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Effect of clipping on soil respiration components in temperate grassland of Loess Plateau

Lin Wei [a], Jian Liu [b], Jishuai Su [b], Guanghua Jing [a], Jie Zhao [b], Jimin Cheng [a, b, c, *], Jingwei Jin [c, **]

[a] Institute of Soil and Water Conservation, Chinese Academy of Sciences and Ministry of Water Resources, Yangling 712100, China
[b] College of Animal Science and Technology, Northwest A&F University, Yangling 712100, China
[c] Institute of Soil and Water Conservation, Northwest A&F University, Yangling 712100, China

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ABSTRACT

Land use practice can profoundly affect carbon (C) cycling in grassland ecosystems. The aim of our study was to examine the effect of clipping on root and microbial respiration in a semiarid grassland in northern China, and to identify the main controlling factors on soil CO_2 flux. In-situ partitioning of total soil respiration into root and microbial respiration was performed by mesh-exclusion technique. Soil respiration, temperature and moisture; microbial respiration; above- and below-ground biomass; root production, water soluble organic carbon and soil microbial biomass C were measured in response to clipping during two growing seasons. The results showed that clipping significantly increased the soil temperature by 0.62 °C and 1.25 °C in 2014 and 2015, respectively; however, there was no influence on soil moisture. Clipping significantly decreased the annual mean soil respiration and its components in both years except for root respiration in 2015, with the reduction of total soil respiration and root respiration significantly greater in a wet year (2014) than in a dry year (2015). Root respiration was sharply reduced by 49.2% and 26.4% within two weeks after clipping in 2014 and 2015, respectively; however, with plant regrowth, it began to increase, and even exceeded the control in 2014. However, the microbial respiration exhibited relatively constant lower values in clipping plots almost throughout the study period. Following clipping, the decreased rates of root respiration were significantly and positively related to root production, while decreased rates of microbial respiration were related to soil microbial biomass C. Temperature sensitivity (i.e., Q10 values) of soil respiration and its components was higher in 2014 than the same period in 2015, and decreased with varying magnitude in response to clipping. Root respiration was more sensitive to clipping, and contributed to the main reduction of total soil respiration. The interannual variations in soil respiration and its components were mainly related to interannual precipitation and summer drought. Our results highlight the different response patterns of root and soil microbial respiration to the spring clipping, and the critical role of water in regulating soil respiration and its components and their responses to clipping in a semiarid grassland.

1. Introduction

As the second largest carbon (C) flux between terrestrial ecosystems and the atmosphere, soil respiration plays an important role in regulating soil C pools and net C balance in terrestrial ecosystems [1]. The rate of soil respiration can be influenced by climate change (global warming, precipitation regimes, etc.), as well as anthropogenic activity (land use change and management practice), with consequent impacts on terrestrial C cycling and feedbacks to climate change [2,3]. Understanding the responses of soil respiration to climate change and/or management practice is imperative for accurate estimations of soil C sequestration in terrestrial ecosystem and predictions of future global C cycling in response to global change.

Clipping or mowing for hay, as a prevalent land-use practice, is considered to be an important component of global change [4].

* Corresponding author. Institute of Soil and Water Conservation, Chinese Academy of Sciences and Ministry of Water Resources, Yangling 712100, China.
** Corresponding author.
E-mail addresses: gyzcjm@ms.iswc.ac.cn (J. Cheng), jinjingweisoil2008@gmail.com (J. Jin).

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Although numerous studies have been investigated, large variation and inconsistencies in the response of soil respiration to clipping have been found in different studies [5,6]. Some studies showed that clipping reduced soil respiration by 19–49% due to the decreased C substrate supply, even though it increased soil temperature [7,8]. However, Jia et al. [6] and Han et al. [3] found no response of soil respiration to clipping treatment due to the unaltered plant growth and soil moisture. The mechanism of clipping effects on soil respiration is controlled by the complex interaction of changing soil microclimate (soil temperature and moisture) and the availability of C substrate for root and microorganisms [9], and varies with vegetation type and soil texture [3]. Therefore, more detailed studies in different ecosystems are needed.

