Proc. Fla. State Hort. Soc. 90:268-270. 1977.

METHYL BROMIDE AND PHOSPHINE FUMIGATION INJURY TO AVOCADOS AND MANGOS[1]

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Additional index words. Mangifera indica L., *Persea americana* Mill., fruit flies.

Abstract. **Methyl bromide (MB) increased the decay of hard mature 'Booth 8', 'Lula', and 'Monroe' avocados** (Persea americana **Mill.) fumigated with 24, 32, 40, or 48 mg MB/liter for 2 hr at 21°C. Phosphine (PH_3) slightly injured 'Booth 8', 'Lula', and 'Taylor', but not 'Booth 3', avocados fumigated with 1000 mg PH_3/liter for 48 hr at 21°C and did not injure 'Booth 3', 'Lula', and 'Taylor' avocados fumigated with 500 mg/liter. Methyl bromide increased decay of hard mature green 'Keitt' and 'Tommy Atkins' mangos** (Mangifera indica **L.) fumigated with 32 and 48 mg/liter, respectively, for 2 hr at 21°C, but caused no obvious injury to fruits of either cultivar fumigated with 16 mg/liter. Residues of MB were less than 0.02 mg/liter in mangos held at 25°C and analyzed 24 hr after fumigation. PH_3 caused injury, increased decay, and retarded ripening of 'Keitt' and 'Tommy Atkins' mangos fumigated with 800 mg/liter (maximum concn) or less for 48 hr at 21°C. Fumigated fruits were not sampled for flavor.**

Mango fruits shipped from Florida to Japan, Hawaii, California, Arizona, or Texas must be fumigated with ethylene dibromide (EDB) to control the Caribbean fruit fly, *Anastrepha suspensa* (Loew). Fruit flies infest partially ripe mangos of various cultivars exposed to flies in infestation cages (3). There is no fumigation requirement for avocados shipped from Florida and no evidence that Caribbean fruit flies can infest the hard mature avocados normally shipped. If it becomes necessary to fumigate avocados, MB is a logical choice, since it is recommended for control of Mediterranean (*Ceratitis capitata* Wiedemann) and Oriental (*Dacus dorsalis* Hendel) fruit flies. However, fruits of each cultivar must be tested for sensitivity to injury (2), since MB has been shown to injure some cultivars (1, 4). Alternative fumigants to MB that would control fruit flies and be safer and easier to handle are needed. One possible alternative is PH_3 which is released as a gas from either aluminum or magnesium phosphide (Phostoxin® or Fumi-cel®, respectively—Degesch, Frankfurt am Main, West Germany) when the dry product is exposed to humid air (5, 8). This report presents the effects of fumigating avocados and mangos with MB and PH_3 on decay and injury.

Materials and Methods

Samples. Avocados ('Booth 7', 'Booth 8', 'Taylor', and 'Lula') were obtained in single-layer fiberboard cartons containing 12-16 fruits, and mangos ('Tommy Atkins' and 'Keitt') were obtained in similar cartons containing 8-12 fruits. Lots of hard mature fruits from a single grower were used for each fumigation treatment. Fruits were randomized, held overnight at 21°C, and then fumigated the next day at 21°C. Fruits were handled in commercial fiberboard cartons throughout the test to simulate the conditions of commercial handling.

Fumigation. For fumigation with MB, cartons of avocados or mangos were placed in a 0.8-m^3 chamber and fumigated for 2 hr at 21°C with 16, 32, or 48 mg/liter of MB. For fumigation with PH_3, cartons of fruits were placed in a 1.4-m^3 chamber or a 60-m^3 van and fumigated for 2 days at 21°C with 200-1000 mg/liter (max concn) of PH_3. The chamber was aerated for 30 min after fumigation, and cartons were removed and aired for 2 hr before placing in storage. The number of cartons used for each treatment varied from 2 to 6.

Storage. Fumigated and unfumigated cartons of avocados and mangos were stored at 7°C and 13°, respectively, for 14-16 days. After storage, fruits were rated for firmness, decay, color (mangos), and injury. Acceptable fruits were transferred to 21°C to determine the time needed to ripen to the soft-ripe eating stage. Ripe fruits were rated for decay, injury, and acceptability. In some tests, fumigated and unfumigated fruits were not stored at low temp, but were ripened at 21°C.

