Influence of Ethylene on Stored Late-season 'Marsh' Grapefruit[1]

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Abstract. **Late-season 'Marsh' grapefruit was stored for 4, 8, and 12 weeks at 10°C in air containing 0, 2, 20, and 200 ppm ethylene. Rind stickiness was noted on all fruit exposed to ethylene for 8 and 12 weeks, while that unexposed to ethylene was not sticky. After 4 weeks storage, only fruit exposed to 200 ppm ethylene was sticky. After 8 weeks storage, and especially after 12 weeks, the rind of fruit exposed to ethylene was significantly more orange-yellow than that of fruit not exposed to ethylene. After 12 weeks storage, rind injury, presumably caused by ethylene, was observed only on fruit exposed to 20 and 200 ppm ethylene. Ethylene had no significant effects on aging and decay. Pitting was never observed throughout the investigation. Ethylene during storage had no significant effects after storage on fruit held for 2 weeks at 21°. Palatability of fruit was acceptable, and no significant treatment differences could be detected.**

Ethylene long has been known to affect the physiology of various fruits in storage. It has been reported to increase disorders in citrus fruits, including pitting and decay (4, 9). One of the commercial uses of ethylene is to degreen citrus fruits. However, decay of 'Hamlin', 'Valencia', and 'Temple' oranges was increased significantly by degreening for only 48 hr with 5, 50, and 120 ppm ethylene (7). In fruit stored for 3 weeks, losses in different types of citrus fruits have been related to ethylene concn used in degreening and to the duration of exposure (5).

Physiologically active amounts of ethylene have been found only in citrus fruits subjected to some form of stress (8). Citrus fruits infected by *Penicillium* spp. have been noted to evolve ethylene (1). For many years the presence of ethylene has been reported in citrus storage rooms. In fact, the atmosphere in a storage room in Michigan with late-season 'Marsh' grapefruit, which had considerable decay, contained 200 ppm ethylene[3].

The purpose of this preliminary investigation was to compare the effects of various levels of ethylene on late-season 'Marsh' grapefruit in storage.

Late-season 'Marsh' grapefruit was harvested from a commercial grove in Indian River County, Fla., on May 12, 1971. It was transported to the U. S. Department of Agriculture Horticultural Research Center in Orlando, where it was washed, treated with 1,000 ppm thiabendazole (TBZ, an approved fungicide), graded, and waxed with a solvent wax.

Fruit was randomized into samples of 150 fruits each (50 in each of 3 single boxes). Samples were then placed in each of 12 gastight chambers where the ethylene level was adjusted and maintained at 0, 2, 20, and 200 ppm with 3 chambers for each concn. Chambers were located in one controlled-temp room at 10°C to eliminate chamber temp differences. Chambers were identical in size and construction, and relative humidity ranged from 88 to 92%, as measured by hygrothermograph. After 4, 8, and 12 weeks, a sample of grapefruit was removed from each ethylene level.

Atmospheres were monitored continuously and automatically by gas chromatographic and gas-handling equipment which has been described (2). Oxygen or air was added to chambers as needed with a flow meter to maintain ambient levels. In the event CO_2 levels began to rise, metering valves were opened to a hydrated lime scrubber.

Chambers' atmospheres without ethylene were scrubbed continuously to remove any possible evolved ethylene. Canisters containing pellets of Purafil[4], activated alumina (Al_2O_3) impregnated with potassium permanganate ($KMnO_4$), were connected to the lines circulating the atmosphere to absorb evolved ethylene. In the test chambers, ethylene levels were adjusted and maintained at 2, 20, and 200 ppm. Ethylene was measured daily by removing a l-ml sample and injecting it into a gas chromatograph with flame ionization detector; the max sensitivity of the equipment was 0.035 ppm per chart division.

