticeable, but not objectionable) (2-10%)

7. *Moderate* (noticeable and objectionable) (>10-20%)

9. *Severe* (very noticeable and very objectionable) (>20-100%)

Skin injury (surface scald and lenticel spotting) readings were generally made ca. 7 days following fumigation. Evaluation of decay (i.e., anthracnose caused by *Colletotrichum gloeosporioides* Penz, and stem-end rot caused by *Diplodia natalensis* P. Evans) and internal injury was made on the first day on which the fruit softened. Defects with mean scores of 7.0 or above were considered to be commercially

unacceptable (non-tolerant to treatment).

Results and Discussion

Of the 30 cultivars tested, 21 (70%) were tolerant to T 102(a)(1) (Table 1). For T 105(c)(1)-the harsher of the two treatments—only 14 cultivars (46.7% of 30 tested) were tolerant (Table 2). In general, late-season cultivars tolerated T 105(c)(1) better than early-season cultivars.

Table 1. Average tolerance of Florida avocado cultivars to methyl bromide fumigation at a dosage of 32 g/m³ for 2½ hr at 70°F or above, at normal atmospheric pressure, followed by 7 days at 45°F. T 102(a)(1))

Avocado cultivar	Adverse fumigation effects[z]
	Tolerant group[y]
Bender[x]	None
Black Prince[x]	"
Booth-1	"
Booth-7	"
Booth-8	"
Catalina[x]	"
Dr. Dupuis #2	"
Gossman[x]	"
Guatemalan seedling[x, w]	Marginally tolerant (darkened vascular bundles in some fruits)
Lisa[x]	None
Loretta[x]	"
Lula	"
Miguel	"
Monroe	"
Nadir	"
Pollock	"
Ruehle[x]	"
Simmonds	"
Tonnage	"
Waldin	Marginally tolerant (darkened vascular bundles in some fruits)
Zio[x]	None
	Non-tolerant group[v]
Beta[x]	Anth. (8.8); external chilling injury.
Choquette	Anth. (7.0); internal discoloration in 62.5% of the fruits.
Fairchild[x]	LS (8.5).
Hall	Anth. (7.4).
Hardee[x]	Tissue breakdown around the seed.
Hickson	Anth. (7.3); tissue breakdown; inhibited ripening.
Nesbitt[x]	Tissue breakdown.
Peterson[x]	Internal chilling injury.
Tower-2[x]	Uneven ripening; darkened vascular bundles.

[z]Numerical scores shown in parentheses indicate mean injury level on a scale of 1 = none to 9 = severe. LS = lenticel spotting; anth. = anthracnose.
[y]Deleterious effects, if any, each scored an average of less than 7.0 (moderate) on the whole, and were thus considered commercially acceptable.
[x]Cultivar of minor commercial importance in Florida.
[w]Not a named variety.
[v]Average injury levels were scored from 7.0 (moderate) to 9.0 (severe) for one or more deleterious effects.

Ten (33.3%) of the 30 cultivars were equally tolerant to either treatment. This group included 'Bender', 'Booth-1', 'Catalina', 'Gossman', 'Loretta', 'Lula', 'Monroe', 'Nadir', 'Tonnage', and 'Zio'. In addition, there were 4 cultivars (13.3% of 30), 'Fairchild', 'Hardee', 'Peterson', and 'Tower-2' that were tolerant to neither treatment. None of the latter cultivars, however, are presently of major commercial importance.

Types of injury observed included the following: *Skin injury:* Avocados may be either thin or thick-skinned, but this factor did not appear to be related to the amount of injury sustained. Fumigant injury to the skin is generally of two types: surface scald and lenticel spotting. *Surface scald* is a general darkening, affecting all or part of the skin surface. It is difficult to detect in cultivars that are normally dark-skinned. Of the 30 cultivars tested, three—Hardee, Peterson, and Waldin—showed scald injury to an extent considered objectionable, when treated with schedule T 105(c)(1). *Lenticel spotting* (also called pitting) is a darkening and slight sinking of the tissue around the lenticels, which gives the fruit a speckled appearance. A certain amount of this type of injury occurs naturally, as evidence in the controls. However, its effect may be accentuated by MB fumigation. Lenticel spotting reached commercially objectionable levels in 14 of the cultivars tested, particularly in fruit that received the 4-hr fumigation, T 105(c)(1). The most susceptible cultivars to this type of injury were 'Black Prince', 'Booth-7', 'Booth-8', 'Dr. Dupuis #2', 'Fairchild', Guatemalan seedling, 'Hardee', 'Lisa', 'Miguel', 'Nesbitt', 'Peterson', 'Ruehle', 'Simmonds', and 'Waldin'. *Avocado scab* (''alligator skin''), caused by *Sphaceloma persea* Jenkins, one of the most recognizable of all avocado diseases, sometimes also occurs in a ''pinpoint'' form at the lenticels particularly in the cultivars 'Beta', 'Booth-8', 'Fairchild 'Loretta', and 'Lula'. This condition, however, is not a manifestation of fumigation injury, and should not be confused with true lenticel spotting.

