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EDITORIAL

Virtual issue: Alpine and subalpine plant communities: importance of plant growth, reproduction and community assemblage processes for changing environments

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Abstract
Natural plant communities are exposed to environmental changes such as global warming and increased human activities. It is thought that alpine and subalpine ecosystems with cool climatic conditions are sensitive to environmental changes. This virtual issue introduces multidisciplinary research at alpine and subalpine plant communities. The articles include research on (1) species diversity, vegetation and biomass, (2) species assembly, (3) climate and growth of alpine plants, (4) reproduction of alpine plants, (5) differences of growth traits among coexisting species, (6) vegetation changes by human activities and overgrazing of deer, and (7) differentiation of growth traits among ecotypes in relation to climatic conditions. These thirteen articles provide valuable information for future research on the effects of environmental changes on alpine and subalpine plant communities.

Natural plant communities are exposed to environmental changes such as global warming and increased human activities (Takahashi et al. 2011a; Takahashi and Hanyu 2015; Mietkiewicz et al. 2017). It is thought that alpine and subalpine ecosystems with cool climatic conditions are sensitive to environmental changes. Furthermore, deer have expanded their range and increased dramatically in abundance worldwide in recent decades through human activities, i.e., wide spread agricultural and silvicultural lands and reductions in hunting and natural predators (Côté et al. 2004; Takatsuki 2009). Overbrowsing of deer reduces plant cover and species diversity in natural plant communities. Therefore, it is necessary to consider effects of environmental changes, including human activities and overgrazing of deer, on plant distribution, species diversity and regeneration dynamics of plant communities at high altitudes.

Plant growth and reproduction are limited at higher altitudes due to low temperatures (Mäkinen et al. 2002; Takahashi et al. 2011b). For example, many studies, using open top chambers (OTC), showed that the growth of alpine plants was limited by low temperature during the growth period because plant growth often increased in the OTC (Arft et al. 1999; Takahashi 2005; Hoffmann et al. 2010; Klady et al. 2011). Global warming prolongs growth periods for plants, but the rate of increase of growth period is greater at higher altitudes with shorter growth periods if the growth period is determined by a certain threshold temperature, irrespective of altitude (i.e., the growth period becomes longer by the same number of days along altitudes). Therefore, the increase of plant growth due to global warming is greater at higher altitudes (Takahashi and Okuhara 2013). Furthermore, increases of growth and decomposition rates due to global warming would alter carbon cycling of ecosystems (Oechel et al. 1993; Hagedorn et al. 2010; Deslippe et al. 2011; Natali et al. 2011).

It is often reported that vegetation distribution changes due to global warming (Parmesan and Yohe 2003; Kelly and Goulden 2008; Parolo and Rossi 2008). For example, the distribution of alpine plants moved upward at the rate of 0–4 m per decade near summits of the Europe Alps (Pauli et al. 1996). In addition, some researchers predicted, using ecological niche models, that distribution area shrank in many plant species due to global warming (Thuiller et al. 2005; Casalegno et al. 2010; Sen et al. 2016). It is expected that the reduction of distribution area is more conspicuous for alpine and subalpine vegetation than lowland vegetation

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(Ishigami et al. 2003). Many researchers have examined the dynamics of treelines and timberlines because their upward shift means forest development and expansion (Kullman 2002; Walther et al. 2005; Danby and Hik 2007; Devi et al. 2008; Takahashi and Yoshida 2009; Takahashi et al. 2012; Takahashi 2014). However, some researchers reported that vegetation distribution did not change (Peñuelas and Boada 2003; Foster and D'Amato 2015). For example, Harsch et al. (2009) clarified that about half of treelines and timberlines had not move upward by the meta-analysis. Thus, effects of global warming on plant distributions are still unknown.