On withdrawal (after 4, 8, or 12 weeks) and after an additional 1 and 2 weeks at 21°C, fruit was inspected for color, pitting, aging, decay, and any other noticeable characteristic. Infected fruit were discarded at the time the decay was detected; other fruit was retained for the next inspection. Rind color was determined visually. Color ratings were based on a comparison with color plates given by Harding as standards for determining the color of grapefruit rind (6). Yellow-green (plates E and F) was rated 1, yellow (plates G and H) was rated 2, and orange-yellow (plate I) was rated 3. Following the last inspection, palatability was evaluated by a taste panel.

A characteristic detected when fruit was removed from storage was a stickiness of the rind noticed when the fruit was touched. Regardless of storage time, stickiness was noticed only on fruit exposed to ethylene. Fruit stored 4 weeks in 200 ppm ethylene was sticky; however, that exposed to lower concn was not. All ethylene-treated fruit was sticky after 8 and 12 weeks storage, regardless of concn. Rind stickiness persisted during the 2 weeks holding period at 21°C in the same fruit on which it was detected at time of removal from storage. Rind stickiness has previously been reported on late-season California 'Navel' oranges at time of harvest with an intensification subsequent to harvest (3).

No significant differences in rind color were found after 4 weeks storage; however, after 8 weeks storage, fruit exposed to 2 or 200 ppm ethylene had significantly more orange-yellow color (Table 1). After 12 weeks storage, rind color of fruit stored in ethylene was significantly more orange-yellow than that stored without ethylene. No color changes were observed during the 2 weeks holding period at 21°C. A yellow rind color (2.0) is the most desirable, followed by a yellow-green color (1.0); the least desirable is an orange-yellow rind color (3.0).

After 12 weeks storage, no rind injury occurred on fruit exposed to 2 ppm ethylene, but rind injury was observed on 14 and 4% of the fruit exposed to 20 and 200 ppm ethylene, respectively. The injury usually occurred on the stylar end of the fruit with scattered and irregular patterns of superficial bronzing on the rind and a

Table 1. **Rind color at late-season 'Marsh' grapefruit after removal from 10°C storage with various levels of ethylene and storage periods.**

Ethylene treatments (ppm)	Rind color rating[z] Storage periods in weeks 4	8	12
0	1.7a	2.0a	2.3ab
2	2.0a	2.7bc	3.0c
20	2.0a	2.3ab	3.0c
200	2.0a	2.7bc	3.0c

[z]Statistical analysis based on 150 fruits per treatment for each storage period. Mean separation by Duncan's multiple range test, 5% level. Values were derived as average color ratings¾ 1 = yellow-green, 2 = yellow, and 3 = orange-yellow.

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[3]D. H. Dewey, Michigan State Univ., personal communication.

[4]Manufactured by Marbon Division, Borg-Warner Corp., Washington, W. Va. Use of trade name and manufacturer's name is for identification purposes only and is not intended as a recommendation by the U. S. Department of Agriculture of the article mentioned over similar articles by other manufacturers.

slight collapsing and darkening of the oil cells. Since the injury was detected on fruit exposed to the higher concn of ethylene and the longest exposure period, 3 months, the injury presumably is caused by ethylene. No further increases in injury were detected when the fruit was held for 2 weeks at 21°C.

Throughout the investigation, pitting was never observed. No significant differences in decay and aging were found in fruit according to the different levels of ethylene concn for each storage period. Phomopsis stem-end rot was the predominant decay observed throughout the tests. Regardless of treatment, decay was negligible after 4 weeks storage averaging less than 1%. After 8 and 12 weeks storage, decay cumulatively averaged 6 and 20%, respectively. Aging averaged 5% after 4 and 8 weeks storage and 6% after 12 weeks storage.

Palatability of fruit, evaluated after 2 weeks at 21°C, was acceptable, and no significant treatment differences could be detected.

