while practically no decay developed in Benlate-treated fruit. Mertect 260 and Dowicide A-hexamine treatments provided less residual decay control.

No change in degreening rate was noted due to dipping either 'Hamlin' oranges or 'Dancy' tangerines in Benlate before degreening. No peel injury was observed due to Benlate treatments. Gloss was not affected by any of the Benlate treatments.

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PARAMETERS CONTROLLING THE USE OF 2-AMINOBUTANE FUMIGATION FOR DECAY CONTROL IN FRESH AND CANNERY CITRUS FRUIT

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ABSTRACT

Parameters for maximum decay control with 2-aminobutane (2AB) fumigation were determined in simulated shipping tests with 'Hamlin' and 'Valencia' oranges, 'Temples,' and 'Dancy' tangerines. The fumigation chamber must be at least three-quarters full. The most effective treatment was to evaporate a single initial charge of 2AB over a period determined by treatment temperature. Optimum duration varied inversely with temperature. Three hours was adequate at 85°F, but 24 hours was required at 40°F. Optimum dosage of 2AB varied inversely with temperature from 1 ml/ft^3 at 85°F to 2 ml/ft^3 at 40°F. Use of "Quick Color" (1,1,1-trichloroethane + methylene dichloride) to eliminate fire hazard had no consistent effect on decay control. No phytotoxicity was encountered in fumigation treatments with 2-aminobutane (2AB) resulting in legally acceptable residues (below 20 ppm). In experiments with mechanically harvested oranges, 2AB vapor was tried in a manner comparable to in-truck fumigation with ethylene dibromide (EDB) for fruit fly sterilization. Decay control was excellent, and the method is considered to have potential for controlling decay in mechanically harvested loads that cannot be processed immediately. Label registration to permit commercial use of the fumigation method has not been obtained.

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INTRODUCTION

Eckert and Kolbezen first reported the possibilities of using 2-aminobutane (2AB) for control of decay in citrus fruit (1, 2). Their exploratory studies of its use in vapor form were, however, largely discontinued in favor of methods using aqueous applications of salts of 2AB. A series of papers from this laboratory have dealt with use of 2AB as a fungicidal fumigant (4, 5, 8, 9, 10). These were originally undertaken seeking a replacement for diphenyl as a vapor phase fungicide. As research at the Citrus Experiment Station progressed, it became apparent that 2AB could be applied either before

or after packing and without use of expensive packing-line equipment. Several needs for such a method are apparent. Very large quantities of gift fruit packages are shipped from Florida, many of which are packed by small gift fruit shippers not having conventional packing lines. Overseas, considerable quantities of fruits produced by small growers for local markets often suffer 50% or more loss during marketing due to the lack of a fungicide that could be applied under the circumstances. A special case is developing in Florida with the advent of mechanical harvesting which, of necessity, causes a certain amount of fruit damage (3). Unless some fungicidal treatment becomes available that can be applied prior to the bulk holding bins, high losses from decay can be expected when movement of fruit between the tree and the cannery extractors is delayed by weather, labor problems, or other unpredictable circumstances. Used solely for post-packing fumigation of fresh fruit, 2AB fumigation would have an additional advantage in that, since no treated "eliminations" would go to the cannery, no trace of 2AB residue could ever contaminate the milk of dairy cows fed citrus pulp made from cannery wastes.

Work of the previous 3 seasons had shown that excellent decay control was possible, but not always achieved. Results were often erractic, and residue levels unknown. A program was, therefore, set up to study the effects of various parameters on residues of 2AB in treated fruit. This has been submitted for publication in a report covering residue levels but not decay control (7). The findings on decay control, as affected by the various parameters in that study are presented here together with results on decay control with 2AB fumigation of mechanically harvested 'Hamlin,' 'Valencia,' and 'Pineapple' oranges.

Materials and Methods

Experimental procedure has been detailed elsewhere (3, 5) and involved the following variables:

Load in chamber: Samples only, half-full, and fully loaded.

