Carbohydrate requirements of peach fruit growth and respiration

T. M. DEJONG[1] and E. F. WALTON[2]

[1] *Department of Pomology, University of California, Davis, CA 95616, USA*
[2] *MAFTech, Rua Kura Agricultural Centre, Private Bag, Hamilton, New Zealand*

Summary

Data on the seasonal patterns of fruit growth and dark respiration of two peach (*Prunus persica* (L.) Batsch) cultivars were combined with temperature data to calculate the carbohydrate requirements of an "average" peach fruit from bloom to harvest. The two peach cultivars used were June Lady (an early maturing (mid-June) cultivar) and O'Henry (a late maturing (early-August) cultivar). At harvest, the mean dry weight of the June Lady fruit was 17.8 g (139.7 g fresh weight) and of O'Henry fruits was 30.9 g (213.9 g fresh weight), and the times from full bloom to harvest were 107 and 154 days, respectively. The total calculated fruit respiration requirements were 132 and 300 mmol CO_2 fruit^{-1} season^{-1} for June Lady and O'Henry fruits, respectively. Total calculated carbohydrate requirements for fruit growth and respiration are 23.9 and 43.8 g CH_2O fruit^{-1} season^{-1} for June Lady and O'Henry fruits, respectively. Fruit respiration accounted for 16.3% of the total carbohydrate requirements of June Lady fruits and 20.5% of the total carbohydrate requirements of O'Henry fruits.

Introduction

Crop yield in tree fruit crops depends on fruit set and the ability of the tree to supply photosynthates to sustain the growth and respiration requirements of the fruit. Because of this relationship to crop yield, there has been much research regarding the physiology of fruit set and photosynthesis in fruit trees. But, even though fruits are widely recognized as major "sinks" for carbohydrates, there have been few attempts to quantify the actual carbohydrate requirements for growth and respiration of tree fruits in the field. Bazzaz et al. (1979) attempted to estimate the reproductive carbohydrate requirements of 15 temperate deciduous tree species. Their estimates indicate that respiration accounts for 11–38% of the total carbohydrate costs of producing a fruit in these species. Loescher et al. (1986) estimated that 16–23% of the total carbohydrate requirement of a developing sweet cherry fruit is utilized in respiration. Neither of these studies was based on detailed field measurement of fruit respiration and canopy microclimate data.

In a previous paper DeJong et al. (1987) presented data on the seasonal patterns of fruit growth and respiration in early and late maturing peach cultivars. In the present work we use some of those data to estimate the actual daily and seasonal carbohydrate requirements for respiration and dry weight accumulation of peach fruits from full bloom to harvest.

Materials and methods

Seasonal patterns of fruit dark respiration measured at 20 °C and the mean seasonal Q_{10} for peach fruit respiration (DeJong et al. 1987) were used to develop seasonal response surfaces for fruit respiration per unit dry weight against temperature and Julian Day (see Figures 1 and 2) for two peach cultivars using linear regression on log transformed data. Respiration response surfaces were developed for early (June Lady) and late (O'Henry) peach (*Prunus persica* (L.) Batsch) fruits growing on trees at the Kearney Agricultural Center near Fresno, CA.

Seasonal mean hourly air temperature data, at heights of 1 and 2 m measured with Campbell Scientific (Logan, UT) Model CR21 data loggers in the peach tree canopies, were used with the respiration response surfaces to calculate specific daily field respiration rates (see Figure 3).

Weekly data on fruit dry weight for the two cultivars (June Lady and O'Henry) (DeJong et al. 1987) were splined against Julian Day, using cubic spline techniques (subroutines ICSSCU and IGSEVU, IMSL Corporation, Houston, TX) (see Figure 4) to estimate daily fruit dry weights. The data generated from the spline were multiplied by the specific respiration rates (see Figure 3) to calculate mean daily respiration rates per fruit (see Figure 5). Fruit dry weight at harvest was converted to carbohydrate equivalents by multiplying by 1.19 (based on an average final fruit C content per unit dry weight of 47.5%, determined by pyrolysis at the Microanalytical Laboratory, Department of Chemistry, University of California, Berkeley, CA). Respiratory losses quantified as CO_2, were converted to carbohydrate equivalents by multiplying by 0.68. Total seasonal carbohydrate requirements for fruit growth and respiration were calculated for fruit from both cultivars by summing the daily fruit respiration rates over the entire season and fruit dry matter carbohydrate equivalents at the end of the season (see Table 1).

