# ALLOCATION AND RESIDENCE TIME OF CURRENT PHOTOSYNTHETIC PRODUCTS IN A BOREAL FOREST USING A LOW-LEVEL $^{14}C$ PULSE-CHASE LABEL

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## ABSTRACT

We tested the utility of a low-level radiocarbon ($^{14}C$) pulse-chase label for quantifying carbon allocation patterns and the contributions of different components to total ecosystem respiration at ambient $CO_2$ concentrations in a black spruce forest stand in central Manitoba, Canada. Approximately .01 moles of $CO_2$ that was isotopically enriched in $^{14}C$ to ~100,000 times background atmospheric $^{14}C$ levels was introduced into the headspace of a 37,000 L translucent dome enclosure. Over a one hour period, ~70% of this label was photosynthetically assimilated by the enclosed vegetation. The label application produced a $^{14}C$ signature well below regulated health standards, and was easily detectable with Accelerator Mass Spectrometry (AMS). We followed the allocation and timing of labeled photosynthetic products by measuring the amount and $^{14}C$ content of $CO_2$ respired from different ecosystem components over the following 30 days

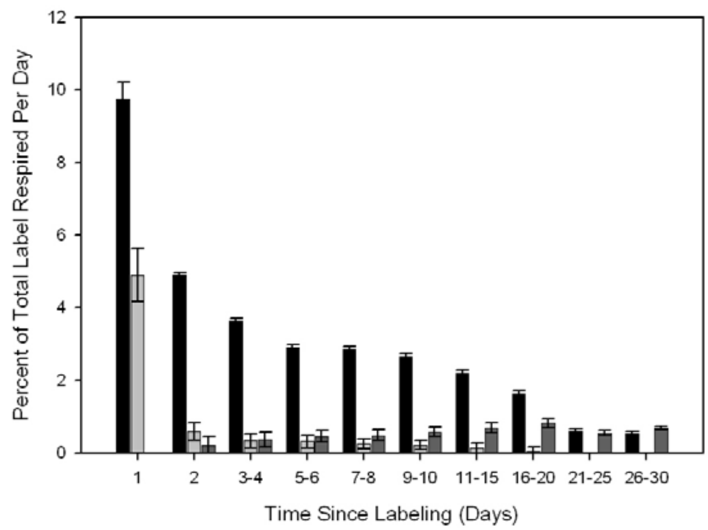
## INTRODUCTION

Pulse-chase labeling (tracer) studies with either $^{13}C$ or $^{14}C$ can follow the allocation of recently assimilated photosynthetic products [*Hanson et al.,* 2000; *Horwarth et al*., 1994]. The $^{13}C$ label is useful to follow the allocation of C into fast cycling pathways (hours to days) such as plant respiration; and it is advantageous because analyses are inexpensive. Yet, because $^{13}C$ is naturally more abundant than $^{14}C$ ($^{13}C/^{12}C \sim 0.01$ vs. $^{14}C/^{12}C < 10^{-12}$), applications of high-level $^{13}C$ labels often require increasing $CO_2$ concentrations significantly above ambient levels. Low-level $^{13}C$ labels become quickly diluted, and cannot be used to follow the fate of C in small or longer-lived pools. Past $^{14}C$ labeling studies have used decay counting techniques to measure $^{14}C$ content, requiring high initial levels of radioactivity [*Howarth et al.,* 1994; *Milchunas and Laurenroth*, 1992; *Olsrud and Christensen*, 2004]. Health and safety regulations have limited most $^{14}C$ labeling studies to enclosures such as chambers and greenhouses, or small stature vegetation, with very few studies conducted under field conditions.

The measurement of $^{14}C$ by more sensitive accelerator mass spectrometry (AMS), which detects individual $^{14}C$ atoms instead of decay counting, allows us to easily distinguish the presence of a label in small amounts (mg) of material. Natural levels of $^{14}C$ in the atmosphere are very small, therefore a $^{14}C$ label with specific activity 30 nCi/g will increase the $^{14}C$ content to well over 100,000 times background levels, with radioactivity levels below what is classified as harmful, or hazardous waste, and easily detectable by AMS. Hence, a low-level $^{14}C$ pulse label can be followed longer (hours to years), with greater sensitivity than a $^{13}C$ label, and can reveal allocation to longer-lived plant C pools such as growth and storage. Such low-level $^{14}C$ methods have been employed in biomedical AMS applications over the past decade [e.g. *Turteltaub and Vogel*, 2000] but has yet to be applied in the environmental sciences.

## RESULTS

The mean residence times (MRT; determined as the e-folding time for loss of $^{14}C$ from the label) of recent photosynthetic products in the understory (feather mosses), canopy (black spruce), and rhizosphere (black spruce roots) were <1, 6 and 15 days, respectively. Respiration from the canopy and understory showed significantly greater influence of labeled photosynthates than root and rhizosphere respiration. After 30 days, ~64% of the label assimilated had been respired by the canopy (black bars), ~17% by the rhizosphere (grey), and ~9% by the understory (white), with ~10% unaccounted for and perhaps remaining in tissues (See Figure). Maximum $^{14}C$ values in root respiration were reached four days after label application. The label was still detectable in rhizosphere and canopy respiration after 30 days.




We attribute the time lag of four days in the appearance of the maximum label content in rhizosphere respiration to translocation between the needles and the roots. The maximum relative contribution of label to respiration in the roots and rhizosphere was ~5 times less than that observed in the canopy and understory. If we assume that the only C source of above ground respiration is current photosynthetic products, which is supported by our unlabeled isotope measurements, then we estimate that a much smaller portion of the C respired by black spruce roots reflects current photosynthate. Therefore, a significant amount of root respiration must be derived from an additional, different aged C source. This result supports the hypothesis that C respired by black spruce roots originates from a combination of sources: storage and recent photosynthetic products.

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