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Editorial: Seed behavior in response to extreme environments

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Editorial on the Research Topic
Seed behavior in response to extreme environments

The success of seeds enables plants to occur over all terrestrial habitats in the world, including those extreme ones that range from saline intertidal zones to arid deserts. Even in the highest mountain Himalayas, seeds of *Desideria himalayensis* were found to establish seedlings at the elevation of 6,212 m.

The final success of a seed becoming a seedling is dependent upon whether it is able to complete germination in the right place at the right time. Various strategies are adopted by seeds to survive the processes of maturation, dispersal, seed burial, and predation before they eventually become adult plants. Exploration of the multiple seed behavior and knowledge about the underlying mechanisms is fundamental for us to understand the success of plants on the planet.

Despite the fundamental roles of seed behavior in plant persistence and ecosystem diversity, our knowledge about multiple seed behavior in response to various types of uncommon environments remains limited. This current Research Topic focuses on seed behavior in different environments, aiming at bringing together papers to answer questions relating in particular to interesting behavior of (1) seed dispersal, dormancy, and germination patterns after fires, drought, floods etc.; (2) ecological significance of the various seed behavior in response to these extreme environments; and (3) evolutionary perspectives of the diverse seed behavior observed in the plant kingdom.

This Research Topic brings together six articles covering four aspects of seed ecology (Figure 1). First, Draper et al. reviewed the literature on the hitherto less understood role of *Carnivorans* in seed dispersal. They conclude that *Carnivorans* are prolific seed dispersers and likely increase long-distance dispersal services that may aid the ability of some plant species to persist in the face of climate change. Second, Bazhenova et al. described the anatomical characteristics of Cenozoic pine seed cones of a new fossil-species, *Pinus prehwangshanensis* sp. nov., from the upper Pleistocene of South China. Their data indicate that the characteristic anatomical features of East Asian pine group were formed no later than the end of the Pleistocene. These fossils confirm the existence of floristic exchange between continental Asia and the Japan archipelago. Their analysis suggests that the regional climate of Maoming Basin used to be similar to the present-day climate of northeastern Vietnam. Third, with qPCR and metabarcoding high-throughput sequencing technology, Liu et al. examined the endophytic bacteria and fungi of three crop wild relatives of the medicinal genus *Panax*. They found that seed bacteria were more abundant than fungi and seed microbiome composition was mainly driven by host plant genotype. Seed endophytic bacterial microbiota was also affected by hypothermal environments. *Panax* seed endophytic bacteria tend to form inter-weaved functional modules

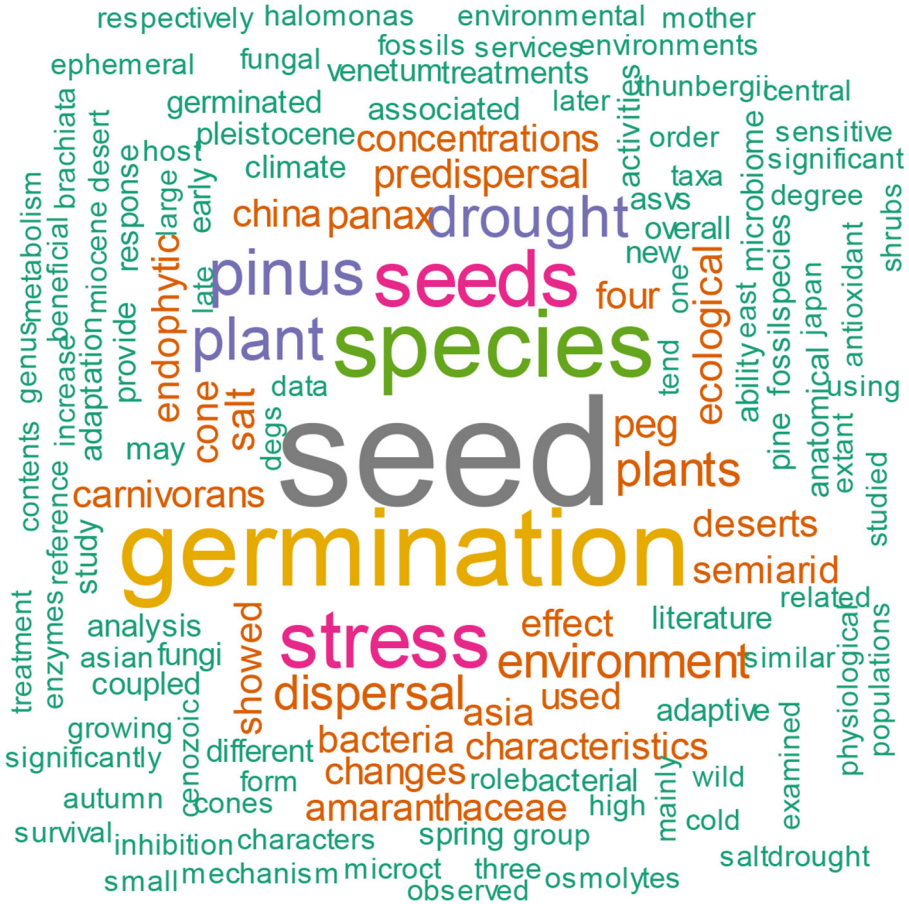

FIGURE 1
Word cloud of the abstracts of the six articles within the Research Topic. Seed, germination, stress, drought, and dispersal are among the most frequent words.

that are majorly connected by genera associated with nutrient cycling, plant disease suppression, and tolerance to environmental fluctuation. The other three out of the six articles are about seed germination. Wu et al. studied the endangered species *Apocynum venetum* and analyzed its adaptive mechanism to semi-arid environment by examining the complex physiological and transcriptional changes during seed germination under different PEG-6000 treatments. They found that the germination characteristics, activities of antioxidant enzymes, and contents of osmolytes were promoted under moderate drought, whereas the CAT and APX activities and the protein content decreased with drought stress. In the desert, plants often have to adapt to not only drought but also salinity. In another study, Lu, Liu, Chen et al. studied the response to drought and salinity of four common desert ephemeral plants. Agreeing with Wu et al., they found that drought and salt alone decreased seed germination. However, interestingly, the coupled salt-drought treatment significantly alleviated the stress effect of one factor and improved the germination characteristics of seeds. While germination rate *per se* is important, the timing of seed germination is also essential for cold desert plants. Lu, Liu, Han et al. investigated the timing of seed germination and found that nearly half of the cold desert species showed pre-dispersal germination on mother plants in early spring. They conclude that such a high percentage suggests that the pre-dispersal germination on the one hand might be adaptive given the unpredictable precipitation in the Asian cold deserts, on the other hand, might be maladaptive because the survival rate of the germinated seedlings is often lower than those germinated from the soil after seed dispersal.

Seeds play a vital role in plant life history to adapt to extreme environments and provide valuable opportunities for plants to adapt to the ongoing climate change and are thus important for ecological conservation and restoration. Understanding how plants adapt to extreme environments through changes in seed behavior is an ongoing challenge in seed ecology. We hope this Research Topic provides some latest development in this exciting area.

Author contributions

JZ wrote the first draft of the editorial. All authors contributed substantially to the revision.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note