

Respiratory Activity of the Red Tart Cherry (*Prunus cerasus*) During Growth¹

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RESPIRATORY activity of different fruits has been followed through their stages of development, both in the pre- and post-harvest stages (1, 4, 5, 7, 14, 18). Such studies resulted in the classification of fruits into two categories—those possessing a climacteric, which is marked by a sudden rise in O₂ uptake and CO₂ output, and those which do not exhibit such a phenomenon (3). Biale (2) pointed out the importance of the climacteric in relation to the ripening process of fruit; the “eating” stage of pears coincides with the climacteric, while in the avocado, apple, and banana, the ripening process follows the climacteric peak.

In our laboratory we are conducting studies on the physiology and biochemistry of the red tart cherry during its pre- and post-harvest stages, and it was important to us to determine whether this fruit exhibits a climacteric during its growth period and post-harvest state.

MATERIALS AND METHODS

As with our previously reported work (12, 13), Montmorency cherries from the orchard of the Delaware Valley College of Science and Agriculture, Doylestown, Pennsylvania, were used in all of the experiments reported here.

Two trees were selected at random and the O₂ and CO₂ exchanges of the fruit from these trees were followed for 4 seasons, 1956–1959.

Color and size were used to obtain a gradation in maturity, similar to the procedure used by Ulrich (17) and Hartman (6) for sweet cherries. Beginning with a stage following full bloom when the cherries were the size of rice grains, fruit representative of the tree average was picked every 2 or 3 days. The respiratory activities of the fruits were thus recorded from shortly after full bloom until past maturity.

For each determination 2 cherries were collected from each of the trees on the day of the experiment by cutting the stems with scissors, leaving only enough stem on the fruit to be grasped by tweezers, thus avoiding handling by the fingers during any phase of the experimental procedure. Cherry weights and volumes were

¹Received for publication April 24, 1961. Presented in part at the IX International Botanical Congress, Montreal, Canada, August 1959.

²The authors are indebted to Professor Joshua Feldstein, Chairman of the Department of Horticulture, Delaware Valley College of Science and Agriculture (formerly the National Agricultural College) for his cooperation in providing fruit; to Dr. R. T. Whittenberger for his technical advice; and to Mr. Harry John, Glassblower, and Mr. Robert Calhoun, Instrument Shop, for their help in constructing the respiration vessels used in this study.

obtained; the latter by water displacement. The 2 cherries in each sample were dried with soft absorbent tissue following the volume determination and placed on a perforated stainless steel disk inside each vessel (Fig. 1). The vessels and fruits were allowed to come to equilibrium in a water bath maintained at a constant temperature of 30° C.

Both O₂ uptake and CO₂ output were determined simultaneously using a modified respiration vessel (Fig. 1). The O₂ utilized by the fruit was determined by manometric differences as in conventional manometric technique (19), while the CO₂ evolved was determined by the change in the electrical conductivity of 0.05 N NaOH as it absorbed the CO₂ (21). The volumes of the vessels were determined by the method of Lazarow (9). The changes in the electrical conductivity of the NaOH solutions were measured with a conductivity meter. Total N was determined on the 1958 and 1959 samples (20).

More recently (1961) fruit was allowed to respire in the presence of ethylene in concentrations ranging from 100 to 10,000 ppm. Fruit was picked at 3 stages of maturity: 2 weeks and

1 week pre-harvest, and at commercial harvest time. Each sample consisted of 6 fruits and served as its own control in that the CO₂ respiratory activity was determined both in the absence and presence of the ethylene. The experiments were conducted in a sealed system which contained the fruit chamber kept in a 30° C water bath, a small air circulating pump, and an infrared absorption apparatus. A stainless steel coil of tubing in the water bath served to prewarm the air to the proper temperature before entering the respiration chamber. A humidifying trap in front of the fruit chamber and a drying tube in front of the infrared apparatus controlled the moisture content at the respective points. The respired air coming from the fruit was continuously circulated, first through the infrared absorption apparatus which recorded the CO₂ concentration, and then back to the fruit chamber.

