Journal of Arid Environments 90 (2013) 69–76

Contents lists available at SciVerse ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

Chronic wind and plant communities in dunes: Total biomass, inter-specific competition, and species abundance

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ARTICLE INFO

Article history:
Received 12 May 2012
Received in revised form
16 October 2012
Accepted 23 October 2012
Available online 1 December 2012

Keywords:
Community composition
Competitive outcomes
Dryland
Environmental filtering

ABSTRACT

Chronic wind is an important ecological factor, but its direct roles in shaping plant communities remain poorly understood. We hypothesized that chronic wind can modulate community productivity, inter-specific competition, and species abundance in inland dunes. We conducted an experiment with three shrubs (*Artemisia ordosica*, *Caragana intermedia*, and *Hedysarum laeve*) common to semi-arid sandlands, set up seven kinds of plant communities (i.e. *Artemisia* monoculture, *Caragana* monoculture, *Hedysarum* monoculture, *Artemisia*–*Caragana* mixture, *Artemisia*–*Hedysarum* mixture, *Caragana*–*Hedysarum* mixture, and *Artemisia*–*Caragana*–*Hedysarum* mixture), and communities subjected to two levels of wind exposure: shielded (by means of fencing) or exposed (no fencing). We measured total biomass per plot, competitive effects, and relative species abundance. Wind exposure did not significantly affect the total biomass of monocultures but increased their root weight ratio. However, wind exposure enhanced the total biomass of three-species mixtures but not two-species mixtures, and had no effects on root weight ratio of all mixtures. Wind exposed condition increased the competitive ability and relative abundance of *Artemisia*, decreased the competitive ability of *Hedysarum* but had no effects on its abundance, and did not affect the competitive ability of *Caragana* but decreased its abundance. These results suggest that chronic wind, as an environmental filter, can directly modulate plant communities through altering competitive outcomes and thus affect community functioning.

1. Introduction

Wind is a fundamental environmental factor in nature, and exhibits important ecological consequences for individual species and communities (Ennos, 1997; Grace, 1977; Mitchell, 2007; Xi and Peet, 2011). Understanding these effects is therefore of major interest in botany, ecology, agriculture and forestry, and many advances have been made in recent years (Anten et al., 2010; Coutts and Grace, 1995; de Langre, 2008; Mitchell, 2007; Ruck et al., 2003). For example, wind can affect physiological processes (Dixon and Grace, 1984; Grace and Russell, 1982), plant functional traits (Anten et al., 2010, 2005; Liu et al., 2007; Wang et al., 2008), and species composition and distribution (Grace, 1977; Mitchell, 2007; Ruck et al., 2003).

A central issue in plant ecology is how communities are assembled from species (Diamond, 1975; Weiher and Keddy, 1999). It is also well documented that wind impacts plant communities through changing microclimate, water transport, energy transfer, and mechanical loading (Anten et al., 2010; Brüchert and Gardiner, 2006; Coutts and Grace, 1995; Grace, 1977; James et al., 2006; Liu et al., 2007; van Gardingen and Grace, 1991; Wang et al., 2008). But in spite of the ubiquitous nature of wind and its strong effect on plant growth, few studies have considered the roles of wind in shaping community structure, particularly in inland ecosystems. Studies that have done so have focused on catastrophic wind events (hurricane, tornados, and severe gales) on the forests in mountains or coastal areas (Coutts and Grace, 1995; de Langre, 2008; Grace, 1977; Mitchell, 2007; Ruck et al., 2003; Xi et al., 2008). Thus, the degree to which wind directly modulates the structure, species composition and functioning of plant communities remains poorly understood.

Inland sandy ecosystems (e.g. prevalent in large parts of China) are characterized by the shortages of soil water and nutrients, extreme climate, frequent disturbance (e.g., wind exposed) and low vegetation cover. The low surface roughness resulting from sparse and low vegetation cover facilitates high wind speeds and implies very limited wind shielding among individual plants (Ennos, 1997; Grace, 1977; Mitchell, 2007). These situations allow inland dunes

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http://dx.doi.org/10.1016/j.jaridenv.2012.10.017

to become an ideal stage for understanding the links between wind and community organization. Additionally, improved understanding of these links is beneficial to prevent soil erosion, stabilize dunes, and restore local vegetation in these areas (Temperton et al., 2004).

The objective of this study is to determine the extent to which chronic wind exposure directly modulates community productivity, inter-specific competition, and species abundance, which are critical in determining community structure and functioning (Cain et al., 2008). We answered the following questions: (1) Does strong wind exposure reduce net primary productivity of plant communities? (2) If wind exposed condition is a stressful factor, inter-specific competition may decrease with increasing wind. (3) Wind exposure may alter relative abundance of species in communities depending on species identity. We addressed these questions by an experiment with three dominant plant species, *Artemisia ordosica*, *Caragana intermedia*, and *Hedysarum laeve* in inland sandy areas.

