Phyton (Austria) Special issue: "APGC 2004"	Vol. 45	Fasc. 4	(385)-(388)	1.10.2005

Contribution of Litter CO_2 Production to Total Soil Respiration in Two Different Deciduous Forests

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Key words: CO_2 production, deciduous forest, litter, respiration, subsoil, topsoil.

Summary

KIM H., HIRANO T., KOIKE T. & URANO S. 2005. Contribution of litter CO_2 production to total soil respiration in two different deciduous forests. - Phyton (Horn, Austria) 45 (4): (385)-(388).

CO_2 efflux from a forest floor is produced in subsoil, topsoil and litter layers. We evaluated topsoil respiration (R_t), subsoil respiration (R_s) and litter CO_2 production (R_L) seperately in a deciduous broadleaf forest and a larch forest in northern Japan from April through November to investigate the contribution of R_L to total soil respiration (R_{all}: $R_L + R_t + R_s$). In the broadleaf forest, R_L peaked at 0.97 gC m^{-2} d^{-1} in late May. The R_L contribution to R_{all} (R_L / R_{all}) was large at 0.15-0.40 in spring, whereas it was less than 0.07 in summer. In the larch forest, only larch litter was examined. R_L of larch litter decreased gradually from 0.32 to 0.08 gC m^{-2} d^{-1} between April and November. R_L / R_{all} decreased rapidly during April and May from 0.19 to 0.04 and was almost constant in summer at 0.01-0.03. Seasonal sums of R_L, R_s and R_t were 85, 683 and 145 gC m^{-2} for the broadleaf forest and 34, 700 and 253 gC m^{-2} for the larch forest, respectively, for 8 months; R_L accounted for 9.3 and 3.4% of R_{all} for the broadleaf and larch forests, respectively.

Introduction

CO_2 emission from soils is a large flux in the global carbon cycle (SCHLESINGER & ANDREWS 2000). In many forest ecosystems, soil CO_2 is a major determinant of net ecosystem carbon exchange. CO_2 efflux from a forest floor is produced in subsoil, topsoil and litter layers. It is useful to partition total soil respiration into the CO_2 production rates of these components of forest soil for the accurate prediction of soil respiration with detailed models, because subsoil, topsoil and litter differ in physical, chemical and biological conditions. We evaluated topsoil

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respiration (R_t), subsoil respiration (R_s) and litter CO_2 production (R_L) separately in two deciduous forests under field conditions to investigate their seasonal variations and to understand the contribution of CO_2 production from relatively fresh litter (R_L) to total soil respiration (R_{all}: $R_L + R_t + R_s$).

Material and Methods

Study site

The field experiment was conducted in two adjacent deciduous forests in Hokkaido, Japan: a broadleaf forest (Tomakomai Experimental Forest, Hokkaido Univ.) and a Japanese larch (*Larix kaempferi*) plantation (Tomakomai FRS). The dominant tree species of the broadleaf forest are oak, magnolia, Japanese elm, maple, and heartleaf hornbeam. In the larch forest, some deciduous broadleaf trees, such as birch and Japanese elm, invaded into the gaps. The occupation of larch trees in the forest was 81% on a stem area basis (HIRANO & al. 2003a). Both broadleaf and larch trees usually begin to foliate in late April. The defoliation of broadleaf trees occurs in October, about half a month earlier than that of larch trees. The annual mean air temperature is 6.5°C. The annual precipitation is about 1200 mm. Snow covers the ground from early December through early April. These forests have the identical soil, classified as volcanogenous regosol with poor nutrients. The A horizon and C horizon underlay 0.01- to 0.02-m thick litter in order; the B horizon is lacking.

Litter CO_2 production

Slightly and moderately decomposed organic horizons, or the O_i and O_e horizons, were included in litter, and highly decomposed one, or the O_a horizon, was in topsoil. Thus topsoil consists of the O_a and A horizons, and subsoil is identical with the C horizon. R_L (gC m^{-2} d^{-1}) was estimated from litter temperature (T, °C) and moisture (θ, g g^{-1}) on a daily basis using a simple model (GULLEDGE & SCHIMEL 2000) expressed as,

$$R_L = a\exp(bT)\frac{\theta}{\theta + c} \quad (1)$$

where a, b and c are fitted constants. The model was fitted every month from April through November 2002 to the monthly results of laboratory experiments (KIM & al. 2005), in which R_L was measured by the chamber method under different conditions of temperature and moisture from leaf litter samples collected from the forests. For the larch forest, only larch litter was collected. Litter temperature was measured between litter and topsoil. Litter moisture was estimated from soil moisture measured at depth of 0.02 m using a linear regression (r^2 = 0.91-0.95) on a daily basis.

Topsoil and subsoil respiration

R_t and R_s were measuerd every half hour using Fick's first law from vertical distribution of soil CO_2 concentration, soil moisture, soil temperature and gaseous CO_2 diffusion coefficients. CO_2 concentration was measured with infrared CO_2 analyzers (GMD20, Vaisala) buried at depths of 0, 0.02, 0.13 and 0.17 m at one point in the broadleaf forest, and 0, 0.02, 0.11 and 0.13 m at two points in the larch forest. The thickness of topsoil was 0.17 and 0.13 m in the broadleaf and larch forests, respectively. The method for measuring R_t and R_s was detailed by HIRANO & al. 2003b.