Sampling:—Biale pointed out (2), that 2 methods are available for following the gaseous exchange of fruits: (a) placing a complete tree at a constant temperature and enclosing individual attached fruits in respiration chambers and (b) determining the respiratory activity of the fruit after it is removed from the tree. The latter method was followed throughout our investigation.

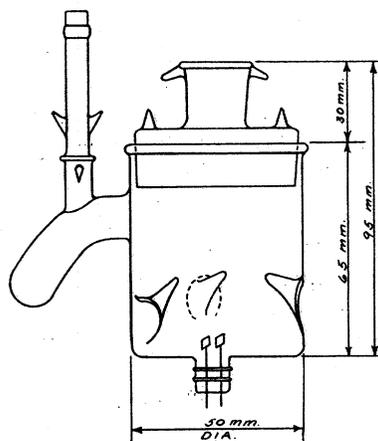


Fig. 1. Respiration vessel showing platinum electrodes in position at bottom of chamber.

In selecting the fruits for study, it is understandable that all of the fruit on a tree would not be precisely at the identical stage of development at any one time and would thus not be replicates of one another, particularly in the early stages when the physiological activity is high and subject to appreciable change. It was this factor which constituted the greatest source of error in attempting to select a continual gradation of representative samples for each day's measurements.

Admittedly, the sampling procedure is far from being a satisfactory one; far larger samples could have been taken and used in order to more adequately represent the population of the tree on any particular day. This was not done for the following reasons:

1. To avoid stripping the trees of an appreciable percentage of the fruit in the early stages and thus physiologically affecting the remaining fruit.
2. To avoid diluting the effect of a climacteric of short duration by including many pre- or post-climacteric fruits.
3. To eliminate any effects of bruising which might come about through the use of large numbers of fruit contained in any one respiration vessel. It is known that such bruising in cherries does bring about an increased CO_2 output (13).
4. To avoid points of contact between individual fruits which would restrict gas exchange (13), and introduce errors in respiratory measurements.

It would have been desirable to pick a number of immature cherries and follow the respiratory drift as they matured, as can be done with apples picked beyond certain stages (8). As with figs (4), however, cherries picked at any immature stage and kept at room temperature remain immature and after a few days begin to dry out. The only way to follow the respiratory pattern was to treat the information obtained from every cherry picked as if it were obtained from a single fruit as it passed from one stage to the next.

RESULTS

Effect of maturity:—The gas exchange determinations were started at a period which corresponded to the end of Stage I (Rapid Development) and the beginning of Stage II (Retarded Development) in the fruit as discussed by Tukey and Young (16). Agreement of the results, both as to the trend and intensity of respiration was obtained for each of the 4 years. Table 1 shows that there was very little variation in size, weight, and respiratory activity of individual samples picked at the same time; further (Table 2) there was little variation in these same factors between samples of approximately similar maturity from one year to another. Fig. 2 shows a representative respiration pattern of the gas exchange of fruit from one tree during one complete season. In terms of microliters per gram of fresh fruit per hour, the respiratory activity was 500–600 at the highest level at the beginning of Stage II. As the fruit matured, the respiratory activity decreased in intensity, finally leveling off

Table 1.—Comparison of size, weight, and respiratory activity of representative red tart cherry samples (duplicates) taken from 2 selected trees during 1956.

Date	Size ml.	Weight g.	Respiration $\mu\text{l/g.F.W./hr.}$	
			O ₂	CO ₂
<i>Tree No. 1</i>				
June 1.....	2.5 ^a	2.43	276	274
	1.25 ^b	1.05	304	266
June 19.....	1.5	1.42	192	185
	1.5	1.60	221	224
June 23.....	2.7	2.75	106	103
	2.6	2.66	115	103
July 3.....	5.2	5.80	46	38
	5.3	5.90	27	18
<i>Tree No. 2</i>				
June 11.....	1.5	1.42	248	188
	1.5	1.60	316	262
June 19.....	1.6	1.60	285	276
	1.8	1.77	213	206
June 23.....	3.8	3.95	125	117
	4.3	4.31	102	89
July 3.....	6.0	6.73	41	21
	6.0	6.62	24	18

^aFour fruits were used in this sample.
^bTwo fruits in every other sample.

