Circadian Rhythm of Carbon Dioxide Production by Anthurium Flowers

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Abstract. A circadian rhythm in CO₂ production was observed in three cultivars of *Anthurium andraeanum* Andre ('Jaya', 'Fla-range', 'Leonette') flowers. The rhythmicity was not affected by light, darkness, and detachment. However, the amplitude was dampened in darkness and after detachment. Spadix respiration accounted for 90% of the total flower respiration. Rhythmicity in CO₂ production continued after spathe removal. Less pronounced rhythmicity was observed following spadix removal.

Anthurium is widely cultivated for its attractive and long-lasting flowers. Research on anthurium physiology has focused mainly on its nutrition (Joiner et al., 1983), tissue culture (George and Sherrington, 1984), and post-harvest handling (Pritchard et al., 1991; Shirakawa et al., 1964). Few studies have been done on anthurium respiration (Paull et al., 1985; Pritchard et al., 1991; Salisbury and Ross, 1992), particularly in relation to growth, development, and postharvest behavior, which is surprising in view of the uniqueness of aroid respiration (Meeuse, 1966, 1975). Interest in aroid respiration began following the pioneering work of Van Herk in 1937 (Beevers, 1961). Aroid respiration is remarkable because of its high rate and resistance to cyanide (Beevers, 1961; Meeuse, 1966, 1975).

We report here the effects of light, dark, and detachment on the rhythmic CO₂ production of three cultivars of *Anthurium andraeanum* flowers.

Materials and Methods

Anthurium 'Jaya' was grown under partial shade in the garden of the Botany Dept., National Univ. of Singapore. Two other anthurium cultivars, 'Fla-range' and 'Leonette', were obtained from Multico Orchids Pte, Singapore. The plants were transported in an air-conditioned van to the laboratory on the day of the experiment and kept under a 12-h photoperiod. Light was supplied by a Philip mercury lamp (HPLR-N 700 W; Philip, Holland). The light intensity measured at plant height was 300 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, and the room temperature was at $22 \pm 1^\circ\text{C}$. Unless otherwise stated, respiration of mature, intact (attached) flowers was studied.

The CO₂ production of intact anthurium flowers was continuously measured with an open gas-flow system (Hew et al., 1978). The CO₂ concentration in the gas stream was mea-

sured with an infrared CO₂ analyzer (Analytical Development Co., Herts, U.K.). The respiration chamber was made of plexiglass with a removable top to allow the introduction of the flower, and a small groove was cut in one of the side walls to hold the peduncle. The air temperature around the flower was controlled by continuous circulation of water into a water

jacket surrounding the chamber, while the water temperature was kept constant using a temperature-controlled water circulator (Thermomix, Braun, Melsungen AG, Germany). The leaf temperature was measured by pressing a thermocouple (module 80TK; John Fluke Manufacturing Co., Everett, Wash.) close to the lower surface of the leaf. The difference in leaf temperature during light and dark exposure was $<1^\circ\text{C}$.

For removal of either spadix or spathe from intact flowers, the top of the respiration chamber was opened after one cycle of respiration measurement, and the spadix or spathe was carefully removed without disturbing the remaining flower parts.

In the experiment with detached flowers, respiration of the intact flower was measured for one cycle. At the end of the first cycle, the flower was excised, immediately recut under water, and placed in a plastic tube containing water.

Carbon dioxide production was measured mainly with 'Jaya'. All determinations were carried out with at least three flowers. As the pattern of rhythmic CO₂ production in each of the three determinations was the same, data of only one are presented.

Fig. 1. Diurnal rhythmicity of CO₂ production by intact flowers of three cultivars of *Anthurium andraeanum* (A) 'Jaya' and (B) 'Leonette' and 'Fla-range'. Note that time scale differs for A and B; they have four and three cycles, respectively.

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Results and Discussion

A circadian rhythm in CO₂ production was observed in the intact flower of three anthurium cultivars. Respiration was low at night, increased to a peak at noon, and followed by a decline thereafter (Fig. 1). The period for the rhythm was ≈ 24 h. The rhythmic CO₂ production decreased gradually with time under constant light and dark cycles.

