韓國環境復元技術學會誌 23(4) : 59～67(2020)
J. Korean Env. Res. Tech. 23(4) : 59～67(2020)

DOI : https://doi.org/10.13087/kosert.2020.23.4.59
ISSN 1229-3032

식생을 이용한 방풍책이 눈잣나무 유묘에 미치는 영향

임효인[1) · 채승범[1) · 이선욱[2) · 구자정[1)

[1)]국 립산림과학원 임업연구사, 석사연구원 · [2)] 설악산국립공원 계장

Effects of Windbreak Fences Composed of Natural Vegetation on Dwarf Siberian Pine (*Pinus pumila*) Seedlings

Lim, Hyo-In[1) · Chae, Seung-Beom[1) · Lee, Seon-Uk[2) and Ku, Ja-Jung[1)

[1)] Forest Bioinformation Division, National Institute of Forest Science, Suwon, Republic of Korea, Research Scientist,

[2)] Seoraksan National Park Office, Korea National Park Service, Sokcho, Republic of Korea, Section Chief.

ABSTRACT

In this study, the effects of windbreak fences composed of natural vegetation on one-year-old seedlings were analyzed to develop restoration methods for an endangered subalpine species, the dwarf Siberian pine (*Pinus pumila* (Pall.) Regel). One-year-old seedlings were planted in 2016 by sowing seeds that had been collected from the Daecheongbong area on Mt. Seoraksan, South Korea, in 2014. The area near Daecheongbong was selected as the experimental site, and treatment and control plots (2m×2m) were installed at the site. To analyze the effects of wind protection, windbreak fences were constructed in the treatment plots using hairy Korean rhododendrons (*Rhododendron mucronulatum* Turcz. var. *ciliatum* Nakai) from the surrounding area and weather stations were installed to investigate atmospheric temperature, humidity, and wind speed. In all control plots without windbreak fences, dwarf Siberian pine seedlings were killed by strong winds seven months after planting. In contrast, the average survival rate of the seedlings in treatment plots was 96.7% after seven months, 64.2% after two years, and 45% after three years, with most (85.3%) of the seedlings showing good initial root establishment. Accordingly, windbreak fences composed of natural vegetation are suitable for promoting the early establishment of seedlings in the restoration of dwarf Siberian pine stands.

First author : Lim, Hyo-In, Forest Bioinformation Division, National Institute of Forest Science, Research Scientist, Tel : +82-31-290-1155, E-mail : iistorm@korea.kr

Corresponding author : Lim, Hyo-In, Forest Bioinformation Division, National Institute of Forest Science, Research Scientist, Tel : +82-31-290-1155, E-mail : iistorm@korea.kr

Received : 22 May, 2020. **Revised** : 23 July, 2020. **Accepted** : 22 July, 2020.

Key Words: Windbreak fence, Establishment, Pinus pumila, Seedlings, Restoration

I. Introduction

The Mt. Seoraksan is an important area for biodiversity conservation (Sung et al. 2020). The Daecheongbong area (1,807 m above sea level) on Mt. Seoraksan is a representative subalpine region in South Korea, dominated by dwarf Siberian pine (*Pinus pumila* (Pall.) Regel), Korean arborvitae (*Thuja koraiensis* Nakai), Khingan fir (*Abies nephrolepis* (Trautv.) Maxim.), rigid-branch yew (*Taxus cuspidata* Siebold & Zucc.), and hairy Korean rhododendron (*Rhododendron mucronulatum* Turcz. var. *ciliatum* Nakai) (Kong 2002; Kwon et al. 2010; Song et al. 2012a).

According to the International Union for Conservation of Nature (IUCN) Red List at the national level, the dwarf Siberian pine is highly valuable as a genetic resource and is at risk of extinction due to climate change, with almost no seedling growth and little natural regeneration within the population (Korea National Arboretum 2009; Park et al. 2014).

