Acta Ecologica Sinica 37 (2017) 133–139

Contents lists available at ScienceDirect

Acta Ecologica Sinica

journal homepage: www.elsevier.com/locate/chnaes

Foliar carbon, nitrogen, and phosphorus stoichiometry in a grassland ecosystem along the Chinese Grassland Transect

Yu Hailing [a,b], Fan Jiangwen [a,*], Li Yuzhe [a]

[a] Key Laboratory of Land Surface Pattern and Simulation, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China
[b] University of Chinese Academy of Sciences, Beijing 100049, China

ARTICLE INFO

Article history:
Received 29 November 2016
Received in revised form 10 March 2017
Accepted 27 April 2017

Keywords:
Ecological stoichiometry
Chinese Grassland Transect
Grassland plant
C, N, P elements
Leaf nutrients

ABSTRACT

Carbon (C), nitrogen (N), and phosphorus (P) are the basic nutrient elements required for plant growth and function. Ecological stoichiometry provides an important method for the determination of plant nutrient utilization and the environmental adaptation strategies of plants. Studying the stoichiometry of C, N and P is crucial to the understanding of nutrient cycling and ecosystem stabilization mechanisms. Most studies so far have focused only on N and P stoichiometry for plant leaves and ignored the stoichiometry characteristics among C, N, and P. As a major element of plant dry matter, C, along with critical nutrient elements (N and P) could regulate and influence the consumption and fixation of organic matter in ecosystems. Therefore, it is necessary to study the ecological stoichiometry of C, N, and P in plants. Here, C, N and P concentrations and their ratios were measured for 329 foliar samples collected at 132 sites along the 4500 km-long Chinese Grassland Transect (CGT) that traverses the Inner Mongolian and Qinghai-Tibet Plateaus. The content of C, N, and P of plant leaves in grassland ranged from 257.40 to 590.77 mg/g, 4.49 to 45.85 mg/g, and 0.20 to 3.40 mg/g, with an average of 463.76 mg/g, 19.94 mg/g, 1.31 mg/g, respectively. The coefficient of variation (CV) of P was highest (0.47) while the CV values of C and N were 0.09 and 0.34, respectively. N and P were positively correlated ($R^2 = 0.491$, $P < 0.0001$), in agreement with previous studies, while no significant correlation was found between C and P or between C and N. The ranges for C/N, N/P, and C/P were 10.93–93.67 (with an average of 26.86 and a CV value of 0.46) for C/N, 1.68–53.00 (with an average of 16.59 and a CV value of 0.39) for N/P, and 61.49–1995.24 (with an average of 436.77 and a CV value of 0.59) for C/P, respectively. The mass ratio of C:N:P in grassland plant was 440:17:1, and the atom ratio was 1136:43:1. C/N and C/P, C/N and N/P were positively correlated ($R^2 = 0.509$, $P < 0.0001$; $R^2 = 0.410$, $P < 0.0001$, respectively), while C/N and N/P were not significantly correlated. C concentrations of grassland plant in the Chinese Grassland Transect were close to those at the global scale, but lower than that in forests in China. N and P concentrations in grassland plant were lower than those in global terrestrial plants, while N concentrations were much higher but P concentrations were much lower than those in forest plants. C/N and C/P were relatively higher, reflecting the higher vegetative utilization efficiency of grassland vegetation. The CV of P was much higher and the N/P in this study was higher than 16, which indicated that grassland plants in China are more restricted by P elements. Our results could help to understand the relationship between C, N, and P stoichiometry in grassland plants and provide basic data for related ecological models.

In 1958, A. Redfield proved that the marine plankton has a specific composition for C, N, and P elements for the first time, and the molar ratio was 106:16:1 [1], which was later called the Redfield ratio. He also proposed that the ratio would be adjusted by the interactions of the marine environment and biological factors [1]. The hypothesis that the C:N:P ratio was constant in marine plankton had promoted the development of biogeochemical research [2,3]. Later studies confirmed that the C:N:P ratio was not constant, especially in terrestrial ecosystems. As the differences in vegetation type, plant organ, growth period, and environment (e.g. precipitation, temperature, altitude, soil, etc.), the ratio of C:N:P also has an obvious variation [4–7].

For a terrestrial ecosystem, several studies have quantified the variation pattern of foliar N and P concentrations and N/P ratios along climatic gradients and geographic coordinates in the last two decades [6, 8–12]. Reich and Oleksyn [12] found that at the global scale, plant N and P concentrations declined toward the equator as average temperature and growing season length increased. They proposed the Tempreature-Plant Physiological Hypothesis, which states that plants increase their nutrient concentrations to compensate for low photosynthetic efficiency at low temperatures. However, the Biogeochemical Hypothesis indicates that low temperatures inhibit the availability of N, P

* Corresponding author.
E-mail address: fanjw@igsnrr.ac.cn (J. Fan).

http://dx.doi.org/10.1016/j.chnaes.2017.06.005
1872-2032/

and other nutrients, leading to plant foliar nutrient concentrations decreasing with decreasing temperature [12,13]. In addition, there are other hypotheses, such as the Soil Substrate Age Hypothesis [6,14] and Growth Rate Hypothesis [4–6], which have been proposed to explain the environmental mechanisms which impact on N and P stoichiometric characteristics. Moreover, He et al. [8,10] also proposed that geographic and climatic factors would change species composition and thus have an impact on the patterns of plant ecological stoichiometry.

