Degreening of Citrus Fruits in Response to Varying Levels of Oxygen and Ethylene

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Abstract. The responses of 'Hamlin' oranges to varying levels of oxygen and ethylene were studied in a series of tests during the fall of 1967. Increasing ethylene levels up to 5 to 10 ppm resulted in rapid losses of chlorophyll. With 2 days' degreening, the optimum ethylene level appeared to be higher than during a 1-day period. High oxygen (50%) alone increased the rate of degreening, but high oxygen plus ethylene did not produce any additive degreening response over ethylene alone. Low oxygen (10%) reduced the degreening response to ethylene in both 'Hamlin' and 'Washington' Navel oranges. In a test on 'Dancy' tangerines, the rate of degreening was slower at 70° than at 85°F. Degreening frequently continued after removal from the degreening atmospheres, resulting in modification or elimination of original treatment differences.

Materials and Methods

Fruit was harvested between September 25 and November 29, 1967. Samples of 20 fruit each were selected (10 fruit for 'Washington' Navel oranges) to minimize differences in size and color among treatments. Treatments were applied to single samples within each test, and all treatments were begun within 6 hr of harvest. All fruit was washed before treatment. Although the standard commercial practice is to wash fruit after degreening, tests have not shown any consistent effect of washing fruit on the loss of chlorophyll during degreening.

Most of the tests were on 'Hamlin' oranges, but 'Washington' Navel oranges and 'Dancy' tangerines also were used. The effects of ethylene levels ranging from 0 to 20,000 ppm, O₂ levels from 10 to 50%, and in one test temperatures of 70 and 85°F were studied. All tests were run for 1-day (22- to 24-hr) and/or 2-day (46- to 48-hr) degreening periods, and data on decay were taken after 2 weeks at 70°F. Specific treatment combinations for each test are given with results.

Changes in color with degreening, based on chlorophyll levels, were measured in individual fruits using a light transmittance difference meter with an integrating-sphere sample-presentation system (13), and recorded as ΔOD 695-740 nm (3). The chlorophyll level was measured prior to degreening, immediately after degreening, and after varying periods at 70°F. With this system, oranges measuring about 0.5 ΔOD would be a medium-green color, while fruits measuring 0.15 to 0.20 ΔOD would be yellow or orange with little or no chlorophyll present.

Test samples were degreened in gas-tight chambers, each with a capacity of 2 bushels. All tests were run at a temperature of 85°F ±1°F, except where 70°F was included. Relative humidity was maintained at 95 to 100%.

Where degreening for both 1 and 2 days was done, 2 chambers were connected for the first day. One chamber was then disconnected before it was opened, leaving the other chamber undisturbed to complete the 2-day degreening period. Each unit of 1 or 2 chambers had its own circulation pump, CO2 absorber, and provision for atmosphere sampling. Atmospheres were established by first adjusting the O₂ level and then adding the necessary volume of ethylene. Atmospheres were recirculated in all treatments except the check which was provided with a continuous flow of air to insure that no ethylene was present.

Ethylene levels were monitored by gas chromatography using a flame ionization detector with a 3-ft column of 50-60 mesh activated alumina. Analyses for O₂, CO₂, and N₂ were made using a gas chromatograph with a thermal conductivity detector. The instrument was equipped with a 6-ft 60-80 mesh silica gel column, an 8-ft 60-80 mesh molecular sieve 5A column, and a column-switching device. Because the samples were in chambers of 2-bu volume, atmospheric composition changed little during 1-day tests. Adjustments were made where necessary, especially during longer tests.

Data from all tests were analyzed statistically. However, these analyses of variance included only the differences found within each measurement date and excluded relative degreening rates between dates or the effect of fruit maturity on color changes.

Results and Discussion

'Hamlin' oranges harvested on November 1 were degreened for 1 and 2 days in all possible combinations of 21% (air) or 50% O₂ and 0, 1, or 50 ppm ethylene. The results (Fig. 1) show rapid degreening with both 1 and 50 ppm ethylene. No difference between these levels was shown after 1 day, but after 2 days, degreening was significantly greater with 50 than with 1 ppm. Fruit degreened 1 day with 50 ppm ethylene continued to degreen during the 70°F holding period, although the difference between 1 and 50 ppm was not significant in this test. Fruit not treated with ethylene gradually degreened during the 70°F holding period.

Responses were similar with 'Hamlin' oranges harvested October 23 in a test using 0, 10, and 20,000 ppm ethylene and on October 25 using 0, 5, and 100 ppm (data not shown).
Fig. 1. Loss of chlorophyll (ΔOD) in 'Hamlin' oranges during (A) 1-day and (B) 2-day degreening periods in response to ethylene and oxygen levels. November 1967. Means not enclosed by the same vertical line are significantly different at the 5% level.

