Plant Fine-root Decomposition in Relation to Biomass Quality in a Mixed-grass Prairie Under Cattle Grazing

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Litter decomposition is a complex process involving a diverse group of biological taxa. Nitrogen limitation of fine-root decomposition occurred under moderate grazing but not under heavy grazing. This has implications on nutrient release and cycling in the mixed-grass prairie ecosystem.

Summary
A modified litter-bag method was used to measure plant fine-root decomposition in relation to biomass quality in a mixed-grass prairie. Measurements were made during three years on moderately and heavily grazed pastures that had been under cattle grazing for 17 years prior to sampling. Although we found no significant difference in initial fine-root litter quality between grazing treatments, nitrogen limitation to fine-root decomposition occurred under moderate grazing but not under heavy grazing, suggesting the dominance of the carbon-limited decomposition in heavily grazed pastures as compared with the nitrogen-limited decomposition in the moderately grazed pastures. Our data and results have implications for not only short-term nutrient release essential for plant growth, but also for long-term carbon sequestration potentials in rangelands under grazing management.

Introduction
Below-ground litter decomposition is a complex process linking nutrient release and cycling and the productivity of the soil-plant system (Gill and Jackson 2000). A consensus of many studies is the strong influence of litter quality, such as initial nitrogen (N) content (Vivanco and Austin 2006) and carbon (C)/N ratio (Silver and Miya 2001) on the decomposition rate. What is unknown, however, is if and to what extent the overriding litter quality control on below-ground decomposition differs among different grazing intensities in rangelands, although research has shown that animal grazing can lead to direct changes in the activity (Tracy and Frank 1998; Liebig et al. 2013) and type (Bardgett et al. 2001) of soil microbes. In this study, we address the problem of fine-root decay in relation to litter quality in a rangeland under cattle grazing.

Procedures
The study was superimposed on a long-term grazing intensity experiment (Patton et al. 2007). From Aug. 7 to 23, 2006, 48 root samples, each from a 10- by 10- by 6-inch soil volume (= 600 in.^{3}), were collected from three moderately grazed (50 percent utilization of the current-year herbage production) and three heavily grazed (80 percent herbage utilization) pastures, eight samples per pasture. Three categories of below-ground plant biomass, including fine roots, were collected by rinsing and washing the soil blocks (Dong et al. 2012).

A modified litter-bag method (Wiegert and Evans 1964) was used to measure root decomposition from 2006 to 2009. Each bag contained about 0.4 ounce of fine roots (dry mass). The samples from each pasture were buried in a 16-foot-long trench (4 inches deep) close to the sampling location. The initial nitrogen (N) content of fine root samples was measured

