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The Ecosystem Effects of Sand-Binding Shrub *Hippophae rhamnoides* in Alpine Semi-Arid Desert in the Northeastern Qinghai–Tibet Plateau

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Abstract: The planting of sand-binding vegetation in the Qinghai Lake watershed at the northeastern edge of the Qinghai–Tibet Plateau began in 1980. For this paper, we took the desert on the eastern shore of Qinghai Lake as the study area. We analyzed a variety of aged *Hippophae rhamnoides* communities and aeolian activities, and we discuss the relationship between them. The main conclusions are as follows: (1) With an increasing number of binding years, the species composition became more abundant, natural vegetation began to recover, and biodiversity increased year by year. At the same time, plant height, canopy width, and community coverage increased, but *H. rhamnoides* coverage was reduced to 36.70% as coverage of *Artemisia desertorum* increased to 25.67% after 10 years of fixing. The biomass of *H. rhamnoides* increased significantly, especially the underground biomass. For example, the biomass of area 15a was about 10 to 30 times that of area 1a. (2) Plants are a useful obstacle to aeolian activity. The presence of plants reduced the wind flow in the upper parts of the plants, but it did not have obvious regular characteristics. The longer the fixation term, the lower the surface sediment transport. It is significant that the sediment transport amount in winter was four times that in the summer. After 15 years of binding, *H. rhamnoides* grows well, and the community is still stable in the study area.

Keywords: desert around the Qinghai Lake; vegetation restoration; *Hippophae rhamnoides*; aeolian activities

1. Introduction

Desertification is one of the world's most serious environmental problems and has attracted worldwide attention [1,2]. Vegetation restoration is a critical and effective measure to control desertification and recover degraded ecosystems [3]. The establishment of sand-binding vegetation is one of the main techniques for ecological restoration in arid and semi-arid zones, and this method has been widely used in desert regions around the world and is one of the most effective ways to combat desertification [4]. China has used sand-binding vegetation to combat desertification for almost 60 years [5]. Shrubs are the main sand-binding pioneer species for their extensive coverage and strong protective performance in spring. In the practice of planting sand-binding vegetation in a desert, the success of the vegetation restoration primarily depends on the adaptability of the pioneer sand-binding plants to the microenvironment. However, there have been few studies examining how different aged introduced sand-binding shrubs adapt to the cold and dry environment in sandy alpine areas. It is necessary to carry out research on the relationship between sand-binding shrubs and aeolian activities in alpine areas so that artificial plant communities can gradually evolve into stable natural plant communities, achieving long-term ecosystem effects.

Hippophae rhamnoides is a dioicous, deciduous, thorny shrub that has a wide distribution across Europe to Asia; it is a coastal species in northwest Europe and is found in mountain ranges from the Pyrenees to the Himalayas [6]. It has an extensive horizontal root structure that forms frequent, rapidly growing aerial parts, and shoots have been shown to achieve 70 cm growth per year [6]. Its high survivorship is closely linked to the rapid growth of its root systems, which are highly flexible and adapt to various soil water conditions [7]. *H. rhamnoides* is mainly distributed in the Loess Plateau and scattered across Qinghai Plateau in China, where it has a natural distribution in the eastern shore of the Qinghai Lake with no typical community. So, it has been used for afforestation in the Qinghai Lake desert region to fix shifting sands since 1980. The Mu Us desert is one of the typical distribution areas of *H. rhamnoides*, but research on *H. rhamnoides* in this area mainly includes dynamic population changes, reproductive proliferation, and the relationship with soil water content [8], while few studies have paid attention to the relationship between community features and aeolian activities. As a typical sand-binding plant in a sandy alpine land, the systematic research on *H. rhamnoides* is still weak.

The wind-sand-vegetation ecosystem is an essential aspect in desert ecology and desertification control [9]. The intensity of aeolian activity directly affects the growth of sand-binding vegetation and community succession. When plant stems, leaves, and roots are subjected to wind-blown sand and wind erosion separately, they will have different degrees of physiological responses [10,11]. The aeolian activity has a dual effect on the growth of desert plants. On the one hand, sand carried by strong winds hits plant stems and leaves, finally adhering as dust and affecting the respiration of plants; on the other hand, different degrees of sand burial of plants affect the survival and growth of underground rhizomes [12]. Strong aeolian activities will directly reduce the plant seedling survival rate, reproduction rate, and growth state and community stability, while moderate wind erosion the sand burial will promote the regeneration of underground rhizomes, high plant growth, and fertility, thereby promoting community succession. Against the hazards of wind-blown activities, desert plants have usually adapted through morphological transformation, reproductive strategies, respiratory regulation, and water and nutrient redistribution [13,14]. However, the current research has always been based on a single environmental control experiment, lacking field verification, and special environmental considerations. At the same time, the research objects are mainly based on the short-term ecological response of an individual plant, and examinations of the plant community response and long-term change response are insufficient. In addition, the study of the response mechanism of desert plants to wind-blown hazards lacks practical guidance for desertification control work, and field observation experiments are needed to guide suitable site conditions, afforestation structures, and methods or species allocation for artificial sand-binding plants.

Plantations face strong aeolian activities in alpine deserts, which are severely endangered by ecological fragility, species scarcity, and desertification. At present, an increasing number of afforestation vegetation has appeared to die or undergo poor growth in alpine sandy areas. The vegetation protection efficiency has decreased year by year with the decline in growth, which has resulted in the mutation of the vegetation community and activation of fixed dunes. The growth potential and sand control effect are inhibited under the low temperature and high wind velocity in alpine desert regions, which are different from the arid and semi-arid deserts in the north of China. Qinghai Lake is one of the typical ecologically fragile areas of the Qinghai–Tibet Plateau, and although *H. rhamnoides* has been planted in the Qinghai Lake watershed for more than 30 years, the research on this vegetation restoration is extremely lacking, especially the relationship between the plant community and aeolian activity. The existing research on vegetation and wind has mainly focused on the attenuation of surface sand activity after afforestation [15], soil improvement [16], plant community changes [17], and water source use on a site scale [18].