Quality ratings. Ratings of fruits for various factors are summarized in Table 1. Fruits with moderate or severe decay were considered unacceptable. Fruits with both slight anthracnose and slight stem-end rot were also considered unacceptable. Percentage decay in Tables 2, 4 and 6 include only moderate and severe anthracnose or stem-end rot.

Fruits were acceptable if they had no unsightly injury and were either free of decay or had no more than the

Table 1. Summary of quality ratings used for avocados and/or mangos.

Rating	Ripe skin color[z] (%)	Anthracnose or injury[y] (%)	Stem-end rot[x] (mm)	Firmness
1	0 (green)	≤2 (trace)	≤3 (trace)	Mushy
2	1-25	3-10 (slight)	4-13 (slight)	Soft-ripe
3	26-50	11-20 (moderate)	14-25 (moderate)	Firm-ripe
4	51-75	>20 (severe)	>25 (severe)	Firm
5	76-100	—	—	Hard

[z]Based on loss of green ground-color.
[y]Anthracnose decay, caused by *Colletotrichum gloeosporioides* Penz., and injury were rated on aggregate percentage of skin areas visibly affected.
[x]Stem-end rot, principally caused by *Diplodia natalensis* P. Evans, was rated on the surface distance that decay had spread from base of stem.

Table 2. Decay of avocados fumigated with methyl bromide (MB) at 21°C for 2 hr followed by ripening at 21°C.[z]

MB concn (mg/liter)	Percent anthracnose-decayed fruits[y]			
	'Booth 7'	'Booth 8'	'Lula'	'Monroe'
0	22	85	0	6
24	87	96	45	47
32	70	100	52	59
40	48	100	28	35
48	70	100	46	65

[z]Each figure represents the average of two cartons of avocados with 9-15 fruits per carton.
[y]Percent decayed fruits includes only those with moderate and severe decay.

[1]Appreciation is expressed to the Florida Mango Forum and the Florida Avocado Administrative Committee for support of this work.

limits described above. Fumigated fruits were not sampled for flavor.

Fumigant analyses. Methyl bromide residues were determined by the head space analysis method of King (unpublished). The method is based on gas chromatographic analysis of the atm above a representative sample of mangos blended in a gas-tight blender.

We used Auer[2] detection tubes (Auergesellschaft GmbH, Berlin, West Germany) in the determination of PH_3

Results and Discussion

Avocado fumigation. Avocados fumigated with MB and ripened immediately after treatment did not develop visible skin injury, but developed more anthracnose decay than unfumigated fruits (Table 2). This increased percentage decay may be directly related to the fumigation treatment. The 24 mg/liter dosage for 2 hr is less than the recommended dosage of 32 mg/liter for 4 hr (not followed by refrigeration) or for 2.5 hr followed by refrigeration at 7°C for 7 days for control of Mediterranean and Oriental fruit flies (2, 6) or the dosage of 48 mg/liter for 2 hr for control of Caribbean fruit flies in grapefruit (Benschoter, C. L., unpublished).

Table 3. Injury to avocados fumigated with phosphine at 21°C for 48 hr and stored at 7°C for 16 days followed by ripening at 21°C.[z]

Maximum phosphine concn (mg/liter)	Percent injured fruits[y]			
	'Booth 3'	'Booth 8'	'Lula'	'Taylor'
Test 1				
0	0	0	0	0
1000	0	21	35	96
Test 2				
0	0	—[x]	0	0
500	0	—	0	0

[z]Each figure represents the average of 2 cartons of avocados with 9-15 fruits per carton.
[y]Symptoms appeared as irregular brown "scalded" areas of skin and were classified as follows on the basis of the percent skin area involved: trace (up to 2% and barely noticeable), slight (up to 10%), moderate (up to 20%), and severe (over 20%). Symptoms averaged slight for 'Booth 8', 'Lula', and 'Taylor' avocados and appeared during softening at 21°C.
[x]Not tested.