Table 2. Average tolerance of Florida avocado cultivars to methyl bromide fumigation at a dosage of 32 g/m³ for 4 hr at 70°F or above, at normal atmospheric pressure. (T 105(c)(1)).

Avocado cultivar	Adverse fumigation effects[z]
	Tolerant group[y]
Beta[x]	None
Bender[x]	"
Booth-1	"
Catalina[x]	Marginally tolerant (20% of fruit developed internal dark blotches).
Choquette	Marginally tolerant (LS, 6.3).
Gossman[x]	None
Hall	"
Hickson	"
Loretta[x]	"
Lula	"
Monroe	"
Nadir	"
Tonnage	"
Zio[x]	"
	Non-tolerant group[y]
Black Prince[x]	LS (7.3).
Booth-7	LS (8.9); anth. (7.3); tissue breakdown.
Booth-8	LS (8.7); anth. (8.1).
Dr. Dupuis #2	LS (7.0).
Fairchild[x]	LS (8.3).
Guatemalan seedling[x, w]	LS (8.3); anth. (7.4); darkened vascular bundles; discoloration of the flesh resembling
Hardee[x]	chilling injury, SS (7.4); LS (7.9); skin turned red in controls, but remained green in treated group.
Lisa[x]	LS (8.5); anth. (7.3).
Miguel	LS (7.4; anth. (8.4); darkened vascular bundles.
Nesbitt[x]	LS (7.7); anth. (7.8).
Peterson[x]	SS (7.5); LS (8.0).
Pollock	Severe discoloration of the flesh resembling chilling injury, but inseparable from anth. (9.0).
Ruehle[x]	LS (8.0).
Simmonds	LS (7.3); severe "external chilling injury" in both treated and control fruits.
Tower-2[x]	Anth. (7.4); inhibited ripening; darkened vascular bundles.
Waldin	SS (8.8); LS (9.0); anth. (7.3).

[z]Numerical scores shown in parentheses indicate mean injury level on a scale of 1 = none to 9 = severe. SS = surface scald; LS = lenticel spotting; anth. = anthracnose.
[y]Deleterious effects, if any, each scored an average of less than 7.0 (moderate) on the whole, and were thus considered commercially acceptable.
[x]Cultivar of minor commercial importance in Florida.
[w]Not a named variety.
[v]Average injury levels were scored from 7.0 (moderate) to 9.0 (severe) for one or more deleterious effects.

Decay: The two most common forms of decay are anthracnose and stem-end rot. *Anthracnose* is manifested in a darkening and softening of affected tissues, usually beginning as black blotches on the skin, which expand and coalesce, then deepen inward to the flesh. In mature infections, patches of salmon-colored spores often develop on the skin surface. Methyl bromide fumigation facilitates the growth of anthracnose (8), especially among cultivars 'Beta', 'Booth-7', 'Booth-8', 'Choquette',

Guatemalan seedling, 'Hall', 'Hickson', 'Lisa', 'Miguel', 'Nesbitt', 'Tower-2', and 'Waldin'. *Stem-end rot* is also aggravated by MB fumigation, but not enough to be commercially objectionable in the cultivars tested.

Internal chilling injury: This type of injury is not obvious until the fruit is cut, which reveals a grayish-brown internal discoloration. Three early-season cultivars developed typical signs of internal chilling injury, which was apparently enhanced by the fumigation treatment: 'Peterson', 'Pollock, and 'Simmonds'—the latter two being of major commercial importance. Significant external chilling injury did not develop as a result of cold storage in these tests, except in 'Beta' and 'Simmonds', in which the skin darkened in both the control and treated lots.