Therefore, in this paper, we intend to discuss the relationship between sand-binding plants and aeolian activities by taking aged *H. rhamnoides* planted in different years on the eastern shore of the Qinghai Lake as a case, in order to provide theoretical guidance for desertification control in alpine desert regions. We hypothesized that the desert habitat is improved with restoration.

2. Materials and Methods

2.1. Study Area

The study was conducted in the Ketu Wind Prevention and Sand Fixation Experimental Range (hereafter, WPSER; 36°46.9′N, 100°46.8′E, 3224 m elevation (above sea level) a.s.l.) in the southeast corner of Haiyan Bay, blocked by the Ruiyue and Tuanbao Mountains on the eastern shore of Qinghai Lake (Figure 1). Mega-dunes and continuous mobile dunes are distributed in WPSER. The field is primarily composed of short barchans and transversal sand ridges which stand on average 6–10 m high and stretch from the north to the south. Since the early 1980s, the local government has taken measures to prevent mobile dunes in the west district, and now a large area of shifting dunes has been fixed with straw checkerboards and shrubs.

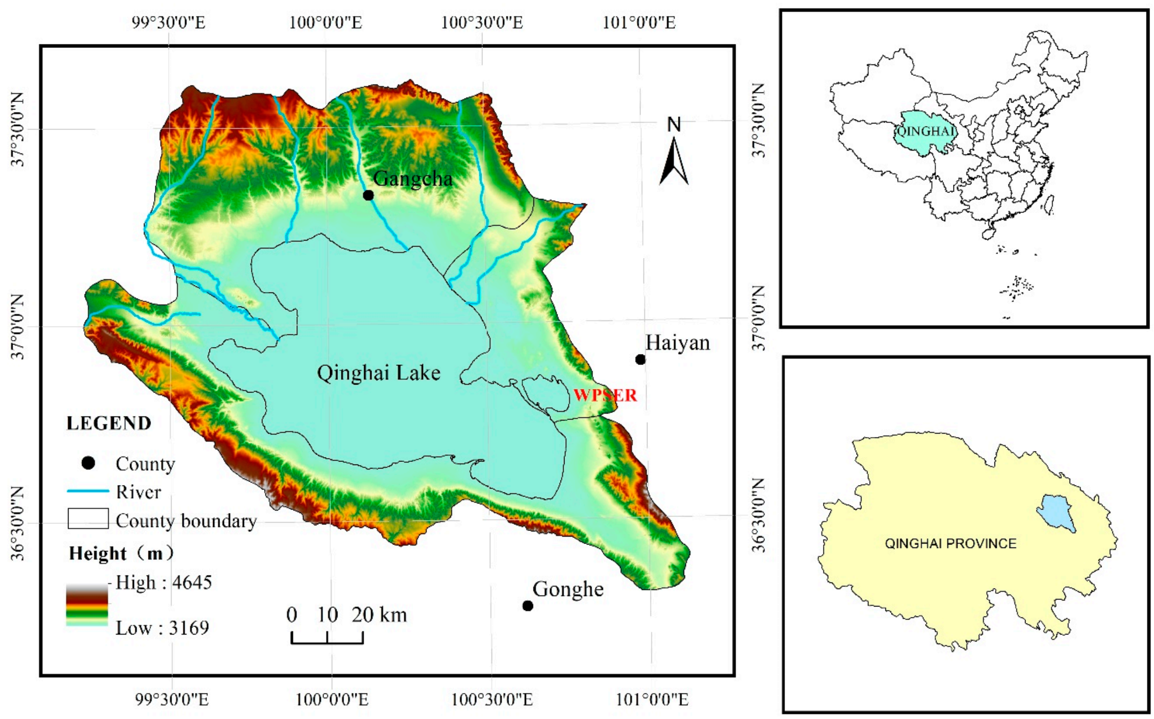

Figure 1. Geographic location of the study area.

WPSER belongs to an alpine semi-arid climatic zone with relatively wet summers and cold winters. Based on data from the Haiyan County National Meteorological Station (2006–2017), which is approximately 20 km away from WPSER, the annual mean temperature is 0.7 °C, with the lowest mean monthly temperature in January (−11.76 °C) and the highest in July (14.97 °C). The annual average precipitation is 370 mm, approximately 80% of which occurs from June to September. The mean annual pan evaporation is 1483.9 mm. According to sandstorm observations from the past five years, the strongest period of sandstorm activity is during late autumn to early spring, controlled by SW-W-NW wind directions, and the mean wind speed is 5.5 m·s^{-1}. According to our field observations, sediment transport is the highest in spring, and the annual synthetic drift potential (DP) is 88.69, classifying it as a low wind energy environment.

During the past 10 years, from 2008 to 2017, all forest land formed a vegetation community dominated by plantations, and large-scale mobile sand dunes gradually transformed into semi-fixed or fixed dunes [17]. We selected five dunes planted with *H. rhamnoides* and a mobile dune (LSD) in WPSER as the study sites (Table 1 and Figure 2). All of dunes are barchans, and our objects were only the communities at the top of dunes. The groundwater level at the study sites ranged from 8 m to 15 m for different dunes.

Table 1. Features of aged *Hippophae rhamnoides* in the study area.