Results and discussion

The three-dimensional fruit respiration response surfaces were quite similar for both cultivars (Figures 1 and 2) except for the length of the season and differences around the period of peak specific respiration rates. When the seasonal patterns of fruit respiration were combined with real-time temperature data to estimate actual daily respiration rates per unit dry weight in the field (Figure 3) the strong influence of temperature on respiration became apparent. Figure 3 indicates that, even though the two cultivars had comparable maximum rates of respiration at 20 °C, the June Lady cultivar reached that maximum a week earlier than O'Henry during a period of warm temperatures. This caused the calculated maximum rates of fruit respiration that occurred in the field to be higher for June Lady than for O'Henry. Later in the season, periods of warmer and cooler weather are also readily apparent in Figure 3.

Even though fruit respiration rates per unit dry weight decreased as the season progressed, the rate of increase in fruit dry weight greatly exceeded the rate of decline in the specific respiration rate (Figure 4), and individual fruit carbohydrate require-
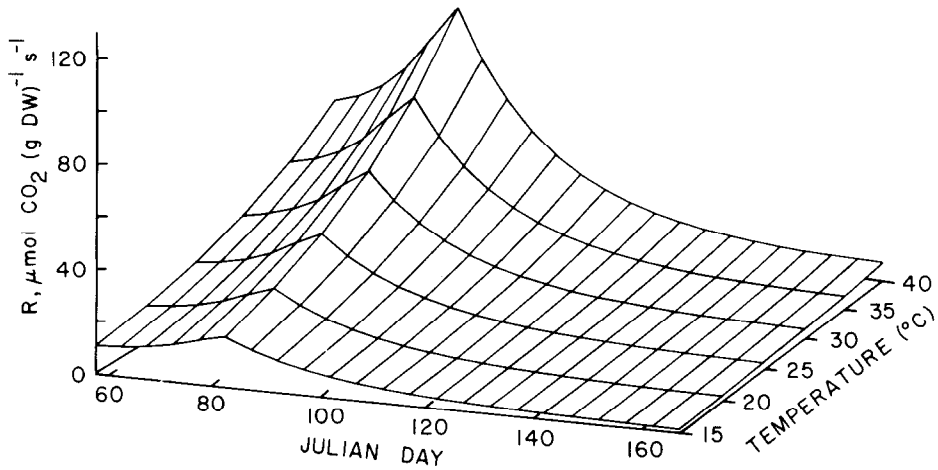
Figure 1. The response surface for June Lady fruit respiration *versus* fruit temperature from bloom to harvest (see text for details).
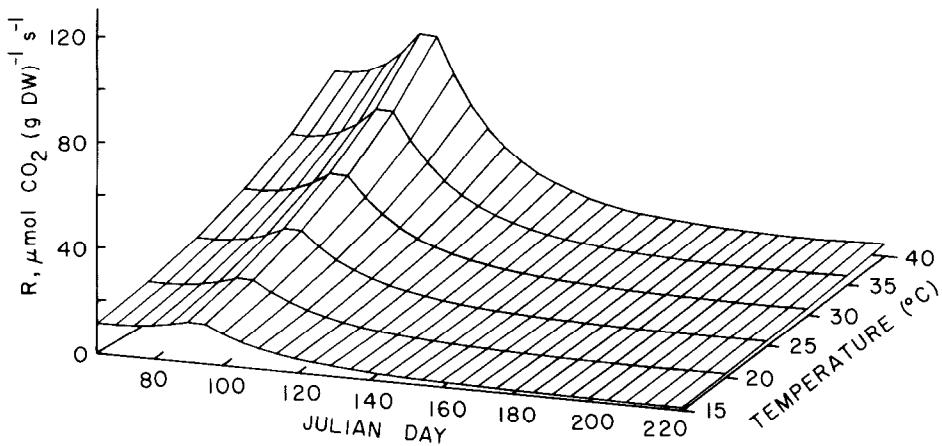

