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Partitioning root and microbial contributions to soil respiration in *Leymus chinensis* populations

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Abstract

Based on the enclosed chamber method, soil respiration measurements of *Leymus chinensis* populations with four planting densities (30, 60, 90 and 120 plants/0.25 m^2) and blank control were made from July 31 to November 24, 2003. In terms of soil respiration rates of *L. chinensis* populations with four planting densities and their corresponding root biomass, linear regressive equations between soil respiration rates and dry root weights were obtained at different observation times. Thus, soil respiration rates attributed to soil microbial activity could be estimated by extrapolating the regressive equations to zero root biomass. The soil microbial respiration rates of *L. chinensis* populations during the growing season ranged from 52.08 to 256.35 mg CO_2 m^{-2} h^{-1}. Soil microbial respiration rates in blank control plots were also observed directly, ranging from 65.00 to 267.40 mg CO_2 m^{-2} h^{-1}. The difference of soil microbial respiration rates between the inferred and the observed methods ranged from -26.09 to 9.35 mg CO_2 m^{-2} h^{-1}. Some assumptions associated with these two approaches were not completely valid, which might result in this discrepancy. However, these two methods' application could provide new insights into separating root respiration from soil microbial respiration. The root respiration rates of *L. chinensis* populations with four planting densities could be estimated based on measured soil respiration rates, soil microbial respiration rates and corresponding mean dry root weight, and the highest values appeared at the early stage, then dropped off rapidly and tended to be constant after September 10. The mean proportions of soil respiration rates of *L. chinensis* populations attributable to the inferred and the observed root respiration rates were 36.8% (ranging from 9.7 to 52.9%) and 30.0% (ranging from 5.8 to 41.2%), respectively. Although root respiration rates of *L. chinensis* populations declined rapidly, the proportion of root respiration to soil respiration still increased gradually with the increase of root biomass.

Keywords: Microbial respiration; Root respiration; *Leymus chinensis* (Trin.) Tzvel.; Belowground biomass; Soil water content; Soil temperature

1. Introduction

Soil respiration is a major component of the global carbon cycle, accounting for about 25% of the global carbon dioxide exchange (Bouwmann and Germon, 1998). Therefore, soil respiration becomes one of the important research issues in the global carbon cycle (Schimel, 1995). Grasslands are one of the major vegetation types, covering about 30% of the world's land surface. Soil respiration from grasslands contributes a large portion to the global CO_2 flux.

Soil respiration originates mainly from root and microbial activities, and partitioning root and microbial contributions to soil respiration is important for calculating the carbon budgets of vegetation and the turnover rate of soil organic matter, as well as for understanding sources and sinks of carbon in terrestrial ecosystems in the face of global climate change. Raich and Tufekcioglu (2000) reported that root contribution to soil respiration was 33–89% in forests, 17–40% in grasslands, 12–38% in croplands, and 50–93% in arctic tundra. There were wide ranges of the reported values in the major biomes worldwide. In addition, of 54 vegetation types cited by Raich and Tufekcioglu (2000), there are 40 forest types, six grassland types and eight other vegetation types. Thus, the study on root contribution to soil respiration in grassland types should be emphasized, especially in temperate zones.

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Root respiration could be accurately measured in nutrient solutions (e.g. Bloom et al., 1992; Lambers et al., 1996). However, it is difficult to measure root respiration in situ because of variable environmental conditions and the difficulty in distinguishing from microbial respiration. Currently, three primary methods are employed in the field studies, including integration of components contributing to in situ soil respiration, comparison of soils with and without root exclusion, and application of stable or radioactive isotopes (Hanson et al, 2000). This study aims to partition root and microbial contributions to soil respiration by greenhouse experiment using two approaches, i.e. inferred and observed methods. The inferred approach would be employed by developing a regressive relationship between soil respiration rates and root biomass at different observation times; the observed method was based on the difference between soil respiration rates of planted and unplanted treatments. *Leymus chinensis* (Trin.) Tzvel. as research object in this study, is a dominant plant species in the typical steppe zone of Inner Mongolia.