No.	Planting Time	Original Topography	Existing Topography	Dune Height /m	Mechanical Barriers	Afforestation Mode
1a	2016	Mobile dune	Mobile dune	10.3	Barley-oat checkerboards	Seedlings
3a	2014	Mobile dune	Mobile dune	8.7	Straw checkerboards	Seedlings
5a	2012	Mobile dune	Semi-fixed dune	7.2	Straw checkerboards	Seedlings
10a	2008	Mobile dune	Fixed dune	10.6	Straw checkerboards	Seedlings
15a	2003	Mobile dune	Fixed dune	5.9	Straw checkerboards	Seedlings
LSD	Natural	Mobile dune	Mobile dune	—	—	—

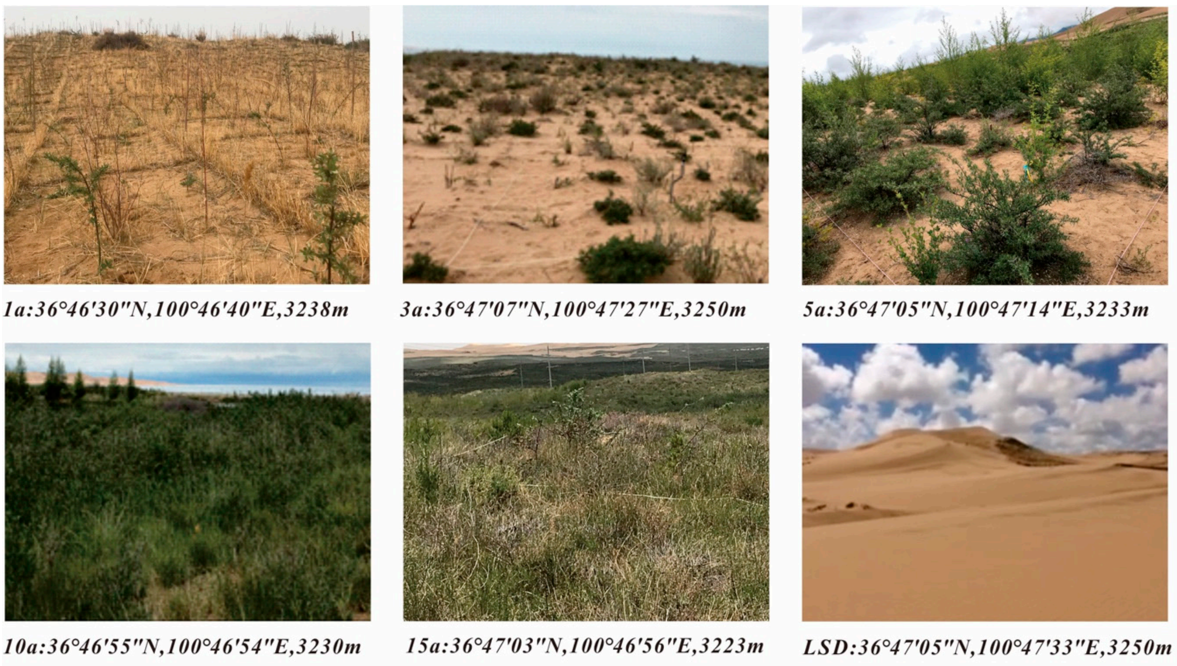

Figure 2. Photos of the study sites

2.2. Plant Feature Investigation and Analysis

The survey area of the shrubs was 5 m × 5 m, whereas that of herbs was 1 m × 1 m. The plant number, height, and coverage for each species in the sand stabilization areas from different years were recorded or measured. In this study, the Simpson index D, Shannon–Wiener index H′, and Pielou evenness index J were used to measure the diversity of plants [19]:

$$D = 1 - \sum {p_i}^2 \tag{1}$$

$$H' = -\sum p_i \ln p_i \quad (2)$$

$$J = H' / \ln S \quad (3)$$

where p_i is the relative importance value (IV) of species i (relative height + relative coverage), and S is the total number of species i in the quadrat, that is, an abundance index.

We used the trenching method to investigate the root biomass and distribution. Six trenches were made in each sampling plot in early August 2017 (two trenches per quadrat, three quadrats per plot). Roots were separated from the soil by washing through a 0.5 mm sieve and sorted into coarse (>2 mm diameter) and fine (<2 mm diameter) fractions. Roots with diameters of <2 mm were generally defined as feeder roots for water and mineral uptake. Roots were then stored in paper bags until oven-drying at 60 °C for 48 h to a constant weight. Root biomass is expressed on a ground area basis (kg·m^{-2}).

2.3. Aeolian Activity Investigation and Analysis

In the spring, summer, and autumn of 2018, hand-held anemometers (Kestrel NK5500, USA) were used at heights of 0.5 m and 2 m to observe the wind speed. The sampling frequency of the data acquisition was 1 time·min^{-1}, the flat top of the mobile dune was used as the control point, and the tops of dunes planted with *H. rhamnoides* with different growth years (1a, 3a, 5a, 10a, and 15a) were used as flow points. Each site was measured with three to five replications. The wind measurement period was from 10:00 to 19:00, and the sampling frequency of the data collection was 10 times·min^{-1}. The wind speed (V'(z)) of each flow point was standardized using wind speed data from the control point in order to compare the wind conditions of the aged *H. rhamnoides* communities at the same time. Then, we calculated the wind increase rate (R, m·s^{-1}) [20]:

$$R = \frac{V_2 - V_1}{H} \times 100\% \quad (4)$$

where H is the height difference for Z_1 and Z_2, and V_1 and V_2 are the wind velocities at heights Z_1 and Z_2, respectively. We divided the height of 2 m into two layers: bottom (0–1.0 m) and upper (1.0–2.0 m).

From January 2018, we set nine sand-collecting bottles (65 mm high and 45 mm in diameter) in strips at each study site for the entire year of 2018. The sand was moved to plastic Ziploc bags, brought back to the laboratory, and impurities were removed for drying and weighing every month. The 12-month surface sediment data recorded in 2018 were divided into four seasons (spring/summer/autumn/winter) on a quarterly basis to calculate the average sediment transport rate and intensity in each season.