Alpine and subalpine regions are areas with reduced tree growth when compared with low-altitude areas due to low air temperatures, strong winds, low soil moisture content, and shallow soil layers (Cho et al., 2016; Müller et al. 2016). The recovery of subalpine areas after severe disturbances is difficult due to the environment, which is unfavorable to tree growth, and the slow plant growth (Pröll et al. 2015; Johnson and Yeakley 2016; Choi and Lee 2018).

The dwarf Siberian pine is a representative subalpine species of the Korean Peninsula, distributed only on Mt. Seoraksan in South Korea (Kwon et al. 2010; Song et al. 2012b). In Japan, however, the dwarf Siberian pine is relatively widely distributed in subalpine regions; its natural regeneration is facilitated by birds (Kajimoto et al. 1998), although the survival rate of its one-year-old seedlings is 4.2~4.4% in 2000 over the four-year period after germination, with drought in spring and summer being the main cause of mortality (Kajimoto 2002). The population of dwarf Siberian pine on Mt. Seoraksan is small, and yet its genetic diversity is relatively high (Song et al. 2012b). However, limited seed dispersal due to excessive damage from feeding caused by birds and rodents during cone maturation has been reported as a major factor for little natural regeneration (Song et al. 2012a).

In general, populations with narrow distribution and small size are characterized by low genetic diversity, which reduces population adaptability due to inbreeding depression among individuals and consequently leads to population extinction (Bozzano et al. 2014). Despite its limited distribution and relatively small size, the population of dwarf Siberian pine in Mt. Seoraksan showed high genetic diversity (Song et al. 2012b). However, the population of dwarf Siberian pine in Mt. Seoraksan is likely to continue being affected by random genetic drifts due to its small size (Song et al. 2012b). In addition, since most cones are damaged by rodents and birds in July and August before they ripen, natural regeneration is unattainable, which ultimately negatively affects its genetic diversity (Song et al. 2012a).

To conserve the population of dwarf Siberian pine in Mt. Seoraksan, it is important to address the issue of seedling regeneration. A stable seed collection is possible using cone protective nets, and propagation methods have been developed to evaluate the seed germination characteristics of dwarf Siberian pine (Song et al. 2012a; Lim et al. 2015). However, for successful restoration of this population, it is critical to develop a method for safe establishment of dwarf Siberian pine seedlings in their natural population. Therefore, this study aimed to develop stable in-situ restoration methods that promote early seedling establishment by evaluating the effects of windbreak fences composed of natural vegetation on the establishment of dwarf Siberian pine seedlings.

II. Materials and methods

1. Plant materials

The one-year-old seedlings used in this study were cultivated from seeds that were collected from the Daecheongbong area on Mt. Seoraksan, South Korea, in 2014 and sown in 2015. The seeds were used after three months of cold stratification treatment at 4 °C to break dormancy after low-temperature (-18 °C) storage (Lim et al. 2015). The mean (± standard deviation, SD) height and mean (±SD) root collar diameter of the one-year-old seedlings were 3.7 ± 1.0 cm and 1.8 ± 0.2 mm, respectively.

2. Experimental site

Daecheongbong area (1,708 m) on Mt. Seoraksan is located from 38°05′25″ to 38°12′36″ N, and from 128°18′03″ to 128°26′43″ E, overlooking the East Sea (Figure 1). Daecheongbong-type granite of the Paleoproterozoic Era is distributed in this area (Korean Institute of Geoscience and Mineral Resources, 2010). Meteorological data in the study area were based on data from 2016 to 2019 obtained from the Automatic Weather System (AWS) located near Jungcheong Shelter. During the study period, the average annual temperature was 4.7 °C, the average annual precipitation was 2,188 mm, the average wind speed was 5.0 m·s-1, and the maximum wind speed was 37.6 m·s-1. The experimental site (1,688 m above sea level) was selected in the Daecheongbong area (Figure 1) in September 2016. Control and treatment plots (2×2m) were installed at the site (Figure 2). Planting in consideration of the surrounding vegetation is important for ecological restoration (Lee and Song. 2011). The windbreak fences used in this study were composed of hairy Korean Rhododendron shrubs that had been distributed in the surrounding area; this species has been reported as an accompanying species to the dwarf Siberian pine (Kwon et al. 2010). To reduce wind speed, five windbreak fences (2m×0.7m×0.3m) were installed in a direction perpendicular to the slope (northwest), at intervals of 0.5 m in the treatment plot. A total of 60 seedlings (one-year-old) were planted 20 cm apart in a 15×4 array in each plot on September 15 (Figure 2). Air temperature, humidity, and wind speed were measured using a HOBO® weather microstation (U30, Onset Inc., Bourne, MA, USA).