Figure 2. The response surface for O'Henry fruit respiration *versus* fruit temperature from bloom to harvest (see text for details).

ments for respiration increased (Figure 5). The carbohydrate requirement for respiration of an individual fruit of either cultivar at any given time is a function of basal metabolic rate, response of respiration to temperature (Q_{10}), ambient temperature and fruit mass. Thus, during their respective last weeks of fruit growth, June Lady had higher respiration rates per unit dry weight at 20 °C than O'Henry (DeJong et al. 1987); but O'Henry fruits had greater mass (Figure 4) and ambient temperatures were higher, so carbohydrate requirements per fruit for respiration were greater in O'Henry than in June Lady.

Such interactions between specific respiration rates, fruit mass and temperature patterns were apparently responsible for some of the differences in estimated respira-
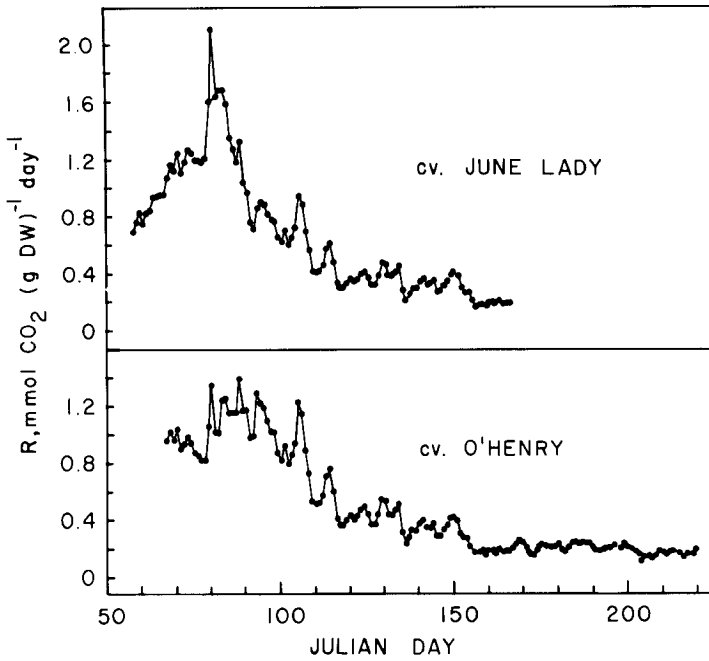
Figure 3. Calculated daily fruit specific respiration through the season for the June Lady and O'Henry peach cultivars in 1984.
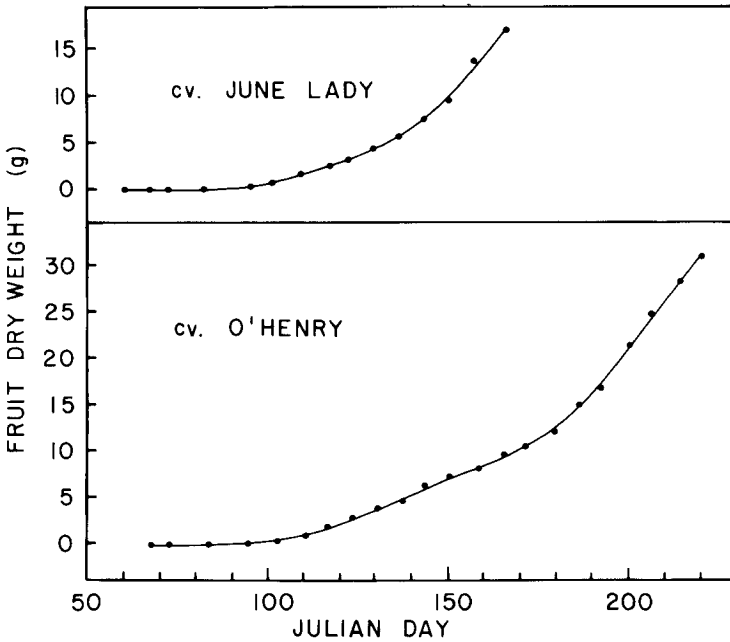
Figure 4. The seasonal pattern of fruit dry weight accumulation for the June Lady and O'Henry peach cultivars in 1984. The symbols indicate mean dry weights and the line was developed with a cubic spline function.
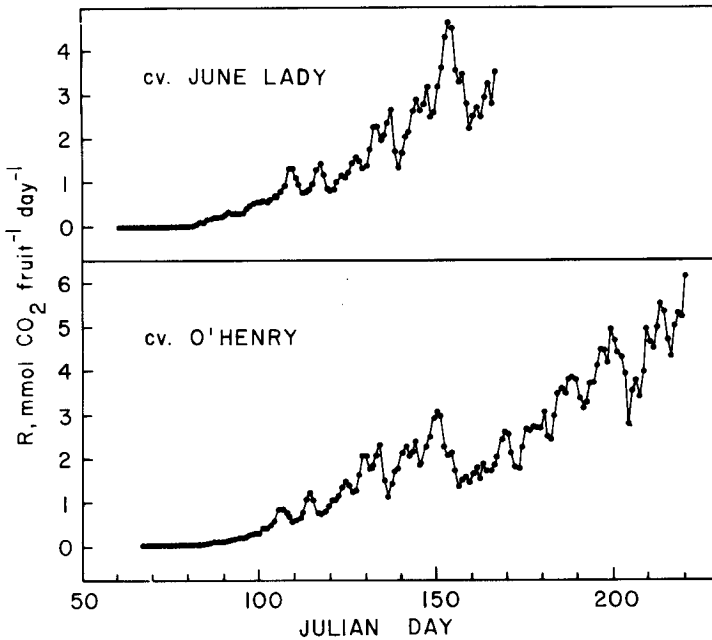
Figure 5. Calculated daily respiration per fruit through the season for June Lady and O'Henry peaches in 1984.

