アカマツ林における幹呼吸速度の測定法の開発とその適用

金　　明顯

広島大学大学院生生物圏科学研究科

Measuring system for the stem respiration rate and its application to the Japanese red pine forest

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Summary

Recently, interest in stem and branch respiration is increasing as many estimates show that it is an important component of the annual carbon cycle in forest ecosystems (Sprugel and Benecke, 1991; Damesin et al., 2002). In this study, the main objective is to understand the carbon cycle of aboveground woody respiration for Japanese red pine (*Pinus densiflora* Sieb. et Zucc) stand. The specific objectives were to: (1) test an open flow system made for continuously measuring stem respiration throughout the year in the field, and (2) characterize the diurnal and seasonal pattern in the stem respiration rates, and (3) estimate the annual amount of carbon released from stems and branches at the stand level based on diameter-respiration relation and the pipe model theory (Shinozaki et al., 1964).

The study was conducted in Japanese red pine (*Pinus densiflora* Sieb. et Zucc) forest near an ecological tower (18 m) in Yosikawa, Higashi-Hiroshima City, west Japan (34° 23′ N, 132° 39′ E). The study site is located on the lower part of a hill, with an elevation of ca. 208 m a.s.l., a southern aspect and an inclination of ca. 5 degrees. According to a tree census at the study site (10 m × 40 m), the basal area (a cross-sectional area at breast height) of Japanese red pine, which is the dominant species of tree layer, was 29.54 m^2ha^{-1} (86.3%), *Illex pendunculosa* Miz., which is the dominant specie of sub-tree layer, was 0.67 m^2ha^{-1} (2.0%), *Eurya japonica* Thunb. and *Rhododendron reticulatum* D. Don, which are the dominant species shrub layer, was 2.57 m^2ha^{-1} (7.5%), 0.50 m^2ha^{-1} (1.5%), respectively. The dominant species of herb layer were *Rhododendron kaepferi* Planch., *R. reticulatum* D.Don, and *I. Crenata* Thunb. etc. The tree density of Japanese red pine was 1000 trees ha^{-1}, mean DBH (diameter breast height = 1.3 m) was 18.7 (±2.33) cm, and mean height was 14.3 (±1.02) m.

This region belongs to the warm-temperature monsoon zone. At a station ca. 5 km northeast

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from the study site, the average of annual mean temperature is 13.5℃ and the average annual precipitation is 1494 mm (Hiroshima Prefectual Agriculture Research Center, based on records from 1992 to 2001). The monthly mean air temperature reached at a maximum (25.6℃) in August and decreased to a minimum (2.4℃) in January.

The measuring system was comprised one reference line and several sample lines consisting of air pump, flow meter controller and electromagnetic valve. Behind the electromagnetic value, the air stream was passed through an air filter and digital flower meter to an infrared gas analyzer (IRGA) with absolute mode.

Diurnal courses of air temperature inside and outside the chambers were approximately the same and no significantly different. However, the relative humidity was higher inside than outside the chambers, and the maximum difference between them was 27.0% on July 3, next day after rainfall stopped. The relative humidity, which increased by rainfall, decreased more slowly inside than outside the chamber after rainfall stopped. If measurements are conducted during sunny days, the climatic conditions inside and outside the chambers may be almost the same.

The stem respiration rate is not affected by the airflow rate passing through the chambers. Presumably the reason being, a thick bark and closed structure of stem tissue prevented high or slow speed flow affecting the CO_2 efflux from the stem surface to ambient air.

When the rectangular chamber (covering only one side of the sample stem segment) is used to measure stem respiration, sufficient attention is necessary. The stem temperatures and respiration rates varied among four sides (east-, west-, south-, and north-side) of the same stem segment. The coefficient of variation of north-side stem temperature was the smallest. The stem respiration rate at 20℃ (R_{20}) in east-, west-, and south-side was 32%, 36, and 23 greater than north-side, respectively. This result indicated that the difference among stem respiration rates of each side was not occurred by only the difference of stem temperature. As other reason of the difference of R_{20}, the distribution of living cell in direction of sample stem was considered, that is, the cross section of stem is not perfect circular shape under the natural state, and then the distribution of living cell also will vary in proportion to the facing-direction at the stem. As the result, the distance from stem surface to center varied in proportion to the facing-direction at the sample stems, and significantly correlated with R_{20}. Therefore, in scaling up chamber measurements to individual or stand level based on the relationship between stem respiration rate and diameter, the difference of stem respiration in chamber position must be considered. On the other hand, the chamber shape (circular and rectangular chamber) did not affect the stem respiration rate.

The diurnal fluctuations in stem respiration rates paralleled those in PPFD ($0 > 0$), air and stem temperature, but not the diurnal fluctuations in other environmental factors (ambient CO_2 concentration, relative humidity). Stem respiration rate increased exponentially with stem temperature, and was more closely correlated with the stem temperature observed at an earlier time than with current stem temperature. The lagged response of stem respiration to temperature was observed in all the sample trees and over the year. A correlation coefficient (R^2) was about 25% higher than when respiration rate was regressed against lagged stem temperature than when respiration rate was regressed against current stem temperature.

However, stem respiration rate at 0℃ and Q_{10} estimated from lagged stem temperature were not statistically different from those estimated from current stem temperature.

In seasonal changes, stem respiration rates of Japanese red pine, longstalk holly, and black locust ranged from 0.11 to 1.32 μmol CO_2 $m^{-2}s^{-1}$, 0.11 to 2.76, and 0.13 to 4.44, respectively. The Q_{10} were relatively constant throughout the year, varied among species (2.59 for Japanese red pine, 1.85 for longstalk holly, and 2.48 for black locust). The time lag in three species became short with increasing of temperature.

Stem and branch respiration rates per unit of volume (μmol CO_2 $m^{-3}s^{-1}$) were closely related the thickness of the stems and branches, and decreased with increasing diameter. The Q_{10} decreased with increasing diameter both in stems and in branches for *Pinus densiflora* trees. According to the respiration-diameter relation and the pipe model theory (Shinozaki et al., 1964; Yoda et al., 1965; Yoda, 1967), total annual woody respiration aboveground was estimated to 2.68 t C ha^{-1} yr^{-1} (1.423 t C ha^{-1} yr^{-1} for stem, and 1.26 t C ha^{-1} yr^{-1} for branch).