Heat and moisture stress impede wood-decomposing microbes

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Summary

R_{DW} of dead *Q. serrata* showed the following responses to environmental factors:

1. Q_{10} decreased significantly with increasing temperature, especially above 25°C (Fig. 3). However, there was no significant relationship between R_{DW} and H_{DW}.
2. R_{DW} decreased in the afternoon during the summer (at temperatures more than 30°C), probably due to short-term heat stress (Fig. 6).
3. R_{DW} decreased during rainfall, probably due to decreased oxygen (Fig. 7).

The model based on data at from 7- and 30-day intervals and the response to environmental factors in results 1 and 3 predict the annual carbon loss of DW with accuracy better than 2%.

Introduction

Dead wood is an important component of forest carbon cycles because of its large carbon stock and persistence for many years in the forest. Decomposition is associated with respiration that results from decomposer physiological activity. Many cultivation studies have shown that heat or moisture stress affects respiration by decomposer microbes, but few studies have observed these stresses under field conditions. To allow estimation of the annual respiratory carbon loss from dead wood, two important points should be clarified: How frequently should measurements be performed? How does the respiration rate in dead wood (R_{DW}) respond to environmental factors? Our objective was to determine the response of R_{DW} to variations in heat and moisture in the field. To answer our two questions, we used an automated opening and closing chamber system (Fig. 1).

Materials & Methods

Study site: Yamashiro Experimental Forest, Kyoto, Japan

Materials: Dead wood of *Quercus serrata* (ϕ 26 cm, length 70 cm, dead wood on the forest floor for ≥ 1 year)

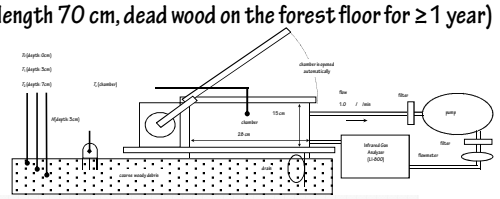

Fig. 1 The automated opening and closing chamber system used for the measurement of R_{DW}.

Measurement: chamber CO_2 concentration (LI-COR, LI800), Temperature at a 3-cm depth in dead wood (DW) (T-type thermocouple; T_{DW}), water content (time-domain reflectometry; H_{DW}) measured for 10 min every 20 min

Measurement period: January 2002 to December 2003

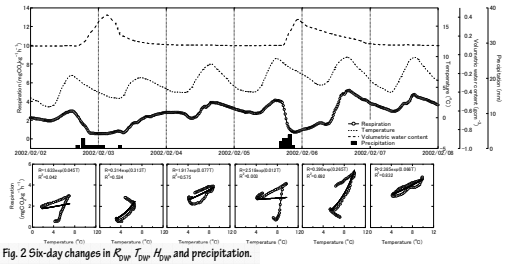

Fig. 2 Six-day changes in R_{DW}, T_{DW}, H_{DW}, and precipitation.

Analysis of R_{DW} response to environmental factors:

We approximated the relationship between R_{DW} and T_{DW} throughout the day using an exponential function (Fig. 2). The regression goodness of fit was small (R^2 < 0.4 for non-rainy days and R^2 < 0.2 for rainy days). Rainy days accounted for 42% of the total. We used only data obtained on non-rainy days to determine the daily temperature response (Q_{10}, the change in R_{DW} per 10°C temperature change; Result 1). To examine the response of R_{DW} to rainfall, we described the exponential relationship between R_{DW} and T_{DW} on the days before and remain the parameters are constant during, and after the rain. We then estimated R_{DW} after the rain using the function, and calculated the % difference between the estimated and observed values (Result 2).