3. Data collection and statistical analyses

Growth characteristics of the dwarf Siberian pine seedlings were investigated at seven months, two years, and three years after planting. In the first year after planting, re-planting was carried out for uprooted seedlings. The weather data were collected from the HOBO® weather microstation for 6 months after planting.

Statistical analyses were conducted using Microsoft Office Excel 2019. A t-test was performed to analyze the statistical differences between the control and treatment groups.

Ⅲ. Results

1. Growth characteristics of dwarf Siberian pine seedlings

The survival rate of dwarf Siberian pine seedlings in the treatment plot was significantly higher ($P < 0.01$, two-tailed t-test) compared with that of the control plot (95% after seven months, 75% after two years, and 50% after three years (Figure 3). All the seedlings in the control plot died seven months after planting (0% survival rate). Three years later, the mean height of the seedlings in the treatment plot was 9.0 ± 2.5 cm, and their mean root collar diameter was 5.0 ± 1.3 mm, which shows a 2.5-fold increase in height and a 2.8-fold increase in root collar diameter from the time of initial planting. All the dead seedlings in the treatment plot were damaged by uprooting, and 20% of the surviving seedlings were found to have survived after uprooting damage (Figure 4C, 4D).

2. Weather conditions

Weather data collection from September 2016 to February 2017 showed that the strongest winds in the region occurred in the winter period (January and February). The monthly average and maximum wind speeds were higher at all times in the control plot (0.95 to 2.56 m·s-1, 7.05 to 12.08 m·s-1) than in the treatment plot (0.75 to 1.83 m·s-1, 9.06 to 18.62 m·s-1) (Figure 5). The soil moisture content was higher in the treatment plot from December 2016 to February 2017 when compared with that in the control plot (Figure 5).

3. Discussion

In this study, the survival rate of one-year-old dwarf Siberian pine seedlings in the presence of a natural windbreak was 50% over the three-year period, which was relatevely higher than the previous studies (less than 20%) investigated under natural conditions (Morihiro 1988; Kajimoto 2002). However, one year after planting of the seedlings, the survival rate of seedlings was 0% in areas without windbreaks. That is indicating even after seed germination, natural regeneration is likely almost unachievable in wind-exposed areas. Thus, the windbreak treatment had increased the survival rate of one-year-old seedlings.

The reduction in wind speed using windbreak fence depends on the height of the fence and the air porosity rate (Heisler and Dewalle 2012). In the study of windbreak effectiveness using black pine (*Pinus thunbergii* Parl.), it was reported that wind speed was reduced by 60-90%, depending on the density of trees planted (Bitog et al. 2012). The hairy Korean rhododendron used in the present experiment reduced the wind speed by 28%, indicating that it had a higher air porosity rate than did pine trees, which is attributed to deciduous character of this species. The windspeed reduction by the windbreak fences composed of the hairy Korean rhododendron was 22-34% in winter (December to February) and similar to that in the autumn period (21-33%). It is presumed that even deciduous species may cause more than a 50% reduction in wind speed in winter compared with the summer period (Heisler and Dewalle 2012) due to snowfall in winter.

The soil moisture content of the treatment plot was lower than that of the control plot in the autumn season (September to November), the period when the growth of plants was relatively active. This is presumed to be due to the absorption of soil moisture by the hairy Korean rhododendron used as a windbreaker in the treatment plot. In contrast, during the winter (December to February) when plant growth is interrupted, the soil moisture content in the windbreak treatment plot was high, presumably due to the fences that lasted longer during the snow-covered periods than the plants in the control plot (Naaim-Bubet and Mullenbach 1998).