Spadix removal resulted in a drastic drop in respiration (Fig. 2A, Table 1). Spadix respiration accounted for $\approx 90\%$ of total flower respiration. Spathe removal only brought about a slight drop in respiration (Fig. 2B; shoulder in diurnal decline). Rhythmicity in CO₂ production remained after spathe removal. Spadix removal reduced the rhythmicity markedly. The low respiration rate of spathe could account for the less pronounced rhythmicity observed.

Circadian rhythm of CO₂ production continued during a 48-h dark cycle and during subsequent exposure to light. The magnitude of respiration was decreased by 25% and 37.5%, respectively, during the 2 days of dark exposure (Table 2, Fig. 3). Upon returning to light, CO₂ production increased. Excision of

the flower from the plant only dampened the amplitude of the rhythmicity (Fig. 4).

When a rhythmic CO₂ production was first observed in orchid flowers (Hew et al., 1978), it was thought to be unique to their flowers. Our present study shows that the anthurium flower also exhibits circadian rhythmicity in respiration, with a peak respiration at noon. Rhythmicity in CO₂ production occurred independently in spadix and spathe. Also, the rhythmicity was not affected by continuous darkness and detachment, although the amplitude of the rhythm was dampened by these two factors. The same has been observed for orchid flowers (Hew et al., 1978). The observation that the diurnal oscillations may proceed independently in different plant parts has led to the suggestion that circadian rhythm is controlled by endogenous oscillator(s) in various plant organs (Bunning, 1973; Sweeney, 1969; Wilkins, 1969).

Changes in *Arum* respiration with flower development have been reported (James and Beevers, 1950; Simon, 1959). Respiration increased, with flower development reaching a peak when the spathe started to open. In another aroid, *Sauromatum*, the spadix respiration started at a low level at night and increased

Table 1. Effect of spathe or spadix removal on CO₂ production (fresh weight basis) of *Anthurium andraeanum* 'Jaya' flowers. Flower and plant were subjected to a 12-h photoperiod.

Treatment	CO ₂ production ($\mu\text{g}\cdot\text{g}^{-1}\cdot\text{h}^{-1}$) ^a	
	Max	Min
Spadix removal		
Before	368 $\pm$ 10.2	62 $\pm$ 1.7
After		
First cycle	63 $\pm$ 2.0	10 $\pm$ 1.7
Second cycle	42 $\pm$ 1.7	---
Spathe removal		
Before	390 $\pm$ 12.9	63 $\pm$ 3.3
After		
First cycle	340 $\pm$ 13.3	47 $\pm$ 1.9
Second cycle	80 $\pm$ 8.3	---

^aMean of three readings $\pm$ SE; --- denotes not determined.

to a peak at noon and was followed by a rapid decline. Carbon dioxide was measured only for 24 h, and, therefore, no daily rhythmicity of CO₂ production was reported (Salisbury and Ross, 1992). The CO₂ outburst was associated with the opening of the spathe and heat production.

In our present study, only the mature flower was used, thereby ruling out the possible association of the rhythmicity in CO₂ production with the opening of the spathe. The significance of the CO₂ rhythmicity in anthurium flowers remains unclear. Further work is needed to confirm whether it is associated with heat production. Many aroids exhibit thermogenic respiration (Meeuse, 1975; Shirakawa et al., 1964). The heat generated brings about the volatilization of amines to attract insects for pollination. Rhythmic CO₂ production in orchid flowers also is associated with the production of fragrance (Hew et al., 1978).

The bulk of anthurium respiration was derived from spadix respiration as reported earlier for other aroids (James and Beevers, 1950; Meeuse, 1975; Simon, 1959). The respiration rate of fully expanded anthurium flowers was not particularly high; in fact, it was comparable to that of the orchid flower. Extremely high rates of respiration (20,000 $\mu\text{l O}_2$ 1 h/g fresh weight) have been reported, however, when the *Arum* spathe started to open (Simon, 1959).