tion costs between the two cultivars (Table 1). The relative costs for respiration and dry matter can be used as estimates of fruit carbon utilization efficiency in these cultivars. Thus, an estimated 84.4 and 80.3% of the carbon required for fruit growth in June Lady and O'Henry fruits, respectively, could be accounted for in the dry matter of the fruit itself. These values are very close to the mean value of 80% that Penning de Vries et al. (1983) estimated by other means for the growth of a number of seeds, fruits and storage organs. Conversely, 16–20% of the seasonal carbohydrate

Table 1. Summary of absolute and relative carbohydrate costs for producing representative fruits of two peach cultivars during the 1984 growing season. The data are based on mean fruit fresh weights of 139.7 and 213.9 g and dry weights of 17.8 and 30.9 g for June Lady and O'Henry, respectively.

	cv. June Lady	cv. O'Henry
Absolute costs (g CH_2O fruit^{-1} a^{-1})		
Respiration	3.9	9.0
Dry matter	20.0	34.8
Total	23.9	43.8
Relative costs (% of total)		
Respiration	16.3	20.5
Dry matter	83.7	79.5

requirements of the fruit were used in respiration.

In this study we attempted to estimate the carbohydrate requirements for growth and respiration of individual peach fruits. We did not attempt to account for fruit photosynthesis in decreasing the net carbohydrate requirements of the fruit for the tree. Although peach fruits like other fruits are capable of photosynthesis (DeJong unpublished data) it is unlikely that a large proportion of the total fruit carbohydrate costs are supplied by fruit photosynthesis. Fruit photosynthesis rates are usually less than fruit dark respiration (Kappes 1986) and because most peach tree canopies are very dense, most fruits are exposed only to low photon flux densities for much of the time. This is not to say that fruit photosynthesis is always unimportant. It may be that photosynthesis occurring in more exposed fruit plays a significant role in the carbon budget of those particular fruit.