Fumigation duration: 10 periods from 1 hour to 4 days.

2AB dosage: 5 rates from 0.3 ml/ft^3 to 2 ml/ft^3.

Temperatures: 32, 40, 50, 60, 70, and 85°F.

Varieties: 'Hamlin' and 'Valencia' *oranges*, 'Dancy' tangerines, and 'Temples' (a reputed tangor).

"Quick Color" (*QC*): This is an F. D. A. approved citrus fumigant consisting of a mixture of 1,1,1-trichloroethane and methylene dichloride which can suppress the potential fire hazard of this flammable vapor. It was used in a series of experiments with 'Hamlin,' 'Dancy,' and 'Temple' to determine the effect on residues and decay control.

All studies with packed fruit involved simulated marketing tests. These seek to reproduce typical conditions of handling, temperature, packaging, etc. from the field to, and including, a week in a fruit bowl in the customer's home. Each sample consisted of eight 5-pound perforated poly bags in a bagmaster carton. The "retail sale" examinations were at 10 to 15 days after picking; the final examinations, 16 to 21 days after picking. Bags having one or more rots at the "retail sale" examination were discarded, and only sound packages continued into the "post-purchase" periods. Records were kept throughout in terms of percentage decay and also percentage of spoiled packages at "retail sale," or "customers" losing one or more

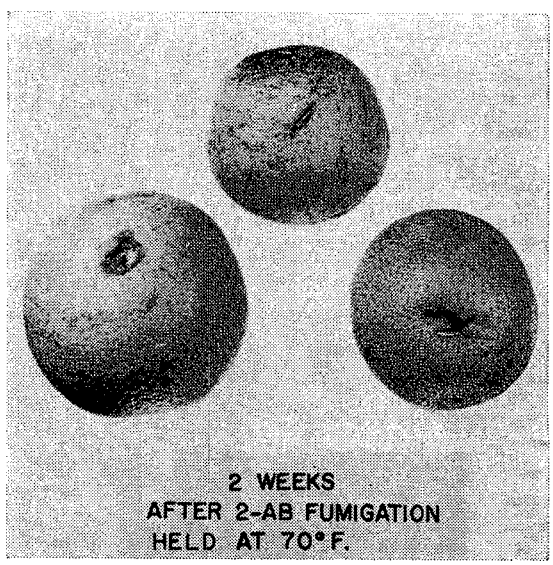

Figure 1.—Deep lesions in mechanically shaken 'Valencia' oranges fumigated with 2AB at 1 ml/ft^3 for 3 hours at 85° F and, thereafter, held in open boxes at 70° F for 2 weeks. These sterilized, but unhealed, lesions are similar to those reported by Millier (11) working with California oranges subjected to controlled injury followed by 2AB at 100 ppm for 4 hours.

fruit to decay during the 6 to 7 days in the "fruit bowls."

The mechanical harvesting experiments have also been described previously (3). For the purpose of this study, single 90-yound samples of field-run fruit were fumigated in the same cabinets as used for the residue study. In one test, 2AB was applied by the field fumigation technique devised for roadside fumigation by small growers (8).

Results and Discussion

Simulated Marketing Tests: I. Exploratory Studies.

The whole pattern of exploratory studies was repeated 3 times on 'Hamlin' oranges, 'Dancy' tangerines, and 'Temples.' Most of the mass of information generated was of only transitory interest as various fumigation parameters were investigated and the optima selected each time on the basis of purely subjective judgment. The optimum conditions selected for maximum decay control on the basis of subjective judgment are, therefore, described below, experimental data being shown only for the final experiments in which the selected parameters were tested with 'Valencia' oranges.

Dispensing methods: It became apparent that a rapid release at the beginning of the fumigation period was desirable; and various wicks were tried, very much as used in the field fumigation method (8). It was finally found that the best results were obtained by turning off the fan, pouring the 2AB into a pie plate placed in the air stream, closing the cabinet, and turning the fan on again.

