Respiratory Oxygen Response and Respiratory Quotient of Apple Stem Sections during Chilling

Eric Young
Department of Horticultural Science, North Carolina State University, Raleigh, NC 27695

Abstract. During natural leaf abscission, 2-year-old potted apple trees (Malus domestica Borkh. cv. MM.111 EMLA) were placed in a room at 6°C for chilling [0, 600, 900, or 1400 chilling units (CU)]. After each chilling treatment, respiration of shoot segments was measured as CO₂ evolved and O₂ consumed at 22°C in several O₂ concentrations. Respiration increased with oxygen concentration after all CU treatments. Carbon dioxide evolved at the several O₂ levels did not show a pattern related to CU, but O₂ consumed decreased at a decreasing rate with additional CU. Respiratory quotient was <1 at 0 and 600 CU and equal to 1 at 900 and 1400 CU, indicating a possible shift in respiratory substrate with chilling.

Material and Methods

Forty 1 -year-old rooted layers of Malling Merton 111 (MM. 111) apple [chilling requirement 1450 chill units (CU) (Haugage and Cummins, 1991; Young and Werner, 1985)] were lifted from a commercial stoolbed (Treco, Woodburn, Ore.). All trees were pruned to 60 cm above the root collar, and all lateral branches were removed. Trees were potted in 3.5-liter containers in damp calcined clay (Turface) and placed in a room at 5 ± 2°C. After each chilling treatment (0, 600, 900, or 1400 CU), 10 trees were removed and terminal shoots cut into four 10-cm sections, excluding the top and bottom 10 cm. One of each of these sections was placed in each of forty 100-ml test tubes containing a piece of moist filter paper to prevent desiccation. Shoot sections were placed randomly into the various oxygen concentrations to randomize any variation due to acrotony and basitony. Groups of four test tubes were each thoroughly blushed with one of 10 gas mixtures containing O₂ at 0.5%, 2%, 4%, 6%, 8%, 11%, 13%, 15%, 18%, or 21% ± 0.5%. Gas mixtures were made by metering compressed air (0.03% CO₂, 21% O₂, 78% N₂) and compressed nitrogen (99.5% N₂, 0.5% O₂) together in various ratios. The final mixtures were monitored each time the tubes were flushed. Tubes were then sealed with a rubber serum stopper and inverted into a pan of 2°C water to prevent gas leaks and maintain a constant temperature. Shoot sections were equilibrated in these atmospheres for 4 h, then tubes were refilled with identical gas mixtures and sealed as before. A 1-ml gas sample was withdrawn through the serum
stopper from each test tube immediately after resealing and after an additional 2 h. Carbon dioxide and O\textsubscript{2} levels were measured on a gas chromatograph using a molecular sieve (13×) column at 50°C with a thermal conductivity detector, with helium as a carrier gas. Fresh weight of each shoot section was determined after obtaining respiration measurements. Respiration was calculated as microliters of CO\textsubscript{2} evolved and O\textsubscript{2} consumed per gram fresh weight. The RQ was calculated as the ratio of CO\textsubscript{2} evolved to O\textsubscript{2} consumed per gram fresh weight. Polynomial regression analysis was applied to the rates of CO\textsubscript{2} evolved and O\textsubscript{2} consumed, and logarithmic regression analysis was used for the RQ data.

**Results and Discussion**

RQ values increased to between 3.0 and 5.5 for trees subjected to O\textsubscript{2} concentrations 14% (data not shown), indicating that respiration had become anaerobic (Wills et al., 1981); therefore, only data for O\textsubscript{2} between 6% and 21% are shown. Respiration, as measured by CO\textsubscript{2} evolved, generally increased as atmospheric O\textsubscript{2} increased across the range of concentrations used for all chilling treatments (Fig. 1). The rate of decrease in respiration appeared to show a slight parabolic curve between 18% and 8% O\textsubscript{2}; however, only the linear portion of the polynomial regression analysis was significant for each curve (Fig. 1). There were no significant differences due to chilling treatments in the response of CO\textsubscript{2} evolution to O\textsubscript{2} concentration (i.e., regression slopes were not significantly different). Trees receiving 600 CU had somewhat higher respiration rates over the whole range than the rest (Fig. 1), although the regression intercept was not significantly different from that of the other chilling treatments.

Respiration as measured by O\textsubscript{2} consumption decreased as O\textsubscript{2} concentration decreased across the range of concentrations (Fig. 2). As in Fig. 1, the data appeared to be curvilinear, particularly at 0 CU, but only the linear portion of a polynomial regression was significant. The apparent increase in respiration between 21% and 18% O\textsubscript{2} for the 0 CU trees (Fig. 2) may have been due to unusually low respiration rates at 21% O\textsubscript{2} rather than an actual increase as O\textsubscript{2} decreased. The change in O\textsubscript{2} consumption with O\textsubscript{2} concentration, as measured by the slope of the regression lines (Fig. 2), decreased significantly as the trees were chilled from 0 to 600 CU and 600 to 900 CU. No significant difference in O\textsubscript{2} consumption was found between trees chilled for 900 and 1400 CU. These data indicate that apple shoot sections consume less O\textsubscript{2} as they progress through chilling, and that the response curve of respiration to O\textsubscript{2} concentration changes with chilling.

The RQ values did not change significantly at O\textsubscript{2} concentrations between 21% and 15%, but increased somewhat from 15% to 6% (Fig. 3). RQ in 21% to 15% O\textsubscript{2} was 0.25 for trees that had received 0 CU, 0.50 for trees chilled 600 CU, and 1.00 for trees chilled 900 or 1400 CU (Fig. 3). The RQ values indicate that these trees were using lipids as a significant portion of the substrate for respiration early in the dormancy period. Since the RQ values had increased to 1.0 after 900 CU, the primary respiratory substrate had probably changed to carbohydrates, such as sucrose, by that point in dormancy development.

The results presented here provide further indications that the change in respiratory energy of activation with chilling, reported previously (Young, 1990), is likely to be due to a change in the dominant respiratory pathway during chilling. This pattern could account for changes in energy of activation and RQ values for respiration of apple shoots during and after chilling.
Fig. 2. Respiration at various atmospheric O₂ concentrations as measured by O₂ consumption of 10-cm-long apple shoot segments that had previously received chilling of 0, 600, 900, or 1400 CU. Data shown are means of four replications. Linear regression equations are as follows: 0 CU, Y = 8.1X + 12.5, r² = 0.71*; 600 CU, Y = 5.7X - 24.4, r² = 0.97*; 900 CU, Y = 2.3X - 1.9, r² = 0.91*; 1400 CU, Y = 1.1X + 10.9, r² = 0.77*.

Fig. 3. Respiratory quotient at different atmospheric O₂ concentrations of 10-cm-long apple shoot segments that had previously received chilling of 0, 600, 900, or 1400 CU. Data shown are means of four replications. Logarithmic regression equations are as follows: 0 CU, Y = 1.8 - 0.3lnX, r² = 0.83*; 600 CU, Y = 4.7 - 1.4lnX, r² = 0.90*; 900 CU, Y = 3.1 - 0.7lnX, r² = 0.83*; 1400 CU, Y = 7.1 - 0.4, r² = 0.71*.


