A precise cost comparison of the chemical and hand methods of sprout control has not been made; such will depend on a more accurate determination of optimum spray concentration and thoroughness, under various conditions, as well as on better knowledge of optimum sprout removal frequency. Our experience indicates that NAA treatment should reduce total control costs by at least one-third. Furthermore, hand removal can always be carried out later without harm to the graft, if spray treatment is delayed.


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# Effect of Reduced Ethylene Levels in Storage Atmospheres on Lemon Keeping Quality[1]


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*Additional index words.* postharvest decay, controlled atmosphere, *Citrus limon*



*Abstract.* **Lemons (*Citrus limon* (L.) Burm. f.) were stored for up to 27 weeks at 10°C in air and in an atmosphere of 3 to 5% $O_2$ and 0.1 to 0.2% $CO_2$, with and without an ethylene absorbent. Mold incidence was high in controlled atmosphere (CA) storage where ethylene accumulated, but removal of ethylene reduced its development. CA storage improved retention of green color in lemons.**


Development of a technique for the successful storage of lemons for a period of up to 6 months would provide the Australian lemon growing industry with marketing flexibility and help overcome "glut" situations that often occur when the winter crop becomes available (6). Problems of green mold [*Penicillium digitatum* (Sacc.)] and stem end rot [*Diaporthe citri* (Faw.) Wolf.] control, which have prohibited storage in the past, have been reduced with the development of the fungicide 1-(butylcarbamoyl)-2-benzimidazole carbamic acid (benomyl)[5] (8), but fruit quality generally declined during these long storage periods and was unacceptable to the fresh fruit markets.

Use of 2,4-dichlorophenoxyacetic acid[6] (2,4-D) and gibberellic acid[7] (GA) in citrus wax coatings was shown to improve keeping quality and appearance of stored lemons (2), but further improvements were needed to make fruit commercially acceptable. Use of controlled atmosphere (CA) storage as a way of obtaining this improvement has not been successful to date with lemons, principally because of excessive breakdown (1). Improved responses to CA treatments were obtained, however, in oranges and bananas by reducing ethylene levels in the CA storage atm (4, 7). Preliminary studies at this Laboratory and reports of increased decay within degreening environments (3, 5) suggested that lemons would also benefit if ethylene levels were reduced in the storage atm. This trial, therefore was to examine more closely the effects of reduced ethylene levels in storage atm on lemon color and mold decay.

Main crop 'Eureka' lemons were obtained from a grower in the Gosford region of New South Wales and dipped within 24 hr of harvest for 30 sec in a 500 mg per liter suspension of benomyl. A citrus polyethylene water-wax emulsion[8], which contained 16% solids and 2,4-D and GA, both at a concn of 500 mg per liter, was then applied by a foam-wax applicator and dried on the fruit under a hot air flow for 2 mins. Fruit of a uniform silver green color were then selected and graded into 3 size groups. Each size group was randomized into 8 units, each containing approx 40 fruits.

Each unit of fruit was carefully placed in a 25-liter steel drum, and 1 of the following storage atm applied to each of 2 units, which were coupled together in the same circulation system: (A) *Air,* flow through system at 60 liters per hr; (B) *Air, ethylene scrubbed,* flow through system at 60 liters per hr; (C) *CA storage, 5% $O_2$, nil $CO_2$,* circulated between drums at 90 liters per hr; (D) *CA, 5% $O_2$, nil $CO_2$, ethylene scrubbed* in a circulation flow of 90 liters per hr.

Air movement within treatment units was obtained with a 7-watt aquarium pump. $CO_2$ levels were controlled with 1 kg of $Ca(OH)_2 \cdot 7H_2O$ per CA treatment unit. Vermiculite moistened with a saturated solution of potassium permanganate absorbed ethylene. Two trays each containing 200 g of this material were then added to each treatment unit. All drums were placed in a 10°C storage room.

Oxygen and $CO_2$ levels were monitored with an "Orsat" absorption analyser, and ethylene concn was determined with a gas chromotograph fitted with a flame ionization detector (4).

Fruit was examined after 13, 21 and 27 weeks storage. Skin color was assessed with a color index system based on sorting fruit into several color classes. Each class was assigned a numerical value, which was multiplied by the no. of fruit in the class; the color index was determined by dividing the sum of the products by the total no. of fruit assessed. Color classes were 1, deep yellow; 2, yellow; 3, light yellow; 4, silver green; and 5, green. The % fruit affected by mold was also determined. Data were analysed by use of an angular transformation with 3 replicates being used for each storage atm tested.

The concn of $CO_2$ sampled from both the air and CA treatments varied


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[5]Marketed by DuPont (Aust.) Ltd. as Benlate 50% w/w benomyl.

