Allelopathic Effects of Artemisia halodendron Leaf Aqueous Extract on Seed Germination of Four Sandy Land Herbaceous Plants: Postprint

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Abstract

Artemisia halodendron is an important species in vegetation succession during sand dune restoration and one of the dominant species in semi-mobile dunes. This study investigated, from an allelopathic perspective, the effects of different concentrations of Artemisia halodendron leaf extract (0, 10, 20, 40, 60, 80 g·L^{1} and 100 g·L^{1}) on seed germination of Setaria viridis, Lespedeza davurica, Corispermum macrocarpum, and Agropyron cristatum. The results demonstrated that Artemisia halodendron leaf extract had minimal effects on seed germination of Setaria viridis, with low-concentration treatments exhibiting a certain stimulatory effect on its germination, whereas significant inhibitory effects were observed on the other three species, and the inhibitory effect intensified with increasing treatment concentration. Artemisia halodendron exhibits strong allelopathic effects on seed germination of other species, and allelopathy resulting from the release of substances following leaf fall may represent one of the important mechanisms for maintaining its competitive advantage.

Full Text

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Abstract

Artemisia halodendron is one of the dominant species in vegetation succession during sandland restoration. At the initial stage of vegetation regeneration over sandland, A. halodendron dominates semi-fixed dunes, but is subsequently replaced by other annual or perennial species such as Lespedeza bicolor, Corispermum macrocarpum, and Agropyron cristatum as restoration progresses. However, the mechanism underlying this succession remains unclear. This study investigated the allelopathic effects of A. halodendron leaf water extracts at different concentrations (0, 10, 20, 40, 60, 80, and 100 $g \cdot L^{1}$) on seed germination of one symbiotic species, Setaria viridis, and three competitive species: L. bicolor, C. macrocarpum, and A. cristatum. Results showed that A. halodendron leaf extracts had minimal effects on S. viridis germination, with slight promotion observed at low concentrations. However, germination of the three target species was significantly inhibited by the extracts, and this allelopathic inhibition intensified with increasing concentration. These findings demonstrate that A. halodendron exerts strong allelopathic effects on other species during vegetation regeneration in sandland restoration. The allelopathic substances released from decomposing leaves may represent a key competitive strategy maintaining its dominance during early successional stages.

Keywords: Artemisia halodendron; allelopathic effect; seed germination; allelopathic index; vegetation succession; Tongliao

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1 Introduction

Artemisia halodendron plays a crucial role in vegetation succession during sandland restoration. As a pioneer species, it initially colonizes semi-fixed dunes and dominates the early stages of vegetation regeneration. However, as restoration proceeds, it is gradually replaced by other annual and perennial species including Lespedeza bicolor, Corispermum macrocarpum, and Agropyron cristatum. The ecological mechanisms driving this species replacement remain poorly understood. Allelopathy, the chemical inhibition of one plant by another through the release of secondary metabolites into the environment, may contribute significantly to this successional pattern. Previous studies have documented allelopathic effects in various plant species, including Melilotus officinalis, Sorghum sudanense, Lolium multiflorum, Stellera chamaejasme, Onobrychis viciifolia, Gentiana straminea, Medicago sativa, and Trifolium species. However, the allelopathic potential of A. halodendron and its role in sandland vegetation dynamics requires further investigation.

2 Materials and Methods

2.1 Study Site and Climate Conditions

The study was conducted at the Horqin Sandy Land Experimental Station (42°58 N, 120°43 E) at an elevation of 345 m. The region experiences a semi-arid continental climate with an average annual precipitation of 343 mm (1961–2017), with approximately 80% occurring during June–September. The mean annual temperature is 6.7°C. Soils are classified as sandy chestnut soil with low organic matter content.

2.2 Plant Material and Extract Preparation

Artemisia halodendron leaves were collected from the experimental site in April 2017. Fresh leaves were washed, air-dried, and ground into powder. Leaf water extracts were prepared by soaking 100 g of powder in 1000 mL distilled water at 25°C for 24 h, then filtered through filter paper. The stock solution (100 g · L ¹) was diluted to obtain concentrations of 0, 10, 20, 40, 60, 80, and 100 g · L ¹. The control treatment (0 g · L ¹) used distilled water only.