2.4. Soil Sample Collection and Analysis

In September 2017, soil samples at depths of 0–5 cm, 5–10 cm, 10–20 cm, 20–40 cm, and 40–60 cm were collected using a soil auger (complete with a regular auger diameter of 2", a 18" rubber-coated cross handle, and a 5/8" stick, which manufactured by AMS, USA) at the study sites in three replicates. The samples were taken back to the laboratory for air drying and were evenly mixed to determine the grain size composition, using a Mastersizer 2000 (Malvern Co., British), and the organic matter and nutrients (available N/P/K, Figure 3).

2.5. Data Analysis

All statistical analyses were conducted using the SPSS software (version 17.0, SPSS Inc., Chicago, IL, USA). After performing one-way ANOVA, the LSD test (Least Significant Difference) for multiple comparisons was used to detect differences among plots in terms of plant shoot and root biomass. Significance was determined at the 95% confidence level (a = 0.05).

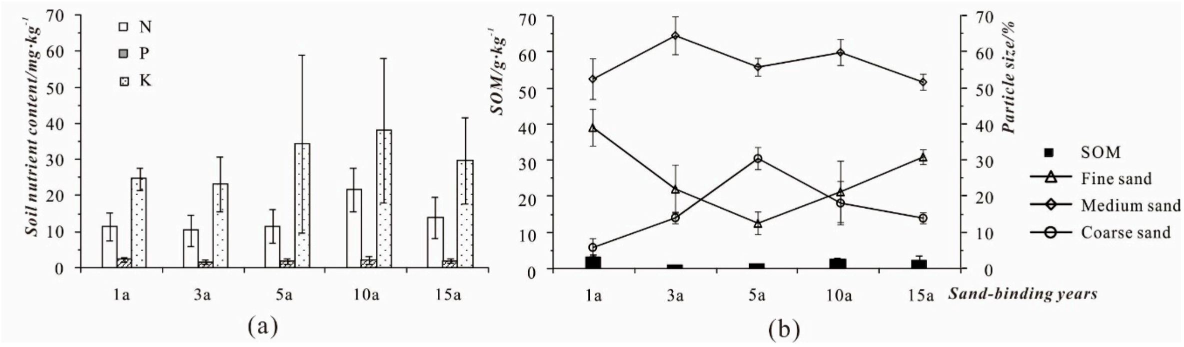

Figure 3. Soil nutrient contents (**a**) and the organic matter and particle sizes (**b**) of aged *H. rhamnoides* communities.

3. Results

3.1. Ecological Features of Aged H. rhamnoides Communities

3.1.1. Community Composition

Since the implementation of artificial measures in 2008, mobile dunes have become basically fixed or semi-fixed in WPSER. After 15 years of succession, the 15a dune became fixed, and a large amount of litter increasing top-soil fertility to reduce soil erosion, and soil evaporation provided a prosperous micro-environment for new species establishment. In the study plots, there were 20 species, belonging to six families and 14 genera, including *Corydalis, Compositae, Salicaceae, Pinaceae, Leguminosae, Gramineae*, and so on (Table 2). There were 17 kinds of perennial herbs, accounting for 85%. Except for the planted shrubs and *Avena sativa* used as checkerboards, other perennial herbs were naturally recovered, like *Artemisia desertorum* and *Oxytropis imbricata*.

Table 2. Species composition of the study sites.

Family	Species
Aphididae	*H. rhamnoides*
Compositae	*Artemisia desertorum*; *Helianthus tuberosus*; *Sonchus oleraceus*
Willow	*Populus simonii*; *Salix cheilophila*
Matsuko	*Pinus sylvestrisvar*
Legume	*Caragana intermedia*; *Oxytropis imbricata*
Gramineae	*Agropyron cristatum*; *Poa annua*; *Leymus secalinus*; *Elymus nutansAvena sativa*

3.1.2. Community Diversity

From Table 3, we can see that the H′ value of the *H. rhamnoides* communities was basically unchanged at 0.36. The D value was the lowest in the 5a and 10a communities, but the overall difference was not significant. The 3a community location is surrounded by mobile dunes; therefore, *H. rhamnoides* dominated in this community with scarce natural species. As a result of the complexity of the artificial sand-binding species planted in the plot, the diversity index of community 1a was higher due to human interference. The lack of significant differences in the diversity index values of the aged *H. rhamnoides* communities indicated that the habitat, community type, and plant species of the *H. rhamnoides* communities in different years were similar.

Table 3. Diversity index values in different *H. rhamnoides* communities.

Diversity Index	1a	3a	5a	10a	15a
H′	0.368[a]	0.367[a]	0.365[a]	0.358[a]	0.368[a]
D	0.597[a]	0.658[a]	0.584[a]	0.541[a]	0.634[a]
J	0.189[a]	0.205[a]	0.175[a]	0.172[a]	0.177[a]

Note: "a" means there were no significant differences in different *H. rhamnoides* communities.

3.1.3. Community Structure

The growth of *H. rhamnoides* increased as years went by, with peaks at 5a and 10a. The plant height of 1a was 50 cm, while that of 3a was only 25 cm as it was seriously damaged by wind erosion and sand burial from a nearby mobile dune. The north-south width was almost the same as the west-east width, which indicated that plants were similarly influenced by each wind direction. As shown in Figure 4, the height and canopy of *H. rhamnoides* increased with age to 10 years and then remained almost unchanged. The height of 10a reached 50 to 60 cm, and the canopy width reached 65 to 70 cm. 5a and 10a were the most vigorous. It is indicated that after 10 years, *H. rhamnoides* gradually declined and shrunk, and the community appears to have transitioned to succession.