The use of "Quick Color" (QC) at 2 parts of QC to one of 2AB to eliminate fire hazard had no consistent effect upon either decay control or 2AB residues (7).

Effect of load: For residue levels to be consistently within the temporary tolerance of 20 ppm (14), it was necessary to have the fumigation cabinet at least three-quarters full. No consistent effect of load on decay control was noted.

Dosage levels resulting in best decay control corresponded very closely to those already chosen to ensure that residues did not exceed the temporary tolerance (7, 14). In general, a higher dosage was needed at lower temperatures. Increasing 2AB dosage above optimum levels tended to give less, rather than more, decay control. A linear scale was selected from 2 ml 2AB/ft^3 at 40°F to 1 ml 2AB/ft^3 at 85°F.

Duration of fumigation to achieve maximum decay control varied inversely with temperature. Three hours were necessary at 85°F, but 24 hours were needed at 40°F. Increasing the fumigation period did not necessarily increase decay control and was often detrimental.

Simulated Marketing Tests: II. Final Studies with 'Valencia' Oranges.

Two commercially practical sets of fumigation conditions were selected. The first of these was a packinghouse fumigation method essentially similar to the fruit fly fumigation with ethylene dibromide (8, 13). Conditions picked for this were 1 ml 2AB/ft^3 for 3 hours at 85°F. It was considered that this would be practical treatment for packed fruit prior to loading into the transit vehicle, especially as a great many Florida packinghouses still have Medfly fumigation rooms. The second treatment simulated adding a charge of 2AB to a refrigerated truck or railway car immediately prior to closing the doors after loading. For this, 2 ml 2AB/ft^3 for 24 hours at 40° was selected. (It was considered that in a moving vehicle it was unlikely that any effective concentrations of 2AB would remain for longer periods.) Such a treatment would be comparable to the "in-transit" sulfur dioxide treatment of grapes (12) or to fruit fly fumigation in stationary vehicles (13).

The experiments with 'Valencia' oranges used these temperatures and concentrations, but spanned considerably wider ranges of fumigation periods to check the validity of the chosen time periods. Decay control was considered extremely satisfactory (Table 1). Although the decay potential was low with these 'Valencia' oranges, losses to the "retailer" or "customer" in terms of spoiled packages were still serious enough to merit rigorous decay control methods. The conditions selected as optimum for the 2 treatments (packinghouse fumigation and "in transit" fumigation) both provided perfect decay control, something that could not be expected with the frailer fruit varieties. Attention is drawn to how apparently low losses in the control can mean economically serious losses to the retailer in terms of unsaleable bags and a high percentage of "customers" discouraged from repeat buying by getting at least one rotten fruit.

Table 1.--Losses as percentage decay and as percentage of bags or "purchases" having one or more rots. 'Valencia' oranges in perforated polybags and bagmaster cartons fumigated either under packinghouse or refrigerated transit conditions.

Method	Fumigation period	"Retail sale" Percent decay	"Retail sale" % spoiled packages	Fruit bowls Percent decay	Fruit bowls % spoiled "purchases"
	Control	5.0	37.5	0.0	0.0
In	1 hour	2.5	25.0	0.0	0.0
	2 hours	0.0	0.0	0.0	0.0
packing-	3 hours†	0.0	0.0	0.0	0.0
	6 hours	0.0	0.0	0.0	0.0
house*	16 hours	1.5	12.5	0.0	0.0
	24 hours	2.5	25.0	1.9	16.7
	Control	1.3	12.5	11.1	71.4
	6 hours	0.0	0.0	0.0	0.0
"In	15 hours	0.0	0.0	1.4	12.5
	1 day†	0.0	0.0	0.0	0.0
transit"**	2 days	0.0	0.0	1.4	12.5
	3 days	1.3	12.5	0.0	0.0
	4 days	0.0	0.0	1.4	12.5

*Packinghouse fumigation: 1.0 ml 2AB/ft^3 for 3 hours at 85° F.
**"In transit" fumigation: 2.0 ml 2AB/ft^3 for 24 hours at 40° F.
†Recommended fumigation periods.