Table 2. Effect of continuous darkness and excision on CO₂ production (fresh weight basis) of *Anthurium andraeanum* 'Jaya' flower. See text for dark and excision treatment.

Treatment	CO ₂ production ($\mu\text{g}\cdot\text{g}^{-1}\cdot\text{h}^{-1}$) ^a	
	Max	Min
Continuous darkness		
Before	406 $\pm$ 14.3	62 $\pm$ 1.7
After		
First cycle	303 $\pm$ 9.4	48 $\pm$ 1.1
Second cycle	238 $\pm$ 6.7	38 $\pm$ 1.4
Excision of flower		
Before	388 $\pm$ 16.4	62 $\pm$ 2.1
After		
First cycle	357 $\pm$ 8.4	47 $\pm$ 1.8
Second cycle	307 $\pm$ 6.4	---

^aMean of three readings $\pm$ SE; --- denotes not determined.

Fig. 2. Effect of (A) spadix and (B) spathe removal on the diurnal rhythmicity of CO₂ production by *Anthurium andraeanum* 'Jaya' flower. Flower remained attached to plant.

Fig. 3. Effect of continuous darkness (black bar on top) on the diurnal rhythmicity of CO_2 production by intact *Anthurium andraeanum* 'Jaya' flower.

Fig. 4. Diurnal rhythmicity of CO_2 production by detached *Anthurium andraeanum* 'Jaya' flower. See text for excision treatment.

Literature Cited

- Beevers, H. 1961. Respiratory metabolism in plants. Harper and Rowe, New York.
- Bunning, E. 1973. The physiological clock. 3rd ed. Springer-Verlag, New York.
- George, E.F. and P.D. Sherrington. 1984. Plant propagation by tissue culture. Exegetics, Basingstoke, England.
- Hew, C.S., Y.C. Thio, S.C. Wong, and T.Y. Chin. 1978. Rhythmic production of CO_2 by tropical orchid flowers. *Physiol. Plant.* 42:226–230.
- James, W.O. and H. Beevers. 1950. The respiration of *Arum* spadix. A rapid respiration, resistant to cyanide. *New Phytol.* 49:353–374.
- Joiner, J.N., R.T. Poole, and C.A. Conover. 1983. Nutrition and fertilization of ornamental greenhouse crops. *Hort. Rev.* 5:317–403.
- Meeuse, B.J.D. 1966. The voodoo lily. *Sci. Amer.* 215:80–88.
- Meeuse, B.J.D. 1975. Thermogenic respiration in aroids. *Annu. Rev. Plant Physiol.* 26:117–126.
- Paull, R.E., N.J. Chen, and J. Deputy. 1985. Physiological changes associated with senescence of cut anthurium flowers. *J. Amer. Soc. Hort. Sci.* 110:156–162.
- Pritchard, M.K., C.S. Hew, and H. Wang. 1991. Low temperature storage effects on sugar content, respiration and quality of anthurium flowers. *J. Hort. Sci.* 66:209–214.
- Salisbury, F.B. and C.W. Ross. 1992. Plant physiology. 4th ed. Wadsworth Publ. Co., Belmont, Calif.
- Salunkhe, D.K., N.R. Bhat, and B.B. Desai. 1990. Postharvest biotechnology of flowers and ornamental plants. Springer-Verlag, Berlin.
- Shirakawa, T., R.R. Dedolph, and D.P. Watson. 1964. N-6-Benzyladenine effects on chilling injury, respiration, and keeping quality of *Anthurium andraeanum*. *Proc. Amer. Soc. Hort. Sci.* 85:642–646.
- Simon, M.B. 1959. Respiration rate and mitochondrial oxidase activity in *Arum* spadix. *J. Expt. Bot.* 10:125–133.
- Sweeney, B.M. 1969. Rhythmic phenomena in plants. Academic, London.
- Wilkins, M.B. 1969. Circadian rhythms in plants, p. 645–671. In: M.B. Wilkins (ed.). The physiology of plant growth and development. McGraw-Hill, London.