'Booth 8', 'Lula', and 'Taylor', but not 'Booth 3', avocados fumigated with PH_3 developed scald-like areas of injured skin after treatment with a maximum of 1000 mg PH_3/liter (Table 3). No injury developed when 'Booth 3', 'Lula', and 'Taylor' avocados were fumigated with 500 mg PH_3/liter for 48 hr. 'Taylor' avocados were most sensitive and 'Booth 3' avocados least sensitive to PH_3 of the cultivars tested. Should PH_3 be considered for use as a quarantine treatment for avocados, these results indicate that the sensitivity of each cultivar to injury would have to be determined. Phosphine would have to be effective at a concn less than 1000 mg/liter to permit safe fumigation of 'Booth 8', 'Lula', and 'Taylor' avocados.

Mango fumigation. 'Keitt' and 'Tommy Atkins' mangos fumigated with MB showed no skin injury after storage (data not shown) but fewer were acceptable after storage and ripening if they had been fumigated at 32 or 48 mg MB/liter (Table 4). Increased decay was the only factor affecting acceptability. Mangos fumigated at 16 mg/liter for 2 hr did not differ significantly from unfumigated fruits in either decay or acceptability.

Table 4. Quality of mangos fumigated with methyl bromide (MB) at 21°C for 2 hr and stored at 13°C for 16 days followed by ripening at 21°C.[z]

MB concn (mg/liter)	Percent decayed fruits[y]		Percent acceptable fruits[x]
	Anth	SER	
Test 1 ('Tommy Atkins')			
0	51.1b	36.1b	24.1a
16	48.0b	38.3b	24.5a
32	41.3b	41.4b	17.8ab
48	68.9a	62.1a	7.6b
Test 2 ('Keitt')			
0	45.8b	32.9b	35.4a
16	36.8b	45.1ab	35.9a
32	55.6b	65.1a	13.7b
48	86.4a	59.0a	1.8b

[z]Each figure represents the average of 6 cartons of size 12 'Tommy Atkins' or size 9 'Keitt' mangos. Mean separation in columns by Duncan's multiple range test, 5% level, for each mango cultivar.
[y]Percent decayed fruits includes only those with moderate and severe decay. Anth = anthracnose and SER = stem-end rot.
[x]Acceptable fruits are those at the soft-ripe stage with no unsightly injury and either free of decay or with no more than slight decay.

'Tommy Atkins' mangos fumigated with PH_3 showed scald-like injury to the skin when treated with 800 but not 320/mg/liter for 48 hr (Table 5). 'Keitt' mangos were injured with as little as 200 mg PH_3/liter. The data indicate clearly that mangos are very sensitive to PH_3. Injury generally occurs as a scald-like discoloration of the skin, increased decay, and bleeding of brown exudate from the stem (in cases of severe injury). 'Tommy Atkins' mangos fumigated with 800 mg PH_3/liter developed less color and more decay (especially stem-end rot) than did unfumigated fruits (Table 6). The high percentage of injured and decayed mangos reduced the percentage of acceptable fumigated fruits to only 11%.

Table 5. Injury to mangos fumigated with phosphine at 21°C for 48 hr and stored at 13°C for 14 days followed by ripening at 21°C.[z]

Phosphine concn (mg/liter)		Percent injured fruits[y]			
		'Tommy Atkins'		'Keitt'	
Max	Final	Control	Treated	Control	Treated
200	—[x]	—	--	0	38
320	200	0	0	—	—
600	360	—	--	0	62
800	700	0	100	—	—
950	900	0	100	—	—

[z]Each figure represents the average of 2 to 3 cartons of size 12 'Tommy Atkins' or size 9 'Keitt' mangos.
[y]Symptoms appeared as scalded areas of skin.
[x]Not tested.

Residues. Residues of MB were less than 0.02 mg/liter in mangos held at 25°C and analyzed 24 hr after fumigation at 16, 32, or 48 mg/liter. Residue tests were not run for avocados because the method was still under development.

Conclusions

Evidence of increased decay in avocados *treated* with MB suggests that it is not enough to simply check for visible

[2]Mention of a trademark or company does not constitute an endorsement or approval to the exclusion of other products that may be suitable.