[6]Marketed by Land Ltd., Sydney as Nocweed, containing 80% w/w 2,4-D sodium salt.

[7]Marketed by ICI Aust. Ltd. as Grocel containing 10% w/w gibberellic acid.

[8]Marketed by S. C. Johnson & Son Pty. Ltd., Rosebery as Primafresh.

between 0.1 and 0.2% for the 6-month storage period. Oxygen concn fluctuated slightly around 5% in the CA treatments during the first 4 months storage and decreased to 3% in the last 2 months as fruit respiration increased. Ethylene levels varied with time for all storage treatments, generally increasing with time (Table 1).

*Color.* The change in color index was greatest with plain air storage (A) and least with the CA low ethylene atm (D) during the first 13 weeks (Table 2). Both CA treatments (C and D) were significantly greener than the control (A), while lowering of ethylene levels with air storage (B) reduced rate of green color loss, so that it was equivalent to that of plain CA (C). Both CA treatments (C and D) were better by the 21st week than either of the air treatments (A and B) and this trend continued up to a storage time of 27 weeks.

*Mold.* Mold decay (Table 2) was slight after 13 weeks with no significant differences being recorded between the treatments. Mold decay in the CA treatment (C) was significantly greater ($P<1\%$), however, than the other 3 treatments (A, B and D) by the 21st week. This difference still existed after 27 weeks. Statistical analysis also showed that the overall effects of CA atm (C and D) after 27 weeks increased mold, while low ethylene treatments (B and D) reduced mold overall.

The results show that the reduction of ethylene levels in storage environments greatly reduces mold, while the use of CA storage reduces the rate of color change. It seems feasible, therefore, that further reduction of ethylene levels in CA storage to those levels obtained in treatment B would result in very low mold development and added color retention in stored lemons.

Table 1. Changes in ethylene levels during storage.

| Treatments[z] | Ethylene level change (ppm) Length of storage (months) 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| A | 0.10 | 0.30 | 0.40 | 0.30 | 0.40 | 0.50 |
| B | 0.05 | 0.10 | 0.05 | 0.10 | 0.07 | 0.10 |
| C | 1.50 | 1.60 | 40.00 | 90.00 | 130.00 | 300.00 |
| D | 0.20 | 0.50 | 0.40 | 0.60 | 2.00 | 1.20 |

[z]See text for explanation of treatments.

Table 2. Color index values and percentage mold decay after storage up to 27 wk.[z]

| Treatment | 13 wk Color index | 13 wk Mold (%) | 21 wk Color index | 21 wk Mold (%) | 27 wk Color index | 27 wk Mold (%) |
|---|---|---|---|---|---|---|
| A | 2.3a | 3.0 | 1.9a | 6.4a | 1.7a | 13.3a |
| B | 2.8ac | 1.3 | 2.0a | 1.4a | 1.8a | 3.2a |
| C | 3.3bc | 2.9 | 3.1b | 35.2b | 2.0b | 41.2b |
| D | 3.8b | 1.5 | 3.3b | 3.3a | 2.3b | 9.9a |

[z]Means in the same column followed by the same letter do not differ significantly, 5% level.

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# Inhibition Effects of Localized Growth Regulator Sprays on Mature Lemon Trees[1]


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*Additional index words.* lemon rid thickness, *Citrus limon,* ammonium ethyl carbamoylphosphonate, ethyl hydrogen 1-propylphosphonate



*Abstract.* **Sprays of a plant growth regulator ammonium ethyl carbamoylphosphonoate (Krenite), applied to top regrowth of mature Lisbon lemon trees [*Citrus limon* (L.) Burmann] resulted in significant inhibition of growth for over 1 year. At concentrations above 0.2% there was excessive foliar and small branch damage.**


Mechanically pruning the tops of lemon trees has been a commercial practice in California for many years (11). The increasing expense of top pruning brush shredding makes the use of a growth inhibitor more attractive (2).

Spraying young regrowth shoots of mechanically topped lemon and avocado trees with certain growth inhibitors resulted in a significant retardation of growth (1, 6, 10). No chemical has been registered for this use on citrus and avocado for various reasons. This study was initiated with hope that the effectiveness of Krenite might be demonstrated and eventually could be approved for commercial use.

Maleic hydrazide (MH) is a chemical growth inhibitor that has been found to reduce or inhibit growth on a number of plants including lemons (10, 12). Growth inhibitors such as succinic acid-2,2-dimethylhydrazide (SADH) and the potassium salt of 6-hydroxy-3-(2H)-pyridacinone (KMH) have been tested as growth inhibitors for lemon top regrowth (6). KMH sprayed lemon showed a significant reduction in top growth 8 months after application. Growth was not reduced significantly and measurements taken 1 year after spraying showed no significant inhibition of top regrowth either KMH or SADH. Two experimental plant growth retar-


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