A plant community consists of many coexisting species. In general, the number of tree species monotonically decreases with altitude or shows hump-shaped patterns (Rahbek 1995), but herbaceous species often show different altitudinal distribution patterns (Miyajima et al. 2007; Tsujino and Yumoto 2013). This means that the number of plant species is not determined by temperature only. Plant species compete for light, soil water and nutrients among coexisting species, but facilitation is more important than interspecific competition for species assemblages at higher altitudes (Callaway et al. 2002). Therefore, examination of species coexisting mechanisms in plant communities along altitudinal gradients is necessary to clarify how environmental changes affect community structures of plants. Studies of plant community dynamics along altitudinal gradients would be also important for understanding of carbon and nutrient cycling because not only growth rates but also the nitrogen to phosphorus ratio of plants changes with altitude (Zhao et al. 2016). Plant morphological and physiolosical traits change plastically to environmental conditions (Cordell et al. 1998; Nicotra et al. 2010; Takahashi and Goto 2012). Thus, examination of plastic responses is crucial for understanding how plants adapt to environmental changes. Furthermore, each plant species is distributed in a wide geographical area along altitudinal and latitudinal gradients, so plant individuals experience different environmental conditions even within the same species. Plant species often differentiate into certain ecotypes to adapt to environmental conditions (Li et al. 1998; Martin et al. 2007; Hirano et al. 2017). Therefore, comparing growth traits among ecotypes of a species will provide valuable information when considering evolution and adaptation of the species.

I have compiled a virtual issue on the website of the *Journal of Plant Research* (https://www.springer.com/10265) with 13 articles published after 2010 for the following 7 subjects of alpine and subalpine plant communities.

1. Species diversity, vegetation and biomass: Namgail et al. (2012) revealed that hump-shaped patterns of biomass and species diversity along altitudinal gradients were caused by livestock grazing at low altitudes in the Indian Himalaya. Manish et al. (2017) also showed hump-shaped patterns of species diversity along altitudinal gradients in the Eastern Himalaya and the combination of ambient energy and water availability was the main driver of altitudinal plant species diversity. Zhu et al. (2010) showed that carbon storage and partitioning among vegetation, detritus and soil varied greatly with forest type and altitude in temperate forests in China. Hirota et al. (2010) revealed that gross primary production and ecosystem respiration rates positively correlated to species diversity and vegetation biomass, respectively, at a meadow in the Tibet Plateau. Sakio and Masuzawa (2012) suggested that the advancing timberline on Mt. Fuji in Japan is a recovery process after the volcanic eruption.
2. Species assembly: Takahashi and Tanaka (2016) clarified that habitat filtering was more important than interspecific competition for species assemblages of alpine and subalpine plant communities in Japan by examining functional traits.
3. Climate and growth of alpine plants: Yoshie (2010) examined the vegetative phenology of 29 alpine species in Japan, and showed the importance of early growth initiation for the increase of growth of alpine plants as the growth period of leaves and stems correlated with the time of growth initiation stronger than with the time of growth cessation. Takahashi and Aoki (2015) also showed that high temperatures at the beginning of the growth period increase the annual shoot length and tree-ring width of alpine dwarf pine *Pinus pumila* in central Japan.
4. Reproduction of alpine plants: Guerrina et al. (2016) examined reproductive traits of an ancient alpine plant species *Berardia subacaulis* that survived past climate changes in the European Alps, and showed that *B. subacaulis* assured reproduction under a pollinator decline because self-pollination was possible.
5. Differences of growth traits among coexisting species: Takahashi and Obata (2014) examined crown architecture and net production of understory saplings of four coexisting subalpine conifer species in Japan, and showed the interspecific differences closely related to their regeneration traits such as shade tolerance.
6. Vegetation changes by human activities and overgrazing of deer: Takahashi and Miyajima (2010) revealed that sunny lowland and montane herbaceous species increased along roadsides in the subalpine zone in Japan. Tsujino et al. (2013) reported that regeneration of subalpine coniferous forests was hindered by browsing of sika deer in Japan.
7. Differentiation of growth traits among ecotypes in relation to climatic conditions: Ozaki et al. (2018) studied how multiple climate variables influence trait values in 44 ecotypes of *Arabidopsis thaliana* grown under com-

mon conditions, and found that genetic variations in growth traits were associated with various climate variables in the original habitats, reflecting their evolutionary processes.

I hope these 13 articles provide valuable information for future research on the effects of environmental changes on alpine and subalpine plant communities.

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