Results from the tests on 'Hamlin' oranges degreened with from 0 to 20,000 ppm ethylene for 1 and 2 days are summarized in Fig. 2-A and -B. For 1 day of degreening, the maximum color change appeared to require about 5 ppm ethylene. With a 2-day degreening period, the maximum response appeared to require an ethylene level nearer 10 ppm. The estimated response curve shown does not take into account the variations in responses due to changing maturity of fruit between tests.

In several tests chlorophyll losses were significantly greater in 50% than 21% O₂. This response was more apparent early in the season than when the fruit was more mature (Fig. 1). This effect of high O₂ was not found when ethylene was present, however, in contrast to recent reports on Navel oranges (4, 14).

Since high O₂ did not greatly influence the fruit’s response to ethylene, reduced O₂ levels were tested on 'Hamlin' and 'Washington' Navel oranges harvested on November 14. Oxygen levels of 10, 21, and 50% were combined with 0 or 50 ppm ethylene for a 1-day degreening period. Data in Fig. 3 show a trend toward more rapid degreening with increased O₂ concentration, with or without the presence of ethylene. However, the effects of 10 and 50% O₂ generally were not significantly different from the effects of 21% O₂ on November 15. Further degreening occurred while the fruit was held at 70° F, a response similar to that shown in Fig. 1. As a result, low O₂ concentrations had no permanent effects in retarding color development. Assuming that CO₂ levels do not become limiting, these results indicate that the need for ventilation during degreening may be less than is currently practiced.

The effect of temperature on degreening was studied using 'Dancy' tangerines harvested on November 29. Temperatures of 70 and 85° were used with concentrations of 0, 4, and 50 ppm ethylene and 21 and 50% O₂; the fruit was degreened for 2 days. Fig. 4 shows that degreening was greater at 85° than at 70° F when ethylene was present. Contrary to the previous results with oranges, no significant difference between ethylene levels was evident, but the degreening rate was significantly greater with the presence of high O₂, especially at 85°. After transfer to the 70° holding room, degreening continued at a greater rate in the samples degreened at 70° than in those degreened at 85°. By December 5, all of the ethylene-treated samples had comparable chlorophyll levels. These results indicate that 'Dancy' tangerines may be degreened at temperatures below the presently recommended 85°.

After 2 weeks at 70°, stem-end decay was more frequent in fruit exposed to ethylene than the checks; however, samples were too small to show consistent relationships between the incidence of decay and the concentration of ethylene as has been reported (10). No evidence of any injury from ethy-
Growth Response of One-Year-Old Pecan Seedlings, Carya illinoensis, Koch, in Sand Culture to Various Levels of Potassium\textsuperscript{1,2,3}

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Abstract. The growth response of 1-year-old pecan seedlings in sand culture to various levels (0, 60, 120, 240, 615, 990, 1365, and 1740 ppm) of K was determined experimentally for the pecan. One-year-old pecan seedlings were grown with various levels of K in sand culture to determine the per cent K in the leaf tissue associated with optimum growth and with symptoms of deficiency and toxicity, and to study changes in per cent K as a function of K supply.

Materials and Methods

One-year-old dormant seedlings grown from seed of the 'Stuart' cultivar, were planted February 2, 1966, in 2 gal glazed crocks filled with sand. Two seedlings, paired according to stem length, were planted per crock. The plants were maintained in the greenhouse and watered daily with distilled water until the terminal buds began to break. The experimental design was a randomized complete block replicated 6 times. As previous observations had indicated differences in time to bud break among seedling pecans, the replications were differentiated on the basis of time to bud break. In this study, bud break occurred over a 3 week period (March 19 - April 8).

Upon completion of each replication, differential application of K was begun. A modified Hoagland's solution (5) was used with K being the only variable at concentrations of 0, 60, 120, 240, 615, 990, 1365, 1740 ppm. Sodium nitrate (NaNO\textsubscript{3}) and NH\textsubscript{4}H\textsubscript{2}PO\textsubscript{4} were used to complete the N requirements in solutions of 120 ppm or lower of K. For K concentrations above 240 ppm, the additional K was supplemented as K\textsubscript{2}SO\textsubscript{4}. The pH did not vary appreciably with K concentration in the solutions.

The plants were watered on alternate days with 400 ml of nutrient solution or 400 ml of distilled water. Iron (5 ppm solution), as Fe chelate (ethylenediamine tetraacetic acid) was added weekly. In mid-April the procedure was altered to the application of 600 ml of nutrient solution daily and leaching weekly with 3 liters of distilled water. To remedy incipient Fe

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and transportation of citrus fruits.


\textsuperscript{1}The growth response of 1-year-old pecan seedlings in sand culture to various levels (0, 60, 120, 240, 615, 990, 1365, and 1740 ppm) of K was determined experimentally for the pecan. One-year-old pecan seedlings were grown with various levels of K in sand culture to determine the per cent K in the leaf tissue associated with optimum growth and with symptoms of deficiency and toxicity, and to study changes in per cent K as a function of K supply.

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