2. Materials and methods

2.1. Experimental design

The experiment was done in a naturally illuminated greenhouse located at Institute of Botany, the Chinese Academy of Sciences. The upper soil (0–30 cm) of the experiment plots was sieved through a 2.5 cm sieve and mixed uniformly. Considering the biomass samplings during the whole experiment, seven sets of the plots responding to biomass samplings were established. Each set of the plots was divided into 15 subplots (50 cm × 50 cm) with four planting densities of *L. chinensis* (30, 60, 90 and 120 plants/0.25 m^2) and no-plant control by three sampling replicates. This design was based on the natural densities of *L. chinensis* steppe, Inner Mongolia, where 292–480 *L. chinensis* per square meter were observed during the growing season from 2001 to 2002 (data not shown). The no-plant subplot (blank control) was used for directly determining the microbial basal respiration. Thus, the whole experiment consisted of 105 subplots: seven plots × 15 subplots each.

2.2. Plant culture

The seeds of *L. chinensis* obtained from natural grassland in Xilinhot, Inner Mongolia, were sterilized by a 5% potassium permanganate solution for 8 min., rinsed, and then placed into an refrigerator below 0 °C for 7 d. They were sown directly in subplots on June 19, 2003, and germinated after about 1 week. Measurements were initiated on 31 July and ended on 27 November, 2003 in the greenhouse with air temperature of 18–24 °C, relative humidity of 60–80% and photosynthetic photon flux density of 130–330 μmol m^{-2} s^{-1}. About 7–10 days before each measurement, all of subplots were sprayed uniformly with water (0.5 L/0.25 m^2).

2.3. Soil respiration

All the soil respiration measurements of *L. chinensis* populations and blank controls were made by an enclosed chamber method. The method allowed short-term and continuous measurements, and it was superior to alkali absorption method (Li and Chen, 1998). The enclosed chamber was made from acrylic material. The chamber was 15 cm high with the surface area of 50 cm × 50 cm. Two air mixture fans (12 V, 0.13 A) and a highly precise temperature and humidity sensors (type: NKHT, Beijing Northking Electronic Technology Development Co., Ltd) were fitted inside the chamber and connected with a Thermohygrograph (type: 3DD150, Beijing JunFang Technical Institute of Physics and Chemistry). CO_2 concentration was directly measured inside the chamber by an infrared gas analyzer (type: GXH-3010D, Beijing Computer Technology and Application Institute), which was connected with the chamber in a closed configuration and calibrated regularly with CO_2 standards.

Fifteen stainless steel frames (50 cm × 50 cm) were inserted into the soil at the depth of 5 cm. The aboveground biomass of the subplots restricted by the stainless steel frames was clipped to ground level. During the measurements, the chambers were put into the grooves outside the stainless steel frames and sealed with distilled water. Between the measurements, the air within the chamber was swapped with the ambient environment on a 1–2 min. basis and allowed to equilibrate. Changes of temperature, humidity and CO_2 concentration in the closed chamber were logged every 10 s interval for 3 min. and used to calculate soil respiration rate. The soil respiration rate was computed from CO_2 concentration changes over the measurement period. It could be calculated as follows (Dong et al., 2000):

$$F = \left(\frac{\Delta m}{\Delta t}\right) D \left(\frac{V}{A}\right) = hD\frac{\Delta m}{\Delta t}$$

where F refers to soil respiration rate (mg m^{-2} h^{-1}), $\Delta m/\Delta t$ denotes linear slope of CO_2 concentration change with time over the measurement period, which is thought to be effective only when the correlation coefficient (R^2) greater than 0.95, D is the gas density of the chamber ($D = P/RT$, mol m^{-3}, P: atmospheric pressure (Pa), T: temperature (K) and R: air constant (8.314 J mol^{-1} K^{-1})), V is the chamber volume (m^3), A is the surface area of the chamber (m^2), and h represents the height of the chamber (m).

Soil respiration rates were measured every 2 h at 15 subplots from 7:00 to 19:00 on July 31, September 10, September 28, November 4 and November 24, 2003. Besides these measurements, 24 h continuous measurements were