Mechanical Harvesting: Decay Control.

As the parameters controlling 2AB fumigation were delineated, the then most effective-known procedures were used to fumigate samples of mechanically harvested fruit. This proved a simple and effective means of reducing decay in mechanically harvested oranges, regardless of whether the damage was external (Fig. 1) as in mechanically shaken crops, or internal as when apparently blemish-free fruit are harvested with the spindle harvester (3).

Table 2 summarizes 7 such experiments. The 5-day examination period was chosen for presentation as typifying the maximum delay that might occur between tree and extractors for cannery fruit or the normal period from tree to cannery for packinghouse eliminations. The 14-day examination was chosen as typical of fresh fruit marketing periods. One-hundred percent decay control was achieved up to the 5-day examination. After 14 days at 70°F, decay control averaged 90% for handpicked controls and 89% in mechanically harvested oranges.

2AB fumigation is not necessarily impractical for cannery fruit. During the Mediterranean fruit fly infestation in 1956, cannery loads were routinely fumigated with ethylene dibromide prior to unloading at the cannery. It is unlikely that fungicidal fumigation with 2AB would be considered necessary except when particularly adverse circumstances are encountered due to

Table 2.--2AB fumigation of mechanically harvested oranges held at 70° F after harvest.*

Variety	Harvest method**	Percentage decay: 5 days from picking, Control		5 days from picking, 2AB		14 days from picking, Control		14 days from picking, 2AB		Comments+
'Hamlin'	Hand	4.3		0.0		26.3		0.0		Washed & waxed; 24 hr
"	M. spindle		7.0		1.2		45.3		3.5	fumigation at 40° F
"	Hand	3.8		0.0		20.4		2.2		" "
"	M. spindle		6.7		1.8		42.2		6.0	" "
'Pineapple'	Hand	0.0		0.0		1.6		0.0		Freeze damaged
"	M. air		8.0		2.9		34.0		7.7	" "
'Valencia'	Hand	0.0		0.0		2.1		0.0		" "
"	M. shaker		1.7		0.8		16.6		1.7	" "
"	Hand	0.0		0.0		13.7		3.2		" "
"	M. shaker		0.0		1.1		6.0		0.0	" "
"	Hand	4.5		0.0		11.4		2.3		Washed & waxed
"	M. spindle		2.5		0.0		11.7		0.0	" "
"	Hand	0.0		0.0		4.8		1.6		Washed & waxed
"	M. spindle		1.3		0.0		23.1		1.3	field fumigation (8)
Averages		1.8	0.4	0	1.1	11.5	25.6	1.3	2.9	
% decay control										
Handpicked				100%				90%		
Mechanical				100%				89%		

*Decay counts at 3 and 7 days from picking have been omitted.
**M = mechanical "Spindle" = rubber auger mechanical picker (3).
"Shaker" = IHC Corp. mechanical shaker (3).
"Air" = FMC Corp. air shaker (3).
+Unless otherwise stated, 90-pound samples were fumigated in the cabinets using 1 ml 2AB/ft^3 at 85° F and held unwashed at 70° F.

weather, unusual delays, exceptional rough handling, etc.

CONCLUSIONS

Fungicidal fumigation with 2AB merits commercial trial in either of 3 forms: packinghouse fumigation using 1 ml/ft^3 at 85°F for 3 hours; "in transit" fumigation using 2 ml/ft^3 at 40°F for 24 hours; and in-truck fumigation using fruit fly fumigation techniques and equipment with dosage adjusted for temperature.

Commercial trials cannot be carried out, however, unless a label registration is obtained to cover use of 2AB as a fumigant. The manufacturer has not taken this action; and until this is done, the method is not commercially available.

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