Consequently, the installation of windbreaks using vegetation has been shown to be very effective for the early establishment of dwarf Siberian pine seedlings. The windbreak fences reduced wind speed by approximately 28% and prevented wind-elicited seedlings' death. It was also presumed that the relatively high soil water content during the winter period improved the rooting of seedlings during the dry season. Therefore, the installation of windbreak fences using vegetation can be used as a restoration method for dwarf Siberian pine trees, as well as other tree species, in subalpine regions. In order to develop a more effective windbreak installation, future research should analyze the effectiveness of various types of vegetation as windbreak.

4. Disclosure statement

No potential conflict of interest was reported by the authors.

References

Bitog JP, Lee IB, Hwang HS, Shin MH, Hong SW, Seo IH, Kwon KS, Mostafa E, Pang Z. 2012. Numerical simulation study of a tree windbreak. Biosyst Eng. 111(1): 40-48.

Bozzano M, Jalonen R, Thomas E, Boshier D, Gallo L, Cavers S, Bordács S, Smith P, Loo J. 2014. Genetic considerations in ecosystem restoration using native tree species. The State of the World's Forest Genetic Resources-Thematic Study. Rome: FAO and Biodiversity International; p. 281.

Cho MG, Chung JM, Lim HI, Noh I, Kim TW, Kim CY, Moon HS. 2016. Ecological characteristics of sub-alpine coniferous forest on Banyabong in Mt. Jiri. J Clim Change Res. 7(4):465-476.

Choi JY, Lee SH. 2018. Climate change impact assessment of *Abies nephrolepis* (Trautv.) Maxim. in subalpine ecosystem using ensemble habitat suitability modeling. J. Korean Env. Res. Tech. 21(1): 103-118.

Gardiner B, Berry P, Moulia B. 2016. Wind impacts on plant growth, mechanics and damage. Plant Sci. 245:94-118.

Grace J. 1977. Plant response to wind. In: Brandle JR, Hintz DL, Sturrock JW, editors. Windbreak Technology. 1st ed. New York (NY): Elsevier Science Publishers; p. 71-88.

Heisler G. M, Dewalle DR. 2012. Effects of windbreak structure on wind flow. Windbreak Technol. 22(23):41-69.

Johnson AC, Yeakley JA. 2016. Seedling regeneration in the alpine treeline ecotone: comparison of wood microsites and adjacent soil substrates. Mt Res Dev. 36(4):443-451.

Kim JH, Chung IU. 2006. Study on mechanisms and orographic effect for the springtime downslope windstorm over the Yeongdong Region. Atmosphere 16(2):67-83.

Kajimoto T, Onodera H, Ikeda S, Daimaru H, Seki T. 1998. Seedling establishment of subalpine stone pine (*Pinus pumila*) by nutcracker

(Nucifraga) seed dispersal on Mt. Yumori, northern Japan. Arctic and Alpine Research 30(4):408-417.

Kajimoto T. 2002. Factors affecting seedling recruitment and survivorship of the Japanese subalpine stone pine, *Pinus pumila*, after seed dispersal by nutcrackers. Ecol Res. 17(4): 481-491.

Kong WS. 2002. Species composition and distribution of Korean alpine plants. J Korean Geogr Soc. 37(4): 357-370.

Korea Institute of Geoscience and Mineral Resources. 2010. Explanatory Text of the Geological Map.< http://www. kigam.re.kr.> (Accessed 10. May 2020).

Korea National Arboretum. 2009. Rare plants data book of Korea. Seoul: Geobook Publishing Co; p. 332.

Kwon HJ, Gwon JH, Han KS, Kim MY, Song HK. 2010. Subalpine forest vegetation of Daecheongbong area, Mt. Seoraksan. Kor J Env Eco. 24(2): 194-201.