Table 6. Quality of 'Tommy Atkins' mangos fumigated with phosphine at 21°C for 48 hr and stored at 13°C for 14 days.[z]

Maximum phosphine concn (mg/liter)	Color[y]	Percent decayed fruits[x] Anth	Percent decayed fruits[x] SER	Percent injured fruits[w]	Percent acceptable fruits[v]
0	4.3	0	0	0	100
800	1.8[u]	6[u]	28[u]	72[u]	11[u]

[z]Each figure represents the average of 3 cartons of size 12 mangos.
[y]Skin color rated on percentage ripe color development as 1 (0%), 2 (up to 25%), 3 (25-50%), 4 (51-75%), and 5 (76-100%).
[x]Percent decayed fruits includes only those with moderate and severe decay. Anth = anthracnose and SER = stem-end rot.
[w]Symptoms appeared as scalded areas of skin.
[v]Acceptable fruits are those at the soft-ripe stage with no unsightly injury and either free of decay or with no more than slight decay.
[u]Significantly different from control at 5% level.

injury and chemical residue, but avocados fumigated with MB must also be checked for increased susceptibility to decay organisms. Thus, decay can be used as an index of fumigation injury. Methyl bromide does not appear promising as a fumigant under the conditions of this study. Phosphine, on the other hand, only shows promise for avocados if the maximum concn was not much more than 500 mg/liter to avoid phytotoxicity. A maximum concn of 475-600 mg PH_3/liter kills Caribbean fruit fly larvae in infested grapefruit (7). Additional research is needed to determine the tolerance of all commercial cultivars of avocados.

Methyl bromide does not appear promising as a fumigant for mangos since the concn of MB (16 mg/liter for 2 hr) which was not toxic to mangos is probably insufficient to control fruit flies in mangos. Phosphine is also too toxic as a fumigant for mangos under the conditions used. Thus neither MB nor PH_3 can be recommended as a substitute for EDB to fumigate mangos.

Results reported here emphasize the sensitivity of avocados and mangos to fumigants, such as MB and PH_3, and the need to find fumigants that have low toxicities for plants and animals. No evaluations were made of effect of fumigants on flavor, but taste tests would be necessary before a fumigant could be approved for use.

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Proc. Fla. State Hort. Soc. 90:270-271. 1977.

ETHION, MALATHION AND SUPRACIDE RESIDUES ON MANGOS[1]

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Abstract. **Mango trees ('Keitt' variety) were sprayed with ethion, malathion and Supracide for the control of oleander scale. Samples of mango fruit were taken at 7, 14, 21 and 28 days following application for residue analysis. Peel and pulp were analyzed separately using flame photometric gas chromatography and thin layer chromatography. Residues declined with time following application. Each of the insecticides appear to have activity against scale in mango.**

Oleander scale is a pest of mango in Florida. Tests were run to determine the effectiveness of ethion, malathion and Supracide (methidathion) in controlling the scale with plans to obtain registration if results were promising. This report deals with the residues of these compounds on mango.

Materials and Methods

Mango trees (cv. 'Keitt') were sprayed on June 16, 1976 with the insecticides plus oil as indicated in Table 1. Plots were single trees with 4 replicates of each treatment and 4-5 gallons of spray were applied per tree. Samples were taken 7, 14, 21 and 28 days following treatment. Five fruit were picked from each tree on the sampling date and frozen whole. At a later date the fruit was partially thawed and 2 of the fruits were peeled. These peels were chopped in a Hobart food chopper, repackaged and the pulp from this fruit was discarded. The pulp and peel of the remaining 3 fruit were separated from the seed, chopped and repackaged; the seeds were discarded. All samples were placed in a freezer immediately after being repackaged. 20-25 g samples were extracted for 30 seconds using a Polytron ultrasonic blender (Brinkman Instruments). Acetone (100 ml) was the extraction solvent for ethion and Supracide treated samples, and chloroform (100 ml) for malathion treated samples. Acetone extracts were partitioned three times with 50 ml portions of benzene which were combined, passed through 200 g of sodium sulfate and concentrated to

[1]Florida Agricultural Experiment Station Journal Series No. 960.