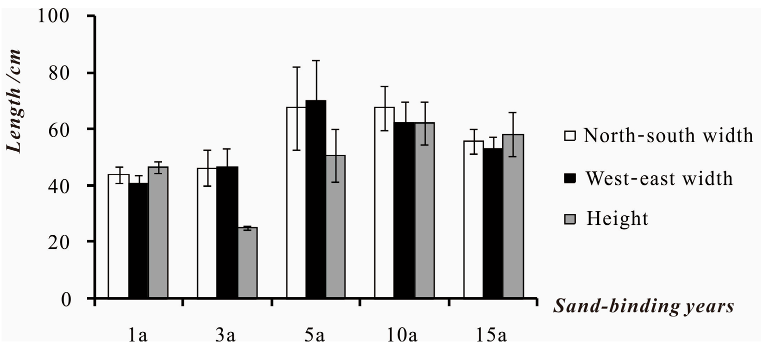

Figure 4. The heights and canopy widths of different *H. rhamnoides* communities.

The survival rate of 1a was more than 50 percent for replanted *H. tuberosus* with coverage of less than 20% in 2018, but its survival rate reached 80% without natural vegetation. However, the survival rate of *H. rhamnoides* was up to 100% in the 3a and 5a communities, and the total coverage was 21% and 45%, respectively. From Table 4, we know that the maximum coverage of 10a reached 45.33%, and the survival rate was 95%. Total coverage was the highest in the 15a dunes, but the coverage of *H. rhamnoides* was 36%, less than that in 10a. It was also found in the field data collection that the 15a community was gradually replaced by *A. desertorum*, with coverage up to 25.67%.

Table 4. Total coverage (%) and shrub coverage (%) in different *H. rhamnoides* communities.

Community	Total Coverage	Shrubs	Coverage	Herbs
1a	19.33	*H. rhamnoides*	9.33	*A. sativa*
		A. desertorum	4.00	
		P. simonii	2.00	
		S. cheilophila	1.00	
		H. tuberosus	3.00	
3a	21.00	*H. rhamnoides*	14.33	*A.cristatum, O. imbricate, E.nutans*
		S. cheilophila	1.00	
		A. desertorum	5.67	

Table 4. *Cont.*

Community	Total Coverage	Shrubs	Coverage	Herbs
5a	45.00	*H. rhamnoides* *P. simonii* *S. cheilophila* *P. sylvestrisvar* *A. desertorum*	22.00 15.00 2.00 4.00 2.00	*A.cristatum*, *O. imbricate*, *L. secalinus*
10a	60.33	*H. rhamnoides* *P. sylvestrisvar* *C. intermedia* *A. desertorum*	45.33 11.00 2.00 2.00	*A.cristatum*, *O. imbricate*, *L. secalinus*, *P. annua*
15a	65.04	*H. rhamnoides* *P. sylvestrisvar* *A. desertorum*	36.70 2.67 25.67	*A.cristatum*, *O. imbricate*, *L. secalinus*, *P. annua*

3.1.4. Community Biomass and Root Distribution

From Table 5, we can see that the aboveground biomass of *H. rhamnoides* in different years was from 71 g to 865 g, and the underground biomass went from about 28 g to 827 g as the years progressed. This indicated that the productivity and nutrient and water absorption capacity were significantly different among different *H. rhamnoides* communities. The biomass of 15a was about 10 to 30 times that of 1a, and the aboveground biomass presented a fold increase after planting. The biomass of 5a was mainly concentrated in the deneness of the branches, which increased the canopy density. The data also reflected that *H. rhamnoides* gradually concentrated its root system in the 10 years after the beginning of planting, with the root biomass increasing fourfold. The root-shoot ratio of *H. rhamnoides* increased with increasing number of years, and the largest was found at 10 years since the roots of 15a were so long horizontally that we could not dig up all of them.

Table 5. Biomass and shoot ratios of the aged *H. rhamnoides* communities.

Aged	Height/ cm	Canopy/ cm		Root Height/cm	Branch Roots	Depth of Roots/cm	Above Biomass/g	Under Biomass/g	Root-Shoot Ratio
1a	40	32	25	-	1	30–50	71.30	28.01	0.39
3a	46	45	50	55	4	30–80	285.33	175.00	0.61
5a	65	110	90	90	5	90–150	275.89	242.76	0.88
10a	63	69	90	80	8	90–260	453.96	885.26	1.95
15a	54	103	78	55	6	100–340	865.22	826.97	0.96

The taproots of *H. rhamnoides* grew thicker and thicker with the increasing number of sand fixation years, with a deeper root distribution, wider horizontal extension, and rhizobia produced on the lateral roots. The root distribution depth of *H. rhamnoides* increased with time after planting, while the taproot length was the longest in 5a, and the number of branch roots was the greatest in 10a. The roots of *H. rhamnoides* in 1a and 3a were distributed in the top 0–60 cm soil layer with medium-fine roots rather than medium-thick roots. The roots in 10a were up to 260 cm deep, and those in 15a were deeper than 340 cm; in addition, they grew horizontally to 220 cm and 345 cm, respectively (Figure 5). This indicated that *H. rhamnoides* had the strongest productivity and strong growth 10 years after planting. The roots of *H. rhamnoides* were highly germinated and had a wide range of horizontal extensions to the surrounding area, called clonality. On the roots of 15a, new *H. rhamnoides* began to sprout.