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Amo-1618 as a Growth Retardant of Citrus Seedlings[1]

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Abstract. **Amo-1618 at 500 to 10,000 ppm reduced plant growth when sprayed on seedlings of 3 species of citrus. The growth retardant affected rate of stem elongation, length of stem internode, and leaf shape, color, and texture. Objectionable tissue abnormalities did not develop.**

Chemical growth retardants for citrus trees may be useful in decreasing the costs of spraying, hedging, and harvesting operations, increasing the resistance of citrus trees to drought and low temperatures, and developing new practices and uses for trees. The vegetative growth of citrus is decreased by several chemicals, some more effective than others (6, 7, 10), but as yet, there is no one class of compounds that has a broad spectrum of use on different citrus cultivars. Apparently, different growth retardants will be needed to fulfill specific requirements for citrus cultivars.

In this work, I used Amo-1618[3], commercially available as HIMT[4], (4 hydroxy-5-isopropyl-2-methyl phenyl trimethyl-ammonium chloride, 1 piperidine carboxylate). Amo-1618 belongs to a series of quaternary ammonium carbamates having considerable plant growth-retarding properties. Variations in the structure of Amo-1618 cause different growth responses (2, 3). The apparent mode of action of Amo-1618 as a plant-growth retardant is interference with the biosynthesis of gibberellins. In cultures of *Fusarium moniliforme* Sheldon, Amo-1618 prevented the conversion of mevalonic acid to gibberellin (8), and this process of inhibition is considered by others to be similar in higher plants (1, 9).

Amo-1618 was applied at different concn as a drenching foliage spray on 4- to 6-month-old seedlings of nucellar 'Pineapple' orange (*Citrus sinensis* [L.] Osbeck), 'Mott' grapefruit (*C. paradisi* Macf.), and rough lemon (*C. jambhiri* Lush.). Seedlings were grown under glasshouse conditions. Plants were potted in 3-liter cans filled with a mixture of 1 part sand, 2 parts vermiculite, 7 parts peat, and a trace of mixed fertilizer. Tests were done on 10 single-plant replicates of uniform seedlings. Measurements of growth were made before treatments and at various intervals thereafter. Sprays were applied with an air-pressurized, metal hand sprayer, at rates of about 5 ml per seedling. This was adequate to wet both sides of the leaves and stem thoroughly and allow some drip onto the soil surface. All concn were made to volume with distilled water and contained 0.02% of a nonionic surfactant[5], Tergitol 15-S-7[4]. The pH of Amo-1618 solutions ranged from 5.8 at 10,000 ppm to 5.1 at 500 ppm; pH of control surfactant solutions was 4.9.

The general overall result of Amo-1618 at concn of 500 to 10,000 ppm was a more compact citrus seedling with darker green color (Fig. 1). The degree of plant response was directly related to concn of chemical used. For example, 500 ppm on rough lemon reduced rate of stem elongation 10% and internode length 38%; whereas 10,000 ppm reduced rate of stem elongation 95% and internode length 90% (Table 1). In addition to a decrease in stem elongation, leaves appeared greener and were more oval and leathery. There was a high risk of contact burn on the leaves with concn more than 10,000 ppm, and concn less than 500 ppm were largely ineffective in retarding growth. This apparent

Fig. 1. Rough lemon seedling on the right was sprayed 4 times at 2-week intervals with 1,000-ppm Amo-1618 during a growing period of 3 months after the first spray. The seedling on the left is a control plant.

Table 1. Effect of Amo-1618 concentration on the growth of rough lemon.

Concns (ppm)	Stem elongation (% of control after 30 days)	Internode length (% of control after 30 days)
500	90	62
1,000	72	49
5,000	34	29
10,000	5	10

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[3]Nutritional Biochemical Corporation, Cleveland, Ohio.

[4]Mention of a trademark name or a proprietary product does not constitute a guarantee or warranty of the product by the U. S. Department of Agriculture, and does not imply its approval to the exclusion of other products that may also be suitable.

[5]Union Carbide Corporation, New York, N. Y.