The model to estimate annual carbon loss from dead wood:

We estimated the annual carbon loss from dead wood as follows: We calculated R_{DW} at 11:00 (when the daily mean T_{DW} occurred) at 7-, 14-, and 30-day intervals. We assumed the parameters of temperature response of R_{DW} remained constant to the next measurement. We used the relationship between Q_{10} and daily mean T_{DW} (Result 1) and the rainfall effect (a 20% R_{DW} decrease on rainy days and the following day; Result 3).We compared the estimated and observed annual carbon losses from dead wood (Result 4)

Result 1. Temperature sensitivity of Q_{10}

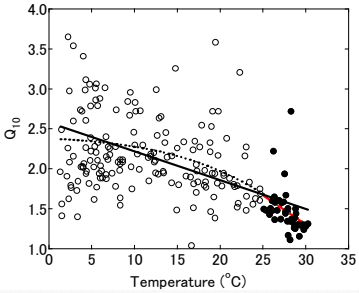

Fig. 3 Relationship between Q10 of RDW and daily mean TDW on non-rainy days. — linear ····· sigmoid

In the long-term, daily Q_{10} decreased significantly as daily mean T_{DW} increased ($P < 0.05$), and Q_{10} decreased most rapidly above 25°C (Fig. 3). The relationship between Q_{10} and H_{DW} was not significant. We successfully used a sigmoid carve to approximate the Q_{10}–temperature relationship (broken line, Fig. 3). The temperature dependence of Q_{10} has been shown in many soil respiration studies but our study appears to be the first description of this phenomenon in dead wood and the more rapid decrease in Q_{10} at high T_{DW} has not been previously reported.

Result 2. Summer heat stress

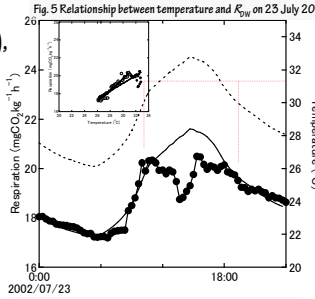

Fig. 4 Diurnal changes in R_{DW} and temperature on 23 July 2002.

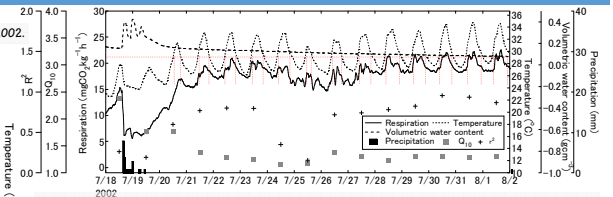

Fig. 6 Relationships among R_{DW}, T_{DW}, H_{DW}, water content, and precipitation, and the resulting effects on Q_{10}, from 18 July to 2 August 2002.

In summer, R_{DW} decreased in the afternoon, when T_{DW} exceeded 30°C. Daily Q_{10} equaled 1.25, but increased to 1.44 based only on data for temperatures less than 30°C (Fig. 5). This result suggests that heat stress decreased respiration by decomposers.

Result 3. Water stress caused by rainfall

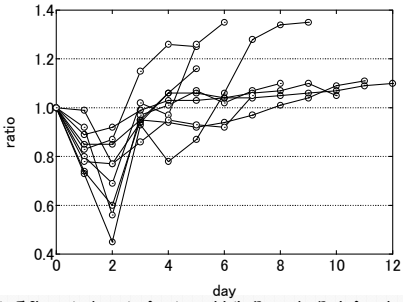

Fig. 7 Change in the ratio of estimated daily R_{DW} to the R_{DW} before, during, and after rainfall.

R_{DW} decreased sharply with increasing H_{DW} during rainfall (by a mean of 20%) and then increased slowly after the rain ended (Fig. 7). R_{DW} showed no evidence of drought stress, even more than 10 days after the rainfall (Fig. 7). This suggests that wood decomposers require oxygen to support their respiration and would rarely show drought condition in dead wood.

Result 4. Annual carbon loss from DW

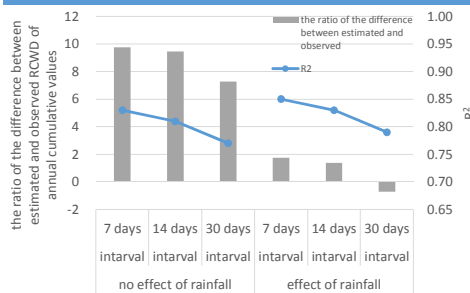

Fig. 8 Accuracy of the estimate of annual carbon loss from dead wood: (left) without and (right) with accounting for rainfall.

Annual carbon loss from dead wood was overestimated by about 10% if we did not account for the effects of moisture; the overestimate decreased to <2% after accounting for the factor (Fig. 8).