This study was not specifically designed to separate growth and maintenance respiration requirements. However, if we use the mean carbon content value of 47.5% and mean ash content of 5.3%, growth respiration requirements can be estimated by the regression method of Vertregt and Penning de Vries (1987). Using this method we estimate that the mean growth respiration requirements for June Lady and O'Henry fruits are 3.87 and 6.73 g CH_2O fruit^{-1}, respectively. It is clear that, if the actual growth respiration requirement for June Lady fruits is 3.87 g CH_2O fruit^{-1} and the total respiration cost calculated from the CO_2 exchange measurements is 3.9 g CH_2O fruit^{-1}, there is not enough difference between these two values to account for maintenance respiration. However, with the O'Henry calculations the difference between the total calculated seasonal respiration (9.0 g CH_2O fruit^{-1}) and the estimated growth respiration requirement (6.73 g CH_2O fruit^{-1}) allows for a maintenance requirement of 2.27 g CH_2O fruit^{-1}. This value is fairly realistic for a fruit (Penning de Vries et al. 1983).

The difference in these estimates of the maintenance respiration requirements between the two fruits is difficult to explain. It is possible that the calculated respiration requirements based on CO_2 exchange measurements made in this paper underestimated the total respiration requirements of the fruits because of refixation of CO_2 within the fruits (Blanke et al. 1987), but it is unlikely that this is a mechanism that would account for the difference in estimated fruit maintenance respiration requirements between two cultivars. High temperatures can also increase the maintenance respiration requirement (Penning de Vries et al. 1983) and ambient temperatures were highest during the later stages of O'Henry fruit growth but this does not explain the unacceptably low estimate of maintenance respiration for the June Lady fruits. Regardless of the problems in reconciling the differences in respiration requirements of the June Lady fruit, the agreement between the two estimates for O'Henry fruit are encouraging and substantiate the fruit carbon utilization efficiency estimate of 80–84%.

It is evident from Figure 3 that the specific respiration requirement was greatest during the early period of fruit growth. It may be important to account for these high respiration requirements during the initial phases of fruit growth when one considers the practical problems of fruit set and early fruit abortion. Further work is needed to

estimate the carbohydrate requirements of the entire fruit crop and the ability of the tree to meet those requirements during various periods of the growing season.

References

Bazzaz, F.A., R.W. Carlson and J.L. Harper. 1979. Contribution to reproductive effort by photosynthesis of flowers and fruits. Nature 279:554–555.

Blanke, M.M., D.P. Hucklesby and B.A. Notton. 1987. Distribution and physiological significance of photosynthetic phosphoenolpyruvate carboxylase in developing apple fruit. J. Plant Physiol. 129:319–325.

DeJong, T.M., J.F. Doyle and K.K. Day. 1987. Seasonal patterns of reproductive and vegetative sink activity in early and late maturing peach *Prunus persica* cultivars. Physiol. Plant. 71:83–88.

Kappes, E.M. 1986. Carbohydrate production, balance and translocation in leaves, shoots and fruits of "Montmorency" sour cherry. Diss. Abstr. 47:1364.

Loescher, W., T. Roper and J. Keller. 1986. Carbohydrate partitioning in sweet cherries. Proc. Washington State Hort. Assoc. 81:240–248.

Penning de Vries, F.W.T., H.H. Van Laar and M.C.M. Chardon. 1983. Bioenergetics of growth of seeds, fruits and storage organs. *In* Proceedings of a Symposium on Potential Productivity of Field Crops Under Different Environments. Internat. Rice Res. Inst., Manila, Philippines, pp 37–59.

Vertregt, N. and F.W.T. Penning de Vries. 1987. A rapid method for determining the efficiency of biosynthesis of plant biomass. J. Theor. Biol. 128:109–119.