One important factor responsible for the variability of previous studies in clipping effects on soil respiration is that soil respiration consists of two components: root respiration from plant roots, mycorrhizal fungi and other associated microorganisms (rhizosphere microorganisms) that depend on the contemporaneous photosynthate and microbial respiration from decomposition of plant litter and soil organic matter that depend on the contemporaneous photosynthate and microbial respiration from decomposition of plant litter and soil organic matter [10]. The differences in turnover rates, magnitudes, and seasonal patterns of the two substrate sources result in different responses of the two components of soil respiration to climate change and land use practice [8]; therefore, the two components of soil respiration may respond differently to climate change and land use practice [4,11,12]. Hanson et al. [13] reported great variations in the contribution of root respiration to total soil respiration in non-forest ecosystems with ranging from 10 to 90%. The diverse contributions of root respiration to total soil respiration in different ecosystem studies may be an important factor to explain the inconsistent results of the clipping effect on soil respiration. However, only a few studies have so far partitioned soil respiration in situ to quantify the individual changes of root and microbial respiration in response to clipping, and the few reported results were inconsistent with each other [4,14,15]. Therefore, quantifying the flux and dynamics of each component of soil respiration has great significance for a comprehensive understanding of ecosystem carbon cycling. Furthermore, calculating C loss through root respiration is helpful to estimate gross primary production more accurately, and heterotrophic respiration is essential for calculating net ecosystem production [10].

Soil temperature and moisture have been considered as the most important environmental factors controlling temporal and spatial variation of soil CO_2 flux [7]. These two factors can directly alter the activities of plant roots and soil microorganisms, and indirectly affect plant growth and belowground C allocation, thus influencing soil respiration and its components [16]. Especially in semiarid ecosystems, where soil water availability is a limiting factor, the total annual precipitation and its seasonal distribution are mainly responsible for the interannual variability of soil respiration and its components alongside Q10 [17,18]. Many previous studies observed that the effect of N addition on soil respiration was determined by the water condition of the study site [3,19]. However, whether the predominant role of water also exists in the clipping effect on soil respiration and its components has been rarely documented [14,18]. Understanding the seasonal and interannual variability of soil respiration and its components and their response to land use change will improve the prediction of ecosystem C cycling.

To investigate the effect of clipping on soil respiration and its components, we conducted a clipping experiment on the grassland of the Loess Plateau, which is characterized by an arid to semiarid climate. We hypothesized that (1) root respiration would be temporarily decreased by clipping considering the sudden reduction of carbon substrate supply from shoots to roots, then it would increase to recover along with the shoots regrowth, because of the close relationship of root respiration with assimilates supply; (2) microbial respiration would be temporarily increased by clipping given that the higher soil temperature after clipping can stimulate SOM mineralization, then it would decrease, because clipping is known to reduce litter input into soil for microorganism decomposition.

2. Materials and methods

2.1. Study site

The study was conducted in a fenced (since 1982) grassland of the Loess Plateau in Ningxia Hui Autonomous Region (106°21′–106°27′E, 36°10′–36°17′N, altitude 1800–2000 m), China. The area is characterized by a semiarid continental climate with an average annual temperature of 7.01 °C. The maximum mean monthly temperature is about 22–25 °C occurring in July, and the minimum mean monthly temperature is about −14 °C occurring in January. Mean annual precipitation is about 425 mm, approximately 60–75% of which occurs in July–September, while mean potential evaporation is 1330–1640 mm. Our experiment site was located on a mountaintop with its flat topography and uniform vegetation distribution. The plant community is dominated by *Stipa grandis*, *Stipa przewalskyi*, and *Artemisia sacrorum* which represented more than 95% of the sum peak aboveground biomass during the experimental period. The type of soil is a mountain gray-cinnamon soil classified as a Calci-Orthic Aridisol according to the Chinese taxonomic system, equivalent to a Haplic Calcisol in the FAO/UNESCO system [20].

2.2. Experimental design

The experiment was designed as a randomized block with five replicate blocks, and each block consisted of two 3 × 4 m^2plots, separated by 2-m walkways. Within each block, the clipping treatment was conducted randomly in one of the two plots, and the other was left as control. Clipping was done once a year in the spring (20 June in 2014 and 16 June in 2015). The plots were clipped to the height of 4 cm above the soil surface, and harvested plant material was removed from the plots to mimic hay harvesting, a major land-use in many types of grassland.

The trenching method was used in this study to separate soil respiration into root and microbial respiration [21]. In each plot, one root-free small plot (0.3 m × 0.3 m) was randomly assigned at least 0.5 m away from the edge. In September 2013, a trench 0.1 m wide and 0.5 m deep was dug, and lined with nylon mesh (0.038 mm mesh size) to prevent root growth into the plots but allow the exchange of water, bacteria, organic matter, and materials [21]. The trench was then refilled with soil according to its original soil profile. During the study period, the root-free plots of both clipping and control were kept free of vegetation by periodic manual removal. The whole-soil plots of control were manipulated nothing during the study period. After eight months of equilibration after the trenches had been built, it was assumed that the CO_2 efflux measured in the root-free plots resulted from only microbial respiration, while that measured in the whole-soil plots comprised both microbial and root respiration. Differences of CO_2 efflux between the whole-soil and root-free plots were used to determine root respiration.