Table 2.—Comparison of size, weight, and respiratory activity of representative red tart cherry samples taken from 2 selected trees during 2 successive years.

Date	Size ml.	Weight g.	Respiration $\mu\text{l/g.F.W./hr.}$		Size ml.	Weight g.	Respiration $\mu\text{l/g.F.W./hr.}$		
			O ₂	CO ₂			O ₂	CO ₂	
<i>Tree No. 1</i>					<i>Tree No. 2</i>				
					1957				
May 29.....	1.9	1.88	339	336	1.4	1.42	347	300	
June 5.....	2.0	2.12	264	268	1.8	1.77	220	215	
June 19.....	8.0	8.33	54	48	5.5	5.69	60	53	
June 27.....	7.9	8.37	44	57	6.6	7.10	38	46	
July 1.....	7.6	8.30	44	53	6.8	6.96	45	42	
					1958				
May 21.....	1.1	1.19	361	382	0.8	0.74	347	297	
June 3.....	2.0	2.04	326	339	1.8	1.99	337	354	
June 18.....	5.2	5.47	135	127	4.9	5.13	144	130	
June 27.....	8.5	8.98	44	82	8.0	8.56	38	48	
July 7.....	9.7	10.04	35	39	10.1	10.63	31	31	

at the end of the third or "final swell" stage at 50 or less. There was very little variation in these values from season to season and from tree to tree.

The agreement between the described growth stages of the fruit (16), and the changes in weight, volume and respiratory activity are shown in Figs. 3 and 4. These data, as well as those in Fig. 2, were obtained from fruit of one tree during 1958. In Fig. 3, the weights of each sample used to obtain the respiratory activities shown in

Fig. 2, are correlated with the time elapsed from full bloom. The weight increase of the fruit in Stage II was definite but not marked. During Stage III the weight of the samples increased markedly and

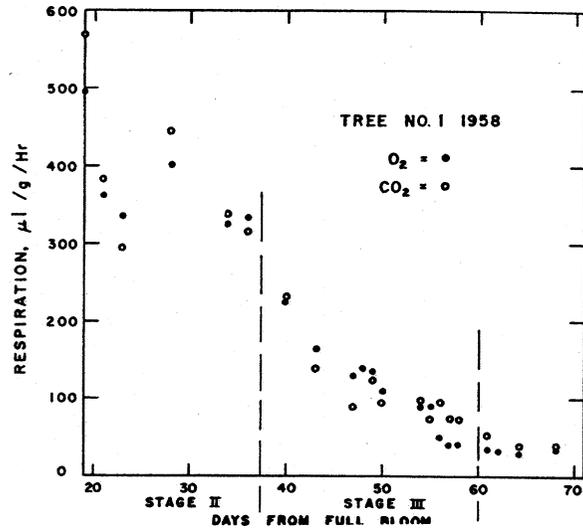


Fig. 2. Respiratory activity of red tart cherries during growth and maturity.

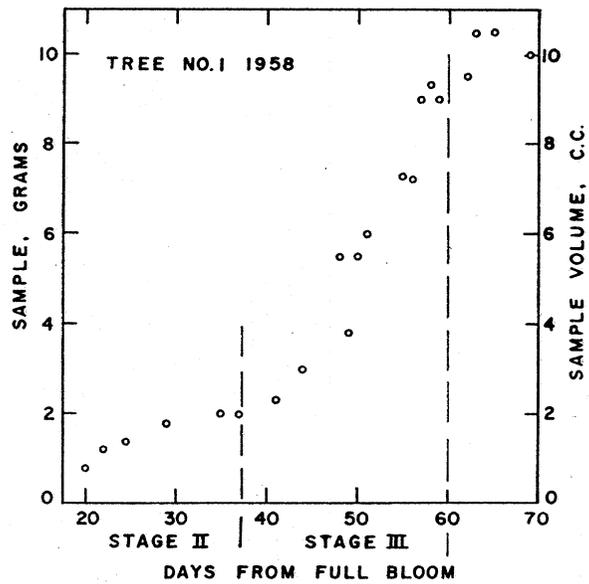


Fig. 3. Weight and volume increase of red tart cherries during growth.

leveled off when this second growth period of rapid enlargement ended. The volume of a sample can be directly substituted for the weight in grams because of the closeness of the specific gravity of the cherry to 1.00.