However, studies relating to these hypotheses have mostly focused on N and P stoichiometry, and fewer have considered the stoichiometry of the C element, while the studies of plant C were usually about carbon sinks [15–17]. C is the main element of plant dry matter, and C, N and P interact closely in terrestrial ecosystems. The difference among the stoichiometric ratios of C and the key nutrient elements (N, P) can regulate and affect carbon consumption and the fixation process in the ecosystem [18]. So it is necessary to develop the study of plant C, N and P elements' stoichiometry. Recently, the stoichiometric studies for C, N and P have mostly focused on woody plants [11,19–21], while studies on grassland mostly discussed about N and P [22–24], such as the study on the eco-stoichiometric characteristics of N and P elements in grassland on the Qinghai-Tibet Plateau [8,25,26], northern grassland region [27–30] and Songnen grassland region [31]. Studies have found that in different life-type plants, the leaf nutrient concentrations are significantly different [21,32]. As the vegetation characteristics were much more different between grassland ecosystem and forests, so what's the C, N, P stoichiometry in grassland and what are the differences in C:N:P stoichiometry between grassland and forests? These issues need to be deeply explored.

The Chinese Grassland Transect (CGT) was established for this study which traverses the Inner Mongolian Plateau (IMP) and the Qinghai-Tibet Plateau (QTP) regions in China. Based on obvious climatic gradients and horizontal and vertical zonal distribution of grassland vegetation of the CGT, we analyzed the statistical characteristics and distribution pattern for the concentrations of C, N, P and the ratio of C/N, C/P, and N/P of grassland plant folia. Meanwhile, we also compared the grassland data with the global vegetation data [5,12], the Chinese terrestrial vegetation data [9] and the Chinese forest data [20]. The objectives of our study were: 1) to explore the patterns of C, N and P stoichiometry for the grassland ecosystem; 2) to determine the differences in C:N:P stoichiometry between grassland and forests in China, and results from other scales. Findings in this study could provide a reference for understanding the relationship among grassland C, N and P elements, and also for grassland nutrition evaluation.

1. Method

1.1. Study area

The Chinese Grassland Transect (CGT) covers the main grassland distribution area in China (Fig. 1) [33]. The climatic gradients are obvious and the distribution of grassland vegetation is horizontal and vertical in the CGT. According to this, we divided CGT into the Inner Mongolian temperate grassland region and the Qinghai-Tibet Plateau alpine meadow region (hereinafter referred to as Inner Mongolian Plateau (IMP) and Qinghai-Tibet Plateau (QTP)). IMP is mostly covered by four temperate grassland types: meadow steppe, typical steppe, desert steppe, steppe desert, and by desert. Mean annual temperature (MAT) ranges from −3 to 9 °C and mean annual precipitation (MAP) ranges from about 50 to 400 mm. The location and areas of these grassland types are principally determined by decreasing precipitation from east to west. QTP is characterized by short growing season, high solar radiation intensity, and other factors of high-altitude environments. The climate is cold and dry in winter and relatively warm and humid in summer. MAP ranges from about 100 to 800 mm, and MAT ranges from −5.8 to 3.7 °C [34].

1.2. Sample collection and element analysis

Along the CGT, samples were obtained at 132 sites (Fig. 1), which were separated by about 50 km. The geographic position of each was recorded using a Magellan GPS (Garmin, Kansas, USA). Plot areas of 10 m × 10 m were demarcated at each site, and five 1 m × 1 m quadrats were randomly located within each sample plot.

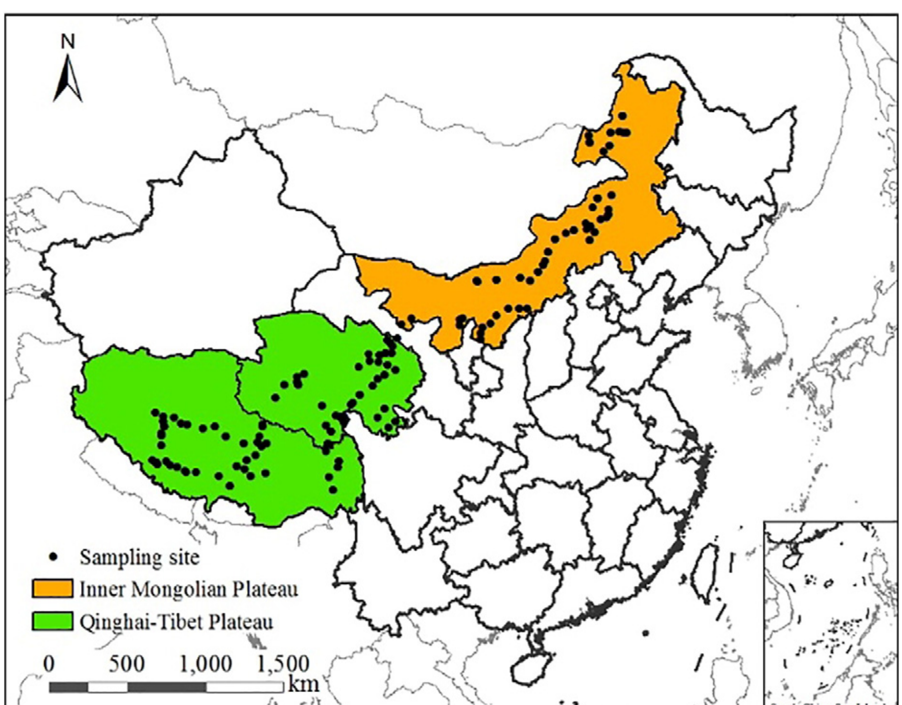

Fig. 1. Distribution map of sampling sites for foliar C, N and P concentrations on the Chinese Grassland Transect across the Qinghai-Tibet and Inner Mongolian Plateaus.