Lee MJ, Song HK. 2011. Vegetation Structure and Ecological Restoration Model of *Quercus mongolica* Community. J. Korean Env. Res. Tech. 14(1): 57-65.

Lim HI, Kim GN, Jang KH, Park WG. 2015. Effect of wet cold and gibberellin treatments on germination of dwarf stone pine seeds. Korean J Plant Res. 28(2): 253-258.

Morihiro N. 1988. Dynamics of *Pinus pumila* scrub in relation to spatial distrubution and seedling establishment. Transactions of the Japanese Ecological Society 35:118.

Müller M, Schwab N, Schickhoff U, Böhner J, Scholten T. 2016. Soil temperature and soil moisture patterns in a Himalayan alpine treeline ecotone. Arct Antarct Alp Res. 48(3): 501-521.

Naaim-Bouvet F, Mullenbach P. 1998. Field experiments on “living” snow fences. Ann Glaciol. 26:217-220.

Park HC, Lee JH, Lee GG. 2014. Predicting the suitable habitat of the *Pinus pumila* under climate change. J Environ Impact Assess. 23(5):379-392.

Pröll G, Darabant A, Gratzer G, Katzensteiner K. 2015. Unfavourable microsites, competing vegetation and browsing restrict post-disturbance tree regeneration on extreme sites in the Northern Calcareous Alps. Eur J For Res. 134(2):293-308.

Song JH, Lim HI, Jang KH, Kim DH, Son JI. 2012a. The effect of cone protective net and the morphological variation of cone and seed of Korea rare endemic *Pinus pumila* Regel. Korean J Plant Res. 25(4):401-406.

Song JH, Lim HI, Hong KN, Jang KH, Hong YP. 2012b. Genetic diversity and spatial genetic structure of dwarf stone pine in Daecheong-bong Area, Mt. Seorak. Korean J Plant Res. 25(4): 407-415.

Sung JW, Kang SG, Kim KH. 2020. Assessment of Protected Mt. Seorak Areas in Korea Applied by the Key Biodiversity Areas (KBAs). J. Korean Env. Res. Tech. 23(1): 37-48.

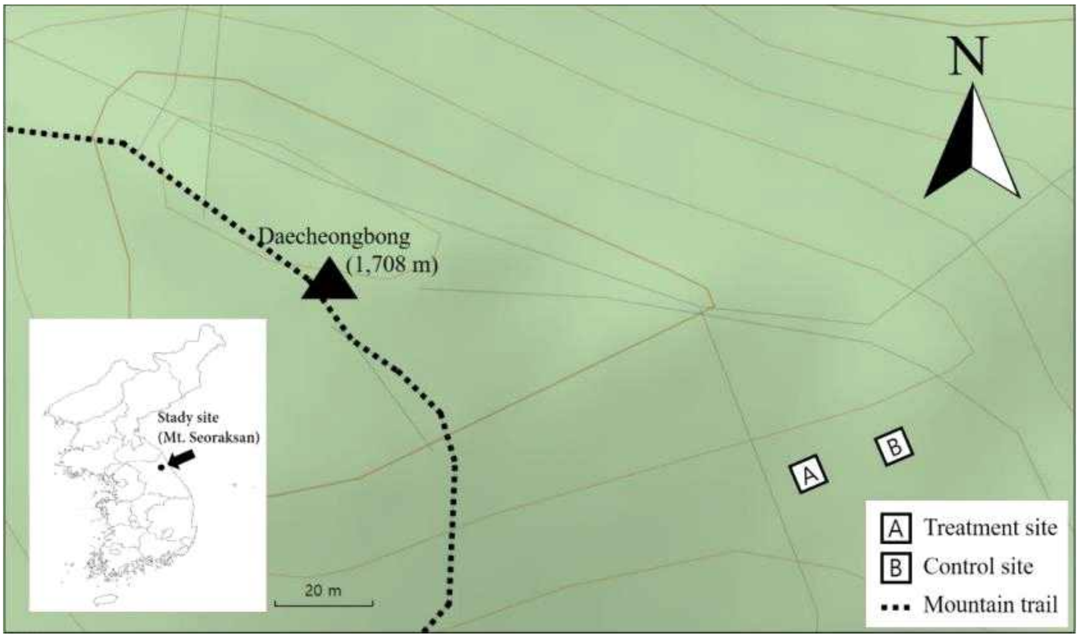

Figure. 1. Location of the study site planted with one-year-old dwarf Siberian pine seedlings in Mt. Seoraksan, South Korea.