Since the increase in weight generally can be used as an accurate indicator of the maturation process, the respiratory activity of the samples was plotted as a function of the sample weights (Fig. 4). The transition phase between Stages II and III (based on days from full bloom as shown in Fig. 3) is quite apparent. Respiratory activity decreased quite sharply in Stage II, but much more gradually during Stage III.

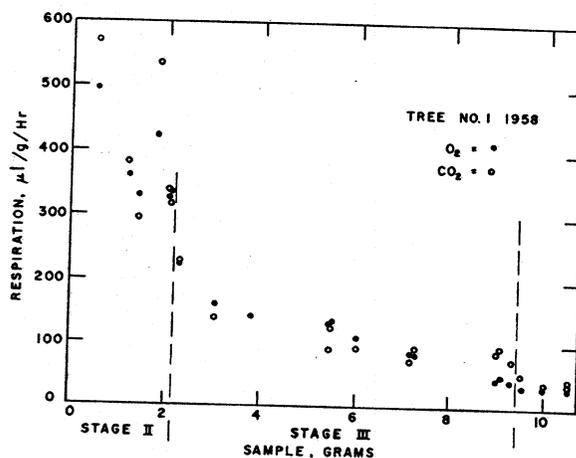


Fig. 4. Change in respiratory activity of red tart cherries with increase in weight.

Respiration per cherry:—Fig. 5 shows the respiratory gas exchanges of the fruit of one tree during the 1959 season. The values start off low in terms of $\mu\text{l}/\text{hour}/\text{fruit}$, rise to a maximum and then decrease. The slopes of the increase and decrease in respiratory activity differed; the former went up sharply whereas the decline was more gradual. Tukey (15) listed the length of the season of the Montmorency cherry from full bloom to maturity as averaging 62 days. He considered the fruits mature when they attained the characteristic color of the variety, "usually approaching softening, and later than the date of 'commercial maturity' ". The trees from which we obtained samples were not fully picked allowing measurements beyond the usual harvest dates.

Nitrogen level and respiration:—Total N (Fig. 6) on fresh weight basis increased steadily during Stages I and II to a maximum value in Stage III. The respiratory activity showed a different trend (Fig. 7), starting off at a high value and dropping sharply in Stage I, decreasing much more slowly in Stage II, and reaching a relatively stable low level in Stage III, at which full maturity was reached.

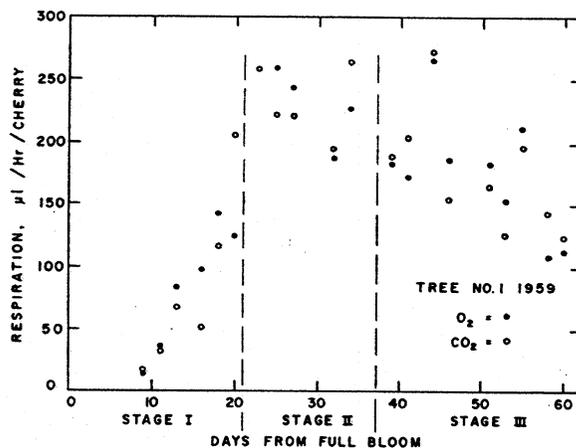


Fig. 5. The respiratory activity per cherry during growth and maturity.

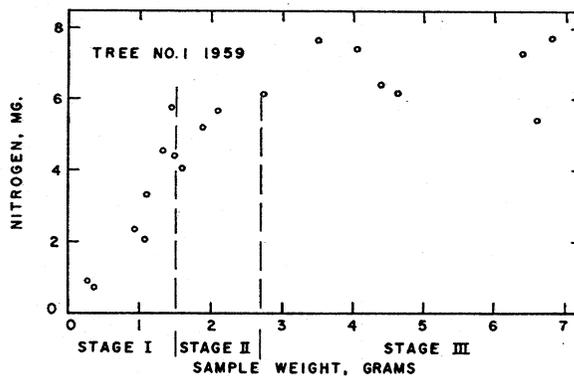


Fig. 6. Change in total nitrogen (per sample) of red tart cherries with increase in weight.