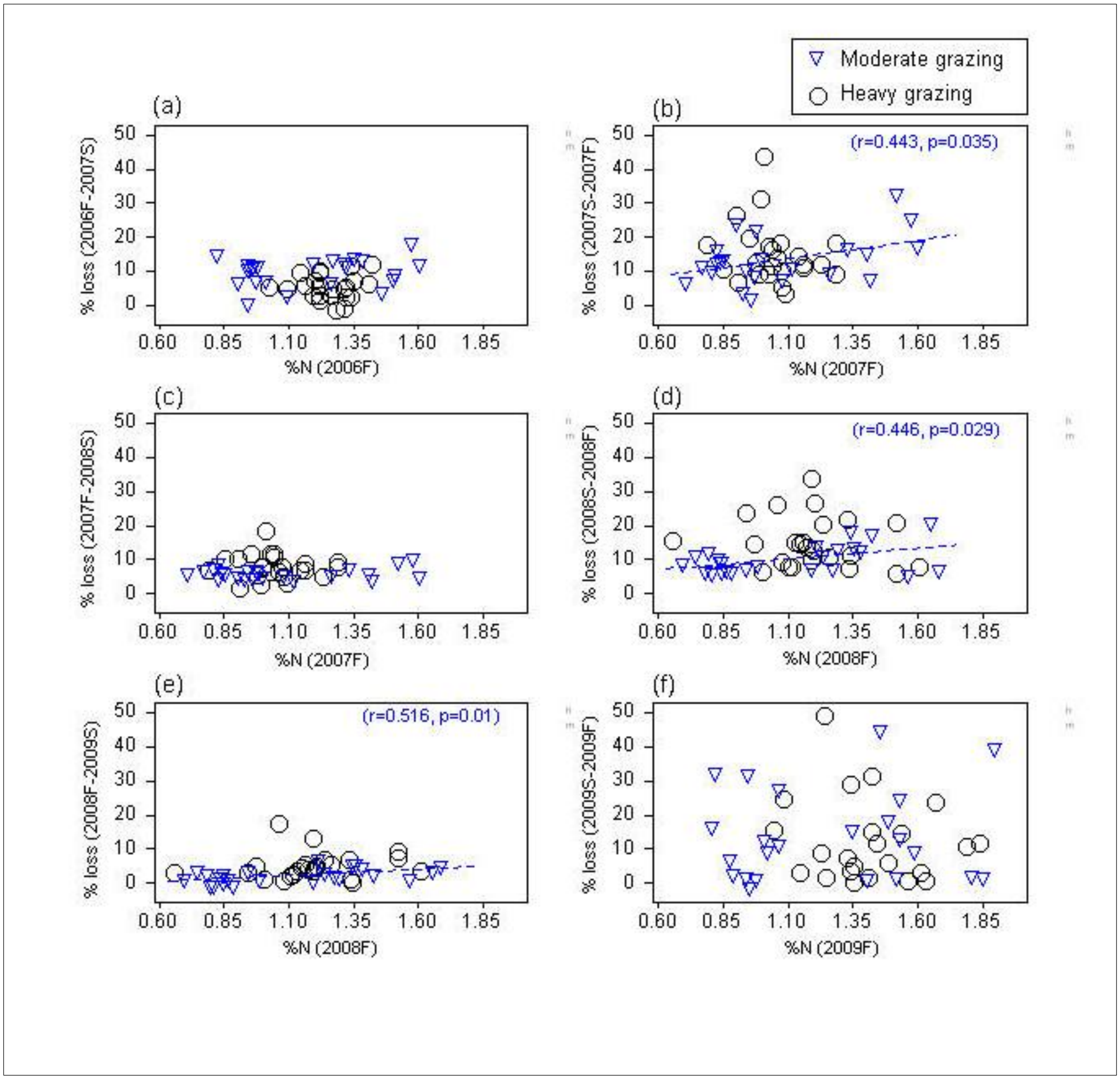

Figure 1: Relationships between percent of mass loss and nitrogen (N) content for the 48 fine-root samples in three dormant seasons (a,c,e) and three growing seasons (b,d,f) from 2006 to 2009. Because nitrogen content was measured only in the fall, the analysis for the dormant season was based on the starting N content, while that for the growing season was based on the ending N content of the 48 fine-root samples. The dormant season from fall 2006 to spring 2007 is represented by "2006F-2007S;" likewise, the growing season of 2007 is represented by "2007S-2007F," with "S" and "F" standing for "spring" and "fall," respectively. The same convention is used to code other seasons. Regression lines are superimposed on data with significant Pearson correlation: (b) $y = 2.05 + 10.6x$ (moderate grazing); (d) $y = 3.55 + 6.15x$ (moderate grazing); and (e) $y = -1.474 + 3.51x$ (moderate grazing), where y and x represent percent mass loss and N content, respectively.

by the Kjeldahl method and the acid detergent fiber (ADF) and acid detergent lignin (ADL) contents were measured according to Goering and Van Soest (1970). During each fall measurement, a subsample was collected from each of the fine-root bags to measure total C (by dry combustion at 1,000º C with nondispersive infrared detection) and total N content. Based on Pinheiro and Bates (2000), we wrote a "self-starting" R function (available on request) to automatically fit the decomposition data of the 144 litter bags (= 48 samples × three categories of biomass) to an exponential decay model (Aber et al. 1990), namely, $F(x) = e^{-kx}$, where $F(x)$ is the fraction of mass remaining at time x (year) and k the relative loss rate constant (year^{-1}).

The relationship between the percent of mass loss and litter quality was explored by correlation analysis, and the decomposition rate constants of different grazing treatments were compared by analysis of variance (ANOVA).