Delayed ripening: Cold-storage (45°F to 55°F) delays softening, a fact which is used to good advantage in the packinghouse and in the marketplace to prolong shelf-life (6). Fumigation, to a lesser extent, also delays softening. Fumigated fruit softened (ripened) in an average of 4.4 days after removal from cold-storage, compared to 3.7 days for controls. This trend was more pronounced in certain cultivars (e.g., 'Catalina', T 102(a)(1); 'Monroe', T 105(c)(1)). Fumigation caused little or no delayed ripening in many cultivars, and ripening was significantly speeded up in one cultivar, 'Beta' (T 105(c)(1)). '

Other disorders: Ripening was entirely prevented in 'Hickson' and 'Tower-2' cultivars by T 102(a)(l). Red color development, which occurs as part of the normal ripening process in Hardee, was inhibited by T 105(c)(l), but much less so by T 102(a)(1). Red color development in Tairchild', however, was not inhibited by either treatment. Objectionable darkening of the vascular bundles occurred in Guatemalan seedling, 'Miguel', and 'Tower-2' when subjected to the 4-hr fumigation, T 105(c)(1). However, in the 2%-hr fumigation (T 102(a)(1)), darkened vascular bundles developed significantly only in 'Tower-2', and to a much lesser extent also in Guatemalan seedling and 'Waldin'. Tissue breakdown (mushiness, punkiness, and/or discoloration of internal tissues) occurred in six cultivars: 'Choquette', 'Hardee', 'Hickson', 'Nesbitt' (T 102(a)(1)); 'Booth-7', and Guatemalan seedling (T 105(c)(1)).

LITERATURE CITED

1. Akamine, E. K. 1963. Treatment of avocados for export. Hawaii Farm Sci. 12:4-5.
2. Benschoter, C. A. 1979. Fumigation of grapefruit with methyl bromide for control of *Anastrepha suspensa.* J. Econ. Entomol. 72: 401-402.
3. Hatten, T. T., Jr., D. O. Wolfenbarger, and W. F. Reeder. 1963. Postharvest effects of dipping and fumigating Florida avocados with ethylene dibromide and ethylene chlorobromide. Proc. Fla. State Hort. Soc. 76: 355-360.
4. Ito, P. J., and R. A. Hamilton. 1980. Fumigation of avocado fruit with methyl bromide. HortScience 15:593.
5. Lindgren, D. L., and W. B. Sinclair. 1951. Tolerance of citrus and avocado fruits to fumigants effective against the oriental fruit fly. J. Econ. Entomol. 44: 980-990.
6. Lutz, J. M., and R. E. Hardenburg. 1958. The commercial storage of fruits, vegetables, and florist and nursery stocks. U.S. Dep. Agr., Agr. Handbook 66. 94 p.
7. Sinclair, W. B., and D. L. Lindgren. 1958. Commodity treatment of avocado fruits

against fruitfly infestation. Spec. Rep. Joint Legislative Comm. on Agr. and Livestock Problems. Calif. State Senate, p. 37.
8. Spalding, D. H., C. A. Benschoter, D. L. von Windeguth, J. R. King, W. F. Reeder, and A. K. Burditt, Jr. 1977. Methyl bromide and phosphine fumigation injury to avocados and mangos. Proc. Fla. State Hort. Soc. 90: 268-270.
9. Tebbetts, J. S. 1981. Grape/avocado tolerance to Mediterranean fruit fly quarantine treatments. Unpubl. memo from U.S. Dept. Agr., Agr. Res. Serv., Stored Products Insects Res. Lab., Fresno, Calif, to Mr. C. M. Amyx, U.S. Dept. Agr., Animal & Plant Health Inspection Serv., Plant Protection & Quarantine, Hyattsville, MD. Sept. 28, 1981.
10. U.S. Code of Federal Regulations (7 CFR) 319.56-2s, as rev. Jan. 1, 1973, also 7 CFR 318.13-4e&f, effective June 24, 1980.
11. U.S. Dept. Agr., Animal & Plant Health Inspection Serv., Plant Protection & Quarantine Prog. 1976. Treatment Manual. Sect. VI, Treatment Schedules T 102(a)(1) and T 105(c)(1).
12. U.S. Dept. Agr., Animal & Plant Health Inspection Serv., Plant Protection & Quarantine Prog. 1978. Port of Entry Manual. Part 319.56-2-A, Sect. II, also Part 318.13-4b.

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