

# Cushion plants as critical pioneers and engineers in alpine ecosystems across the Tibetan Plateau

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## Abstract

Cushion plants are widely representative species of the alpine ecosystem due to their vital roles in the abiotic and biotic environments, ecological succession processes, and ecosystem engineering. Importantly, Cushion plants, such as *Androsace L.* and *Arenaria L.*, can be regarded as critical pioneers of ecosystem health, restoration and sustainability across the Tibetan Plateau because these plants (i) exhibit tenacious vitality, regulate regional climates, substrates and soil nutrients and keep warmth in extreme regions; (ii) facilitate relationships with surrounding and maintain the diversity of above- and below-ground communities; and (iii) have high sensitivity to environmental changes, which can indicate grassland ecosystem health and resilience in the context of global change.

## Cushion plants as critical pioneers and engineers in alpine ecosystems across the Tibetan Plateau

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## Abstract

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**KEYWORDS:** Cushion plants; *Androsace* L.; *Arenaria* L.; Tibetan Plateau; ecosystem succession.

### **The cushion plant is a key builder of abiotic environments**

Cushion plants, with more than 70 kinds, are widely distributed in high elevations and inhabit extreme environments across the Tibetan Plateau (Badano & Cavieres, 2006; Yang & Sun, 2006). The Tibetan Plateau is an important centre of global cushion plants, e.g., *Androsace* L. and *Arenaria* L., which play a vital role in the development of modern flora and vegetation (Luo et al., 2018). Firstly, the "microspace" formed by convex structure and developed root system of cushion plants could function in heat, nutrient and water preservation (Fig. 1a-c) (Cavieres et al., 2006; Zhao et al., 2020). Actually, these plants act as an ecological engineer to accelerate the enrichment of nutrients for the substrate, which can last for hundreds of years for tenacious vitality (Fig. 1d) (Yang et al., 2010). Second, the special structure and strong adaptability of cushion plants reduce the damage of wind and water erosion and maintain the warmth of extreme regions (Byers et al., 2006). Ultimately, dead cushion plants provide sufficient fertilizer for the soil and promote nutrient cycling.

**Fig. 1** (a-c) The cushion plant, such as *Androsace* L., has the median uplifting structure to create "micro space" with developed root system; (f) The death cushion plant provides sufficient fertilizer for the surrounding plants.

### **The cushion plant is a critical facilitator for biotic environments**

Cushion plants provide physical protection in extreme environments and promote the growth and reproduction of surrounding species, especially species of pioneer settlers (Cavieres et al., 2006; Francisco et al., 2020). Thus, cushion plants exhibit interspecific facilitation, which may be beneficial to maintain species diversity (Fig. 2) (Erfanzadeh et al., 2020). The main effects of cushion plants on the below-ground community are the promotion of the activity of soil microorganism and the enhancement fungal communities to increase the absorption area of roots and maintain microbial community diversity (Fig. 3) (Casanovakatny et al., 2011; Chang et al., 2018; Wang et al., 2020).

**Fig. 2** The cushion plant promotes the propagation of other plants, such as *Leontopodium*, *Carex* and *Artemisia*.

**Fig. 3** The cushion plant and fungi form symbionts to improve the activity of soil microbe.

### **The cushion plant is an indicator of ecosystem health and resilience**

Cushion plants have high sensitivity to global change (e.g., climate, nitrogen deposition, species invasion and land use), such as their response to freezing-thawing and stress gradients, which may indicate ecosystem health and resilience (Gorsuch et al., 2001). Besides, cushion plants may be indicators of whether the ecosystem is healthy or degradation succession occurs (Erfanzadeh et al., 2020; Luo et al., 2018). Specifically, in the context of alpine grassland ecosystem degradation, the cushion plants play an important role in improving abiotic and biotic environments and the maintenance of alpine ecosystem stability (Fig. 4).

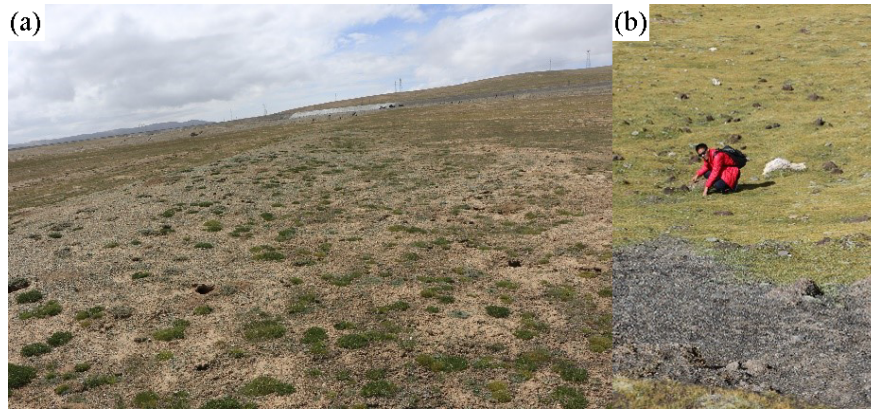


Fig. 4 *Androsace L.* and *Arenaria L.* live in degraded grassland.

#### 4. Conclusions

The cushion plant is a key species for the maintenance of the stability of the grassland ecosystem across the Tibetan Plateau. These plants are key builders of abiotic environments due to their vital roles in regional warmth maintenance, wind reduction and nutrient accumulation. These plants are also protectors of surrounding plants and show interspecific facilitation. Cushion plants promote species reproduction and are hotbeds for maintaining plant and microbial diversity. Notably, these plants are essential indicators of ecosystem health and sustainability and play an important role in the restoration of alpine grassland ecosystems under the influence of global change. Therefore, cushion plant appears to be both important pioneers and ecosystem engineers in alpine ecosystems of the Tibetan Plateau.

#### Author Contributions

YW and JS conceived the idea and study design, YW, JS and BL took photos and drafted the paper, JW and TZ revised the paper.

#### Disclosure Statement

The authors declare that they have no competing interests.

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#### Data and Materials Availability

All data needed to evaluate the conclusions in the paper are presented.

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