Results and Discussion

Grazing intensity did not have a significant effect on percent N, percent C, C/N ratio or percent ADF of litter. The decomposition rate constant k in heavily grazed pastures (0.23 year^{-1}) was

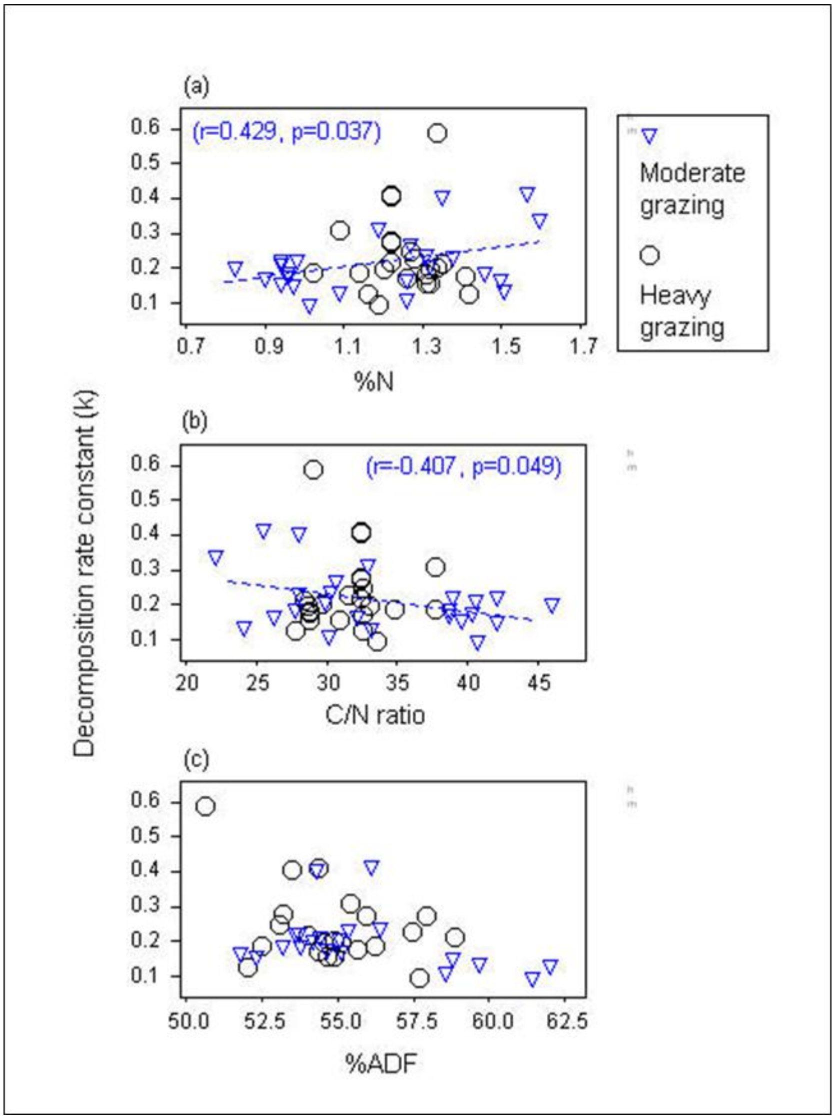

Figure 2: Relationships between the relative loss rate constant (k) and (a) initial total nitrogen (N) content, (b) C/N ratio and (c) acid detergent fiber (ADF) content for the 48 fine-root samples collected from three moderately grazed pastures and three heavily grazed pastures. Note that regression lines were only significant for samples originating from the moderately grazed pastures.

significantly higher than that in moderately grazed pastures (0.21 year^{-1}) (p = 0.036).

The decomposition rate as a function of percent of N or C/N ratio exhibited distinct contrast among grazing treatments, with N limitation of decomposition occurring in moderately but not in heavily grazed pastures. This is seen when the decomposition rate is expressed as a percent of mass loss for each season (see Fig. 1b, d, e) and when the overall decay rate constant *k* (during three years) is considered (Fig. 2).

As a matter of fact, several samples in heavy-grazing pastures displayed rather high decay rates in two dormant seasons (Fig. 1c, e) and two growing seasons (Fig. 1b, d), even at a relatively low percent N level. One possible explanation is that the long-term cattle grazing in this mixed-grass grassland has led to changes in activity or type of soil microorganisms that rendered N-limited decomposition in moderately grazed pastures but a more efficient C substrate-limited decomposition in heavily grazed pastures.

The above explanation is in line with findings of Liebig et al. (2013) and Bardgett et al. (2001). Our result that the fine-root decomposition rate in moderately grazed pastures was positively correlated with percent N and negatively correlated with C/N ratio of initial root quality agrees with similar studies (Moretto et al. 2001; Vivanco and Austin 2006). The result that N limitation of root decomposition occurred under moderate grazing but not under heavy grazing, however, suggests the importance of further study on the activity and type of soil microorganisms regulating nutrient release and cycling in the mixed-grass prairie ecosystem.

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