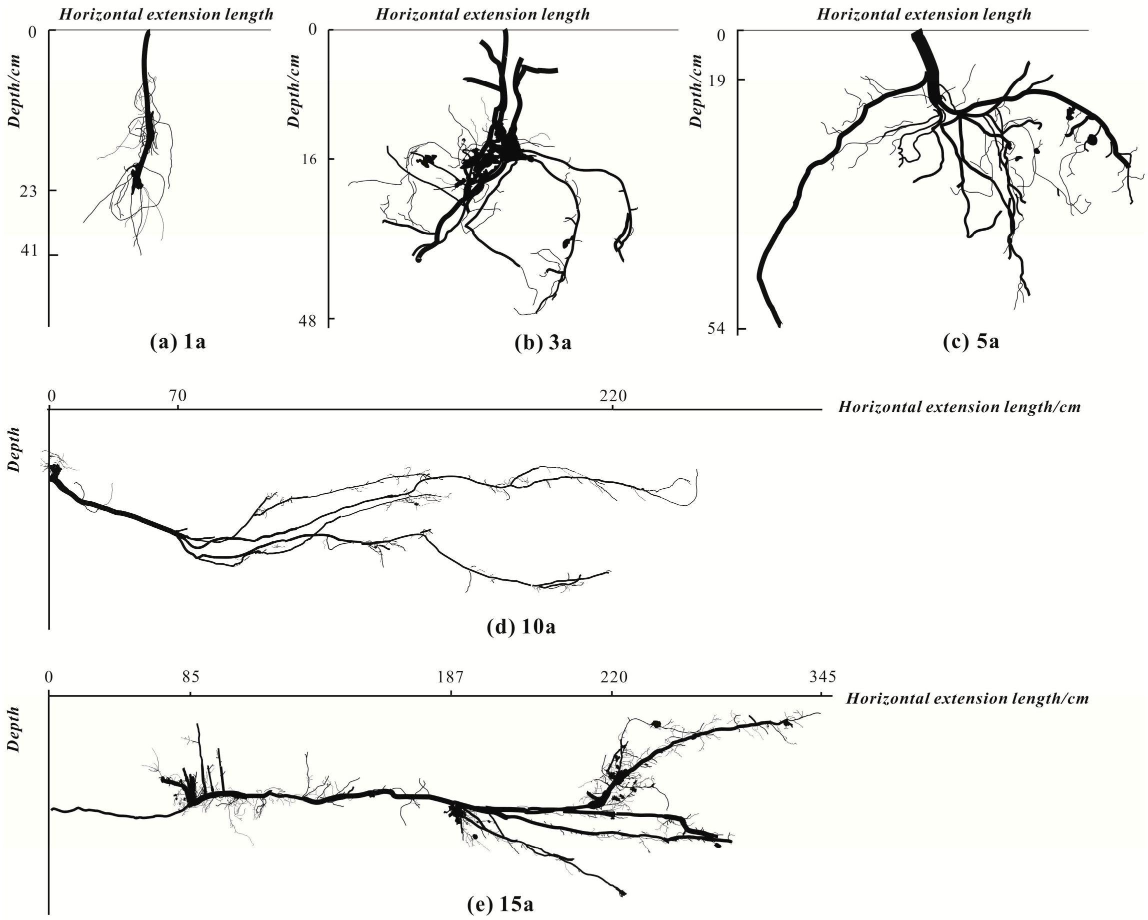

Figure 5. The root distributions in different years of *H. rhamnoides*.

3.2. Aeolian Activities of H. rhamnoides Communities

3.2.1. Wind Speed Characteristics of the Study Sites

At the height of 0.5 m, the wind velocity varied slightly in the range of 0 to 1 m·s^{-1} due to the blocking effect of plants near the surface (Figure 6a). However, at the height of 2 m, the variation in the wind speed across different dunes was relatively large and showed obvious seasonal changes (Figure 6b). The lowest wind speed was found on the 5a and 10a dunes. The wind velocity presented a decreasing trend with increasing plant age across the first 10 years, and then increased for plants aged 15 years; March was an exception to this, with the strongest wind in the whole year.

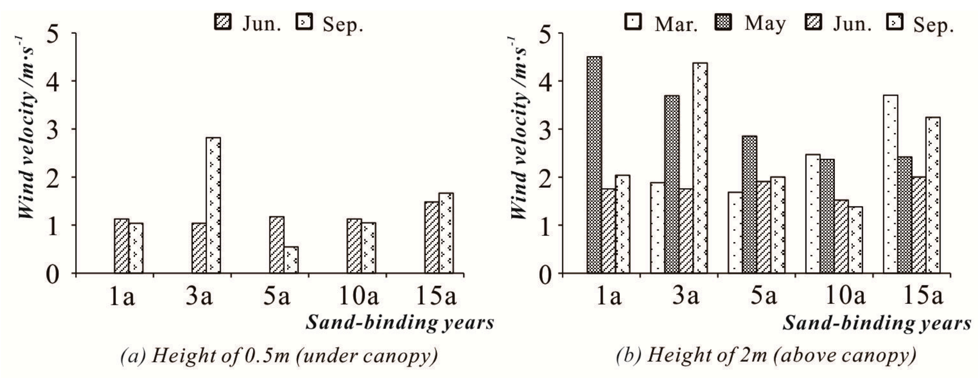

Figure 6. Wind environment for different ages of *H. rhamnoides* communities.

3.2.2. Vertical Wind Increase Rate (R)

Calculating the wind velocity increase rates for two levels of different dunes (bottom: 0–1 m, upper: 1.0–2.0 m) (see Table 6) resulted in different values of R. The wind speed of the upper layer at the shifting dune was obviously increased at three times that of the low layer. In the early stage of replanting, wind speed at the upper level was obviously weakened due to surface sand barriers. However, with the passing of treatment years, the community structure became stable, and the upper-layer wind speed began to increase. When combined with the previous investigation of the growth potential of *H. rhamnoides*, this variation law echoes the height variation, that is, wind velocity decreases at its corresponding height. This shows that vegetation cover blocks aeolian activities, and the effect of reducing wind kinetic energy is obvious. With the increase of the growth period of *H. rhamnoides*, the vegetation community gradually recovered, and the restoration of the vegetation community played a role in weakening the wind speed for the entire sand dune.

Table 6. Wind velocity increase rates (R, m s^{-1}) at different heights in *H. rhamnoides* communities.