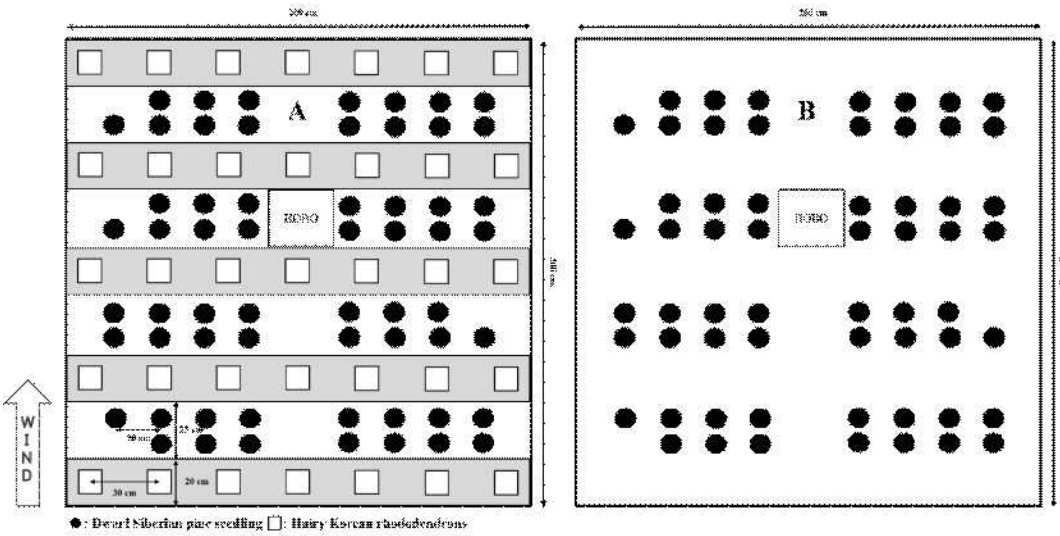

Figure. 2. Treatment (A) and control (B) plots in the study site. To reduce wind speed, five windbreak fences were installed in a direction perpendicular to the slope in the treatment plot. The prevailing winds blow from the southwest to the northeast (Kim and Chung 2006) .

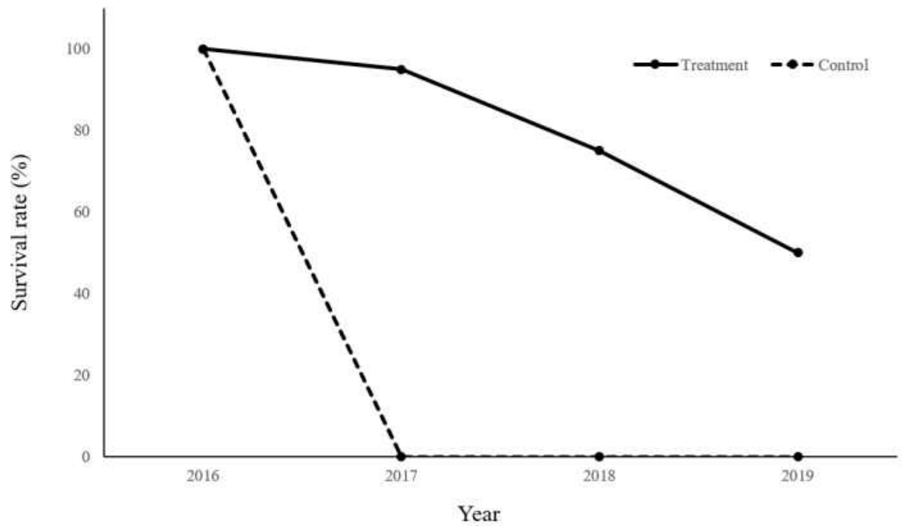

Figure. 3. Mean survival rate of dwarf Siberian pine seedling in treatment and control plots. The control plot had no seedlings that survived one year after planting in 2016.

