Biogeochemical dynamics of nutritional elements in Moso bamboo 
*(Phyllostachys pubescens)* forests

Mitsutoshi UMEMURA
Graduate School of Bioagricultural Sciences, Nagoya University, Nagoya, 464-8601, Japan.
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Summary

Moso bamboo (*Phyllostachys pubescens*) is one of the major giant bamboo species growing in Japan, and the invasion of mismanaged bamboo populations into contiguous forests has been a serious problem. In order to control and manage the bamboo forests, it is important to understand the nutrients dynamics in bamboo organs and their roles in the fast growing characteristics of bamboo, and also in bamboo forests. The bamboo is characterized by high growth rates of vertical shoot growth (e.g., >10 m in approx. 2 months) and horizontal rhizome growth (e.g., average 1-2 m/year). And, the bamboo is gramineous plant and classified as silicon (Si) accumulators. These characteristics are considered to be reflected to the seasonal or interannual changes of nutritional concentrations including Si in leaves, culms, and the other organs, and also to the distribution of nutrients in various organs. From a viewpoint of biogeochemical cycle of nutrients in bamboo forests, Si has various functions such as processes of soil formation and regulating species composition of vegetation in terrestrial ecosystems. Bamboo forests are one of the forest ecosystems that accumulate large quantities of amorphous Si. In addition, recently, the rapid expanding due to mismanaged of the bamboo forests has caused the invasion into contiguous forests. The bamboo invasion is possible to change the nutrient cycle in a forest ecosystem. Therefore, the purposes of this study are to understand the relationship between the fast growing mechanism and the concentrations of nutritional elements in *P. pubescens*, and to clarify the biogeochemical role of Si in *P. pubescens* forest and the impacts of bamboo invasion to contiguous forests. Firstly, we investigated both seasonal change of elemental concentrations in leaves and elemental distribution in mature and growing organs from a viewpoint of the retranslocation and the physiological role. Secondly, we evaluated Si dynamics in *P. pubescens* forests to understand their role in the Si biogeochemical cycle of forest ecosystems. Thirdly, we evaluated the impact of bamboo invasion on soil properties of Hinoki cypress (*Chamaecyparis obtusa*) forest, which is one of the major forest ecosystems in Japan.

Corresponding author: M. Umemura
E-mail address: mitsutoshi.ume@gmail.com
The studies were conducted at three sites, Kanpachi (35°07' N, 137°13' E, 110 m altitude), Seto (35°11' N, 137°07' E, 200 m altitude), and Noguchi (35°07' N, 137°15' E, 160 m altitude) all in Aichi prefecture, central Japan. In these sites, not only *P. pubescens* forests but also hinoki cypress forests invaded by the bamboo were observed.

In order to clarify the relationship between the fast growing mechanism and the concentrations of nutritional elements in *P. pubescens*, we investigated the seasonal change of nutritional elements in leaves at three *P. pubescens* forests and those distribution in mature organs (culms, branches, leaves, roots, and rhizomes) and growing organs (shoots and rhizomes). Potassium (K) and phosphorus (P) concentrations in leaves commonly showed seasonal decreasing, and eventually lost the 87-92% and 86-92% in leaf litters, respectively. In growing rhizomes and shoots, higher K and P concentrations were found in younger organs. It is possible that the losses from leaves were caused by retranslocation from mature leaves to these growing organs, leaving the possibility of K leaching. We found seasonal accumulation of Si and calcium (Ca) into leaves without clear evidence of their retranslocation. Silicon was found in higher concentration in surface parts of the culms and sheaths in the growing rhizomes and shoots. In contrast, boron (B) showed both seasonal increasing and decreasing which were most synchronous through all sites and among nutritional elements. The B concentrations in the growing rhizomes and shoots were higher in younger parts. In addition, B was detected in higher concentration only in these growing organs and mature leaves. These results indicate that *P. pubescens* actively utilizes B for their reproduction by the retranslocation and the local accumulation behaving as mobile B. *P. pubescens*, one of Si accumulating plants, was also characterized as a low accumulating plant for Ca and B, indicating that *P. pubescens* could utilize more Si for their cell wall enhancement rather than Ca and B. In both mature culms and rhizomes, much higher concentrations of zinc (Zn) were found in the nodes with meristematic tissue than those in internodes. It is suggested that Zn accumulations in the nodes play a role to promote elongation of the culms and rhizomes. We suggest that *P. pubescens* makes a success the reproduction and rapid growth with specifically and locally utilizing B, Zn, and Si, which play a role of steady development of primary cell wall and the apical growth, internode elongation, and their protection against physical damages, respectively.

Next, we investigated a silicon cycle in *P. pubescens* forests. We conducted a study on the organic accumulation and biological cycle of Si in three *P. pubescens* forests in central Japan with different site characteristics. The amounts of Si accumulation
aboveground and underground were 200-360 kg/ha and 180-460 kg/ha, respectively. These values indicate that Si accumulation underground was comparable to that aboveground. Si supply to the forest floor through litterfall was 77-330 kg/ha/year corresponding to 165-706 kg/ha/year as phytoliths (SiO$_2$), and 72-88% was supplied as leaf litter. These results showed that a huge biogenic Si pool derived from bamboo plants exists in the floor of bamboo forests. Furthermore, we estimated the Si turnover time in *P. pubescens* forests as being 1.3-12.2 years, although this variation may depend on forestry conditions such as soil water content or stem density.

As the third topics, we clarified the changes in chemical characteristics of surface soils in hinoki cypress forests induced by the invasion of *P. pubescens*. We established three successive quadrats along bamboo invasion (allotted to a bamboo stand, a mixed stand of bamboo and hinoki, and a hinoki stand) at three observation sites. Then, we measured the density and basal area of bamboo and hinoki shoots. Surface soil was sampled from each quadrat to analyze pH, water content, and exchangeable cation contents. The values of soil pH were significantly higher in the mixed stands than the hinoki stands at all sites, showing positive correlations with exchangeable Ca contents in the soil. Exchangeable K and magnesium (Mg) contents in the soil of the mixed stand showed significant differences compared with the hinoki stand only in Seto, but these values in the mixed stand were similar to those in the bamboo stand. This characteristic is consistent with the invasion degree determined from the density ratio of living bamboo culms to living hinoki trunks: Seto > Kanpachi > Noguchi. We conclude that increases in the soil pH due to bamboo invasion into hinoki forests resulted in distinct and sensitive changes in the soil chemistry.

In conclusion, we found that *P. pubescens* forests are possible to improve the chemical property of the surface soil through the invasion into forests with acidified soils such as hinoki plantation. In addition, the bamboo forests form a huge Si pool and supply numerous phytolith on the forest floor, circulating them at the fast turnover time of 1.3-12.2 years. These findings also indicate that the change of soil physical and chemical property in the forest can be accelerated by the specific reproduction and rapid growth which can be promoted by function of nutritional elements such as Si, B, and Zn.