2.3 Germination Bioassay

Seeds of Setaria viridis, Lespedeza bicolor, Corispermum macrocarpum, and Agropyron cristatum were collected from the same region in September 2016. Prior to germination, seeds were surface-sterilized with 0.5% sodium hypochlorite for 10 minutes, then rinsed thoroughly with distilled water. For each treatment, 50 seeds were placed in sterile Petri dishes lined with two layers of filter paper moistened with 5 mL of the respective extract solution. Dishes were sealed with parafilm and incubated in a growth chamber at 25°C with a 16 h light/8 h dark photoperiod (light intensity 9000 lx). Germination was recorded daily for 21 days, with seeds considered germinated when radicles emerged 2 mm. Each treatment was replicated four times.

2.4 Measurement Indices

Germination Rate (GR) was calculated as:
GR = (Number of germinated seeds / Total seeds) × 100%

Germination Index (GI) was calculated following Williamson and Richardson (1988):

$GI = \Sigma(G \ / D \ )$
where G is the number of germinated seeds on day t, and D is the corresponding germination day.

Allelopathic Index (AI) was calculated as:
AI = (Treated GR - Control GR) / Control GR

Data were analyzed using SPSS 13.0 software. One-way ANOVA was performed to test for significant differences among treatments, followed by LSD post-hoc tests at $P < 0.05$ significance level.

3 Results

3.1 Effects on Germination Rate

The leaf water extracts of Artemisia halodendron had concentration-dependent effects on seed germination rates (Table 1). Germination rates across all species ranged from 44.7% to 58.7% under different extract concentrations, with no significant differences among treatments for individual species ($F = 1.86$, $P > 0.05$). However, significant differences were observed in germination indices.

3.2 Effects on Germination Index

The germination index varied significantly among extract concentrations ($F = 6.33$, $P < 0.01$). The lowest germination index (17.1 ± 3.1%) occurred at 60 $g \cdot L^{1}$ concentration, which was significantly lower than the control (12.9 ± 3.2%). These results indicate that while germination rates were only moderately affected, the speed and synchrony of germination were substantially inhibited by higher extract concentrations.

4 Discussion

4.1 Allelopathic Mechanisms

Our results demonstrate that Artemisia halodendron leaf extracts exert significant allelopathic effects on co-occurring species during sandland vegetation succession. The inhibition of germination index, rather than final germination percentage, suggests that allelochemicals primarily affect germination speed and seedling vigor. This finding aligns with previous studies on allelopathic effects in arid ecosystems, where water-soluble compounds from decomposing litter influence seed bank dynamics and community composition.

The concentration-dependent response observed in this study is consistent with the hormesis hypothesis, where low concentrations of allelochemicals may stimulate germination while higher concentrations cause inhibition. This pattern has been documented in other Artemisia species and may reflect evolutionary adaptations to resource competition in nutrient-poor sandy soils.

4.2 Ecological Implications

The strong allelopathic effect of A. halodendron on Lespedeza bicolor, Corispermum macrocarpum, and Agropyron cristatum may explain its initial dominance in early successional stages. By suppressing the germination and establishment of potential competitors, A. halodendron can maintain its population advantage during critical establishment phases. However, as litter accumulates and allelochemicals leach into the soil, the selective pressure may shift, allowing more tolerant species to establish and eventually replace A. halodendron.

This allelopathic-mediated succession represents an important mechanism in sandland restoration. Understanding these chemical interactions can inform management practices, such as optimizing planting densities and timing to facilitate natural succession processes. Future research should identify specific allelochemical compounds and their persistence in sandy soils to better predict long-term community dynamics.

5 Conclusion

Artemisia halodendron exhibits significant allelopathic effects on symbiotic and competitive species in sandland ecosystems. The leaf water extracts inhibit germination index in a concentration-dependent manner, with stronger inhibition observed at concentrations $40\ g \cdot L^{1}$. These allelopathic interactions likely contribute to species replacement patterns during vegetation succession in restored sandlands. The release of allelochemicals from decomposing leaves represents a key competitive strategy that influences community assembly and restoration trajectories.

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Note: Figure translations are in progress. See original paper for figures.