Windbreak and Sand Fixation Benefits of Giant Juncao Stubble Sand Barriers and Their Suitable Patterns: A Postprint

Authors: Wang Qiang, Hejun Zuo, Li Gangtie, Guo Jingyu, Wei Xianghong, Liu Yusheng, Yan Min

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Abstract

Based on the observation and analysis of data from windbreak and sand fixation experiments using Pennisetum giganteum with similar plant spacing (10-15 cm), different row spacing (1 m, 2 m), and different stubble heights (10 cm, 30 cm) along the Yellow River at Liuguaishatou in the Ulan Buh Desert. The results demonstrate that: The windbreak and sand fixation efficacy of Pennisetum giganteum stubble sand barriers is directly related to barrier height and row spacing; with a fixed height, increased row number and decreased strip spacing yield superior protection effects, albeit with greater material requirements. Sand transport within Pennisetum giganteum stubble sand barriers is primarily concentrated below 15 cm from the surface, with pronounced obstruction capacity against wind-sand flow at 0-5 cm near the surface. For barrier row spacing of 1 m and 2 m, 10 cm high barriers reduce wind speed below the threshold for sand movement after 9 and 12 strips, respectively; 30 cm high barriers exhibit enhanced wind obstruction capacity, eliminating surface sand movement after 7 and 9 strips, respectively. Barrier installation should minimize costs while ensuring high efficiency. The Pennisetum giganteum stubble sand barrier configuration with 2 m row spacing and 30 cm height can reduce wind speed below the sand-moving threshold after airflow passes through 9 strips (18 m width), making this configuration suitable for promotion in arid regions.

Full Text

Abstract

This research aimed to evaluate the windbreak and sand-fixation efficiency of *Pennisetum giganteum* sand barriers with different stubble heights (10 cm and 30 cm) at Liuguaishatou along the riparian zone of the Yellow River in the Ulan

Buh Desert. The sand barriers were established using *P. giganteum* with row spacing of 1 or 2 m and plant distance of 10–15 cm. The results showed that: (1) The windbreak and sand-fixation efficiency was closely related to the height and row spacing of *P. giganteum* sand barriers. For a given height level, more rows and smaller plant distance yielded better windbreak and sand-fixation efficiency, but required increased materials. (2) Sediment discharge in the *P. giganteum* sand barrier was mainly concentrated within a 15 cm height from the ground, and the capacity to prevent wind-blown sand was strong below 5 cm. When the row spacing of sand barriers was 1 or 2 m, wind speed was reduced below the sand-removing threshold after wind blew over 9 or 12 sand barriers. (3) High efficiency and low cost should be ensured in sand barrier establishment. It is considered that the *P. giganteum* sand barrier with 30 cm height and 2 m row spacing is suitable in arid areas.

Keywords: *Pennisetum giganteum*; sand barrier; windbreak efficiency; sediment; Ulan Buh Desert

2 Methods

2.1 Wind Speed Measurement

In April 2017, HOBO anemometers were installed at the experimental site to measure wind speed profiles. The measurement range was 0–45 $\text{m} \cdot \text{s}^{1}$ with an accuracy of ±1.1 $\text{m} \cdot \text{s}^{1}$ and resolution of 4%. Wind speeds were recorded at heights of 10 cm, 20 cm, 30 cm, 50 cm, 100 cm, and 200 cm above ground level. Data were collected at 2-second intervals over 20-minute periods, with three replicates for each measurement.

The wind speed reduction efficiency was calculated using the formula:

$$E_{X,Z} = \frac{V_{0,Z} - V_{X,Z}}{V_{0,Z}} \times 100\%$$

where $V_{X,Z}$ represents the wind speed at distance X and height Z behind the barrier, and $V_{0,Z}$ represents the wind speed at height Z in the open field without barriers.

2.2 Sediment Collection

Sediment discharge was measured using sand traps placed at different positions relative to the barriers. The traps were positioned at heights of 10 cm and 30 cm, with the collection opening facing the windward side. Each trap had a collection area of 5 cm × 5 cm, with 10 replicate traps installed at each measurement point. The sampling duration was 10 minutes per measurement period.

[Figure 2: see original paper] Schematic diagram of sand trap

3 Results and Discussion

3.2 Wind Speed Reduction Effects

Wind speed reduction varied significantly with barrier configuration. Under three reference wind speeds of 6.55 m · s^{1}, 8.81 m · s^{1}, and 10.32 m · s^{1} measured at 20 cm height, the windbreak efficiency showed clear patterns. At 6.55 m · s^{1}, the wind speed at 6 m behind 10 cm high barriers was reduced to 2.24 m · s^{1} at 20 cm height, representing a 53.14% reduction. This compares favorably with previous studies showing 2.26 m · s^{1} wind speed at 2 m behind barriers under 5 m · s^{1} conditions [14].

Strong correlations ($R^2 > 0.99$) were observed between wind speed reduction and distance behind the barriers for both row spacing and stubble height configurations [15]. The regression relationships were statistically significant at p > 99.99% confidence level. For 30 cm high barriers, wind speed reduction was more pronounced than for 10 cm barriers at equivalent distances. At 4-7 m behind 30 cm barriers, wind speed was reduced by 69.04%, 67.22%, and 62.38% under the three test wind speeds.

With 2 m row spacing, the wind speed reduction efficiency at 1 m behind 10 cm barriers was 0.46, 0.86, and 0.87 times that of 1 m spacing under the three wind speeds. At 9-12 m behind 2 m-spaced barriers, the efficiency remained high, with R^2 values of 0.99 for the regression relationships. For 30 cm barriers with 2 m spacing, the efficiency was 1.96, 1.27, and 2.24 times higher than for 1 m spacing at 1 m distance, indicating that wider spacing with taller stubble maintains effectiveness while reducing material requirements.

3.3 Sediment Discharge Characteristics

Sediment discharge showed distinct patterns related to barrier height and spacing. The mass of captured sediment was highest for 30 cm barriers, with 28.7 g collected per trap, compared to 14.9 g for 1 m-spaced barriers and 23.9 g for 2 m-spaced barriers. This demonstrates that taller barriers with appropriate spacing significantly enhance sediment capture.

Field observations revealed that sediment was primarily deposited within 0–15 cm above ground level, with the strongest sand-blocking capacity below 5 cm. When row spacing was 1.5–2 m, the sand-trapping effect was maximized, with 80% of total sediment captured in the 0–10 cm layer. This aligns with previous research showing that 20–25% porosity barriers provide optimal windbreak efficiency [20–21].

The sediment distribution pattern indicates that *P. giganteum* barriers effectively reduce near-surface wind velocity, causing sand particles to settle quickly. The barriers create a protective zone where wind speed remains below the sand transport threshold over distances of 9–12 barrier rows. For 10.32 m · s^{1} wind speed, sediment capture efficiency was 11.16% at 10 cm height and 6.57% at 30 cm height for 1 m-spaced barriers, increasing to 19.21% and 10.54% respectively for 2 m-spaced barriers.

4 Conclusions

(1) *Pennisetum giganteum* sand barriers demonstrate effective windbreak and sand-fixation functions. The efficiency is closely related to stubble height and row spacing, with 30 cm height and 2 m spacing providing optimal performance while minimizing material costs.

(2) Sediment discharge is concentrated within the 0–15 cm layer above ground, with maximum deposition below 5 cm. The barriers maintain wind speed below the sand-moving threshold for distances covering 9–12 rows.

(3) For practical application in arid regions, the configuration of 30 cm stubble height and 2 m row spacing is recommended as it balances high efficiency with economic feasibility.

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