Results and Discussion

Seasonal variations in R_L, R_t and R_s from April through December 2002 are shown in Figs. 1 and 2 for the broadleaf and larch forests, respectively. R_L was somewhat discontinuous at the change of months because the fitted constants of the model (Eq. 1) differed among months. In the broadleaf forest, the accumulation of relatively fresh litter consisting of the O_i and O_e horizons decreased gradually from

20 g (dry weight) m^{-2} in April to 10 g m^{-2} in September, and increased in October because of the supply of new litter. In the larch forest, larch litter decreased gradually form 4 g m^{-2} in April to 1 g m^{-2} in October and increased in November. The litterfall of larch needles accounted for about 70% of total leaf litterfall in 2003.

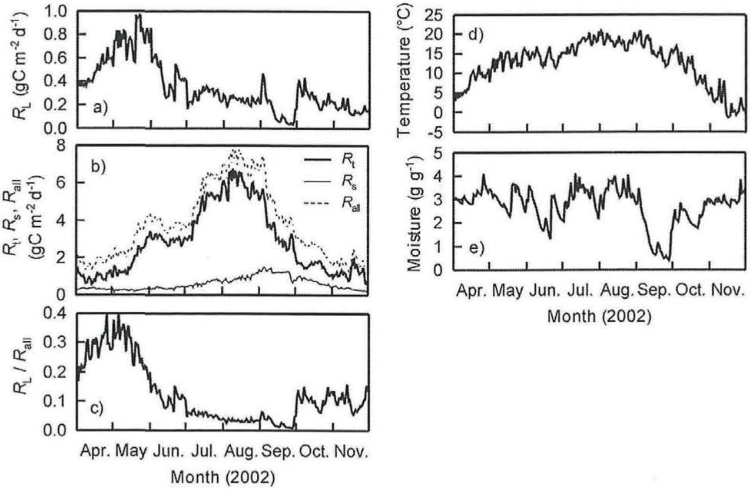

Fig. 1. Seasonal variations in daily means of R_L, R_s, R_t, R_L / R_{all}, litter temperature and litter moisture from 1 April to 30 December 2002 for the broadleaf forest.

In the broadleaf forest (Fig. 1), R_L increased in April and May with temperature and peaked in late May at 0.97 gC m^{-2} d^{-1}. R_L decreased rapidly in June to less than 0.3 gC m^{-2} d^{-1} and decreased gradually in July and August; the large decrease in June was chiefly due to desiccation. In September R_L decreased rapidly again because of severe desiccation. R_L increased in October because of wetting and the supply of new litter, whereas it decreased in November as temperature decreased. On the other hand, R_t increased gradually with soil temperature and peaked in August at about 7 gC m^{-2} d^{-1}. R_s peaked at 1 gC m^{-2} d^{-1} in September, about one month later than R_t. The contribution of R_L to R_{all} (R_L / R_{all}) was large at 0.15-0.40 in April and May for reasons of more litter accumulation, better chemical quality of litter for decomposition (KIM & al. 2005), higher litter moisture and lower soil temperature, whereas it was less than 0.05 in summer between July and September. In the larch forest (Fig. 2), R_L of larch litter decreased from 0.2-0.3 gC m^{-2} d^{-1} in April to 0.07-0.08 gC m^{-2} d^{-1} in November with fluctuations caused by moisture variation. This seasonal pattern was due to decrease in litter accumulation and the deterioration of litter chemical quality (KIM & al. 2004). In contrast, R_t and R_s peaked in August and September, respectively, in the same manner as in the broadleaf forest. R_L / R_{all} decreased rapidly in April and May from 0.19 to 0.04 and was almost constant between June and September at 0.01-0.03. R_L / R_{all} increased gradually in October and November.

Seasonal sums of R_L, R_A and R_C were 85, 683 and 145 gC m^{-2} for the broadleaf forest and 34, 700 and 253 gC m^{-2} for the larch forest, respectively, for the snow-free period of eight months in 2002. R_L accounted for 9.3 and 3.4% of R_{all} for the broadleaf and larch forest, respectively.

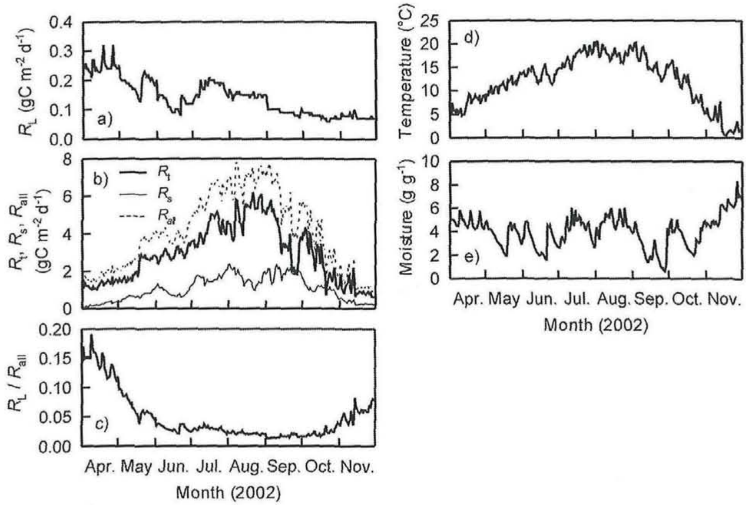

Fig. 2. Seasonal variations in daily means of R_L, R_t, R_s, R_L / R_{all}, litter temperature and litter moisture from 1 April to 30 December 2002 for the larch forest. R_L was only from larch litter. R_t and R_s were means of two measurements, respectively.

Acknowledgements

We thank Dr. Y. TANAKA for assisting in the field experiment in the broadleaf forest, and Dr. Y. FUJINUMA and K. INUKAI for permitting the field experiment in the larch forest. This study was supported by Grants-in-Aid for Scientific Research (No.13480150) from the Japanese Ministry of Education, Culture, Sports, Science and Technology.

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