2. Materials and methods

2.1. Study site and species

The Mu Us Sandland is located in the ecotone between arid areas and semiarid areas in northern China and characterized by low annual precipitation (i.e., mean precipitation of 360 mm), low vegetation cover, low species richness, poor soil nutrients, and frequent high wind (Zhang, 1994). Semi-mobile, semi-fixed, and fixed sand dunes are primary landscapes in this region. The Mu Us Sandland, where the local vegetation mainly consists of diverse artificial communities that were shaped through aerial seeding, has experienced severe desertification due to intensive human activities and is thus highly vulnerable (Zhang, 1994). Monocultures or mixtures, consisting of *Artemisia*, *Caragana*, or *Hedysarum*, are common in the Mu Us Sandland, and are among the most important components of the local artificial vegetation (Zhang, 1994). For our study, we used the following three shrub species. *A. ordosica* Kraschen. (Asteraceae) is a perennial shrub that can grow up to 1.5 m (Zhang, 1994). *C. intermedia* Kuang et H. C. Fu (Fabaceae) and *H. laeve* (Maxin.) H. C. Fu (Fabaceae) are N-fixing perennial shrubs that can grow up to 3.0 m (Wang et al., 2008; Zhang, 1994). These three dominant shrubs commonly occupy semi-mobile, semi-fixed, or fixed dunes, playing important roles in combating desertification. From here on all species are referred to with their genus names only (i.e., *Artemisia*, *Caragana*, and *Hedysarum*).

2.2. Experimental design

We selected two flat dunes (about 40 m × 40 m) near the Ordos Ecological Station (OES, 110°15′ E, 39°34′ N, 1, 250 m) of the Institute of Botany, Chinese Academy of Sciences. These two dunes share the same aspect, precipitation, belowground water-table, height (i.e. ranging from 1150 to 1160 m in elevation) and soil texture (i.e., aeolian sandy soil); and they were 100 m apart from each other. Two wind treatments were implemented. In one plant communities were sheltered thus creating an environment with strongly reduced wind exposure while in other the communities were not sheltered and thus exposed to natural wind speeds. Each wind treatment was established on a separate dune. This experiment was conducted on dune ecosystems, as dunes represent the major landscape feature in the Mu Us Sandland.

Low wind environments were established using windbreaks. The high-wind dune was unfenced (hereafter denoted as “wind exposed”) and covered eight sub-dunes (6 m × 6 m) forming eight experimental replicates. The low-wind dune (hereafter “wind sheltered”) also covered eight sub-dunes (6 m × 6 m) forming eight experimental replicates, each of which was fenced with plastic netting (100 cm in height) with 0.5 cm in diameter of mesh. More specifically, each dune was equally divided into three blocks horizontally, and then each block was equally divided into three sections vertically. Sub-dunes were randomly positioned in eight out of nine sections. The distance was over 8 m among sub-dunes. Windbreaks were set up after the establishment of a series of artificial plant assemblages (see below). In other words, we fenced each sub-dune with the plastic net described above. Microclimatic conditions (wind speed, temperature and humidity) were monitored throughout the experiment. Wind speeds were measured close to the top of the canopy of communities (about 0.5 m in height) at 2-min intervals using a Thermo Anemometer (AVM-01, Prova Instruments Inc., Taiwan) and air temperature and air relative humidity at 30-min intervals using a HOBO Data Logger (Onset Computer Corporation, USA) placed in each of the two wind regimes. The anemometers and dataloggers were calibrated prior to the experiment. Due to the partial loss of equipment, only one anemometer and one datalogger were available for each wind regime. Detailed information of these microclimatic conditions is presented in Fig. 1. The wind speed in the dune with windbreaks was approximately 5-fold lower than in the wind exposed condition

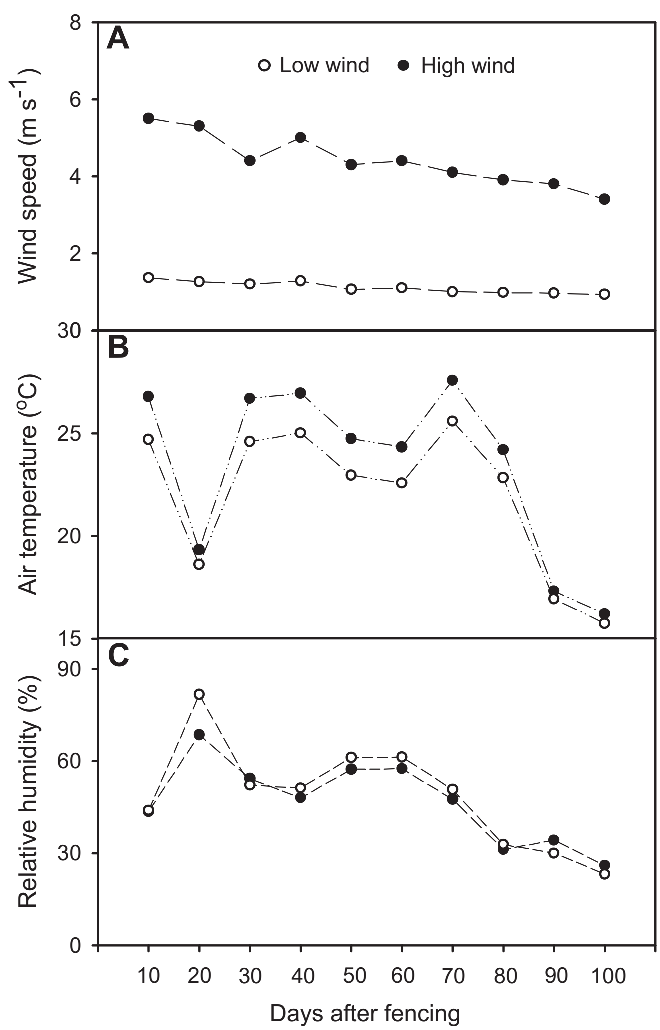

Fig. 1. Wind speed (A), atmospheric temperatures (B) and atmospheric relative humidity (C) in either the wind sheltered or the wind exposed condition. Each point represents means at 10-d intervals. The available data were from one anemometer and one datalogger. Wind speed was measured only during the day, and temperature and humidity were determined during the day and night.