Figure. 4. Control (A) and treatment (B, C, D) plots after three years. Dead seedling (C) and live seedling (D) after uprooting. All the seedlings in the control plot died, but 50% of the seedlings in the treatment plot survived. The dead seedlings in the treatment plot were damaged by uprooting, and 20% of the surviving seedlings were found to have survived after uprooting damage.

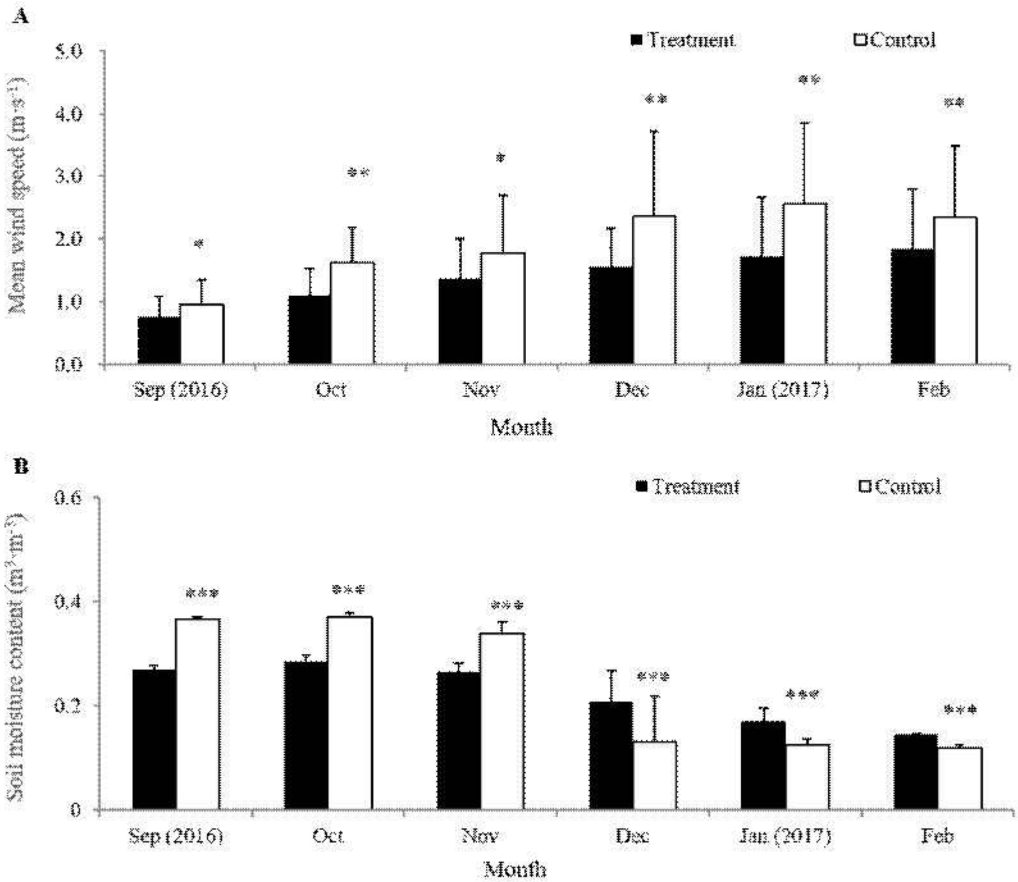

Figure. 5. Effect of windbreak fences on environmental factors: mean wind speed (A) and soil moisture content (B). All values are mean monthly data ± standard deviation (SD). *, **, *** indicate significant differences at $P < 0.05$, $P < 0.01$, and $P < 0.001$, respectively.