Height Layer/m	LSD [1]	1a [2]	3a [2]	5a [2]	10a [2]	15a [2]
0–1	0.62	1.66	2.39	0.04	0.61	1.26
1–2	2.00	0.29	0.36	0.97	0.45	1.62

[1] LSD means mobile dune. [2] 1a, 3a, 5a, 10a, 15a represents planted one year, three years, five years, ten years, and fifteen years, respectively.

3.2.3. Sediment Transport

The amounts of surface sediment at the different *H. rhamnoides* plots in winter were greater than those in spring and summer and decreased as the number of planting years increased (Figure 7). Except for the 3a plot, the amount of sediment in the plots was almost the same, arrayed as 3a > 5a > 1a > 10a > 15a. Due to the fact that the 3a plot was located in an area surrounded by mobile dunes, community cover and species diversity were low and aeolian activities were strong. According to our field investigation, many of the *H. rhamnoides* plants were subject to wind erosion and sand burial, so the height and canopy width of these *H. rhamnoides* were smaller than those at other sites. This echoed the conclusions of our study on the height, canopy, and biodiversity of *H. rhamnoides* and indicated that surface vegetation coverage could greatly reduce the movement of sand.

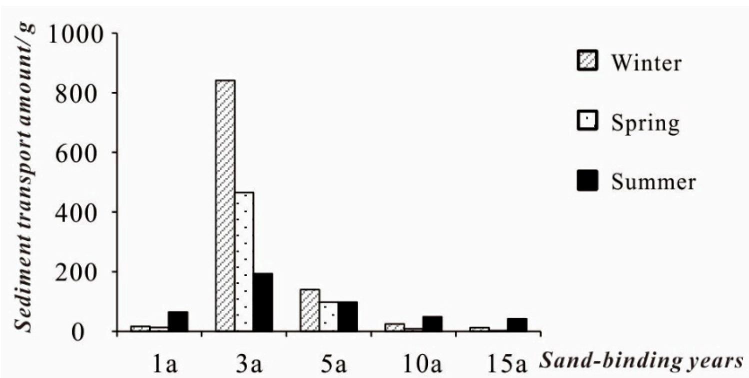

Figure 7. Sediment transport amounts at the *H. rhamnoides* communities (collected by bottles).

4. Discussion

4.1. H. rhamnoides Community Evolution

According to the evolution of typical sand-binding plant *H. rhamnoides* communities in WPSER (Table 3, Table 4, and Figure 3), it can be seen that each community has dominant species and biodiversity related to the stability of the community. With the increasing number of fixing years, the ecosystem effects become more and more obvious. General natural threats and moderate biological disturbance cannot destroy the stability of the community, but severe short-term effects like drought, waterlogging, dust, and artificial economic activities lead to community devastation [21,22]. For example, the 15-year-old *Salix* community in Shazhuyu sandy land was enriched in water after waterlogging; almost all species died and could not be restored. However, semi-fixed and fixed dunes planted with *H. rhamnoides* can maintain community growth for nearly 10 years. Even in the case of wind-induced plaque in some semi-fixed dunes, there has been effective restoration by replanting and management in recent years in WPSER.

As usual, a simple community with fewer species is more susceptible to external disturbances, but this does not mean that higher biodiversity produces a more stable community. In artificial plant communities, the number of species and biodiversity are improved in a short period of time, but the coexistence mechanisms and competitiveness of species affect community stability [23,24]. In the theory of redundancy, the versatility and parallel combinations of species within a community are the keys to maintaining community stability. When functions are consistent, and resource requirements are heterogeneous, even if a species is missing, other species can effectively compensate [25–27]. When there are concentrated ecological types, ecologically identical species, and different ecological functions in the community, invasive species will occupy a large amount of space and resources, which promotes the attenuation of important species and decay of ecological processes. Once important species are destroyed, the community will have difficulty in maintaining the original ecological function. In WPSER, *S. cheilophila* would not survive in a mixed community of *P. euphratica* and *S. cheilophila*. It is difficult to have *P. sylvestris* and *C. intermedia* in fixed dunes planted with *H. rhamnoides* due to the inconsistent ecological functions of the above- and underground ecological functions triggering survival of the fittest.

The return of leaves to the topsoil is a non-negligible factor in the nitrogen fixation capacity of plants. At the same time, *H. rhamnoides* roots can form nodules in the early stage of individual development. When a taproot is 15 cm long, nodules can form on the taproot and the first lateral root, and this ability is gradually enhanced as time goes on. In addition, nodules not only fix nitrogen in the air but also promote mineral organic matter, poorly soluble inorganic compounds, and organic compounds in the soil nutrient pool into an effective state, which is beneficial to plant absorption and utilization [28]. Root nodulation is a biological basis for the vigorous growth of *H. rhamnoides* in that only well-grown plants have strong nodulation ability [29]. *H. rhamnoides* is often used as a sand-fixing pioneer species for four main reasons: First, its roots can be symbiotic with Frankia bacteria, which can solve the problem of resource poverty in a desert. The second is its cloning habit for expanding the population and occupying new territories in harsh habitats in a rooted manner. The third is cloning behavior, which provides physiological integration functions such as resource sharing and risk self-bearing to adapt to harsh habitats and enhance stress resistance. Fourthly, its root system is highly divided; the first roots store rainwater, and secondary roots mainly absorb and transform soil water, thus alleviating the contradiction between water shortage and water retention in arid areas [30].