Ethylene effect:—The increase in the CO₂ concentration was linear during the 3 hour period used for each phase of the determination, and thus showed no apparent effect of the increase in CO₂ on the respiratory activity of the fruit during this time interval. The fruit showed no change in the CO₂ output during the test period when allowed to respire in the presence of any of the ethylene concentrations used.³

³Tests were conducted in 1959, using the method of Young *et al.* (Anal. Chem. 24, (3) 551-555, 1952) to determine if ethylene is given off by tart cherries. No ethylene production was found.

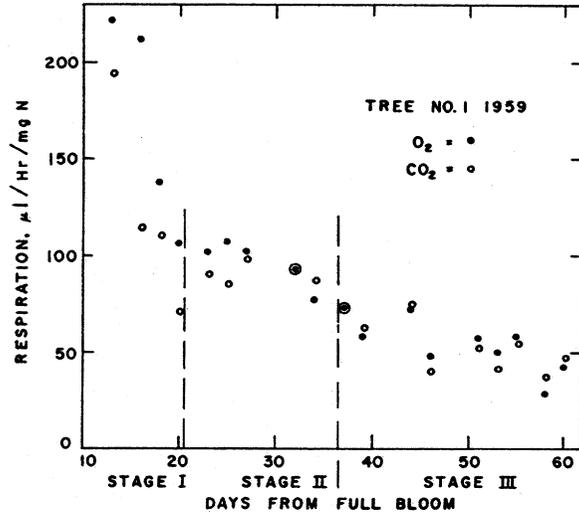


Fig. 7. Change in the respiratory activity (based on total nitrogen) of red tart cherries during growth and maturity.

DISCUSSION

Ulrich (17) found no climacteric in sweet cherries when measurements were made on freshly harvested fruit, but Hartmann (6) reported that when sweet cherries were picked and stored for a period of time a climacteric was exhibited just prior to senescence.

Maxie *et al.* (10) found that the olive exhibited a climacteric but that it occurred only while the fruit was on the tree; with each stage of increasing ripeness from green to black, the initial respiration of the picked olive fruit (in terms of $\text{ml. CO}_2/\text{kg./hr.}$) was higher. In our studies of red tart cherries the respiratory activity of each succeeding sample, in terms of $\mu\text{l/g/hour}$ was always lower. This trend was consistent throughout each of the 4 seasons and for both trees that were used.

It is generally believed that among those fruits exhibiting such a phenomenon, a true climacteric would occur during ripening on the tree or at a corresponding stage of maturity when ripened off the tree. But if a respiratory rise occurs only by prolonged post-harvest ripening, it may be due to physiological deterioration preceding cell breakdown or microbial infection.

In our studies, samples of fruit were also picked at full maturity as judged by color and ease of separation of the fruit from the stem. The respiratory exchanges of these samples were followed for two weeks and showed no marked rises followed by declines in respiration that would characterize the climacteric.

SUMMARY

1. The respiratory activities of red tart cherries were studied from shortly after full bloom to senescence for 4 crop seasons.
2. On the basis of gas exchange per gram of fresh tissue, the respiratory activity was at a high level in the very young fruits and declined steadily with no subsequent rise during any late stage of fruit development. The respiratory activity per cherry rose to a maximum during Stage II, and then steadily decreased during maturation.
3. The cherry fruit showed no evidence of a climacteric state of respiratory activity while on the tree as interpreted by the fact that the respiratory activities of succeeding samples of fruit showed constantly decreasing intensities throughout the season. At maturity the respiratory activity of stored fruit (post-harvest state) showed no evidence of a climacteric.
4. Year-to-year variations in respiratory activity were small. The rates of respiration at the earliest stages ranged from 400–500 microliters of gas exchanged per gram of fresh tissue per hour to less than 50 microliters per gram per hour at maturity.

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