Compared with the sand-binding plants used in the ecological restoration process in other deserts in China, alpine desert plants show three unique characteristics. First, sand-binding plants grow rapidly in the early stage (within three years), and their sand-fixing function is significant. However, plant growth and biodiversity are limited in the middle and late stages [31,32]. Second, the ecological restoration function of the sand-binding plants is mainly reflected in wind and sand fixing, followed by natural vegetation restoration, and the ecosystem effects of water conservation, microclimate, and soil improvement are limited. Thirdly, different types of dunes can be configured with different patterns of mixed shrubs and different techniques such as seedlings, branch cuttings, and seeding, or deep-planting. Methods like fencing, sand barrier protection, and replanting can be used to repair mobile dunes, and *H. rhamnoides* is the perfect pioneer species in alpine desertification control [33].

4.2. Effects of Aeolian Activities on H. rhamnoides Communities

The 1a *H. rhamnoides* plots theoretically have few species, with low biodiversity and few natural restoration species. However, due to the subsequent large-scale planting of *Jerusalem artichoke*, the community coverage was almost the same as that of the 3a community. So, surface sediments were significantly finer, and the SOM (soil organic matters) was greater (Figure 3); in particular, aeolian activities were weakened even below the levels in the 3a community (Figure 7). This special case gives us a new line of thinking that a good combination of shrubs and perennial herbs can provide better ecological benefits in a desert. 10a had the highest height, canopy width, community coverage, and shrub cover, while its SOM, N, P, and K content and root-shoot ratio were also the highest, so it had the most vigorous productivity. However, 15a had the highest biomass, the deepest and widest root distribution, and the strongest wind-sand protection ability. Lu et al. [34] proposed that biomass increases year by year during the growth period. The fastest growth period was the first four to five years, and the growth was the highest at nine years and then decreased. It was also noted in our field observations that the mother plants of 15a showed a trend of decay, and some died. However, the regeneration ability became stronger with nascent seedling roots growing out from horizontal roots. Therefore, in desertification control work in alpine deserts, *H. rhamnoides* should be reared and renewed after 10 years to maximize the use of land resources and restore ecological benefits.

For strong sand flow, on the one hand, plants adopt an avoidance strategy to distribute more energy to their underground biomass and enhance the lateral growth of the canopy rather than longitudinal growth [16]. *H. rhamnoides* also forms a low and round crown shape to reduce wind force, and a wax layer and fine blade plush leaves to avoid direct damage from the sand flow [35,36]. On the other hand, desert plants can adopt a resistance strategy by strengthening the growth of rhizomes; roots are deepened, and the horizontal development of lateral roots strengthens the resistance of plants to wind and sand [36]. In addition, alpine sand-binding plants reduce stomatal conductance and water evaporation from the leaves under strong winds, strengthen the reproductive growth of adventitious roots under the action of sand burial, and improve wind-sand protection by using regular and reasonable afforestation spacing, density, and morphology when planting [37,38]. Through wind erosion corridors and sand-fixed piles, an erosion-deposit balance in the surface of sand dunes can be achieved. Although *H. rhamnoides* has significant wind and sand fixation benefits and has the adaptability to wind erosion and sand burial, it suffers from strong aeolian activities at the early stages of plant growth, directly affecting the survival rate and preservation rate. Subsequent long-term wind-sand stress has inevitable effects on the growth and reproduction of plants, which leads to a decrease in density and the coverage of dunes and, in turn, strengthens the local aeolian activities. This cyclical negative feedback is the main cause of the high death rate and low growth of *H. rhamnoides* in alpine deserts [17]. However, in the early stage of transplanting, there is long-term protection from straw checkerboard sand barriers and a reasonable afforestation density. The survival rates and preservation rates of *H. rhamnoides* are always above 90%, and mobile dunes are transformed into fixed ones after two to three years. The annual sediment transport rate and accumulation depth are smaller than those for other plots, which also promotes the settlement of herbaceous species and shrubs and increases community diversity. Therefore, in order to ensure the survival, growth, and community succession of *H. rhamnoides*, we need to pay attention to laying mechanical sand barriers with different specifications and forms when transplanting via the "three steps and one burial" procedure and to strengthening replanting work after transplantation. Moreover, it is necessary to mix with other herbs or shrubs.

From the results, we know that the species composition became more abundant, and the plant height, community coverage, biodiversity, and biomass increased as the number of binding years increased. At the same time, the presence of plants reduced wind flow in the upper part of the plants; the more fixation years, the lower the surface sediment transport. Our results will provide theoretical support for alpine desertification management and governance planning of the Qinghai Lake Basin. However, we only paid attention to the qualitative relationship between vegetation and aeolian activities in this manuscript. It is not enough to qualitatively evaluate the effect of plantations. Therefore, in future work, we will try to find quantitative relationships between vegetation and aeolian activities, such as the correlation between vegetation height, coverage, and wind velocity, and the responses of aged plantations to the same wind speed.

5. Conclusions

The climate in the alpine desert regions is extremely harsh, and plants grow slowly. After *H. rhamnoides* were planted in mobile dunes, they were gradually fixed. With the increasing number of binding years, the species composition became more abundant, natural vegetation began to recover, and biodiversity increased year by year. At the same time, the plant height, canopy width, and coverage increased, but *H. rhamnoides* coverage was reduced after 10 years as coverage of *A. desertorum* increased. The biomass of *H. rhamnoides* increased significantly, the underground biomass in particular. The taproot was thickened year by year, and it grew to a depth of 1 m, while the horizontal extensions reached more than 3 m. The roots of *H. rhamnoides* have strong sprouting ability, and new branches were grown on horizontal roots. Plants are a useful obstacle to aeolian activity. The presence of plants reduced the wind in the upper parts of the plants, but it did not have obvious regular characteristics. We observed lower amounts of sediment transport with the increasing number of fixation years. It is significant that sediment transport in winter is larger than that in spring and summer. In extremely cold winters the wind velocity is very strong (so-called Buran, because high pressure is located in central-Asia); therefore, the sediment transport is also stronger in winter. After 15 years of binding, *H. rhamnoides* grow well in the study area, and the community is still stable.

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